Journal of Threatened Taxa

JoTT

Building evidence for conservation globally

10.11609/jott.2020.12.17.17263-17386
www.threatenedtaxa.org

26 December 2020 (Online & Print)
Vol. 12 | No. 17 | Pages: 17263– 17386

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

PLATINUM OPEN ACCESS

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

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

Host
Zoo Outreach Organization
www.zooreach.org

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

EDITORS

Founder & Chief Editor
Dr. Sanjay Molur
Wildlife Information Liaison Development (WILD) Society & Zoo Outreach Organization (ZOO), 12 Thiruvannamalai Nagar, Saravanampatti, Coimbatore, Tamil Nadu 641035, India

Deputy Chief Editor
Dr. Neelesh Dahanukar
Indian Institute of Science Education and Research (IISER), Pune, Maharashtra, India

Managing Editor
Mr. B. Ravichandran, WILD/ZOO, Coimbatore, India

Associate Editors
Dr. B.A. Daniel, ZOO/WILD, Coimbatore, Tamil Nadu 641035, India
Dr. Mandar Paingankar, Department of Zoology, Government Science College Gadchiroli, Chamorshi Road, Gadchiroli, Maharashtra 442605, India
Dr. Ulrike Streicher, Wildlife Veterinarian, Eugene, Oregon, USA
Ms. Priyanka Iyer, ZOO/WILD, Coimbatore, Tamil Nadu 641035, India

Editorial Board
Ms. Sally Walker
Founder/Secretary, ZOO, Coimbatore, India

Dr. Robert Lacy
Department of Conservation Biology, Chicago Zoological Society (also known as the Brookfield Zoo), Brookfield, Illinois 60513 USA; and Committee on Evolutionary Biology, University of Chicago

Dr. Russel Mittermeier
Executive Vice Chair, Conservation International, Arlington, Virginia 22202, USA

Prof. Mewa Singh Ph.D., FASc, FNA, FNASc, FNAPsy
Ramanna Fellow and Life-Long Distinguished Professor, Biopsychology Laboratory, and Institute of Excellence, University of Mysore, Mysuru, Karnataka 570006, India; Honorary Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore; and Adjunct Professor, National Institute of Advanced Studies, Bangalore

Dr. Ulrike Streicher, DVM
Wildlife Veterinarian / Wildlife Management Consultant, 1185 East 39th Place, Eugene, OR 97405, USA

Stephen D. Nash
Scientific Illustrator, Conservation International, Dept. of Anatomical Sciences, Health Sciences Center, T-8, Room 045, Stony Brook University, Stony Brook, NY 11794-8081, USA

Dr. Fred Pluthero
Toronto, Canada

Dr. Martin Fisher
Senior Associate Professor, Battcock Centre for Experimental Astrophysics, Cavendish Laboratory, JJ Thomson Avenue, Cambridge CB3 0HE, UK

Dr. Ulf Gärdenfors
Professor, Swedish Species Information Center, SLU, Uppsala, Sweden

Dr. John Fellowes
Honorary Assistant Professor, The Kadoorie Institute, 8/F, T.T. Tsui Building, The University of Hong Kong, Pokfulam Road, Hong Kong

Dr. Philip S. Miller
Senior Program Officer, Conservation Breeding Specialist Group (SSC/IUCN), 12101 Johnny Cake Ridge Road, Apple Valley, MN 55124, USA

Prof. Dr. Mirco Solé
Universidade Estadual de Santa Cruz, Departamento de Ciências Biológicas, Vice-coordenador do Programa de Pós-Graduação em Zoologia, Rodovia Ilhéus/Itabuna, Km 16 (45662-000) Salobrinho, Ilhéus - Bahia - Brasil

English Editors
Mrs. Mira Bhojwani, Pune, India
Dr. Fred Pluthero, Toronto, Canada
Mr. P. Ilangovan, Chennai, India

Web Development
Mrs. Latha G. Ravikumar, ZOO/WILD, Coimbatore, India

Typesetting

Mr. Arul Jagadish, ZOO, Coimbatore, India
Mrs. Radhika, ZOO, Coimbatore, India
Mrs. Geetha, ZOO, Coimbatore India
Mr. Ravindran, ZOO, Coimbatore India

Fundraising/Communications
Mrs. Payal B. Molur, Coimbatore, India

Editors/Reviewers
Subject Editors 2017–2019

Fungi

Dr. B. Shivaraju, Bengaluru, Karnataka, India
Prof. Richard Kiprono Mibey, Vice Chancellor, Moi University, Eldoret, Kenya
Dr. R.K. Verma, Tropical Forest Research Institute, Jabalpur, India
Dr. V.B. Hosagoudar, Bilagi, Bagalkot, India
Dr. Vatsavaya S. Raju, Kakatiay University, Warangal, Andhra Pradesh, India
Dr. D.J. Bhat, Retd. Professor, Goa University, Goa, India

Plants

Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India
Dr. N.P. Balakrishnan, Ret. Joint Director, BSI, Coimbatore, India
Dr. Shonil Bhagwat, Open University and University of Oxford, UK
Prof. D.J. Bhat, Retd. Professor, Goa University, Goa, India
Dr. Ferdinando Boero, Università del Salento, Lecce, Italy
Dr. Dale R. Calder, Royal Ontaro Museum, Toronto, Ontario, Canada
Dr. Cleofas Cervancia, Univ. of Philippines Los Baños College Laguna, Philippines
Dr. F.B. Vincent Florens, University of Mauritius, Mauritius
Dr. Merlin Franco, Curtin University, Malaysia
Dr. V. Irudayaraj, St. Xavier's College, Palayamkottai, Tamil Nadu, India
Dr. B.S. Kholia, Botanical Survey of India, Gangtok, Sikkim, India
Dr. Pankaj Kumar, Kadoorie Farm and Botanic Garden Corporation, Hong Kong S.A.R., China
Dr. V. Sampath Kumar, Botanical Survey of India, Howrah, West Bengal, India
Dr. A.J. Solomon Raju, Andhra University, Visakhapatnam, India
Dr. Vijayasankar Raman, University of Mississippi, USA
Dr. B. Ravi Prasad Rao, Sri Krishnadevaraya University, Anantpur, India
Dr. K. Ravikumar, FRLHT, Bengaluru, Karnataka, India
Dr. Aparna Watve, Pune, Maharashtra, India
Dr. Qiang Liu, Xishuangbanna Tropical Botanical Garden, Yunnan, China
Dr. Noor Azhar Mohamed Shazili, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia
Dr. M.K. Vasudeva Rao, Shiv Ranjani Housing Society, Pune, Maharashtra, India
Prof. A.J. Solomon Raju, Andhra University, Visakhapatnam, India
Dr. Mandar Datar, Agharkar Research Institute, Pune, Maharashtra, India
Dr. M.K. Janarthanam, Goa University, Goa, India
Dr. K. Karthigeyan, Botanical Survey of India, India
Dr. Errol Vela, University of Montpellier, Montpellier, France
Dr. P. Lakshminarasimhan, Botanical Survey of India, Howrah, India
Dr. Larry R. Noblick, Montgomery Botanical Center, Miami, USA
Dr. K. Haridasan, Pallavur, Palakkad District, Kerala, India
Dr. Analinda Manila-Fajard, University of the Philippines Los Banos, Laguna, Philippines
Dr. P.A. Sinu, Central University of Kerala, Kasaragod, Kerala, India

Invertebrates

Dr. R.K. Avasthi, Rohtak University, Haryana, India
Dr. D.B. Bastawade, Maharashtra, India
Dr. Partha Pratim Bhattacharjee, Tripura University, Suryamaninagar, India

continued on the back inside cover

Caption: Blue-spotted Mudskipper *Boleophthalmus boddarti* battle on land (surface behavior). © A. Kumaraguru

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17263–17275

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

DOI: https://doi.org/10.11609/jott.6532.12.17.17263-17275

#6532 | Received 08 August 2020 | Finally accepted 08 December 2020

PLATINUM OPEN ACCESS

Genetic and reproductive characterization of distylous *Primula reinii* in the Hakone volcano, Japan: implications for conservation of the rare and endangered plant

Masaya Yamamoto [1], Honami Sugawara [2], Kazuhiro Fukushima [3], Hiroaki Setoguchi [4] & Kaoruko Kurata [5]

[1] Hyogo University of Teacher Education, 942-1 Shimokume, Kato-city, Hyogo 673-1494, Japan.
[2,3,5] Graduate School of Education, Yokohama National University, 79-2 Tokiwadai, Hodogaya-ku, Yokohama, Kanagawa 240-8501, Japan.
[4] Graduate School of Human and Environmental Studies, Kyoto University, Yoshida Nihonmatsu, Sakyo-ku, Kyoto 606-8501, Japan.
[1] myamamo@hyogo-u.ac.jp (corresponding author), [2] xxhonami.s@gmail.com, [3] kazuhiro-kazuhiro-73@docomo.ne.jp,
[4] setoguchi.hiroaki.2c@kyoto-u.ac.jp, [5] kaoruko@ynu.ac.jp

Abstract: Genetic and ecological evaluation are crucial in effective management of rare and endangered species, including those exhibiting complex breeding systems such as distyly. We studied a threatened distylous herb *Primula reinii* in the Hakone volcano, central Japan, to obtain baseline information of reproductive and genetic status towards conservation. In two representative populations inhabiting a central cone and somma of the volcano, population size, floral morph ratio, stigmatic pollen deposition, and fruit-set were measured. Using microsatellite markers, we evaluated genetic diversity, structure and differentiation of populations. Population bottlenecks and historical changes in population size were also estimated from genotype data. We found significant deviation from equal morph ratios in the central cone population, which also exhibited skewed mating success together with a high frequency of pollination within the same morph. These trends were not detected in the somma population. From genetic insights, the central cone population showed slightly lower genetic diversity, whereas no significant deviation from Hardy-Weinberg equilibrium was found in either population. The estimated moderate genetic differentiation and admixed genetic structure suggest recent lineage divergence and/or gene flow between populations. While robust evidence for a recent bottleneck was not obtained in our analyses, a clear signature of historical population contraction was detected in the central cone population. Our findings suggest that the skewed morph ratio strongly influenced the reproduction of small and isolated populations in the short-term, highlighting the vulnerability of distylous plant populations under ongoing anthropogenic pressure.

Keywords: Distyly, morph bias, reproduction, genetic diversity, volcanism

Editor: Mandar Paingankar, Government Science College Gadchiroli, Gadchiroli, India. **Date of publication:** 26 December 2020 (online & print)

Citation: Yamamoto, M., H. Sugawara, K. Fukushima, H. Setoguchi & K. Kurata (2020). Genetic and reproductive characterization of distylous *Primula reinii* in the Hakone volcano, Japan: implications for conservation of the rare and endangered plant. *Journal of Threatened Taxa* 12(17): 17263–17275. https://doi.org/10.11609/jott.6532.12.17.17263-17275

Funding: This work was financially supported by ProNatura Foundation Japan, Support Society of Faculty of Education and Human Science of Yokohama National University, and Grants-Aid for Science Research from Japan Society for Promotion of Science (#19K16219)

Competing interests: The authors declare no competing interests.

Author details: Masaya Yamamoto is an assistant professor in Hyogo University of Teacher Education. Honami Sugawara is a school teacher in Tokyo, Japan. Kazuhiro Fukushima is also a school teacher in Shizuoka Pref., Japan. Hiroaki Setoguchi is a professor in Kyoto University. Kaoruko Kurata is an associate professor in Yokohama National University.

Author contribution: KK conceived the project; MY, HS and KF collected the data; MY led the writing of the manuscript. HS and KK contributed critically to the drafts and give final approval for publication.

Acknowledgements: Fieldworks are conducted under permits from Kanto Regional Environment Office, Ministry of the Environment. We are grateful to Misato Wakai and Saki Sugihara, undergraduate and graduate students in the Kurata laboratory (Yokohama National University) for help in field surveys.

INTRODUCTION

Worldwide, numerous plants are already threatened by human-caused stress (e.g., habitat destruction) and climate changes (Jackson & Kennedy 2009). Among these plants, species having a sophisticated entomophilous breeding system such as distyly (heterostyly) are likely to be the most vulnerable to the detrimental effects of isolation and unreliable pollination service due to anthropogenic environmental alteration (Washitani et al. 2005).

Distyly is a floral polymorphism, where populations have two floral morphs (a long- and short-styled morph; hereafter, referred to as the L- and S-morphs) that differ reciprocally in the heights of stigmas and anthers in flowers. Besides the morphological differences, distylous plants usually have a heteromorphic incompatibility system that prevents selfing and intra-morph mating (Barrett 2002); only cross-pollination (i.e., legitimate pollination) between L- and S-morphs results in seed setting. In theory, such morphologically and physiologically disassortative mating between floral morphs generally leads to an equilibrium with equal morph ratios, as a result of negative frequency-dependent selection and simple inheritance of distyly (Heuch 1979; Barret & Shore 2008). Accumulated evidence in distylous plants, however, has provided numerous examples of variation in population morph ratios (e.g., Kéry et al. 2003; Brys et al. 2008; Meeus et al. 2012). It has been advocated that floral morph bias can be governed by several factors, such as stochastic and deterministic events (Matsumura & Washitani 2000; Kery et al. 2003), maternal fitness differences between morphs (Hodgins & Barret 2006), and a combination of weak heteromorphic incompatibility and pollen limitation (Barret 1989; van Rossum et al. 2006; Brys et al. 2008).

Skewed morph ratios have often been found in small isolated distylous plant populations (e.g., Matsumura & Washitani 2000; Kery et al. 2003). Furthermore, it is well known that the deviation of morph frequencies from a 1:1 ratio can have negative reproductive and genetic consequences for populations. Indeed, skewed morph ratios result in the limited availability of compatible mates, which can contribute to reduced reproductive success (Kery et al. 2003; Wang et al. 2005; Pedersen et al. 2016) and increase the effects of genetic drift (Byers & Meagher 1992). Moreover, a combination of the loss of effective pollinators and the absence of a strict heteromorphic incompatibility system can increase inbreeding (selfing and biparental inbreeding) in morph-biased populations (Barret 1989; Wilcock & Neiland 2002; van Rossum & Triest 2006). Another consequence of skewed morph ratios is an increase in genetic drift and inbreeding, which can lead to a loss of genetic diversity (van Rossum & Triest 2006; Meeus et al. 2012) and may eventually result in the breakdown of distyly (Washitani 1996). Therefore, conservation studies on threatened distylous species which integrate ecological and genetic approaches are indispensable for assessing current status and predicting future extinction probability, as well as for planning effective conservation and/or restoration strategies (Washitani et al. 2005).

The present paper investigated *Primula reinii* Franch. et Sav. (Primulaceae), an endemic primrose that inhabits mountainous regions of Japan. As in most primroses, the plant is a self-incompatible distylous species (Richards 2003). Because of its attractive and relatively large flowers with dwarf foliage, the primrose has suffered from anthropogenic activity (e.g. horticultural exploitation) in the wild. Based on the rarity and serious reductions in numbers and populations, the species is listed in the 'Vulnerable' category of the latest Japanese Red List (Ministry of the Environment 2019). Despite required effective management, especially for small populations exposed to ongoing human activities, little is known about their population status, reproductive success, or remnant genetic diversity. Simultaneously, this might provide an opportunity to study the immediate responses of a distylous plant population to demographic changes. In this study, we assessed the genetic and reproductive status of two neighborhood populations of *P. reinii* to provide baseline information pertinent to the conservation and preservation of this rare and endangered primrose. To discuss factors affecting reproductive success in natural habitats, we measured population size, morph frequency, stigmatic pollen deposition, and fruit-set within a population, and evaluated the genetic diversity and structure within and among populations.

MATERIALS AND METHODS

Plant species and study site

Primula reinii is a diploid (2n = 24) perennial herb occurring as a chasmophyte on wet shaded rocky cliffs in the mountains (Image 1). The natural populations are rare and usually small and isolated from each other because of their narrow edaphic niche and low dispersal ability arising from the nature of the species. A single ramet produces one to two pink flowers from mid-April to early May. Although flower visitors are not well-known in this species, its narrow corolla tube and recent pollinator observations in their related species (Yamamoto et al. 2018) imply that long-tongued flying insects, such as bumblebees and bee flies can be effective pollinators for the species. Under cultivation conditions, the generation time (between seed germination and first flowering) of the species is estimated to be 2–3 years (Yamamoto et al. 2017).

Fieldwork was conducted from April 2013 to October 2014. We selected *P. reinii* populations from two sites in the Hakone volcano within a special protected zone of the Fuji-Hakone National Park in central Japan (Fig. 1a). These sites were severely isolated by a volcanic landform, i.e., caldera (distance: ca. 7 km) (Fig. 1b). One was on Mt. Kintoki (KIN population, 35.289'N, 139.004'E, 1,212m) and the other was on Mt. Komagatake (KOM population, 35.228'N, 139.021'E; 1,275m). In both sites, the primrose occurs on rock outcrops near the mountain top in which populations are composed of scattered patches within an area of approximately 20 × 20 m^2. Although a few smaller patches also located alongside the studied populations, these rim populations were sparse and separated geographically from the studied center population (>100 m). Thus, each studied population was considered to be one reproductive unit.

Formation and strong eruptive activities of the Hakone volcano initiated 650–350 ka and continued until 3ka (Nagai & Takahashi 2008). The mean annual precipitation and average air temperature at this area are 2,132mm and 8.8^{0}C, respectively (http://en.climate-data.org/location/769594/, accessed 7 February 2019).

Image 1. Flowering ramet of *Primula reinii* on Mt. Komagatake. Photographed by Honami Sugawara in May 2013.

Currently, the Hakone volcano is an attractive destination to tourists. There is more than 10,000 people living within the caldera, and an approximate average of 60,000 tourists visit the area every day. Including *Primula reinii*, approximately 80% of endangered plants

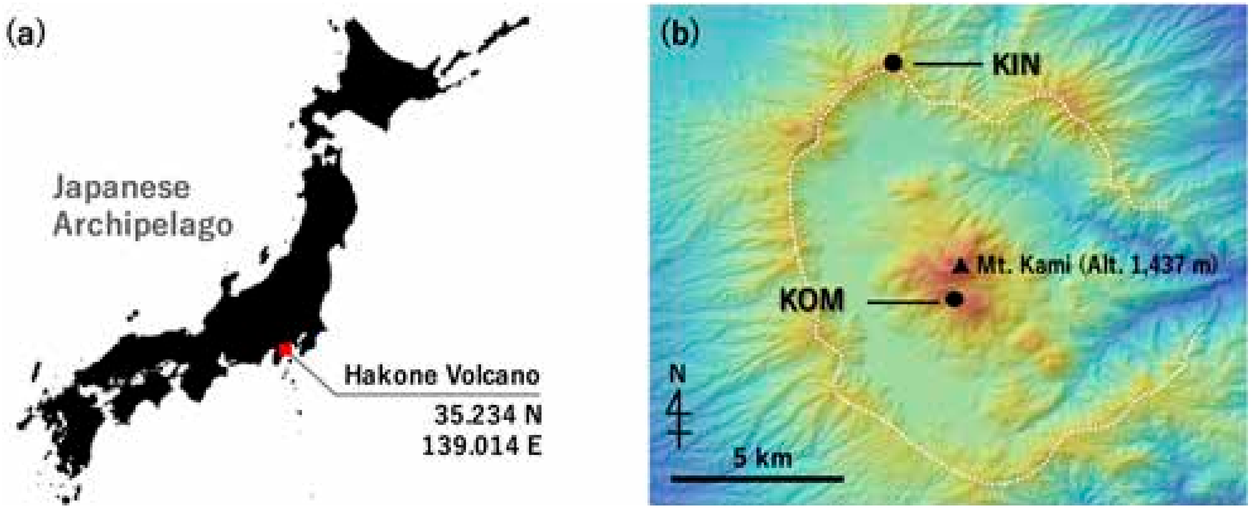


Figure 1. a—Location of Hakone volcano | b—Geographical map of Hakone volcano and location of the two populations of *Primula reinii* included in this study. KIN and KOM are population codes. The dashed line indicates the caldera rim of the Hakone volcano: Mt. Kami is the heist peak of the polygenetic volcanoes.

found in the volcano are presumed to have decreased due to habitat destruction and horticultural exploitation (Osawa & Inohara 2008).

Measurements of basic population traits, pollen deposition, and fruit-set

During the flowering season, the number of all flowering individuals and flowers within each population, along with flower morph (L- or S-morph), were recorded. Whether the two morphs were equally frequent within a population (i.e., deviations from a 1:1 morph ratio) was investigated with Chi-square goodness-of-fit tests.

To elucidate the role of pollen limitation and morph-ratio variation on female reproductive success, we measured the stigmatic pollen load. In the natural fields, 20 fully-opened flowers were collected from each population in the afternoon and carefully transported to the laboratory the same day. In the laboratory, flowers were dissected, and stigma removed and mounted on a microscope slide in aniline blue staining solution (0.1% aniline blue in 0.1 M K_3PO_4). Under a compound microscope (Olympus), we directly counted the number of legitimate (pollen from the opposite morph) and illegitimate (pollen from the same morph) pollen grains on stigmas of each floral morph based on pollen size differences (L-morph: 18.0 ± 0.1 µm; S-morph: 28.6 ± 0.1 µm; Y. Ojima, unpublished data).

At the beginning of the fruiting season (August), the population mean for fruit-set per flower was measured with the exception of some flowers that were used for the measurements of stigmatic pollen loads. Even if the fruit was set, the reproductive success will strongly depend on fruit predation (e.g., Matsumura & Washitani 2000; Yamamoto et al. 2013). Thus, we continued observations until October that was immediately before avulsion of the capsules.

All field surveys described above were conducted in 2013 and 2014 for KOM and KIN population, respectively.

Population sampling, DNA extraction, and microsatellite genotyping

In each population, 32 plants were sampled randomly (without distinction of floral morph types) from the entire area occupied by each population for genetic analysis. Leaf materials were collected and dried in silica gel. Before DNA extraction, leaves were homogenized with a disposable homogenizer (Biomasher 2; Nippi Co., Tokyo, Japan) to a fine powder. Total DNA was extracted from 40 to 80 mg silica-dried leaf tissue using the grass-fiber filter method (Takakura 2011). The extracted DNA was dissolved in a TE solution and stored at 4^0C until use.

After the preliminary marker screening, the genotypes of each individual were characterized following seven microsatellite markers that were originally developed for *Primula sieboldii* E. Morren: ga0161, ga0218, ga0580, ga0691, ga1140, Pri0141, and 2ca135 (Ueno et al. 2003, 2006, 2009; Kitamoto et al. 2005). PCR amplifications and allele-size determination of fragment analysis were performed in accordance with the methods described by Yamamoto et al. (2017).

Population genetic analysis

For all seven microsatellite loci, the absence of linkage disequilibrium (LD) and the presence of null alleles were tested using Genepop v4.2 (Raymond & Rousset 1995). The LD test was verified using a Markov chain method with 1,000 dememorization steps, and 1,000 iterations per batch. Null allele frequencies were estimated by maximum-likelihood estimator based on the expectation-maximization algorithm (Dempster et al. 1977) with the default setting.

The following measures were calculated for each population: number of alleles (A), effective number of alleles (A_E), number of private alleles (A_P), expected heterozygosity (H_E), and inbreeding coefficient (F_{IS}). Deviations from the Hardy-Weinberg equilibrium were determined by the exact test and permutations. All measurements were calculated using GenoDive v2.0 (Meirmans & van Tienderen 2004). GenoDive was also used to compute the population's genetic differentiation pairwise F_{ST} and G'_{ST} indices (Hedrick 2005), and F_{ST} was tested for significance using 10,000 permutations.

To estimate genetic structure of *P. reinii* populations in Hakone volcano, we used the model-based clustering method STRUCTURE 2.3.4 (Pritchard et al. 2000) and non-model-based method principal component analysis (PCA). STRUCTURE analysis was conducted for all samples across the two populations. Under an admixture model with correlated allele frequency, 20 independent simulations were run for each K (K = 1–5) with 5 × 10^5 Markov chain Monte Carlo (MCMC) steps and a burn-in period of 10^5 interactions. The most likely value of K was determined by the ΔK method (Evanno et al. 2005) with STRUCTURE HARVESTER 0.6.94 (Earl & vonHoldt 2012). CLUMPAK (Kopelman et al. 2015) was used to average the outputs from multiple STRUCTURE runs and produce the graphical results. The F value, the amount of genetic drift between each cluster and a common ancestral population, was also calculated for each cluster. The PCA analysis was performed using the package *adegenet* 2.0.1 (Jombart 2008) in R 3.5.2 (R core Team 2018).

To detect a genetic imprint of past population bottlenecks, we first used the heterozygosity excess method (Cornuet & Luikart 1996) implemented within the program BOTTLENECK v1.2 (Piry et al. 1999). This method is suitable to detect very recent and less severe bottlenecks, and has low false positive error rates (Williamson-Natesan 2005). All simulations were done with mutation-drift equilibrium conditions (2,000 replicates) under the stepwise mutation model (SMM), infinite allele model (IAM), and two-phase mutation model (TPM: 70% SMM and 30% IAM). A two-tailed Wilcoxon signed-rank test was used to determine a significant excess of heterozygosity.

We also calculated the *M*-ratio (Garza & Williamson 2001) for each population using Arlequin (Excoffier et al. 2005). The *M*-ratio test is considered to have a greater detection power for ancient and moderate-to-severe population declines in comparison with the former method (Williamson-Natesan 2005). *M*-ratio represents the number of alleles relative to the range in allele sizes. After a severe bottleneck, the number of alleles should reduce faster than the allelic size range, which results in a reduced *M*-ratio (Garza & Williamson 2001). Thus, the magnitude of the decrease reflects the severity and duration of the reduction in population size, and generally an *M*-ratio <0.68 is indicative of the presence of a bottleneck (Garza & Williamson 2001).

Finally, we conducted a Bayesian demographic analysis using the R package, Vareff (Nikolic & Chevalet 2014). In contrast to the first two moment-based methods, this coalescent-based approach can examine temporal changes in the effective population size (Ne). The function Vareff simulates prior changes in the effective population size from microsatellite data by resolving coalescent theory and using an approximate likelihood MCMC (Nikolic & Chevalet 2014). After a series of preliminary runs, we used the prior parameter settings for each population (Table S1), following recommendations from Nikolic & Chevalet (2014). We set the estimated mutation rate to 5×10^{-4} (Estoup et al. 2002) for all loci, and ran each analysis under a two-phased mutation model with a proportion of 0.22 for multiple mutations (Peery et al. 2012), for 10^5 MCMC steps (NumberBatch = 1,000,000, LengthBatch = 10), sampling every 10 steps (SpaceBatch = 10) with an acceptance ratio of 0.25 (AccRate = 0.25), after burning of 10,000 steps. Estimations of sizes were searched for from sampling time to 5,000 and 500 generations ago.

RESULTS

Population traits and morph ratio

Each population trait is summarized in Table 1. A total of 72 flowering individuals and 99 flowers were found in the KIN population, whereas the KOM population had fewer (52 individuals and 69 flowers). The morph ratio in KIN did not deviate significantly from a 1:1 ratio (L-morph ratio = 0.54), even in the number of flowers (L-morph ratio = 0.52). In contrast, the number of flowering individuals of the L-morph was significantly higher than that of the S-morph in KOM (L-morph ratio = 0.65) and even higher for the number of flowers (L-morph ratio = 0.70).

Pollen deposition

Stigmas of both floral morphs received pollen grains in each population, but the numbers varied greatly between the individuals, ranging from zero to 321. In the KIN population, no differences in stigmatic pollen loads were detected between morphs (Fig. 2a). In addition, the proportion of deposited legitimate pollens was not significantly different between both morphs (Fig. 2c), while the proportions varied greatly among the L-morph stigmas in comparison with the S-morph. This is complemented by the result that the S-morph stigmas received significantly more legitimate pollen grains than the L-morph stigmas (Fig. 2b), implying that S-morph stigmas were pollinated more effectively than the opposite morph.

Table 1. Number of blooming plants during the flowering season in each population. Results of χ^2 goodness-of-fit tests for the similarity between the two morphs.

Number of	L-morph	S-morph	Total	χ^2	*P*
KIN pop.					
Flowering individuals	39	33	72	0.50	0.48
Flowers	51	48	99	0.09	0.76
KOM pop.					
Flowering individuals	34	18	52	4.92	0.03
Flowers	48	21	69	10.57	0.001

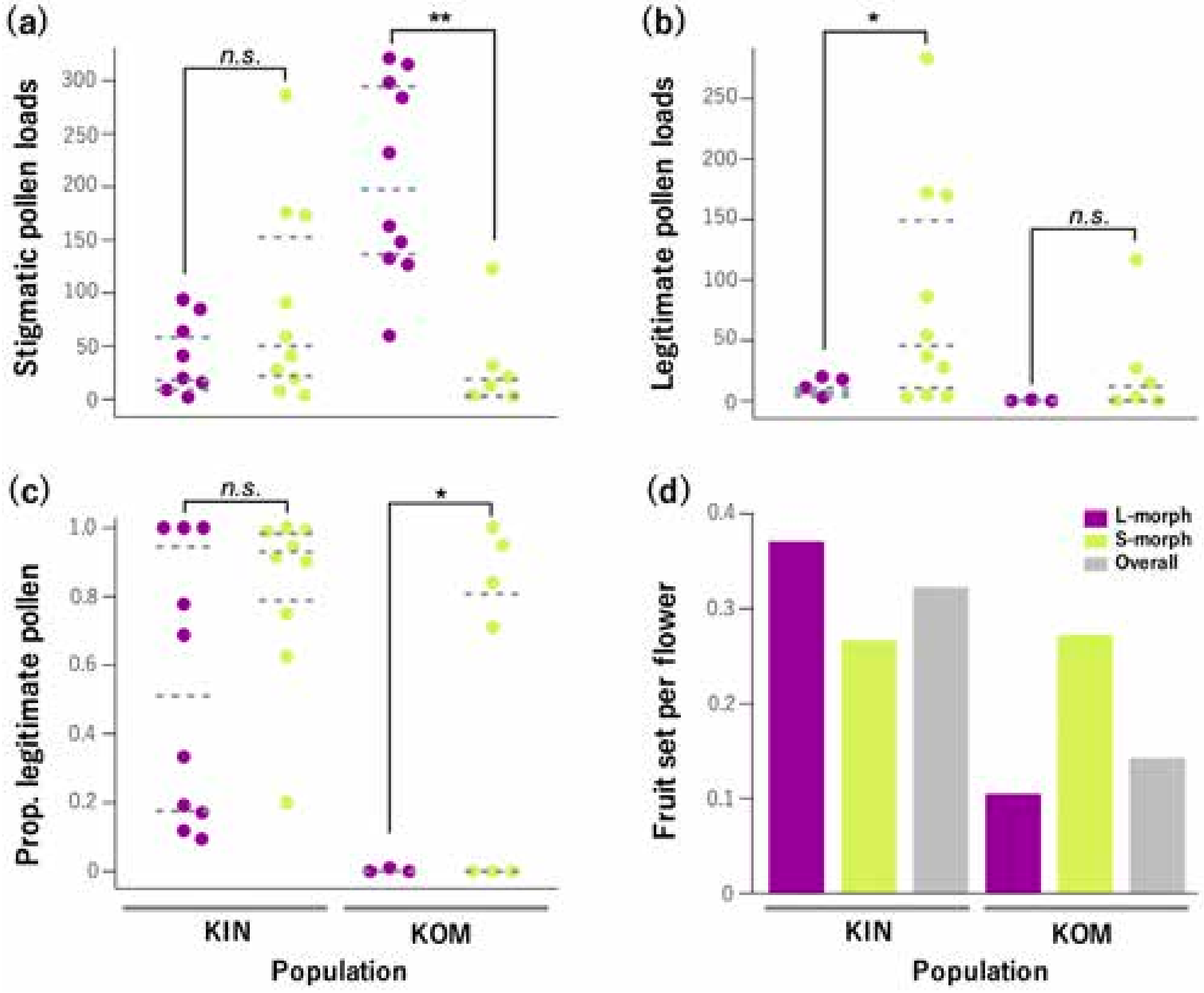


Figure 2. Pollen deposition on stigmas and the reproductive status of *Primula reinii* in the Hakone volcano. a—Stigmatic pollen loads | b—legitimate pollen loads | c—proportion of legitimate pollen within stigmatic pollen loads. a– c—are represented as beeswarm plots. Purple and green dots indicate L- and S-morphs, respectively. The dashed lines show the first quartile (lower line), median (center line), and third quartile (upper line). Asterisk denotes significant differences (Mann-Whitney U-test) between morphs: *$P < 0.05$, **$P < 0.0001$. d—Mean population of fruit set per flower.

In contrast, in the KOM population, L-morph stigmas received a significantly greater number of pollen grains than the S-morph stigmas (Fig. 2a). After classifying pollen grains, however, we found no legitimate pollen grains loaded on the L-morph stigmas (Fig. 2b); that is, most L-morph stigmas were covered with a large quantity of illegitimate pollen. Although several S-morph stigmas were legitimately pollinated, similar to other populations (Fig. 2c), there was no significant difference in the number of legitimate deposited pollen grains between the two morphs (Fig. 2b).

Fruit-set

At the population level, fruit-set ratio was much higher in the KIN population than in the KOM population (32.3 % and 14.3 %, respectively) (Fig. 2c). Within a population, both L- and S-morph scored comparable values in the KIN population (37.1 % and 26.7 %, respectively). In contrast, fruit-set of L-morph in the KOM population was less than half of the opposite morph (10.5 % and 27.3 %, respectively). We continued monitoring until October, but no evidence of fruit predation was found in either population, namely fruit-set was almost unchanged throughout the fruiting season.

Genetic diversity

LD between locus pairs was not significant. Although the frequencies of the majority of the null alleles were lower than 0.1, higher frequencies of null alleles were detected on 2ca135 and ga1140 loci in the KOM

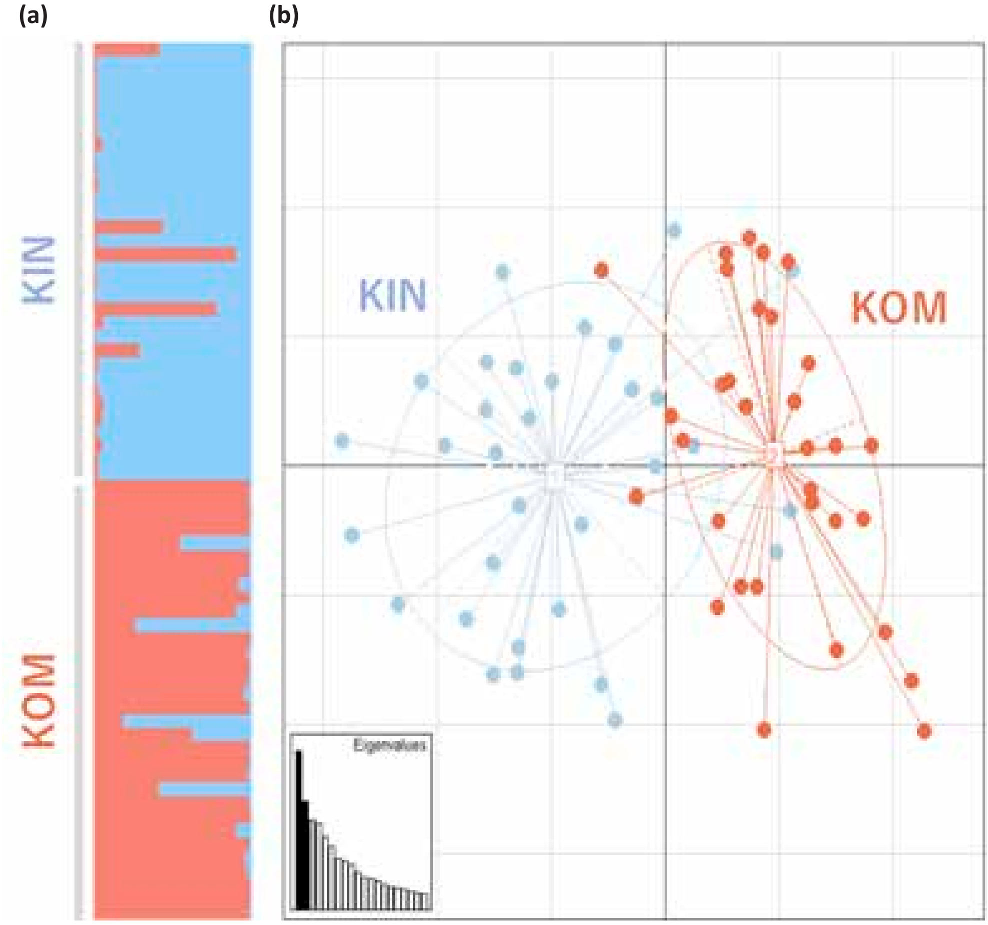


Figure 3. Genetic structure of 64 individuals of *Primula reinii* in the Hakone volcano. a—Assignment of individuals to clusters based on a STRUCTURE analysis for *K* = 2. b—Plots of individual scores on the principal component analysis (axis 1–2 are shown). Each plot is connected by a line to the 95% confidence ellipse centroid of the respective population. KIN and KOM are represented population codes.

Table 2. Genetic diversity and detection of a recent population bottleneck of the two *Primula reinii* populations.

Pop. code	Genetic diversity measurements					*P* values of Wilcoxon test			*M*-ratio	
	A	A_E	A_P	H_E	F_{IS}	IAM	SMM	TPM	Mean	SD
KIN	6.3	3.3	2.9	0.652	0.068	0.109	0.297	0.813	0.312	0.221
KOM	6.1	2.6	1.9	0.544	0.073	0.296	0.007	0.015	0.338	0.199
total	9.0	2.8	-	0.598	0.070	-	-	-	-	

A, mean number of alleles; A_E, mean number of effective alleles; A_P, mean number of private alleles; H_E, expected heterozygosity; F_{IS}, coefficient of inbreeding; IAM, infinite allele model; SMM, stepwise mutation model; TPM, two-phase mutation model.

population (0.227 and 0.114, respectively). As the presence of null alleles may affect the estimation of genetic diversity or differentiation, we excluded the two loci and repeated several analyses to compare results between seven and five microsatellites. This trial revealed no clear difference in the results based on 5 vs. 7 loci (Table S2). Thus, seven loci were used in all analyses described below.

Genetic diversity parameters for the two populations are presented in Table 2. In total, 63 alleles were amplified by seven microsatellite markers, with an average 9.0 alleles per locus. All diversity measurements were slightly higher in the KIN population (A = 6.3, A_E = 3.3, A_P = 2.9 and H_E = 0.652) than in the KOM population

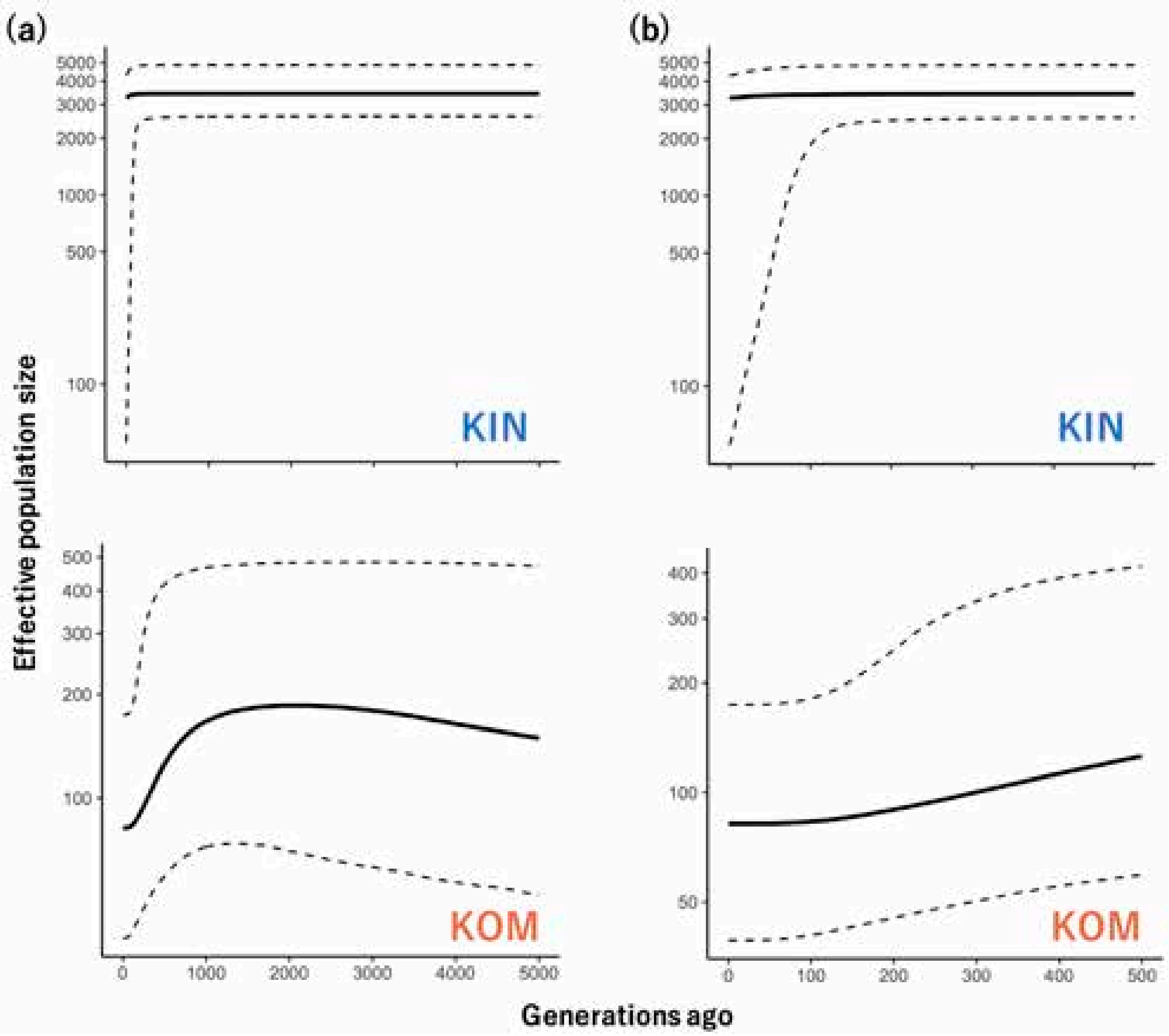


Figure 4. Estimates of effective population size of the two populations for a—the past 5,000 generations, and b—the past 500 generations. Bold lines indicate the median estimations, while the dashed lines above and below represent the 95% highest posterior density intervals.

($A = 6.1$, $A_E = 2.6$, $A_P = 1.9$ and $H_E = 0.544$). The inbreeding coefficient value (F_{IS}) was positive and comparable between the populations, but each value did not deviate significantly from zero.

Genetic structure and evidence a recent bottleneck

A moderate genetic differentiation was detected between populations ($F_{ST} = 0.115$, $P < 0.001$; $G'_{ST} = 0.286$). The STRUCTURE analysis based on the ΔK method indicated that ΔK was 462.5 for $K = 2$ and ΔK were <3 for other values of K. Therefore, the optimal ΔK for $K = 2$ showed that the best-fit model for the 64 sampled individuals of *P. reinii* revealed two clusters (Fig. 3a). Although several admixed individuals were found in each population, all samples formed a clear genetic structure between the two populations. The F values of clusters produced by STRUCTURE analysis were higher in the KOM population ($F = 0.186$) than in the KIN population ($F = 0.086$), indicating that the KOM population had undergone a larger genetic drift compared to that of the KIN population. In the PCA (Fig. 3b), the first two axes explained 17.0% and 10.7% of the variances in the experimental data, respectively. The results also distinguished the two populations, suggesting the existence of two genetic units corresponding to each population.

In BOTTLENECK analyses, the two-tailed Wilcoxon signed-rank test provided statistical support ($P < 0.025$) to the presence of a recent bottleneck in the KOM population under the SMM and TPM, whereas no evidence was found in KIN (Table 2). On the contrary, the *M*-ratio test indicated that both populations experienced a reduction in population size. The *M*-ratio values were 0.312 and 0.338 for the KIN and KOM populations, respectively (Table 2). A clear signature of historical population contraction was detected only in KOM via the third method, the Bayesian population demographic analysis. The bottleneck began approximately 1,000 generations ago (Fig. 4a), whereas a gradual decline was settled at least 100 generations ago (Fig. 4b). In contrast, the KIN population seems to have historically had a large constant population size (Fig. 4a); however, recent changes were unclear due to the broad confidence levels (Fig. 4b).

DISCUSSION

Reproductive status and genetic diversity

The observed low reproduction in KOM is congruent with reports that morph-biased populations experience reduced reproduction (Byers & Meagher 1992; Kery et al. 2003; Wang et al. 2005; Pedersen et al. 2016). Given that almost all stigmas were covered with L-morph pollen grains (Fig. 2), it is plausible that frequent self- or intra-morph (i.e., illegitimate) pollination had occurred among the KOM L-morphs. Therefore, our ecological data indicate that the low fruiting success in KOM L-morphs was caused by stigmatic clogging (Yeo 1975) as a consequence of the skewed morph ratio. Because L-morph flowers generally produce greater amounts of pollen grains than S-morph flowers (Richards 2003), it is apparent that the total pollen pool within KOM was occupied by a large amount of L-morph pollen. Similar to our results, previous studies in distylous plants showed higher female reproductive success in the relatively less abundant morph than the dominant morph (e.g., Wyatt & Hellwig 1979; Thompson et al. 2003; Wang et al. 2005; García-Robledo & Mora 2007). Thus, these results may demonstrate negative frequency-dependent patterns of reproductive success in the distylous primrose.

The indices of genetic diversity were relatively high and comparable between the two populations (Table 2), despite the skewed morph ratio observed. In addition, each population exhibited low F_{IS} levels with no significant deviation from the Hardy–Weinberg equilibrium. These results allow for the conclusion that *Primula reinii* growing in the volcano had maintained sufficient genetic diversity as a result of outbreeding.

Overall, this study suggests the persistence of distylous self-incompatibility system in the *P. reinii* populations. Nevertheless, determination of the exact causes of floral morph bias in KOM was not possible based on the limited ecological and genetic data currently available. Because skewed morph ratios are often explained by several biotic and abiotic factors as discussed in the Introduction, there is a need for future studies investigating the ability of selfing and intra-morph mating, maternal fitness differences between morphs, pollinator assemblage, and population demography.

Genetic differentiation and structure

Our molecular analysis showed that genetic differentiation was moderate between the two populations (F_{ST} = 0.115). Additionally, signs of genetic admixture between the populations were detected in PCA and STRUCTURE analyses (Fig. 3). There are at least two non-exclusive explanations for this: recent lineage divergence and gene flow. According to accumulated geographical surveys, Mt. Kintoki (locality of KIN pop.) and Mt. Komagatake (locality of KOM pop.) formed approximately ca 350–300 ka (Nagai & Takahashi 2008) and ca 27–20 ka (Kobayashi 1999; Nagai & Takahashi 2008), respectively. Formation of the central cone (i.e., Mt. Komagatake) clearly corresponded to the period of the last glacial maximum (LGM; ca 25–15 ka), suggesting that the KOM population was established at least after the last glacial period. The observed high *F* value (STRUCTURE analysis) and low private alleles in KOM may support a migration scenario that the population experienced a founder effect arising from a post-glacial refugial isolation and subsequent migration from the lowland of the caldera to the high-altitude areas of the central cone during the late Pleistocene and Holocene. Hence, it is plausible that the detected genetic admixture between populations suggests incomplete lineage sorting (i.e., sharing ancestral polymorphism between populations) due to recent lineage divergence.

Given the geographically close relationship between the populations (Fig. 1b), the presence of contemporary gene flow will also be taken into consideration. Because the two populations are severely isolated by a volcanic landform, gene flow mediated by pollen would be a plausible hypothesis. Moreover, in the flowering season we found claw marks, a useful indicator for the pollination services provided by bumblebees (Washitani et al. 1994), on the petals of each population. This may suggest that the bumblebees have a key role in pollination within the *Primula reinii* populations. Although bumblebees are known as strong-flying insects (e.g., Rao & Strange 2012), previous observations in other *Primula* species have demonstrated that pollen transfer by bumblebees generally occurs within short distances (e.g., Ishihama et al. 2006). Therefore, we determined that the pollen flow between the populations might occur contemporarily but on very rare occasions. Nevertheless, deciding among the possible explanations for the genetic composition of the primrose in the Hakone volcano is difficult due to the weak evidence based on an insufficient number of loci.

Recent and historical demography

The two tests for a recent bottleneck yielded mixed results (Table 2). Based on the BOTTLENECK analysis, only the KOM population exhibited excess heterozygosity. In contrast, the *M*-ratio test supported a recent population size reduction in both populations. As mentioned above, however, because these inconsistent results might be attributed to the low statistical power of our sample size (e.g., number of loci or individuals), our results should be interpreted with caution. Nevertheless, such conflicting results often indicate the severity or timing of the reduction in population size (Williamson-Natesan 2005; Marshall et al. 2009; Padilla et al. 2015; Tóth et al. 2019), and were expected due to the differences in power detecting a bottleneck (Peery et al. 2012).

Considering the robust results in KOM, it is likely that the morph-biased population may have undergone more recent and severe bottlenecks in comparison with another population. In theory, the BOTTLENECK analysis can demonstrate population bottlenecks over a period of 0.2–4.0 Ne generations (Cornuet & Luikart 1996). Assuming for KOM population of Ne = 100 (Fig. 4) and a generation time of 2–3 years, it translates into approximately 50–1000 years before the present. On the other hand, a clear sign of recent (within 100 generations) population bottleneck was not found in the Bayesian demographic analysis (Fig. 4). Therefore, based on results from a series of demographic analyses, it is difficult to draw a definitive conclusion on whether recent bottlenecks occur or not, and thus, we defer a final conclusion until more genetic data are available in the future.

Contrary to this, the Bayesian demographic analysis provided strong evidence in support of a historical population bottleneck in KOM inhabiting the central volcanic cone. The first signs of population decline would have occurred 2–3 ka (assuming a generation time of 2–3 years). This timeframe post-dates a climatic warming, known as the Jomon optimum transgression, that occurred approximately 6ka, implying that historical population bottlenecks were likely due to volcanic activities as opposed to climatic events. According to geological records, the last major eruption of the volcano was from the central cone in 2.7–2.9 ka (Kobayashi 1997; Kobayashi et al. 2006), and intermittent phreatic eruptions continued until present-day. Although speculative, these evidences may support the idea that the historical population declines experienced by the KOM could have been associated with repeated eruptive activities in the central cone. Perhaps, the detected recent bottlenecks in KOM are caused by eruptive activities rather than human activities.

On the other hand, the estimated effective population size in the KIN population inhabiting the somma mountains was large and constant in the long term, suggesting that the population has been maintained without suffering from volcanic eruptions occurring in the central cone. Further studies for the lineage divergence and demographic history of *P. reinii* in this region, using more informative datasets (e.g., single nucleotide polymorphisms), will be valuable because volcanism is one of the key abiotic factors in the plant's diversification and distribution in Japan (e.g., Yoichi et al. 2017; Nagasawa et al. 2020), located in the Pacific Ring of Fire.

Implication for conservation

Our study suggests that morph imbalances are striking effects on the reproduction of *P. reinii* population in the short-term. Accordingly, a measure of morph ratio should be given top priority in conservation management of the species, and enhancement of habitat monitoring should be considered as in situ managements to protect remnant individuals and to maintain optimum morph frequencies from horticultural exploitation. Considering the observed negative frequency-dependent patterns of reproductive success, if heteromorphic self-incompatibility is totally strict in *P. reinii*, the skewed morph ratio in KOM may be improved in the future when regeneration is successful. However, the exact breeding system of the species remains poorly understood. Therefore, in addition to other examinations (e.g., the germination requirements and the effect of storage time of seeds) towards a future ex situ conservation strategy, the levels of within morph fertility and selfing ability should be resolved immediately to evaluate the medium- to long-term risk of extinction in the remnant populations across species distribution ranges.

The two surveyed populations in the Hakone volcano were distinguished by two genetic clusters, suggesting that each population should be divided into a different management unit to maintain evolutionary distinctiveness and ecological viability (Moritz 1994; Frankham et al. 2002). The moderate genetic differentiation and the presence of large amounts of private alleles between the populations highlight this suggestion; thus, artificial inter-population crossing should be avoided in this case. Nevertheless, the lack of samples from other parts of the volcano will influence the estimated genetic structure. Thus, an exhaustive population sampling, including other remnant small population, is required to elucidate the genetic structure and demographic history of *P. reinii* occurring in the Hakone volcano as is also needed for planning conservation strategies.

To our knowledge, this is the first conservation genetics study on threatened plants in the Hakone volcano, which harbors approximately 1,800 plant species (Tanaka 2008). Thus, the results discussed here will be useful for designing both in situ and ex situ conservation strategies for *P. reinii* as well as other plants inhabiting the volcano and shed light on the instability of plant populations due to the impacts of volcanism and human activities. Our study highlights the importance of studies in conservation, integrating ecological and genetic approaches to accurately assess the population status of endangered species and draw up effective conservation strategies.

REFERENCES

Barret, S.C. (1989). The evolutionary breakdown of heterostyly, pp. 151–169. In: Bock J.H & Y.B. Linhart (eds.). *The Evolutionary Ecology of Plants*. Westvier Press, USA, 614pp. https://doi.org/10.1201/9780429310720

Barrett, S.C. (2002). Evolution of sex: the evolution of plant sexual diversity. *Nature Reviews Genetics* 3: 274.

Barrett, S.C. & J.S. Shore (2008). New insights on heterostyly: comparative biology, ecology and genetics, pp. 3–32. In: Franklin-Tong V. (ed.). *Self-incompatibility in Flowering Plants*. Springer, Germany, XLI+313pp. https://doi.org/10.1007/978-3-540-68486-2

Brys, R., H. Jacquemyn & T. Beeckman (2008). Morph-ratio variation, population size and female reproductive success in distylous *Pulmonaria officinalis* (Boraginaceae). *Journal of Evolutionary Biology* 21: 1281–1289.

Byers, D.L. & T.R. Meagher (1992). Mate availability in small populations of plant species with homomorphic sporophytic self-incompatibility. *Heredity* 68: 353–359.

Cornuet, J.M. & G. Luikart (1996). Description and power analysis of two tests for detecting recent population bottlenecks from allele frequency data. *Genetics* 144: 2001–2014.

Dempster, A.P., N.M. Laird & D.B. Rubin (1977). Maximum likelihood from incomplete data via the EM algorithm. *Journal of the Royal Statistical Society. Series B (methodological)* 39: 1–22.

Earl, D.A. & B.M. vonHoldt (2012). STRUCTURE HARVESTER: a website and program for visualizing STRUCTURE output and implementing the Evanno method. *Conservation Genetics Resources* 4: 359–361.

Estoup, A., P. Jarne & J.M. Cornuet (2002). Homoplasy and mutation model at microsatellite loci and their consequences for population genetics analysis. *Molecular Ecology* 11: 1591–1604.

Evanno, G., S. Regnaut & J. Goudet (2005). Detecting the number of clusters of individuals using the software STRUCTURE: a simulation study. *Molecular Ecology* 14: 2611–2620.

Excoffier, L., G. Laval & S. Schneider (2005). Arlequin (version 3.0): An integrated software package for population genetics data analysis. *Evolutionary Bioinformatics* 1: 47–50.

Frankham, R., D.A. Briscoe & J.D. Ballou (2002). *Introduction to conservation genetics*. Cambridge university press, UK.

García-Robledo, C. & F. Mora (2007). Pollination biology and the impact of floral display, pollen donors, and distyly on seed production in *Arcytophyllum lavarum* (Rubiaceae). *Plant Biology* 9: 453–461.

Garza, J.C. & E.G. Williamson (2001). Detection of reduction in population size using data from microsatellite loci. *Molecular Ecology* 10: 305–318.

Hedrick, P.W. (2005). A standardized genetic differentiation measure. *Evolution* 59: 1633–1638.

Heuch, I. (1979). Equilibrium populations of heterostylous plants. *Theoretical Population Biology* 15: 43–57.

Hodgins, K.A. & S.C. Barrett (2006). Female reproductive success and the evolution of mating-type frequencies in tristylous populations. *New Phytologist* 171: 569–580.

Ishihama, F., S. Ueno, Y. Tsumura & I. Washitani (2006). Effects of density and floral morph on pollen flow and seed reproduction of an endangered heterostylous herb, *Primula sieboldii*. *Journal of Ecology* 94: 846-855.

Jackson, P.W. & K. Kennedy (2009). The global strategy for plant conservation: a challenge and opportunity for the international community. *Trends in Plant Science* 14: 578–580.

Jombart, T. (2008). adegenet: a R package for the multivariate analysis of genetic markers. *Bioinformatics* 24: 1403–1405.

Kéry, M., D. Matthies & B. Schmid (2003). Demographic stochasticity in population fragments of the declining distylous perennial *Primula veris* (Primulaceae). *Basic and Applied Ecology* 4: 197–206.

Kitamoto, N., M. Ueno, Y. Tsumura, I. Washitani & R. Ohsawa (2005). Development of microsatellite markers in *Primula sieboldii* E. Morren, a threatened herb. *Japanese Journal of Conservation Ecology* 10: 47–51.

Kobayashi, M. (1997). ^{14}C ages of pyroclastic-flow deposits from central cones on the western slope of old somma of Hakone volcano, central Japan. *Bulletin of Volcanological Society of Japan* 42: 355–358.

Kobayashi, M. (1999). Tephrochronology and eruptive activity on Hakone volcano in the past 50 ka. *The Quaternary Research* 38: 327–343.

Kobayashi, M., K. Mannen, M. Okuno, T. Nakamura & K. Hakamata (2006). The Owakidani Tephra group: A newly discovered post-magmatic eruption product of Hakone Volcano, Japan. *Bulletin of Volcanological Society of Japan* 51: 245–256.

Kopelman, N.M., J. Mayzel, M. Jakobsson, N.A. Rosenberg & I. Mayrose (2015). Clumpak: a program for identifying clustering modes and packaging population structure inferences across K. *Molecular Ecology Resources* 15: 1179–1191.

Marshall, J., B. Kingsbury & D. Minchella (2009). Microsatellite variation, population structure, and bottlenecks in the threatened copperbelly water snake. *Conservation Genetics* 10: 465–476.

Matsumura, C. & I. Washitani (2000). Effects of population size and pollinator limitation on seed-set of *Primula sieboldii* populations in a fragmented landscape. *Ecological Research* 15: 307–322.

Meirmans, P.G. & P.H. van Tienderen (2004). GENOTYPE and GENODIVE: two programs for the analysis of genetic diversity of asexual organisms. *Molecular Ecology Notes* 4: 792–794.

Meeus, S., O. Honnay, R. Brys & H. Jacquemyn (2012). Biased morph ratios and skewed mating success contribute to loss of genetic diversity in the distylous *Pulmonaria officinalis*. *Annals of Botany* 109: 227–235.

Ministry of the Environment (2019). The Japanese red lists 2019. Retrieved from http://www.env.go.jp/press/files/jp/110615.pdf

Moritz, C. (1994). Defining 'evolutionarily significant units' for conservation. *Trends in Ecology & Evolution*, *9*, 373–375.

Nagai, M. & M. Takahashi (2008). Geology and eruptive history of Hakone volcano, central Japan. *Research Report of the Kanagawa Prefectural Museum Natural history*, 13: 25–42.

Nagasawa, K., H. Setoguchi, M. Maki, H. Goto, K. Fukushima, Y. Isagi, Y. Suyama, A. Matsuo, Y. Tsunamoto, K. Sawa & S. Sakaguchi (2020). Genetic consequences of plant edaphic specialization to solfatara fields: Phylogenetic and population genetic analysis of *Carex angustisquama* (Cyperaceae). *Molecular Ecology* 29(17): 3234–3247. https://doi.org/10.1111/mec.15324

Nikolic, N. & C. Chevalet (2014). Detecting past changes of effective population size. *Evolutionary Applications* 7: 663–681.

Osawa, T. & S. Inohara (2008). Understanding current status and factors of degradation of threatened plants in the Hakone region of the Fuji-Hakone-Izu National Park –Investigation using park volunteer research data. *Japanese Journal of Conservation Ecology* 13: 179–186.

Padilla, D.P., L.G. Spurgin, F.A. Fairfield, J.C. Illera & D.S. Richardson (2015). Population history, gene flow, and bottlenecks in island populations of a secondary seed disperser, the southern grey shrike (*Lanius meridionalis* koenigi). *Ecology and Evolution* 5: 36–45.

Pedersen, J.L., S.E. Macdonald & S.E. Nielsen (2016). Reproductive ecology of the distylous species *Houstonia longifolia*: implications for conservation of a rare species. *Botany* 94: 983–992.

Peery, M.Z., R. Kirb, B.N. Reid, R. Stoelting, E.L.E.N.A. Doucet-Bëer, S. Robinson, C. Vásquez-Carrillo, J.N Pauli & P.J. Palsbøll (2012). Reliability of genetic bottleneck tests for detecting recent population declines. *Molecular Ecology* 21: 3403–3418.

Piry, S., G. Luilart & J.M. Cornuet (1999). BOTTLENECK: a computer program for detecting recent reductions in the effective population size using allele frequency data. *Journal of Heredity* 90: 502–503.

Pritchard, J.K., M. Stephens & P. Donnelly (2000). Inference of population structure using multilocus genotype data. *Genetics* 155: 945–959.

R Core Team (2018). R: A Language and Environment for Statistical Computing. Retrieved from https://www.r-project.org/

Rao, S. & J.P. Strange (2012). Bumble bee (Hymenoptera: Apidae) foraging distance and colony density associated with a late-season mass flowering crop. *Environmental entomology* 41: 905–915.

Raymond, M. & F. Rousset (1995). Genepop (Version-1.2) –population-genetics software for exact tests and Ecumenicism. *Journal of Heredity* 86: 248–249.

Richards, J. (2003). *Primula*. Timber Press, USA.

Takakura, K. (2011). Improved method of plant DNA extraction using glass-fiber filter. *Bunrui*, 11: 139–149.

Tanaka, N. (2008). Plants in Hakone [translated from Japanese]. *Newsletter of the Kanagawa Prefectural Museum of Natural History*, 14: 21.

Thompson, J.D., S.C. Barrett & A.M. Baker (2003). Frequency–dependent variation in reproductive success in Narcissus: implications for the maintenance of stigma–height dimorphism. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 270: 949–953.

Tóth, E.G., F. Tremblay, J.M. Housset, Y. Bergeron & C. Carcaillet (2019). Geographic isolation and climatic variability contribute to genetic differentiation in fragmented populations of the long-lived subalpine conifer *Pinus cembra* L. in the western Alps. *BMC Evolutionary Biology* 19: 190.

Ueno, S., Y. Tsumura & I. Washitani (2003). Development of microsatellite markers in *Primula sieboldii* E. Morren, a threatened Japanese perennial herb. *Conservation Genetics* 4: 809–811.

Ueno, S., N. Kitamoto, R. Ohsawa, Y. Tsumura & I. Washitani (2006). Nine additional microsatellite markers for *Primula sieboldii* E. Morren. *Conservation Genetics* 6: 1063–1064.

Ueno, S., Y. Yoshida, Y. Taguchi, M. Honjo, N. Kitamoto, I. Washitani, R. Ohsawa & Y. Tsumura (2009). Development of 120 microsatellite markers for *Primula sieboldii* E. Morren for linkage mapping. *Conservation Genetics* 10: 1945–1952.

van Rossum, F. & L. Triest (2006). Within-population genetic variation in the distylous *Primula veris*: Does floral morph anisoplethy matter in fragmented habitats?. *Perspectives in Plant Ecology, Evolution and Systematics* 7: 263–273.

van Rossum, F., S.C. De Sousa & L. Triest (2006). Morph-specific differences in reproductive success in the distylous *Primula veris* in a context of habitat fragmentation. *Acta Oecologica* 30: 426–433.

Wang, Y., Q.F. Wang, Y.H. Guo & S.C. Barrett (2005). Reproductive consequences of interactions between clonal growth and sexual reproduction in *Nymphoides peltata*: a distylous aquatic plant. *New Phytologist* 165: 329–336.

Washitani, I. (1996). Predicted genetic consequences of strong fertility selection due to pollinator loss in an isolated population of *Primula sieboldii*. *Conservation Biology* 10: 59–64.

Washitani, I., M. Kato, J. Nishihiro & K. Suzuki (1994). Importance of queen bumble bees as pollinators facilitating inter-morph crossing in *Primula sieboldii*. *Plant Species Biology* 9: 169–176.

Washitani, I., F. Ishihama, C. Matsumura, M. Nagai, J. Nishihiro & M. Nishihiro (2005). Conservation ecology of *Primula sieboldii*: synthesis of information toward the prediction of the genetic/demographic fate of a population. *Plant Species Biology* 20: 3–15.

Wilcock, C. & R. Neiland (2002). Pollination failure in plants: why it happens and when it matters. *Trends in plant science* 7: 270–277.

Williamson-Natesan, E.G. (2005). Comparison of methods for detecting bottlenecks from microsatellite loci. *Conservation Genetics* 6: 551–562.

Wyatt, R. & R.L. Hellwig (1979). Factors determining fruit set in heterostylous bluets, Houstonia caerulea (Rubiaceae). *Systematic Botany* 4: 103–114.

Yamamoto, M., K. Horita, D. Takahashi, Y. Murai & H. Setoguchi (2018). Floral morphology and pollinator fauna of sister species *Primula takedana* and *P. hidakana* in Hokkaido Island, Japan. *Bulletin of the National Museum of Nature and Science Series B* 44: 97–103.

Yamamoto, M., K. Kurata & H. Setoguchi (2017). Conservation genetics of an ex situ population of *Primula reinii* var. *rhodotricha*, an endangered primrose endemic to Japan on a limestone mountain. *Conservation Genetics* 18: 1141–1150.

Yamamoto, M., M. Yasui, H. Setoguchi & K. Kurata (2013). Conservation of an endangered perennial herb, *Primula reinii* var. *rhodotricha*. *Journal of Nature Restoration and Conservation* 6: 23–29.

Yoichi, W., X.F. Jin, C.I. Peng, I. Tamaki & N. Tomaru (2017). Contrasting diversification history between insular and continental species of three-leaved azaleas (*Rhododendron* sect. *Brachycalyx*) in East Asia. *Journal of Biogeography* 44: 1065–1076.

Table S1. Prior parameter settings for each population using VarEff software.

Parameters	KIN	KOM	Description
JMAX	4	4	Number of when the effective size has changed
DMAX	10	7	the maximal distance between alleles
NBAR	100	100	prior value for the effective population size
RHOCORN	0	0	coefficient of correlation between effective population size in successive intervals
VARP1	3	3	variance of prior log-distribution of effective population size
VARP2	3	3	variance of prior log-distribution of time intervals
GBAR	10000	5000	number of generations since the assumed origin of the population
Diagonale	0.5	0.5	a smoothing parameter

Table S2. Genetic diversity measurements and population differentiation between the two populations based on the selected five loci (*ga0161*, *ga0218*, *ga0580*, *ga0691* and *Pri0141*).

Pop. code	A	A_E	H_E	F_{IS}	F_{ST}	G'_{ST}
KIN	6.0	3.3	0.637	0.020	0.111	0.249
KOM	5.0	2.1	0.472	0.029		

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17276–17286

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

DOI: https://doi.org/10.11609/jott.6243.12.17.17276-17286

#6243 | Received 29 May 2020 | Final received 10 November 2020 | Finally accepted 02 December 2020

A review about fish walking on land

Arumugam Kumaraguru [1], **Rosette Celsiya Mary** [2] & **Vijayaraghavalu Saisaraswathi** [3]

[1] Honorary Wildlife Warden, Thiruvarur Forest Division, Tamil Nadu Forest Department, Tamil Nadu 620021, India.
[1] Biodiversity Conservation Foundation, #360, Indira Gandhi Street, KK.Nagar, Trichy, Tamil Nadu 620021, India.
[2] Nature Club, [2,3] School of Advanced Sciences, Vellore Institute of Technology University, Vellore, Tamil Nadu 632007, India.
[1] tiger.kguru@gmail.com, [2] rosetconserve@gmail.com, [3] sainaturevit@gmail.com (corresponding author)

Abstract: Mudskippers are amphibious species inhabiting semi-terrestrial ecosystems like mudflats, mangroves, marshy swamps, intertidal regions, and estuaries. Around 34 diversified species are found across the globe. Mudskipper belongs to the Oxudercidae family and the subfamily is Oxudercinae. The occurrence of species is vastly found across the Indo-West Pacific region, the tropical western coast of Africa and in the Indian Ocean. Mudskippers are known for being the biological indicator and also an indicator of estuarine safety monitoring. They are used by people for prey-catching baits. This review paper explains the ecological indicators, taxonomy, species diversity, habitat, behavioural pattern, respiration & kinematics, feeding ecology, reproduction, nutrition content & its medicinal value, and threats to mudskippers.

Keywords: Amphibious fish, distribution, ecological indicator, mudskippers, species diversity.

பரவெட்டிமீன்(மட்ஸ்கிப்பர்(கள்) (Mudskipper) நிலநீர் வாழிகள் வகுப்பைச்சார்ந்த, சேற்று திட்டுகள், சதுப்புநிலங்கள், அலைஏற்ற பகுதிகள், ஆற்று முகத்துவாரம் மற்றும் கழிநிலங்கள் போன்ற பகுதிகளை வாழ்விடமாக கொண்டவை. ஏறக்குறைய 34 பன்முகப்பட்ட பரவெட்டிமீன் இனங்கள் உலகில் காணப்படுகின்றன. பரவெட்டிமீன்/மட்ஸ்கிப்பர்கள் ஆக்ஸூடெர்சிடே கோபிடே (Oxudercidae Gobiidae) குடும்பத்தை சேர்ந்தவை. இந்தோ-மேற்கு பசிபிக் பகுதி, ஆப்பிரிக்காவின் வெப்பமண்டல மேற்கு கடற்கரை மற்றும் இந்தியப் பெருங்கடலில் இந்த உயிரினங்களின் நிகழ்வு பரவலாகக் காணப்படுகிறது. பரவெட்டிமீன் உயிரியல் குறிகாட்டியாகவும், ஆற்று முகத்துவாரம்களின் பாதுகாப்பு கண்காணிப்பின் குறிகாட்டியாகவும் அறியப்படுகின்றன. மனிதர்களின் பயன்பாட்டிற்கு பெரிதும் உபயோகபடாததால், இவை பெரும்பாலும் இரையை பிடிக்கும் தூண்டிலில் பயன்படுத்தப்படுகின்றன. இந்த ஆய்வுக் கட்டுரை, சுற்றுச்சூழல் குறிகாட்டிகள், வகைபிரித்தல், இனங்களின் பன்முகத்தன்மை, வாழ்விடம், நடத்தை முறை, சுவாசம் மற்றும் இயக்கவியல், உணவு சூழலியல், இனப்பெருக்கம், ஊட்டச்சத்து தரவுகள், அதன் மருத்துவ மதிப்பு மற்றும் அபாயங்கள் ஆகியவற்றை விளக்குகிறது.

Editor: A. Biju Kumar, University of Kerala, Thiruvananthapuram, India.

Date of publication: 26 December 2020 (online & print)

Citation: Kumaraguru, A., R.C. Mary & V. Saisaraswathi (2020). A review about fish walking on land. *Journal of Threatened Taxa* 12(17): 17276–17286. https://doi.org/10.11609/jott.6243.12.17.17276-17286

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Dr. A. Kumaraguru is working as conservation scientist specialized in wildlife biology and genetic studies on tiger. Ms. Rosette is currently doing her MSc in biotechnology and her research interests include marine biology, biodiversity and conservation, phytochemical studies, molecular docking. Dr. V. Sai Saraswathi is an expert in environmental sciences, working for the conservation of biodiversity, climate change, ethnobotany, pharmacognosy, and phytochemistry.

Author contribution: In this review paper, VS contributed in the literature review collection, paper editing, proof reading. ER collected literature review, paper drafting. AK prepared the review design, proof reading and editing. All authors were involved in the mansuscript revision.

INTRODUCTION

Osche (1962) suggested that mudskippers would be useful for interpreting the transition of species from water to land. There is some evidence about the transition of fishes to tetrapods, which occurred more than 360 million years ago (Ulrich & Elliott 2013). There are about 40 species classified under 10 genera. Mudskippers predominantly inhabit the mangrove forest and mudflats of the Indo-West Pacific region, the tropical western coast of Africa, and Indian Ocean coastlines. Mudskippers are known to be burrow dwellers preferring the swampy marshes, estuaries, and the intertidal regions for their living (Murdy 1989). The feeding ecology of the Mudskipper *Periophthalmus barbarous* was found to be 'opportunistic feeders' meant to be satisfying the food needs with the available resources (Chukwu & Deekae 2013). Generally, mudskippers feed on algae, detritus, diatoms, nematode, polychaetes and eggs of fishes, along with mud and sand particles (Ravi 2013).

Since long ago, researchers have explored mudskipper's distribution pattern, species diversity, behavioural patterns and their locomotory activities. In 1989, Murdy studied the morphological features of mudskippers, which paved the way for taxonomic classification of mudskippers. Also, he hypothesized the relationship of *Oxudericnae* gobies with other genera and groups. Mudskipper's early developmental age & growth, respiratory & circulatory adaptations, and feeding ecology were also studied by many researchers across the globe (Jaafar & Murdy 2017).

Due to the medicinal properties found in mudskippers, it gains commercial value either through food consumption or as traditional medicine by humans (Kanejiya et al. 2017a). Sometimes they are even used as bait for catching prey (Gadhavi et al. 2017). A few of the vernacular names used in different places for referring to mudskippers are *Periophthalmus darwini*, *Periophthalmus* sp., and *Periophthalmus novaeguineaensis* as sakomo, *Periophthalmus* as nebesokera, *Periophthalmus weberi* as paraguamo, *Periophthalmodon freycineti* as genora, *Boleophthalmus caeruleomaculatus* as ebanea, *Boleophthalmus* sp. as poti, *Scarpellos histophorus* as seekakowea, *Oxuderces wirzi* as canipo (Polgar & Lim 2011). Mudskippers are known as 'vaetti uluvai' in Tamil (Ragunathan 2010).

Ecological Indicator

Monitoring the intertidal and estuarine health depending on their abundance mudskippers have direct affection towards salinity and temperature variations (Kanejiya et al. 2017c). They also contribute towards the growth of mangrove trees, when the population of mudskippers is abundant, consequently providing appropriate nutrients supporting the growth of mangroves (Shenoy et al. 2012).

Polgar (2009) attempted the studies of Malayan mudskippers as a biomonitor in mangroves concerning species area relationship (SAR) and revealed that the destruction of habitats resulted from reduced species abundance. Mudskippers bioaccumulate pollutants through ingestion as they tend to be prey for many mudflat species. Mudskippers ensure the coastal, intertidal, and estuary's health (Polgar & Lim 2011). Studies have shown that mudskippers act as a biological indicator of addressing the severity of oil pollution in the coastal areas of the Persian Gulf. Biomarker responses of *Periophthalmus waltoni* were recorded and discovered that it acts as the ideal candidate for bioindicator in the coastal regions and mudflats. Correspondingly, it can be utilized for achieving sustainable development (Shirani et al. 2012).

Similarly, at Kuwait Bay, *Periophthalmus waltoni* acts as a bioindicator in identifying the bioaccumulation of metals (Bu-Olayan & Thomas 2008). It tends to be a feeble indicator at the Persian Gulf marine ecosystem, a biomonitor candidate-Boleophthalmus dussumieri used in the monitoring of polycyclic aromatic compounds (PAH). It might be various other environmental factors which are acting in that ecosystem leading *B. dussumieri* to be helpless (Sinaei & Mashinchian 2014). Metal toxicity and accumulation of metal toxicants like Zn, Cd, Pb, Cu have suggested that mudskippers are an ideal biomonitor. It was observed that their fins and liver are the biomonitors and accumulate metal toxins. Due to the contaminants of various metal pollutant, it is not recommended for human consumptions (Ikram et al. 2010).

Taxonomy

Mudskippers belong to the family Oxudercidae and the subfamily *Oxudercinae*. Some of the species are tabulated in Table 1 and Image 1.

Species Diversity

Globally, 34 diverse species of mudskippers were recognized, and among them, nine were found in Indian coastlines (Murdy et al. 1989). Nearly five diversified mudskipper species have been effectively documented from Gujarat coastlines (Devendra et al. 2016). In the southeastern coast of India, mudskippers were recorded

Table 1. Taxonomic rank, genus, and species of mudskippers around the world with reference to various authors belonging to different periods.

	Tribe (taxonomic rank)	Genus	Species	References
1	*Oxudercini*	Parapocryptes	*Parapocryptes rictuosus,* *Parapocryptes serperaster*	Valenciennes 1846
2	*Oxudercini*	Apocryptodon	*Apocryptodon madurensis,* *Apocryptodon punctatus*	Tomiyama 1934
4	*Oxudercini*	Oxuderces	*Oxuderces dentatus,* *Oxuderces wirzi*	Koumans 1938
5	*Periophthalmini*	Apocryptes	*Apocryptes bato*	Hamilton 1822
6	*Periophthalmini*	Pseudapocryptes	*Pseudapocryptes borneensis,* *Pseudapocryptes lanceolatus*	Bloch & Schneider 1801
7	*Periophthalmini*	Zappa	*Zappa confluentus*	Roberts 1978
8	*Periophthalmini*	Scartelaos	*Scartelaos cantoris,* *Scartelaos gigas,* *Scartelaos histophorus,* *Scartelaos tenuis*	Chu & Wu 1963
9	*Periophthalmini*	Boleophthalmus	*Boleophthalmus hirdsongi,* *Boleophthalmus boddarti,* *Boleophthalmus caeruleomaculatus,* *Boleophthalmus dussumieri,* *Boleophthalmus pectinirostris,*	Pallas 1772
10	*Periophthalmini*	Periophthalmodon	*Periophthalmodon freycineti,* *Periophthalmodon schlosseri,* *Periophthalmodon septemradiatus,*	Valenciennes 1846; Pallas 1772 Hamilton 1822
11	*Periophthalmini*	Periophthalmus	*Periophthalmus argentilineatus,* *Periophthalmus harbarus,* *Periophthalmus chrysospilos,* *Periophthalmus gracilis,* *Periophthalmus kalolo,* *Periophthalmus malaccensis,* *Periophthalmus minutus,* *Periophthalmus modestus,* *Periophthalmus novaeguineaensis,* *Periophthalmus novemradiatus,* *Periophthalmus waltoni,* *Periophthalmus weberi*	Valenciennes 1846 Hamilton 1822

most during the post-monsoon season, and their preferred habitats are estuarine lands and mangrove areas. A group of eight species from the Malay Peninsula and 12 species from Sumatra is present along the Straits of Malacca (Takita & Ali 1999). Earlier, there were nine species of mudskippers recorded in peninsular Malaysia (Polgar 2009). Recent studies have updated the total count to 17 in peninsular Malaysia (Khaironizam & Rashid 2005). Nineteen species have been recorded recently in the Ramsar site, Johor, Malaysia (Hui et al. 2019). Some of the mudskipper species found in Merauke District, Indonesia are *Boleophthalmus boddarti, B. pectinirostris, P. takita, P. argentilineatus, Scartelaos histophorus,* and *Oxuderces dentatus* (Elviana et al. 2019). *Periophthalmus waltoni* is maximally distributed along the Persian Gulf though there are many threats to its population density (Sharifian et al. 2018). Though there is a diverse population of *Periophthalmus barbarus* around southeastern Nigeria, it is affected by overexploitation (Abiaobo & Udo 2017). People do not consume *Periophthalmus novemradiatus* as a result of which their growth rate is rapidly increasing along the Bakkhali River Estuary, Bangladesh (Rahman et al. 2015). Complete phylogeographic studies of *Periophthalmus* distributed along Indo-Pacific region helped to understand its evolutionary history (Polgar et al. 2014). *Periophthalmus spilotus*, a new species of mudskipper, was identified from Sumatra, Indonesia (Murdy & Takita 1999). Similarly, a new species *Parapocryptes serperaster* has been recorded in peninsular Malaysia (Khaironizam & Rashid 2000). *Periophthalmus walailakae* has been recorded in southeastern India (Mahadevan et al. 2019a). There were about 24 newly recorded species during the recent studies in Indonesian waters (Pormansyah et al. 2019).

Living Habitat

Mudskippers inhabit riparian areas with soft and muddy plains. Also, they inhabit where the salinity level is found to be low and the place rich with benthic invertebrates (Baeck et al. 2008). Numerous species were living on the rocky coastline as much, as they occupy mudflats, mangroves, and sand flats (Gordon et al. 1968). Rehabilitating the coastal region with mangrove

Image 1. Blue-spotted Mudskipper *Boleophthalmus boddarti*. © A. Kumaraguru

saplings gives a better habitat for various species, and it was observed that large-sized mudskippers were found in the breakwater (sheltered area for mangroves) (Hashim et al. 2010). *Pseudapocryptes elongatus* is able to tolerate the salinity, and hence it survives in the open sea, coastal mangroves and inland habitat during different stages of their growth (Bucholtz et al. 2009). Mudskippers alter the environmental conditions improving the growth of young mangroves as they mix the soil with detritus (Ravi et al. 2013). Studies related to the microhabitat selection of Chinese mudskippers identified their preferences, such as salinity levels, land or water; water and air temperatures; light or dark; and various combinations among them were conveyed (Gordon et al. 1985). The major threats to the mudflats are soil erosion, macro algae, terrestrialization, and lack of estuarine water, human interference, and discharge of effluents (Ravi 2012). *Periophthalmodon septemradiatus* species is found to be the first species inhabiting and breeding from a saline environment to a completely fresh water region of the Mekong River (Mai et al. 2019). *Boleophthalmus pectinirostris* has shown behavioural preferences in choosing their microhabitat at their early juvenile stage (Chen et al. 2008). To determine the habitat selection, genomic studies were performed, and also the comparative analysis among different species were conducted (Cai 1996). Different mudskippers inhabit different microhabitats and have different burrow construction methods (Clayton 1993). Habitat selection is dependent on its ecological interactions (Polgar & Crosa 2009). Some species such as *Periophthalmodon septemradiatus* is found to survive in habitats with low salinity and far from the sea, whereas *B. boddarti* survives close to the sea with high salinity (Khaironiazam & Rashid 2003). Mudskippers preferred thick mudflat areas for carrying out their burrowing activity effortlessly (Kanejiya et al. 2017c). Burrows constructed by *Bolephthalmus boddartti* are classified as follows: burrows with single apertures represent newly constructed one, and the other single and double openings ones currently exist. In contrast, the burrows with multiple apertures represent collapsed ones due to human interventions (Ravi et al. 2004).

Behavioral pattern of mudskipper

Population density is inversely proportional to the growth rate as the availability of food decreases due to an increased population. *Boleophthalmus pectinirostris* (Blue-spotted Mudskipper) is found to have the longest lifespan; seven and six years in males and females, respectively (Nanami & Takegaki 2005). A study on the terrestrial life of mudskippers with *Periophthalmus sobrinus* showed their survival capacity out of water is one and a half days. Surprisingly, there was no affection in metabolic and heart rates as well as the lactic acid concentration in blood during their living out of the water (Gordon et al. 1969). Whereas Chinese Mudskipper *Periophthalmus cantonensis* survives for two and a half days out of the water and observed medium sensitiveness of metabolism towards temperature. Starvation for 9.5 days did not affect the excretion of ammonia but affected excretion of urea (Gordon et al. 1978).

Boleophthalmus dussumieri has separate exit and entry for males and females. Juveniles pierce deep into mud during high tides. Adults neglect to build chimneys surrounding their holes as the consistency of the soil is between sand and clay (Rathod et al. 2019). Mudskippers growth rate is affected when being exposed to pollution at the embryonic stage (Kruitwagen et al. 2006). There is a significant role played by aquaporins (integral membrane proteins) for adapting themselves to the terrestrial lifestyle. The selective changes, like pore formation and substrate selection, have a substantial contribution to their adaptation to an amphibious lifestyle (Lorente-Martinez et al. 2018). The species *Periophthalmodon schlosseri* is found to be an ideal species for aquaculture and more mudskipper studies (Quang 2016). Mudskippers like *Boleophthalmus boddarti* constructs mud-walls, for territorial exclusion or spacing, territory, and reduces hostility. This is based on their abundance. These regional behavioural patterns give better knowledge about the elastic disc concept of territories (Clayton 1987). Mudflats are vital for the survival of mudskippers but global warming is a serious threat as the mudflats are greatly affected due to high temperature. Spawning season in *Scartelaos gigas* is from May to July. The growth rate is dependent on diet, water temperature, and mudflat exposure (Park et al. 2002).

Some mudskipper species tend to be more comfortable with a terrestrial lifestyle rather than an aquatic lifestyle. One among them is *Periophthalmodon schlosseri*, which has gill arrangements which are highly adaptable for air-breathing, and they spend less time in marine habitats (Takeda et al. 1999). *Boleophthalmus boddarti* builds mud walls for two significant reasons: to avoid hostility between neighbours and as assistance for feeding. Diatoms are the most preferred food for mudskippers. They prefer feeding on mud slopes as a measure of preventing intervention by their neighbours (Clayton & Wright 1989). *Periophthalmus sobrinus* prefers to live unaccompanied and rarely lives within closed groups. There were large spacings between nests and dark places were preferred for foraging (Gordon et al. 1968). The growth rates and life duration of both the sexes of *Pseudapocryptes elongatus* obtained from Sundarbans, India is four-plus years for both the sexes as the maximum age. Their growth index (Φ) is 4.394 (males) and 4.503 (females) possessing larger caudal fins (Mahadevan et al. 2019c).

The reason for aggressiveness in *Periophthalmus modestus* is the hypothalamic hormone, arginine-vasotocin (VT) (Nao et al. 2013). The foraging behaviours in *Periophthalmus waltoni* are not influenced by environmental factors. They hunt in the same area as their prey stays inside the burrow for a longer period of time (Clayton & Snowden 2000). The growth of *Bolepthalmus boddarti* has been recorded high during their juvenile period, decreasing in successive years because of maturation and spending their energy in spawning (Ravi & Rajagopal 2007).

Respiration and kinematics

Anatomical characteristics of mudskipper gills decide on adaptations of their habitat and *B. boddarti* is one that shows excellent adaptation to aquatic lifestyle. In comparison, terrestrial adaptations were favoured more at odds with their amphibious lifestyle (Low et al. 1988). Since mudskippers appear to change the way their skin breathes, their epidermis and skin layers have been studied in detail (Beon et al. 2012). They adapt towards terrestrial lifestyle by secreting mucus, and their head containing dense capillary network assists cutaneous respiration (Jie et al. 2003). Studies related to gaseous exchange and their demand for oxygen were done in the intertidal regions (Karen 1993). Ammonia excretion happens in mudskippers (*Periophthalmodon schlosseri*) through their head. Ammonia gets collected in their burrow through the acidification process, preventing them from reverse fluctuation (Randall et al. 2004). Mudskippers maintain the air phases according to the tide. They can breathe both aquatically and aerially when there is a high tide, while at low tides they transfer air into their burrow for breathing (Lee et al. 2005). Comprehensive research was conducted in *Periophthalmus magnuspinnatus* on cutaneous respiration and its relationship with skin layers (Park 2002). Several mudskippers reported evaporative water loss along with their behavioural adaptations (Dabruzzi et al. 2011). Significant characteristics of gills found in *Periophthalmodon schlosseri*, contribute to their ability to live inland for a longer period of time (Wilson et al. 1999). The modifications and transformations that occur in the gill respiratory vasculatures and the mudskippers of the bucco-opercular cavities were examined using the technique of corrosion casting. This has helped to define their adaptation to an amphibious lifestyle (Gonzales et al. 2011). Histological studies using the paraffin method have studied the ambiguity in the structure of the gills and simultaneously compared their aquatic and terrestrial lifestyles (Supriyati et al. 2019). For their survival, condition-specific biochemical adaptations occurred during hypoxia, where the glycolysis process is modified to provide energy during muscle movements, and lactate is accumulated (Chew & Ip 1992).

Contradictory circumstances occur concerning their adaptations between *Periophthalmodon schlosseri* and *Boleophthalmus boddarti*. Around the same time, *P. schlosseri* tends to be adaptable to a terrestrial lifestyle and is an excellent candidate for aquaculture studies related to air-breathing fish. *B. boddarti*, however, appear as opposed to the earlier one (Kok et al. 1998). Mudskipper is an anomaly that stores pre-entry air inside their burrow and has no metabolism affection. They regularly maintain their air stages and adapt them to their amphibious lifestyle (Ishimatsu et al. 1998). The essential feature of their adaptation to terrestrial life is the presence of dermal bulges, thick middle cell layer and a vascularized epidermis (Zhang et al. 2000). In low tide conditions, the intertidal fishes, like mudskippers, tend to have many options to choose from. Mudskippers either agree to be an aquatic or temporary terrestrial living being (Karen 1995). Mudskipper's locomotion has been experimentally tested using water on gelatin and glass along with the assistance of a system for digital image processing. Wang et al. (2013) discovered through their study that mudskipper uses both body and pectoral fins for movement in the water and on gelatin, whereas they use only pectoral fins for land action. Escapism is a critical behaviour that is required for their survival. A few studies have shown that, during aquatic and terrestrial lifestyles, mudskippers alter their position as escapists (Swanson & Gibb 2004).

Feeding ecology

The mudskipper *Pseudapocryptes dentatus* follows herbivorous feeding patterns. Their main order is Diatoms-Bacillariophyceae, green algae and blue-green algae. Levels in size and metabolism are inversely proportional (Sarker et al. 1980). Both plants and animals were documented while studying the *Periophthalmus barbarous* stomach. This included mainly crabs, fish scales, and insects. We can recognize from this that mud-skippers are opportunistic feeders and are an ideal aquaculture choice (Chukwu & Deekae 2013). As described, their key food items include -diatoms, nematode, polychaetes, fish eggs, algae, detritus, along with particles of mud and sand (Ravi 2013). It has been shown, according to the study conducted with *Periophthalmodon schlosseri*, that there are differential preferences in the selection of food products between male and female. Females preferred small-scale fish, namely *Oryzias* sp., and males over small-scale fiddler crabs because they were highly involved in land activities (Zulkifli et al. 2012).

The *periophthalmus sobrinus* feeds on small animals. Their food sources are polychaetes, polydora, terebellid, nematodes, crustaceans, copepods, tanaids, prawns, schizopod larvae, alpheid shrimp juveniles, *Uca chlorophthalmus*, and tiny sand crab (Stebbins & Kalk 1961). The discerned food items of *Periophthalmus waltoni* are crustaceans (high occurrence), snails (slightly lower occurrence), 3.4% insects (lower appearance), and fishes (least) (Mhaisen & Al-maliki 2013). *Boleophthalmus pectinirostris* selects their meal based on the abundance, availability, size of the diatoms and temperature. The size of the species reflects over its feeding apparatus (Yang et al. 2003).

Boleophthalmus boddarti likewise feeds on Bacillariophyta (Quang 2015). The anatomical characteristics in *Periuphthalmus kuelreuteri* are examined by light and X-ray cinematography. It pushes forward with its pelvic fins when the prey gets near, and brings the jaws near to the target. Opercular bones, aid swallowing into the pharynx to position the prey. They found it easy to capture the prey in the land by biting and open mouth. It reaches the stomach via an esophagus after passing the pharyngeal jaws (Sponder & Launder 1981).

Reproduction

Studies were conducted in Nigeria's lagoon swamps, which concentrated primarily on sex ratios, egg diameters, gonodosomatic index and levels of maturation (Lawson 2010). Reports on the growth of eggs with artificial fertilization and larval reports in the species *Periophthalmus cantonensis* were carried out (Tsuhako et al. 2003). The mudskipper's eggs were laid deep within the burrows where there is a hypoxic environment, and male mudskippers supply the oxygen by depositing oxygen through water. Once the development of the eggs is complete, they are released from the burrows and hatched by tides, making them prepare themselves during severity (Ishimatsu et al. 2007). A research on *Apocryptes bato*'s (Gobiidae) reproductive biology in the Payra River, southern Bangladesh, helped to understand the basics of reproduction in mudskippers (Ferdous et al. 2018). Studies related to reproductive biology, fertilization, maximum sizes achieved along with spawning will allow local fishermen to know the exact time of catching them, rather than disturb them during spawning seasons. The concept was prominent from the studies of sex maturation of *Boleophthalmus boddarti* (Quang et al. 2015). The species *Periophthalmodon septemradiatus* lays eggs year-round. Observing their complete duration during the maturation stages helped to understand reproductive biology and to learn about the methods of conservation (Dinh et al. 2018). Studies at intertidal swamps of the Imo River estuary dealt about the reproductive biology of *Periophthalmus barbarous* along with growth, mortality, recruitment pattern, gonadosomatic index, and spawning season (Etim et al. 2002).

Studies on nutrition content and medicinal value

Nutrient content of three species *Periophthalmus waltoni*, *Boleophthalmus dussumieri*, and *Scartelaos histophorus* were measured, such as starch, protein, and lipid. *Boleophthalmus dussumieri* is rich in nutrients and it comes from the liver. Because of this adventitious effect, people consume them in the Bhavnagar coast, Gujarat (Kanejiya et al. 2017a). Mudskippers are known to be very rich in proteins and other nutrients. They are either used in traditional medicines in countries like Malaysia or as bait and also utilized for consumption. During winter, mudskippers are caught and sold at the market by fishermen using net trap methods (Kanejiya et al. 2017b). Likewise, there are growing demands for mudskippers at Narmada estuary, Gujarat, and they are favoured by local people. As a result of this, the ecosystem can get highly exploited and can impact biodiversity (Bhakta et al. 2018). Though mudskipper meat possess nutritional benefits there are researchers stating about metal toxicity and bioaccumulation when consumed.

The research by Looi et al. (2016) concluded that the bioaccumulation of mercury in *Periophthalmodon schlosseri* did not cause any serious effects when consumed. From the evaluation of the nutrient content of *Pseudapocryptes elongatus*, it has been shown to contain sufficient protein, carbohydrate, lipid, important and non-essential amino acids, polyunsaturated fatty acid (PFA) with a greater amount than saturated fatty acid (SFA). For consumption it is highly recommended because of its nutritive value (Mahadevan et al. 2019b). Mudskippers are widely available in Nigeria and their prices are comparatively low, and they are consumed by the elderly (Edun et al. 2010). Exposure of mudskipper *Boleophthalmus boddarti* to natural radionuclides (^{238}U, ^{226}Ra and ^{210}Pb and ^{210}Po), the radionuclide concentration was found to be below the limit and therefore, did not have a profound impact in Bombay Harbour and coastal zone (Bangera & Patel 1984).

Threats to mudskippers

The effect on mudskipper density was recorded in the mudflats of Hathab coast, Gujarat, considering salinity and temperature as independent variables. Accordingly, mudskipper abundance and distribution have become a vital indicator for determining intertidal region health (Kanejiya et al. 2017c). Post-tsunami studies at Mudasolodai, Tamil Nadu, revealed that rapid changes in soil morphology led to changes that directly affected the mudskippers' livelihood. For construction, they usually prefer clay-rich soil, rather than sandy soil (Ravi 2005). Although metal uptakes were increasingly high during lower salinity, the levels of salinity in the intertidal mudskipper *Periophthalmus cantonensis* did not affect the metal (Cd, Se, & Zn) concentration factors (CF) (Ni et al. 2006). Mudskippers face other menaces due to metal toxicity. To illustrate, when exposed to Cr (VI), *Boleophthalmus dentatus* causes affection in the activity of Na^+ , K^+ and ATPase, and further affects membrane activity, also causing metabolic stress (Kundu et al. 1995). Similarly, the same has also been deduced in other studies pertaining to *Boleophthalmus dentatus* obtained from the Gulf of Katch (Lakshmi et al. 1991). The shrimp effluents collected at the mudskipper habitat in the northern Persian Gulf have proved to support mudskipper enrichment, which helps them increase their species density and length. Despite severe changes and reduced dissolved oxygen, shrimp effluents create favourable physical conditions for their growth; it survived amid these adversities (Kohan et al. 2018). Mudskippers are known for their versatile behaviour and amphibious character. They have less understanding of the public and have lost interest. The most striking characteristic of them is their survival ability and adaptation to different environmental changes. Surprisingly, mudskippers feed on the available foodstuffs, rather than relying on specific foods. Further research can be done with them as they define themselves as an ideal candidate for aquaculture. Gills' anatomical features are specifically built to suit both the terrestrial and aquatic lifestyles. They got adapted from the initial stages of egg production to adjust to severities such as high tide, and airflow maintenance.

CONCLUSION

Mudskippers are known for their significant behaviour of adapting themselves to different environment and amphibious nature. Mudskippers are less popular among people and aren't noticed much. Their most amazing feature is their capacity to survive and their adaptation to various changes in the environment. Surprisingly, mudskippers feed on the foodstuffs available, rather than rely on particular foodstuffs. Further research can be carried out as they may be an ideal candidate for aquaculture. The anatomical characteristics of gills are designed primarily to accommodate both the terrestrial and aquatic lifestyles. From the initial stages of egg production, they are taught to adjust themselves to severities such as high tide and maintenance of the airflow. The most striking aspect about them is their position in coastal areas as a biological indicator, pollution monitor, and estuarine health monitor.

REFERENCES

Abiaobo, N.O. & M.T. Udo (2017). The population dynamics of the Mudskipper, *Periophthalmus barbarous* (Linneaus, 1766) (Teleostei, Gobiidae) and the implication for conservation and management in the mangrove swamp of Iko River Estuary, southeastern Nigeria. *Journal of Applied Life Sciences International* 14(4): 1–19. https://doi.org/10.9734/JALSI/2017/37007

Baeck, G.W., T. Takita & Y.H. Yoon (2008). Lifestyle of Korean mudskipper *Periophthalmus magnuspinnatus* with reference to a congeneric species *Periophthalmus modestus*. *Ichthyological Research* 55: 43–52.

Bangera, V.S. & B. Patel (1984). Natural radionuclides in sediment and in arcid clam (*Anadara granosa L.*) and gobiid mudskipper (*Boleophthalmus boddaerti* Cuv. and Va.). *Indian Journal of Geo-Marine Sciences* 13(1): 5–9.

Beon, M.S., M.K. Oh, Y.J. Lee, C.H. Kim & J.Y. Park (2012). A comparative study on vascularization and the structure of the epidermis of an amphibious mudskipper fish, *Scartelaos gigas* (Gobiidae, Teleostei), on different parts of the body and the appendages. *Journal of Applied Ichthyology* 29(2): 410–415.

Bhakta, D., W.A. Meetei, G. Vaisakh, S. Kamble, T.N. Chanu & S.K. Das (2018). Mudskipper Fishery and Indigenous Fishing Devices in Narmada Estuary, Gujarat. *Journal of the Indian Society of Coastal Agricultural Research* 36(2): 74–78.

Bloch, M.E. & J.G. Schneider (1801). Systema Ichthyologiae Iconibus CX Illustratum. Post Obitum Auctoris Opus Inchoatum Absolvit, Correxit, Interpolavit Jo. Gottlob Schneider. Jo. Gottlob Schneider, Berlin, 584pp.

Bucholtz, R.H., A.S. Meilvang, T. Cedhagen, J.T. Christensen & D.J. Macintosh (2009). Biological Observations on the Mudskipper *Pseudapocryptes elongatus* in the Mekong Delta, Vietnam. *Journal of World Aquaculture Society* 40(6): 711–723.

Bu-Olayan, A.H. & B.V. Thomas (2008). Trace metals toxicity and bioaccumulation in Mudskipper *Periophthalmus waltoni* Koumans, 1941 (Gobiidae: Perciformes). *Turkish Journal of Fisheries and Aquatic Sciences* 8: 215–218.

Cai, Z. (1996). Population structure and reproductive characteristics of mudskipper *Boleophthalmus pectinirostris*, in Shenzhen Bay, China. *Acta Ecologica Sinica* 16 (1): 77–82.

Chen, S.X., W.S. Hong, Y.Q. Su & Q.Y. Zhang (2008). Microhabitat selection in the early juvenile mudskipper *Boleophthalmus pectinirostris* (L.). *Journal of Fish Biology* 72(3): 585–593. https://doi.org/10.1111/j.1095-8649.2007.01723.x

Chew, S.F. & Y.K. Ip (1992). Biochemical adaptations of the mudskipper *Boleophthalmus boddaerti* to a lack of oxygen. *Marine Biology* 112: 567–571.

Chu, Y.T. & H.L. Wu (1963). A study on the classification of the sciaenoid fishes of China. Shanghai Fisheries Institute, China, 1pp. https://www.google.com/books/edition/A_study_on_the_classification_of_the_sci/GN1gnAEACAAJ?hl=en

Chukwu, K.O. & S.N. Deekae (2013). Foods of the mudskipper (*Periophthalmus barbarus*) from New Calabar River, Nigeria. *Journal of Agriculture and Veterinary Science* 5(6): 45–48.

Clayton, D.A. (1987). Why Mudskippers build walls. *Behaviour* 102(3-4): 185–195. https://doi.org/10.1163/156853986X00117

Clayton, D.A. (1993). Mudskippers. *Oceanography Marine Biology: An Annual Review* 31: 507–577.

Clayton, D.A. & J.M. Wright (1989). Mud-walled territories and feeding behaviour of *Boleophthalmus boddarti* (Pisces: Gobiidae) on the Mudflats of Kuwait. *Journal of Ethology* 7(2): 91–95.

Clayton, D.A. & R. Snowden (2000). Surface activity in the mudskipper, *Periophthalmus waltoni* Koumans 1941 in relation to prey activity and environmental factors. *Journal of Tropical Zoology* 13(2): 239–249.

Dabruzzi, T.F., M.L. Wygoda, J.E. Wright, E. John & A.B. Wayne (2011). Direct evidence of cutaneous resistance to evaporative water loss in amphibious mudskipper (family Gobiidae) and rockskipper (family Blenniidae) fishes from Pulau Hoga, southeast Sulawesi, Indonesia. *Journal of Experimental Marine Biology and Ecology* 406(1–2): 125–129.

Devendra, S., J. Kanejiya, I. Beleem & G. Bharatsinh (2016). Checklist of intertidal marine fauna in mangrove ecosystem, Ghogha coast, Gulf of Khambhat, India. *Journal of Entomology and Zoology Studies* 4(4): 1281–1284.

Dinh, Q.M., L.T. Tran, N.C. Ngo, T.B. Pham & T.T.K. Nguyen (2018). Reproductive biology of the unique mudskipper *Periophthalmodon septemradiatus* living from estuary to upstream of the Hau River. *Acta Zoologica* 101(2): 206–217.

Edun, O.M., O.A. Akinrotimi, A. Uka & K.N. Owhonda (2010). Patterns of mudskipper consumption in selected communities of Rivers State, Nigeria. *Journal of Agriculture and Social Research* 10(2): 100–108. https://doi.org/10.4314/jasr.v10i2.67578

Elviana, S., S. Sunarni, M.R. Maturbongs, M.R. Sajriawati & S. Fakhriyyah (2019). Mudskipper diversity and its relationship to an environmental condition in estuary, pp. 1–5. In: IOP Conference Series: Earth and Environmental Science, The 1st International Conference of Interdisciplinary Research on Green Environmental Approach for Sustainable Development (ICROEST). Indonesia.

https://doi.org/10.1088/1755-1315/343/1/012191

Etim, L., R.P. King & M.T. Udo (2002). Breeding, growth, mortality and yield of the mudskipper *Periophthalmus barbarus* (Linneaus 1766) (Teleostei: Gobiidae) in the Imo River estuary, Nigeria. *Fisheries Research* 56(3): 227–238.

Ferdous, A., N. Saha, Z.F. Ahmed, M.Y. Hossain & J. Ohtomi (2018). Reproductive biology of *Apocryptes bato* (Gobiidae) in the Payra River, southern Bangladesh. *Journal of Applied Ichthyology* 34(5): 1169–1175.

Gadhavi, M.K., D. Kukadia, S. Dar, N. Gokulakkannan, G. Talukdar, K. Sivakumar & G.V. Gopi (2017). Indigenous techniques of catching mudskipper in Bhavnagar and Bharuch districts, Gujarat. *Indian Journal of Traditional Knowledge* 16(3): 533–538.

Gonzales, T.T., M. Katoh, A.G. Mazlan & A. Ishimatsu (2011). Gross and Fine Anatomy of the Respiratory Vasculature of the Mudskipper, *Periophthalmodon schlosseri* (Gobiidae: Oxudercinae). *Journal of Morphology* 272(5): 629–640.

Gordon, M.S., J. Boëtius, D.H. Evans & L.C. Oglesby (1968). Additional Observations on the Natural History of the Mudskipper, Periophthalmus sobrinus. *Copeia* 1968(4): 853–857.

Gordon, M.S., I. Boetius, D.H. Evans, M. Rosemary & L.C. Oglesby (1969). Aspects of the physiology of terrestrial life in amphibious fishes. *Journal of Experimental Biology* 50: 141–149.

Gordon, M.S., W.W. Ng & A.Y. Yip (1978). Aspects of the physiology of terrestrial life in amphibious fishes: III. The Chinese mudskipper Periophthalmus cantonensis. *Journal of Experimental Biology* 72: 57–75.

Gordon, M.S., D.J. Gabaldon & A.Y.W. Yip (1985). Exploratory observations on microhabitat selection within the intertidal zone by the Chinese mudskipper fish Periophthalmus cantonensis. *Marine Biology* 85(2): 209–215.

Hamilton, F. (1822). *An account of the Fishes in the River Ganges and its Branches*. Archibald Constable and Company, Edinburgh, 405pp.

Hashim, R., B. Kamali, N.M. Tamin & R. Zakaria (2010). An integrated approach to coastal rehabilitation: Mangrove restoration in Sungai Haji Dorani, Malaysia. *Estuarine, Coastal and Shelf Science* 86(1): 118–124.

Hui, N.Y., M. Mohamed, M.N.A. Othman & L. Tokiman (2019). *Diversity and Behaviour of Mudskippers of Tanjung Piai, Pontian, Johor*. IOP Conference Series: Earth and Environmental Science, 269pp.

Ikram, M.M., A. Ismail, C.K. Yap & A.A. Nor (2010). Levels of heavy metals (Zn, Cu, Cd, and Pb) in Mudskippers (*Periophthalmodon schlosseri*) and sediments collected from intertidal areas at Morib and Remis, Peninsular Malaysia. *Toxicological and Environmental Chemistry* 92(8): 1471–1486.

Ishimatsu, A., A. Hishida, T. Takita, T. Kanda, S. Oikawa, T. Takeda & K.H. Khoo (1998). Mudskippers store air in their burrows. *Nature* 391: 237–238.

Ishimatsu, A., Y. Yu, I. Naoko, T. Takeda, H.J. Lee & J.B. Graham (2007). Mudskippers brood their eggs in air but submerge them for hatching. *Journal of Experimental Biology* 210: 3946–3954.

Jaafar, Z. & E.O. Murdy (2017). *Fishes Out of Water: Biology and Ecology of Mudskippers*. CRC Press, Florida. 410pp.

Jie, Z., T. Taichi, T. Takita & A.B. Ali (2003). A study on the epidermal structure of *Periophthalmodon* and *Periophthalmus* mudskippers with reference to their terrestrial adaptation. *Ichthyological Research* 50: 310–317.

Kanejiya, J., D. Solanki & B. Gohil (2017a). Nutrient content of three species of Mudskipper (Gobiidae; Oxudercinae) in Bhavnagar coast, Gujarat, India. *The Journal of Zoology Studies* 4(3): 48–51.

Kanejiya, J., D. Solanki, I. Beleem & B. Gohil (2017b). Mudskipper fishing in the coast of Bhavnagar, Gulf of Khambhat, Gujarat, India. *Journal of Fisheries* 5(1): 461–464.

Kanejiya, J.R., D.A. Solanki & B.M. Gohil (2017c). Distribution of Mudskippers in the Mudflats of Hathab Coast, Gujarat, India. *Cibtech Journal of Zoology* 6(2): 1–9.

Karen, L.M.M. (1993). Aerial CO_2 release and respiratory exchange ratio in marine intertidal fishes. *Environmental Biology of Fishes*. 37: 189–196.

Karen, L.M.M. (1995). Time and tide wait for no fish: Air-breathing in intertidal fishes. *Environmental Biology of Fishes* 44: 165–181. https://doi.org/10.1007/BF00005914

Khaironizam, M.Z. & Y.N. Rashid (2000). A new record of the mudskipper *Parapocryptes serperaster* (Oxudercinae: Gobiidae) from Peninsular Malaysia. *Malaysian Journal of Science* 19(1): 101–104.

Khaironizam, M.Z. & N.Y. Rashid (2003). First record of the mudskipper, *Periophthalmodon septemradiatus* (Hamilton) (Teleostei: Gobiidae) from Peninsular Malaysia. *The Raffles Bulletin of Zoology* 51(1): 97–100.

Khaironizam, M.Z. & N.Y. Rashid (2005). Distribution of Mudskippers (Gobiidae: Oxudercinae) on the Selangor Coast. University of Malaya Press, Kuala Lumpur, 101–114pp.

Kohan, A., Z. Badbardast & A. Kohan (2018). Effects of shrimp effluents on Mudskippers (Gobiidae: Oxudercinae) in the northern Persian Gulf. *Marine Environmental Research*. 136: 174–178.

Kok, W.K., C.B. Lim, T.J. Lam & Y.K. Ip (1998). The Mudskipper *Periophthalmodon schlosseri* respires more efficiently on land than in water and vice versa for *Boleophthalmus boddaerti*. *Journal of Experimental Zoology* 280(1): 86–90. https://doi.org/10.1002/(SICI)1097-010X(19980101)280:1<86::AID-JEZ10>3.0.CO;2-U

Koumans, A.K.J. (1938). The development of atrial fibrillation and block states due to new views on stimulus formation in the heart muscle. *Archive for Cycle Research* 2(9-12): 327–348. https://doi.org/10.1007/bf02127310

Kruitwagen, G., T. Hecht, H.B. Pratap & S.E.W. Bonga (2006). Changes in morphology and growth of the mudskipper (*Periophthalmus argentilineatus*) associated with coastal pollution. *Marine Biology* 149: 201–211.

Kundu, R., R. Lakshmi & A.P. Mansuri (1995). Effects of Cr (VI) on ATPases in the brain and muscle of mudskipper*, Boleophthalmus dentatus*. *Bulletin of environmental contamination and toxicology* 55(5): 723–729. https://doi.org/10.1007/BF00203759

Lakshmi, R., R. Kundu, E. Thomas & A.P. Mansuri (1991). Mercuric chloride-induced inhibition of different ATPases in the intestine of mudskipper, *Boleophthalmus dentatus*. *Ecotoxicology and Environmental Safety* 21(1): 18–24. https://doi.org/10.1016/0147-6513(91)90003-8

Lawson, E.O. (2010). Aspects of Reproductive Biology in Mudskipper, *Periophthalmus papilio* from Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. *Journal of Fisheries International* 5(2): 36–43.

Lee, H.J., C.A. Martinez, K.J. Hertzberg, A.L. Hamilton & J.B. Graham (2005). Burrow air phase maintenance and respiration by the mudskipper *Scartelaos histophorus* (Gobiidae: Oxudercinae). *Journal of Experimental Biology* 208: 169–177.

Looi, L.J., A.J. Aris, H. Haris, F.M. Yusoff & Z. Hashim (2016). The levels of mercury, methylmercury and selenium and the selenium health benefit value in grey-eel catfish (*Plotosus canius*) and giant mudskipper (*Periophthalmodon schlosseri*) from the Strait of Malacca. *Chemosphere* 152: 265–273.

Lorente-Martínez, H., A. Agorreta, M. Torres-Sanchez & M.D. San (2018). Evidence of positive selection suggests possible role of aquaporins in the water-to-land transition of mudskippers. *Organisms, Diversity and Evolution* 18(4): 499–514.

Low, W.P., D.J.W. Lane & Y.K. Ip (1988). A comparative study of terrestrial adaptations of the gills in three Mudskippers: *Periophthalmus Chrysospilos, Boleophthalmus Boddaerti,* and *Periophthalmodon Schlosseri. Biological Bulletin* 174(3): 434–438.

Mahadevan, G., G. Polgar & P. Murugesan (2019a). First record of the mudskipper *Periophthalmus walailakae* (Gobiidae) from southeast India. *Cybium: International Journal of Ichthyology* 43: 373–375.

Mahadevan, G., M. Pouladi, A. Stara & C. Faggio (2019b). Nutritional evaluation of elongate mudskipper *Pseudapocryptes elongatus* (Cuvier, 1816) from Diamond Harbor, West Bengal, India. *Natural Product Research* Sep 16: 1–7. https://doi.org/10.1080/14786419.2019.1666388

Mahadevan, G., P. Bharathirajan, V. Ravi, M. Pouladi & M.V.K. Maryam (2019c). Short Communication: Age and growth of elongated mudskipper, *Pseudapocryptes elongatus* (Cuvier, 1816) from Sundarbans, India. *Biodiversitas Journal of Biological Diversity* 20(1): 85–90. https://doi.org/10.13057/biodiv/d200111

Mai, H.V., X.T. Loi, Q.M. Dinh, D.D. Tran, M. Mizuri, H. Sagara, A. Yamada, K. Shirai & A. Ishimatsu (2019). Land Invasion by the Mudskipper, *Periophthalmodon septemradiatus*, in Fresh and Saline Waters of the Mekong River. *Scientific Reports* 9(1): 1–11. https://doi.org/10.1038/s41598-019-50799-5

Mhaisen, F.T & N.S. Al-Maliki (2013). Parasites Diseases and Food of the Dark-blotched Mudskipper *Periophthalmus waltoni* (perciformes: Gobiidae) in the Khor Al-Zubair estuary (Iraq). *Journal of Zoology in Middle East* 13(1): 85–88. https://doi.org/10.1080/09397140.1996.10637708.

Murdy, E.O. & T. Takita (1999). *Periophthalmus spilotus*, a new species of mudskipper from Sumatra (Gobiidae: Oxudercinae). *Ichthyological Research* 46(4): 367–370.

Murdy, E.O. (1989). Taxonomic Revision and Cladistic Analysis of the Oxudercine Gobies (Gobiidae: Oxudercinae). *Records of the Australian Museum* (Suppl. 11): 1–93. https://doi.org/10.3853/j.0812-7387.11.1989.93

Nanami, A. & T. Takegaki (2005). Age and growth of the mudskipper *Boleophthalmus pectinirostris* in Ariake Bay, Kyushu, Japan. *Fisheries Research* 74(1–3): 24–34.

Nao, K., N. Yudai, K. Kato, H. Takahashi, Y. Kobayashi, H. Sakamoto & T. Sakamoto, (2013). Potential roles of arginine-vasotocin in the regulation of aggressive behavior in the Mudskipper (*Periophthalmus modestus*). *General and Comparative Endocrinology* 194: 257–263.

Ni, I.H., S.M. Chan & W.X. Wang (2006). Influences of salinity on the biokinetics of Cd, Se, and Zn in the intertidal mudskipper *Periophthalmus cantonensis*. *Chemosphere* 61(11): 1539–1758.

Osche, G. (1962). The pre-adaptation phenomenon and its importance for the Evolution. *Zoological Scoreboard* 169: 14–49.

Pallas, P.S. (1772). Spicilegia Zoológica, which come new in the first place, and obscure, of animals, like icons, in the descriptions of the recorder, and the enlightened care of the PS Pallas 9: 1–86.

Park, J.Y. (2002). Structure of the skin of an air-breathing Mudskipper, *Periophthalmus magnuspinnatus. Journal of Fish Biology* 60(6): 1543–1550.

Park, K.D., J.K. Kim, D.S. Chang, J. Kim & W.O. Chul (2002). Age and growth of the Mudskipper, *Scartelaos gigas* (perciformes, gobiidae) from Korea. *Journal of Animal Cells and Systems* 12(4): 305–311. https://doi.org/10.1080/19768354.2008.9647186

Polgar, G. (2009). Species-area relationship and potential role as a biomonitor of mangrove communities of Malayan Mudskippers. *Wetland Ecology and Management* 17 (2): 157–164.

Polgar, G. & G. Crosa (2009). Multivariate characterisation of the habitats of seven species of Malayan Mudskippers (Gobiidae: Oxudercinae). *Marine Biology* 156(7): 1475–1486.

Polgar, G. & R. Lim (2011). Mudskippers: Human use, ecotoxicology and biomonitoring of mangrove and other soft bottom intertidal ecosystems. Open Publication of UTC Scholar, 51–86pp. https://opus.lib.uts.edu.au/handle/10453/117614

Polgar, G., L. Zane, M. Babbucci, F. Barbisan, T. Patarnello, R. Lukas & C. Papetti (2014). Phylogeography and demographic history of two widespread Indo-Pacific Mudskippers (Gobiidae: Periophthalmus). *Molecular Phylogenetics and Evolution* 73: 161-176.

Pormansyah, I.M., S. Arum, Y. Indra & Z. Hilda (2019). A review of recent status on Mudskippers (Oxudercine Gobies) in Indonesian Waters. *Oceanography and Fisheries* 9(4): 555769. https://doi.org/10.19080/OFOAJ.2019.09.555769

Quang, D.M. (2015). Preliminary study on dietary composition, feeding activity and fullness index of *Boleophthalmus boddarti* in Mekong Delta, Vietnam. *Academia Journal of Biology* 37(2): 252–257. https://doi.org/10.15625/0866-7160/v37n2.6599

Quang, D.M. (2016). Growth and body condition variation of the giant Mudskipper *Periophthalmodon schlosseri* in dry and wet seasons. *Academia Journal of Biology* 38(3): 352–358.

Quang, D.M., N.T.T. Giang & N.T.K. Tien (2015). Reproductive biology of the mudskipper Boleophthalmus boddarti in Soc Trang. *Academia Journal of Biology* 37(3): 362–369. https://doi.org/10.15625/0866-7160/v37n3.6720

Rahman, M.M., M.S. Parvez, N. Mallik & M.S.U. Nabi (2015). Population Dynamics of Mudskipper *Periophthalmus novemradiatus* from Bakkhali River Estuary, Cox's Bazar, Bangladesh. *Agricultural Science Research Journal* 5(8): 118–123.

Randall, D.J., Y.K. Ip, S.F. Chew & J.M. Wilson (2004). Air Breathing and Ammonia Excretion in the Giant Mudskipper, *Periophthalmodon schlosseri*. *Physiological and Biochemical Zoology* 77(5): 783–788.

Rathod, S., A.S. Morajkar & H.L. Pratipada (2019). Behavioural Studies of *Boleophthalmus dussumieri* (VAL., 1837) on the silted Intertidal Mudflats of Ulhas river Estuary. *International Journal of Advance and Innovative Research* 6(1): 137–140.

Ravi, V. (2005). Post-tsunami studies on the mudskipper *Boleophthalmus boddarti* (Pallas, 1770) from Mudasalodai, Tamil Nadu, southeast coast of India. *Journal of International Goby Society* 4: 9–17.

Ravi, V. (2012). Habitat Loss and Population Reduction of Mudskippers (Family: Gobiidae) from Tamil Nadu, S.E. Coast of India. *Marine Biodiversity: Present Status and Prospects* 37–49.

Ravi, V. (2013). Food and Feeding Habits of the Mudskipper, *Boleophthalmus boddarti* (Pallas, 1770) from Pichavaram Mangroves, Southeast Coast of India. *International Journal of Marine Science* 3(12): 98–104.

Ravi, V. & S. Rajagopal (2007). Age and Growth of the Mudskipper, *Boleophthalmus boddarti* (Pallas, 1770). *Journal of Aquatic Biology* 22(1): 123–128.

Ravi, V., S. Rajagopal, S.A. Khan & T. Balasubramanian (2004). On the Classification of Burrows of the Mudskipper, *Boleophthalmus boddarti* (Pallas) (Gobiidae: Oxudercinae) in the Pichavaram Mangroves, Southeast Coast of India. *Journal of Annamalai University, Science* September(2004): 235–239.

Ravi, V., G. Mahadevan & R. Bharathi (2013). Mudskipper Fishery at Namkhana Region – Sundarban Mangrove Forest, India. *Fishing Chimes* 33(4): 42–44.

Ragunathan, A.V. (2010, July 02). A Fish Species in Missing Evolutionary Link Traced, Cuddalore, The Hindu. http://www.thehindu.com/news/states/tamil-nadu/article495616.ece

Roberts, R.J. (1978). Fish Pathology. Bailliere Tindall, UK. https://www.google.com/books/edition/Fish_Pathology/8n-1T2mK0tIC?hl=en

Sarker, A.L., N.K. Al-Daham & M.N. Bhatti (1980). Food habits of the mudskipper, *Pseudapocryptes dentatus* (Val.). *Journal of Fish Biology* 17(6): 635–639.

Sharifian, S., M.R. Taherizadeh, A. Salarpouri & M. Dehghani (2018). Population dynamic of the Mudskipper *Periophthalmus waltoni* Koumans, 1941 from the Bay of Hormozgan Province, Persian Gulf. *Russian Journal of Marine Biology* 44: 149–158.

Shenoy, L., V.K. Patro & X. Ying (2012). Effects of Mudskippers On the soil composition and texture in mangrove forests, and hence the growth of Mangroves (*Avicennia alba*). Temasek Junior College, Singapore. https://nss.org.sg/documents/LGD%202012%20Project%20Mudskipper%20Temasek%20JC.pdf

Shirani, M., A. Mirvaghefi, H. Farahmand & M. Abdollahi (2012). Biomarker responses in Mudskipper (*Periophthalmus waltoni*) from the coastal areas of the Persian Gulf with oil pollution. *Environmental Toxicology and Pharmacology* 34(3): 705–713.

Sinaei, M. & A. Mashinchian (2014). Polycyclic aromatic hydrocarbons in the coastal sea water, the surface sediment and Mudskipper *Boleophthalmus dussumieri* from coastal areas of the Persian Gulf: source investigation, composition pattern and spatial distribution. *Journal of Environmental Health Science and Engineering* 12(1): 59.

Sponder, D.L. & G.V. Lauder (1981). Terrestrial feeding in the Mudskipper *Periophthalmus* (Pisces: Teleostei): A Cinerodiographic analysis. *Journal of Zoology* 193(4): 517–530. https://doi.org/10.1111/j.1469-7998.1981.tb01501.x

Stebbins, R.C. & M. Kalk (1961). Observations on the Natural History of the Mud-Skipper, Periophthalmus Sobrinus. *Copeia* (1961)1: 18–27. https://doi.org/10.2307/1440166

Supriyati, H., N.S. Apriliani & M.J. Luthfi (2019). Histological Study of Mudskipper (*Periophthalmus gracilis*) Gills. In: Proceeding International Conference on Science and Engineering, Universitas Islam Negeri Sunan Kalijaga, Indonesia 2: 177–179.

Swanson, B.O. & A.C. Gibb (2004). Kinematics of aquatic and terrestrial escape responses in mudskippers. *Journal of Experimental Biology* 207: 4037–4044.

Takeda, T., A. Ishimatsu, S. Oikawa, T. Kanda, Y. Hishida & K.H. Khoo (1999). Mudskipper *Periophthalmodon schlosseri* can repay Oxygen debt in air but not in water. *Journal of Experimental Zoology* 284(3): 265–270.

Takita, T. & A.B. Ali (1999). Distribution and habitat requirements of oxudercine gobies (Gobiidae: Oxudercinae) along the Straits of Malacca. *Ichthyological Research* 46: 131–138.

Tomiyama, I. (1934). Four new species of gobies from Japan. *Journal of the Tokyo Imperial University* 3(3): 325–334.

Tsuhako, Y., A. Ishimatsu, T. Takeda, K.K. Huat & K. Tachihara (2003). The eggs and larvae of the giant mudskipper, *Periophthalmodon schlosseri*, collected from a mudflat in Penang, Malaysia. *Ichthyological Research* 50(2): 178–181.

Ulrich, K. & J.M. Elliott (2013). Do mudskippers and lungfishes elucidate the early evolution of four-limbed vertebrates?. *Evolution: Education and Outreach* 6(8). https://doi.org/10.1186/1936-6434-6-8.

Valenciennes, A. (1846). Natural History of Fish. France. 19. https://books.google.co.in/books?hl=en&lr=&id=4tBcAAAAcAAJ&oi=fnd&pg=PA1&dq=Histoire+Naturelle+des+Poissons&ots=75SD1EbV-3&sig=BGqsMA5Og4ze3gQrCbOykDNl-48&redir_esc=y#v=onepage&q=Histoire%20Naturelle%20des%20Poissons&f=false

Wang, L., M. Xu, B. Liu, T. Jiang, S. Zhang & J. Yang (2013). Experimental Study on Morphology and Kinematics of Mudskipper in Amphibious Environments. In: IEEE International Conference on Robotics and Biomimetics (ROBIO), Shenzhen, China. Date of conference 12–13 December 2013. https://doi.org/10.1109/ROBIO.2013.6739610

Wilson, J.M., T.W.K. Kok, D.J. Randall, W.A. Vogl & K.Y. Ip (1999). Fine structure of the gill epithelium of the terrestrial Mudskipper, *Periophthalmodon schlosseri. Cell and Tissue Research* 298(2): 345–356.

Yang, K.Y., S.Y. Lee & G.A. Williams (2003). Selective feeding by the mudskipper (*Boleophthalmus pectinirostris*) on the microalgal assemblage of a tropical mudflat. *Marine Biology* 143: 245–256. https://doi.org/10.1007/s00227-003-1067-y

Zhang, J., T. Taniguchi, T. Takita & A.B. Ali (2000). On the epidermal structure of *Boleophthalmus* and *Scartelaos* mudskippers with reference to their adaptation to terrestrial life. *Ichthyological Research* 47: 359–366. https://doi.org/10.1007/BF02674263

Zulkifli, S.Z., F.M. Yusuff, A. Ismail & N. Miyazaki (2012). Food preference of the giant mudskipper *Periophthalmodon schlosseri* (Teleostei: Gobiidae). *Knowledge and Management of Aquatic Ecosystem* 405: 10. https://doi.org/10.1051/kmae/2012013

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17287–17298

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

DOI: https://doi.org/10.11609/jott.5026.12.17.17287-17298

#5026 | Received 24 April 2019 | Final received 21 July 2020 | Finally accepted 05 November 2020

COMMUNICATION

Diversity, distribution and conservation status of the Adder's-tongue ferns in Goa, India

Sachin M. Patil [1] & **Kishore Rajput** [2]

[1,2] Laboratory of Plant Anatomy & Pteridology, Department of Botany, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat 390002, India.

[1] sach2010d@gmail.com (corresponding author), [2] ks.rajput15@yahoo.com

Abstract: The cosmopolitan fern genus *Ophioglossum* (Ophioglossaceae) is distributed from low to high altitude plateaux, coastal plains and forest floors of India. This genus has received special attention from pteridologists worldwide since the discovery that *Ophioglossum reticulatum* possesses the largest number of chromosomes. There are, however, no reported studies of *Ophioglossum* in Goa, hence the present investigation was undertaken to study the diversity, distribution and conservation status of *Ophioglossum* in that state. A total of six species were collected from different localities, of which four (*O. nudicaule*, *O. lusitanicum*, *O. parvifolium*, and *O. reticulatum*) are reported as new distributional records for Goa State. A detailed morpho-taxonomy, illustration and photographs of all collected species are given, along with a key to the species.

Keywords: Illustration, morpho-taxonomy, new record, Western Ghats.

Editor: Sanjaykumar R. Rahangdale, PDEA's A. W. Arts, Science & Commerce College, Pune, India. **Date of publication:** 26 December 2020 (online & print)

Citation: Patil. S.M. & K. Rajput (2020). Diversity, distribution and conservation status of the Adder's-tongue ferns in Goa, India. *Journal of Threatened Taxa* 12(17): 17287–17298. https://doi.org/10.11609/jott.5026.12.17.17287-17298

Funding: Science and Engineering Research Board (SERB), Government of India [File No. PDF/2016/003706]

Competing interests: The authors declare no competing interests.

Author details: Dr. Sachin M. Patil, Laboratory of Plant Anatomy & Pteridology, The Maharaja Sayajirao University of Baroda, area of interest: taxonomy, molecular systematics and anatomy of pteridophytes; limnology and phytoplankton diversity. Dr. Kishore S. Rajput, Laboratory of Plant Anatomy & Pteridology, The Maharaja Sayajirao University of Baroda, area of Interest: anatomy of angiosperms and pteridophytes; taxonomy and molecular systematics of pteridophytes and fungi.

Author contribution: SMP—collection & identification of Ophioglossum species and preliminary writing of present manuscript. KSR—confirmation of identity, proof reading, finalizing the current manuscript and administrative responsibilities.

Acknowledgements: Authors are thankful to anonymous reviewers and the handling editor for their valuable suggestions on the earlier version of the manuscript. Also, thankful to Science and Engineering Research Board (SERB) for financial support under NPDF programme to SMP.

INTRODUCTION

The state of Goa is located on the western coast of India between Maharashtra and Karnataka states, with a geographical area of 3,702km^2. It lies on the coastal plains of the Western Ghats between 14.899–15.799 ^{0}N and 3.681–74.336 ^{0}E. The major rivers are Mandovi and Zuari (Meteorological Centre, Goa 2020), and the climatic features fall under the tropical monsoon climate, making the region generally warm and humid throughout the year. The average rainfall ranges between 2,500–4,500 mm/annum, and highest rainfall is observed during June–August. The average temperature ranges between 16.2°C–36.7°C, with maximum temperature during the month of April–May. The state has a national park (Molem) and six wildlife sanctuaries which covers an area of 755km^2 (Hiremath 2003; Jadhav & Patil 2012).

The genus *Ophioglossum* L. belongs to the primitive family Ophioglossaceae. About 50 species are accepted internationally (Hassler & Schmitt 2020), and 19 species are documented from India (Patil & Dongare 2014; Patil et al. 2018 & Kachhiyapatel et al. 2018), of which the status of a few were unresolved (Hassler & Schmitt 2020). All are terrestrial forms except the epiphytic *O. pendulum* L. The genus was studied in India for the first time by Beddome (1883). After his monumental contribution on the Indian ferns, the genus *Ophioglossum* L., received further attention from Blatter & d'Almedia (1922), Chakravarty (1951), Mahabale (1962), Panigrahi & Dixit (1969), Khandelwal (1987), Khullar (1994), and Goswami (2007), in their respective works. It is characterized by simple trophophyll with a spike (rarely bi or trifurcate) bearing two rows of sporangia. In all species the trophophyll is pale green, green, dark or light green at maturity, and produces a paler spike (Khullar 1994; Goswami 2007; Goswami et al. 2008). *Ophioglossum gomezianum* Welw. ex A.Braun, *O. indicum* B.L.Yadav & Goswami, *O. lusitanicum* L., and *O. rubellum* Welw. ex A.Braun, however, produce yellow, pink, reddish to brown tinge of trophophyll, respectively (Goswami 2007). Patil & Dongare (2014) studied the diversity and distribution of *Ophioglossum* from the Western Ghats and reported 06 species. Recently, Fraser-Jenkins et al. (2018) accepted only 12 species for India.

The diversity of pteridophytes in Goa is less understood, with few reports. Dalgado 1898; Blatter & d'Almedia 1922; Vartak 1966; Rao 1985–1986; Naithani et al. 1997, and Irudayaraj & Bir 1997. Manickam et al. (2004) studied the pteridophytes of the Western Ghats of Goa and recorded 51 species. Further, Kerkar & Shetkar (2009) studied the order Pteridales and recorded 16 species in Goa belonging to six genera from five families. In 2010, Datar & Lakshminarasimhan (2010) studied the pteridophyte flora of the Western Ghats of Goa and documented 47 species. These studies reported two species of *Ophioglossum*: *O. costatum* R.Br., and *O. gramineum* Willd., from the Western Ghats of Goa. While studying the pteridophytes of the Western Ghats, however, the authors visited different places in Goa and observed that the plateaux and coastal plains are favourable for *Ophioglossum* and earlier workers may have missed some species. Thus the present investigation was undertaken to study the morpho-taxonomy, species composition, distribution and conservation status of *Ophioglossum* from Goa.

MATERIALS AND METHODS

Field visits were carried out during 2014–2018 in different areas of Goa State. The collected specimens of *Ophioglossum* were processed in the laboratory. Pressed specimens were fixed with 4% formalin and affixed to herbarium sheets using synthetic gum (Fevicol). Specimens were identified using literature, including Blatter & d'Almedia (1922); Panigrahi & Dixit (1969); Fraser-Jenkins et al. (2017), and Patil & Dongare (2014). The voucher specimens are deposited in the herbarium of the Department of Botany, Maharaja Sayajirao University of Baroda, Vadodara, Gujarat (BARO).

RESULTS

During the present investigation authors collected six species of *Ophioglossum: O. costatum* R.Br.*, O. gramineum* Willd.*, O. lusitanicum* L.*, O. nudicaule* L.f.*, O. parvifolium* Grev. & Hook.*,* and *O. reticulatum* L. The detailed morphology, diversity, distribution, illustrations, photographs, phenology, ecology, and conservation status of each species is given. An identification key for the taxa recorded from Goa State is given below.

Key to the species for Goa state

1a. Trophophylls having costa or yellow band at centre .... *O. costatum*
1b. Trophophylls without costa or yellow band at centre 2

2a. Trophophylls base cordate, strobili having > 20 pairs of sporangia .... *O. reticulatum*
2b. Trophophylls base not cordate, strobili having

< 20 pairs of sporangia 3

3a. Trophophylls attached to substratum .... *O. parvifolium*
3b. Trophophylls above the ground 4

4a. Trophophylls ovate-lanceolate, 1–2 cm above the ground .... *O. nudicaule*
4b. Trophophylls liner-lanceolate or spathulate not flat on ground 5

5a. Trophophylls linear-lanceolate or grass like .... *O. gramineum*
5b. Trophophylls spathulate-lanceolate not grass like .... *O. lusitanicum*

Ophioglossum costatum R. Br., Prod. Fl. Nov. Holl. 163. 1810. Panigrahi & Dixit, Proc. Nat. Inst. Sci. India 35: 249. 1969; Patil & Dongare, Indian Fern J., 31: 17–24. 2014.

Lectotype: from Australia, Queensland, Arnhem North Bay, R. Brown 118. 14.2.1803.

Ophioglossum pedunculosum Desv., Mag. Nat. Fr. Berlin 5: 306. 1811.

O. brevipes Bedd., Ferns. Southern India 23. t. 72. 1863.

O. bulbosum Bedd., Ferns. Brit. India Supl. t. 28. 1876.

O. fibrosum Schum., Bedd., Handb. 465. t. 289. 1883.

Plant terrestrial, 12–25 cm in height, pale-green; rhizomorph 0.5–1 cm, subterranean, disc like or globose, bearing numerous yellow-brown, fleshy, unbranched, roots; common stalk 2–3 cm, subterranean-terranean; trophophylls 2–6 x 0.5–1 cm, 1–3 simple, elliptic-lanceolate, apex acute-apiculate or obtuse-round, base cuneate, margin entire, green-pale green, glabrous on both sides, coriaceous, costa present, prominent, yellow; texture coriaceous, thick; veins indistinct, simple reticulate, anastomosing; fertile segment 9–19 cm, unbranched, inserted on adaxial position of leaf; strobili 2–5 cm, liner-lanceolate, apex blunt-lanceolate, 20–55 pairs of sporangia, pale yellow, unbranched; spores 20–40 µm in diameter, trilete, foveolate.

Phenology: sterile phase – June–July; fertile phase: July–September (rarely in October)

Distribution: India (Andhra Pradesh, Assam, Chhattisgarh, Goa (Canacona, Dharbandora, Mapusa, Pernem, Phonda, Quepem, & Sattari), Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal), Bangladesh, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand, Africa, and Australia.

Ecology: Very common, collected from grassy plateau. The population size varies according to the water content of the soils. The population size is larger when water availability is more and vice-versa.

Conservation status: It is collected from throughout the Goa except seashore areas. Population comprises about 300–400 individuals per km^2 and the area of occupancy (AOO) is 50–60 km^2. Therefore, as per IUCN categories and criteria (IUCN red list of Threatened Species ver. 2017-1), it is assessed as Least Concerned (LR) species for Goa State.

Ophioglossum gramineum Willd. Nov. Act. Acad. Erfurt. 2: 18. t.f.1. 1802; Beddome, Handb. Suppl. Ferns Brit. India 108. 1892; Balakrishnan et al., Bull. Bot. Surv. India 2: 337. 1960; Panigrahi & Dixit, Proc. Nat. Inst. Sci. India 35: 250. 1969; Patil & Dongare, Indian Fern J. 31: 17–24. 2014.

Type: from West Africa, St. Thomae, De Friedland B.

Ophioglossum dietrichiae Prantl, Ber. Deut. Bot. Ges. 1: 352. 1883.

O. gregarium Christ, Nova Guinea Bot. 8: 164. 1909;

O. inconspicuum (Racib.) Alderw., Bull. Dépt. Agric. Ind. Néerl. 21: 9. 1908.

O. prantlii C.Chr., Ind. Fil. 2: 471. 1906.

O. inconspicuum forma *majus* Alderw., Bull. Dépt. Agric. Ind. Néerl. 21: 9. 1908.

Ophioglossum gramineum var. *majus* (Alderw.) Wieff., Blumea 12(2): 324. 1964. *Ophioglossum gregarium* Christ, Nova Guinea, Bot., 8: 164. 1909.

Ophioglossum gracile Pocock ex J.E.Burrows, Bothalia 25(1): 61. 1995.

O. vulgatum var. *gramineum* (Willd.) Hook. f., Fl. Nov. Zel. 2: 50. 1854.

Plant terrestrial, 4–8 cm in height, green-pale green; rhizomorph sub-globose-tuberous, subterranean, bearing numerous, fleshy, fibrous roots; common stalk 0.5–2 cm, subterranean-terranean, flat; trophophylls 1–2 cm, 1–2, linear grass-like, apex acuminate, margin entire, soft, green-pale green; texture coriaceous, thin; veins parallel, anastomosing, forming parallel areoles; fertile segment 3.5–6 cm, unbranched, pale green, flat-round; strobili 0.5–1.5 cm, linear-lanceolate, apex pointed, 6–10 (rarely >10) pairs of sporangia, arranged in two alternate rows, pale green-yellow; spores 25–40 µm dia., trilete, exine reticulate.

Phenology: Sterile phase: Jun–July; fertile phase: July–August (rarely September–October)

Distribution: India (Andhra Pradesh, Chhattisgarh, Goa (Cancona, Dharbandora, Mapusa, Pernem, Phonda, Quepem, & Sattari), Gujarat, Karnataka, Kerala, Madhya

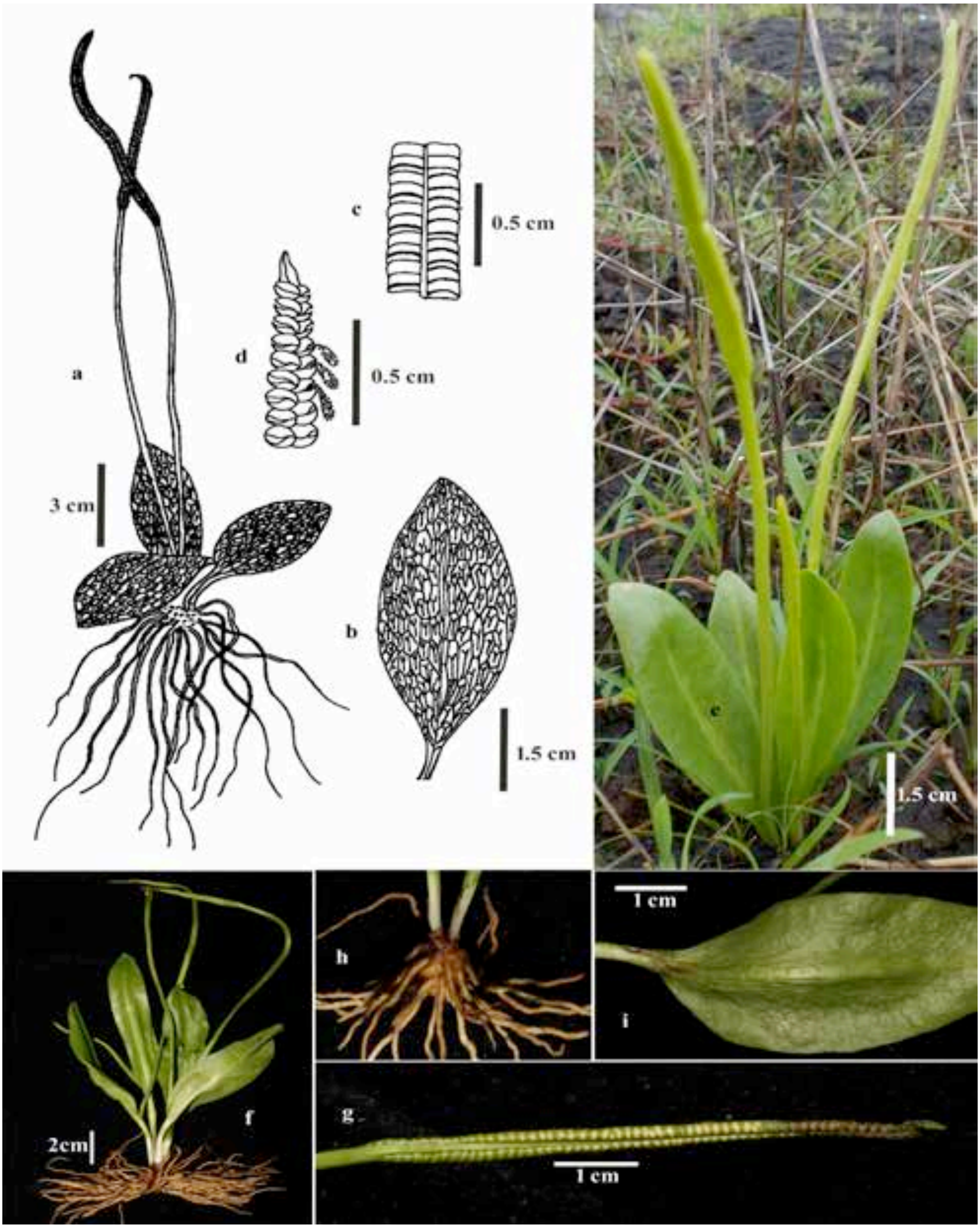


Image 1. *Ophioglossum costatum*: a, e–f—habit | b—enlarged trophophyll showing venation | c–d, g—enlarged strobilus | h—globous rhizomorph | i—trophophyll showing costa. © Sachin M. Patil

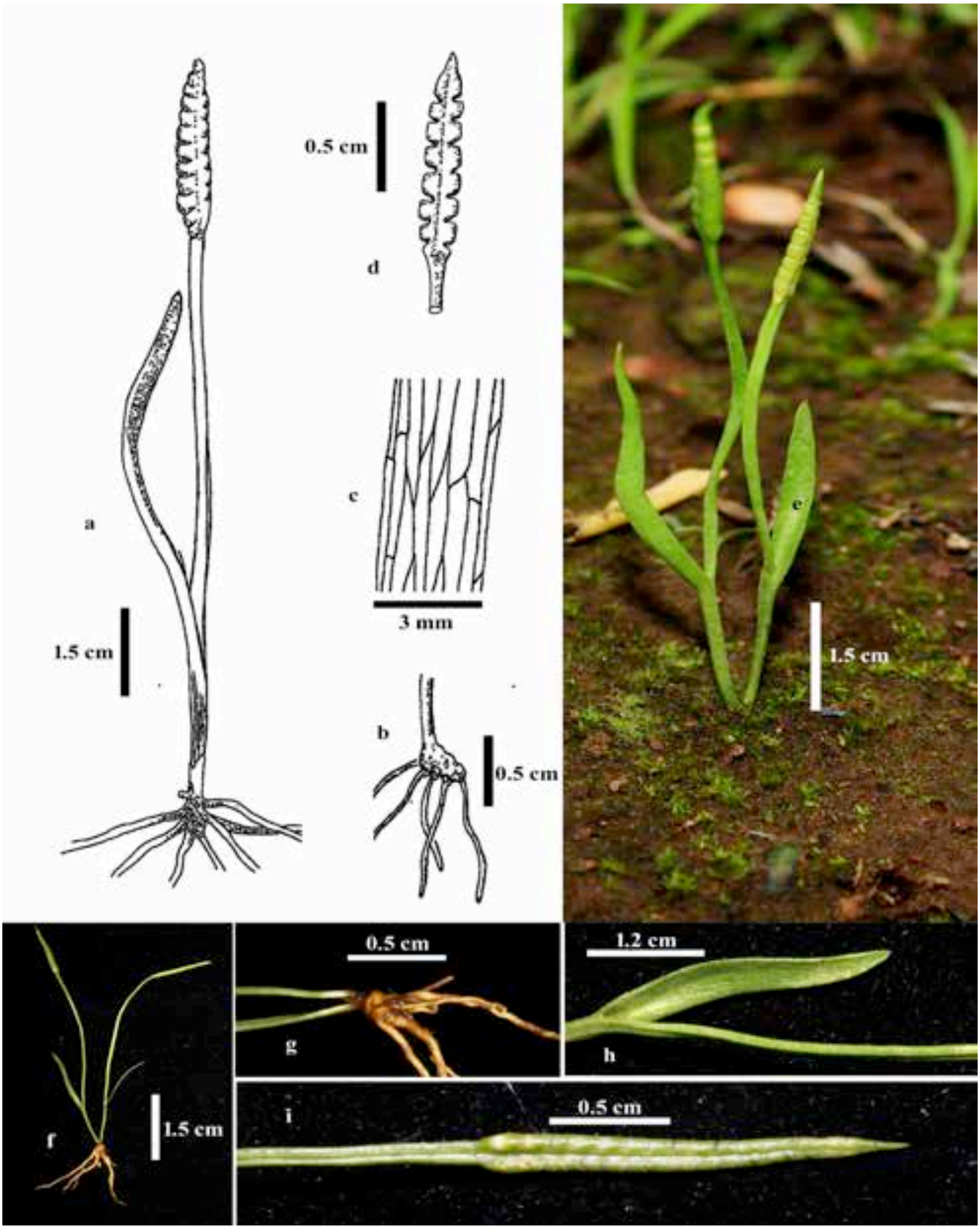


Image 2. *Ophioglossum gramineum*: a, e–f—Habit | b, g—enlarged rhizomorph | c—enlarged view of venation pattern | d, i—enlarged strobilus | h—enlarged trophophyll. © Sachin M. Patil

Pradesh, Maharashtra, Meghalaya, Rajasthan, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, & West Bengal), Indonesia, Malaysia, Myanmar, Philippines, East Borneo, East Java, New Guinea, Vietnam, Africa, and Sri Lanka.

Ecology: Common fern collected from grassy plateaux associated with *O. nudicaule*, *O. parvifolium* and *O. costatum*.

Conservation status: It is collected from plateaux situated in Goa State. Population comprises about 300–400 individuals per km^2 and the area of occupancy (AOO) is 50–60 km^2. Therefore, as per IUCN categories and criteria (IUCN red list of Threatened Species ver. 2017-1), it is assessed as Least Concerned (LR) species for Goa State.

Ophioglossum lusitanicum L., Sp. Pl., 2: 1063. 1753; Clausen, Mem. Torry Bot. Club, 19 (2): 159. 1938; Mahable, Bull. Bot. Surv. India, 4: 71. 1962; Panigrahi & Dixit, Proc. Nat. Inst. Sci. India 35: 251. 1969; Patil & Dongare, Indian Fern J., 31: 17-24. 2014.

Type: from Portugal, "Habitat in Lusitania", not designated.

Ophioglossum loureirianum C.Presl, Suppl. Tent. Pterid. 55. 1845.

O. braunii Prantl, Ber. Deutsch. Bot. Ges. 1: 351. 1883.

Plant terrestrial, 3–10 cm in height, small; rhizomorph 0.5–1 cm, subterranean, sub-globose-tuberous with or without stoloniferous fleshy roots; common stalk subterranean, white; trophophylls 1–2, erect, red-brown-green, spathulate, linear-lanceolate or elliptic-lanceolate, acute-acuminate apex, cuneate- attenuate base, entire margin; texture coriaceous, thin; veins indistinct, anastomosing, forming parallel areoles; fertile segment round, unbranched, green-yellow brown; strobili 1–2 cm, linear-lanceolate, 8–10 (rarely >10) sporangia in two rows, green-yellow; spores 20–25 µm dia., trilete, exine reticulate.

Phenology: sterile phase: June–July; fertile phase: August–September

Distribution: India (Andhra Pradesh, Assam, Bihar, Goa (Mapusa, Pernem, & Phonda), Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Tamil Nadu, & Uttar Pradesh), Algeria, Morocco, Portugal, Spain, Tanzania, Tunisia, and Uganda.

Ecology: Common species, collected from grassy plateaux of Goa, associated with *O. costatum, O. nudicaule, O. parvifolium* and *O. reticulatum*.

Conservation status: It is collected from plateaux situated at Mapusa, Pernem, and Phonda. A population of about 100–200 individuals was found. The area of occupancy (AOO) is 10–20 km^2 per locality and considered as Data Deficient (DD) because the explorations in the state are not completed and there is a possibility of more locations of occurrence.

Ophioglossum nudicaule L.f., Suppl. Pl. Syst. 443. 1781; Beddome, Handb. Ferns Br. India, 464, t. 228. 1883; Panigrahi & Dixit, Proc. Nat. Inst. Sci. India 35. 252. 1969; Manickam & Irudayaraj, Pterid. Fl. West Ghats 48-49. t. 27. 1992; Patil & Dongare, Indian Fern J. 31: 17-24. 2014.

Type: South Africa: Cape of Good Hope.

Ophioglossum capense Sw., Schard. Journ. 1801(2): 308. 1803.

Ophioglossum capense Schlech. var. *nudicaule* (L.) Schlech., Fil. Prom. Bonae Sp.: 9. 1825.

Ophioglossum ellipticum Hook. & Grev., Icon. Filic. t. 40 A. 1828.

Ophioglossum lineare Schlechter & Brause, Bot. Jerb., 49: 59, fig. 3F. 1912.

Ophioglossum luersseni Prantl, Ber. Deut. Bot. Ger. 1: 352. 1883.

Plant 4–12 cm height, green, terrestrial herb; rhizomorphs subterranean, sub-globose (at young)-tuberous (at maturity), bearing many soft, pale brown, unbranched, fleshy, fibrous, stoloniferous roots; common stalk 1–3 cm, subterranean-terranean, white (subterranean), green (terranean); trophophylls 0.5–2 x 1–2 cm, 1–2 (rarely 3), green, tuft ovate-elliptic, apex acute-obtuse, base cuneate, margin entire, glabrous; veins indistinct, simple reticulate, anastomosing, with or without included veinlets; fertile segment 2–8 cm, unbranched (rarely branched), green at young, yellow at maturity; strobili 1.5–2.5 cm long, with 10–20 sporangia per strobilus, arranged in two alternate rows, linear-lanceolate, apex pointed; spores 30–40 µm dia., trilate, with reticulate ornamentation.

Distribution: India (Andhra Pradesh, Himachal Pradesh, Jammu & Kashmir, Goa (Phonda & Canacona), Gujarat, Jharkand, Karnataka, Kerala, Maharashtra, Sikkim, Tamil Nadu, & West Bengal), China, Indonesia, Malaysia, and Thailand.

Phenology: sterile phase**:** July–August; fertile phase: August–September.

Ecology: The species is growing in patches on fully exposed plateaux or open grassland, associated with *O. costatum, O. gramineum* and *O. parvifolium*.

Conservation status: It is collected from open grasslands on plateaux situated in Phonda and Canacora. The area of occupancy (AOO) is 10–20 km^2 per locality and considered as Data Deficient (DD) because the explorations in the state are not completed and there is

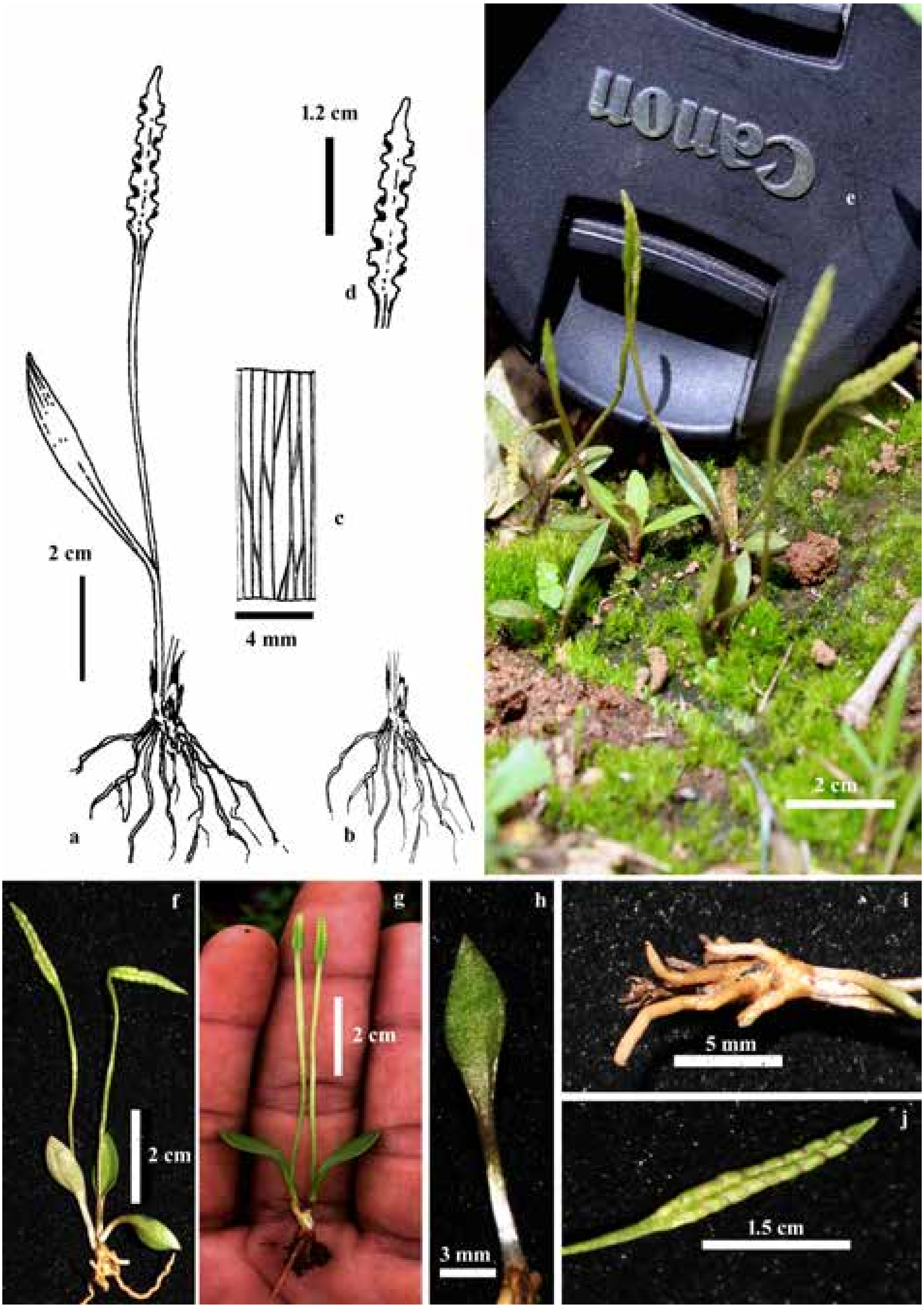


Image 3. *Ophioglossum lusitanicum*: a, e–g—Habit | b, i—enlarged rhizomorph | c—enlarged trophophyll showing venation | d, j—enlarged strobilus | h—enlarged trophophyll. © Sachin M. Patil

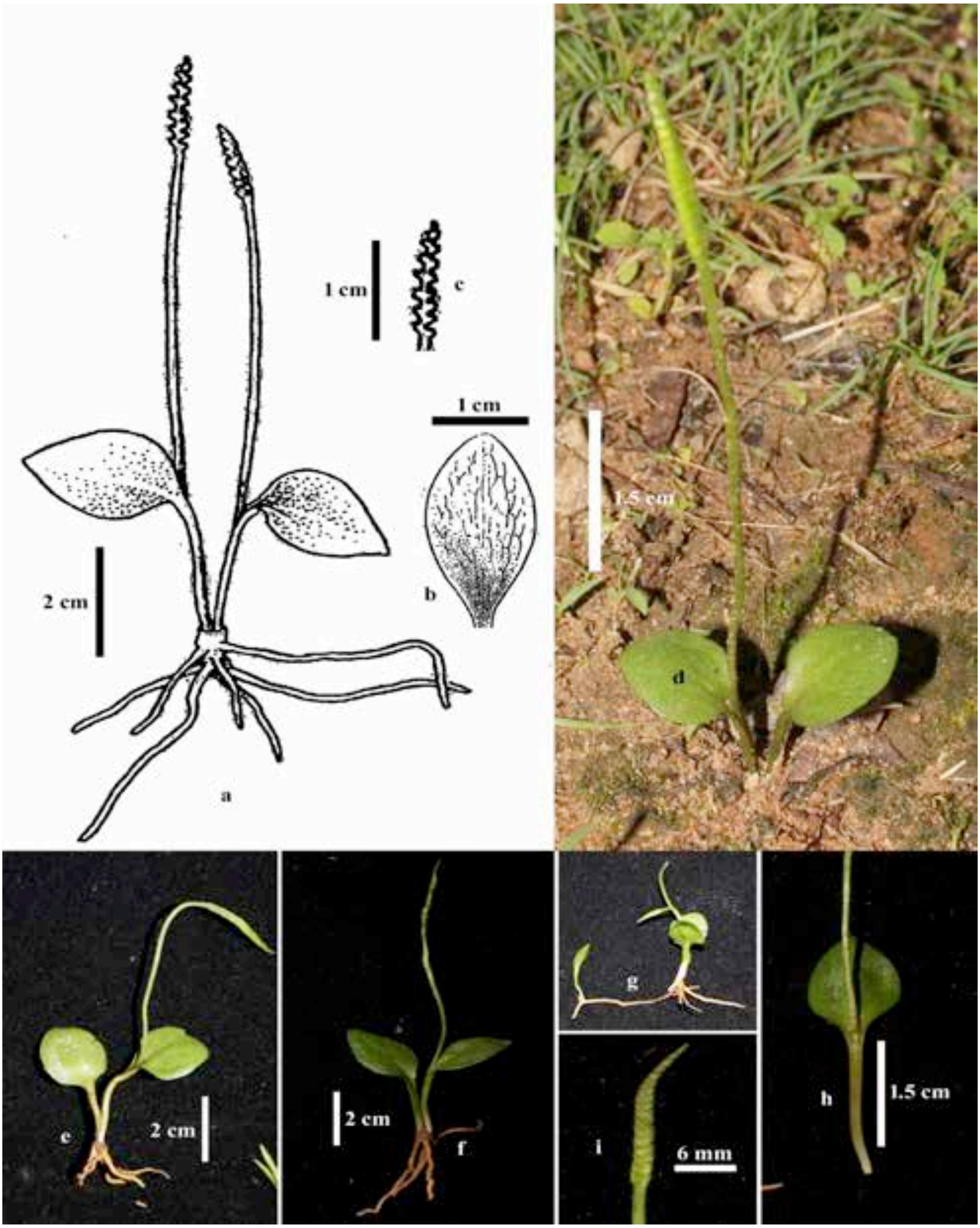


Image 4. *Ophioglossum nudicaule*: a, d–f—Habit | b, h—enlarged trophophylls | c—enlarged strobilus | g—stoloniferous roots. © Sachin M. Patil

possibility of more locations of occurrence.

Ophioglossum parvifolium Grev. & Hook., Bot. Misc. 3: 218. 1833; Patil & Dongare, Indian Fern J. 31: 17–24. 2014.

O. macrorrhizum Kunze Analecta Pteridogr.: 2. 1837.

O. schmidii Kunze in Linnaea 24: 246. 1851.

O. luerssenii Prantl Ber. Deutsch. Bot. Ges. 1: 352. 1883.

O. pumilum (Racib.) Alderw. Malayan Ferns: 774. 1909.

Type: India, Gujarat, Valsad District, Wilson Hills, 24 Aug 2014, Patil & Kachhiyapatel 38 (BARO No. 1234500700). *typ. cons. prop.* (Mazumdar et al. 2018)

Plant 4–8 cm, terrestrial herbs; rhizomorph subterranean, sub-globose-tuberous, pale brown, bearing many soft, fleshy, unbranched, fibrous, stoloniferous roots; common stalk subterranean, white, round, glabrous; trophophylls 0.4–1 cm, 1–2 (rarely 3–4), pale green-green, ovate-lanceolate, apex acute-apiculate, margin entire, base cordate; texture coriaceous, thin; *veins* indistinct, simple reticulate, four or five veins passing up through the stalk of the blade; fertile segment 2–6 cm long, unbranched, green-pale green; strobili 0.5–1 cm long, 5–7 (rarely >10) pairs of sporangia, arranged in two alternate rows; *spores* 25–45 µm dia., trilete, exine reticulate.

Distribution: India (Madhya Pradesh, Goa (Canacona, Dharbandora, Mapusa, Pernem, Phonda, Quepem, & Sattari), Gujarat, Maharashtra, Karnataka, Rajasthan, Kerala, & Tamil Nadu), China, South America, Sumatra, Malaysia, and Thailand.

Ecology: Common species grows in patches on fully exposed areas from low land to high land areas.

Conservation status: It is collected from different plateaux of Goa state. Population comprises about 300–400 individuals per km^2. The area of occupancy (AOO) is 50–60 km^2. Therefore, as per IUCN categories and criteria (IUCN ver. 2017-1), it is assessed as Least Concerned (LC) species for Goa state.

Ophioglossum reticulatum L. Sp. Pl. 2: 1063. 1753; Beddome, Ferns. Southern India 23. t. 70. 1863; Beddome, Handb. Ferns. Bri. India, 465. t. 290. 1883; Panigrahi & Dixit, Proc. Nat. Inst. Sci. India 35. 257. 1969; R.D. Dixit, Cens. Ind. Pterid. 24. 1984; Manickam & Irudayaraj, Pterid. Fl. West Ghats: 51. t. 29. 1992; Patil & Dongare, Indian Fern J. 31: 17-24. 2014.

Lectotype: (Tardieu Blot, in Aubreville, Flor. Gabon 8: 30. 1964): from C. America, "*Ophioglossum cordatum* et *reticulatum*" in Plumier, Traité Foug. Amér., 141, t. 164, 1705.

Ophioglossum peruvianum Presl, Suppl. Tent. Pterid 52. 1845.

Ophioglossum petiolatum sensu Wieffering, Blumea, 12: 327. 1964.

Ophiglossum cordifolium Roxb., Hort. Bengal. 75. 1814;

Plant 15–25 cm, terrestrial herb; rhizomorph 3–7 mm long, subterranean, tuberous, bearing few long, thick fleshy unbranched, pale brown roots, with 1–2 trophophylls; common stalk 2–5 cm, terranean, white at base, green above; trophophylls 1, 2–5 x 1–3 cm, cordate-broadly ovate, rarely elliptic-oblong, apex rounded or acute, base cordate; veins reticulate, areoles with or without included free veinlets; fertile segment 12–18 cm long, round; strobili 1–5 cm, 20–45 pairs of sporangia, apex pointed, sporangia arranged in two alternate compact rows; spores 30–45 µm dia., spherical, trilete, exine hemispherical.

Distribution: India (Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa (Sattari & Canacona), Gujarat, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Odisha, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, & West Bengal), Malay Peninsula, tropical America, Africa, Philippines, and Sri Lanka.

Phenology: sterile phase: July–August; fertile phase: August–October

Ecology: Very common, found beneath trees in the forest along with *Ophioglossum costatum, O. gramineum* and *O. parvifolium*.

Conservation Status: It is collected from forest regions at Sattari and Canacona. The area of occupancy (AOO) is 10–20 km^2 per locality and considered as Data Deficient (DD) because the explorations in the state are not completed and there is possibility of more locations of occurrence.

DISCUSSION

Earlier only two species, *Ophioglossum costatum* and *O. gramineum* were reported from Goa (Manikam et al. 2004; Datar & Lakshminarsimhan 2010). During the present investigation six species were collected, of which *O. lusitanicum, O. nudicaule, O. parvifolium*, and *O. reticulatum* have been added to the flora of Goa. *O. costatum, O. gramineum*, and *O. parvifolium* are considered least concerned (LC) species, while *O. lusitanicum, O. nudicaule*, and *O. reticulatum* are

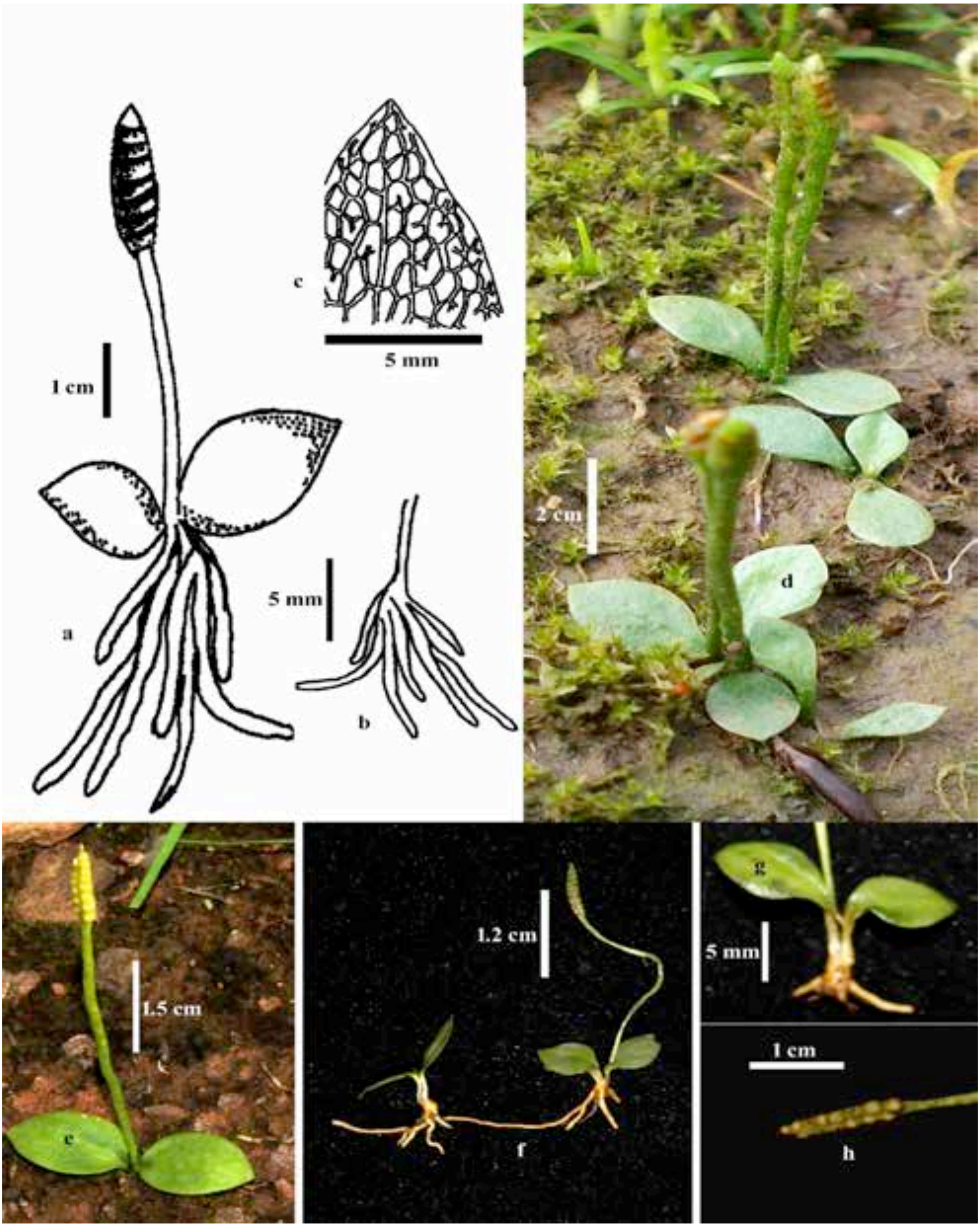


Image 5. *Ophioglossum parvifolium*: a, d–e—Habit | b, g—enlarged rhizomorph | c—enlarged trophophylls showing venation | f—stoloniferous roots | h—enlarged strobilus. © Sachin M. Patil

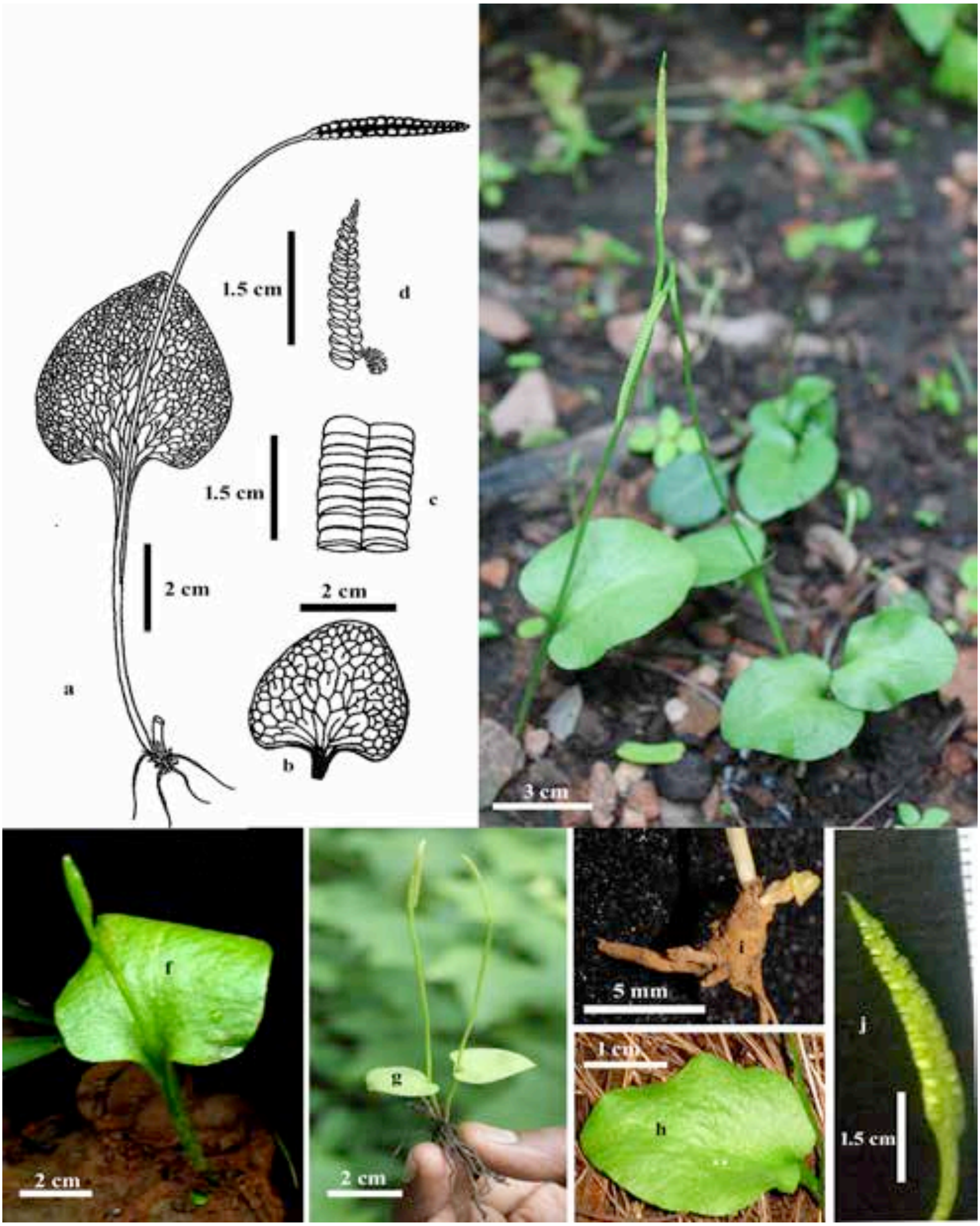


Image 6. ***Ophioglossum reticulatum*****: a, e–g—Habit | b—enlarged trophophyll showing venation | c–d, j—enlarged strobilus | h—enlarged trophophyll | i—rhizomorph. © Sachin M. Patil**

considered data deficient (DD) species. The maximum diversity was observed in open grassy habitat and plateaux, where we collected *O. costatum, O. gramineum, O. lusitanicum, O. nudicaule*, and *O. parvifolium*. Coastal plains contained *O. costatum* and *O. gramineum,* and on forest floors we collected *O. nudicaule* and *O. reticulatum*.

In *Ophioglossum costatum* the trophophylls (leaf-like segment) have a central yellow band (i.e. costa), hence the specific epithet is *O. costatum*. Amongst the taxa reported from India, *O. costatum* is only one with a costa (Image 1), thus it can be easily differentiated from other Indian residents. In the field it is difficult to locate *O. gramineum* because this species is found on grassy plateaux and its appearance is similar to a grass (hence specific epithet *O. gramineum*). Generally the trophophylls are linear-lanceolate like grass, and are part underground and part above ground with a common stalk (Image 2). A species similar to *O. gramineum* is *O. lusitanicum*, however, the latter has green-brown, spathulate-lanceolate trophophylls and a subterranean common stalk (Image 3). *Ophioglossum nudicaule* and *O. parvifolium* are closely allied and commonly confused species. *O. nudicaule* is smaller in size, hence the specific epithet is *parvifolium* (*parvum* = small and *folium* = trophophylls). *Ophioglossum nudicaule* has trophophylls that are ovate-obovate, 1–2 cm above the ground, common stalk subterranean-terranean, whereas in *O. parvifolium* the trophophylls are ovate-broadly lanceolate, attached or flat on the ground, common stalk subterranean only (Image 4–5). *Ophioglossum reticulatum* is well-known and popular in biological world because it has the highest number of chromosomes (*n*=740). It is allied and confused with *O. petiolatum*, however, *O. reticulatum* has cordate trophophylls, 2–5 cm above ground, epetiolate, common stalk subterranean-terranean, having maximum number of sporangia (Image 6).

REFERENCES

Beddome, R.H. (1883). *Handbook to the ferns of British India*. Ceylon and Malay Peninsula Thacker Spink & Co., Calcutta, 500pp. https://doi.org/10.5962/bhl.title.101756

Blatter, E. & J.F. d'Almeida (1922). *The Ferns of Bombay*. D B Taraporevala and Sons & Co, Bombay, 233pp. https://doi.org/10.5962/bhl.title.24062

Chakravarty, H.L. (1951). Indian *Ophioglossum*. *The Botanical Society Bengal* 5: 1–10.

Dalgado, D.G. (1898). *Flora de Goa e Savantwadi*. Sociedade Geographia de Lisboa, Lisbon, 290pp.

Datar, M.N. & P. Lakshminarasimhan (2010). Habitat based Pteridophyte diversity from Western Ghats of Goa, India Habitat based Pteridophyte diversity from Western Ghats of Goa, India. *Phytotaxonomy* 10: 70–76

Fraser-Jenkins, C.R., K.N. Gandhi, B.S. Kholia & A. Benniamin (2017). *An Annotated Checklist of Indian Pteridophytes Part-1 (Lycopodiaceae to Thelypteridaceae).* Bishen Singh Mahendra Pal Singh, Dehradun, 562pp.

Fraser-Jenkins, C.R., K.N. Gandhi & B.S. Kholia (2018). *An annotated checklist of Indian Pteridophytes Part–2 (Woodsiaceae to Dryopteridaceae).* Bishen Singh Mahendra Pal Singh, Dehra Dun, 573pp.

Goswami, H.K. (2007). Biology of *Ophioglossum* L. *Bionature* 27: 1–73.

Goswami, H.K., S.C. Verna & B.D. Sharma (2008). *Biology of Pteridophytes –I. Ophioglossum, Linnaeus*. Bionature Monograph, Catholic Press, Ranchi. 135pp.

Hassler M. & B. Schmitt (2020). Checklist of ferns and lycophytes of the world Version 8.30. With special support by Ralf Knapp (https://worldplants.webarchiv.kit.edu/ferns/).

Hiremath, K.G. (2003). *Recent advances in environmental science*. Discovery Publishing House. 470pp.

Irudayaraj, V. & S.S. Bir (1997) Notes on some Pteridophytes from the Western Ghats of Goa state South India. *Indian Fern Journal* 14: 113–117.

Jadhav, S. & S.K. Patil (2012). *Fauna of Protected areas of Goa*. Zoological Survey of India, Kolkata, 10pp.

Kachhiyapatel, R.N., S.M. Patil, S.K. Patel & K.S. Rajput (2018). Genus *Ophioglossum* L., from Western Part of India with special reference to Gujarat State. *Notulae Scientia Biologicae* 10(03): 373–378. https://doi.org/10.15835/nsb10310243

Kerkar, V. & P. Shetkar (2009). Diversity and distribution of Pteridales (Pteridophyta) from Goa. pp. 82-86 In: Krishnan, S. and Bhat, D.J. (eds.) *Plant and Fungal Biodiversity and Bioprospecting.* Broadway Book Centre, Panaji, Goa. 187pp.

Khandelwal, S. (1987). New species of *Ophioglossum* L. from India. *Indian Fern Journal* 3: 89-94.

Khullar, S.P. (1994). *An illustrated fern flora of the West Himalaya Vol I*. International Book Distributors Dehradhun. 459pp.

Mahabale, T.S. (1962). Species of *Ophioglossum* in India. Their taxonomy and phylogeny. *Bulletin Botanical Survey India* 4: 71–84.

Manickam, V.S. & V. Irudayaraj (1992). *Pteridophyte flora of Western Ghats, South India.* B. I. Publication, New Delhi. 635pp.

Manickam, V.S., A. Benniamin & S. Harikrishnan, (2004). Diversity of the ferns and fern allies Goa in Western Ghats of India. *Malaysian Journal of Science* 23: 85–93.

Meteorological Centre, Goa (2020). Topography of Goa state. http://www.imdgoa.gov.in. Electronic version accessed in 2020.

Mazumdar, J., S.M. Patil, R.N. Kachhiyapatel, R.V. Patel & K.S. Rajput (2018). (2629) Proposal to conserve the name *Ophioglossum parvifolium* (Ophioglossaceae) with conserved type. *Taxon* 67(4): 807.

Naithani, H.B., K.C. Sahni & S.S.R. Bennet (1997). *Forest Flora of Goa*. International Book Distributors, Dehra Dun, 666pp.

Panigrahi, G. & R.D. Dixit (1969). Studies in Indian Pteridophytes IV: The Family Ophioglossaceae in India. *Proceedings National Academy of India* 35B: 230–266.

Patil, S.M. & M.M. Dongare (2014). The genus *Ophioglossum* from Western Ghats of India. *Indian Fern Journal* 31: 17–24.

Patil, S.M., R.N. Kachhiyapatel, R.S. Patel & K.S. Rajput (2018). *Ophioglossum gujaratense*, a new species from Gujarat State, India. *Phytotaxa* 351(4): 273–280. https://doi.org/10.11646/phytotaxa.351.4.3

Rao, R.S. (1985–86). *Flora of Goa, Diu, Daman, Dadra & Nagarhaveli. Vols. 1 & 2.* Botanical Survey of India, Calcutta, 544pp.

Vartak, V.D. (1966). *Enumeration of Plants from Gomantak*. MACS, Pune, 167pp.

Yadav, B.L. & H.K. Goswami (2010). A new pink-brown *Ophioglossum* (Ophioglossaceae) from India. *Bulletin of the National Museum of Nature and Science Series* B 36(4): 155–159.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17299–17322

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

DOI: https://doi.org/10.11609/jott.6241.12.17.17299-17322

#6241 | Received 29 May 2020 | Final received 25 November 2020 | Finally accepted 01 December 2020

An inventory of the native flowering plants in East Siang District of Arunachal Pradesh, India

Momang Taram [1], Dipankar Borah [2], Hui Tag [3] & Ritesh Kumar Choudhary [4]

[1,3]Department of Botany, Rajiv Gandhi University, Rono Hills, Itanagar, Arunachal Pradesh 791112, India.
[2]Department of Botany, Goalpara College, PO & District Goalpara, Assam 783101, India.
[4]Biodiversity & Palaeobiology (Plants & Diatoms) Group, Agharkar Research Institute, G.G. Agarkar Road, Pune, Maharashtra 411004, India.
[1] momangtaram9@rgu.ac.in, [2] dipankar.borah@rgu.ac.in, [3] huitag2008rgu@gmail.com,
[4] rkchoudhary@aripune.org (corresponding author)

Abstract: The present study is an outcome of floristic surveys of East Siang District of Arunachal Pradesh, carried out during 2016–2019, and also a compilation of earlier published reports. Vegetation analysis of this area along with a checklist of 508 taxa is presented. A total of 503 species, one subspecies and four varieties of native flowering plants belonging to 348 genera and 102 families are reported. Among these, 11 taxa are endemic to India, two Critically Endangered, one Vulnerable, one Near Threatened, two Data Deficient, and others either Least Concern or Not Evaluated as per IUCN criteria. The study also documents two new distributional records for the flora of Arunachal Pradesh, and range extension of six lesser-known endemic species. The most dominant families were found to be Poaceae (27 species), followed by Lamiaceae (23 species), Gesneriaceae (22 species), and Rubiaceae (20 species). The number of new taxa described from the region, endemism, and the Red Listed plants strongly reflect the floristic importance of the region, which is in dire need of conservation.

Keywords: Checklist, conservation, endemism, Himalayan flora, northeastern India, taxonomy.

Abstract (in Adi language): Ager Sim East Siang District Arunachal Pradesh lo 2016 – 2019 Ditag delo Ito. East Siang lo deddine nesi - neyang em pado, ajokon ee Tani gidangso India petom lo Kapanekom kado delokke akon akon ee Arunachal Pradesh lok East Siang Goralok nyomrang kider petom lo panekom kado. Ditag anyi aum solo East Siang lok Nesi-Neyang Researchers kider ee deddine ani-ani neyang em report delokke new species discoveries em itung. Deddine angu angu kangki kangki manam nesi- neyang em padoaai idola ajo kon nesi neyang kider si nyoknam lo adung aipe kajun tatjun la bulum ijun mamil apena ditag kider lo bulu tani among holok nyoknam lo kadung. Nesi Neyang si Tani ngolum delokke Simon-sili, Takom-taruk lope ager abido. Donam tiinam lokke ila dungkeng - dakkeng, kusureng dadi lope ager amangko kamangdo. Bulu mai ngoluk turkeng ngakeng em bilenne ila bulum ngolukom ayang pe ido delokke atel kokom tani among sok nyokmo mape aido. Ngolu east siang monam lo magola ditag aum 508 Nesi- Neyang ko kalen malen la atlendung. Akokom nyomrang kider em gairupe mamil deddine malen penam ee kadungaai.

Editor: K. Haridasan, Pallavur, Palakkad, Kerala, India. **Date of publication:** 26 December 2020 (online & print)

Citation: Taram, M., D. Borah, H. Tag & R.K. Choudhary (2020). An inventory of the native flowering plants in East Siang District of Arunachal Pradesh, India. *Journal of Threatened Taxa* 12(17): 17299–17322. https://doi.org/10.11609/jott.6241.12.17.17299-17322

Funding: Self-financed, freelance work.

Competing interests: The authors declare no competing interests.

Author details: Momang Taram, a PhD scholar, has authored more than 20 research articles and has described 10 taxa new to science. She is involved in two major projects 'Biocultural studies of the Adi tribe in Arunachal Pradesh' and 'Revision of the family Gesneriaceae in Arunachal Pradesh'. Dipankar Borah has authored several research articles and has described 11 taxa new to science. He is interested in native and endemic vascular flora of northeastern India as well as ethnobotany of the region. His current research project is 'Enumeration of the biodiversity of Behali Reserve Forest, Biswanath, Assam.' Hui Tag has been involved in biocultural studies of the ethnic communities of Arunachal Pradesh. He is also working in the field of nutraceutical and drug discovery targeting some medicinal plants. Ritesh Kumar Choudhary has worked on the flora of all four biodiversity hotspots of India, and also in Vietnam and Korea. He has described 12 new plant species, authored three books and more than 70 research papers. He is actively engaged in resolving the taxonomy and phylogeny of plants using molecular data. He has been recently nominated for Prof. V.V. Sivarajan Gold Medal by Indian Association of Plant Taxonomy for his contribution to the field of plant taxonomy.

Author contribution: MT, DB, HT, and RKC conceptualized the research. MT and DB carried out the field work. All authors contributed in data compilation, analysis and writing of the manuscript.

Acknowledgements: We are thankful to: Mr. Ojar Taku, for his help during field visits; Prof. Abhaya Prasad Das for his valuable insights in identification, and taxonomic inputs; and the authorities of Rajiv Gandhi University to carry out this work. RKC thanks the Director, Agharkar Research Institute for facilities. Comments received from the anonymous reviewers are also acknowldeged.

INTRODUCTION

Northeastern India is situated in the transition zone between the Himalayan and Indo-Burma global biodiversity hotspots (Olson & Dinerstein 1998). The region has a long international boundary of about 2,000km with China and Bhutan in the north, Myanmar in the east, Nepal in the west, and Bangladesh in the south-west; it harbours more than one-third of the country's total biodiversity and 50% of the floral wealth (Takhtajan 1969). Arunachal Pradesh is the largest among the seven administrative states of northeastern India, covering an area of about 83,700km^2, of which 82% is under forest cover. It hosts a rich floral and faunal diversity due to its physiographic variation of elevations ranging 150–6,500 m and unique climatic conditions (Chakravarty et al. 2012; Taram et al. 2018). The vegetation ranges from tropical mixed and broadleaf evergreen forest to alpine meadow and scrubs (Singh & Singh 1991), and comprises many hill ranges such as Mishmee Hills, Abor Hills, Patkai Hills, Dafla Hills, and Aka Hills. The study area of East Siang is an important administrative district of Arunachal Pradesh and part of the erstwhile Siang frontier division. It also falls under the Abor Hills of the eastern Himalaya. In 1980, Siang frontier division was bifurcated into two districts namely West Siang and East Siang, headquartered at Along and Pasighat, respectively. In 1994, East Siang District was further divided into Upper Siang and East Siang, and in 2015 and 2017 Siang and Lower Siang districts were separated from East Siang. East Siang District is a mountainous area with river plains as well as rocky slopes and has a total area of 3,603km^2, lying approximately between 27.71 and 28.85 North latitudes and 94.70 and 95.58 East longitudes (Figure 1).

Griffith (1836), carried out the first floristic work in the Abor and Mishmi Hills, and published the 'Flora of Mishmi Hills'. With the advent of the 20th Century, many more plant explorations were carried out resulting in significant publications such as 'On the botany of Abor Expedition' by Burkill (1925); 'Botanical exploration in the Mishmi Hill' by Ward (1929), 'Observation of the Flora of Siang Frontier Division' by Rao & Joseph (1965), 'Floristic diversity assessment and vegetation analysis of Upper Siang District of Eastern Himalaya' by Choudhary (2008a,b), and Choudhary et al. (2012). Moreover, several studies on the taxonomy and ethnobotany of the plants of the region were also published (Tag et al. 2008; Singh et al. 2011; Yumnam et al. 2011; Yumnam & Tripathi 2013; Baruah et al. 2013; Boko & Narsimhan 2014; Mibang & Das 2017) which documented more than 300 ethnobotanically useful plant species present in the Siang belt. Considering its floristic richness, a large chunk of this district was demarcated as the erstwhile Lali Reserve Forest, which was notified as Lali Wildlife Sanctuary in 1978 and subsequently renamed Daying Ering (D'Ering) Memorial Wildlife Sanctuary in 1986.

Although the general floristic account of the region was documented in several scattered publications, a comprehensive checklist for this important area highlighting the endemic and native species was not available. The recent discovery and documentation of several new species and new records (Jeyaprakash et al. 2014; Gogoi & Borah 2015; Tatum & Das 2016; Nangkar et al. 2017; Borah & Das 2018; Borah et al. 2018, 2020a,b; Taram & Borah 2020; Taram et al. 2020a,b,c,d,e) from the East Siang District and other districts of Arunachal Pradesh and its neighbouring regions, highlights the rich biodiversity of the area and warrants more exploration and research. The present study is, therefore, aimed to provide an updated checklist of the native flowering plants of East Siang District. It also provides information on the endemic and Red list plant species (IUCN 2020) distributed in the area, based on the field surveys and scrutiny of herbarium collections and published literature.

METHODS

Several field surveys of different localities of East Siang District were carried out from April 2016 to December 2019, covering most vegetation types and different elevations. The plant specimens collected were photographed in the field, press dried and mounted on herbarium sheets following standard methods (Jain & Rao 1977). Nomenclature was followed using online databases (POWO 2019; Tropicos 2020; WFO 2020) and classified as per Angiosperm Phylogeny Group system, APG IV (Chase et al. 2016). Identification was done using relevant literature (Hooker 1872; Kanjilal et al. 1934; Hajra et al. 1996; Chauhan et al. 1996; Giri et al. 2008; Chowdhery et al. 2009; Ambrish 2013) and scrutiny of the herbarium specimens housed in ASSAM, ARUN, HAU, North East Institute of Folk Medicine (NEIFM), Pasighat and several virtual herbaria like K, E, PE, etc. Information on the conservation status was noted following the International Union for Conservation of Nature (IUCN 2020) Red List. The voucher specimens were deposited in HAU (Herbarium of Rajiv Gandhi University, Arunachal Pradesh). The field number of the specimens scrutinized at the herbarium of North East Institute of Folk Medicine

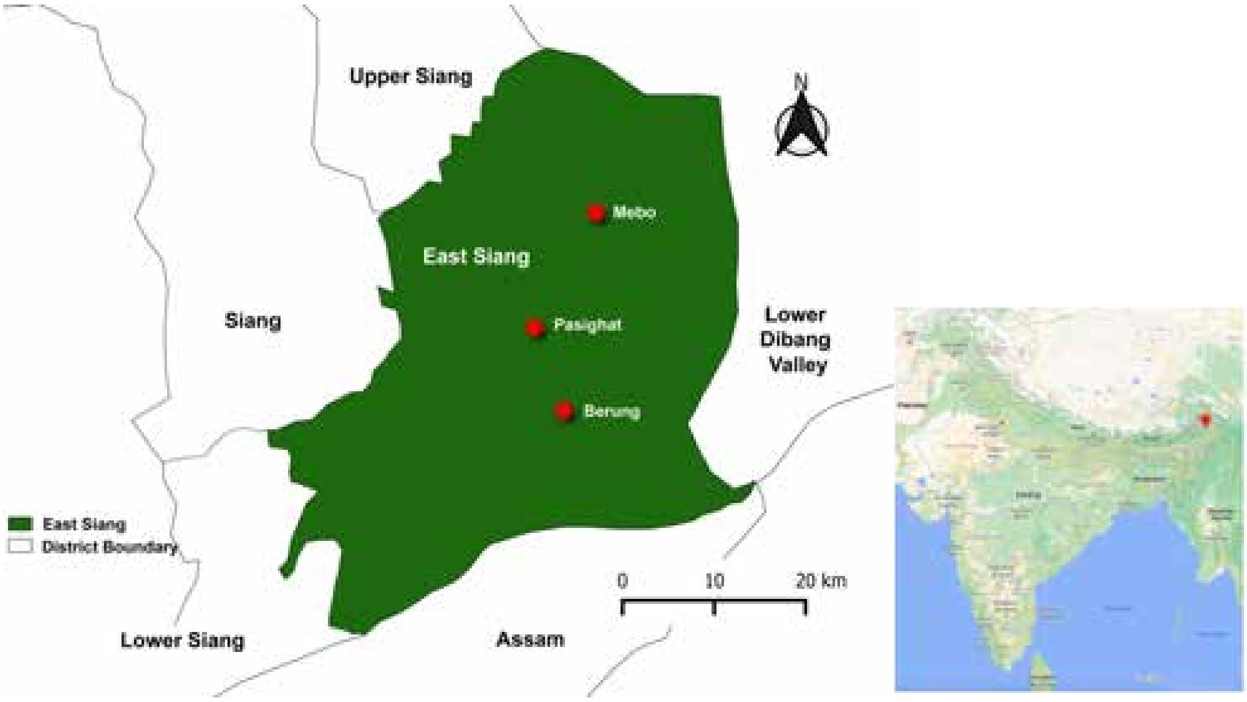


Figure 1. East Siang District.

(NEIFM), Pasighat, Arunachal Pradesh, are prefixed with NEIFM in the Appendix 1.

RESULTS AND DISCUSSION

The structure and composition characteristics of the flora of East Siang District can be classified into two major climatic zones and five vegetation zones following the earlier classification pattern proposed by Champion & Seth (1968) and Kaul & Haridasan (1987) (Image 1; Table 1). These are discussed below:

Tropical forest

This type of vegetation can be mainly seen in the area of lower elevation such as Pasighat, Ruksin, Balek, Ledum, Magnang, Sille, Rani, Bilat, Mebo, Ngopok, Kiyit up to an altitude of 900m. This forest is characterized by tall trees with close canopy and receives heavy rainfall during monsoon season. The lower elevation areas of the district are occupied by tree species like *Gynocardia odorata*, *Liquidambar excelsa*, *Trevesia palmata*, *Garcinia pedunculata*, *Terminalia myriocarpa*, *Dillenia indica*, *Actinodaphne obovata*, *Cinnamomum bejolghota*, *Litsea glutinosa*, *Litsea monopetala*, *Duabanga grandifolia*, *Magnolia hodgsonii* etc. A large chunk of this forest is being invaded by exotic weeds like *Ageratum houstonianum*, *Chromolaena odorata*, *Cuscuta cassytoides*, *Mikania micrantha*, and *Paederia foetida* (not included in the present checklist). Many common species of bamboos and orchids can also be found throughout these forests. The tropical forest of the district can be further divided into three subtypes:

A. Grasslands: The grasslands are found in the alluvial soils of the Siang River basin. Daying Ering Memorial Wildlife Sanctuary of this district occupies mostly this vegetation. Several scattered trees are also found in the areas, though the diversity is very less. *Carex baccans*, *Oplismenus burmanni*, *Erioscirpus comosus*, *Themeda villosa*, *Saccharum spontaneum*, *Saccharum arundinaceum*, *Phragmites karka*, and *Thysanolaena latifolia* are the most commonly found grasses and sedges as well as a few grassland orchids such as *Pachystoma pubescens* are also found.

B. Tropical semi-evergreen forest: This type of forest can be encountered in Sirki, Bodak, Ponging, and adjacent areas, which are dominated by trees like *Cordia dichotoma*, *Duabanga grandiflora*, *Ficus auriculata*, *F. crassiramea*, and *Toxicodendron hookerii*. In the next storey, *Maesa indica*, *Abroma augustum*, *Leea indica*, *Mussaenda glabra*, *Buddleja asiatica*, *Coffea bengalensis*, *Saurauia sinohirsuta*, *Sabia lanceolata*, and several species of wild *Citrus* can be commonly found. The ground storey is composed of herbs like *Viola betonicifolia*, *Lobelia nummularia*, *Persicaria capitata*, and *P. hydropiper*.

Image 1. Different habitat types of East Siang District: A—perennial waterfall at Sirki | B—evergreen forest along the Siang river basin | C—dense tropical forests at Pasighat | D—open tropical forests at Ruksin. © Dipankar Borah

Table 1. Major climatic and vegetation zones of East Siang District.

Climatic zone	Vegetation zone	Champion & Seth (1968)	Altitudinal range (in m)
1. Tropical	Grasslands	Unclassified	alluvial plains
	Tropical semi-evergreen	2/B/C1/Ia, 2/B/C1b/ISI	near alluvial plains
	Tropical evergreen	1/B/C1, 1/B/C2	up to 600
	Tropical wet evergreen	8/B/C1	up to 900
2. Subtropical	Subtropical evergreen	3C3/Bb, 3C/IS2	900–1500

C. Tropical evergreen forest: This type of forest can be seen in most of the areas of the district such as Renging, Ledum, Mikong, and Pasighat. Due to heavy rainfall in the area, luxuriant growth of the tropical flora can be seen. The common tree species of this forest are *Actinodaphne obovata*, *Alstonia scholaris*, *Artocarpus lacucha*, *Callicarpa arborea*, *Canarium strictum*, *Litsea monopetala*, *Wallichia oblongifolia*, *Trevesia palmata*, *Rhus chinensis*, *Liquidambar excelsa*, *Morus macroura*, *Ficus semicordata*, *F. tinctoria, F. variegata*, and *F. virens*. The second storey, however, comprises of *Saurauia punduana* and *Litsea cubeba*. Epiphytic plants like *Aeschynanthus micranthus*, *A. acuminatus*, *A. superbus*, *Thunbergia coccinea*, and *Dischidia bengalensis* are also common. The ground storey comprises of *Brachystemma calycinum*, *Hellenia speciosa*, *Phrynium pubinerve*, *Alpinia nigra*, *Curculigo capitulata*, and several others.

D. Tropical wet evergreen forest: These forests receive comparatively high rainfall (ca. 2,000mm or more) and the temperature ranges from 10–30 ^{0}C. These forests harbour the most diverse flora in the district comprising of three storeys. Ruksin, Rani, Sile, and Magnang host such forests where the elevation is very low compared to the other areas of the district. Being mostly plains, the regions are most prone to deforestation for agriculture, and hence large chunks of such forests are under threat. A lot of tall tree species with close canopy can be seen growing luxuriantly in these areas. The commonest tree species of this storey are *Castanopsis indica*, *Chisocheton cumingianus*, *Toona hexandra*, *Aesculus assamica*, *Garcinia pedunculata*, *Balakata baccata*, *Gmelina arborea*, and *Bauhinia variegata*. Whereas the second storey comprises of small trees, lianas, and shrubs like *Saurauia napaulensis*, *S. armata*, *Fissistigma polyanthum*, *F. bicolor*, *Entada phaseoloides*, *Dalhousiea bracteata*, *Phlogacanthus curviflorus*, *Aralia armata*, *Caryota urens*, and *Calamus erectus*. The rich epiphytic flora can be seen holding the branches of the tree species in the area. Some of the common orchids of this forests are *Cymbidium aloifolium*, *Dendrobium aphyllum*, *D. nobile*, and *D. lasiopetalum*. The herbaceous flora of this area includes *Bonnaya antipoda*, *Lobelia zeylanica*, *Cynoglossum wallichii*, and several Begoniaceae, Balsaminaceae, & Zingiberaceae members.

Subtropical forest

This type of forest can be occasionally seen in the northern and eastern parts of the district, on high hilltops. Most of these forests lie at elevations of 900m and above. The elevational gradient plays a significant role in vegetation composition of the forest and a subtle change in the floristic composition can be observed in the areas. The ground storey is composed of various species of Urticaceae (e.g., *Elatostema*, *Pilea*, and *Boehmeria*), *Paris polyphylla*, *Wallichia triandra*, *Argostemma verticiliatum*, *Phlogacanthus vitellinus*, *Zeuxine flava*, *Cheirostylis parvifolia*, even *Ficus hederacea*, and *Henckelia mishmiensis* are seen growing luxuriantly on the rocky walls. The top storey comprises of sporadic distribution of *Phoenix rupicola*, *Pandanus furcatus*, and *Pterospermum lanceifolium*.

The present study documents a wide range of flowering plant diversity of East Siang District and altogether reports 503 species, one subspecies and four varieties, representing 348 genera belonging to 102 families (Appendix 1). The most species-rich families are Poaceae (27 species), Lamiaceae (23 species), Gesneriaceae (22 species), Rubiaceae (20 species), Fabaceae, Acanthaceae, Orchidaceae (19 species each), and Moraceae (18 species) (Appendix 1).

New records for the flora of Arunachal Pradesh

The present study documents two interesting species which were never recorded from Arunachal Pradesh. A brief taxonomic description of these species is given below to facilitate their easy identification:

Table 2. Ten dominant families of East Siang District.

	Family	No. of genera	No. of species
1	Poaceae	21	27
2	Lamiaceae	15	23
3	Gesneriaceae	08	22
4	Rubiaceae	17	20
5	Fabaceae	18	19
6	Orchidaceae	17	19
7	Acanthaceae	10	19
8	Moraceae	05	18
9	Urticaceae	09	15
10	Malvaceae	10	13

Mycetia mukerjiana Deb & Ratna Dutta (Image 2A–D)

Mycetia mukerjiana can be distinguished from its closely allied species *M. fangii* K.J.Yan & Z.Q.Song by its eglandulose calyx (vs. glandulose calyx), calyx lobes subequal to the corolla (vs. calyx lobes much shorter than the corolla), and longer bracts and bracteoles (Yan et al. 2016). *M. mukerjiana* was known so far from Assam, Mizoram, and Nagaland states of India and Bangladesh (Das & Rahman 2010; Chaturvedi et al. 2011; Barbhuiya et al. 2014), but never from Arunachal Pradesh. It was collected from Sirki area of East Siang District of Arunachal Pradesh during our floristic survey.

Specimens examined: (MT2075) (HAU), 06.vii.2018, 28.103N & 95.267E; 500m, India, Arunachal Pradesh, East Siang, Pasighat, Sirki.

Citrus indica Yu. Tanaka (Image 2E–I)

Citrus indica can be recognized from other *Citrus* species growing in the region by its unifoliate leaves, 5–7 pairs of prominent secondary veins, globose to obovoid fruits, depressed-obtuse at apex, deep orange to scarlet red when ripe, thin pericarp, as well as soft and thin mesocarp, 8–11 endocarp segments, polygonal pulps, sticky and yellow as well as 5–7 flattened, ovoid seeds per fruit. It was so far known from Assam, Manipur, Meghalaya and Nagaland (Borah et al. 2018b) but never from Arunachal Pradesh. During the present study, it was collected from Pasighat area of East Siang District.

Specimens examined: (MT2074) (HAU), 28.063N & E 95.324E; 180m, 24.iv.2019, India, Arunachal Pradesh, East Siang, Pasighat.

Endemism and range extension

Within the investigated regions, 11 species endemic to India were recorded. Out of which, five species are narrowly endemic to East Siang District of Arunachal

Image 2. New records for the flora of Arunachal Pradesh. (A–D)—*Mycetia mukerjiana* Deb & Ratna Dutta: A—leaf | B—inflorescence | C—flower-top view | D—open flower showing stamens. (E–I)—*Citrus indica* Yu. Tanaka: E—leaf | F & G—flower | H—fruit | I—seed. © Dipankar Borah

Pradesh, and six endemic to the eastern Himalaya (Appendix 1). Among these, new distribution localities were recorded for two endemic species. Their details are as follows:

(1) *Hornstedtia arunachalensis* S. Tripathi & V. Prakash (Zingiberaceae) described from Papum Pare District of Arunachal Pradesh (Tripathi & Prakash 1999) was recorded during the present investigation from Sirki, East Siang District, extending its known range by 200km (Image 3E).

(2) *Henckelia mishmiensis* (Debb. ex Biswas) D.J. Middleton & Mich. Möller, earlier known only from Mishmi Hills of Arunachal Pradesh (Sinha & Dutta 2016), was recorded during the present investigation from Pasighat and Bodak of East Siang District, extending its known range by 100km (Image 3D).

Moreover, four species reported from only one or two locations in Arunachal Pradesh from India and few other neighbouring countries were also recorded in the present study, extending their present known range to some extent. These are:

(1) *Lysionotus gamosepalus* W.T.Wang: Earlier reported only from Lohit and Upper Siang districts of Arunachal Pradesh from India (Akhil et al. 2019; Taram et al. 2020a), is also reported here from Pasighat of East Siang District (Image 3A). It is also distributed in China (POWO 2019).

(2) *Rhynchotechum parviflorum* Blume: So far known from Upper Siang District of Arunachal Pradesh (Taram et al. 2020d) and Andaman & Nicobar Islands in India (POWO 2019) is reported here from Sirki of East Siang District. Its distribution extends to New Guinea (POWO 2019).

(3) *Wallichia triandra* (J. Joseph) S.K.Basu: Earlier

Table 3. Rare and threatened plants recorded from the study area.

	Species name	Family	IUCN status
1	*Saurauia punduana* Wall.	Actinidiaceae	CR
2	*Larsenianthus arunachalensis* M. Sabu, Sanoj & Rajesh Kumar	Zingiberaceae	CR
3	*Piper pedicellatum* C.DC	Piperaceae	VU
4	*Phoenix rupicola* T.Anderson	Arecaceae	NT
5	*Zingiber zerumbet* (L.) Roscoe ex Sm.	Zingiberaceae	DD
6	*Amomum subulatum* Roxb.	Zingiberaceae	DD

reported only from Anjaw and Lohit District of Arunachal Pradesh (Henderson 2007) is reported here from Sirki of East Siang District. It is also distributed in China (POWO 2019).

(4) *Saurauia sinohirsuta* J.Q. Li & Soejarto: So far known from Upper Siang District of Arunachal Pradesh in India (Taram & Borah 2020) is reported here from Sirki of East Siang District. It is also distributed in China (POWO 2019).

Conservation

Out of the 508 taxa reported during this study, 108 species are designated under 'Least Concern', whereas most of them belong to 'Not Evaluated' category following IUCN 2020. Some rare and threatened plants recorded from the study area are listed in Table 3 along with their IUCN status.

Plants of medicinal and economic importance

During the present study it was found that 20 species (3.9%) are used to formulate different forms of traditional medicine, 126 species (24.8%) are edible, and 362 (71.3%) plants have no known uses (Appendix 1). Most of recorded usage show similarity to the earlier reports (Tag et al. 2008; Singh et al. 2011; Yumnam et al. 2011; Baruah et al. 2013; Yumnam & Tripathi 2013; Boko & Narsimhan 2014), except *Hornstedtia arunachalensis* S. Triphathi & V.Prakash, *Helixanthera parasitica* Lour., *Curculigo prainiana* (Deb) Bennet & Raizada, *Rhynchotechum obovatum* (Griff.) B.L.Burtt, *Rhynchotechum parviflorum* Blume, *Brachystemma calycinum* D.Don and *Balanophora dioica* R. Br. ex Royle, which are new ethnobotanical records for the region.

Excluded taxa

Several studies conducted by Jeyaprakash K. (https://orcid.org/0000-0001-8780-3487) during 2015-2017 on the floristic diversity of East Siang District are not cited here complying with the journal's policy of curbing publications in the predatory journals. These studies also included exotic, introduced and cultivated taxa to their list. We, however, have excluded them from the present checklist as our main aim was to document the native flora of the district. Moreover, *Champereia manillana* (Blume) Merr. reported by the same author as a new distributional record to Arunachal Pradesh was found to be an incorrect identification of *Lepionurus sylvestris* Blume, and hence, excluded from the present checklist.

CONCLUSION

There is still a gap in the research conducted so far to determine the approximate floral wealth of East Siang District. So far only one protected area, i.e., Daying Ering Memorial Wildlife Sanctuary has been designated in the district and much of the biodiversity finds its place in the private lands. We believe that our checklist will help in conservation planning of this sanctuary. The outburst of the human population, however, has created a need for new settlements as well as agricultural lands which pose serious threats to the present biodiversity in the area. Geographically, East Siang District is about 4% of Arunachal Pradesh, yet it represents around one-fourth of the state's flora. The tropical climate, along with its location in the eastern Himalaya biodiversity hotspot is the probable explanation for the high diversity. The present study should be considered a preliminary account of this floristically rich region, and more survey and research should be conducted to document its accurate floral wealth. Besides, the rich medicinal wealth of the district should also be conserved following several exercises such as Conservation Assessment and Management Prioritization (Ved et al. 2005), in association with the leading Indian institutions such as BSI, CIMAP, FRI, FRLHT, etc.

REFERENCES

Akhil, M.K., S. Nampy & P. Javad (2019). *Lysionotus gamosepalus* var. *gamosepalus* (Gesneriaceae): A new record for India. *Rheedea* 29(3): 232–235. https://doi.org/10.22244/rheedea.2019.29.3.08

Ambrish, K. (2013). Floristic Diversity of Arunachal Pradesh: Upper Subansiri District. Bishen Singh Mahendra Pal Singh, Dehra Dun, 534pp.

Barbhuiya, H.A., B.K. Dutta, A.K. Das & A.K. Baishya (2014). The family Rubiaceae in southern Assam with special reference to endemic and rediscovered plant taxa. *Journal of Threatened Taxa* 6(4): 5649–5659. https://doi.org/10.11609/JoTT.o3117.5649-59

Baruah, S., S.K. Borthakur, P. Gogoi & M. Ahmed (2013). Ethnomedicinal plants used by Adi-Minyong tribe of Arunachal

Image 3. Some endemic and endangered species found in East Siang: A—*Lysionotus gamosepalus* W.T. Wang | B—*Saurauia punduana* Wall. | C—*Peliosanthes ligniradicis* N. Tanaka, Taram & D. Borah | D—*Henckelia mishmiensis* (Debb. ex Biswas) D.J. Middleton & Mich.Möller | E—*Hornstedtia arunachalensis* S. Tripathi & V. Prakash | F—*Wallichia oblongifolia* Griff. | G—*Phoenix rupicola* T. Anderson. © A-C, F-G: Dipankar Borah; D-E: Momang Taram

Pradesh, Eastern Himalaya. *Indian Journal of Natural Products and Resources* 4(3): 278–282.

Boko, N. & D. Narsimhan (2014). Rapid survey of plants used by Adi tribe of Bosing Banggo, East Siang District, Arunachal Pradesh, India. *Pleione* 8(2): 271–282.

Borah, D. & A.P. Das (2018). Rediscovery of *Sterculia striatiflora* Mast. (Malvaceae) and its new record for the flora of India. *Pleione* 12(1): 105–109. https://doi.org/10.26679/Pleione.30.6.2018.105-109

Borah, D., N. Tanaka, L.V. Averyanov, M. Taram & D.K. Roy (2020a). Rediscovery of *Tupistra stoliczkana* (Asparagaceae) in northeastern

India and the identity of *T. ashihoi*. *Phytotaxa* 443(2): 207–210. https://doi.org/10.11646/phytotaxa.443.2.8

Borah, D., P. Kafley, S.Tangjang & A.P. Das (2018). Population structure and conservation of endangered *Citrus indica* Yu.Tanaka (Rutaceae) in Behali Reserve Forest of Assam, India. *Pleione* 12(2): 181–186. https://doi:10.26679/Pleione.12.2.2018.181-186

Borah, D., M. Taram, S. Tangjang, A. Upadhyaya & N. Tanaka (2020b). *Peliosanthes macrophylla* var. *assamensis* (Asparagaceae), a new variety from Behali Reserve Forest in Assam, Northeast India. *Blumea* 65: 121–125. https://doi.org/10.3767/blumea.2020.65.02.05

Burkill, I.H. (1925). *The Botany of the Abor Expedition*. 10 (1–2). Superintendent Government Printing, India.

Chakravarty, S., C.P. Suresh, A. Puri & G. Shukla (2012). North-East India, the Geographical Gateway of India's Phytodiversity. *Indian Forester* 138 (8): 702–709.

Champion, H.G. & S.K. Seth (1968). A revised classification of forest types of India. Manager Publications, New Delhi, 397pp.

Chase, M.W., M.J.M. Christenhusz, M.F. Fay, J.W. Byng, W.S. Judd, D.E. Soltis, D.J. Mabberley, A.N. Sennikov, P.S. Soltis & P.F. Stevens (2016). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* 181(1): 1–20. https://doi.org/10.1111/boj.12385

Chaturvedi, S.K., B.K. Sinha & S. Dey (2011). *Mycetia mukerjiana* Deb & Dutta (Rubiaceae): new distributional record for Nagaland, India. *Pleione* 5(2): 345–347.

Chauhan, A.S., K.P. Singh & D.K. Singh (1996). *A Contribution to the Flora of Namdapha, Arunachal Pradesh*. Botanical Survey of India, Calcutta, 422pp.

Choudhary, R.K. (2008a). *Floristic divserity of Upper Siang District, Arunachal Pradesh*. PhD Thesis. Department of Botany, Rajiv Gandhi University, Arunachal Pradesh, India, 795pp.

Choudhary, R.K. (2008b). A preliminary report on floristic diversity of Dihang Dibang Biosphere Reserve of Arunachal Pradesh. *Bulletin of Arunachal Forest Research* 24: 29–34.

Choudhary, R.K., R.C. Srivastava, A.K. Das & J. Lee (2012). Floristic diversity assessment and vegetation analysis of Upper Siang District of Eastern Himalaya in North East India. *Korean Journal of Plant Taxonomy* 42(3): 222–246.

Chowdhery, H.J., G.S. Giri & A. Pramanik (2009). *Materials for the Flora of Arunachal Pradesh (Vol. 3).* Botanical Survey of India, Kolkata, 357pp.

Das, S.C. & A.R. Rahman (2010). Notes on the Rubiaceae. 3. Five new records for Bangladesh. *Bangladesh Journal of Botany* 39(2): 215–222.

Giri, G.S., A. Pramanik & H.J. Chowdhery (2008). Materials for the flora of Arunachal Pradesh (Vol. 2). Botanical Survey of India, Kolkata, 498pp.

Gogoi, R. & S. Borah (2015). *Impatiens siangensis* (Balsaminaceae), a new species from Arunachal Pradesh, India. *Phytotaxa* 192(2): 117–120. https://doi.org/10.11646/phytotaxa.192.2.5

Hajra, P.K., D.M. Verma & G.S. Giri (1996). *Materials for the Flora of Arunachal Pradesh (Vol. 1)*. Botanical Survey of India, Kolkata, 693pp.

Henderson, A. (2007). A revision of *Wallichia* (Palmae). *Taiwania* 52(1): 1–11. https://doi.org/10.6165%2ftai.2007.52(1).1

Hooker, J.D. (1872–1897). *Flora of British India (Vol. 1-7).* L. Reeve & Co., London.

IUCN (2020). The IUCN Red List of Threatened Species. Version 2020-1. https://www.iucnredlist.org (Accessed 11 April 2020).

Jain, S.K. & R.R. Rao (1977). *A Handbook of Field and Herbarium Methods*. Today & tomorrow's Printers and Publishers, New Delhi, 107pp.

Jeyaprakash, K., N. Balachandran, K. Karthigeyan, S. Rathinavel & O. Dai (2014). *Ampelocissus hoabinhensis* C.L. Li [Vitaceae]: a new record for Indian flora from Arunachal Pradesh. *Pleione* 8(1): 163–166.

Kanjilal, U.N., P.C. Kanjilal & A. Das (1934–1946). *Flora of Assam*, Vol. 1–5, Published by Government of Assam.

Kaul, R.N & K. Haridasan (1987). Forest types of Arunachal Pradesh, a preliminary study. *Journal of Economic and Taxonomic Botany* 9: 383–389.

Mibang, T. & A.K. Das (2017). Taxonomic investigation on genus *Larsenianthus* (Zingiberaceae) of Siang Valley, Arunachal Pradesh. *Bulletin of Arunachal Forest Research* 32(1&2): 41–48.

Nangkar, A., A.P. Das & H. Tag (2017). *Arisaema arunachalensis* A. Nangkar; A.P. Das & H. Tag, sp. nov. (Araceae) from Arunachal Region of Indian Himalayan Region. *Pleione* 11(2): 480–484. https://doi:10.26679/Pleione.11.2.2017.480-484

Olson, D.M. & E. Dinerstein (1998). The global 200: a representation approach to conserving the Earth's most biologically valuable Eco regions. *Conservation Biology* 12: 502–515. https://doi.org/10.1046/j.1523-1739.1998.012003502.x

POWO (2019). "Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://www.plantsoftheworldonline.org/ (Retrieved 09 April 2020).

Rao, R.S. & J. Joseph (1965). Observation of the Flora of Siang Frontier Division NEFA. *Bulletin of Botanical Survey of India* 7: 138–161.

Singh, L. & J.S. Singh (1991). Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. *Annales of Botany* 68: 263–273. https://doi.org/10.1093/oxfordjournals.aob.a088252

Singh, R.K., R.C. Srivastava, A. Community & T.K. Mukerjee (2009). Culturally important Dekang (*Gymnocladus burmanicus* C. E. Parkinson) - An addition to the flora of India from Arunachal Pradesh. *Indian journal of traditional knowledge* 8(4): 482–484.

Singh, R.K., S.N. Bhowmik & C.B. Pandey (2011). Biocultural Diversity, Climate change and livelihood security of the Adi community: Grassroot conservation of Eastern Himalaya Arunachal Pradesh. *Indian Journal of Traditional Knowledge* 10(1): 39–56.

Sinha, B.K. & S. Datta (2016). Taxonomic account of the family Gesneriaceae in northeast India. *Nelumbo* 58: 1–43. https://doi.org/10.20324/nelumbo%2Fv58%2F2016%2F105932

Tag, H., G. Murtem, A.K. Das & R.K. Singh (2008). Diversity distribution of ethnobotanical plants used by Adi tribe of East Siang District of Arunachal Pradesh, India. *Pleione* 2(1): 123–136.

Takhtajan, A. (1969). *Flowering Plants: Origin and Dispersal*. Oliver Byod, Edinburgh, U.K., 310pp.

Taram, M. & D. Borah (2020). A new record of *Saurauia sinohirsuta* (Actinidiaceae) for India. *Journal of Japanese Botany* 95(4): 249–251.

Taram, M., D. Borah & A. Joe (2020a). *Lysionotus gamosepalus* var. *gamosepalus* (Gesneriaceae) - A New Record for the Flora of India. *Journal of Japanese Botany* 95(1): 47–50.

Taram, M., D. Borah & N. Tanaka (2020c). *Peliosanthes ligniradicis*, a new species (Asparagaceae) from Arunachal Pradesh, NE India. *Phytotaxa* 438(1): 43–48. https://doi.org/10.11646/phytotaxa.438.1.5

Taram, M., D. Borah & S. Nampy (2020b). *Boeica multinervia* K.Y. Pan (Gesneriaceae): a new record for India. *Check List* 16 (1): 89–92. https://doi.org/10.15560/16.1.89

Taram, M., D. Borah, O. Taku & H. Tag (2020e). *Henckelia siangensis* (Gesneriaceae): a remarkable new species from Northeast India. *PhytoKeys* 160: 1–6. https://doi.org/10.3897/phytokeys.160.54459

Taram, M., D. Borah, R. Rubu & H. Tag (2018). Wild food plant resources of Komkar Adi tribe of Upper Siang district in Arunachal Pradesh, India. *Bulletin of Arunachal Forest Research* 33(2): 27–35.

Taram, M., P. Mipun, D. Borah (2020d). *Rhynchotechum parviflorum* Blume (Gesneriaceae): a new record to mainland *India. Journal of Threatened Taxa* 12(1): 15208–15211. https://doi.org/10.11609/jott.5306.12.1.15208-15211

Tatum, M. & A.K. Das (2016). *Zingiber sianginensis* (Zingiberaceae): a new species from Arunachal Pradesh, India. *Pleione* 10(1): 169–173.

Tripathi, S. & V. Prakash (1999). A new species of *Hornstedtia* (Zingiberaceae) from Arunachal Pradesh, N. E. India. *Nordic Journal of Botany* 19(3): 329–332. https://doi.org/10.1111/j.1756-1051.1999.tb01120.x

Tropicos (2020). http://www.tropicos.org Missouri Botanical Garden. Accessed 09 Apr 2020.

Appendix 1. Plant diversity of East Siang District.

Family	Taxon	Field no.	IUCN Status
Acanthaceae			
	Codonacanthus pauciflorus (Nees) Nees	MT2001	NE
	Dicliptera babui Karthik. & Moorthy	MT2500	NE
	Justicia adhatoda L.	MT2002	NE
	Mackaya neesiana (Wall.) Das	MT1742	NE
	Phlogacanthus curviflorus (Nees) Nees	MT2502	NE
	Phlogacanthus gracilis P.Anderson ex Burkill	NEIFM-306	E
	Phlogacanthus thyrsiformis (Roxb. ex Hardw.) Mabb.	MT2127	NE
	Phlogacanthus vitellinus (Roxb.) T.Anderson	MT2003	NE
	Pseuderanthemum leptanthus (C.B.Clarke) Lindau	MT2004	NE
	Rhinacanthus calcaratus (Wall.) Nees	MT2005	NE
	Rungia pectinata (L.) Nees	MT2501	NE
	Strobilanthes hamiltoniana (Steud.) Bosser & Heine	MT2128	NE
	Strobilanthes mastersii T.Anderson	MT2129	E
	Strobilanthes oxycalycina J.R.I. Wood	MT2007	E
	Strobilanthes pauciflora (Merr.) Y.F. Deng	MT2006, MT2101	NE
	Strobilanthes secunda T.Anderson	MT2008	NE
	Strobilanthes tubiflos (C.B.Clarke) J.R.I.Wood	MT2009	E
	Thunbergia coccinea Wall. ex D.Don	MT2010	NE
	Thunbergia grandiflora (Roxb. ex Rottler) Roxb.	MT2011	NE
Achariaceae			
	Gynocardia odorata R.Br.	MT1731	NE
Acoraceae			
	Acorus calamus L.	MT2533	LC
Actinidaceae			
	Saurauia armata Kurz #	MT1619	NE
	Saurauia sinohirsuta J.Q.Li & Soejarto	MT1829	NE
	Saurauia napaulensis DC. #	MT1590	LC
	Saurauia punduana Wall. #	MT1589	CR
Altingiaceae			
	Liquidambar excelsa (Noronha) Oken	MT1692	LC
Amaranthaceae			
	Achyranthes aspera L.	MT2134	NE
	Achyranthes bidentata Blume	MT2503	NE
	Alternanthera sessilis (L.) R.Br. ex DC.	MT2135	LC
	Amaranthus viridis L.	MT1564	NE
	Chenopodium album L. #	MT1700	NE
	Chenopodium giganteum D.Don. #	MT1617	NE
	Cyathula prostrata (L.) Blume	MT1235	NE
	Deeringia amaranthoides (Lam.) Merr. #	MT1747	NE

Family	Taxon	Field no.	IUCN Status
Amaryllidaceae			
	Allium hookeri Thwaites	MT1634	NE
Anacardiaceae			
	Mangifera sylvatica Roxb. #	MT1686	LC
	Rhus chinensis Mill. *	MT1580	LC
	Spondias pinnata (L.f) Kurz.	MT1530	NE
	Choerospondias axillaris (Roxb.) B.L.Burtt & A.W.Hill #	MT2534	NE
	Toxicodendron hookeri (Sahni & Bahadur) C.Y.Wu & T.L.Ming	MT1626	NE
Annonaceae			
	Fissistigma bicolor (Roxb.) Merr.	MT1816	NE
	Fissistigma polyanthum (Hook.f and Thomson) Merr. #	MT1772	NE
	Miliusa dioeca (Roxb.) Chaowasku & Kessler	MT200	NE
	Polyalthia suberosa (Roxb.) Thwaites	NEIFM-394	NE
	Trivalvaria costata (Hook.f. & Thomson) I.M.Turner	NEIFM-513	NE
Apiaceae			
	Centella asiatica (L.) Urb *	MT1711	LC
	Oenanthe javanica (Blume) DC.	MT1821	LC
Apocynaceae			
	Aganosma cymosa (Roxb.) G.Don	NEIFM-483	NE
	Alstonia scholaris (L.) R.Br.	MT2133	LC
	Beaumontia grandiflora Wall.	MT1636	NE
	Dischidia bengalensis Colebr.	MT2134	NE
	Hemidesmus indicus (L.) R.Br.	MT2135	NE
	Hoya arnottiana Wight	NEIFM-215	NE
	Hoya verticillata (Vahl) G.Don	MT2012	NE
	Rauvolfia verticillata (Lour.) Baill.	NEIFM-353, NEIFM-486	NE
	Tabernaemontana divaricata (L.) R.Br. ex Roem. & Schult.	MT2136	NE
	Wrightia coccinea (Roxb. ex Hornem.) Sims	NEIFM-247	NE
Araceae			
	Alocasia fornicata (Kunth) Schott	MT2014	LC
	Amorphophallus bulbifer (Roxb.) Blume	NEIFM-560	NE
	Amorphophallus napalensis (Wall.) Bogner & Mayo	NEIFM-551	NE
	Arisaema arunachalensis A.Nangkar, A.P. Das & H.Tag	cf. Nangkar et al. 2017	E
	Colocasia fallax Schott	MT2013	LC
	Homalomena aromatica (Spreng.) Schott	MT2535	NE
	Pothos scandens L. *	MT1722	NE
	Pothos chinensis (Raf.) Merr.	NEIFM-213	NE
	Rhaphidophora decursiva (Roxb.) Schott	MT1571	NE
	Rhaphidophora glauca (Wall.) Schott	MT2130	NE
	Rhaphidophora hookeri Schott	MT1572	NE
	Steudnera assamica Hook.f.	MT2131	E

Family	Taxon	Field no.	IUCN Status
Araliaceae			
	Aralia armata (Wall ex. Don) Seem. #	MT1552	LC
	Brassaiopsis glomerulata (Blume) Regel	MT1579	LC
	Eleutherococcus trifoliatus (L.) S.Y.Hu	NEIFM-307	NE
	Heteropanax fragrans (Roxb.) Seem.	MT1656	NE
	Hydrocotyle himalaica P.K.Mukh.	MT1830	NE
	Hydrocotyle sibthorpioides Lam.	MT2504	LC
	Hydrocotyle javanica Thunb.	MT1712	NE
	Schefflera bengalensis Gamble	NEIFM-207	NE
	Trevesia palmata (Roxb. ex Lindl.) Vis. #	MT1679	LC
Arecaceae			
	Calamus erectus Roxb. #	MT1562	NE
	Calamus flagellum Griff. Ex Walp #	MT1541	NE
	Caryota urens L.	MT1570	LC
	Phoenix rupicola T.Anderson	DB2015	E, NT
	Pinanga gracilis Blume	MT2016	NE
	Wallichia oblongifolia Griff.	MT1538	NE
	Wallichia triandra (J.Joseph) S.K.Basu	MT1537	LC
Aristolochiaceae			
	Aristolochia platanifolia (Klotzsch) Duch	DB2152	NE
Asparagaceae			
	Dracaena angustifolia (Medik.) Roxb.	MT2407	NE
	Dracaena petiolata Hook.f.	MT2409	E
	Peliosanthes ligniradicis N.Tanaka, Taram & D. Borah	MT&DB 651	E
	Peliosanthes macrophylla Wall. ex Baker	MT2411	NE
	Tupistra stoliczana Kurz	MT2412	NE
Asteraceae			
	Artemisia indica Willd *	MT1646	NE
	Blumea balsamifera (L.) DC. *	MT1655	NE
	Gnaphalium polycaulon Pers. #	MT1758	NE
	Grangea maderaspatana (L.) Poir.	NEIFM-91	NE
	Gynura cusimbua (D.Don) S.Moore #	MT1743	LC
	Laggera crispata (Vahl) Hepper & J.R.I.Wood	MT2407	NE
	Pseudognaphalium affine (D.Don) Anderb. #	MT1757	NE
	Youngia japonica (L.) DC. #	MT1536	NE
Balanophoraceae			
	Balanophora dioica R. Br. ex Royle #	MT1558	NE
Balsaminaceae			
	Impatiens arguta Hook f. & Thomson	MT2019	NE
	Impatiens latiflora Hook.f. & Thomson	MT2018	NE
	Impatiens porrecta Wall. ex Hook.f. & Thomson	MT2017	NE
	Impatiens siangensis Gogoi	MT2417	E

Family	**Taxon**	**Field no.**	**IUCN Status**
Begoniaceae			
	Begonia aborensis Dunn #	MT1595	NE
	Begonia acetosella Craib. #	MT1638	NE
	Begonia annulata K.Koch	MT2019	NE
	Begonia biserrata Lindl. #	MT1639	NE
	Begonia burkillii Dunn	MT2020	NE
	Begonia josephi A.DC	MT2021	NE
	Begonia roxburghii (Miq.) A.DC #	MT1594	NE
	Begonia silletensis (A.DC.) C.B. Clarke #	MT2022	NE
	Begonia xanthina Hook.	MT2024	NE
Bignoniaceae			
	Oroxylum indicum (L.) Kurz	MT2406	NE
	Radermachera gigantea (Blume) Miq.	NEIFM-535	LC
	Stereospermum chelonoides (L.f.) DC	MT2025	NE
Boraginaceae			
	Bothriospermum zeylanicum (J.Jacq.) Druce	NEIFM-254	NE
	Cordia dichotoma G.Forst	MT1514	LC
	Cynoglossum wallichii G.Don	MT2405	NE
	Ehretia acuminata R.Br.	NEIFM-109, NEIFM-185	LC
	Ehretia wallichiana Hook.f. & Thomson ex C.B.Clarke	DB2023	NE
	Rotula aquatica Lour.	NEIFM-413	NE
Brassicaceae			
	Cardamine hirsuta L. #	MT1751	NE
	Rorippa dubia (Pers.) H.Hara #	MT1753	NE
Burseraceae			
	Canarium strictum Roxb. #	MT1687	NE
Campanulaceae			
	Lobelia nummularia Lam.	MT2403	NE
	Lobelia zeylanica L.	MT2404	LC
Capparaceae			
	Capparis acutifolia Sweet subsp. *sabiifolia* (J. D. Hooker & Thomson) Jacobs	MT2026	NE
	Capparis assamica Hook.f. & Thomson	MT2027	E
	Capparis multiflora Hook.f. & Thomson	MT1776	NE
	Crateva magna (Lour.) DC.	NEIFM-543	NE
	Stixis suaveolens (Roxb.) Baill. #	MT1613	NE
Caryophyllaceae			
	Brachystemma calycinum D.Don *	MT1746	NE
	Stellaria media (L.)Vill #	MT1694	LC
Celastraceae			
	Microtropis discolor (Wall.) Wall. ex Meisn.	MT2412	NE
	Loeseneriella pauciflora (DC.) A.C.Sm.	NEIFM-357	NE

Family	Taxon	Field no.	IUCN Status
Chloranthaceae			
	Chloranthus elatior Link	NEIFM-322	NE
Clusiaceae			
	Garcinia anomala Planch. & Triana #	MT2411	NE
	Garcinia lanceifolia Roxb. #	MT1560	NE
	Garcinia pedunculata Roxb. ex Buch.- Ham *	MT1586	NE
	Garcinia xanthochymus Hook.f. ex T.Anderson	NEIFM-487	NE
Colchicaceae			
	Disporum longistylum (H.Lév. & Vaniot) H.Hara	NEIFM-484	NE
Combretaceae			
	Terminalia chebula Retz. #	MT3003	NE
	Terminalia myriocarpa Van Heurck & Mull.Arg	MT3004	NE
Commelinaceae			
	Amischotolype hookeri (Hassk.) H.Hara	MT2505	NE
	Commelina benghalensis L	MT2401	LC
	Floscopa scandens Lour.	MT2402	LC
	Murdannia nudiflora (L.) Brenan	MT1693	NE
	Rhopalephora scaberrima (Blume) Faden	MT2400	NE
Convolvulaceae			
	Argyreia argentea (Roxb.) Sweet	NEIFM-407	NE
	Argyreia nervosa (Burm.f.) Bojer	MT2029	NE
Cornaceae			
	Alangium chinense (Lour.) Harms	MT2507	NE
Costaceae			
	Hellenia speciosa (J.Koenig) S.R.Dutta	MT2028	NE
Cucurbitaceae			
	Cucumis maderaspatanus L.	NEIFM-365	NE
	Hodgsonia macrocarpa (Blume) Cong. #	MT1552	NE
	Solena heterophylla Lour. *	MT2538	NE
	Thladiantha cordifolia (Blume) Cong. #	MT1738	NE
	Trichosanthes nervifolia L.	MT2299	NE
Cyperaceae			
	Carex baccans Nees	MT1677	LC
	Cyperus digitatus Roxb.	MT2536	LC
	Cyperus rotundus L.	MT2537	LC
	Cyperus distans L.f.	NEIFM-552	LC
	Cyperus mindorensis (Steud.) Huygh	NEIFM-129	NE
	Cyperus pilosus Vahl	NEIFM-555	NE
	Eleocharis geniculata (L.) Roem. & Schult.	MT2298	LC
	Erioscirpus comosus (Wall.) Palla	MT2291	NE
	Fimbristylis bisumbellata (Forssk.) Bubani	MT2288	LC
	Fimbristylis dichotoma (L.) Vahl	NEIFM-073, NEIFM-297	

Family	Taxon	Field no.	IUCN Status
Dilleniaceae			
	Dillenia indica L. #	MT1593	NE
Dioscoreaceae			
	Dioscorea alata L. #	MT1778	NE
	Dioscorea bulbifera L. #	MT1652	NE
	Dioscorea esculenta (Lour.) Burkill #	MT1832	NE
	Dioscorea pentaphylla L. #	MT1544	NE
	Tacca integrifolia Ker Gawl.	MT2030	NE
Ericaceae			
	Agapetes bhutanica N.P.Balakr. & Sud.Chowdhury	NEIFM-528	NE
	Agapetes macrantha var. *grandiflora* (Hook.f.) D.Banik and Sanjappa *	MT1502	NE
	Agapetes serpens (Wight) Sleumer	MT2031	NE
Euphorbiaceae			
	Balakata baccata (Roxb.) Esser	MT22188	LC
	Bridelia montana (Roxb.) Willd.	NEIFM-232	NE
	Croton caudatus Geiseler	MT2508	NE
	Homonoia riparia Lour.	NEIFM-100	LC
	Mallotus paniculatus (Lam.) Müll.Arg.	MT22187	LC
	Mallotus tetracoccus (Roxb.) Kurz	MT2509	NE
	Ostodes paniculata Blume	MT1556	LC
Fabaceae			
	Albizia odoratissima (L.f.) Benth	MT1550	LC
	Archidendron chevalieri (Kosterm.) I.C. Nielsen	NEIFM-478	NE
	Bauhinia purpurea L.#	MT2178	LC
	Bauhinia variegata L.#	MT1745	LC
	Crotalaria spectabilis Roth	MT2177	NE
	Dalbergia rimosa Roxb.	NEIFM-355	LC
	Dalbergia sissoo Roxb. ex DC.	MT2176	NE
	Dalhousiea bracteata (Roxb.) Graham ex Benth	MT2175	NE
	Entada phaseoloides (L.) Merr.	MT1773	NE
	Erythrina variegata L.	MT2173	LC
	Gymnocladus burmanicus C.E.Parkinson	cf. Singh et al. 2009	NE
	Leptodesmia microphylla (Thunb.) H.Ohashi & K.Ohashi	NEIFM-265, NEIFM-177	NE
	Mastersia assamica Benth.	MT2177	NE
	Mucuna macrocarpa Wall.	MT2510	NE
	Ohwia caudata (Thunb.) H.Ohashi	NEIFM-411	NE
	Ototropis multiflora (DC.) H.Ohashi & K.Ohashi	MT2178	NE
	Pueraria montana (Lour.) Merr. *	MT1775	NE
	Senegalia catechu (L.f.) P.J.H.Hurter & Mabb.	NEIFM-080, NEIFM-252	NE
	Senegalia rugata (Lam.) Britton & Rose	MT1501	NE
	Tephrosia candida DC	MT2171	NE

Family	Taxon	Field no.	IUCN Status
Fagaceae			
	Castanopsis indica (Roxb. Ex Lindl.) A.DC.#	MT1602	LC
	Castanopsis purpurella (Miq.) N.P.Balakr. #	MT1618	NE
Gesneriaceae			
	Aeschynanthus acuminatus Wall. ex A.DC	MT2042	NE
	Aeschynanthus gracilis C.S.P.Paris ex C.B Clarke	MT1505	NE
	Aeschynanthus micranthus C.B. Clarke	MT1504	NE
	Aeschynanthus monetarius Dunn	MT1811	NE
	Aeschynanthus parasiticus C.B. Clarke	MT1503	NE
	Aeschynanthus superbus C.B.Clarke	MT2041	NE
	Boeica filiformis C.B.Clarke	MT2040	NE
	Boeica fulva C.B. Clarke #	MT1704	NE
	Epithema carnosum Benth	MT2039	NE
	Henckelia siangensis Taram, D.Borah & Tag	MT2300	E
	Henckelia grandifolia A.Dietr.	MT2038	NE
	Henckelia mishmiensis (Debb. ex Biswas) D.J.Middleton & Mich.Möller	MT2037, MT2172	NE
	Henckelia oblongifolia (Roxb.) D.J.Middleton & Mich. Möller	MT2170	NE
	Henckelia pumila (D.Don) A.Dietr	MT2036	NE
	Lysionotus gamosepalus W.T.Wang var. *gamosepalous*	MT2035	NE
	Lysionotus serratus D.Don	MT2034	NE
	Rhynchotechum ellipticum (Wall. ex D.Dietr.) A.DC. #	MT1705	NE
	Rhynchotechum obovatum (Griff.) B.L.Burtt #	MT22167	NE
	Rhynchotechum parviflorum Blume #	MT1814, MT22168	NE
	Rhynchotechum vestitum Wall. ex C. B. Clarke #	MT1706, MT22169	NE
	Stauranthera grandifolia Benth.	MT2033	NE
	Tetraphylloides bengalensis (C.B.Clarke) Doweld	MT2032	NE
Gentianaceae			
	Exacum teres Wall.	MT2166	NE
Hydrangeaceae			
	Hydrangea febrifuga (Lour.) Y. De Smet & Granados	MT2043	NE
Hydroleaceae			
	Hydrolea zeylanica (L.) Vahl	MT2165	LC
Hypoxidaceae			
	Curculigo capitulata (Lour.) Kuntze *	MT1815	NE
	Curculigo prainiana (Deb) Bennet & Raizada (SE, Ethnomedicine)	MT2133	NE
Lamiaceae			
	Achyrospermum densiflorum Blume	NEIFM-401	NE
	Anisomeles indica (L.) Kuntze	MT1894	NE
	Callicarpa arborea Roxb. #	MT2164	LC
	Callicarpa macrophylla Vahl	MT1517	LC
	Clerodendrum chinense (Osbeck) Mabb.	MT2512	LC
	Clerodendrum colebrookeanum Walp. #	MT2163	NE

Family	Taxon	Field no.	IUCN Status
	Clerodendrum indicum (L.) Kuntze	NEIFM-471	NE
	Clerodendrum japonicum (Thunb.) Sweet	MT2162	LC
	Clerodendrum laevifolium Blume	MT2044	NE
	Elsholtzia ciliata (Thunb.) Hyl.	NEIFM-359	NE
	Gmelina arborea Roxb. ex Sm	MT1545	LC
	Isodon coetsa (Buch.-Ham. ex D.Don) Kudô	NEIFM-240	NE
	Leonurus japonicus Houtt.	NEIFM-452	NE
	Leucas chinensis (Retz.) Sm.	NEIFM-065	NE
	Leucas zeylanica (L.) W.T.Aiton	NEIFM-296	NE
	Leucosceptrum canum Sm.	MT1733	NE
	Perilla frutescens (L.) Britt. #	MT2161	NE
	Pogostemon brachystachyus Benth.	NEIFM-312	NE
	Pogostemon elsholtzioides Benth.	NEIFM-148	NE
	Pogostemon plectranthoides Desf.	NEIFM-382	NE
	Rotheca serrata (L.) Steane & Mabb.	MT 2511	NE
	Tectona grandis L.f	MT2160	NE
	Teucrium viscidum Blume	NEIFM-319, NEIFM-490	NE
Lauraceae			
	Actinodaphne obovata (Nees) Blume	MT1690	NE
	Beilschmiedia assamica Meisn.	NEIFM-541	NE
	Cinnamomum bejolghota (Bucc-Ham) Sweet #	MT1777	LC
	Lindera communis Hemsl.	NEIFM-443	NE
	Litsea cubeba (Lours.) Pers. #	MT2159	NE
	Litsea glutinosa (Lour.) C.B.Rob.	MT2540	LC
	Litsea monopetala (Roxb.) Pers.	MT1563	LC
	Phoebe cooperiana P.C.Kanjilal and Das #	MT2158	E
Linderniaceae			
	Bonnaya antipoda (L.) Druce	MT2157	NE
	Bonnaya ciliata (Colsm.) Spreng.	MT2156	NE
	Torenia bicolor Dalzell	MT2154	LC
	Torenia crustacea (L.) Cham. & Schuldt	MT2153	LC
	Torenia fournieri Linden ex E.Fourn.	MT2541	NE
Loranthaceae			
	Helixanthera parasitica Lour. #	MT2046	NE
Lythraceae			
	Duabanga grandiflora (Roxb. Ex DC) Walp.	MT2045	LC
	Rotala rotundifolia (Buch.-Ham. ex Roxb.) Koehne	MT20542	NE
Magnoliaceae			
	Magnolia hodgsonii (Hook.f. & Thomson) H.Keng	MT2047	LC
Malvaceae			
	Abroma augustum (L.) L.f.	MT1699	NE
	Ayenia grandifolia (DC.) Christenh. & Byng	NEIFM-216, NEIFM-463	NE
	Bombax ceiba L.	MT2050	NE

Family	Taxon	Field no.	IUCN Status
	Grewia asiatica L.	NEIFM-351	LC
	Kydia calycina Roxb.	MT1691	LC
	Melochia corchorifolia L.	NEIFM-270, NEIFM-325	NE
	Pterospermum acerifolium (L.) Willd	MT2049	LC
	Pterospermum lanceifolium Roxb. ex DC.	MT2048	NE
	Sida acuta Burm.f.	MT2054	NE
	Sterculia lanceolata var. *coccinea* (Jack) Phengklai #	MT1786	LC
	Sterculia striatiflora Mast. #	MT&DB 0206	NE
	Sterculia villosa Roxb. ex Sm	MT2052	NE
	Urena lobata L.	MT2051	NE
Marantaceae			
	Phrynium pubinerve Blume #	MT2050	NE
Mazaceae			
	Mazus pumilus (Burm.f.) Steenis	MT2150	NE
	Mazus surculosus D.Don	MT2513	NE
Melanthiaceae			
	Paris polyphylla Sm. *	MT2051	NE
Melastomataceae			
	Melastoma malabathricum L #	MT2149	NE
	Osbeckia nepalensis Hook.	MT2148	NE
	Osbeckia nutans Wall.	MT2147	NE
	Oxyspora paniculata DC.	MT2054	NE
	Pseudodissochaeta assamica (C.B.Clarke) Nayar	MT2052	NE
	Sarcopyramis napalensis Wall.	DB2053	NE
Meliaceae			
	Chisocheton cumingianus (C.DC.) Harms	DB2055	LC
	Dysoxylum alliaceum (Blume) Blume	NEIFM-488	LC
	Melia azedarach L.	MT2126	LC
	Toona hexandra (Wall.) M.Roem	MT2056	NE
Menispermaceae			
	Stephania japonica (Thunb.) Miers	MT2057	NE
	Stephania rotunda Lour.	MT2058	NE
	Tinospora cordifolia (Willd.) Hook.f. & Thomson	MT2514	NE
Molluginaceae			
	Trigastrotheca pentaphylla (L.) Thulin	NEIFM-345	NE
Moraceae			
	Artocarpus heterophyllus Lam. #	MT1779	NE
	Artocarpus lacucha Buch.Ham. #	MT1756	NE
	Broussonetia papyrifera (L.) L'Hér. ex Vent.	NEIFM-228	LC
	Ficus auriculata Lour. #	MT1601	LC
	Ficus crassiramea (Miq.) Miq.	MT1641	NE
	Ficus drupacea Thunb.	NEIFM-545	LC

Family	Taxon	Field no.	IUCN Status
	Ficus hederacea Roxb.	MT1790	NE
	Ficus heteropleura Blume	MT1764	NE
	Ficus hispida L.f.#	MT2124	LC
	Ficus oligodon Miq. #	MT1600	LC
	Ficus religiosa L.	MT1574	NE
	Ficus semicordata Buch-Ham ex Sm.#	MT1575	LC
	Ficus simplicissima Lour.	MT1599	NE
	Ficus tinctoria G.Forst.	MT1588	LC
	Ficus variegata Blume	MT1833	LC
	Ficus virens Aiton #	MT1808	LC
	Maclura cochinchinensis (Lour.) Corner #	MT1647	NE
	Morus macroura Miq.	MT2123	NE
Musaceae			
	Musa aurantiaca G.Mann ex Baker #	MT1726	LC
	Musa balbisiana Colla #	MT1760	LC
	Musa sanguinea Hook.f. *	MT2069	LC
Myricaceae			
	Myrica esculenta Buch.Ham Ex D.Don #	MT2121	NE
Myrtaceae			
	Syzygium formosum (Wall.) Mason #	MT1826	NE
	Syzygium fruticosum DC. #	MT1828	NE
	Syzygium aqueum (Burm.f.) Alston #	MT2068	NE
	Syzygium cumini (L.) Skeels #	MT2120	LC
Nyctaginaceae			
	Boerhavia diffusa L.	NEIFM-537	NE
Olacaceae			
	Erythropalum scandens Blume	MT2517	LC
Oleaceae			
	Jasminum pentaneurum Hand.-Mazz.	NEIFM-445	NE
	Jasminum laurifolium Roxb. ex Hornem. var. *laurifolium*	MT2067	NE
Orchidaceae			
	Arundina graminifolia (D.Don) Hochr	DB2137	NE
	Bulbophyllum odoratissimum (Sm.) Lindl. ex Wall.	MT2066	NE
	Cheirostylis parvifolia Lindl.	DB2138	NE
	Coelogyne fimbriata Lindl. var. *fimbriata*	MT2065	NE
	Corymborkis veratrifolia (Reinw.) Blum	DB2139	NE
	Cymbidium aloifolium (L.) Sw.	MT2064	NE
	Dendrobium aphyllum (Roxb.) C.E.C.Fisch.	MT2140	LC
	Dendrobium chrysanthum Wall. ex Lindl.	MT2141	NE
	Dendrobium nobile Lindl.	MT2142	NE
	Dendrolirium lasiopetalum (Willd.) S.C.Chen & J.J.Wood	MT2144	NE
	Eulophia dabia (D.Don) Hochr.	NEIFM-102, NEIFM-234	NE

Family	Taxon	Field no.	IUCN Status
	Geodorum densiflorum (Lam.) Schltr.	NEIFM-191	NE
	Goodyera procera (Ker Gawl.) Hook.	MT2063	NE
	Nervilia macroglossa (Hook.f.) Schltr.	NEIFM-214	NE
	Pachystoma pubescens Blume	DB2143	NE
	Pholidota pallida Lindl	MT2062	NE
	Rhynchostylis retusa (L.) Blume	MT2061	NE
	Vanda bicolor Griff.	MT2060	NE
	Zeuxine flava (Wall. ex Lindl.) Trimen	DB2059	NE
Orobanchaceae			
	Lindenbergia hookeri C.B.Clarke ex Hook.f. #	MT2119	NE
	Aeginetia indica L.	NEIFM-493	NE
Pandanaceae			
	Pandanus furcatus Roxb. #	MT1788	NE
Phyllanthaceae			
	Actephila excelsa (Dalzell) Mull.Arg	MT1508	NE
	Baccaurea ramiflora Lour. #	MT1629	NE
	Bischofia javanica Blume	NEIFM-495	LC
	Breynia androgyna (L.) Chakrab. & N.P.Balakr.#	MT2118	NE
	Leptopus clarkei (Hook.f.) Pojark.	NEIFM-387	NE
	Phyllanthus assamicus Müll.Arg.	NEIFM-121	LC
	Phyllanthus fraternus G.L.Webster	NEIFM-389, NEIFM-431	NE
	Phyllanthus lanceolarius (Roxb.) Müll.Arg.	NEIFM-298	NE
	Phyllanthus reticulatus Poir.	MT2070	NE
Piperaceae			
	Piper attenuatum Buch.-Ham. ex Miq.	NEIFM-174, NEIFM-362	NE
	Piper griffithii C.DC.	NEIFM-334	NE
	Piper mullesua Buch.-Ham. ex D.Don	MT1609	NE
	Piper pedicellatum C.DC #	MT2071	E,VU
	Piper sylvaticum Roxb.	NEIFM-435, NEIFM-386	NE
Plantaginaceae			
	Plantago asiatica L. #	MT1631	NE
Poaceae			
	Arundinella nepalensis Trin.	NEIFM-361	NE
	Bambusa tulda Roxb. *	MT2117	NE
	Chrysopogon aciculatus (Retz.) Trin	MT2555	NE
	Cynodon dactylon (L.) Pers.	MT1653	NE
	Dendrocalamus giganteus Munro *	MT1643	LC
	Dendrocalamus hamiltonii Nees and Arn.ex Munro *	MT1581	NE
	Digitaria abludens (Roem. & Schult.) Veldkamp	NEIFM-130, NEIFM-131	NE
	Digitaria ciliaris (Retz.) Koeler	NEIFM-133	NE
	Dinochloa macclellandii (Munro) Kurz	MT2072	NE
	Echinochloa colonum (L.) Link	MT2553	LC

Family	Taxon	Field no.	IUCN Status
	Echinochloa crus-galli (L.) P. Beauv.	NEIFM-098	LC
	Eragrostis unioloides (Retz.) Nees ex Steud.	NEIFM-344	LC
	Eulalia hirtifolia (Hack.) Kuntze	NEIFM-410	NE
	Hemarthria compressa (L.f.) R.Br.	NEIFM-291	LC
	Oplismenus burmanni (Retz.) P. Beauv.	MT2550	NE
	Oplismenus compositus (L.) P. Beauv.	MT 2551	NE
	Phragmites karka (Retz.) Trin. ex Steud.	MT1585	LC
	Phyllostachys manii Gamble	MT1566	NE
	Pseudoraphis minuta (Mez) Pilg.	NEIFM-290	NE
	Saccharum arundinaceum Retz. #	MT1782	NE
	Saccharum spontaneum L. #	MT1584	LC
	Sacciolepis indica (L.) Chase	NEIFM-161	NE
	Setaria palmifolia (J.Koenig) Stapf	MT2554	NE
	Setaria pumila (Poir.) Roem. & Schult.	MT2552	NE
	Stapletonia seshagiriana (R.B. Majumdar) H.B. Naithani	MT1820	NE
	Themeda villosa (Lam.) A. Camas	MT1708	NE
	Thysanolaena latifolia (Roxb. ex Hornem.) Honda	MT2116	NE
Polygonaceae			
	Koenigia mollis (D.Don) T.M. Schust. & Reveal #	MT1710	NE
	Persicaria barbata (L.) H. Hara	MT1632	LC
	Persicaria capitata (Buch - Ham Ex D.Don) H. Gross	MT1624	NE
	Persicaria chinensis (L.)H.Gross #	MT1787	NE
	Persicaria hydropiper (L.) Delarbre	MT1633	LC
	Persicaria nepalensis (Meisn.) H. Gross	MT1623	NE
	Persicaria orientalis (L.) Spach	NEIFM-89	NE
	Persicaria strigosa (R.Br.) H. Gross	NEIFM-540	NE
Primulaceae			
	Ardisia solanacea Roxb. #	MT1680	NE
	Lysimachia debilis Wall.	NEIFM-531	NE
	Maesa indica (Roxb.) Sweet #	MT1654	LC
Ranunculaceae			
	Ranunculus cantoniensis DC.	NEIFM-105	NE
Rafflesiaceae			
	Sapria himalayana Griff.	MT3010	NE
Rosaceae			
	Potentilla indica (Andrews) Th. Wolf #	MT1648	NE
	Rubus ellipticus Sm. #	MT1759	NE
	Rubus moluccanus L. #	MT1567	NE
	Rubus niveus Thumb #	MT1542	NE
	Rubus paniculatus Sm. #	MT1569	NE
	Rubus rosifolius Sm. #	MT1831	NE
	Rubus sumatranus Miq. #	MT1713	NE

Family	Taxon	Field no.	IUCN Status
Rubiaceae			
	Argostemma sarmentosum Wall.	MT2081	NE
	Argostemma verticillatum Wall.	MT2080	NE
	Catunaregam spinosa (Thunb.) Tirveng.	NEIFM-466	NE
	Chassalia curviflora var. *ophioxyloides* (Wall) Deb & B.Krishna	DB2079	NE
	Coffea benghalensis B.Heyne ex Schult.	MT1697	LC
	Dentella repens (L.) J.R.Forst. & G.Forst.	NEIFM-95	LC
	Dimetia scandens (Roxb.) R.J.Wang	DB1111	NE
	Exallage auricularia (L.) Bremek.	NEIFM-125	NE
	Gomphostemma lucidum Wallich ex Bentham	MT3006	NE
	Ixora polyantha Wight	MT2078	NE
	Mussaenda glabra Vahl #	MT2077	NE
	Mussaenda roxburghii Hook.f. #	MT2076	NE
	Mycetia mukerjiana Deb & Ratna Dutta	MT2075	E
	Oldenlandia umbellata L.	MT2519	NE
	Paederia foetida L. *	MT2115	NE
	Psychotria monticola Kurz	NEIFM-425	NE
	Psychotria silhetensis Hook.f.	NEIFM-426	NE
	Scleromitrion diffusum (Willd.) R.J.Wang	NEIFM-158	NE
	Uncaria macrophylla Wall.	MT3005	NE
	Wendlandia budleioides Wall. ex Wight & Arn.	MT2114	NE
Rutaceae			
	Citrus indica Yu. Tanaka #	MT2074	E
	Citrus latipes (Swingle) Yu.Tanaka #	MT1688	NE
	Citrus medica L. #	MT2073	NE
	Glycosmis pentaphylla (Retz.) DC.	NEIFM-424	LC
	Murraya koenigii (L.) Spreng. #	MT2113	NE
	Murraya paniculata (L.) Jack	MT1675	NE
	Murraya tetramera C.C.Huang	NEIFM-429	NE
	Toddalia asiatica (L.) Lam.	MT1535	NE
	Zanthoxylum armatum D.C #	MT1534	LC
	Zanthoxylum oxyphyllum Edgew. #	MT1533	NE
	Zanthoxylum rhetsa (Roxb.) DC. #	MT2112	LC
Sabiaceae			
	Sabia lanceolata Colebr.	MT2111	NE
Salicaceae			
	Casearia vareca Roxb.	MT1597, MT2110	NE
Sapindaceae			
	Aesculus assamica Griff.	MT2109	NE
	Nephelium lappaceum L. #	MT2100	LC
Saurauraceae			
	Houttuynia cordata Thunb. *	MT2108	NE

Family	Taxon	Field no.	IUCN Status
Schrophulariaceae			
	Buddleja asiatica Lour	DB2107	LC
Simaroubaceae			
	Brucea mollis Wall. ex Kurz	NEIFM-243	NE
	Ailanthus integrifolia Lam.	MT2106	LC
Smilaceae			
	Smilax ovalifolia Roxb. ex D.Don	MT2105	NE
	Smilax zeylanica L	MT2104	NE
Solanaceae			
	Solanum spirale Roxb. #	MT1524	NE
	Solanum villosum Mill. #	MT2103	NE
	Solanum violaceum Ortega #	MT1583	NE
	Lycianthes biflora (Lour.) Bitter	NEIFM-402	NE
Stemonaceae			
	Stemona tuberosa Lour	MT2099	NE
Styraceae			
	Styrax serrulatus Roxb.	MT2098	NE
Tamaricaceae			
	Tamarix dioica Roxb. ex Roth	MT2520	NE
Theaceae			
	Pyrenaria barringtoniifolia (Griff.) Seem.	NEIFM-180	NE
	Schima wallichii (DC.) Korth.	MT2089	LC
Typhaceae			
	Typha angustifolia L.	MT1740	LC
Urticaceae			
	Boehmeria penduliflora Wedd. ex D.G.Long	MT1739	NE
	Boehmeria pilosiuscula (Blume) Hassk.	MT1741	LC
	Debregesia longifolia (Burm.f.) Wedd.	MT1762	NE
	Dendrocnide sinuata (Blume) Chew	MT1825	NE
	Elatostema dissectum Wedd. #	MT2088	NE
	Elatostema sessile J.R.Forst. & G.Forst.	MT1755	NE
	Gonostegia hirta (Hassk.) Miq. #	MT1568	NE
	Gonostegia pentandra (Roxb.) Miq.	NEIFM-173, NEIFM-264	NE
	Pilea insolens Wedd. #	MT1749	NE
	Pilea umbrosa Wedd. ex Blume #	MT1744	NE
	Poikilospermum suaveolens (Blume) Merr. #	MT1701	NE
	Pouzolzia calophylla W.T.Wang & C.J.Chen	NEIFM-412	NE
	Pouzolzia zeylanica (L.) Benn.	MT1750	NE
	Urtica ardens Link. *	MT1729	NE
	Urtica dioica L. #	MT2097	LC
Viburnaceae			
	Sambucus adnata Wall. ex DC.	MT2096	NE

Family	Taxon	Field no.	IUCN Status
Violaceae			
	Viola betonicifolia Sm.#	MT1540	NE
	Viola pilosa Blume #	MT1539	NE
	Viola thomsonii Oudem.	NEIFM-249	NE
Vitaceae			
	Ampelocissus hoabinhensis C.L.Li	NEIFM-514	NE
	Causonis trifolia (L.) Mabb. & J.Wen	NEIFM-455	NE
	Cissus assamica (M.A.Lawson) Craib	NEIFM-256	NE
	Leea indica (Burm.f.) Merr.	MT2093	LC
	Parthenocissus semicordata (Wall.) Planch.	NEIFM-198, NEIFM-454	NE
	Tetrastigma leucostaphylum (Dennst.) Alston	MT2087 ; MT2095	NE
Zingiberaceae			
	Alpinia nigra (Gaertn.) Burtt #	MT1683	LC
	Alpinia roxburghii Sweet #	MT1591	NE
	Amomum maximum Roxb. #	MT1578	LC
	Amomum pterocarpum Thwaites #	MT1592	LC
	Amomum subulatum Roxb. #	MT2086	DD
	Globba multiflora Wall. ex Baker	MT2085	NE
	Hedychium coccineum Buch.-Ham. ex Sm	MT2084	NE
	Hedychium stenopetalum G.Lodd.	MT1627	NE
	Hornstedtia arunachalensis S. Triphathi & V. Prakash #	MT2083	E
	Larsenianthus arunachalensis M. Sabu, Sanoj & Rajesh Kumar	cf. Mibang & Das 2017	E, CR
	Larsenianthus assamensis S. Dey, Mood & S. Choudhury	cf. Mibang & Das 2017	E
	Larsenianthus careyanus (Benth. & Hook.f.) W.J. Kress & Mood	DB2082	NE
	Zingiber sianginensis Tatum & A.K. Das *	MT2083	E
	Zingiber zerumbet (L.) Roscoe ex Sm.	MT2084	DD

*—Ethnomedicine | #—Edible
CR—Critically Endangered | LC—Least Concern | NT—Near Threatened | E—Endemic | VU—Vulnerable | DD—Data Deficient.

Ved, D.K., G.A. Kinhal, K. Ravikumar, R.V. Sankar & K. Haridasan (2005). Conservation Assessment and Management Prioritisation (CAMP) for wild medicinal plants of North-East India. *Medicinal Plant Conservation* 11: 40–44.

Ward, F.K. (1929). Botanical Exploration in the Mishmi Hills. *The Himalayan Journal* 1: 51–59.

WFO (2020). World Flora Online. Published on the Internet; http://www.worldfloraonline.org. Accessed 09 April 2020

Yan, K.J., D.X. Xu & Z.Q. Song (2016). *Mycetia fangii* (Rubiaceae), a New Species from South China, with notes on *M. cauliflora*. *Systematic Botany* 41(1): 229–237. https://doi.org/10.1600/036364416X690624

Yumnam, J.Y. & O.P. Tripathi (2013). Ethnobotany: plant used in fishing and hunting by adi tribe of Arunachal Pradesh. *Indian Journal of Traditional Knowledge* 12(1): 157–161.

Yumnam, J.Y., S.I. Bhuyan, O.P. Tripathi & M.L. Khan (2011). Study on the ethnomedicinal plants used by Adi tribe of East Siang District, Arunachal Pradesh. *Journal of Economic and Taxonomic Botany* 35(2): 369–377.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17323–17329

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

DOI: https://doi.org/10.11609/jott.5397.12.17.17323-17329

#5397 | Received 09 September 2019 | Final received 20 October 2020 | Finally accepted 01 November 2020

COMMUNICATION

Crepuscular hunting of swiftlets (Family: Apodidae) by Besra (Family: Accipitridae) in the urban areas of the Andaman Islands, India

Amruta Dhamorikar [1], Dhanusha Kawalkar [2], Prathamesh Gurjarpadhye [3] & Shirish Manchi [4]

[1,2,3,4] Division of Conservation Ecology, Sàlim Ali Centre for Ornithology and Natural History, Anaikatty (Post), Coimbatore,
Tamil Nadu 641108, India.
[1] ahdhamorikar@gmail.com, [2] dhanushakawalkar@gmail.com, [3] gurjarpadhyeprathamesh@gmail.com,
[4] ediblenest@gmail.com (corresponding author)

Abstract: We report the crepuscular hunting behavior by the Besra *Accipiter virgatus*, on the Glossy Swiftlets *Collocalia esculenta affinis* and the Edible-nest Swiftlets *Aerodramus fuciphagus inexpectatus* in urban areas the Andaman & Nicobar Islands. Unlike other raptors in the islands, the Besra hunts at twilight often in the absence of moonlight or/and artificial light. Glossy and Edible-nest Swiftlets have been ranched in human habitations and their nests harvested for livelihood support of local communities under an ex situ conservation program. Using the focal animal sampling method, we recorded the hunting behavior of the Besra (the predator) on the swiftlets (the prey) for 40h (120 min/day for 20 days) at the ex situ swiftlet colony established in a house in the Middle Andamans. The Besra made 84 hunting attempts, with the highest success rate (15.4%) between 17.00–18.00 h. The catch rate was a mean of 4±11 (SD) per day. The maximum time that was used for attempt to kill the prey was two hours. Depredation of the Edible-nest Swiftlet by the Besra could affect ex situ conservation efforts, which can also lead to economic losses and retaliation against the raptor. Restricting perch sites for the raptor around ranching houses might reduce predation risks for the swiftlets.

Keywords: Andaman & Nicobar Islands, Besra, crepuscular hunting, Edible-nest Swiftlet, ex situ conservation, predatory behavior.

Editor: Anonymity requested. **Date of publication:** 26 December 2020 (online & print)

Citation: Dhamorikar, A., D. Kawalkar, P. Gurjarpadhye & S. Manchi (2020). Crepuscular hunting of swiftlets (Family: Apodidae) by Besra (Family: Accipitridae) in the urban areas of the Andaman Islands, India. *Journal of Threatened Taxa* 12(17): 17323–17329. https://doi.org/10.11609/jott.5397.12.17.17323-17329

Funding: Ministry of Environment and Forest and Climate Change (MoEF&CC), Government of India.

Competing interests: The authors declare no competing interests.

Author details: Amruta Dhamorikar, MSc, a researcher in the Edible-nest Swiftlet conservation program (2017–2019) and is currently working as an ecologist in AECOM India Pvt. Ltd. Dhanusha Kawalkar, Msc, a researcher in the Edible-nest Swiftlet conservation program (2017–2020) and currently engaged in studying the Indian Swiftlet towards its conservation in Maharashtra. Prathamesh Gurjarpadhye, PhD scholar and a researcher is involved in the Edible-nest Swiftlet conservation program (2018 onwards). He is presently exploring the population dynamics of the species through ecological and molecular approach. Manchi Shirish, PhD, Principal Scientist is involved in research and conservation of the Edible-nest Swiftlet in the Andaman and Nicobar Islands for around two decades.

Author contribution: AD—conceptualization, data curation, methodology, writing – original draft; DK—conceptualization, data curation, formal analysis, methodology, writing – original draft; PG—conceptualization, methodology, data curation, writing – original draft; SM—funding acquisition, investigation, project administration, resources, conceptualization, supervision, validation, writing – review & editing.

Acknowledgements: We thank the Ministry of Environment, Forest and Climate Change for funding the in situ and ex situ conservation of endemic Andaman Edible-nest Swiftlet project under which the present study was conducted. We are grateful to the Department of Environment and Forests, Andaman and Nicobar Island for providing the necessary permissions. We especially thank Mr. Russogi (Divisional Forest Officer, Mayabunder, WL) for his support during the fieldwork. We are indebted to Miss. Pallavi Poojari and Justin Sumit Kumar for their help during the data collection. We acknowledge reviewers for their inputs to improve the quality of the manuscript.

INTRODUCTION

Availability of food and potential nesting sites play an essential role in adapting birds to survive urban environments (Marzluff 2016). Glossy Swiftlet *Collocalia esculenta affinis* and the Edible-nest Swiftlet *Aerodramus fuciphagus inexpectatus* (Cranbrook et al. 2013) are examples of birds that are adapted to urban habitats in the Andaman & Nicobar Islands (Manchi & Mane 2012). This successful adaptation is due to the availability of nesting locations and food. Some cave-dwelling swiftlets such as the Edible-nest Swiftlet are of human interest and famous worldwide for 'bird's nest soup,' a delicacy in Chinese cuisine, and traditional Chinese medicine (Koon & Cranbrook 2002; Chantler & Boesman 2019). The nests exclusively built using bird's saliva have a high market value due to their medicinal properties. These birds are farmed for mass production of the edible nests to sustain international demand (Hobbs 2004; Thorburn 2015).

In the past several decades, the nests have been illegally harvested from caves in the Andaman Islands, impacting the population. For sustainable use of the birds' nest and to reduce the pressure on wild populations, an ex situ conservation program was started in urban houses, which habituated the Edible-nest Swiftlet to nest in human-made structures. The Glossy Swiftlet also nests in abandoned houses, bridges, and jetties. As part of the conservation program, the swiftlets are attracted to human habitation and reared in an artificial structure, known as ex situ swiftlet house (Manchi & Mane 2012). Scientists and managers with years of efforts, have successfully attracted the Edible-nest Swiftlet population to breed in one such ex situ structure (henceforth 'swiftlet house') in the Middle Andamans by using the sympatric Glossy Swiftlet as foster parents to hatch the eggs and rear the chicks (Sankaran & Manchi 2008). This swiftlet house supports a colony of Glossy Swiftlet (~1,000 individuals) and Edible-nest Swiftlet (8–10 individuals). The Edible-nest Swiftlet (ENS) shares the nesting site with the Glossy Swiftlet. Some young ENS birds are also known to build nests on existing Glossy Swiftlet nests.

During our study, the swiftlet population in the house was hunted by the raptor, Besra *Accipiter virgatus abdulalii,* at dawn and dusk. Besra is a small, diurnal bird of prey of the Order Falconiformes. Out of 11 subspecies of *A. virgatus*, *A.v. abdulalii* is an endemic subspecies restricted to the Andaman Islands (Naoroji 2006; Clark & Marks 2020). Due to the easy availability of the prey, and its nesting locations, Besra has adapted to the urban habitats in the Andaman Islands. As the other members of the genus Accipiter, the Besra is a swift and silent hunter. The species is quick on the wing in quest of prey, often twisting and turning to chase the bird and escape hindrances. Besra breeds from March to May and nests on roadside trees, near human habitation, mangrove forests, and Padauk plantations (Ali & Ripley 1978). Being an opportunistic hunter, the diet of Besra includes small birds, insects, and some mammals and reptiles, depending on the season and availability of prey. It primarily preys on birds during the breeding season (Huang et al. 2004). In the Andaman Islands, the Besra predates on poultry near human habitation. It is also a potential predator of swiftlets breeding in the limestone caves of the Andaman Islands, according to Manchi & Sankaran (2009).

Foraging in twilight is generally regarded as an end or beginning of diurnal or nocturnal activity. While crepuscular foraging is uncommon, many nocturnal predators such as owls, nightjars, and waders begin hunting at dusk. The circumstances under which crepuscular hunting occurs are not well understood or documented (Martin 1990). Among diurnal raptors other than owls, the smaller species of the genus Falco (Lesser Kestrel *F. naumanni*, Kestrel *F. tinnunculus*, Hobby *F. Subbuteo* and Sooty Falcon *F. concolor*) and large-bodied falcons such as the peregrine falcon hunt at night under artificial lights such as street lamps, and moonlight (Ratcliffe 1980; Pierson & Donahue 1983).

As the swiftlet ranching in the ex situ houses aims to provide livelihood support for the economic development of the local populations in the Andaman Islands, the threat from Besra can have significant implications. Therefore, we studied the crepuscular hunting behavior of Besra. Further, we hypothesized that the successful hunting of swiftlets by Besra is associated with i) time of day (diurnal vs. crepuscular), ii) availability of perch sites, and iii) flock size of swiftlets.

MATERIALS AND METHODS

Study Area

The Andaman group of islands is in the northeastern Indian Ocean, along the southern extension of the Arakan Yoma mountain range, are peaks of a submerged continuous mountain ridge extending up to Sumatra in the south, between latitude 6.75–13.68 ^{0}N and 92.20—93.95 ^{0}E. The Andaman group of islands are divided into (a) South Andaman, (b) Middle Andaman, (c) North Andaman, (d) Baratang, and (e) Rutland. The forest

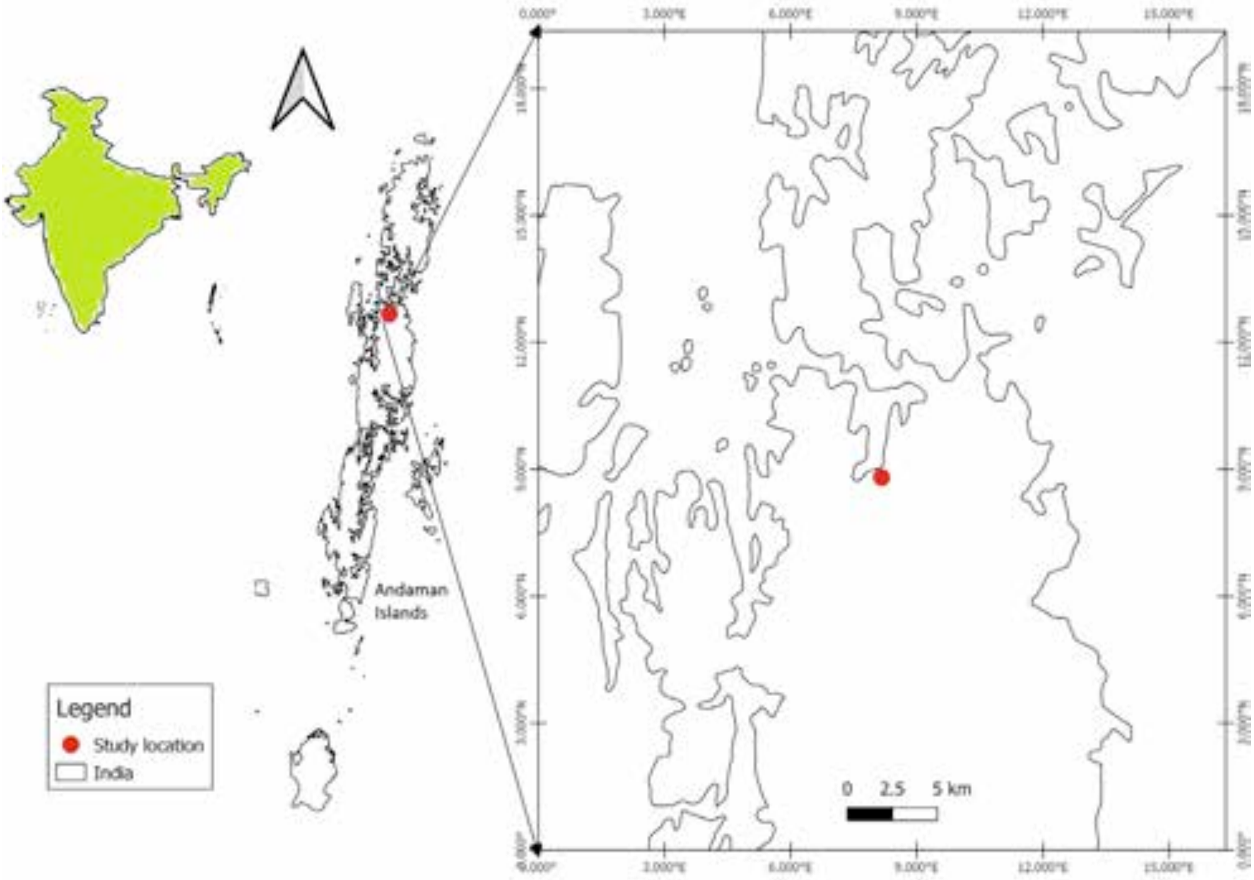


Figure 1. Geographical location of the study site.

types range from the tropical wet evergreen forest towards the south to tropical moist deciduous forest in the North Andaman group of islands (Davidar et al. 2001; Champion & Seth 2005). Parts of the islands also have human settlements and agricultural fields surrounded by deciduous forests. This island group, with a high proportion of endemic flora and fauna, is one of the global biodiversity hotspots in the world (Conservation International 2005). The archipelago has 19 identified Important Bird and Biodiversity Areas (Rahmani et al. 2016) and is also recognized as an endemic bird area (Birdlife International 2019). Including endemic species such as Andaman Serpent Eagle *Spilornis elgini*, Great Nicobar Serpent Eagle *Spilornis klossi*, Central Nicobar Serpent Eagle *Spilornis minimus,* and Nicobar Sparrowhawk *Accipiter butleri*; the Andaman & Nicobar Islands have 22 raptor species.

We conducted the present study in the northernmost part of Middle Andaman in Tugapur near Mayabunder town (Figure 1). The temperature in Tugapur during April was between 27°C and 35°C (Accuweather 2018). Sunrise and sunset were between 05.01h & 05.16h and 17.31h & 17.33h, respectively (Time and Date 2018). Human habitation and small patches of deciduous forest surround the swiftlet house. Plant species such as *Azadirachta indica* A. Juss, *Gliricidia sepium* (Jacq.) Walp., *Calamus* sp. L., *Tectona grandis* L.f., and *Ficus religiosa* L. are seen around the swiftlet house. We made daily visits to the swiftlet house during the late summer season from 02 April to 28 April 2018 between 16.00h and 18.00h. The study period coincided with the breeding season of the Besra (Ali & Ripley 1978) and swiftlets (Manchi & Sankaran 2014). The activities of the Besra near the swiftlet house were studied using focal animal sampling (Altmann 1974). We made observations from the moment the individual arrives around the swiftlet house until it leaves the site. Simultaneously, swiftlets around the house were observed to understand the interaction between the prey and predator. Three observers were stationed at different observation stations around the house to observe and note the behavior of the Besra along with the time (Figure 2). With 120 min of observation every day, we collected data for 2,400 min in 20 days. Occasionally, we prolonged the observations

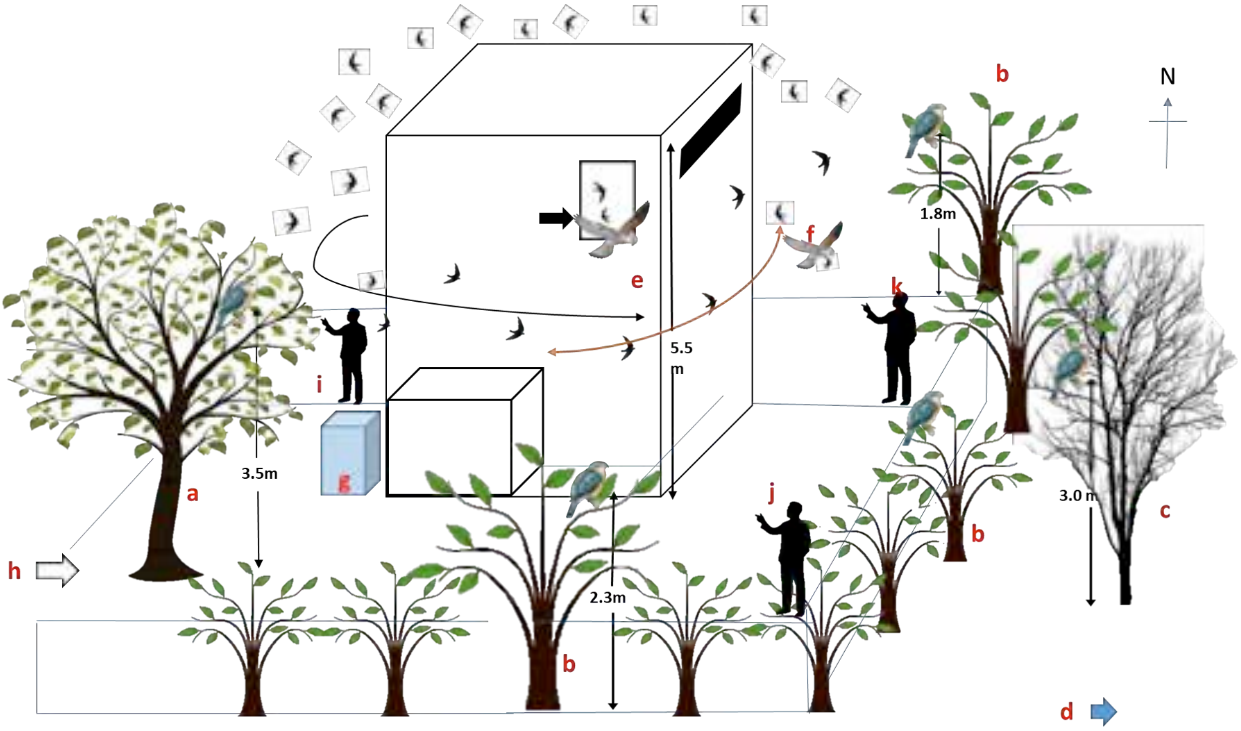


Figure 2. Study site: a—*Azadirachta indica* | b—*Gliricidia sepium* | c—*Tectona grandis* | d—towards *Ficus religiosa* | e—entrance of the swiftlet house for swiftlets | f—frequently used path by Besra | g—water tank | h—entry of the study site | i–j–k—observation stations.

until 18.30h to check the presence and activity of Besra. Because of unfavorable circumstances, we could make only one observation during the morning hours (04.45–07.00 h). To process the collected data, we used XL-STAT software (Ver. 2020, Addinsoft 2020). We excluded the set of data from the single morning visit during analysis. Ethograms of Besra was made based on behavioral observations. No ethical approval was obligatory for this study.

RESULTS

The present study confirms the Besra as a predator of the swiftlets. Swiftlets being diurnal foragers, the breeding individuals keep returning to the breeding location to feed their nestlings, and the arrival of the Besra was at 16.00h. During the 20 days of observations, the Besra made 84 hunting attempts per day to catch swiftlets with 4±11 (Mean±SD). It preyed upon 1±0.5 swiftlets per day, with 14.92% (n=84) successful attempts. The most hunting attempts were between 17.31–17.50 h (67.80 %), and most successful (11.48%) and unsuccessful (56.32%) attempts were also made during the same period (Figure 3). Comparing the sunset timings (17.31h to 17.33h on observation days) and the period of most hunting attempts were during the crepuscular (twilight) hours (Time and Date 2018). It confirmed the crepuscular hunting behavior of Besra, the predator. Out of the total time the besra spent near the ex situ house, 48% was spent attempting a kill while 35% time was spent on the perch (Figure 4).

All the hunting attempts, successful or unsuccessful, were on the flock of swiftlets swarming in the lower canopy (2–5 m above ground) and never above the canopy. The number of attempts increased as the swiftlet flock size increased (Table 1). The Besra captured and carried its kill with its claws. Immediately after capture, the predator brought each kill to the same perch of attack (mostly *Azadirachta indica)* or the nearest landing site (mostly *Tectona grandis* within 10m). As the swiftlets gathered around the house in small groups (15–20 birds), the Besra would chase the selected prey with athletic ease, twisting, turning, and swooping close to the ground (6 in Figure 2) as the aerodynamic swiftlet tried to break away from its grasp. The predator and the prey are swift flyers, and thus sometimes swiftlets managed to evade the predator successfully. The height at which the chase was made, particular areas around the swiftlet house , and the time of the hunt influenced a successful kill.

Table 1. Table 1. The hunting attempts by the Besra (the predator) at a given time in relation to the flock size of swiftlets (the prey) (Note: flock size: <50—small | 50–200—medium | 200–500—large)

Time (h)	Flock size of swiftlets	Total hunting attempts (% success)
16.20–16.30	small	1 (0)
16.30–16.40	small	1 (0)
16.40–16.50	small	6 (50)
16.50–17.00	large	3 (0)
17.00–17.10	large	0
17.10–17.20	large	6 (0)
17.20–17.30	large	11 (0)
17.30–17.40	large	35 (14.28)
17.40–17.50	small	21 (23.80)
17.50–18.00	small	0
	Total	84

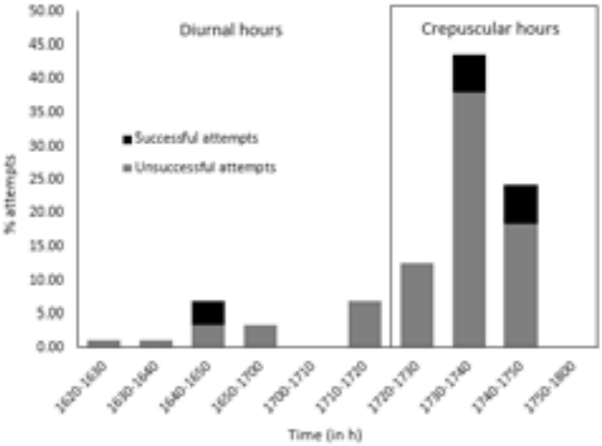


Figure 3. Hunting attempts (in %) by the Besra in relation to the time of the day.

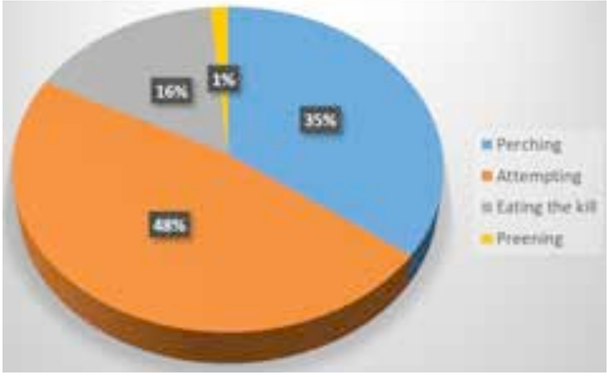


Figure 4. Activity time budget of Besra near the ex situ swiftlet house, Middle Andaman Island.

The Besra usually ripped off the feathers of its prey before consuming the kill. Occasionally, it would swallow the feathers too. The Besra spent 16% of its time in consuming the kill (Figure 4). By examining the kill remnants, we confirmed that the prey species was Glossy Swiftlet, however, once the population of the Edible-nest Swiftlet grows, we cannot deny the possibility of it being hunted by the Besra.

The most hunting attempts by Besra were from a particular perch in the canopy of a large *Azadirachta indica* (46.17%), beside the swiftlet house, however, the Besra was observed using other perching sites around the swiftlet house as well (Table 2). After each attempt, it often perched (30.76%) on *Gliricidia sepium* (2 in Figure 2). The predator returned to the same perch on *Azadirachta indica* for the next attempt to catch a swiftlet.

DISCUSSION

Swiftlets are known to flock near their breeding and roosting sites during dawn and dusk while leaving or returning to their roosts (Tarburton 2009; Mane & Manchi 2017). The cave-dwelling swiftlets are usually known to be vulnerable while entering and exiting the caves (Mane & Manchi 2017). The present study, however, is the first to document aerial predation of swiftlets by the Besra around human-habitation. Flying in flocks equips the swiftlets to successfully evade predators. The time of arrival at the roost (Mane & Manchi 2017, 2019) and the speed used for entering the breeding/roosting sites (Tarburton 2009) are counted as the anti-predatory behaviors of the swiftlets.

Approximately 20km from the swiftlet house, we located a Besra chasing the swiftlets during morning and evening twilight hours. This location hosts thousands of Glossy Swiftlets. Here, we observed the swiftlets forming to chase away the predator. Therefore, we can see two anti-predatory mechanisms in the swiftlets, one to escape the predator by forming groups, and secondly by mobbing the predator by forming larger groups. The anti-predatory behavior may limit the number of prey obtained by the Besra. Apart from the Besra, we noticed that the Shikra *Accipiter badius* attempting to hunt swiftlets near the swiftlet house between 16.00 and 16.30 h from the *Ficus benghalensis* L. trees which was the tallest in the study site. The Shikra chased the swiftlets swarming in the open air but was unsuccessful in catching a bird.

As the number of Glossy Swiftlets in the swiftlet

Table 2. Perch sites used by Besra while hunting the swiftlets near the ex situ swiflet house, Middle Andaman.

	Scientific name of the perch tree	Common name of the perch tree	Height of perch (meters)	Total hunting attempts (% success)
1	*Azadirachta indica* A. Juss	Neem	3.5	13 (46)
2	*Gliricidia sepium* (Jacq.) Walp	Gliricidia	2.3	13 (15)
3	*Gliricidia sepium* (Jacq.) Walp	Gliricidia	1.8	13 (8)
4	*Gliricidia sepium* (Jacq.) Walp	Gliricidia	2.3	13 (8)
5	*Tectona grandis* L.f.	Teak	3	7 (14)
6	*Ficus religiosa* L.	Peepal	~7	26 ((8)

house is greater than the Edible-nest Swiftlet, we can say that the Besra may be preying on the more easily available target. It makes the Edible-nest Swiftlet as vulnerable to predation as the Glossy Swiftlets, putting the already low population at risk.

Sparrow-hawks use at least a 15cm circumference branch of a tree or a moderately flat surface for perching (Owen 1932). Although we could not confirm the same for the Besra, the repetitive use of the same perch shows some preference for perches. To avoid predation of swiftlets, it is essential to avoid such ideal 'perches' or trees near the swiftlet house. Removal of these ideal available perches might drastically reduce the rate of predation of the swiftlets by the Besra, at least till the individual finds and learn to use any other perching site and hunting strategy. The predation behavior depends mostly on the cognitive ability of an individual; it is challenging at present to ascertain the change in the predation rates by the Besra after removal of the perch trees around the house.

Many raptors have shown adaptations in hunting and foraging behavior according to the prey resources. The Bat Hawk *Macheiramphus alcinus* in sub-Saharan Africa, South Asia, and New Guinea, is known to hunt bats during the twilight hours. The bat hawk's adaptation in morphology and behavior results from the prey's biology (Black et al. 1979). The Bat Falcon *Falco rufigularis*, found in Mexico, and Central and South America, is another bird that hunts bats at dusk. The Bat Falcon has also adapted to hunting in urban environments (Seijas 1996). The Peregrine Falcon, a diurnal bird, is also reported to prey on bats (Pierson & Donahue 1983), and some even during dusk or at night (Rejt 2001). Mester & Oliver (2018) reported an unusual fishing behavior of the Eurasian Sparrowhawk during winter when the prey are scarce. Their report suggested, 'Raptors may be able to adopt unusual hunting or foraging behavior and prey selection in response to changing environmental conditions and changing availability of potential prey resources.' Therefore, with a more focused study and observations throughout the islands, it can be concluded whether *A. v. abdulalii* of Andaman Islands has adapted to crepuscular hunting owing to the swiftlet's ecology, and whether this behavior is limited to urban areas (in ex situ structures) or exists everywhere.

CONCLUSION

Since the swiftlet-farming efforts are in the direction of livelihood development and economic growth in the islands, any hindrance to such a program will ultimately affect the local human populations. The raptor-human conflict that may arise from this is a threat to the survival of both (prey and predator) species. Based on the observations discussed, we now recommend maintaining the premises of the swiftlet houses by restricting the vegetation growth for better management of the swiftlet populations in urban areas and also to avoid future raptor-human interaction.

REFERENCES

Accuweather (2018). Mayabunder April Weather 2018. www.accuweather.com. Electronic version accessed 31 July 2018.

Addinsoft (2020). XLSTAT statistical and data analysis solution. New York, USA. https://www.xlstat.com.

Ali, S. & S.D. Ripley (1978). *Handbook of the Birds of India and Pakistan*, Vol. 1. Oxford University Press, India, 247–251pp.

Altmann, J. (1974). Observational Study of Behavior: sampling methods. *Behavior* 49: 227–267. https://doi.org/10.1163/156853974X00534

Black, H.L., G. Howard & R. Stjemstedt (1979). Observations on the feeding behavior of the Bat Hawk (Macheiramphus alcinus). *Biotropica* 11: 18–21. https://doi.org/10.2307/2388165

Champion, H.G. & S.K. Seth (2005). *A revised survey of the forest types of India*. Natraj Publishers, India, 105pp.

Chantler, P. & P. Boesman (2019). Edible-nest Swiftlet (*Aerodramus fuciphagus*). In: del Hoyo, J., A.Elliott, J.Sargatal, D.A. Christie & E.de Juana (eds.). *Handbook of Birds of the World Alive*. Lynx Edicions, Barcelona. http://www.hbw.com/node/55287. Electronic version accessed on 20 October 2020

Clark, W.S. & J.S. Marks (2020). Besra (*Accipiter virgatus*), version 1.0.

In Birds of the World. del Hoyo, J., A. Elliott, J. Sargatal, D. A. Christie, & E. de Juana (eds.). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.besra1.01

Conservation International (2005). Biodiversity hotspots. Conservation International Facts. www.conservation.org. Electronic version accessed on 9 August 2019.

Cranbrook, E.O., G.W. Lim, L.C. Koon & M.A. Rahman (2013). The species of white-nest swiftlets (Apodidae, Collocaliini) of Malaysia and the origins of house-farm birds: Morphometric and genetic evidence. *Forktail* 29: 107–119.

Davidar, P., K. Yoganand & T. Ganesh (2001). Distribution of forest birds in the Andaman islands: importance of key habitats. *Journal of Biogeography* 28(5): 663–671. https://doi.org/10.1046/j.1365-2699.2001.00584.x

Hobbs, J.J. (2004). Problems in the harvest of edible birds' nest in Sarawak and Sabah, Malaysia Borneo. *Biodiversity and Conservation* 13: 2209–2226. https://doi.org/10.1023/B:BIOC.0000047905.79709.7f

Huang, K.Y., Y.S. Lin & L.L. Severinghaus (2004). The Diet of Besra Sparrowhawk (*Accipiter virgatus*) in Yangmingshan Area, Northern Taiwan. *Taiwania* 49: 149–158. https://doi.org/10.6165%2ftai.2004.49(3).149

Birdlife International (2019). Endemic Bird Areas factsheet: Andaman Islands. Birdlife International. www.birdlife.org, Electronic version accessed on 11 June 2019.

Koon, L.C. & E. Cranbrook (2002). *Swiflets of Borneo: Builders of Edible Nests*. Natural History Publications, Borneo, 61–63pp.

Manchi, S. & A. Mane (2012). Conservation of the Edible-nest Swiftlet Collocalia fuciphaga in the Andaman and Nicobar Islands. Salim Ali Centre for Ornithology and Natural History, Coimbatore, 16–32pp.

Manchi, S. & R. Sankaran (2009). Predators of swiftlets and their nests in the Andaman & Nicobar Islands. *Indian Birds* 5: 118–120.

Manchi, S. & R. Sankaran (2014). Protection of the White-nest swiftlet *Aerodramus fuciphagus* in the Andaman. *Oryx* 48(2): 213–217. https://doi.org/10.1017/S0030605311000603

Mane, A.M. & S.S. Manchi (2017). Roosting patterns of the Edible-nest Swiftlet (*Aerodramus fuciphagus*) of the Andaman Islands: effects of lunar phase and breeding chronology. *Emu - Austral Ornithology* 117: 325–332. https://doi.org/10.1080/01584197.2017.1336065

Mane, A.M. & S.S. Manchi (2019). Spatiotemporal roosting movements of the cave- dwelling Andaman Edible-nest Swiftlet (*Aerodramus fuciphagus inexpectatus*). *Wilson Journal of Ornithology* 131(1): 62–71. https://doi.org/10.1080/01584197.2017.1336065

Martin, G. (1990). *Birds by Night*. T & AD Poyser Ltd., London, 79-93pp.

Marzluff, J.M. (2016). A decadal review of urban ornithology and a prospectus for the future. *Ibis* 159: 1–13. https://doi.org/10.1111/ibi.12430

Mester, B. & T. Oliver (2018). Unusual Fishing Behavior of the Eurasian Sparrowhawk (*Accipiter nisus*). *Journal of Raptor Research* 52: 112–114.

Owen, J.H. (1932). The Feeding Habits of the Sparrow-Hawk. *British Birds* 26: 34–40.

Pierson, J.E. & P.Donahue (1983). Peregrine Falcon feeding on bats in Suriname, South America. *American Birds* 37(3): 257–259.

Rahmani, A.R., M.Z. Islam & R.M. Kasambe (2016). Important bird areas in India: priority sites for conservation, Second Edition: Revised and Updated, Vol. I. Bombay Natural History Society, Indian Bird Conservation Network, India; Royal Society for the Protection of Birds and BirdLife International, UK, 64pp

Ratcliffe, D.A. (1980). *The Peregrine Falcon*. T & AD Poyser Ltd, London, 416pp.

Naoroji, R. (2006). *Bird of Prey of the Indian Subcontinent*. Om Books International, India, 692pp.

Rejt, L. (2001). Feeding activity and seasonal changes in prey composition of urban Peregrine Falcons *Falco peregrinus*. *Acta Ornithologica* 36(2): 165–169. https://doi.org/10.3161/068.036.0201

Seijas, A.E. (1996). Feeding of the bat falcon (*Falco rufigularis*) in an urban environment. *Journal of Raptor Research* 30: 33–35.

Tarburton, M.K. (2009). Swiftlet behavior responses to predators in proximity to their nests. *Corella* 33: 99–102.

Thorburn, C.C. (2015). The Edible Nest Swiftlet industry in Southeast Asia: Capitalism meets commensalism. *Human Ecology* 43(1): 179–184. https://doi.org/10.1007/s10745-014-9713-1

Time and Date (2018). Port Blair, Andaman and Nicobar Islands, India — Sunrise, Sunset, and Daylength, April 2018. www.timeanddate.com. Electronic version accessed on 31 July 2018.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17330–17339

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

DOI: https://doi.org/10.11609/jott.6465.12.17.17330-17339

#6465 | Received 22 July 2020 | Final received 03 December 2020 | Finally accepted 18 December 2020

COMMUNICATION

A study on diversity of mammalian species using camera traps and associated vegetation in Mizoram University Campus, Aizawl, Mizoram

J.H. Zothanpuii [1], Sushanto Gouda [2], Abinash Parida [3] & G.S. Solanki [4]

[1–4] Department of Zoology, Mizoram University, Aizawl, Mizoram 796009, India.
[1] zothanpuii84@gmail.com, [2] sushantogouda@gmail.com, [3] abinash.wild@gmail.com,
[4] drghanshyam.solanki@gmail.com (corresponding author)

Abstract: Fragmented forests often have conservation value, serving as a refuge or corridors for small mammalian species. In the study, the diversity of mammals was studied within Mizoram University (MZU) campus. Forty-eight plant species from 25 families were recorded on different sites. Thirty quadrates were nested at the locations of occurrence of mammalian species for vegetation type analysis. *Schima wallichi* was the most dominant plant species with the highest IVI values of (31.7%), followed by *Aporosa octandra* (22.93%) and *Castanopsis tribuloide* (21.17%). Camera trap method was used to collect information about the mammalian diversity in the campus. The mammalian species recorded in this study makes 15% of mammalian fauna of the state of Mizoram. Twelve mammal species and six bird species were recorded by the camera traps. With proper awareness among residents of the campus and a planned approach for developmental activities, the findings of our study can make an important extension for the coexistence of mammalian species and long term survivability within MZU campus.

Keywords: Camera traps, coexistence, mammalian diversity, Mizoram University, Urban biodiversity.

Editor: Anwaruddin Choudhury, The Rhino Foundation for Nature in North East India, Guwahati, India. **Date of publication:** 26 December 2020 (online & print)

Citation: Zothanpuii., S. Gouda, A. Parida & G.S. Solanki (2020). A study on diversity of mammalian species using camera traps and associated vegetation in Mizoram University Campus, Aizawl, Mizoram. *Journal of Threatened Taxa* 12(17): 17330–17339. https://doi.org/10.11609/jott.6465.12.17.17330-17339

Funding: We are thankful to the Department of Zoology, Mizoram University for providing necessary supports for the study. Facilities developed in NMHS project were also utilized. NMHS project sanction letter no. GBPNI/NMHS-2017/MG-221/5561.

Competing interests: The authors declare no competing interests.

Author details: J.H. ZOTHANPUI is a MSc student of Department of Zoology, Mizoram University and the work is a part of her dissertation work. She is currently preparing for future possible research opportunities. SUSHANT GOUDA is a PhD scholar and is currently engaged in a NMHS based project under the Department of Zoology, Mizoram University. He is active in the field of wildlife biology and conservation education. His major research area is ecology and distribution of Himalayan bear. ABINASH PARIDA is a senior research fellow in the NMHS project in department of zoology. He is a vigorous field biologist and working on faunal diversity and conservation. His major research area is primate diversity, ecology, and conservation. G.S. SOLANKI is Professor in Zoology and Principal Investigator of Nation Mission on Himalayan Studies (NMHS) project in the Department of Zoology. This project is funded by G.B. Pant National Institute Himalayan Environment and Sustainable Development, Almora,Uttarakhand. Major research area is ecology and conservation of wilderness species with main emphasis on primates.

Author contribution: JHZ and AP have carried out the research work and collected the data. SG helped in preparation of this the manuscript. GSS was Principal Investigator and guiding teacher, and provided work plan and all logistic suppot required.

Acknowledgements: The authors are thankful acknowledge the support and logistic provided by Department of Zoology and administration of Mizoram University. First author also extend thanks to principal investigator of NMHS project who very kindly allowed me to use camera traps of the project. Thanks are also due to the security in charge of MZU for the necessary permission and co-operation during the study.

INTRODUCTION

The northeastern region of India shares two biodiversity hotspots and has rich mammalian and avian diversity (Choudhury 2006). The state of Mizoram is part of the Indo-Myanmar Biodiversity Hotspot region and harbours 126 species of mammals including 37 threatened species (Lalthanzara 2017). The rapid expansion of shifting cultivation and urbanization in the region has, however, led to a contemporary changes in landscape, forest fragmentation, and ecosystem modification (Teegalapalli et al. 2009; Yadav 2013). Such anthropogenic activities have created a mosaic of remnant forest patches of varying size, demarcated by a network of roads, concerts, and settlements areas (Mazumdar et al. 2011). Recent researches on biodiversity conservation had put urban areas having rich biodiversity into the limelight for the long-term persistence of native species (Ordenana et al. 2010; Lopucki & Kitowski 2017; Hill et al. 2018). Urbanization is often considered to have several negative impacts on the native flora and fauna; nevertheless, it also serves as valuable habitat and corridor for dispersal of certain animal species (Opdam et al. 2003; Fernandez & Simonetti 2013). Urban and semi-urban green forest patches serves as surrogate and refuge habitat to be utilized for dispersal and migration for birds and many small to medium size mammals (Gallo et al. 2017). The role of degraded forest landscapes and patches within the campus of academic institutions as a potential habitat for small mammals and birds has also been acknowledged in some studies (Vallejo et al. 2008; Mazumdar et al. 2011; Voon et al. 2014; Nerlekar et al. 2016).

The camera trap is a useful technique widely used for collecting information on elusive species (Kelly et al. 2008; Linkie & Ridout 2011). Information on species diversity and distribution is considered to be the primary need for conservation activities (Geldmann et al. 2013; Brncic et al. 2015). While information on biodiversity in megacities and large urban areas are easily available, the same is scarce in small cities and educational campuses (Lopucki et al. 2013; Lopucki & Kitowski 2017). Mizoram University (MZU) campus at Aizawl, Mizoram encompasses a large area with lush green landscape having several patches of natural forest vegetation. Although research on herpetofauna (Vanlalhlimpuia 2012), butterfly (Baruah 2017), spiders (Lalthafamkima 2017), and birds (Sailo et al. 2019) are available from MZU campus, no study has been undertaken on the distribution of mammalian species. Therefore, a study was planned to determine the mammalian diversity using mainly camera traps and direct observations within the campus.

MATERIALS AND METHODS

Study area

Mizoram University (MZU) is located at the western end of the Aizawl town, the state capital of Mizoram at a distance of about 15km. The campus of MZU is spread in an area of 978.1988 acres and lies between 23.7394°N & 92.6651°E. The elevation ranges between 300–880 m. University campus encompasses the administrative block, academic blocks, hostels, and other facilities which are sparsely embedded within regenerating tropical wet evergreen and semi-evergreen forests (Image 1). The campus also harbors a protected forested water catchment reserve in the north and a small biodiversity park. In the vicinity of the campus, there are settlement areas, where residents undertake agriculture practice (jhum cultivation), which is the primary source of income and livelihood. Several small natural and seasonal streams also flow through the campus. Vegetation profile is dominated by trees comprised of 384 species of vascular plants from 290 genera and 107 families (Lalchhuanawma 2008; Rai 2016; Sailo et al. 2019). A map of the university is presented in Figure 1.

Vegetation analysis

A preliminary survey of campus area was carried out to select the sampling site for vegetation study. Transects were set up in areas where signs and evidence of animals' presence were observed. For vegetation sampling 10m x 10m quadrates were plotted at every 200m interval along transects for tree diversity analysis. Thirty quadrates were plotted in different sites and only trees having DBH more than 10cm were considered for the analysis (Daniels et al. 1996). Vegetation analysis was done for the relative frequency of occurrence of the species; relative density, relative abundance and important value index (IVI) were determined following methods of Lalchhuanawma (2008) and Ahmed (2012).

Camera trapping

The camera traps are often used for understanding the secretive behavior or nocturnal activity, and estimating animal population comprehensively even at relatively low densities of animals (Ordenana et al. 2010; Gouda et al. 2020). Camera deployment points were chosen based on the presence of visible animal trails, footprints,

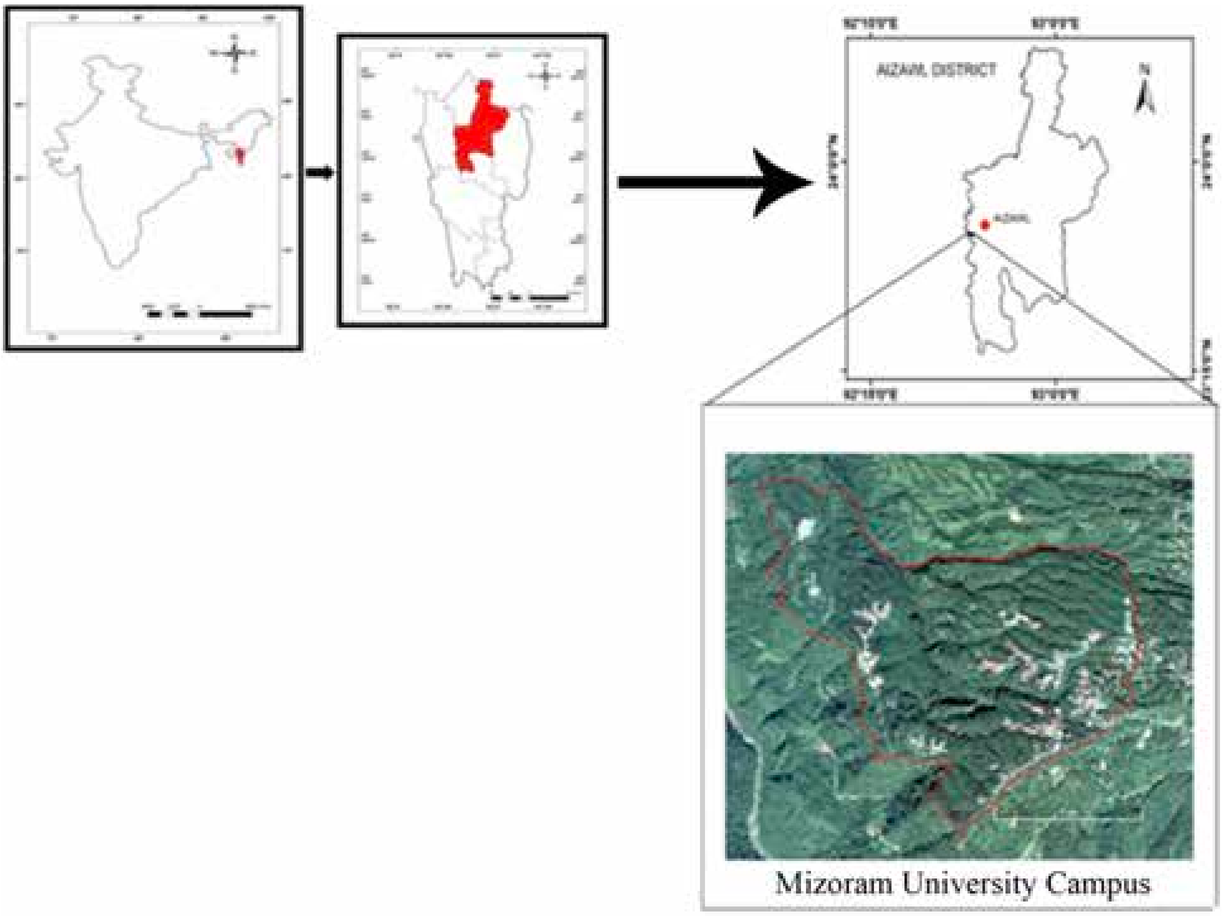


Figure 1. Location of Aizawl City and Mizoram University campus.

scats, activity areas such as dens or close to streams (Sasidhran et al. 2016). Nine camera traps (Cuddeback) were randomly deployed at 15 sampling points within the study sites for 45 days as presented in Figure 2. The cameras were installed on a tree trunk at a suitable height of 30–50 cm above the ground at optimum angles based on slope conditions for viewing the animal trails without the camera view being blocked by any objects (Image 1). Camera traps were programmed to take sequential photographs with five seconds delay registering date and time for each exposure. On average the camera traps were operational for five days and were checked every two days for photos and battery replacement. GPS (Garmin map 78S) was also used to record coordinates, elevation, and slope of camera trap locations. The relative abundance index (RAI) value was calculated using the method suggested by Jenks et al. (2011). Whenever possible we also recorded directly observed species especially arboreal ones around the camera trap locations.

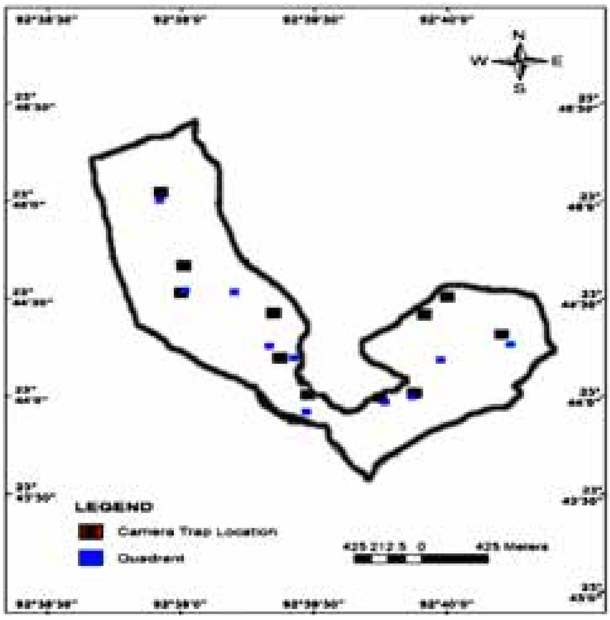


Figure 2. Location of camera traps and quadrates for vegetation sampling.

Image 1. a & b—view of MZU campus | c—installation of camera traps | d—habitat with water source, footprints, and tracks of different animal species. © Abinash Parida.

RESULTS

Forty-eight plant species which belongs to 25 families were recorded along the transect lines during the vegetation study. Vegetation samples were analyzed for the parameters mentioned in Table 1. The analysis showed that *Schima wallichi* is the most dominant plant species having the highest IVI values (31.7%), followed by *Aporosa octandra* (22.93%), *Castanopsis tribuloide* (21.17%), and *Syzgium praecox* (17.86%). Plant species such as *Hibiscus macrophyllus*, *Bischofia javanica*, *Cinnamomum cassia*, and *Acer laevigatum* were some of the least available species (Table 1). The family Euphorbiaceae contributed for the highest IVI, followed by Theaceae and Fagacae while the family Pandanaceae had the lowest IVI values among the recorded plant families (Figure 3).

The mammalian diversity on MZU campus is 19 mammalian species; 12 were captured through camera traps (Table 2) (Image 2) and seven were recorded by direct observations (Table 3). Six bird species were also photo-captured during this study (Table 4) (Image 3). Among the mammalian species, civets are predominant with 30.17% followed by felids (25%). The presence of Marbled Cat *Pardofelis marmorata* (Near Threatened), Clouded Leopard *Neofelios nebulosa* (Vulnerable), and Golden Jackal *Canis aureus* (Least Concern) were important and majestic mammalian species. Such valuable observations from the fragmented habitat of an urban landscape are significant for species conservation. Other recorded species are categorised as Least Concern. The relative abundance index (RAI) value was highest (16.67) for Crab-eating Mongoose *Herpestes urva* followed by Common Palm Civet *Paradoxurus hermaphroditus* (13.3), and Leopard Cat *Prionailurus bengalensis* (10) (Table 2). Sites with minimal human disturbance and water bodies within the campus had higher RAI values. Among directly observed mammalian species squirrels and shrews were the major ones (Table 3). Seven avian species namely Khalij Pheasant (male and female), Blue Whistling Thrush, Forktail, Asian Barred Owlet, Long-tailed Nightjar, and Large Cuckoo

Table 1. Vegetation composition and analysis.

	Name of species	Mizo name	Family	Relative density (%)	Relative Frequency (%)	Relative Dominance (%)	Important Value Index(IVI)
1	*Acer laevigatum*	Thingkhim	Aceraceae	0.54	0.36	0.38	1.28
2	*Albizia chinensis*	Vang	Mimosaceae	2.20	1.84	1.93	5.97
3	*Albizia richardiana*	Theichhawl	Mimosaceae	2.20	1.65	3.23	7.08
4	*Albizia procera*	Kangtek	Mimosaceae	1.37	1.10	2.48	4.95
5	*Anogeissus acuminate*	Zairum	Combretaceae	0.29	0.73	0.69	1.71
6	*Aporosa octandra*	Chhawntual	Euphorbiaceae	10.09	4.61	8.23	22.93
7	*Artocarpus lakoocha*	Theitat	Moraceae	0.83	1.10	1.01	2.94
8	*Balakata baccata*	Thingvawkpui	Euphorbiaceae	1.37	3.68	1.84	6.89
9	*Bischofia javanica*	Khuangthli	Euphorbiacea	0.12	0.01	0.15	0.28
10	*Bombax insigne*	Pang	Bimbaceae	1.78	1.47	3.29	6.54
11	*Callicarpa arborea*	Hnahkiah	Verbenaceae	4.4	3.13	1.95	9.48
12	*Castanopsis indica*	Sehawr	Fagaceae	3.74	1.84	1.40	6.98
13	*Castanopsis lanceifolia*	Vawmbuh	Fagaceae	0.41	1.29	0.87	2.57
14	*Castanopsis tribuloides*	Thingsia	Fagaceae	8.43	3.13	9.61	21.1
15	*Cedrellatoona*	Tei	Meliaceae	0.29	0.36	0.30	0.95
16	*Cinnamomum cassia*	Thakthing	Lauraceae	0.12	0.01	0.13	0.26
17	*Cinnamomum tamala*	Tespata	Lauraceae	2.36	1.47	1.81	5.64
18	*Colona floribunda*	Hnahthap	Tiliaceae	0.12	0.36	0.17	0.65
19	*Cordiawallichi*	Muk	Boraginanaceae	0.83	2.02	2.05	4.9
20	*Derris robusta*	Thingkha	Fanaceae	1.12	1.29	0.92	3.33
21	*Derris thrysiflora*	Hulhu	Papillionaceae	0.12	0.01	0.19	0.32
22	*Drymicarpus racemosus*	Vawmbal	Anacardiaceae	3.44	1.65	5.24	10.3
23	*Duabanga grandiflora*	Zuang	Sonneratiaceae	0.12	0.01	0.28	0.41
24	*Embilica officinales*	Sunhlu	Euphorbiaceae	0.54	0.55	0.51	1.6
25	*Erythrina variegate*	Fartuah	Papillionaceae	0.41	0.73	1.99	3.13
26	*Ficus hirta*	Sazutheipui	Moraceae	0.54	0.62	0.67	2.13
27	*Glochidion heyneanum*	Thingpawnchhia	Euphorbiaceae	2.78	2.02	2.15	6.95
28	*Gmrlina arborea*	Thlanvawng	Verbenaceae	0.71	0.55	1.22	2.48
29	*Haldina cordifolia*	Lungkhup	Rubiaceae	2.20	1.10	1.62	4.92
30	*Hibiscus macrophyllus*	Vaiza	Malvaceae	0.12	0.01	0.07	0.20
31	*Ilex godajam*	Thinguihahni	Aquifoliaceae	0.41	0.73	0.82	1.96
32	*Lithocarpus elegans*	Thingpuithing	Fagaceae	0.70	0.36	0.72	1.78
33	*Litseamono petala*	Nauthak	Lauraceae	2.07	1.84	1.60	5.51
34	*Macaranga indica*	Hnahkhar	Euphorbiaceae	4.86	2.94	3.74	11.54
35	*Macropanax undulatum*	Phuanberh	Araliaceae	0.41	0.92	0.85	2.18
36	*Messua ferrea*	Herhse	Guttiferae	0.70	0.36	0.31	1.37
37	*Pandanus fasicularis*	Ramlakhuih	Pandanaceae	0.41	1.47	0.33	2.21
38	*Protium serratum*	Bil	Burseraceae	1.37	0.92	1.45	3.74
39	*Saurauia punduana*	Tiar	Actinidiaceae	2.78	1.29	1.96	6.03
40	*Schima khasiana*	Khiangzo	Theaceae	0.64	0.92	0.67	2.23
41	*Schima wallichi*	Khiang	Theaceae	13.29	4.05	14.36	31.70
42	*Sterculia villosa*	Khaupui	Sterculaceae	1.12	0.92	1.33	3.37
43	*Stereospermum tetragonum*	Zinghal	Bignoniaceae	0.41	1.17	0.75	2.63

	Name of species	Mizo name	Family	Relative density (%)	Relative Frequency (%)	Relative Dominance (%)	Important Value Index(IVI)
44	*Syzigiumcumini*	Lenhmui	Myrtaceae	0.71	1.47	1.43	3.61
45	*Syzigium praecox*	Hmuifang	Myrtaceae	6.35	2.76	8.75	17.86
46	*Toona ciliate*	Teipui	Meliaceae	0.41	0.55	0.94	1.90
47	*Trema orientalis*	Belphuar	Cannabaceae	0.41	0.92	9.03	10.36
48	*Wendlandia budieioides*	Batling	Rubiaceae	3.19	2.21	1.73	7.13

Table 2. Mammalian diversity based on photo captured and their status

	Family	Common name	Scientific name	IUCN status	RAI
1	Felidae	Clouded Leopard	*Neofelis nebulosa*	Vulnerable	3.33
2	Felidae	Marbled Cat	*Pardofelis marmorata*	Near threatened	3.33
3	Felidae	Leopard Cat	*Prionailurus bengalensis*	Least concern	10.00
4	Suidae	Wild Pig	*Sus scrofa*	Least concern	3.33
5	Viverridae	Large Indian Civet	*Viverra zibetha*	Least Concern	13.33
6	Viverridae	Small Indian Civet	*Viverricula indica*	Least concern	10.00
7	Viverridae	Common Palm Civet	*Paradoxurus hermaphroditus*	Least concern	13.33
8	Herpestidae	Crab-eating Mongoose	*Herpestes urva*	Least concern	16.67
9	Canidae	Golden Jackal	*Canis aureus*	Least concern	3.33
10	Viverridae	Himalayan Palm Civet	*Paguma larvata*	Least concern	6.67
11	Mustelidae	Ferret Badger	*Melogale sp.*	Least concern	3.33
12	Tupaiidae	Tree Shrew	*Cladobats belangari*	Least concern	3.33

Shrike were also captured by camera traps in different areas of the campus (Table 4, Image 3).

DISCUSSION

This study can make an important extension in documentation and range of faunal species available within a university campus. The IVI and other quantitative values obtained for different plant species in the study coincide with the findings of Lalramenga (2006) and Lalchhuanawma (2008) that were carried out within the campus. The rich floral diversity plays a key role in supporting both the avifauna and mammalian fauna in the campus. The presence of roadside plants like *Ficus benghalensis*, *F. religiosa*, *Trema orientalis*, *Lantana camara*, *Musa paradise*, and *Casia auriculata* in MZU campus can serve as good habitat and feeding grounds for birds and small mammals as reported by Lalchhuanawma (2008) and Rai (2016).

The undisturbed forest patches within MZU campus appears to support a diverse group of mammalian species. The record of 19 mammalian species in the campus is an evidence of its rich mammalian diversity, which contributes for 15% of the mammalian fauna of the state of Mizoram. Family viverridae is highly diverse in MZU campus; five species of family viverridae were also reported earlier in Mizoram (Lalthanzara 2017). Presence of felids (three species) in the campus also forms 37.5%, as eight fields were previously reported by Lalthanzara (2017) in Mizoram. Species such as Clouded Leopard, Marbled Cat, Golden Jackal, and Ferret Badger not only indicates the potential of the university campus to support the cohabitation and co-existence with mammals but also highlights the values of urban diversity.

The relative abundance index (RAI) indicates that ground dwelling birds such as Khalij Pheasant (male and females) were dominant (RAI= 13.33) and also are the prey species for carnivorous mammals. The mammalian species evident in MZU campus are very rare and may be difficult to record even in a protected forest. Dense shrub forests, tall fruiting trees, and low lying natural streams along the edges of the campus that provides ideal forest

Table 3. Mammalian species observed directly during study and their status.

	Family	Common name	Scientific name	IUCN status
1	Mustelidae	Yellow-throated Martin	*Martes flavigula*	Least Concern
2	Cervidae	Barking Deer	*Muntiacus muntjak*	Least Concern
3	Sciuridae	Pallas's Squirrel	*Callosciurus erythraeus*	Least Concern
4	Sciuridae	Himalayan Hoary-bellied Squirrel	*Callosciurus pygerythrus*	Least Concern
5	Tupaiidae	Northern Tree Shrew	*Tupaia belangeri*	Least Concern
6	Muridae	Black Rat	*Rattus rattus*	Least Concern
7	Soricidae	House Shrew	*Suncus murinus*	Least Concern

Table 4. Avian sapecies photo-captured during the study and their status.

	Family	Common name	Scientific name	IUCN	RAI
1	Phasianidae	Khalij Pheasant	*Lophura leucomelanos*	Least Concern	13.33
2	Muscicapidae	Blue Whistling Thrush	*Myophonus caeruleus*	Least Concern	3.33
3	Muscicapidae	Forktail	*Enicurus leschenaulti*	Least Concern	3.33
4	Strigidae	Asian-barred Owlet	*Glaucidium cuculoides*	Least Concern	6.67
5	Campephagidae	Large Cuckoo Shrike	*Coracina macei*	Least Concern	3.33
6	Caprimulgidae	Long-tailed Nightjar	*Caprimulgus climacurus*	Least Concern	3.33

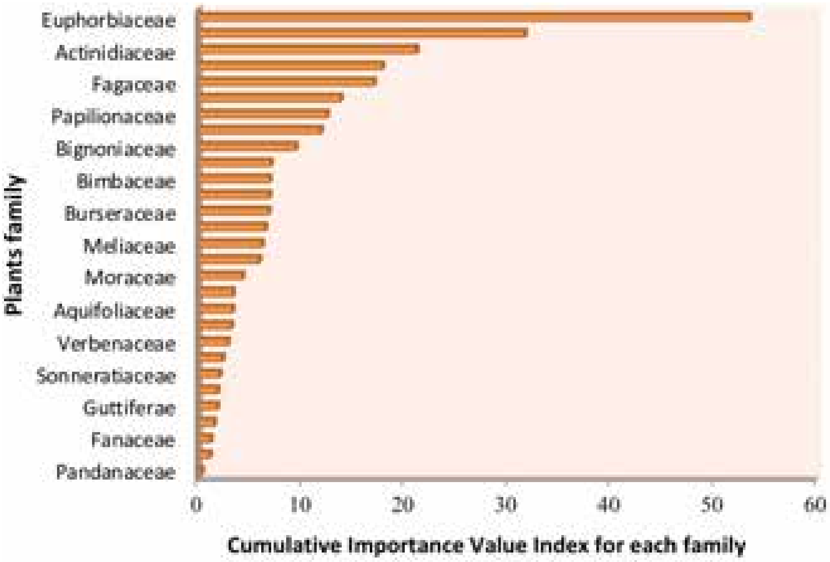


Figure 3. Plant families and their IVI values.

cover and feeding opportunities are contributing to the abundance of these species within the campus. The low resident human population (little over 2000 individuals) with a good sense of conservation value and long forest corridors are also key factors for the distribution of such majestic species within the campus. Anthropogenic activities like hunting, jhumming or shifting cultivation in the vicinity of the campus, collection of NTFP's and the ever-increasing chain of construction works can have negative impacts on biodiversity in general and particularly on mammals of MZU campus. Information on mammalian diversity recommends that a long-term and systematic study on biodiversity profile of the MZU campus is needed.

Image 2. a—Clouded Leopard | b—Golden Jackal | c—Himalayan Palm Civet | d—Crab-eating Mongoose | e—Leopard Cat | f—Large Indian Civet | g—Small Indian Civet | h—Himalayan Hoary-bellied Squirrel | i—Common Palm Civet | j—Ferret Badger | k—Wild Boar | l—Marbled Cat.

REFERENCES

Ahmed, A. (2012). Analysis of forest vegetation in Ranikhet, Kumaon Himalayas, Uttarakhand, India. *Indian Journal of Fundamental and Applied Life Sciences* 2(4): 16–23.

Baruah, P. (2017). Diversity of butterflies in Mizoram University campus, Aizawl. MSc dissertation submitted to Mizoram University. India.

Brncic, T., B. Amarasekaran, A. McKenna, R. Mundry & H.S. Kuhl (2015). Large mammal diversity and their conservation in the human-dominated land-use mosaic of Sierra Leone. *Biodiversity Conservation* 24: 2417–2438.

Choudhury, A. (2006). Notable bird records from Mizoram in north-east India. *Forktail* 22: 152–155.

Daniels, R.J.R., J. Venkatesan & C. Anuradha (1996). Biodiversity indexing in AgricultureLandscapes to species. M.S. 5waminathan Research Foundation, Chennai. FAO/UNDP.PER CENT 43.

Fernández, I.C. & J.A. Simonetti (2013*).* Small mammal assemblages in fragmented shrublands of urban areas of Central Chile. *Urban Ecosystems* 16: 377–387. https://doi.org/10.1007/s11252-012-0272-1

Gallo, T., M. Fidino, E.W. Lehrer & S.B. Magle (2017). Mammal diversity and meta-community dynamics in urban green spaces: Implications for urban wildlife conservation. *Ecological Applications* 27(8): 1–12.

Image 3. Birds captured by camera trap: a—Blue Whistling Thrush | b—Large Cuckoo Shrike | c—Long-tailed Nightjar | d—Khalij Pheasant female | e—Khalij Pheasant male | f—Forktail.

Geldmann, J., M. Barnes, L. Coad, I.D. Craigie, M. Hockings & N.D. Burgess (2013). Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. *Biological Conservation* 161: 230–238.

Gouda, S., N.S. Chauhan, J. Sethy & H.K. Sahu (2020). Daily activity pattern of Malayan Sun bear in Dampa Tiger Reserve, Mizoram, India. *Journal of Wildlife and Biodiversity* 4(2): 56–64.

Hill, M.J., J. Biggs, I. Thornhill, R.A. Briers, M. Ledger, D.G. Gledhill, P.J. Wood & C. Hassall (2018). Community heterogeneity of aquatic macro-invertebrates in urban ponds at a multi-city scale. *Landscape Ecology* 33: 389–405.

Jenks, K.E., P. Chanteap, K. Damrongchainarong, P. Cutter, T. Redford, A.J. Lynam, J. Howard & P. Leimgruber (2011*).* Using relative abundance indices from camera-trapping to test wildlife conservation hypotheses - an example from KhaoYai National Park, Thailand. *Tropical Conservation Science* 4: 113–131.

Kelly M.J., A.J. Noss, M. Di-Bitetti, L. Maffei, R.L. Arispe, A. Paviolo, C. De Angelo & Y.E. Di Blanco (2008). Estimating Puma densities from camera trapping across three study sites: Bolivia, Argentina, and Belize. *Journal of Mammalogy* 89(2): 408–418.

Lalramenga, P.C. (2006). Studies on plant diversity of undisturbed forest in Mizoram University campus, Tanhril. M.Sc. dissertation submitted to Mizoram University, India.

Lalthanzara, H. (2017). A systematic list of mammals of Mizoram, India. *Science Vision* 17(2): 104–121.

Lalthafamkima, K. (2017). Study on diversity of spiders inside Mizoram University campus, Aizawl, Mizoram. MSc dissertation submitted to Mizoram University, India.

Lalchhuanawma (2008). Ecological studies on plant diversity and productivity of herbaceous species in Mizoram university campus at Tanhril, Aizawl, Mizoram (N.E. India). PhD Thesis. Submitted to Mizoram University, India.

Linkie, M. & M.S. Ridout (2011). Assessing tiger-prey interactions in Sumatran rainforest. *Journal of Zoology* 284(3): 224–229.

Lopucki, R. & I. Kitowski (2017). How small cities affect the biodiversity of ground-dwelling mammals and the relevance of this knowledge in planning urban land expansion in terms of urban wildlife. *Urban Ecosystem* 20: 933–943.

Lopucki, R., I. Mroz, Ł.B. Ski & M. Burzych (2013). Effects of urbanization on small-mammal communities and the population structure of synurbic species: an example of a medium-sized city. *Canadian Journal of Zoology* 91: 554–561.

Mazumdar, K., R. Soud & A. Gupta (2011). Mammalian diversity of degraded forest habitats around Assam University Campus, Cachar, Assam, India, with notes on conservation status. *Our Nature* 9: 119–127.

Nerlekar, A.N., A.M. Warudkar, G.G. Gowande, S.S. Salve, A. Raut, S.R. Patankar & S.B. Nalavade (2016). A review of the faunal diversity of the Fergusson College campus, Pune, India. *Zoo's Prints* 29(10): 4–25.

Opdam, P., J. Verboom & R. Pouwels (2003). Landscape cohesion: an index for the conservation potential of landscapes for biodiversity. *Landscape Ecology* 18: 113–126.

Ordenana, M.A., K.R. Crooks, E.E. Boydston, R.N. Fisher, L.M. Lyren, S. Siudyla, C.D. Haas, S. Harris, S.A. Hathaway, G. M. Turschak, A.K. Miles & D.H. van Vuren (2010). Effects of urbanization on carnivore species distribution and richness. *Journal of Mammalogy* 91(6): 1322–1331. https://doi.org/10.1644/09-MAMM-A-312.1

Rai, P.K. (2016). Biodiversity of roadside plants and their response to air pollution in an Indo-Burma hotspot region: implications for urban ecosystem Restoration. *Journal of Asia-Pacific Biodiversity* 9: 47–55.

Sailo, L., G.S. Solanki & C. Lalhruaizela (2019). Avian diversity in Mizoram University Campus, Aizawl, Mizoram. *Science and Technology Journal* 7(1): 54–68.

Sasidhran, S., N. Adila, M.S. Hamdan, L. Samantha, D. Aziz, N. Kamarudin & B. Azhar (2016). Habitat occupancy patterns and activity rate of native mammals in tropical fragmented peat swamp reserves in Peninsular Malaysia. *Forest Ecology and Management* 363:140–148. https://doi.org/10.1016/j.foreco.2015.12.037

Teegalapalli, K., G.V. Gopi & P.K. Samal (2009). Forest recovery following shifting cultivation: an overview of existing research. *Tropical Conservation Science* 2(4): 374–387.

Vallejo, B., A. Aloya, P. Ong, A. Tamino & J. Villasper (2008). Spatial patterns of bird diversity and abundance in an urban tropical landscape: The University of the Philippines Diliman campus. *Science Diliman* 20(1): 1–10.

Vanlalhlimpuia (2012). Diversity of herpetofauna in Mizoram University campus, Aizawl, Mizoram. MSc dissertation submitted to Mizoram University, India.

Voon, A.M., K.A. Nasradhi, M.A. Rahman & J.M. Azlan (2014). Bird diversity, density and foraging activities in a university campus landscape in Sarawak. *Borneo Journal of Resources Science and Technology* 4(2): 9–20.

Yadav, P.K. (2013). Slash-and-burn agriculture in north-east India. *Expert Opinion in Environment and Biology* 2(1): 1–4. https://doi.org/10.4172/2325- 9655.1000102

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17340–17346

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

DOI: https://doi.org/10.11609/jott.5231.12.17.17340-17346

#5231 | Received 16 July 2019 | Final received 23 November 2020 | Finally accepted 09 December 2020

SHORT COMMUNICATION

Distribution of *Syzygium travancoricum* Gamble (Myrtaceae), a Critically Endangered tree species from Kerala part of Western Ghats, India

V.B. Sreekumar [1], K.A. Sreejith [2], M.S. Sanil [3], M.K. Harinarayanan [4], M.P. Prejith [5] & R.V. Varma [6]

[1,2,3,5] Forest Ecology and Biodiversity Conservation, Kerala Forest Research Institute, Peechi, Kerala 680653, India
[4] Department of Botany, Sree Krishna College, Guruvayur, Thrissur, Kerala 680602, India
[6] Research Council Member, Kerala Forest Research Institute, Peechi, Kerala 680653, India
[1] sreekumar@kfri.res.in (corresponding author), [2] sreejith@kfri.res.in, [3] sanilmadambi2010@gmail.com, [4] harinmk@yahoo.co.in,
[5] prejimad88@gmail.com, [6] varmarv@gmail.com

Abstract: *Syzygium travancoricum* Gamble is an endemic, Critically Endangered tree species found in marshy swamps of the Western Ghats. An assessment was conducted on existing distribution pattern and population structure of this species in Kerala. Most of the existing populations are mainly located in sacred groves and this tree is an ideal example on role of sacred groves in conserving biodiversity especially IUCN red listed species. A total of 465 individuals were recorded in which maximum number of sapling density was recorded in Kalasamala Sacred grove followed by patches of Myristica swamps in Kulathupuzha. Fragmentation of populations, habitat modification, over exploitation, pollution and invasion of exotics are major threats to *S. travancoricum*. Hence urgent intervention is required for restoration programmes, management of habitat and subsequently delisting this species from IUCN red list of threatened species.

Keywords: Endemic, Kalasamala, Myrtaceae, population structure, southern Western Ghats.

The genus *Syzygium* Gaertner (Myrtaceae) comprises more than 1,200 species all over the world, distributed in tropical regions of Asia, Africa, Australia, and in southwestern Pacific regions (Parnell et al. 2007; Govaerts et al. 2008). As an economically and ecologically important genus, *Syzygium* species are commercially cultivated for their fruits (*S. cumini* (L.) Skeels, *S. jambos* (L.) Alston), timber (*S. aqueum* (Burm. f.) Alston, *S. malaccense* (L.) Merr. & L. M. Perry), or for medicinal properties (*S. aromaticum* (L.) Merr. & L. M. Perry) or as spices. In India, 54 species have been so far reported (Govaerts et al. 2008) with the highest concentration in the Western Ghats with 48 species, among which 27 species are exclusively endemic to this region (Sujanapal & Kunhikannan 2017). The forests of the Western Ghats, especially tropical wet evergreen and high-altitude Shola peaks are ideal habitats for the *Syzygium*, however, most of these species are threatened and as per the IUCN (v1.18-2019) Red List, three species are Critically Endangered, eight as Endangered, five Vulnerable and four as Least Concern. The species like *S. palghatense* and *S. courtallense* are known from single locality and *S. beddomei* and *S. rubicundum* are known only by their type collections. *Syzygium travancoricum* Gamble is an evergreen tree species endemic to the Western Ghats and it was first discovered in the swampy lowlands (altitude <65m) of Travancore by Bourdillon (1908). Later Gamble described it in 1918 in Kew Bulletin and Flora of the Presidency of Madras in 1919. According to Byng et

Editor: Anonymity requested.

Date of publication: 26 December 2020 (online & print)

Citation: Sreekumar, V.B., K.A. Sreejith, M.S. Sanil, M.K. Harinarayanan, M.P. Prejith & R.V. Varma (2020). Distribution of *Syzygium travancoricum* Gamble (Myrtaceae), a Critically Endangered tree species from Kerala part of Western Ghats, India. *Journal of Threatened Taxa* 12(17): 17340–17346. https://doi.org/10.11609/jott.5231.12.17.17340-17346

Funding: KFRI Plan Grants (748/2018) supported by KSCSTE, Thiruvananthapuram.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are grateful to the Director, Kerala Forest Research Institute, Peechi, Thrissur for providing facilities. We express our sincere thanks to Mr. Sarath, R. and Mr. Prasad, T. S. for help during the field work.

al. (2015), *S. travancoricum* is conspecific with *S. stocksii* (Duthie) Gamble, as both share long petioles, elliptic leaves and highly branched inflorescences, however, Sujanapal & Kunhikannan (2017) treated this as different species and commented that detailed studies based on molecular and population data are essential for fixing the status of *S. travancoricum*. This is a medium sized tree growing up to 25m in height. The bark surface is longitudinally fissured, grayish-brown in colour and inner bark is grey. Leaves are simple, opposite, 8–16.5 × 5–8.5 cm, exstipulate and large in size; lateral nerves are 10–15 pairs, parallel, distant, with intra-marginal nerve; petiole 10–20 mm long, grooved above. Flowers are bisexual, white, mostly in axillary lax cymose corymbose with peduncle 4.5–5 (8) cm long, their branches are also long and ascending. Stamens are numerous, free, bent inwards at middle when in bud. Ovary is inferior, two-celled with many ovules. Fruit is a berry, oblong-obtuse on sides, 1 × 0.5 cm, deep violet, and pericarp juicy containing single seed (Image 1). As per IUCN Red list (2019), only 200 trees are found in the Western Ghats and treated as Critically Endangered C2a ver 2.3. It is also reported that the sacred grove of Aikad reported to harbour four individuals and another subpopulation of 15 to 20 trees has been seen at Guddrikal. Nair & Mohanan (1981) quoted that “Apparently no tree is surviving in the type locality. Recently only four trees have been spotted in a sacred grove of Aikad in Quilon District”. In Kerala, *S. travancoricum* have been reported from evergreen and semi-evergreen forests and few sacred groves in Thiruvananthapuram, Kollam, Pathanamthitta, Alapuzha, Thrissur, and Kasaragod districts (Sasidharan 2004) and locally known as Poriyal, Vathamkollimaram or Kulavetty. Ray (2011) reported this species from three groves namely, Devaravattibana (Mattigar), Kadkod Choudammabana (Aralihonda) and Choudammabana (Dugdimane) with high seedlings and sapling density in Karnataka region. It has also been reported from the freshwater Myristica swamps of Kaan forests of Uttara Kannada (Chandran et al. 2008 & 2010), Kulathupuzha (Robi 2009) and from a relic Myristica swamp at Brahma Karmali of Valpoi Taluka in Goa (Prabhugaonkar et al. 2014). From Tamil Nadu, this species was reported in five sites, viz., Pandiar, Nadugani, Tropical Gene Pool Garden, Kilnadugani and Poonoor forest areas in Nadugani Village of Gudalur Taluk in Nilgiri District (Udhayavani et al. 2013) and Megamalai Wildlife Sanctuary (Karuppusamy & Ravichandran 2016). Udhayavani et al. (2013) also recorded *S. travancoricum* from the Nilgiri District growing in association with species like *Aporosa lindleyana*, *Sterculia guttata*, *Syzygium cumini* and *Litsea coriacea*. The population of *S. travancoricum* has declined considerably mainly because of over exploitation and habitat destruction. A vast stretch of virgin forest is being converted for agriculture purpose and pressure from exotics plants, grazing and forest fire also caused decline in regeneration (Udhayavani et al. 2013). The swampy wetland habitat has been widely drained and converted into paddy fields have also caused the reduction of its population, leading to a critically endangered state (IUCN 2019). The plants are under great threat due to fragmentation of populations, high rate of inbreeding and habitat specificity which accounts for poor regeneration and seed viability (Sujanapal & Kunhikannan 2017; present observation). In this context, a thorough understanding of existing population structure and composition of *S. travancoricum* will be helpful in developing a proper conservation plan.

Material and Methods

The forest areas and sacred groves in Kerala part of the Western Ghats were thoroughly surveyed during 2016, samples were collected and identified using relevant literature (Gamble 1919; Sasidharan 2004). All specimens were deposited at Kerala Forest Research Institute herbarium (KFRI). Several new locations were identified and total number of individuals in a population, site characteristics, important threats, and pattern of regeneration in each site were noted. Moreover, all previous literature available in Kerala part of Western Ghats were also compiled and revisited.

Results

It was found that among newly identified populations in Kerala, except for the population at Kalasamala Sacred grove, others are represented with few isolated, scattered individuals. In this context, we conducted a detailed investigation on Kalasamala population including total enumeration of individuals with detailed vegetation analysis, especially on population structure, species composition and contribution of individuals. This population might be the second largest population represented with mature reproductively viable individuals distributed outside in the protected areas in the state.

Kalasamala is situated at Thrissur District (Figure 1) and the area lies between 11.128^0 N & 76.150^0 E at 30 m above the sea level with an annual average rainfall of over 2,600 mm. The major proportion (77%) of annual rainfall occurs from the south-west monsoon which usually starts in early June and continues until

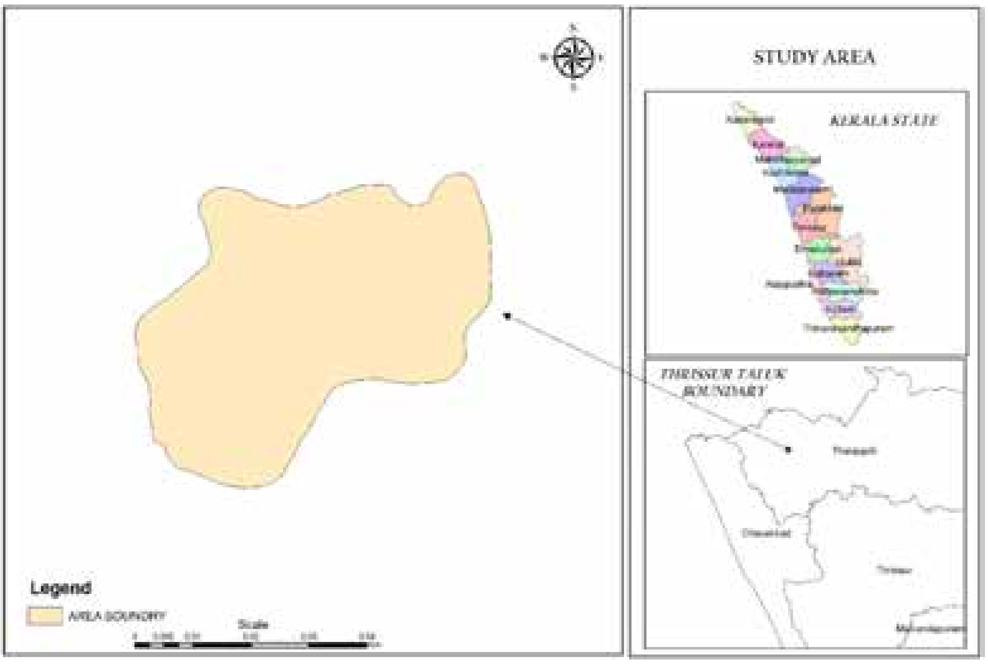


Figure 1. Study area of *Syzygium travancoricum*in Kalasamala Sacred grove.

September. The north-east monsoon starts in October and lasts until the end of November. The mean annual maximum and minimum temperature is 37^0C and 19^0C, respectively. There is a small sacred groove under private ownership in this area with an extent of 3.5 acres of land crammed with an isolated patch of *S. travancoricum*. For getting effective protection measures, the last author initiated legal procedures to declare this as a 'biodiversity heritage site' and the process has almost in completion. Total stem count was carried out for the population with an area of 0.21ha which in turn divided into 21 blocks of 10m × 10m size for enumeration of tree species. All individuals above 10cm GBH (Girth at Breast Height) girth at 1.37m above ground were measured and identified. Population density, frequency, basal area, IVI (Important value index) and girth class distribution were calculated.

Since *S. travancoricum* is a critically endangered species, our survey throughout the Kerala State located six new localities in which five were represented with very small population size (<10 individuals) except for Kalasamala. The results of total enumeration of individuals in Kalasamala population shows presence of 246 stems (>10.1cm) representing in 236 individuals highlights conservation significance of this area (Table 1). This population covers a total area of 0.21ha and results of vegetation structure shows that the vegetation is over dominated by *S. travancoricum* which represent 86.74% of total Important Value Index (Table 1). The basal area of *S. travancoricum* was accounting for $109.37m^2$/ha. The basal area value is higher than the normal value may be due to the presence of more number of higher girth class trees and higher density value. *S. travancoricum* also represents the 100% frequency of distribution (Table 1) and associated species are *Alstonia scholaris*, *Caryota urens*, *Holigarna arnottiana*. In Uttara Kannada (Chandran et al. 2008, 2010), reported the position of *S. travancoricum* in terms of IVI as 17th and the values range from 0.1065 to 0.5483. The mean IVI of 0.3044 is slightly higher than 0.2988, the mean of the IVI recorded

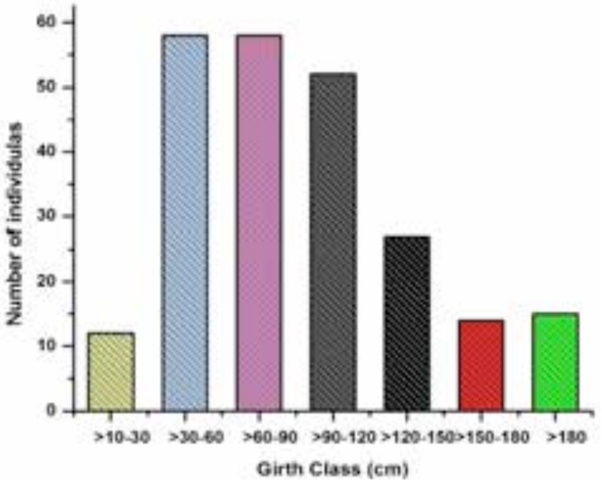


Figure 2. Girth class distribution of *Syzygium travancoricum* population in Kalasamala, Kerala, India.

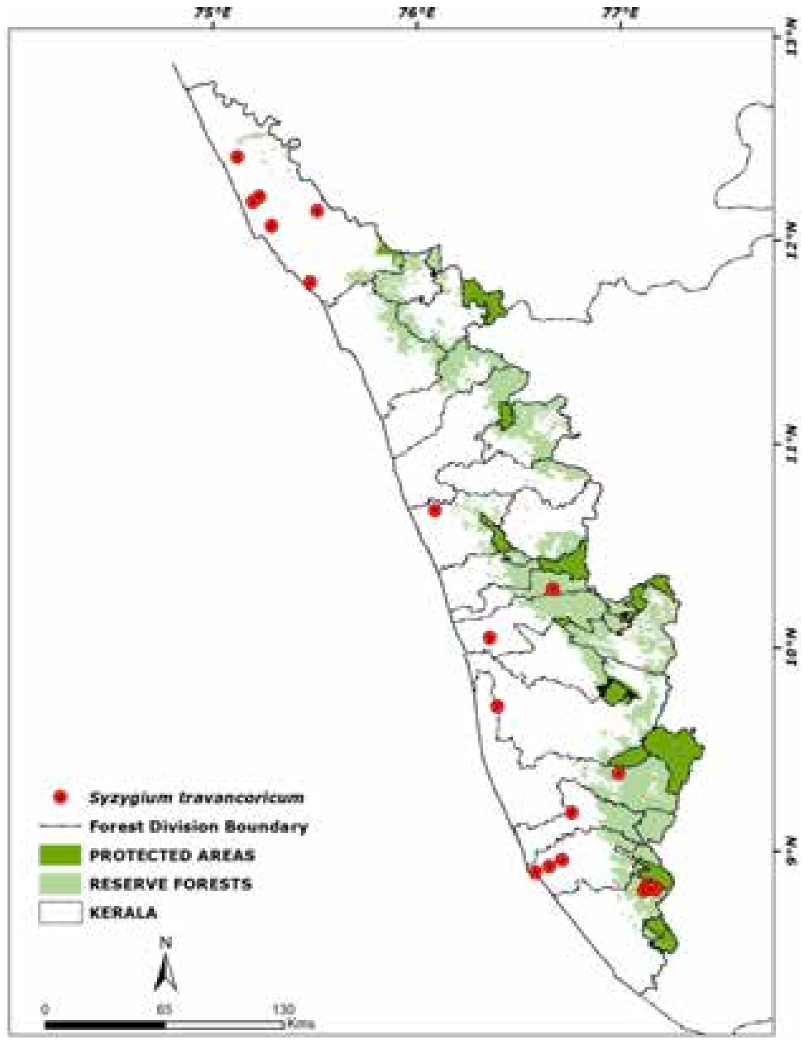


Figure 3. Distribution of *Syzygium travancoricum* in Kerala.

Table 1. Plant species and their contribution to the population dominated by *Syzygium travancoricum* in Kalasamala, Kerala, India.

Species	Basal area m²/ha	Density (Individuals/ ha)	Percentage of Frequency	IVI	Relative IVI
Alstonia scholaris	3.46	14	10	11.20	3.73
Caryota urens	6.48	14	10	13.65	4.55
Holigarna arnottiana	3.17	19	14	14.92	4.98
Syzygium travancoricum	109.37	1171	100	260.23	86.74

from transects in six swamps of southern Kerala. In Uttara Kannada (Chandran et al. 2008), reported that *Aglaia anamallayana*, *Calophyllum apetalum*, *Diospyros paniculata*, *D. pruriens*, *Dipterocarpus indicus*, *Gymnocranthera canarica*, *Holigarna grahamii*, *Hydnocarpus pentandra*, *Hopea ponga*, *Mastixia arborea*, *Myristica fatua* var. *magnifica*, and *Pinanga dicksonii* as the main associates of *S. travancoricum*. Robi (2009) surveyed different swamp patches in Kulathupuzha and counted only 20 trees from 17 transects in six specific swamps like Emponge, Karinkurinji, Marappalam Major, PerumPadappy, PlavuChal, and Pullu Mala. Density was 11 trees/ha and sixth most important position with an IVI of 0.1198 girth class distribution shows that there was less number of individuals in the smaller girth size which means the lowest size class of 10–30cm gbh was less abundant and formed 5.08% of the total density. The highest number of individuals were record in girth

Image 1. A—habit | B—flowering branch; C—inflorescence | D & E—fruiting twigs. (© A–C - M.S. Sanil | D–E - V.B. Sreekumar)

class 30–60 and 60–90 cm gbh which is accounting for 49.14% of the total density and the density of large trees (girth >180cm) was 6.36%. The study on size class distribution in five sites of Nadugani Village (Udhayavani et al. 2013) shows that 37% of mature stems, 50% sub-adults, 13% saplings. Here in the present study, the size

Table 2. Details of existing status *Syzygium travancoricum* reported from forest areas and sacred groves in Kerala.

	Number of individuals	Place	Current status of the population	References
1	236	Kalasamala, Kunnamkulam, Thrissur	Alteration of swampy habitat, moderate regeneration, very low seedling establishment.	Present study
2	2	Konginichal Kavu, Alakkadu, Kannur	No regeneration, poor fruit set	Present study
3	2	Mazhuvancheril Sree Khandakarna Kavu, Vaikom, Kottayam	No regeneration, poor fruit set	Present study
4	2	Paliyerikavu, Kannur	No regeneration, poor fruit set	Present study
5	2	Ponnakkudam Sacred grove, Ernakulum; Kerala	No regeneration, poor fruit set	Present study
6	16	Vazhachal forests, Thrissur; Kerala	No regeneration.	Present study
7	2	Andallur Kavu, Dharmadam Kannur	No regeneration, poor fruit set	Present study
8	5	Pariyaram, Kannur	Habitat modification,	Present study
9	4	Aickad Sacred grove Kodumon, Pathanamthitta	No regeneration and unhealthy trees	IUCN, 2017
10	20	Goodrical, Kerala	Population was not traced	IUCN, 2017
11	153	Emponge, Karinkurinji, Marappalam Major, PerumPadappy, PlavuChal, Pullu Mala and other swampy patches, Kulathupuzha (Kerala)	Habitat modification, moderate regeneration and fruit set.	Robi 2009
12	8	Kuzhumathikkad Chirakkadavu Bhagavathi Temple Sacred grove, Kollam	No regeneration and unhealthy trees	Present study
13	5	Mampuzha Shri Indaliyappan Temple, Kottamkara, Kollam	Invasion of exotics, very low fruit set and regeneration	Present study
14	3	Moonamkadavu Sacred grove, Kasaragod district	Habitat modification	Present study
15	5	Asramam, Kollam	Habitat modification	Present study

class distribution of tree species shows that inadequate or poor regeneration status with most of the trees in medium to large size class and few are young trees (Figure 2) which need to be investigated thoroughly. In Kulathupuzha, the girth class distribution for *S. travancoricum* (Robi 2009) shows reduced number of individuals in the lower girth classes and the graph plotted is an almost perfect 'J' instead of the expected inverted 'J'. Whereas, in the Uttara Kannada sub-population of *S. travancoricum,* graphical representations of girth class distribution return an almost perfect inverted 'J' indicating a healthy regeneration pattern (Chandran et al. 2010). Similarly, the seedlings density reported from the sacred groves of Karnataka (Ray 2011) is 8235.44/ha (Mattigar, Devarabatti Bana), 4549.52/ha (Aralihonda, Kadkod Choudamma Bana) and 52.736/ha (Dugdimane, Choudi Bana), however, in the present study, observation of phenological pattern indicates normal fruiting and seed germination patterns for *S. travancoricum*, whereas germinated seedlings do not survive after the two-leaf seedling stage as other studies (Chandran et al. 2008; Robi 2009) and consider that swamps might be inundated at the time of fruit fall and seed germination. It was also presumed that fungal attack in the intense humid nature of swamp conditions is the major problem of the survival of *S. travancoricum*. In Kalasamala, seedlings are totally absent and the main threat to the population is degradation of swampy habitat due to intense soil erosion from the top hill. Table 2 shows the compilation of number of individuals recorded so far from different localities of Kerala and a total of 465 individuals were counted in which the maximum number of sapling density was found in Kalasamala followed by Myristica patches of Kulathupuzha. Figure 3 shows that the current distribution locations of *S. travancoricum* in Kerala region. As a part of this study, we could revisit all populations reported by the previous authors (Table 2), except the population in Goodrical which is not traceable. In most cases, alteration of swampy habitat is the major factor for poor seedling establishment which gradually result in declining total number of the individuals.

In conclusion, disjunct distribution pattern, alteration of habitats, changes in landuse pattern and poor fruit set affected the distribution pattern of *S. travancoricum*. In Kalasamala, the swampy habitat of this species has altered due to deposition of silt and waste as a result of construction activities and other human interventions. The State Biodiversity Board has already taken urgent steps to declare this site as 'heritage site', and to support the temple management for protection of this highly threatened species. As a first step towards eco-restoration programmes, Kerala Forest Research Institute (KFRI) has raised sufficient seedlings, around

100 seedlings were restored at Kalasamala initially and planning to restore 2,000 seedlings in different sites of sacred groves involving officials of concerned panchayat, temple management, students as well as through public support.

REFERENCES

Bourdillon, T.F. (1908). *The Forest Trees of Travancore.* The Travancore Government Press, Trivandrum, xxxii+456pp.

Byng, W.J., P.G. Wilson & N. Snow (2015). Typifications and nomenclatural notes on Indian Myrtaceae. *Phytotaxa* 2: 101–116.

Chandran, M.D.S., D.K. Mesta, G.R. Rao,S. Ali, K.V. Gururaja & T.V. Ramachandra (2008). Discovery of Two Critically Endangered Tree Species and Issues Related to Relic Forests of the Western Ghats. *The Open Conservation Biology Journal* 2: 1–8. https://doi.org/10.2174/1874839200802010001

Chandran, M.D.S., G.R. Rao, K.V. Gururaja & T.V. Ramachandra (2010). Ecology of the swampy relic forests of Kathalekan from central Western Ghats, India. *Bioremediation, Biodiversity and Bioavailability, Global Science Books* 4: 54–68.

Gamble, J.S. (1919). *Flora of the Presidency of Madras,* Adlard and Son, Ltd., London, 480pp. https://doi.org/10.5962/bhl.title.21628

Govaerts, R.H.A., M. Sobral, P. Ashton, F.R. Barrie, B.K. Holst, L. Landrum, K. Mastsumoto, F.F. Mazine, E.M.N. Lughadha, C.E.B. Proenca, L.H. Soares-Silva, P.G. Wilson & E. Lucas (2008). World Checklist of *Myrtaceae,* Royal Botanic Gardens, Kew, London. Assessed on 03 April 2019. http:// apps.kew.org/wcsp.

IUCN (2017). *The IUCN Red List of Threatened Species.* Version 2. Downloaded on 05 May 2018.

IUCN (2019). *The IUCN Red List of Threatened Species*. Version 2019-2. Downloaded on 11 May 2020.

Karuppusamy, S. & V. Ravichandran (2016). Diversity Assessment of Woody Plants of Megamalai Wildlife Sanctuary, Theni District, Tamil Nadu. *Bio Bulletin*2: 74–89.

Nair, N.C. & C.N. Mohanan (1981). On the rediscovery of four threatened species from the sacred groves of Kerala. *Journal of Economic and Taxonomic Botany* 2: 233–235.

Parnell, J.A.N., L.A. Craven & E. Biffin (2007). Matters of scale: Dealing with one of the largest genera of angiosperms, pp. 251-274. In: Hodkinson, T. & J. Parnell (eds.). *Reconstructing the Tree of Life, Taxonomy and Systematics of Species Rich Taxa*. Boca Raton, FL. Taylor & Francis, 368pp. https://doi.org/10.1201/9781420009538

Prabhugaonkar, A., D.K. Mesta & M.K. Janarthanam (2014). First report of three red-listed tree species from swampy relics of Goa State, India. *Journal of Threatened Taxa* 6(2): 5503–5506. https://doi.org/10.11609/JoTT.o3376.5503-6

Ray, R. (2011). *Developing Strategies for Conservation of Threatened Endemic Biodiversity of the Sacred Groves of central Western Ghats Project report*. Centre for Ecological Sciences, Indian Institute of Science, Bangalore.

Robi, T.J. (2009). Floristic structure and diversity of Myristica swamps at Kulathupuzha in a GIS perspective. Dehradun University, viii+148pp.

Sasidharan, N. (2004). *Biodiversity Documentation for Kerala Part 6: Flowering Plants.* Kerala Forest Research Institute, Peechi, 702pp.

Sujanapal, P. & C. Kunhikannan (2017). The Genus *Syzygium* in Western Ghats. In: Nair, K.N. (ed.).*The Genus Syzygium: Syzygiumcuminiand Other Underutilized Species*. Taylor & Francis, Boca Raton, FL, 288pp. https://doi.org/10.1201/9781315118772

Udhayavani, C., V.S. Ramachandran & H.A. John (2013). Ecology and population study on *Syzygium travancoricum* Gamble (Myrtaceae) - A critically endangered species from Nilgiris. *NeBIO* 4: 68–71.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17347–17360

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

DOI: https://doi.org/10.11609/jott.5142.12.17.17347-17360

#5142 | Received 02 June 2019 | Final received 25 September 2020 | Finally accepted 20 November 2020

Butterflies (Lepidoptera: Rhopalocera) of the undivided Midnapore District, West Bengal, India: a preliminary report

Anirban Mahata [1], **Niladri Prasad Mishra** [2] & **Sharat Kumar Palita** [3]

[1,3] Department of Biodiversity and Conservation of Natural Resources, Central University of Odisha, Koraput, Odisha 764021, India.
[2] PG Department of Zoology, Tamralipta Mahavidyalaya, Tamluk, Purba Medinipur, West Bengal 721636, India.
[1] anirbanmahata1608@gmail.com, [2] prasadmishra.niladri@gmail.com, [3] skpalita@gmail.com (corresponding author)

Abstract: A butterfly study in the biodiversity rich biogeography transition zone of the undivided Midnapore District of West Bengal was carried out from March 2014 to March 2017. A total of 98 species of butterflies under five families, 19 subfamilies, and 70 genera were documented by the study. Maximum species diversity was found in Nymphalidae family with 31 species (31.63%), followed by Lycaenidae 24 species (24.48%), Hesperiidae-17 (17.34%), Pieridae 16 (16.32%), and the least by Papilionidae 10 (10.28%). Among the families, the highest common species (n=10) was recorded under the family Nymphalidae and maximum rare species (n=4) under the family Lycaenidae. Highest species richness has been recorded in post-monsoon season (97 species) followed by monsoon (78 species), winter (66 species), and pre-monsoon (47 species). During the study, five species of butterflies (*Castalius rosimon*, *Neptis jumbah*, *Discophora sondaica*, *Lethe europa*, and *Papilio clytia*) under Schedule-I, three species (*Euchrysops cnejus*, *Mahathala ameria*, and *Cepora nerissa*) under Schedule-II and three species (*Baoris farri*, *Hyarotis adrastus*, and *Euploea core*) under Schedule-IV were legally protected under the Indian Wildlife (Protection) Act, 1972. A good species to genera ratio (1.4: 1) along with 10 newly recorded species and their range extension provide information for better understanding of the ecology and distribution pattern of the butterfly fauna. The information of the study will thus help to develop conservation strategies for management of the unique bio-geographical transitional zone.

Keywords: Checklist, new records, species diversity, seasonality, biogeography transition zone.

Butterflies are highly sensitive to changes in the environment (Landres et al. 1988; Simberloff 1988), act as ecological indicators (New 1991; Pollard & Yates 1993; Thomas 2005; Bonebrake et al. 2010), and serve as surrogate species for floral and faunal diversity (Ehrlich & Raven 1964) by improving community structure. Further, they are primary consumers in forest ecosystems (Rosenberg et al. 1986) and their diversity increases with an increase in habitat scale and vegetation structure complex (Price 1975). Therefore, the conservation of butterflies is necessary to understand their natural history and ecology for the maintenance of ecosystem health.

Transition zones are defined as the boundaries between biogeographical regions, which represent areas of biotic overlap, and being favoured by ecological and historical changes allow a combination of taxa belonging to various biotic components (Morrone 2004). As the boundaries between these regions are areas of high biotic interaction (Ruggiero & Ezcurra 2003), with increased richness and abundance as well as unique ecotonal species (Odum 1953), they deserve special attention. The undivided Midnapore District of West Bengal which lies in the transition zone of three distinct biogeographic regions of India (Deccan Peninsula: Chotta-Nagpur biotic province, Gangetic Plains: Lower Gangetic Plain biotic province, and Coast: Eastern Coastal biotic province) makes it a perfect habitat for species diversity (Payra et

Editor: Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic. **Date of publication:** 26 December 2020 (online & print)

Citation: Mahata, A., N.P. Mishra & S.K. Palita (2020). Butterflies (Lepidoptera: Rhopalocera) of the undivided Midnapore District, West Bengal, India: a preliminary report. *Journal of Threatened Taxa* 12(17): 17347–17360. https://doi.org/10.11609/jott.5142.12.17.17347-17360

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to the Head, Department of Biodiversity and Conservation of Natural Resources, Central University of Odisha, Koraput, Odisha for support and encouragement.

al. 2017; Samanta et al. 2017; Paria et al. 2018; Biswas et al. 2019) and acts as a connecting path of species distribution and migration from Western Ghats zone to northeastern zone (Abdulali 1949; Ali 1949; Hora 1949). Dry peninsular Sal forest and dry deciduous scrub vegetation along with different orchard plantation and agriculture practices in this region act as refuges for butterflies (Mahata et al. 2019).

Limited studies have been carried out on butterfly fauna in the undivided Midnapore District, and previous records from the region include the report of 112 species from the coastal area of Purba Medinipur (Payra et al. 2017) and 82 species from Midnapore Municipality area of West Midnapore District (Biswas et al. 2019) and remaining part was untouched. The present study aims to document butterflies in the undivided Midnapore district and prepare a checklist along with habitat ecology and management status for undertaking proper conservation action in near future.

MATERIALS AND METHODS

Study sites

The study was conducted at undivided Midnapore district (22.953°–21.610° N & 88.211°–86.564° E) of West Bengal, India. The undivided Midnapore district is now divided into three districts (Purba Medinipur, Paschim Medinipur, and Jhargram) and covers an area of 14,081km^2. Of which 2,971km^2 is under forest cover contributing 3.35% of the total geographical area of the state (FSI 2017). This region covers northern dry mixed deciduous forest of Chotta-Nagpur Plateau ecozone, Eastern Highlands moist deciduous forests of the eastern part of Eastern Ghats along with dry peninsular Sal Forest, and deciduous scrub forest of Lower Gangetic Plain and saltwater mixed forest (Champion & Seth 1968; Figure 1). The topography of this region is highly variable from undulating southwestern region to Gangetic Plains and wetlands towards the eastern side. This undivided Midnapore District is characterized by

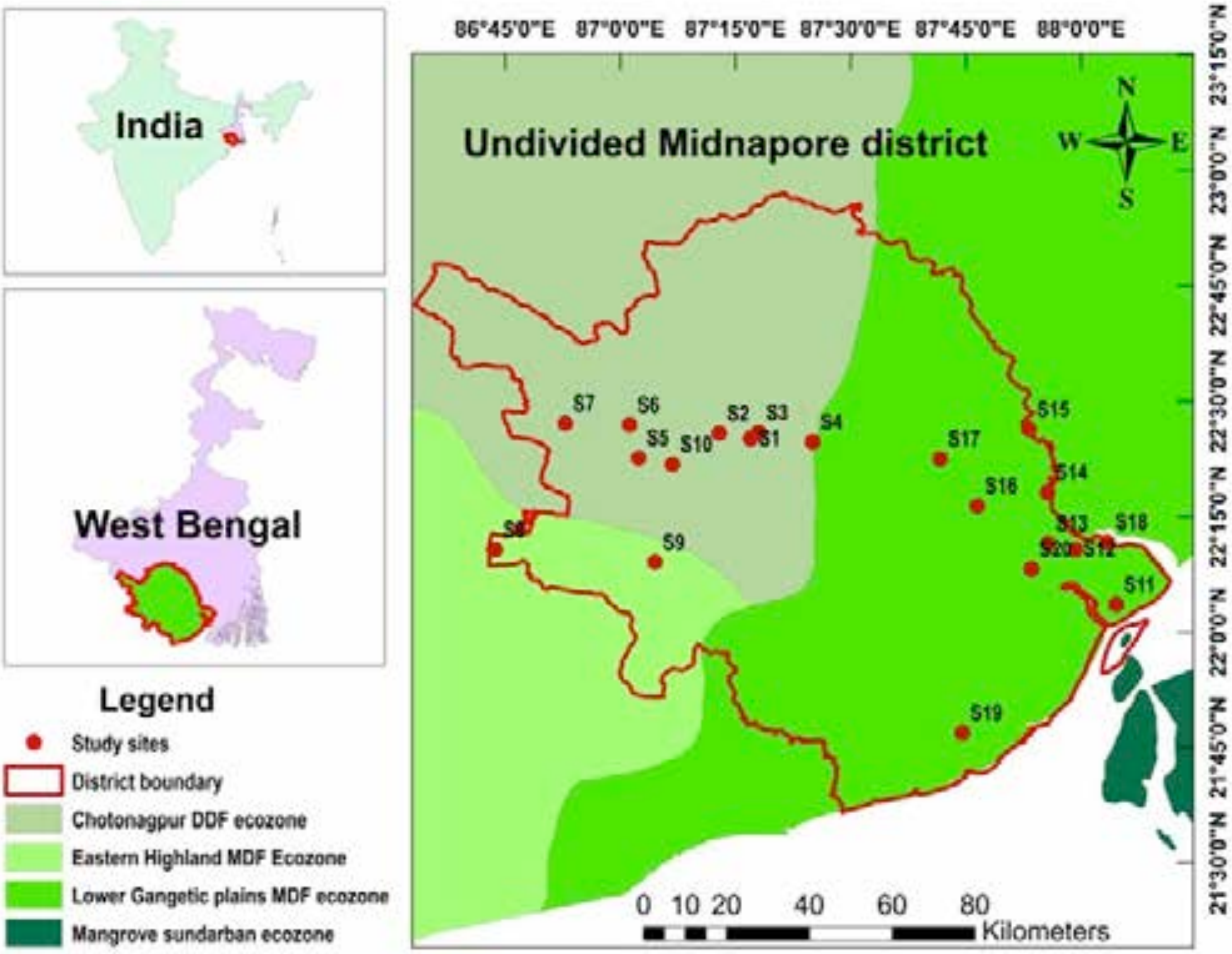


Figure 1. The map of study sites in undivided Midnapore District, West Bengal, India (DDF- Dry Deciduous Forest, MDF- Moist Deciduous Forest)

a variety of soil ranging from lateritic red soil towards the western region, alluvial along the rivers and sandy saline soil in the coastal belt. The average temperature in this region lies in between 10°C and 39°C with average annual precipitation of 1,752mm (Anonymous 2011a, b). The climate is characterized by tropical hot summer, cold winter, abundant rainfall and humidity in monsoon. Floods are quite regular in monsoon (Anonymous 2011a,b). A total of 20 different sites have been surveyed on the basis of different vegetation patterns to document the butterfly fauna. Elevations of these sites vary between 2–90 m (Table 1).

Data collection

The study was carried out over a period of three years during March 2014 to March 2017 in four distinct seasons: pre-monsoon (March to May), monsoon (June to August), post-monsoon (September to November), and winter (December to February). We adopted opportunistic sampling methods by walking through trails and recorded the species visually by using close focusing binocular (Olympus WP II, Olympus Corporation, Japan). Butterfly sampling was carried out only in good weather conditions (>10°C, <18 miles/hour wind speed and no rain) from 09.00 to 13.00 h. Butterflies were identified in the field with the help of field guides (Wynter-Blyth 1957; Kunte 2000; Kehimkar 2008). Butterflies which could not be identified in flight, were caught with butterfly-net, identified and then released safely. Photograph of the documented species was taken during the survey with the help of a DSLR camera (Nikon D5300 with Nikon 70–300 mm lens, Nikon Corporation, Japan) for further confirmations. Taxonomy and species names of butterflies were followed after Varshney & Smetacek (2015). A checklist of butterfly fauna was prepared along with their legal protection status. The status of a butterfly was decided based on the frequency of sighting of the butterfly during the total study period. Status of the butterfly was categorized under five categories: rare (R), not rare (NR), not common (NC), common (C), and very common (C). Butterflies having <20 % sightings were marked as rare butterflies, 20–40 % not rare, 40–60 % not common, 60–80 % common, and >80% very common (Payra et al. 2017; Samanta et al. 2017).

RESULTS AND DISCUSSION

A total of 98 species of butterflies under five families, 19 subfamilies and 70 genera were documented from the study area (Table 2, Image 1, 2, 3, 4 & 5). Maximum species richness was observed in the family Nymphalidae with 31 species (31.63%), followed by Lycaenidae 24 species (24.48%), Hesperiidae 17 species (17.34%), Pieridae 16 species (16.32%), and least by Papilionidae 10 species (10.20%) (Table 2). The Nymphalidae family was very common in occurrence (10 species) whereas the maximum number of rare species were found in the Lycaenidae family (four species) (Table 2, Figure 3). Highest species richness was recorded in post-monsoon season (97 species), followed by monsoon (78 species), winter (66 species) and pre-monsoon (47 species) (Figure 4). Among the species recorded, 11 species are under schedule category of Indian Wildlife (Protection) Act 1972. Under Schedule-I, there are five species (*Castalius rosimon*, *Neptis jumbah*, *Discophora sondaica*, *Lethe europa*, and *Papilio clytia*), under Schedule-II, three species (*Euchrysops cnejus*, *Mahathala ameria*, and *Cepora nerissa*) and under Schedule-IV three species (*Baoris farri*, *Hyarotis adrastus*, and *Euploea core*) (Table 2). Five species are placed under Least Concern (LC) category and the rest 93 species are not assessed (IUCN 2020) (Table 2, Image 1, 2, 3, 4 & 5).

Among the recorded 17 species of Hesperiidae (Image 1), *Ampittia dioscorides* was very common, whereas *Badamia exclamationis* and *Matapa aria* were rare. *Baoris farri* and *Pelopidas subochracea* were recorded for the first time from the region. Among 24 species of Lycaenidae family (Image 2), *Arhopala atrax*, *Iraota timoleon*, *Mahathala ameria*, *Rathinda amor*, and *Virachola isocrates* were found to be rare. *Zizina otis* and *Arhopala atrax* were recorded for the first time from this region. *Iraota timoleon* and *Rathinda amor* were recorded only during post monsoon period. Out of 31 species recoded under Nymphalidae (Image 3), *Ariadne ariadne*, *A. merione*, *Danaus chrysippus*, *Danaus genutia*, *Euploea core*, *Acraea violae*, *Phalanta phalantha*, *Junonia almana*, *J. iphita*, and *J. lemonias* were very common whereas *Tirumala septentrionis* and *Discophora sondaica* were rare and *T. septentrionis*, *Phaedyma columella*, and *Ypthima baldus* were recorded for the first time from this region. Among 10 species under Papilionidae family (Image 4), *Papilio demoleus* was very common, whereas *Papilio crino* was rare and *Graphium nomius* was newly recorded from this region. Out of 16 species under Pieridae family (Image 5), *Delias eucharis* was very common and two species (*Eurema laeta* and *E. sari*) were recorded for the first time from undivided Midnapore region (Table 2, 3).

In our study, the presence of *Symphaedra nais*, *Danaus melanippus indicusand* and *Ypthima baldus* showed the species range extension from central India towards eastern India. Our study also recorded several Eastern Ghats species such as *Pseudozizeeria maha*,

Table 1. Location and Habitat conditions of the study sites.

Site No.	Site name	GPS Location	Elevation (m)	Habitat type	Vegetation type (dominant)	Management status
1	Gopegarh Eco-park (S1)	22.419°N 87.283°E	52.43	Managed park surrounded by natural vegetation	Non-native flowering plants and *Anacardium occidentale*	Managed by park authority, no grazing
2	Gurguripal Eco-park (S2)	22.430°N 87.215°E	48.77	Degraded park with natural vegetation	*Shorea robusta* and *Eucalyptus tereticornis*	Moderately anthropogenic activity, no grazing
3	VU Campus, Midnapore (S3)	22.432°N 87.299°E	58.22	Natural vegetation surrounded by Non-native flowering plants	*Anacardium occidentale* and *Eucalyptus tereticornis*	Least management, no grazing
4	Pathra (S4)	22.412°N 87.418°E	33.18	Natural rural vegetation with agriculture field	*Eucalyptus tereticornis, Bambusa* spp.	Grazing along with high human interference
5	Amlachati Vesaj Udyan (S5)	22.377°N 87.039°E	89	Managed herbal garden surrounded by sal forest.	Medicinal plants and *Shorea robusta*	Highly managed, no grazing
6	Jhargram Mini Zoo (S6)	22.449°N 87.020°E	81.38	Managed mini zoo in sal forest	*Shorea robusta*	Managed, no grazing
7	Chilkigarh (S7)	22.451°N 86.881°E	73.85	Rural area	*Shorea robusta*	Moderate grazing with anthropogenic activity
8	Jhilli Pakhiralaya (S8)	22.179°N 86.729°E	66.45	Forest area along marshy water body	*Shorea robusta*	No management, moderate grazing with anthropogenic activity
9	Kodopal fruit garden (S9)	22.151°N 87.075°E	35.66	Fruit orchards along with ornamental flowering plant	*Mangifera indica, Psidium guajava, Citrus* spp., *Zizyphus vulgaris*	Managed. No grazing and anthropogenic activity
10	Banantika (S10)	22.363°N 87.113°E	79.55	Fruit orchards	*Mangifera indica, Psidium guajava, Phyllanthus emblica*	Poorly managed. grazing and anthropogenic activities limited
11	Haldia (S11)	22.059°N 88.077°E	07.32	Park Garden	Ornamental flowering plants	Managed park
12	Mahishadal (S12)	22.178°N 87.988°E	06.10	Shrub land with natural fruit orchards	*Mangifera indica*	Rural area, No management
13	Nandakumar (S13)	22.192°N 87.928°E	04.87	Shrub land beside rail tracks	*Lantana camara*	No management
14	Tamluk (S14)	22.302°N 87.927°E	06.10	Natural Vegetation	Ornamental flowering plants	Urban area, no management
15	Kolaghat (S15)	22.439°N 87.887°E	09.45	Shrub land and agriculture land	*Hibiscus rosa-sinensis, Tabernaemontana divaricate*	Rural area, less grazing and anthropogenic activity
16	Moyna (S16)	22.273°N 87.775°E	04.57	Bogs and Marshy area	Grass and *Eucalyptus tereticornis*	Rural area, less grazing and anthropogenic activity
17	Khirai (S17)	22.375°N 87.694°E	06.10	Riverside agriculture land	*Oryza sativa, Tagetes* spp.	Rural area, less grazing and anthropogenic activity
18	Geonkhali (S18)	22.195°N 88.057°E	02.13	Riverside Park	Natural shrub and ornamental flower	Rural park, less management
19	Contai (S19)	21.782°N 87.742°E	07.32	Shrub land and agricultural fields	*Lantana Camara* and *Oryza sativa*	Rural area, less grazing and anthropogenic activity
20	Narghat (S20)	22.137°N 87.892°E	06.10	Riverside semi urban park	*Casuarina equisetifolia*	Semi urban area, less grazing and anthropogenic activity

Anthropogenic Activities (AA) are based upon number of human encounters and grazing seen during 30 minutes transect walk.
Least: 0–1 time, moderately AA: 3–4 times, highly AA: 8–10 times encounter

Junonia orithya, *Catopsilia pyranthe*, *Cepora nerissa*, *Spindasis vulcanus*, *Papilio demoleus*, *Arhopala atrax*, *Tarucus nara*, *Papilio hector*, and *Graphium nomius*. The study further revealed the presence of *Papilio crino* known from northeastern India as as well as species such as *Colotis amata*, *Catopsilia pomona*, *Catopsilia pyranthe*, *Cepora nerissa*, *Danaus chrysippus*, *Tirumala limniace*, *Zizeeria karsandra*, and *Catochrysops strabo* known from northwestern India (Kehimkar 2008). This species checklist represents the species distribution information for better understanding the butterfly fauna and making conservation strategies for similar biogeographical ecozones.

CONCLUSION

The present study provides a checklist of butterfly fauna in a biogeographically transitional region of undivided Midnapore District; the first attempt at a relatively larger scale documentation of butterflies of this region. A record of 98 species of butterfly along

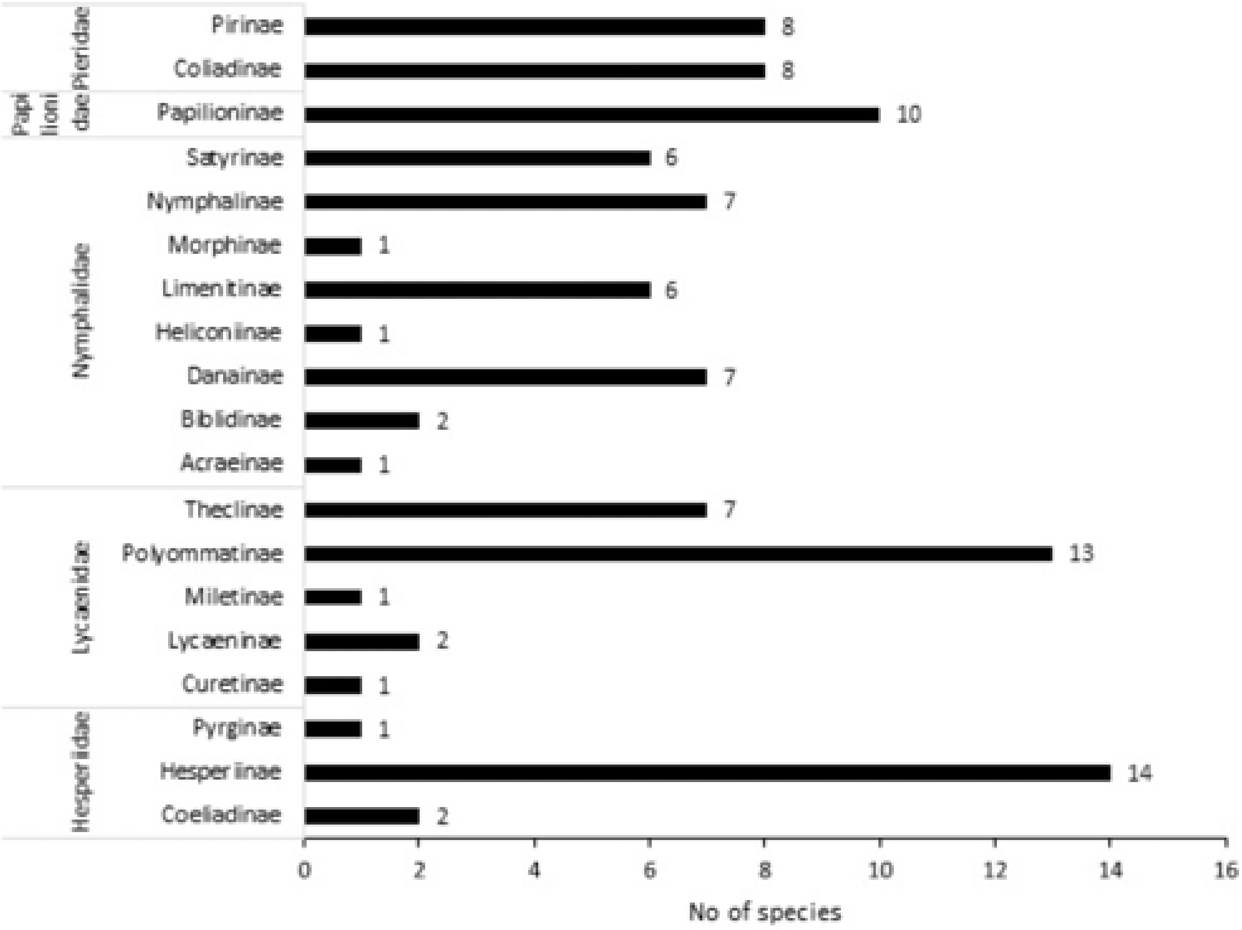


Figure 2. Subfamily wise recorded butterfly species in study sites.

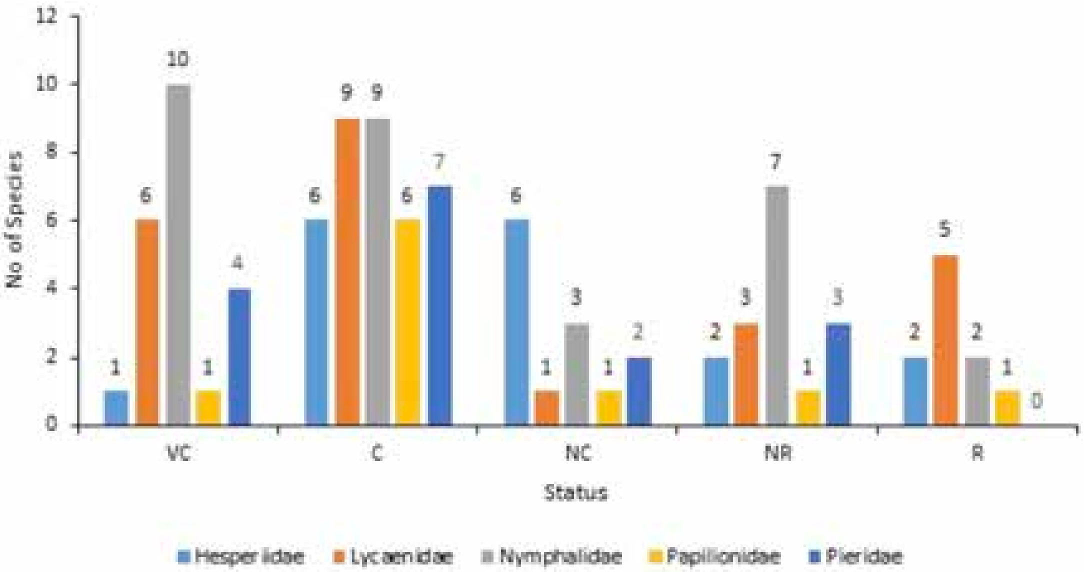


Figure 3. Status of butterfly in the study: VC—Very Common | C—Common | NC—Not common | NR—Not Rare | R—Rare.

Table 2. Checklist of butterfly fauna recorded in the study.

	Scientific name	Common name	Status	Flight period	IUCN/IW(P)A
Family Hesperiidae					
Subfamily Coeliadinae					
1	*Badamia exclamationis* (Fabricius, 1775)	Brown Awl	R	2, 3	NE
2	*Hasora chromus* (Cramer, [1780])	Common Banded Awl	NR	1, 2, 3,4	NE
Subfamily Hesperiinae					
3	*Suastus gremius* (Fabricius, 1798)	Indian Palm Bob	C	1,3	NE
4	*Ampittia dioscorides* (Fabricius, 1793)	Bush Hopper	VC	3,4	NE
5	*Baoris farri* (Moore, 1878)*	Paintbrush Swift	NC	2,3,4	NE/ Sch IV
6	*Borbo cinnara* (Wallace, 1866)	Rice Swift	NC	2,3,4	NE
7	*Erionota thrax* (Linnaeus, 1767)	Palm Redeye	NR	2,3	NE
8	*Hyarotis adrastus* (Stoll, [1780])	Tree Flitter	NC	1,3	NE/ Sch IV
9	*Iambrix salsala* (Moore, [1866])	Chestnut Bob	C	1, 2, 3, 4	NE
10	*Matapa aria* (Moore, [1866])	Common Redeye	R	1, 4	NE
11	*Parnara guttatus* (Bremer & Grey, [1852])	Straight Swift	NC	2,3,4	NE
12	*Pelopidas subochracea (Moore, 1878)**	Moore's Swift	C	1,2,3,4	NE
13	*Pelopidas thrax* (Huebner, [1821])	Small Branded Swift	C	2,3,4	NE
14	*Telicota colon* (Fabricius, 1775)	Common Palm Dart	NC	2,3,4	NE
15	*Telicota bambusae* (Moore, 1878)	Dark Palm Dart	C	3,4	NE
16	*Udaspes folus* (Cramer, [1775])	Grass Demon	NC	2,3,4	NE
Subfamily Pyrginae					
17	*Spialia galba* (Fabricius, 1793)	Indian Skipper	C	1,2,3,4	NE
Family Lycaenidae					
Subfamily Curetinae					
18	*Curetis thetis* (Drury,1773)	Indian Sunbeam	C	3,4	NE
Subfamily Lycaeninae					
19	*Pseudozizeeria maha* (Kollar, [1844])	Pale Grass Blue	VC	1,2,3,4	NE
20	*Zizina otis* (Fabricius, 1787)*	Lesser Grass Blue	VC	1,2,3,4	NE
Subfamily Miletinae					
21	*Spalgis epius* (Westwood, 1852)	Common Apefly	NR	2, 3	NE
	Subfamily Polyommatinae				NE
22	*Anthene emolus* (Godart, 1824)	Common Ciliate Blue	C	2,3,4	NE
23	*Castalius rosimon* (Fabricius, 1775)	Common Pierrot	VC	1, 2, 3	NE/ Sch I (Part IV)
24	*Catochrysops strabo* (Fabricius, 1793)	Forgetmenot	C	1,2,3,4	NE
25	*Chilades lajus* (Stoll, [1780])	Lime Blue	C	2,3,4	NE
26	*Euchrysops cnejus* (Fabricius,1798)	Gram Blue	NR	2,3,4	NE/ Sch II (Part II)
27	*Jamides bochus* (Stoll, [1782])	Dark Cerulean	C	1,2,3,4	NE
28	*Jamides celeno* (Cramer, [1775])	Common Cerulean	C	3,4	NE
29	*Luthrodes pandava* (Horsfield, [1829])	Plains Cupid	VC	1.2.3.4	NE
30	*Neopithecops zalmora* (Butler, 1870)	Quaker	VC	2,3,4	NE
31	*Prosotas dubiosa* (Semper, [1879])	Tailless Lineblue	C	1,2,3	NE
32	*Tarucus nara* (Kollar, 1848)	Striped/ Rounded Pierrot	C	2,3,4	NE

	Scientific name	Common name	Status	Flight period	IUCN/IW(P)A
33	*Zizeeria karsandra* (Moore, 1865)	Dark Grass Blue	C	1,2,3,4	NE
34	*Zizula hylax* (Fabricius, 1775)	Tiny Grass Blue	VC	1,2,3,4	NE
Subfamily Theclinae					
35	*Arhopala atrax* (Hewitson, 1862)*	Indian Oakblue	R	2,3	NE
36	*Iraota timoleon* (Stoll, [1790])	Silverstreak Blue	R	3	NE
37	*Mahathala ameria* (Hewitson, 1862)	Falcate Oakblue	R	3	NE/ Sch II (Part II)
38	*Rapala manea* (Hewitson, 1863)	Slate Flash	NR	2,3	NE
39	*Rathinda amor* (Fabricius, 1775)	Monkey Puzzle	R	3	NE
40	*Spindasis vulcanus* (Fabricius, 1775)	Common Silverline	NC	2, 3	NE
41	*Virachola isocrates* (Fabricius, 1793)	Common Guava Blue	R	1, 3, 4	NE
Family Nymphalidae					
Subfamily Biblidinae					
42	*Ariadne* (Linnaeus, 1763)	Angled Castor	VC	1, 2,3,4	NE
43	*Ariadne merione* (Cramer, [1777])	Common Castor	VC	1, 2,3, 4	NE
	Subfamily Danainae				NE
44	*Danaus chrysippus* (Linnaeus, 1758)	Plain Tiger	VC	1,2,3,4	NE
45	*Danaus genutia* (Cramer, [1779])	Common Tiger/ Striped Tiger	VC	1,2,3,4	NE
46	*Danaus melanippus indicus* (Fruhstorfer, 1899)	White Tiger	C	2,3,4	NE
47	*Euploea core* (Cramer, [1780])	Common Crow	VC	1, 2,3, 4	LC/Sch IV
48	*Euploea klugii* kollari (C. & R. Felder, 1865)	King Crow	C	3,4	NE
49	*Tirumala limniace* (Cramer, [1775])	Blue Tiger	NC	1, 2, 3	NE
50	*Tirumala septentrionis* (Butler, 1874)*	Dark Blue Tiger	R	2,3	NE
Subfamily Acraeinae					
51	*Acraea violae* (Fabricius, 1793)	Tawny Coster	VC	1, 2, 3,4	NE
Subfamily Heliconiinae					
52	*Phalanta phalantha* (Drury, [1773])	Common Leopard	VC	1, 2,3, 4	NE
Subfamily Limenitinae					
53	*Euthalia aconthea* (Cramer, [1777])	Common Baron	NR	2, 3	NE
54	*Moduza procris* (Cramer, [1777])	Commander	C	2, 3	NE
55	*Neptis hylas* (Linnaeus, 1758)	Common Sailer	C	2, 3, 4	NE
56	*Neptis jumbah* Moore, [1858]	Chestnut-streaked Sailer	NR	2, 3	NE/ Sch I (Part IV)
57	*Phaedyma columella* (Cramer, [1780])*	Short-banded Sailer	NC	2,3,4	NE
58	*Symphaedra nais* (Forster, 1771)	Baronet	C	1, 2, 3	NE
Subfamily Morphinae					
59	*Discophora sondaica* Boisduval, 1836	Common Duffer	R	3	NE/ Sch I (Part IV)
Subfamily Nymphalinae					
60	*Hypolimnas bolina* (Linnaeus, 1758)	Great Eggfly	c	1,2,3,4	NE
61	*Junonia almana* (Linnaeus, 1758)	Peacock Pansy	VC	2,3,4	LC
62	*Junonia atlites* (Linnaeus, 1763)	Grey Pansy	c	2,3,4	NE
63	*Junonia hierta* (Fabricius, 1798)	Yellow Pansy	NC	2,3	LC
64	*Junonia iphita* (Cramer, [1779])	Chocolate Pansy	VC	1, 2, 3, 4	NE
65	*Junonia lemonias* (Linnaeus, 1758)	Lemon Pansy	VC	1,2,3,4	NE
66	*Junonia orithya* (Linnaeus, 1758)	Blue Pansy	NR	2, 3	NE

	Scientific name	Common name	Status	Flight period	IUCN/IW(P)A
Subfamily Satyrinae					
67	*Elymnias hypermnestra* (Linnaeus, 1763)	Common Palmfly	NR	2, 3, 4	NE
68	*Lethe europa* (Fabricius, 1775)	Bamboo Treebrown	NR	3,4	NE/Sch I (Part IV)
69	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	C	**1, 2, 3, 4**	NE
70	*Mycalesis perseus* (Fabricius, 1775)	Common Bush Brown	NR	2,3,4	NE
71	*Ypthima baldus* (Fabricius, 1775)*	Common Fivering	NR	2, 3, 4	NE
72	*Ypthima huebneri* Kirby, 1871	Common Fourring	C	1,2,3,4	NE
Family Papilionidae					
Subfamily Papilioninae					
73	*Graphium agamemnon* (Linnaeus, 1758)	Tailed Jay	C	1,2,3	NE
74	*Graphium doson* (C. & R. Felder, 1864)	Common Jay	C	1, 2, 3	NE
75	*Graphium nomius* (Esper, 1799)*	Spot Swordtail	C	1,2,3	NE
76	*Pachliopta aristolochiae* (Fabricius, 1775)	Common Rose	C	1, 2, 3, 4	NE
77	*Papilio clytia* Linnaeus, 1758	Common Mime	C	2, 3	NE/Sch I (Part IV)
78	*Papilio crino* Fabricius, 1793	Common Banded Peacock	R	3, 4	NE
79	*Papilio demoleus* Linnaeus, 1758	Lime Butterfly	VC	1,2,3,4	NE
80	*Papilio hector* (Linnaeus, 1758)	Crimson Rose	NR	1,2,3,4	NE
81	*Papilio polymnestor* Cramer, [1775]	Blue Mormon	NC	2,3,4	NE
82	*Papilio polytes* Linnaeus, 1758	Common Mormon	C	2, 3, 4	NE
Family Pieridae					
Subfamily Coliadinae					
83	*Catopsilia pomona* (Fabricius, 1775)	Common Emigrant	C	1, 2, 3, 4	NE
84	*Catopsilia pyranthe* (Linnaeus, 1758)	Mottled Emigrant	VC	1,2,3,4	NE
85	*Eurema andersoni* Moore, 1886	One-spot Grass Yellow	C	1,2,3,4	LC
86	*Eurema blanda* (Boisduval, 1836)	Three-spot Grass Yellow	VC	1,2,3,4	NE
87	*Eurema brigitta* (Stoll, [1780])	Small Grass Yellow	VC	1,2,3,4	LC
88	*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow	C	2, 3, 4	NE
89	*Eurema laeta* (Boisduval, 1836)*	Spotless Grass Yellow	C	1,2,3,4	NE
90	*Eurema sari* (Horsfield)*	Chocolate Grass Yellow	C	2, 3, 4	NE
Subfamily Pirinae					
91	*Appias libythea olferna* (Swinhoe, 1890)	Striped Albatross	NR	2,3	NE
92	*Cepora nerissa* (Fabricius, 1775)	Common Gull	C	2, 3	NE/Sch II (Part II)
93	*Colotis amata* (Cramer, 1775)	Small Salmon Arab	NC	1,2,4	NE
94	*Delias eucharis* (Drury, 1773)	Common Jezebel	VC	1, 2, 3, 4	NE
95	*Ixias pyrene* (Linnaeus, 1764)	Yellow Orange Tip	NC	1,2,3	NE
96	*Leptosia nina* (Fabricius, 1793)	Psyche	C	1,2,4	NE
97	*Pareronia valeria* (Cramer, [1776])	Common Wanderer	NR	2,3	NE
98	*Pieris canidia* (Linnaeus, 1768)	Indian Cabbage White	NR	2,3	NE

VC—very common | C—common | NC—not common | NR—not rare | R—rare | 1—pre-monsoon | 2—monsoon | 3—post-monsoon | 4—winter | NE—not evaluated | LC—Least Concern | Sch—schdule.
* indicates newly recorded species from this region

Table 3. List of newly recoded species along with their distribution and legal protection status.

	New records	Distribution[a]	Legal protection[b]	Reference
Family Hesperiidae				
1	*Baoris farri*	West Bengal (Alipurduar, South 24 Parganas, Bankura, Purulia district), NEI, A & N Is., SI, CI	NE/ Sch IV	Saji & Manoj (2020)
2	*Pelopidas subochracea*	West Bengal (northern Bengal, southwestern Bengal), NEI, SI, CI	NE	Saji (2020)
Family Lycaenidae				
3	*Zizina otis*	India	NE	Saji & Mahajan (2020)
4	*Arhopala atrax*	West Bengal (Alipurduar, Bankura, Purulia district) NEI, CI, NI	NE	Anonymous (2020a)
Family Nymphalidae				
5	*Tirumala septentrionis*	NEI, NI, SI, CI	NE	Saji et al. (2020)
6	*Phaedyma columella*	West Bengal (Alipurduar, Bardhaman district), NEI, NI, SI, CI, A&N Is	NE	Churi & Bagli (2020)
7	*Ypthima baldus*	West Bengal (Northern Bengal to southern Bengal), NEI, NI, CI, SI	NE	Ogale & Saji (2020)
Family Papilionidae				
8	*Graphium nomius*	West Bengal (Bardhaman, Bankura, Purulia district), SI, CI, NEI	NE	Churi (2020)
Family Pieridae				
9	*Eurema laeta*	West Bengal (Bankura, Purulia district), SI, CI, NEI, NI	NE	Bhakare & Bhagwat (2020)
10	*Eurema sari*	NEI, SI	NE	Anonymous (2020b)

[a] Emphasis on regional distribution along with National level distribution (NEI: Northeastern India, NI: Northern India, SI: Southern India, CI: Central India, A&N Is: Andaman & Nicobar island of newly recoded species in this study.

[b] Legal protection of newly recorded butterfly species based on IUCN Red list (NE: Not Evaluated)/IW(P)A (Sch IV: Schedule IV).

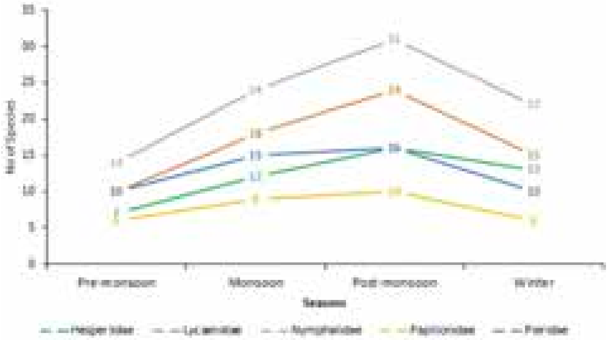


Figure 4. Flight period of butterfly fauna during entire study.

with good species to genera ratio (1.4: 1) indicates good butterfly diversity in the region. Presence of 11 legally protected species under the Indian Wildlife (Protection) Act, 1972 and 10 newly recorded species from this region draws attention towards the conservation priorities of this flagship species. The present comprehensive checklist of the butterfly fauna along with their habitat types and seasonality provide information for better understanding the ecology and distribution pattern of the butterfly fauna so that it can help to develop specific conservation measures for this unique biogeographical transitional zone.

REFERENCES

Abdulali, H. (1949). Some peculiarities of avifaunal distribution in peninsular India. *Proceedings of the National Academy of Sciences* 15(8): 387–393.

Ali, S. (1949). The Satpura trend as an ornithological highway. *Proceedings of the National Academy of Sciences* 15(8): 379–387.

Anonymous (2011a). District Human Development Report: Purba Medinipur. Development & Planning Department, Government of West Bengal, 254pp.

Anonymous (2011b). District Human Development Report: Paschim Medinipur. Development & Planning Department, Government of West Bengal, 306pp.

Anonymous (2020a). *Arhopala atrax* (Hewitson, 1862) – Indian Oakblue. Kunte, K., S. Sondhi & P. Roy (chief editors). *Butterflies of India, v. 3.04*. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/1135/Arhopala-atrax

Anonymous (2020b). *Eurema sari* (Horsfield, 1829) – Chocolate Grass Yellow. India Biodiversity Portal. https://indiabiodiversity.org/biodiv/species/show/279632

Bhakare, M. & T. Bhagwat (2020). *Eurema laeta* (Boisduval, 1836) – Spotless Grass Yellow. Kunte, K., S. Sondhi & P. Roy (chief editors). *Butterflies of India, v. 3.04*. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/633/Eurema-laeta

Biswas, S.J., D. Patra, S. Roy, S.K. Giri, S. Paul & A. Hossain (2019). Butterfly diversity throughout Midnapore urban area in West Bengal, India. *Journal of Threatened Taxa* 11(14): 14816–14826. https://doi.org/10.11609/jott.4587.11.14.14816-14826

Bonebrake, T.C., C. Ponisio & C.L. Boggs (2010). More than just indicators: a review of tropical butterfly ecology and conservation. *Biological Conservation* 143: 1831–1841.

Champion, H. G. & S.K. Seth (1968). *A Revised Survey of Forest Types of India*. Govt. of India Press, New Delhi, 404pp.

Churi, P. (2020). *Graphium nomius* (Esper, 1799) – Spot Swordtail. Kunte, K., S. Sondhi, & P. Roy (Chief Editors). *Butterflies of India, v. 3.04*. Indian Foundation for Butterflies. http://www.

Image 1. Species of Hesperiidae family recorded in the present study: 1—*Badamia exclamationis* | 2—*Hasora chromus* | 3—*Suastus gremius* | 4—*Suastus gremius* | 5—*Baoris farri* * | 6—*Borbo cinnara* | 7—*Erionota thrax* | 8—*Hyarotis adrastus* | 9—*Iambrix salsala* | 10—*Matapa aria* | 11—*Parnara guttatus* | 12—*Pelopidas subochracea* * | 13—*Pelopidas thrax* | 14—*Telicota colon* | 15—*Telicota bambusae* | 16—*Udaspes folus* | 17—*Spialia galba.*

ifoundbutterflies.org/sp/590/Graphium-nomius

Churi, P. & K. Bagli (2020). *Phaedyma columella* (Cramer, [1780]) – Short-banded Sailer. Kunte, K., S. Sondhi & P. Roy (chief editors). *Butterflies of India, v. 3.04*. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/753/Phaedyma-columella

Ehrlich, P.R. & P.H. Raven (1964). Butterflies and plants: a study in coevolution. *Evolution* 18: 586–608.

FSI (2017). India State of Forest Report. Forest Survey of India, Dehradun, India, 314–319pp.

Hora, S.L. (1949). Satpura Hypothesis of the distribution of Malayan fauna and flora of peninsular India. *Proceedings of National Institute of Science of India* 15(8): 309–314.

IUCN (2020). The IUCN Red List of Threatened Species. Version 2020-2. https://www.iucnredlist.org.

Kehimkar, I. (2008). *The book of Indian Butterflies*. Bombay Natural History Society, Oxford University press. Walton Street, Oxford, New York, 497pp.

Kunte, K. (2000). *Butterflies of Peninsular India*. Universities Press (Hyderabad) and Indian Academy of Sciences (Bangalore), 254pp.

Landres, P.B., J. Verner & J.W. Thomas (1988). Ecological uses of vertebrate indicator species: a critique. *Conservation Biology* 2: 316–328.

Mahata, A., K.T. Samal & S.K. Palita (2019). Butterfly diversity in agroforestry plantations of Eastern Ghats of southern Odisha, India. *Agroforestry Systems* 93: 1423–1438. https://doi.org/10.1007/s10457-018-0258-y

Morrone, J.J. (2004). La Zona de Transición Sudamericana: caracterización y relevancia evolutiva. *Acta Entomológica Chilena* 28: 41–50.

New, T.R. (1991). *Butterfly conservation*. Oxford University Press,

Image 2. Species of Lycaenidae family recorded in the present study: 18—*Curetis thetis* | 19—*Pseudozizeeria maha* | 20—*Zizina otis* *| 21—*Spalgis epius* | 22—*Anthene emolus* | 23—*Castalius rosimon* | 24—*Catochrysops strabo* | 25—*Chilades lajus* | 26—*Euchrysops cnejus* | 27—*Jamides bochus* | 28—*Jamides celeno* | 29—*Luthrodes pandava* | 30—*Neopithecops zalmora* | 31—*Prosotas dubiosa* | 32—*Tarucus nara* | 33—*Zizeeria karsandra* | 34—*Zizula hylax*| 35—*Arhopala atrax* * | 36—*Iraota timoleon* | 37—*Mahathala ameria* | 38—*Rapala manea* |39—*Rathinda amor* | 40—*Spindasis vulcanus* | 41—*Virachola Isocrates*.

Image 3. Species of Nymphalidae family recorded in the present study: 42—*Ariadne ariadne* | 43—Ariadne merione | 44—*Danaus chrysippus* | 45—*Danaus genutia* | 46—*Danaus melanippus indicus* | 47—*Euploea core* | 48—*Euploea klugii* kollari | 49—*Tirumala limniace* | 50—*Tirumala septentrionis* *| 51—*Acraea violae* | 52—*Phalanta phalantha* | 53—*Euthalia aconthea* | 54—*Moduza procris*| 55—*Neptis hylas*| 56—*Neptis jumbah* | 57—*Phaedyma columella* * | 58—*Symphaedra nais* | 59—*Discophora sondaica* | 60—*Hypolimnas bolina* | 61—*Junonia almanac* | 62—*Junonia atlites* | 63—*Junonia hierta* | 64—*Junonia iphita* | 65—*Junonia lemonias* | 66—*Junonia orithya* | 67—*Elymnias hypermnestra* | 68—*Lethe europa* | 69—*Melanitis leda* | 70—*Mycalesis perseus* | 71—*Ypthima baldus* * | 72—*Ypthima huebneri*.

Image 4. Species of Papilionidae family recorded in the present study: 73—*Graphium Agamemnon* | 74—*Graphium doson* | 75—*Graphium nomius** | 76—*Pachliopta aristolochiae* | 77—*Papilio clytia* | 78–*Papilio crino* | 79—*Papilio demoleus* | 80—*Papilio hector* | 81—*Papilio polymnestor* | 82—*Papilio polytes*.

Image 5. Species of Pieridae family recorded in the present study: 83—*Catopsilia Pomona* | 84—*Catopsilia pyranthe* | 85—*Eurema andersoni* | 86—*Eurema blanda* | 87—*Eurema brigitta* | 88—*Eurema hecabe* | 89—*Eurema laeta* * | 90—*Eurema sari* * | 91—*Appias libythea olferna* | 92—*Cepora nerissa* | 93–*Colotis amata* | 94—*Delias eucharis* | 95—*Ixias pyrene* | 96—*Leptosia nina* | 97—*Pareronia valeria* | 98—*Pieris canidia*.

Melbourne, 224pp.

Odum, E.P. (1953). *Fundamentals of ecology*. W.B. Saunders, Philadelphia. xii + 384 pp.

Ogale, H. & K. Saji (2020). *Ypthima baldus* (Fabricius, 1775) – Common Five-ring. Kunte, K., S. Sondhi & P. Roy (chief editors). *Butterflies of India, v. 3.04*. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/559/Ypthima-baldus

Paria, S., S. Ghosh, P.C. Mardaraj, P.H. Mallick & S.K. Chakraborty (2018). Habitat heterogeneity and butterfly diversity of Kuldiha wildlife Sanctuary, Odisha, India. *Journal of Biodiversity Conservation and Bioresource Management* 4(1): 93–100. https://doi.org/10.3329/jbcbm.v4i1.37880

Payra, A., R.K. Mishra & K. Mondal (2017). Butterflies (Lepidoptera - Rhopalocera) of coastal areas of southern West Bengal, India. *Tap chi Sinh hoc* 39(3): 276–290. https://doi.org/10.15625/0866-7160/v39n3.9243

Pollard, E. & T. J. Yates (1993). *Monitoring butterflies for ecology and conservation.* Chapman and Hall, London, 274pp.

Price, P.W. (1975). *Insect Ecology*, John Wiley & Sons, New York, NY, USA, 888pp.

Rosenberg, D.M., H.V. Danks & D.M. Lehmkuhl (1986). Importance of insects in environmental impact assessment. *Environmental Management* 10: 773–783.

Ruggiero, A. & C. Ezcurra (2003). Regiones y transiciones biogeográficas: complementariedad de los análisis en biogeografía histórica y ecológica, pp. 141–154. In: Morrone, J.J. & J. Llorente (ed.). *Una perspectiva Latinoamericana de la Biogeografía*. Las Prensas de Ciencias, UNAM: Mexico City, Mexico, 307pp.

Saji, K. (2020). *Pelopidas subochracea* (Moore, 1878) – Large Branded Swift. Kunte, K., S. Sondhi, & P. Roy (Chief Editors). *Butterflies of India, v. 3.04*. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/1089/Pelopidas-subochracea

Saji, K & P. Manoj (2020). Baoris farri (Moore, 1878) – Complete Paint-brush Swift. Kunte, K., S. Sondhi & P. Roy (chief editors). Butterflies of India, v. 3.04. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/793/Baoris-farri

Saji, K. & R.P. Mahajan (2020). *Zizina otis* (Fabricius, 1787) – Lesser Grass Blue. Kunte, K., S. Sondhi & P. Roy (chief editors). *Butterflies of India, v. 3.04*. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/829/Zizina-otis

Saji, K., K. Kunte & P. Manoj (2020). *Tirumala septentrionis* (Butler, 1874) – Dark Blue Tiger. Kunte, K., S. Sondhi & P. Roy (chief editors). *Butterflies of India, v. 3.04*. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/560/Tirumala-septentrionis

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. https://doi.org/10.11609/jott.2841.9.5.10198-10207

Simberloff, D. (1988). Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? *Biological Conservation* 83: 247–257.

Thomas, J.A. (2005). Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. *Philosophical Transactions of the Royal Society*, *B* 360: 339–357. https://doi.org/10.1098/rstb.2004.1585

Varshney, R.K. & P. Smetacek (2015). *A Synoptic Catalogue of the Butterflies of India*. Butterfly Research Centre, Bhimtal and Indinov Publishing, New Delhi, 261pp.

Wynter-Blyth, M.A. (1957). *Butterflies of Indian Region.* Bombay Natural History Society, Bombay, 523pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17361–17365
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
DOI: https://doi.org/10.11609/jott.5983.12.17.17361-17365
#5983 | Received 11 April 2020 | Final received 05 November 2020 | Finally accepted 17 November 2020

Occurrence of *Corica soborna* Hamilton, 1822 (Clupeiformes: Clupeidae) in the Godavari basin, India

Kante Krishna Prasad [1], Mohammad Younus [2] & Chelmala Srinivasulu [3]

[1,3] Wildlife Biology and Taxonomy Lab, Department of Zoology, University College of Science, Osmania University, Hyderabad, Telangana 500007, India.
[2] Centre for Biodiversity and Conservation Studies, Osmania University, Hyderabad, Telangana 500007, India.
[3] Systematics, Ecology & Conservation Laboratory, Zoo Outreach Organization, No. 12 Thiruvannamalai Nagar, Saravanampatti-Kalapatti Road, Saravanampatti, Coimbatore, Tamil Nadu 641035, India.
[1] kpmanjeera@gmail.com, [2] mdyounusou@gmail.com, [3] chelmala.srinivasulu@osmania.ac.in (corresponding author)

Abstract: We record for the first time, *Corica soborna* Hamilton, 1822 from Godavari River, based on a single specimen collected from stream near Talai Village, Kumaram Bheem Asifabad District of Telengana State. In addition to a detailed description of its morphological characters, we also provide details on distribution, habitat and threats to the species.

Keywords: Bejjur, Clupeoid, freshwater fish, Pranahita River sub-basin, Telangana State.

Approximately 420 species of clupeoids are known from around the world, distributed in marine, estuarine and freshwater habitats (Fricke et al. 2020). In India, more than 80 species of clupeoid fishes have been recorded (Froese & Pauly 2019), of which around 34 species are distributed in freshwaters and estuaries (Jayaram 2010; Froese & Pauly 2019). The Ganges River Sprat, *Corica soborna* Hamilton, 1822 is a small freshwater clupeid primarily known from the Ganges river basin, with a record from the Bharathapuzha River basin in Kerala (Bijukumar & Sushama 2000). Other records are from Indonesia, Malaysia, and Singapore in southeastern Asia (Hardenberg 1936; Herre & Myers 1937; Whitehead 1967, 1972). This species was described from Aiyargunj in erstwhile Bengal Presidency (Hamilton 1822; also see Britz 2019), at the confluence of Punarbhaba River with Mahananda River, located in current day Bangladesh (Bhattacharya 1974). Previous records of the species are mostly from the Ganges and its tributaries – Dehri-on-Sone on river Sone in Bihar (Motwani & David 1957), Goribaba on river Ken in Uttar Pradesh (Srivastava et al. 1970), Dighwara on the Ganges in Bihar (Karamchandani 1962), from several other locations on the Ganges in Patna and Bhagalpur districts in Bihar, and Sahibganj district in Jharkhand (Kamal & Ahsan 1978). The only record of this species in India, outside the Ganges River system is from the Ponnani Estuary, Kerala (Bijukumar & Sushama 2000). Whitehead (1972) inadvertently mentioned 'Mahanadi' river as type locality instead of 'Mahananda' river from where the species was described by Hamilton (1822). It has so far not been recorded from the Godavari River basin (Talwar & Jhingran 1991; Krishnan & Mishra 2001; Jayaram 1981, 2010), or from anywhere in Telangana

Editor: Rajeev Raghavan, Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, India. **Date of publication:** 26 December 2020 (online & print)

Citation: Prasad, K.K., M. Younus & C. Srinivasulu (2020). Occurrence of *Corica soborna* Hamilton, 1822 (Clupeiformes: Clupeidae) in the Godavari basin, India. *Journal of Threatened Taxa* 12(17): 17361–17365. https://doi.org/10.11609/jott.5983.12.17.17361-17365

Funding: The study was funded by UGC-BSR scheme.

Competing interests: The authors declare no competing interests.

Acknowledgements: We acknowledge the Head, Department of Zoology, University College of Science, Osmania University, Hyderabad for providing facilities and encouragement. KKP acknowledges the research funding from University Grants Commission (UGC), New Delhi. MY acknowledges the internship support at the Centre for Biodiversity and Conservation Studies, Osmania University, Hyderabad. We also thank Tokala Venkatesh and his family members for assistance in the the field and hospitality.

State (Barman 1993; Chaudhry 2010; Jayaram 2010). Through this communication, we report for the first time, the occurrence of *Corica soborna* in the Godavari River basin in Telangana State, India.

MATERIAL AND METHODS

While conducting ichthyological surveys in Telangana State, we collected a single specimen of a fish that resembled *C. soborna* with a dragnet operated by a local fisher at Talai Village, Kumaram Bheem Asifabad District. The voucher specimen was photographed, labeled, and fixed in 4% formalin (Jayaram 2010), and deposited in the Natural History Museum, Department of Zoology, University College of Science, Osmania University, Hyderabad, Telangana State, India (NHMOU). Morphometric measurements were taken using Mitutoyo digital calipers following Jayaram (2010) and Armbruster (2012), and the fish was subsequently identified as *C. soborna* following Whitehead (1972, 1985), Talwar & Jhingran (1991), and Jayaram (1981, 2010).

Corica soborna Hamilton, 1822
(Image 1)

Materials examined: NHM.OU.F-993, 05.i.2019, a stream near Talai Village, Pranahita sub-basin of Godavari, Kumarambheem Asifabad District, Telangana, India, 19.296^{0}N & 79.952^{0}E, 110m, coll. Kante Krishna Prasad & Md. Younus.

Distinguishing characters: *Corica soborna* is a small fish, attaining about 50mm in standard length. The following characters distinguish the species from its congeners: body moderately elongate; abdomen keeled; 10 pre-pelvic and eight post-pelvic scutes; mouth terminal; second supra-maxilla equal to, or as long as maxilla blade; teeth absent or minute; gill rakers of first gill 19–21 (Whitehead 1972; Talwar & Jhingran 1991); dorsal fin inserted above pelvic origin with two simple (Talwar & Jhingran 1991) and 13–14 branched rays (Hamilton 1822; Talwar & Jhingran 1991); pectoral with 12–13 rays (Hamilton 1822; Talwar & Jhingran 1991); pelvic fin insertion in advance of dorsal fin origin with one simple and seven branched rays (Talwar & Jhingran 1991); anal fin with two simple and 12–13 branched rays and two rays in a distinct finlet (Talwar & Jhingran 1991); caudal fin deeply forked with 18 rays and faint dark edges (Hamilton 1822); scales small; lateral line absent; lateral series scales 40 to 42 (Jayram 2010).

The present specimen matches the general description provided by Hamilton (1822), Talwar & Jhingran (1991), and Jayram (2010). Morphometric measurements and meristic counts are presented in Table 1. Minor variations with respect to simple and branched rays could likely be due to the manner in which counts were taken by previous researchers with those made in the present study. In the present specimen, dorsal fin is inserted above pelvic origin, with three simple and 13 branched rays; pectoral fin with one simple and 13 branched rays; pelvic fin with one simple and seven branched rays; anal fin with three simple and 11 branched rays and two branched rays in the finlet;

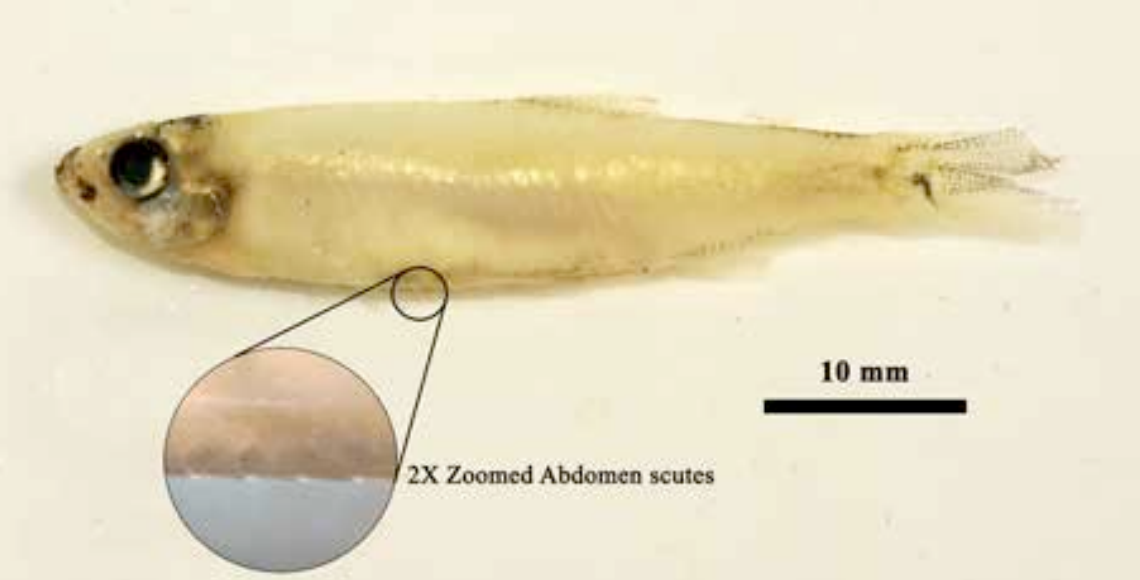


Image 1. Lateral view of the preserved specimen of *Corica soborna* (NHM.OU.F-993). © K. Krishna Prasad

Table 1. Morphometric characters and meristic counts of *Corica soborna* from Godavari River basin, Telangana State, India.

Morphometric Characters	**Specimen voucher NHM.OU.F-993**
Total length (mm)	50.5
Standard length (mm)	41.6
Head length (mm)	9.0
% of Standard length	
Body depth	20.4
Head length	21.6
Head depth	16.9
Head width	9.2
Eye diameter	7.9
Snout length	6.4
Inter orbital width	4.8
Dorsal fin base length or dorsal fin width	14.6
Pre-dorsal distance	50.8
Dorsal fin length	19.1
Dorsal fin origin to hypural distance	46.2
Pectoral fin length	17.3
Pelvic fin length	13.7
Caudal peduncle length	11.0
Caudal peduncle depth	9.2
Pre-pelvic distance	49.0
Pre-anal distance	70.7
Anal fin base length	17.7
Anal fin length	12.1
% of Head length	
Head depth	78.3
Head width	42.5
Eye diameter	36.6
Snout length	29.8
Inter orbital width	22.2
Meristic counts	
Scales in Lateral Series	41
Transverse scale rows	9
Pre pelvic scutes	10
Post pelvic scutes	8
Pre-dorsal scales	17
Pre-pelvic scales	14
Pre-anal scales	23
Dorsal fin rays	iii+13
Pectoral fin rays	i+13
Pelvic fin rays	i+7
Anal fin rays + (finlet)	iii+11+(2)
Principal caudal fin rays	18
Procurrent caudal fin rays	12

caudal fin deeply forked with 18 principal rays and 12 procurrent rays; lateral series scales 41; and 22 gill rakers on lower arch of first gill.

Habitat: One individual of *Corica soborna* was collected in an eighth-order stream (Strahler 1957) of six-meter depth, with rapid water flow (1.2 m/s) and bedrock, submerged boulders, sand, silt and detritus swamp as substrates. Riparian vegetation on the left bank of the stream was occupied with shrubs and scattered trees of *Tectona grandis*, *Cassia fistula*, *Albizia amara*, and *Acacia leucophloea*, and right bank with cultivated lands. Co-occurring fish fauna included *Amblypharyngodon mola*, *Barilius barila*, *Chanda nama*, *Channa marulius*, *C. striata*, *Glossogobius giuris*, *Labeo calbasu*, *Macrognathus pancalus*, *Mastacembelus armatus*, *Mystus bleekeri*, *M. vittatus*, *Puntius sophore*, *Rasbora daniconius*, *Sperata seenghala,* and *Systomus sarana*.

Discussion

The present record of *Corica soborna* in the Godavari River basin extends its distribution to the middle of peninsular India. This species is currently known from few locations in the Ganga basin from Uttar Pradesh to West Bengal in India, and in Bangladesh (Mahananda, Ken, and Sone river drainages), as well as in the Bharathapuzha River (in Ponnani Estuary) in Kerala. The presence of *C. soborna* in the Godavari River basin suggest that this species may be more widespread in peninsular India than previously thought. In addition to the inland waters of India and Bangladesh (Rahman 1989, 2005; Payne et al. 2004; Wahab 2007; Alam et al. 2013; Arefin et al. 2018), *C. soborna* also occurs in the estuaries of Southeast Asian countries (Fig. 1) including Indonesia (Hardenberg 1936; Whitehead 1967, 1972), Malaysia (Whitehead 1967, 1972), and Singapore (Herre & Myers 1937; Whitehead 1967). This species has also specifically been recorded from Mekong and Bangpakong rivers in Thailand (Taki 1978; Suvatti 1981); however, Chaudhry (2010) doubted the validity of these records. The discontinuous distribution of this species may suggest data-deficiency in surveys and non-availability of verified checklists from other parts of southern and Southeast Asian countries, indicating 'Wallacean shortfall'.

Alteration, fragmentation, and destruction of critical habitats as a result of the construction of irrigation and hydropower projects in the middle and upper reaches of the Godavari, as well as indiscriminate fishing could be detrimental to the survival of the newly detected population of *C. soborna* in Telangana State. We

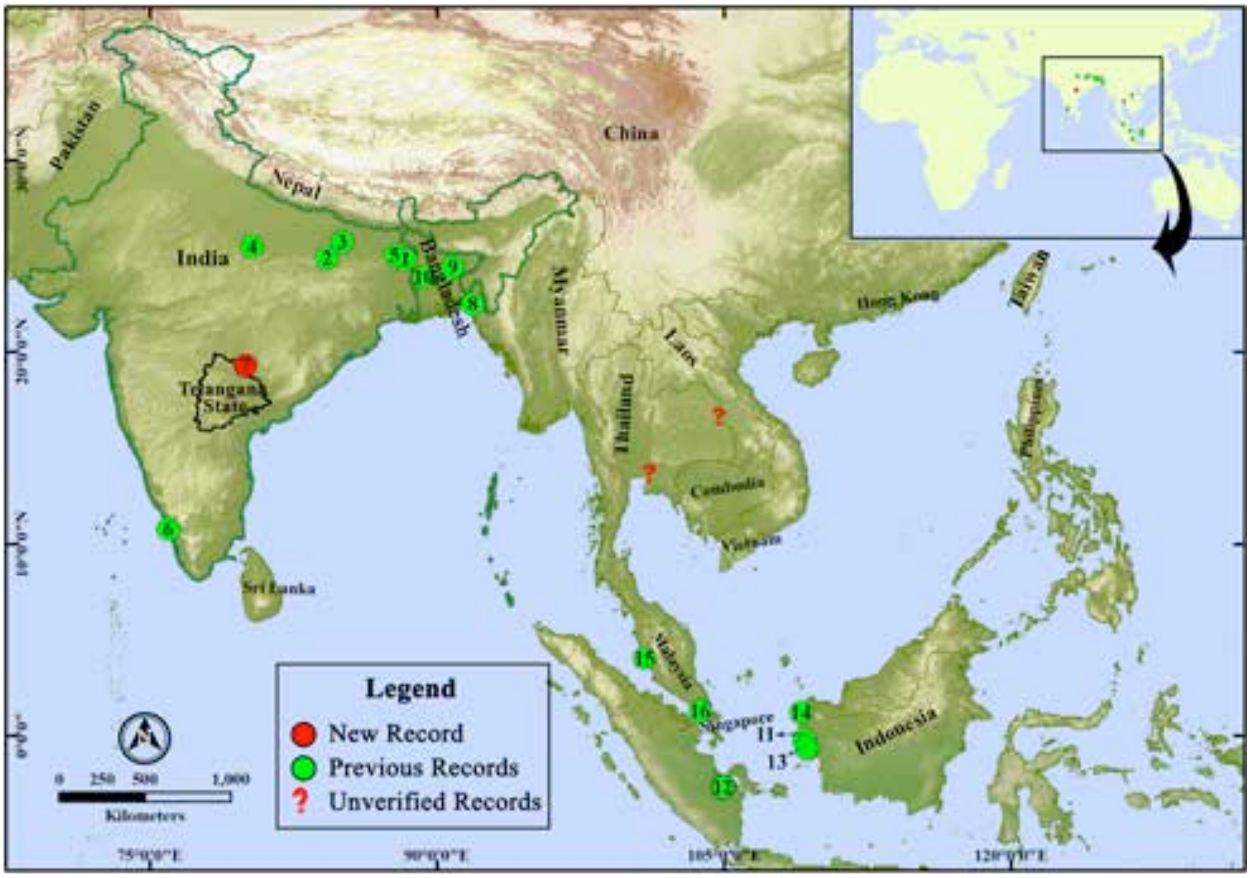


Figure 1. Global distribution of *Corica soborna*. Verified records in green circles, present record in red circle, and unverified records as red question mark. Numerical numbers in the circles represent ID numbers mentioned in Table 2.

Table 2. Global distribution of *Corica soborna*. Location names in brackets are historic names.

ID	Location	River Basin/ Estuary	Country	Source
1	Aiyargunj, Mahananda River, Bangladesh (Aiargunj, Mahananda River, India)*	Ganga	Bangladesh	Hamilton 1822; Britz 2019
2	Dehri-on-Sone, Sone River, Bihar	Ganga	India	Motwani & David 1957
3	Dighwara, Ganga River, Bihar	Ganga	India	Karamchandani 1962
4	Goribaba, Ken River, Banda, Uttar Pradesh	Ganga	India	Srivastava et al. 1970
5	Rajmahal, Ganga River, Jharkhand	Ganga	India	Kamal & Ahsan 1978**
6	Ponnani Estuary, Kerala	Bharathapuzha	India	Bijukumar & Sushama 2000
7	Talai, Kumarambheem Asifabad District, Telangana State	Godavari	India	Present Study
8	Halda River, Chittagong, Bangladesh	Karnaphully	Bangladesh	Alam et al. 2013
9	Narsunda River, Kishoreganj District, Bangladesh	Surma-Meghna	Bangladesh	Arefin et al. 2018
10	Padma River, Bangladesh	Ganga	Bangladesh	Payne et al. 2004
11	Kapuas River, West Kalimantan (S.W. Borneo)	Kapuas	Indonesia	Whitehead 1967, 1972
12	Musi River, South Sumatra, Indonesia (S.E. Sumatra)	Musi	Indonesia	Whitehead 1967
13	Padang Tikar Bay, Indonesia	Estuary	Indonesia	Hardenberg 1936; Whitehead 1967
14	Pamangkat, Indonesia (Pemangkat, S.W. Borneo)	Estuary	Indonesia	Whitehead 1967, 1972
15	Perak River, Malaysia (Malaya)	Perak	Malaysia	Whitehead 1967, 1972
16	Singapore	Estuary	Singapore	Herre & Myers 1937; Whitehead 1967

*Type locality; **Kamal & Ahsan (1978) report *C. soborna* being collected from various locations of Ganga River in Patna and Bhagalpur districts in Bihar, and Sahibganj District in Jharkhand, India.

propose further research on understanding the micro-level distribution, population status and dynamics, and threats (both direct and indirect) of this species in Telangana State.

REFERENCES

Alam, M.S., M.S. Hossain, M.M. Monwar, M.E. Hoque & F.M. Taimur (2013). Check-list of bony fish collected from the Upper Halda River, Chittagong, Bangladesh. *Aquaculture, Aquarium, Conservation & Legislation Bioflux* 6(4): 333–338.

Arefin, F., Md. Moniruzzaman, S.T. Lupa, M.A. Rahman, A. Islam & S. Akter (2018). Status of threaten fish species in Narsunda river. *Research in Agriculture Livestock and Fisheries* 5(2): 259–268. https://doi.org/10.3329/ralf.v5i2.38116

Armbruster, J.W. (2012). Standardized measurements, landmarks, and meristic counts for cypriniform fishes. *Zootaxa* 3586: 8–16.

Barman, R.P. (1993). Pisces: Freshwater Fishes, pp. 89–334. In: Director, ZSI (eds.). *State Fauna Series 5, Fauna of Andhra Pradesh, Part-I,* Zoological Survey of India, Kolkata, 334pp.

Bhattacharya, A. (1974). Historical geography of Ancient and early medieval Bengal. PhD Thesis submitted to Calcutta University, Calcutta, India, 257pp.

Bijukumar, A. & S. Sushama (2000). Ichthyofauna of Ponnani Estuary, Kerala. *Journal of the Marine Biological Association of India* 42(1–2): 182–189.

Britz, R. (ed.) (2019). *Francis Hamilton's Gangetic Fishes in Colour: A New Edition of the 1822 Monograph with Reproductions of Unpublished Coloured Illustrations*. Ray Society, NHM, London, UK, 698pp.

Chaudhry, S. (2010). *Corica soborna*. The IUCN Red List of Threatened Species 2010: e.T166428A6207091. Downloaded on 20 January 2020. https://doi.org/10.2305/IUCN.UK.20104.RLTS.T166428A6207091.en

Fricke, R., W.N. Eschmeyer & R. van der Laan (eds.) (2020). Eschmeyer's catalog of fishes: Genera, Species, References. (http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp). Accessed on 20 January 2020.

Froese, R. & D. Pauly (eds.) (2019). Fish Base. Available online at www.fishbase.org (version 02/2019). Accessed on 20 May 2019.

Hamilton, F. (1822). *An account of the fishes found in the river Ganges and its branches*. Archibald Constable & Company, Edinburgh, 405pp.

Hardenberg, J.D.F. (1936). On a collection of fishes from the estuary and the lower and middle course of the river Kapuas (W. Borneo). *Treubia* 15: 225–254.

Herre, A.W.C.T. & G.S. Myers (1937). A contribution to the ichthyology of the Malay Peninsula. *Bulletin of the Raffles Museum* 13: 5–75.

Jayaram, K.C. (1981). *The freshwater fishes of India, Pakistan, Bangladesh, Burma and Sri Lanka-a handbook.* Zoological Survey of India, Kolkata, xxii+475pp.

Jayaram, K.C. (2010). *The Freshwater Fishes of the Indian Region. 2nd edition.* Narendra Publishing House, Delhi, xxxi+616pp.

Karamchandani, S.J. (1962). On a collection of fish from the Ganga River at Dighwara (Bihar). *Tropical Ecology Varanasi* 3(1&2): 79–83.

Kamal, M.Y. & S.N. Ahsan (1978). *Corica biharensis* sp. nov. (Pisces: Clupeidae) from the River Ganga in Bihar (India). *Journal of the Inland Fishery Society of India* 10: 28–31.

Krishnan, S. & S.S. Mishra (2001). Fishes, pp. 85–166. In: Director, ZSI (eds.). *Fauna of Godavari Estuary, Estuarine Ecosystem Series 4*, Zoological Survey of India, Kolkata, 166pp.

Motwani, M.P. & A. David (1957). Fishes of the River Sone with observations on the Zoogeographical significance. *Journal of Zoological Society of India, Calcutta* 9(1): 9–15.

Payne, A.I., R. Sinha, H.R. Singh & S. Huq (2004). A review of the Ganges Basin; Its fish and fisheries, pp. 229–252. In: Welcomme R. & T. Petr (eds.). *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume I*. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, 358pp.

Rahman, A.K.A. (1989). *Freshwater Fishes of Bangladesh.* The Zoological Society of Bangladesh, Department of Zoology, University of Dhaka, Dhaka, xvii+364pp.

Rahman, A.K.A. (2005). *Freshwater Fishes of Bangladesh. Second Edition.* Zoological Society of Bangladesh, Dhaka, 263pp.

Strahler, A.N. (1957). Quantitative analysis of watershed geomorphology. *Transactions, American Geophysical Union* 38(6): 913–920. https://doi.org/10.1029/TR038i006p00913

Srivastava, C.B., R. Chandra & S.K. Wishard (1970). On a collection of fish from River Ken in Banda District (U.P.). *Records of the Zoological Survey of India* 64(1–4)[1966]: 131–134.

Suvatti, C. (1981). *Fishes of Thailand.* Royal Institute of Thailand, Bangkok, 379pp.

Taki, Y. (1978). *An Analytical Study of The Fish Fauna of the Mekong Basin As A Biological Production System in Nature. Special Publications No. 1 of RIEB*. Research Institute of Evolutionary Biology, Tokyo, Japan, 77pp.

Talwar, P.K. & A.G. Jhingran (1991). *Inland Fishes of India and Adjacent Countries.* Volume 1&2, Oxford-IBH Publishing Co., New Delhi, 1158pp.

Wahab, M.A. (2007). *Corica soborna*, pp. 15–16. In: Siddiqui, K.U., M.A. Islam, S.M.H. Kabir, M. Ahmad, A.T.A. Ahmed, A.K.A. Rahman, E.U. Haque, Z.U. Ahmed, Z.N.T. Begum, M.A. Hassan, M. Khondker & M.M. Rahman (eds.). *Encyclopedia of Flora and Fauna of Bangladesh, Vol. 23.* Freshwater Fishes. Asiatic Society of Bangladesh, Dhaka, 300pp.

Whitehead, P.J.P. (1967). The clupeoid fishes of Malaya. A synopsis, with keys to all Indo-Pacific Genera. *Journal of the Marine Biological Association of India* 9(2): 223–280.

Whitehead, P.J.P. (1972). A synopsis of the Clupeoid fishes of India. *Journal of the Marine Biological Association of India* 14(1): 160–256.

Whitehead, P.J.P. (1985). *FAO species catalogue. Clupeoid fishes of the world (suborder Clupeioidei), Part-1. An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings*. United Nations Development Programme, Food and Agriculture Organization of the United Nations, Rome. *Fisheries Synopsis Number* (125)7: 1–303. http://www.fao.org/3/ac482e/ac482e00.htm

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17366–17369
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
DOI: https://doi.org/10.11609/jott.4750.12.17.17366-17369
#4750 | Received 08 December 2018 | Final received 12 July 2020 | Finally accepted 27 November 2020

Strobilanthes affinis (Acanthaceae): a new addition to the flora of Manipur, India

Sanjeet Kumar [1] & **Rajkumari Supriya Devi** [2]

[1] Ambika Prasad Research Foundation, First Floor, Sarswati Tower, Laxmisagar, Bhubaneswar, Odisha, 751006 India.
[2] Biodiversity & Conservation Division, Regional Centre, Ambika Prasad Research Foundation, Imphal, Manipur 795001, India.
[1] sanjeet.biotech@gmail.com (corresponding author), [2] supriyark91@gmail.com

The genus *Strobilanthes* Blume (1826: 781) from the family Acanthaceae (Wood & Scotland 2009) is a genus of perennial flowering herbs and shrubs with about 453 species worldwide (Biju et al. 2017; Mabberly 2017; Thomas et al. 2019, 2020; Wood et al. 2019). In India, the genus is represented by ca. 150 species (Scotland 1998; Gopalan & Chitra 2008; Karthikeyan et al. 2009; Wood 2014; Biju et al. 2017), and it is found mostly in evergreen forests. The name *Strobilanthes* is derived from the Latin word "*Strobilos*" meaning cone and "anthos" meaning flower or shoot. For the first time, the genus was scientifically described by Christian Gottfried Daniel Nees Von Esenbeck in the 19th century for the plants which bloom after long intervals, while some species of *Strobilanthes* bloom annually (Preethi & Suseem 2014; Josekutty et al. 2016, 2017, 2018; Augustine et al. 2017). The genus is distributed in the tropical regions of Asia starting from Afghanistan through India and Southeast Asia to Australia (Josekutty et al. 2018). During 2017–2018, while surveying floral diversity around Imphal, Manipur, when the weather was clear and the vegetation was on the verge of blooming, an exciting view of a blue patch of herbs was recorded. The site was an isolated place near an abandoned old temple-like structure. It appeared like a small hill at the periphery of a human inhabitation which might have been used in the past as a sacred place where local deities may have been worshipped. It was a moist shady place with huge aged trees sheltering and nurturing vegetation beneath. A significant patch of blue coloured herbs with a height of 45–85 cm were blooming with bright blue coloured flowers in the area of around 4.5–6.5 m^2 on the slopes of a small hillock. After careful observation in the field, the first author confirmed that the specimen belongs to the genus *Strobilanthes* but confused it with *S. auriculata* or *S. jeyporensis*. After a detailed study of the specimen's morphology (Image 1) and pollen morphology (Image 2), and comparison with *S. kunthiana*, it was confirmed that the collected species was *S. affinis*. This specimen was again confirmed by professor John Wood, University of Oxford, United Kingdom. After confirmation, literature survey and critical characterization, it was noticed that collected plant had been earlier reported from China (Wood et al. 2003) and the species was also collected by J.D. Hooker and T. Thomson from Meghalaya as *S. acrocephala* more than 10 decades ago. Therefore, it was concluded that the present specimen that was collected is identified as *S. affinis* and reported here for

Editor: K. Haridasan, Pallavur, Palakkad, Kerala, India. **Date of publication:** 26 December 2020 (online & print)

Citation: Kumar, S. & R.S. Devi (2020). *Strobilanthes affinis* (Acanthaceae): a new addition to the flora of Manipur, India**.** *Journal of Threatened Taxa* 12(17): 17366–17369. https://doi.org/10.11609/jott.4750.12.17.17366-17369

Funding: Core works of APRF, India.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to the director, Institute of Bioresources and Sustainable Development (IBSD), Imphal; Dr. S.B. Ummalyma, Dr. S.S. Thorat, & Dr. B.G. Somkuwar, IBSD, Imphal; and the local communities of the study area. The authors are also thankful to Smt. Padma Mahanti, director, Directorate of Environment and Climate Change, Thiruvananthapuram and Smt. Lekshmi R, Eravikulam National Park, Munnar, Kerala.

the first time from Manipur as an extended distribution.

During our field survey of the flora of Manipur (24.916 N & 93.961 E, 803m), some unidentified species of the genus *Strobilanthes* were collected. The specimens were packed in cloth bags and brought to the laboratory for analysis. The relevant floras were consulted for confirming its identity. A thorough review of the literature, detailed morphological and consultation of herbarium provided by professor Wood revealed that the specimen was *Strobilanthes affinis* (Griff.) Terao ex J.R.I.Wood J.R.Benn. The mounting of herbarium specimens was accomplished using standard taxonomic procedure (Jain & Rao 1977; Bridson & Forman 1998). The voucher specimens (APRF-MAN-BCD/2018-0004) were deposited in the "APRFH" Herbaria, Ambika Prasad Research Foundation, Odisha, India. The photographs of the diagnostic characteristics were taken by Stereo Microscope, (Leica MC 120 HD).

Taxonomic enumeration

Strobilanthes affinis (Griff.) Terao ex J. R. I. Wood J. R. Benn

Description: Herbs, 50–82.5 cm tall with many branches. Stems angular (quadrangular) with white pubescent, hairs. Leaves ovate-elliptic, 7–5 x 4–3 cm to 9–0 x 6–3 cm. Leaves simple, petiole, 3.5–4.3 cm long. Inflorescences axillary or terminal,3.0–7.5 cm. Each inflorescence has two flowers that have bloomed, after drying another couple of flowers bloom. Flowers size, 1.9–2.3 cm long, 1.2 x 1.2–2.0 x 1.8 cm wide. Floral bracts imbricate with large-celled trichomes. Corolla violet or bluish-violet. Stamens 4 and glabrous, 5.0–2.2 mm. Fruits capsule, pubescent, four seeded, 4.0–7.0 mm. Seeds brown ovate (Image 1).

Flowering & Fruiting: August—March

Distribution: China and India (Manipur, Meghalaya).

Specimen examined: APRF-MAN-BCD-2018-004, India, Manipur, Imphal, 24.916^0N & 93.961^0E, 803m, Kumar Sanjeet 012 (Holotype APRFH) (Image 4).

Habitat & Ecology: The collected species is *Strobilanthes affinis* found on a small hill top of Manipur State. The collected area lies in the Indo-Burma Biodiversity Hotspot region. It was observed that the habitat is Moist-deciduous vegetation. The most

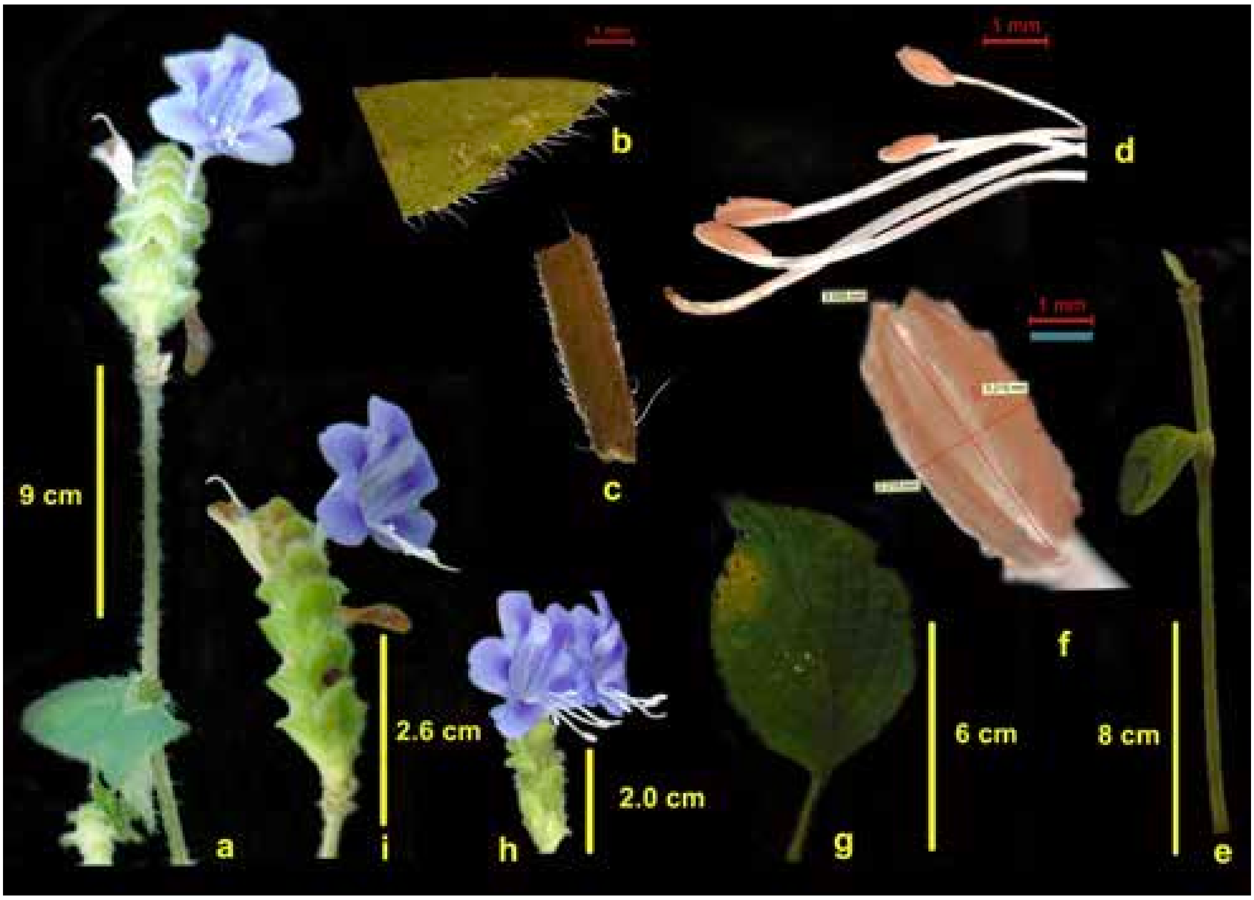


Image 1. Floral parts and morphology of collected *Strobilanthes affinis.* © Sanjeet Kumar

Image 2. Pollen of collected *Strobilanthes affinis*

common associated herbs and climbers are *Passiflora foetida, Solanum nigrum, Sida cordifolia*, *Cissampelos pareira*, and *Phyllanthus reticulatus* with some tree species like *Bombax ceiba* and *Pongamia pinnata*. It was found in 6.09 x 9.14 – 4.57 x 7.01 m area of a hill top of said region.

Remarks: The most unique characters of collected specimen are four exerted stamens (Image 3). Wood et al. (2003) described it from China and recorded that the flowering period is only from September to November. In the present study, however, it was observed that it flowers from August to March. It was also observed that *Sida acuta* is the main associate flora of the collected species. As it is found only one region of Manipur, it should be assessed for threat status using categories of IUCN, and take necessary conservation action.

References

Augustine, J., E.J. Josekutty & P. Biju (2017). *Strobilanthes sainthomiana* - a new species of *Strobilanthes* Blume (Acanthaceae) from Western Ghats, India. *Taiwania* 62(1): 63–66. https://doi.org/10.6165/tai2017.62.63

Biju, P., E.J. Josekutty, D. Rekha & R.I. John (2017). *Strobilanthes jomyi* (Acantheceae), a remarkable new species from South India. *Phytotaxa* 332(1): 075–080. https://doi.org/10.11646/phytotaxa.332.1.8

Bridson, D. & L. Forman (1998). *The Herbarium Handbook.* Royal Botanic Gardens, Kew, UK, 334pp.

Gopalan, R. & V. Chithra (2008). *Strobilanthes pothigaiensis* (Acanthaceae) - a new species from Southern Western Ghats, India. *Kew Bulletin* 63(3): 499–501. https://doi.org/10.1007/s12225-008-9042-x

Jain, S.K. & R.R. Rao (1977). *A Handbook of Field and Herbarium Methods*. Today & Tomorrow Printers & Publishers, New Delhi, 157pp.

Josekutty, E.J., P. Biju & J. Augustine (2016). *Strobilanthes malabarica* (Acanthaceae), a new species from South Western Ghats, India. *Webbia* 71(2): 1–5. https://doi.org/10.1080/00837792.2016.1205818

Josekutty, E.J., P. Biju, J.R.I. Wood & J. Augustine (2018). *Strobilanthes kannanii*- a new species of Acanthaceae from the Western

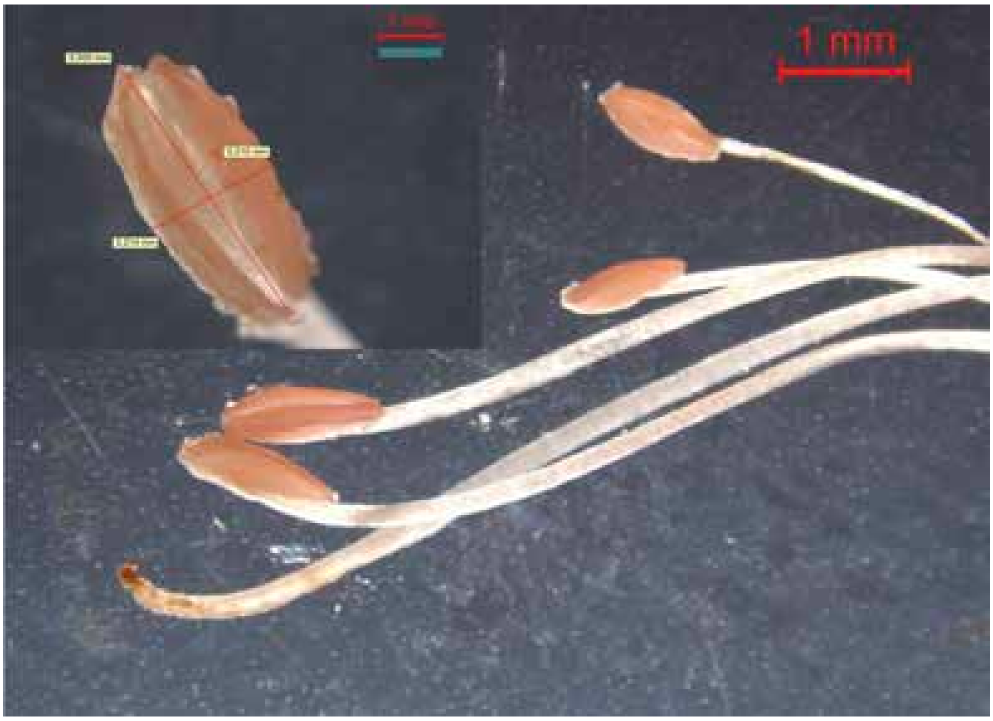


Image 3. Four exerted stamens *Strobilanthes affinis* (Griff.) Terao ex J.R.I. Wood J.R. Benn. © Sanjeet Kumar

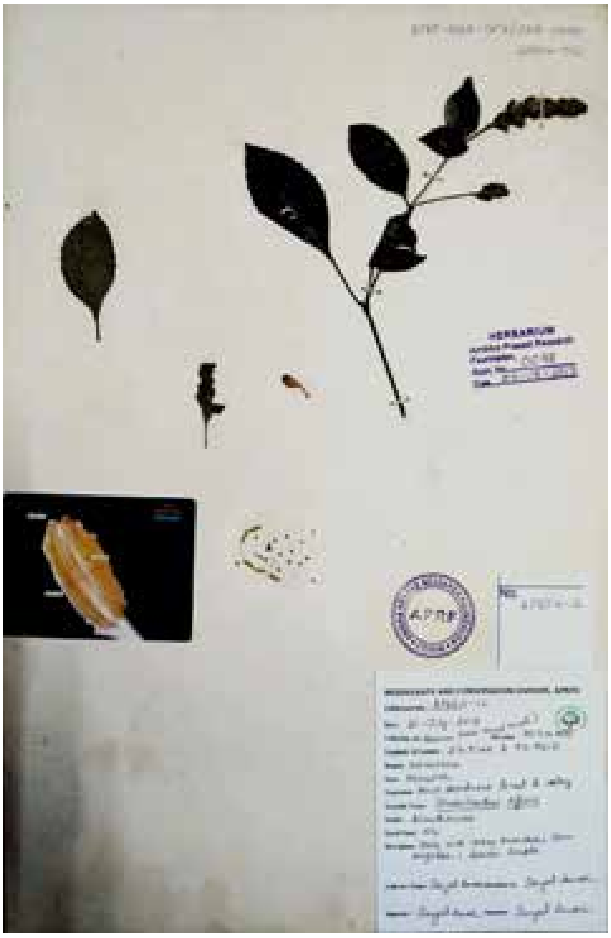


Image 4. Herbarium image of *Strobilanthes affinis.*

Ghats, India. *Nordic Journal of Botany* e01689: 1–5. https://doi.org/10.1111/njb.01689

Josekuty, E.J., Biju, P. & J. Augustine (2017). Notes on the extended distribution of two threatened species of *Strobilanthes* Blume (Acanthaceae) in Kerala, India. *Journal of Threatened Taxa* 9(5): 10236–10239. https://doi.org/10.11609/jott.3186.9.5.10236-10239.

Karthikeyan, S., M. Sanjappa & S. Moorthy. (2009). *Flowering plants of India-dicotyledons (Acanthaceae-Avicenniaceae)*. Botanical Survey of India, Kolkata, India, 60pp.

Mabberley, D.L. (2017). *Mabberley's Plant-book*. Cambridge University Press, Cambridge, UK, 1102pp.

Preethi, F. & S.R. Suseem (2014). A comprehensive study on an endemic Indian genus- *Strobilanthes*. *International Journal of Phytochemical Research* 6(3): 459–466.

Scotland, R.W. (1998). One new and one rediscovered species of *Strobilanthes* Blume (Acantheceae). *Botanical Journal of the Linnean Society* 128: 203–210. https://doi.org/10.1111/j.1095-8339.1998tb02116.x

Thomas, S., B. Mani, S.J. Britto & P.A.V. Pillai (2019). *Strobilanthes tricostata*, a new species of Acanthaceae from the Western Ghats, India. *Phytotaxa* 413(3): 244–250. https://doi.org/10.11646/phytotaxa.413.3.5

Thomas, S., B. Mani, S.J. Britto & P.A.V. Pillai (2020). A new species of Strobilanthes (Acanthaceae) from the Western Ghats, India. *Taiwania* 65(2): 167–171. https://doi.org/10.6165/tai.2020.65.167

Wood, J.R.I. (2014). New names and Combination in Indian Acanthaceae. *Novon*: *A Journal for Botanical Nomenclature* 23(3): 385–395. https://doi.org/10.3417/2013046

Wood, J.R.I. & R.W. Scotland (2009). New and little-known species of *Strobilanthes* (Acanthaceae) from India and South East Asia. *Kew Bulletin* 64(1): 3–47. https://doi.org/10.1007/s12225-009-9098-2

Wood, J.R.I., D. Borah, L. Yama & P. Mipun. (2019). *Strobilanthes twangensis* (Acanthaceae), a new species from the East Himalayas. *Kew Bulletin* 74: 41. https://doi.org/10.1007/S12225-019-9829-Y

Wood, J.R.I., J.R. Bennett & R.W. Scotland (2003). Notes on *Strobilanthes*: The Sympagis group. *Kew Bulletin* 58: 131–173. https://doi.org/10.2307/4119358

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17370–17373
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
DOI: https://doi.org/10.11609/jott.6141.12.17.17370-17373
#6141 | Received 12 May 2020 | Final received 08 December 2020 | Finally accepted 10 December 2020

NOTE

A new species of the genus *Opius* Wesmael, 1835 (Hymenoptera: Braconidae: Opiinae) from Kashmir Himalaya, India

Zaheer Ahmed [1], **Ahmad Samiuddin** [2], **Altaf Hussain Mir** [3] & **Mohammad Shamim** [4]

[1,3] Entomology Research laboratory, Department of Zoology, University of Kashmir, Srinagar-Jammu & Kashmir 190006, India.
[2] Department of Plant Protection, Faculty of Agricultural Sciences, [4] Entomology Section, Department of Zoology,
Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.
[1] zaheermir1979@gmail.com, [2] asamiuddin@gmail.com (corresponding author), [3] draltaf_786@yahoo.com, [4] drmshamim@gmail.com

Abbreviations: AOL—Anterior ocellar line | POL—Posterior ocellar line | OOL—Ocello ocular line | OOD—Ocellus diameter | F—Flagellomere | T_1—First metasomal tergite | MDZUK—Museum Department of Zoology, University of Kashmir.

Opiinae is one of the largest subfamily of Braconidae (Hymenoptera: Ichneumonoidea) with 39 genera and 2,061 described species worldwide. Species of the subfamily Opiinae are solitary koinobiont endoparasitoids of larvae of cyclorraphous Diptera, but oviposition may take place in the egg of the hosts (egg-larval parasitoids). They play significant role in the control of dipterous pests such as fruit flies (Tephritidae) and leaf-miner flies (Agromyzidae) (Wharton 1984, 1997; Schuster & Wharton 1993). The parasitoid larvae complete their development within the host larvae, pupate and emerge as adults (Li et al. 2013). *Opius* Wesmael is the largest genus of subfamily Opiinae and also one of the largest in the family Braconidae, with 33 subgenera and 1,202 described species (Yu et al. 2019). Some species of *Opius* have great potential in biological control of Agromyzid leaf miners. *O. tirolensis* is recorded as a biological control agent against *Phytomyza flavicornis*, *O.* (*G*) *caucasi* against *Chromatomyia horticola*, and *O.* (*A*) *nowakowskii* against *Phytomyza thysselini* (Yu et al. 2012). The genus is represented by 51 species spread over 11 subgenera (including four species of subgenera *Utetes* from India, i.e., *Opius* (*Utetes*) *mudigerensis*; *Opius* (*Utetes*) *poonchicola*; *Opius* (*Utetes*) *parempiformis*; *Opius*(*Utetes*) *minicorpus* (Fischer, 1966, 1980, 1987, 1996, 2005, 2012; Samiuddin et al. 2009). In the present work a new species *Opius* (*Utetes*) *hazratbalensis* sp. nov. from Kashmir, Himalaya has been described and illustrated.

The specimens were collected by using sweeping net. Slides and card mount specimens were examined under the binocular microscope. The ocular micrometer was used to measure (linear side of 100 divisions) fitted in one of the two eye pieces of the binocular. The ocular micrometer was calibrated with the help of stage micrometer under 8x,10x magnifications. Photographs were taken at different magnifications (4–16x) by the camera attached to Stereozoom binocular (SMZ1500) and Nikon SMZ 25. The terminology and the venation were followed by Achterberg (1993) and for surface sculpture Eady (1968) has been followed.

ZooBank: urn:lsid:zoobank.org:pub:5E270366-48B8-40A9-88F2-48B172B070F8

Editor: Anonymity requested. **Date of publication:** 26 December 2020 (online & print)

Citation: Ahmed, Z., A. Samiuddin, A.H. Mir & M. Shamim (2020). A new species of the genus *Opius* Wesmael, 1835 (Hymenoptera: Braconidae: Opiinae) from Kashmir Himalaya, India. *Journal of Threatened Taxa* 12(17): 17370–17373. https://doi.org/10.11609/jott.6141.12.17.17370-17373

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: We thank Dr. Mohd Kamil Usmani, professor and head, Entomology section, Department of Zoology, Aligarh Muslim University for providing laboratory facilities.

***Opius* (*Utetes*) *hazratbalensis* sp. nov.**

(Image 1 A–G)

urn:lsid:zoobank.org:act:DBDA5D24-0C95-47DD-B8DB-DAF7DAAD65AE

Material examined: Holotype: MDZUK ZoKU Art/ 06180, 15.v.2019, female, University campus, Hazratbal, Jammu & Kashmir, India; coll. Zaheer Ahmed. In near future it will be deposited in the Department of Zoology, Aligarh Muslim University, Aligarh.

Paratype: 1 female, same data as holotype.

Female: Body length 5.95mm; forewing 6.07mm.

Head: The width of head in dorsal view 1.7x its length and 1.3x its height; occipital carina complete; length of eye in lateral view 1.3x its width and 2.7x its temple; temple smooth, OOL:POL:AOL:OOD=3:3:14:3; vertex anterio-medially smooth, remaining rugose and sparsely setose, width of vertex 2.7x its length; frons smooth, shiny and densely setose near antennal sockets, width of frons 4.3x its length; face punctate reticulate with median longitudinal groove and densely setose, width of face 1.6x its length; tentorial pits deep and wide; intertentorial line 2.6x tentorio-ocular line; malar suture present, length of malar space 1.7x basal width of mandible; clypeus concave, rugose and densely setose, length of clypeus 2x its width; antennae 47-segmented, length of scape 1.3x its width, length of pedicel 1.16x its width, basal flagellar segments relatively long, first segment (F_1) 3.2x as long as wide, length of F_2 5.3x: F_3-F_4 5x: F_5-F_6 4.3x: F_7-F_{12} 4x: F_{13}-F_{22} 3.3x: F_{23}-F_{26} 3x: F_{27}-F_{34} 4.5x: F_{35}-F_{44} 4x: and F_{45} 4.5x their widths respectively.

Mesosoma: Length of mesosoma 1.8x its width and 2.2x , 2.7x as high as head (95:30) and 1.15x wide as head (52:60), mesonotum 2.3x as long medially, as wide between tegulae; dorsal surface of scutellum punctate, laterally striate; median lobe of mesoscutum reticulate, lateral lobe smooth, polished; notauli deep, crenulate anterio-medially, remaining rugose; mesopleuron anterio-medially granulate remaining smooth, metapleuron reticulate rugose; mid pit present; precoxal sulcus absent; scutellar sulcus deep and broad with two median carinae; metanotum concave, smooth; propodeum coriacious entirely without five sided areola.

Wings: Length of forewing 2.7x its width; pterostigma long cylindrical, length of pterostigma 10.2x its width (72:7), length of vein 1-R1, 1.1x length of pterostigma; vein r arising 1/3rd of pterostigma; m-cu and cu-a

Image 1. Female *Opius* (*Utetes*) *hazratbalensis* sp. nov. (magnifications 4–16x): A—adult female | B—dorsal head | C—frontal head | D—mesosoma dorsal | E—metasoma lateral | F—hindwing | G—forewing. © Zaheer Ahmed

Opius **(*Utetes*)** ***hazratbalensis*** **sp. nov.**	***Opius*** **(*Utetes*)** ***mudigerensis*****, Fischer**
1. Body length 5.95mm	1. Body length 4mm
2. Basal flagellar segments relatively long, first segment (F$_1$) 3.2x as long as wide	2. Basal flagellar segments relatively short, first segment (F$_1$) 2x as long as wide
3. Mesonotum 2.3x as long medially as wide between tegulae	3. Mesonotum 1.2x wider between tegulae than longitudinally
4. First tergite 1.75x longer than wide at hind (posteriorly)	4. First tergite 1.25x longer than wide at hind (posteriorly)
5. Propodeum without five-sided areola	5. Propodeum with five-sided areola
6. Hind tibia 3.4x as long as ovipositor sheath	6. Hind tibia as long as ovipositor sheath

Key to the Indian species of the subgenus *Utetes*

1 Antennae 24–28 segmented; T$_1$ 1.2x–1.5x as long as wide; ovipositor sheaths as long as T1 in lateral view (12:12); body length 1.9–4 mm 2
Antennae 47 segmented; T$_1$ 1.7x as long as wide; ovipositor sheaths short as compared to T1 in lateral view (8:12); body length 5.95mm .... *Opius* (*Utetes*) *hazratbalensis* sp. nov. female

2 F$_1$ 2x as long as wide .... *Opius* (*Utetes*) *mudigerensis* Fischer, 1980, female
F$_1$ 4–6x as long as wide 3

3 F$_1$ 6x as long as wide; clypeus 3x as wide as high; sternaulus with some notches.....*Opius* (*Utetes*) *parempiformis* Fischer, 2012, female
F$_1$ 4–5x as long as wide; clypeus 1.5x–2x as wide as high; sternaulus densely crenulated 4

4 Face as wide as high; propodeum with a broad pentagonal area .... *Opius* (*Utetes*) *minicorpus* Fischer, 2012, female
Face 1.25x as wide as high; propodeum with basal carina, pentagonal area and costulae, irregularly sculptured ....
....*Opius* (*Utetes*) *poonchicola* Fischer, 2012, female

postfurcal; SR1+3-SR slightly curved; r: 2-SR:S-R1+3-SR = 11:20:115; vein 3-SR 1.7x as long as 2-SR; 1-CU1: 2-CU1: 3-CU1 = 5:27:3; length of hind wing 4.2x its width; 1M: 1-r-m: 2-SC+R= 26:4:5

Legs: Hind coxa rugose, 1.5x as long as wide; length of hind femur, tibia and basitarsus 5.5x, 9.3x and 7.5x their width respectively; length of hind tibial spurs 0.06x hind basitarsus.

Metasoma: Length of metasoma 2.4x its width and 4.4x its height; first metasomal tergite 1.75x longer than wide at hind (posteriorly); length of first metasomal tergite 2.6x its apical width, apical width 1.5x its basal width, its surface longitudinally striate throughout the length; dorsope present; spiracles present medially; ovipositor short and pointed, ovipositor sheaths short as compared to T1 in lateral view (8:12); hind tibia 3.4x as long as ovipositor sheaths.

Colour: Head, face, mesosoma brownish to blackish except tegula brown, wings membranous with brown venation except pterostigma dark brown, antennae uniformly dark brown, legs brownish-yellow, mandibles dark brown with black teeth, eyes blackish, ocelli transparent, ocellar area black, maxillary and labial palpi yellowish, metasoma blackish, ovipositor reddish, ovipositor sheaths dark brown.

Male: Unknown

Host: Unknown

Etymology: The new species name refers to its type locality.

Discussion: *Opius* (*Utetes*) *hazratbalensis* sp. nov. closely resembles with Indian species *Opius* (*Utetes*) *mudigerensis* Fischer, 1980. However, it differs from *mudigerensis* in having body length 5.95mm; basal flagellar segments relatively long, first segment (F1) 3.2x as long as wide; mesonotum 2.3x as long medially as wide between tegulae; first tergite 1.75x longer than wide at hind (posteriorly); propodeum without five sided areola and ovipositor sheath short in lateral view, hind tibia 3.4x as long as ovipositor sheath.

References

Achterberg, C.V. (1993). Illustrated key to the subfamilies of the Braconidae (Hymenoptera: Ichneumonoidea). *Zoologische Verhandelingen, Leiden* 283: 1–189.

Eady, R.D. (1968). Some illustrations of microsculpture in the Hymenoptera. *Proceedings of the Royal Entomological Society of London* 43(4–6): 66–72.

Fischer, M. (1966). Beschreibungen und Wiederbeschreibungen von einigeneuropäischen und kanarischen Opiinae (Hymenoptera: Braconidae). *Zeitschrift der Arbeitsgemeinschaf tÖsterreichischer Entomologen* 48: 49–62.

Fischer, M. (1980). *Opius mudigerensis* n. sp., eineneue Braconidaeaus Indien. *Steenstrupia,* Kopenhagen 6(11): 173–176.

Fischer, M. (1987). Hymenoptera Opiinae III - aethiopische, orientalische, *australische und ozeanische Region. Das Tierreich* 104: 1–734.

Fischer, M. (2005). Some new Opiinae (Insecta: Hymenoptera:

Braconidae) in the Natural *History* Museum Vienna. *Annalen des Naturhistorischen Museums in Wien* 106 B: 107–133.

Fischer, M. (2012). New and other maggot wasps and jaw wasps from donated by Zubair Ahmad to the Museum of Natural Vienna (Insecta: Hymenoptera: Braconidae: Opiinae, Alysiinae). *Annalen des Naturhistorischen Museums in Wien. Serie B für Botanik und Zoologie* 113: 49–93.

Li, X.Y., C.V. Achterberg & J.C. Tan (2013). Revision of the subfamily Opiinae (Hymenoptera, Braconidae) from Hunan (China), including thirty-six new species and two new genera. *ZooKeys* 268: 1–168. https://doi.org/10.3897/zookeys.268.4071

Samiuddin, A., Z. Ahmad & M. Shamim (2009). Taxonomic studies of the genus *Opius*(Hymenoptera: Braconidae: Opiinae) From India. *Oriental Insects* 43: 159–199.

Schuster, D.J. & R.A. Wharton (1993). Hymenopterous parasitoids of leafmining Liriomyza spp. (Diptera: Agromyzidae) on tomato in Florida. *Environmental Entomology* 22: 1188–1191.

Wharton, R.A. (1984). The status of certain Braconidae (Hymenoptera) cultured for biological control programs, and description of a new species of Macrocentrus. *Proceedings of the Entomological Society of Washington* 86: 902–912.

Wharton, R.A. (1997). Generic relationships of opine Braconidae (Hymenoptera) parasitic on fruit-infesting Tephritidae (Diptera). *Contributions of the American Entomological Institute* 30: 1–53.

Yu, D.S., C.V. Achterberg & K. Horstmann (2012). World Ichneumonoidae, Taxonomy, Biology, Morphology and Distribution. Taxapad (Scientific names for information management) Interactive catalogue on DVD/CDROM. Vancouver. Available from: http://www.taxapad.com (accessed 30 December 2019).

Yu, D.S., C.V. Achterberg & K. Horstmann (2019). Biological and taxonomical information: Ichneumonoidea 2004 – Taxapad Interactive Catalogue, Vancouver.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17374–17379
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
DOI: https://doi.org/10.11609/jott.5740.12.17.17374-17379
#5740 | Received 28 January 2020 | Final received 10 November 2020 | Finally accepted 04 December 2020

Larvae of the blow fly *Caiusa testacea* (Diptera: Calliphoridae) as egg predators of *Polypedates cruciger* Blyth, 1852 (Amphibia: Anura: Rhacophoridae)

W.G.D. Chathuranga [1], K. Kariyawasam [2], Anslem de Silva [3] & W.A.Priyanka P. de Silva [4]

[1,2,4] Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.
[1] Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.
[3] No 15/1, Dolosbage Road, Gampola, Sri Lanka.
[1] dilanchathuranga9@gmail.com, [2] kalpakdkc@gmail.com, [3] kalds@sltnet.lk, [4] depriyanka@pdn.ac.lk (corresponding author)

Habitat destruction and alteration have been identified as the most detrimental causes of amphibian decline (Kiesecker 2003). The effects of climate change and amphibian diseases, however, are emerging topics, and have taken increased attention in conservation approaches regarding the amphibian fauna (Hayes et al. 2010; Li et al. 2013). Predatory pressure during different life stages of amphibians is another factor that significantly affects populations (Chivers et al. 2001; Blaustein et al. 2012). Diverse invertebrate and vertebrate fauna prey on eggs and tadpoles of aquatic and terrestrial nesting anurans (De Silva 2001a,b; Lingnau & Di-Bernardo 2006). According to Downie (1990), terrestrial foam nests of Rhacophoridae have evolved to protect eggs and embryos from aquatic predators. Some vertebrates (e.g., monkeys and snakes) and invertebrates (e.g., beetles, ephydrid flies, phorid flies, spiders, ants, and blow flies), however, have been identified as egg predators of anuran foam nests (Vonesh 2000; Rödel et al. 2002; Menin & Giaretta 2003; Lingnau & Di-Bernardo 2006; Banerjee et al. 2018). Blow flies of the genus *Caiusa* (Diptera: Calliphoridae) are one of the major predators of terrestrial Rhacophoridae eggs (Rognes 2015). These flies are one of the major reasons for embryo mortality of some rhacophorid genera, including *Chiromantis*, *Feihyla*, *Polypedates*, and *Rhacophorus* (Lin & Lue 2000). So far, seven known species of *Caiusa* (*C. borneoensis* Rognes, 2015, *C. coomani* Séguy, 1948, *C. indica* Surcouf, 1920, *C. karrakerae* Rognes, 2015, *C. kurahashii* Rognes, 2015, *C. violacea* Séguy, 1925, and *C. pooae* Rognes, 2015) have been identified as foam nest predators and predators of jelly-like egg masses of anurans (Lin & Lue 2000; Rognes 2015; Banerjee et al. 2018). The emerging larvae of these fly species consume eggs and developing embryos in egg masses. There are knowledge gaps in our understanding of the fly-anuran interactions and the wider impact of these flies on anuran population dynamics.

Sri Lanka is a tropical country with more than 120 species of anurans, nearly 104 of which are endemic to the country (De Silva & Wijayathilaka 2019). Approximately 83 (69%) of the reported species belong to the family Rhacophoridae, including arboreal foam nesting *Polypedates* and *Taruga* species (Meegaskumbura et al.

Editor: Daniel Whitmore, State Museum of Natural History Stuttgart, Rosenstein, Germany. **Date of publication:** 26 December 2020 (online & print)

Citation: Chathuranga, W.G.D., K. Kariyawasam, A.D. Silva & W.A.P.P. de Silva (2020). Larvae of the blow fly *Caiusa testacea* (Diptera: Calliphoridae) as egg predators of *Polypedates cruciger* Blyth, 1852 (Amphibia: Anura: Rhacophoridae). *Journal of Threatened Taxa* 12(17): 17374–17379. https://doi.org/10.11609/jott.5740.12.17.17374-17379

Funding: National Research Council Sri Lanka (Grant No: NRC 16-059) and Amphibian Specialist Group/IUCN/ SSC Seed Grant.

Competing interests: The authors declare no competing interests.

Acknowledgements: Financial assistance from National Research Council Sri Lanka (Grant No: NRC 16-059) to W.A.P.P. de Silva. Amphibian Specialist Group/IUCN/ SSC Seed Grant to A. de Silva for threats to amphibians of Sri Lanka study.

2010). The majority (more than 75%) of anuran species in the country are categorized as threatened, mainly due to anthropogenic activities (Manamendra-Arachchi & Meegaskumbura 2012; De Silva & Wijayathilaka 2019). Current conservation approaches are mainly aimed at minimizing habitat destruction and other adverse human activities. Only a few studies, however, have reported the effect of amphibian diseases on the population structure of anurans in Sri Lanka (De Silva 1999; Rajakaruna et al. 2007; Jayawardena et al. 2010; De Silva 2011), and hardly any studies have investigated predatory pressure on different life stages of amphibians in the country. Morgan-Davies (1958) reported *Caiusa indica* as predatory in foam nests of *Polypedates cruciger* Blyth, 1852 (Anura: Rhacophoridae) in Sri Lanka. According to De Silva & De Silva (2000), a species of Calliphoridae fly acts as an egg predator of *P. cruciger* frogs, however, these authors did not provide a species-level identification for the flies. Therefore, there are some literature gaps in information about predatory flies and their pressure on the developmental stages of anurans in Sri Lanka. Thus, detailed investigations including systematic and quantified studies to assess the damage caused by the egg predators to anuran eggs are important in relation to conservation actions. In this study, we identified natural dipteran predators of foam nests of *P. cruciger*, an endemic Rhacophoridae species in Sri Lanka. Further, we quantified the egg mortality of *P. cruciger* due to the infestation of the predatory dipteran fly.

The study was conducted from May 2019 to August 2019, at two localities [Gampola (7.150^{0}N, 80.555^{0}E) and Peradeniya (7.259^{0}N, 80.597^{0}E)] in the Kandy District of Sri Lanka. Spawns were searched for in microhabitats with *P. cruciger* (i.e., man-made ponds, cement water tanks, domestic wells, tree-holes, and organically managed agricultural lands). When a fresh spawn was located, it was observed and video recorded for about 10–15 minutes to report spawn visitors. The location of the foam nest and the height from the ground level to the nest were recorded. The spawns were examined daily at both selected localities until the embryos developed into tadpoles. A plastic container filled with 1,000ml of dechlorinated water was kept below each egg mass to collect emerging tadpoles. Observations were made at 24-hour intervals and the developed tadpoles were released to the respective water sources after recording the number. A similar procedure was followed for both infected and non-infected spawns. The presence of maggots, color changes, and the shape of the foam nests were used to distinguish infected nests from uninfected ones. Three severely infected spawns were carefully removed from the attached substrates and brought to the Insectary, Department of Zoology, University of Peradeniya for further investigations. At the laboratory, the foam nests were placed in dechlorinated water in a tray and transferred to fine-mesh mosquito rearing cages (50 × 50 × 50 cm) for maintenance of the fly colonies (at 25°C temperature, 75% relative humidity, and 12 D: 12 L photoperiodicity). Emerged flies were euthanized at -20°C in a freezer and pinned for identification. Morphological identification was done using the standard taxonomic key in Rognes (2015).

To confirm the identity of the dipteran species, DNA barcoding was also performed. DNA was extracted from some of the collected flies following Livak (1984). The mitochondrial Cytochrome Oxidase I (COI) gene was amplified using the previously described primers C1–J–1718F (5'–GGA GGA TTT GGA AAT TGA TTA GTT CC–3') and C1–N–2191R (5'–CCC GGT AAA ATT AAA ATA TAA ACT TC–3') (Simon et al. 1994). PCR amplification was done in a thermal cycler (Techne–Flexigene, England) following Nolan et al. (2007). Positive PCR products were sequenced using an automatic DNA sequencer (Applied Biosystems Series 3500, U.S.A.) in the Department of Molecular Biology and Biotechnology, University of Peradeniya. The sequence trace files were manually inspected using MEGA V7 (Kumar et al. 2016) and low-quality sequences were excluded from the analysis. The DNA sequences were annotated using the GenBank database (https://www.ncbi.nlm.nih.gov/) and BLASTn tool. The newly generated sequences were deposited in GenBank under the accession numbers MN786865 and MN786866.

The dissection and examination of male genitalia were done following Rognes (2009). The tip of the abdomen (from tergite 4) was removed and transferred to a 10% potassium hydroxide solution, then heated in a water bath for about 20 minutes. The abdomen was then transferred to distilled water and rinsed with 95% ethanol for 10 minutes to fix the integument. The male genital organs were separated using fine forceps, for preparation of microscopic slides. The separated male genitalia were mounted using Canada Balsam, and photographs of the prepared slides were taken using an Olympus BX53 Digital Upright Microscope (Olympus Corporation, Florida, USA).

Morphological identification confirmed that the emerged flies belonged to *Caiusa testacea* Senior-White, 1923 of the family Calliphoridae. According to Rognes (2015), the following morphological features were

Image 1. Infected and non-infected foam nests of *Polypedates cruciger* and different life stages of *Caiusa testacea* flies: a—adult *Polypedates cruciger* | b—uninfected fresh foam nest attached to a *Polyscias scutellaria* leaf | c—tadpoles from an uninfected foam nest | d—putrefying foam nest due to *C. testacea* infection | e—*C. testacea* fly on a fresh foam nest | f—*C. testacea* 3rd instar larva | g—*C. testacea* pupae | h—lateral aspect of adult *C. testacea* fly. © a,b—Anslem de Silva; c-h— W.G.D. Chathuranga.

identified for them. Cerci short, backwardly bent, and with a pronounced distal separation between the apices in dorsal view. Base of cerci wide proximal to separation (Image 2A). In lateral view, surstylus rather broad and short, very gently curved below. Thoracic dorsum yellow and tergites 4 and 5 of abdomen with slight darkening and lack of metallic bluish sheen (Image 2D). A BLAST search of the GenBank database showed a 96.92% identity to available *Caiusa testacea* sequences together with a 100% query cover.

A total of 24 spawns of *P. cruciger* were studied (Image 1a–1d). Observations were carried out on 10 spawns in Gampola (including the three collected spawns) and 14 spawns from the Peradeniya study site. These spawns were located at a height of 0.1–3.0 m above the ground. Plant species such as *Polyscias scutellaria* (Araliaceae), *Nelumbo nucifera* (Nelumbonaceae), *Gliricidia sepium* (Fabaceae), *Echinodorus palifolius* (Alismataceae), *Persea americana* (Lauraceae), and artificial substrates including cement walls, metal wire mesh, ceiling sheets, metal or plastic pipes just above a water source, were the most common spawning sites of *P. cruciger*. Of the examined spawns, 16 (66.7%) were not infected while eight (33.3%) were infected with fly larvae (Image 1f). All the infected spawns were reported from the Gampola study location, representing 80% of the total.

During this study, we observed oviposition of *C. testacea* flies only three times (Image 1e) on fresh foam nests of *P. cruciger*, and the larvae of *C. testacea* emerged from two-day-old infected spawns. An average of 354 ± 67 embryos developed into tadpoles (Image 1c) from healthy spawns (n=15), except one that produced an exceptionally high number of tadpoles (approximately 800). When compared with the healthy spawns, none of the embryos of the infected spawns (n=8) developed into tadpoles (Image 1d). According to our observation of eight infected spawns, approximately 400 embryos were destroyed with a single nest infestation. An average of 52 ± 9 *C. testacea* larvae pupariated (Image 1g) and 17 ± 8 emerged as adults from the three collected spawns (Image 1h). Accordingly, an average of 33% (17/52) of the larvae were able to complete their life cycle from a single spawn. The 1st to 3rd instar larval stages of the fly lasted around 6–7 days, while the puparial period lasted 8–11 days. The life cycle of *C. testacea* was completed within 18 to 20 days. Emerged adult flies were freeze-killed and pinned for identification. Larval instars, puparia, and a few adults of *C. testacea* were also preserved in 70% ethanol as voucher specimens and deposited in the Zoonotic and Disease Ecology Laboratory of the Department of Zoology, University of Peradeniya, Sri Lanka. Different morphological body aspects of *C. testacea*, including taxonomic features, are shown in Images 1h, 2A–2D.

Our study highlights the threat caused by *C. testacea* flies to the foam nests of *Polypedates cruciger* frogs and provides an indication of the major impact of these flies on the population dynamics of *P. cruciger*. Even though studies have reported the impact of predatory pressure causing the population decline of amphibians (Lin & Lue 2000; Kiesecker 2003), it has not been listed as a priority factor in conservation approaches in Sri

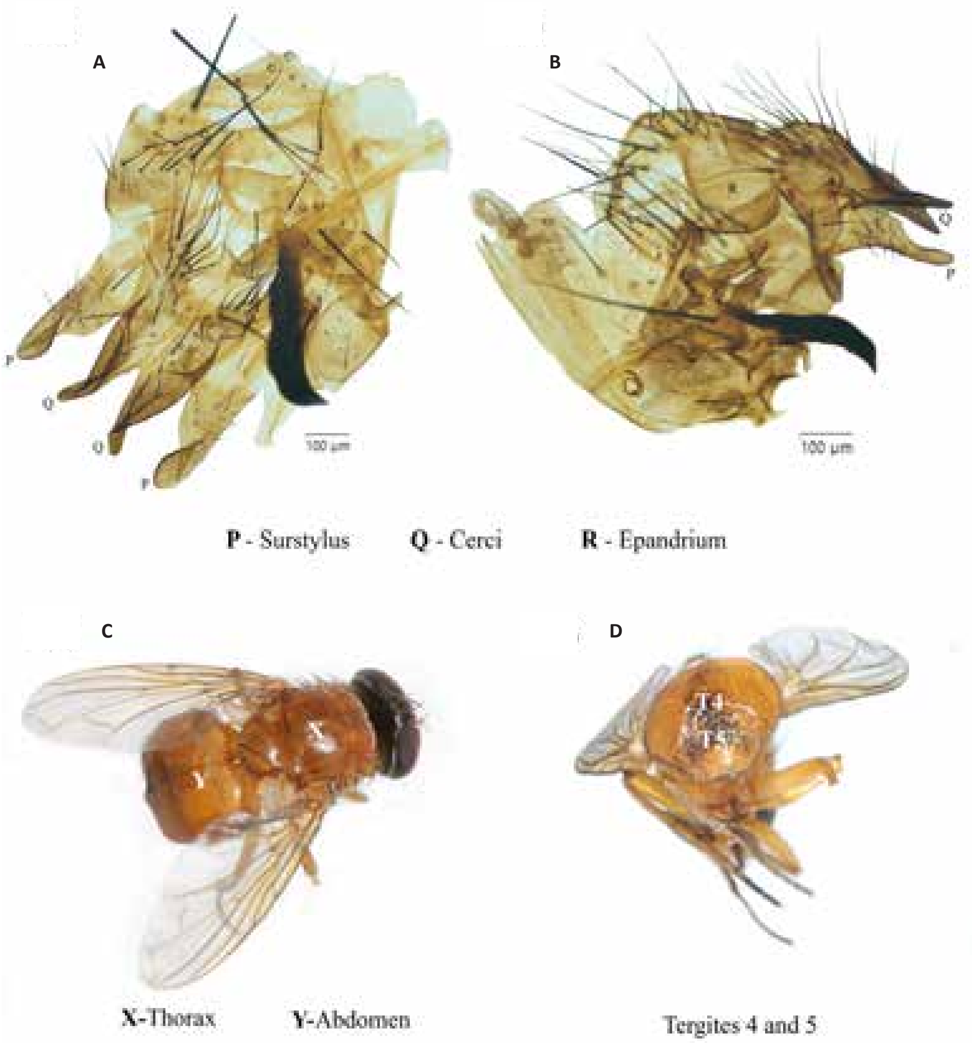


Image 2. Morphological features of *Caiusa testacea* flies: A—posterior aspect of the genitalia |B—lateral aspect of the genitalia | C—yellowish thorax and abdomen | D—yellowish T4 and T5 with slightly darkened patch. © a,b—W.G.D. Chathuranga; c-d—Kumudu Wijesooriya.

Lanka. In this study, we provide data on the natural predatory pressure of the calliphorid fly *Caiusa testacea* on the population structure of the rhacophorid tree frog *Polypedates cruciger*. Further, our results provide evidence of natural threats of Rhacophoridae anurans in Sri Lanka.

The presence of these flies had been reported from Sri Lanka, India, and Nepal by Rognes (2015), however, these flies had not been identified as egg predators of Sri Lankan Rhacophoridae species by any of the earlier studies. Our results reveal that larvae of *C. testacea* flies destructively consume eggs and embryos of *P. cruciger*. In an earlier study, *Caiusa indica* was identified as an egg predator of *P. cruciger* in Sri Lanka (Morgan-Davies 1958); however, previous studies had not identified *C. testacea* as a predator of foam nests of Rhacophoridae, and this is the first study that reports on the feeding behavior and the life history of *C. testacea*.

Rognes (2015) estimated that the time from the infestation of spawns by *Caiusa* flies to the completion of metamorphosis is nearly a week. In contrast, we observed a relatively longer developmental period, where *C. testacea* flies complete metamorphosis within three weeks. Lin et al. (2000) and Lin & Lue (2000) described the oviposition behavior of *Caiusa violacea* (as *C. coomani*). According to those authors, the flies lay their eggs when the outer surface of the foam nest is soft, within a few hours after the foam nest is formed. Similarly, Banerjee et al. (2018) reported that *Caiusa* flies lay their eggs on foam nests seven hours after the construction of the nest. Our study confirmed the oviposition of *C. testacea* flies on fresh foam nests of *P. cruciger* (Image 1e), however, we were not able to provide more specific information about the timeframe during which the flies are attracted to the nests. Our observations showed that larvae appeared within 2 to 3 days after oviposition and that the life cycle was completed (to metamorphosis) within 18 days.

Rognes (2015) reported that most of the dipteran predators of foam nests are able to respond to chemical cues released from the fresh foam nests built by the frogs. Thus, the gravid females of *C. testacea* flies may respond to chemical cues of freshly formed foam nests or chemical signals produced by *P. cruciger* frogs during spawning. Our data could not, however, confirm this hypothesis. There are interesting hypotheses explaining the selection of foam nests by dipteran flies as oviposition sites. For example, Banerjee et al. (2018) hypothesized that the frog eggs represent easier prey for *Caiusa* larvae compared to mobile tadpoles, which may allow these flies to overcome environmental constraints and resource limitations.

The distribution of *P. cruciger* extends 1,500m in the wet zone of central and southwestern parts of Sri Lanka (De Silva & De Silva 2000). *Caiusa testacea* has also been reported from similar locations in the central part of Sri Lanka, including Maskeliya, Suduganga, Kandy, and Niroddumunai (Rognes 2015), where *P. cruciger* is also reported. This habitat overlap of the predatory flies and *P. cruciger* may have driven the evolution of the predatory behavior of this fly species on the foam nests of *P. cruciger*. At the same time, this habitat overlap may negatively affect *P. cruciger* as it gives more opportunities for *C. testacea* flies to attack their nests. According to IUCN Red list 2012 categories, *P. cruciger* is listed as a Least Concern (LC) anuran species (Manamendra-Arachchi & Meegaskumbura 2012); however, the continual increase of anthropogenic impacts and changing climatic factors, together with infestations of *C. testacea*, may negatively affect *P. cruciger* populations, causing it to become a 'threatened species'. Furthermore, Sri Lanka harbors four more foam nesting anuran species in the family Rhacophoridae [(*Polypedates maculates* Gray 1830, *Taruga eques* Günther, 1858, *Taruga fastigo* (Manamendra-Arachchi & Pethiyagoda, 2001), and *Taruga longinasus* (Ahl, 1927)] (Meegaskumbura et al. 2010). As a result, there are possibilities for all other foam nesting Rhacophoridae anurans to be endangered by nest predation by *Caiusa testacea* flies. As we have seen the habitat overlap of Rhacophoridae species and these flies, there is a high chance of egg predation by *Caiusa* on these tree frogs in Sri Lanka. A proper understanding of the biology, distribution, and population assessments of both *C. testacea* and *P. cruciger*, however, will be vital in assessing the threats of *C. testacea* flies on the population dynamics of *P. cruciger* in the country.

In summary, we report *C. testacea* as a predator of foam nests of *P. cruciger* frogs of the family Rhacophoridae in Sri Lanka for the first time. More importantly, we recognize the predatory pressure of these flies on spawns of *P. cruciger*, highlighting their needful consideration in conservation approaches concerning these frogs.

References

Banerjee, A., K. Rognes & D. Whitmore (2018). Two species of *Caiusa* Surcouf (Diptera: Calliphoridae) new to India, with data on larval behavior and morphology. *Biodiversity Data Journal* 6: e27736. https://doi.org/10.3897/BDJ.6.e27736

Blaustein, A.R., S.S. Gervasi, P.T. Johnson, J.T. Hoverman, L.K. Belden, P.W. Bradley & G.Y. Xie (2012). Ecophysiology meets conservation: understanding the role of disease in amphibian population declines. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* 367(1596): 1688–1707. https://doi.org/10.1098/rstb.2012.0011

Chivers, D., J. Kiesecker, A. Marco, J. De Vito, M. Anderson & A. Blaustein (2001). Predator-Induced Life History Changes in Amphibians: Egg Predation Induces Hatching. *Oikos* 92(1): 135–142. http://www.jstor.org/stable/3547689

De Silva, A. (1999). New amphibian parasites from Sri Lanka. *Froglog* 31: 2.

De Silva, A. (2001a). Some aquatic insects: predators of anuran larvae at Horton Plains National Park. The Amphibia of Sri Lanka: Recent Research. *Lyriocephalus Special Edition* 4 (1-2): 145–146.

De Silva, A. (2001b). Some insect predators of anuran larvae observed in Gampola, Sri Lanka. The Amphibia of Sri Lanka: Recent Research. *Lyriocephalus Special Edition* 4 (1-2): 147–149.

De Silva, A. (2011). Some observations of malformation, eye disease, parasitic and viral infection, and the effects of agrochemicals on amphibians in Sri Lanka. *FrogLog* 97: 19–20.

De Silva, A. & P. De Silva (2000). Some observations on the spawn and larval success of *Polypedates cruciger* Blyth 1852 in Gampola Sri Lanka. *Lyriocephalus Special Edition* 4 (1–2): 28–35.

De Silva, S. & N. Wijayathilaka (2019). Bioacoustics of Sri Lankan Amphibians: a Review of Current Knowledge and Conservation Significance. *Journal of Tropical Forest and Environment* 9(1): 1–6. https://doi.org/10.31357/jtfe.v9i1.3944

Downie, J.R. (1990). Functions of the foam in foam-nesting leptodactylids: anti-predator effects of *Physalaemus pustulosus* foam. *Herpetology Journal* 1: 501–503.

Jayawardena, U.A., R.S. Rajakaruna, A.N. Navaratne & P.H. Amerasinghe (2010). Monostome cercariae induced malformations in amphibians: effect of infection at the pre-limb-bud stage tadpoles of *Polypedates cruciger* Blyth. *Journal of National Science Foundation of Sri Lanka* 38(4): 241–248. http://doi.org/10.4038/jnsfsr.v38i4.2651

Hayes, T.B., P. Falso, S. Gallipeau & M. Stice (2010). The cause of global amphibian declines: a developmental endocrinologist's perspective. *The Journal of experimental biology* 213(6): 921–933. https://doi.org/10.1242/jeb.040865

Kiesecker, J.M. (2003). Invasive species as a global problem: toward understanding the worldwide decline of amphibians, pp. 113–126. In: Semlitsch, R.D. (eds.). *Amphibian Conservation*. Smithsonian Institution Press, Washington, D.C.

Kumar, S., G. Stecher & K. Tamura (2016). MEGA7: Molecular Evolutionary Genetics Analysis version 7.0 for bigger datasets. *Molecular Biology and Evolution* 33: 1870–1874.

Li, Y., J.M. Cohen & J.R. Rohr (2013). Review and synthesis of the effects of climate change on amphibians. *Integrative Zoology* 8: 145–161. https://doi.org/10.1111/1749-4877.12001

Lin, S.S. & K.Y. Lue (2000). The sources of amphibian embryo mortality. *Biological Bulletin of National Taiwan Normal University* 35: 1–11.

Lin, S.S., C.H. Kuo & K.Y. Lue (2000). Oviposition behavior and host selection of the frog fly, *Caiusa coomani* (Diptera: Calliphoridae). *Chinese Journal of Entomology* 20: 281–292.

Lingnau, R. & M. Di-Bernardo (2006). Predation on foam nests of two leptodactylid frogs by *Solenopsis* sp. (Hymenoptera, Formicidae) and *Liophis miliaris* (Serpentes, Colubridae). *Biociencias* 14(2): 223–224.

Livak, K.J. (1984). Organization and mapping of a sequence on the *Drosophila melanogaster* X and Y chromosomes that are transcribed during spermatogenesis. *Journal of Genetics* 107: 611–634.

Manamendra-Arachchi, K. & M. Meegaskumbura (2012). The taxonomy and conservation status of amphibians in Sri Lanka, pp. 88–98. In: Weerakoon, D.K. & S. Wijesundara (eds.). *The National Red List 2012 of Sri Lanka: Conservation Status of the Fauna and Flora*. Ministry of Environment, Colombo, Sri Lanka, 451pp.

Meegaskumbura, M., S. Meegaskumbura, G. Bowatte, K. Manamendra-Arachchi, R. Pethiyagoda, J. Hanken & C. Schneider (2010). *Taruga* (Anura: Rhacophoridae), a new genus of foam-nesting tree frogs endemic to Sri Lanka. *Ceylon Journal of Science* 39(2): 75–94. https://doi.org/10.4038/cjsbs.v39i2.2995

Menin, M. & A.A. Giaretta (2003). Predation on foam nests of leptodactyline frogs (Anura: Leptodactylidae) by larvae of *Beckeriella niger* (Diptera: Ephydridae). *Journal of Zoology* 261: 239–243. https://doi.org/10.1017/S0952836903004138

Morgan-Davies, A.M. (1958). Some notes on the reproduction, metamorphosis, and ecology of a Ceylonese tree frog *Rhacophorus cruciger cruciger* (Blyth, 1852). *Journal of the Bombay Natural History Society* 55: 11–16.

Nolan, D.V., S. Carpenter, J. Barber, P.S. Mellor, J.F. Dallas, A.J.L. Mordue & S.B. Piertney (2007). Rapid diagnostic PCR assays for members of the *Culicoides obsoletus* and *Culicoides pulicaris* species complexes, implicated vectors of bluetongue virus in Europe. *Veterinary Microbiology* 124(1–2): 82–94. https://doi.org/10.1016/j.vetmic.2007.03.019

Rajakaruna, R.S., V.A.M.P.K. Samarawickrama & K.B. Ranawana (2007). Amphibian declines and possible etiologies: the case for Sri Lanka. *Journal of National Science Foundation of Sri Lanka* 35(1): 3–8. http://doi.org/10.4038/jnsfsr.v35i1.3655

Rödel, M.O., F. Range, J.T. Seppanen & R. Noe (2002). Caviar in the Rain Forest: Monkeys as Frog-Spawn Predators in Tai National Park, Ivory Coast. *Journal of Tropical Ecology* 18(2): 289–294. https://doi.org/10.1017/S0266467402002195

Rognes, K. (2009). Revision of the Oriental species of the Bengalia peuhi species-group (Diptera, Calliphoridae). *Zootaxa* 2251: 1–76. https://doi.org/10.11646/ZOOTAXA.2251.1.1

Rognes, K. (2015). Revision of the frog fly genus *Caiusa* Surcouf, 1920 (Diptera, Calliphoridae), with a note on the identity of *Plinthomyia emimelania* Rondani, 1875. *Zootaxa*. 3952: 1. https://doi.org/10.11646/zootaxa.3952.1.1

Simon, C., F. Frati, A. Beckenbach, B. Crespi, H. Liu & P. Flook (1994). Evolution, weighting, and phylogenetic utility of mitochondrial gene sequences and a compilation of conserved polymerase chain reaction primers. *Annual Review of Entomology* 87(6): 651–701. https://doi.org/10.1093/aesa/87.6.651

Vonesh, J.R. (2000). Dipteran predation on the arboreal eggs of four *Hyperolius* frog species in western Uganda. *Copeia* 2000(2): 560–566. https://doi.org/10.1643/0045-8511(2000)000[0560:DPOTAE]2.0

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17380–17382
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
DOI: https://doi.org/10.11609/jott.6694.12.17.17380-17382
#6694 | Received 10 September 2020 | Final received 10 November 2020 | Finally accepted 12 November 2020

Blank Swift *Caltoris kumara moorei* (Evans, 1926) (Lepidoptera: Hesperiidae) in Dehradun Valley, Uttarakhand, India: a new record for the western Himalaya

Arun Pratap Singh

Forest Entomology Division, Forest Research Institute, P.O. New Forest, Dehradun, Uttarakhand 248006, India
ranoteaps@gmail.com

Caltoris kumara (Moore, 1878) (Hesperiidae: Hesperiinae: Baorini) is known to occur as three races. The nominate race *C. k. kumara* (Moore, 1878) occurs from northern Gujarat to southern India (Western Ghats –(Maharashtra southwards to Kerala, Bangalore, Tamil Nadu), Madhya Pradesh, and Chattisgarh). The second race *C. k. moorei* (Evans, 1926) is found from western Nepal to Myanmar (Dawnas), through Sikkim, Arunachal Pradesh, northeastern India besides West Bengal, Bangladesh, and southern Yunnan (China). While the third race *C. k. lanka* is restricted to Sri Lanka (Wynter-Blyth 1957; Smith 1989, 2006; Zhang et al. 2010; Kehimkar 2016; Gasse 2017). The species is known to prefer forested areas up to 1,950m and is in flight from January–December (Kehimkar 2016), however, the species has never been reported from Uttarakhand or even the western Himalaya (Singh & Sondhi 2016).

On 21 September 2018 the author recorded *C. k. moorei* (Evans, 1926) in the New Forest Campus of Forest Research Institute, Dehradun (30.341^{0}N & 79.997^{0}E; 670m), India. The butterfly was trapped in the window of the Forest Research Institute building. The specimen was collected, pinned, and preserved as an unidentified specimen, however, it was recently identified by the author based on wing morphology and its genitalia. Distinctive morphological features of this individual (female; forewing length: 21mm; Image 1) being: no spot in upper forewing cell area, prominent large round spots in 1b in the upper forewing inner edge which is visible as a diffuse spot on the underside (Wynter-Blyth 1957). The female genitalia was dissected (Image 2, Figure 1) and the species was identified and compared with that of three other congeners [*C. confusa* (Evans, 1932)*; C. philippina* (Herrich-Schäffer, 1869) & *C. tulsi* (de Nicéville, [1884]] in the *Caltoris* group (Devyatkin 2010). In the female genitalia of *C. k. moorei* the postvaginal plate (PPL) is distally concave, with its outer angles acute and lateral lobes of the antevaginal plate projections are only slightly narrower than PPL which is distinct from others (Devyatkin 2010) .

The larval food plants of this species are known to be Poaceae (Robinson et al. 2010), *Bambusa* (Swinhoe 1913; Wynter-Blyth 1957), *Bambusa vulgaris* (Kalesh & Prakash 2015), *Bambusa tuldoides* (Nitin et al. 2018), *Imperata cylindrica* (Wynter-Blyth 1957; Robinson et al. 2010), *Ochlandra scriptoria* (Kalesh

Editor: B.A. Daniel, Zoo Outreach Organisation, Coimbatore, India. **Date of publication:** 26 December 2020 (online & print)

Citation: Singh, A.P. (2020). Blank Swift *Caltoris kumara moorei* (Evans, 1926) (Lepidoptera: Hesperiidae) in Dehradun Valley, Uttarakhand, India: a new record for the western Himalaya. *Journal of Threatened Taxa* 12(17): 17380–17382. https://doi.org/10.11609/jott.6694.12.17.17380-17382

Funding: None.

Competing interests: The author declares no competing interests.

Acknowledgements: Help of Tribhuwan Singh (JRF) is acknowledged for dissection of the specimen genitalia.

Image 1. Blank Swift *Caltoris kumara moorei* (Evans, 1926) female collected from New Forest, Dehradun, Uttarakhand (lower western Himalaya) on 21.ix.2018: a—dorsal view | b—ventral view. © Arun Pratap Singh

Image 2. Female genitalia organ of Blank Swift *Caltoris kumara moorei* (Evans, 1926) collected from the New Forest, Dehradun, Uttarakhand (lower western Himalaya) on 21.ix.2018.

& Prakash 2015), *Ochlandra travancorica* (Kalesh & Prakash 2015), and *Oryza sativa* (Davidson & Aitken 1890). Amongst these the genus *Bambusa* is present at a number of places in the New Forest Campus in plantations, botanical garden, bambusetum and also as clumps in hedge-groves, thus it also likely that the species is breeding here but needs further investigation.

This is the first record of this species from the state of Uttarakhand, India and the western Himalaya.

References

Davidson, J. & E.H. Aitken (1890). Notes on the larvae and pupae of some of the butterflies of the Bombay presidency. *Journal of the Bombay Natural History Society* 5: 349–375.

Devyatkin, A.L. (2010). Taxonomic notes on Oriental Hesperiidae, 4. A key to the continental species of *Baoris* Moore, [1881] and *Caltoris* Swinhoe, 1893, based on the female genitalia (Lepidoptera, Hesperiidae). *Atalanta* 41 (1/2): 239–244.

Evans, W.H. (1932). *The Identification of Indian Butterflies*. 2nd Edition. Bombay Natural History Society, Bombay, x+454pp+32pl.

Kalesh, S. & S.K. Prakash (2015). Additions to the larval host plants of butterflies of the Western Ghats, Kerala, South India (Rhopalocera, Lepidoptera): Part 2. *Journal of the Bombay Natural History Society* 112: 111–114.

Kehimkar, I. (2016). *The Book of Indian Butterflies*. BNHS, Oxford University, Delhi Press, 497pp.

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

Robinson, G.S., P.R. Ackery, I.J. Kitching, G.W. Beccaloni & L.M. Hern¡ndez (2010). HOSTS - A Database of the World Lepidopteran Hostplants. Natural History Museum, London. http://www.nhm.ac.uk/hosts. Electronic version accessed on 05 November 2020.

Singh, A.P. & S. Sondhi (2016). Butterflies of Garhwal, Uttarakhand, western Himalaya, India. *Journal of Threatened Taxa* 8(4): 8666–8697. https://doi.org/10.11609/jott.2254.8.4.8666-869

Smith, C. (1989). *Butterflies of Nepal (Central Himalaya)*. Tecpress Service L.P., Bangkok, 352pp.

Smith, C. (2006). *Illustrated Checklist of Nepal Butterflies*. Craftman Press, Bangkok, 129pp.

Wynter-Blyth, M.A. (1957). *Butterflies of the Indian Region*. Bombay Natural History Society, Bombay, xx+523pp+72pls.

Zhang, Ya-Lin, G.-X. Xue & F. Yuan (2010). Descriptions of the female genitalia of three species of *Caltoris* (Lepidoptera: Hesperiidae: Baorini) with a key to the species from China. *Proceedings of the Entomological Society of Washington* 112(4): 576–584. https://doi.org/10.4289/0013-8797.112.4.576

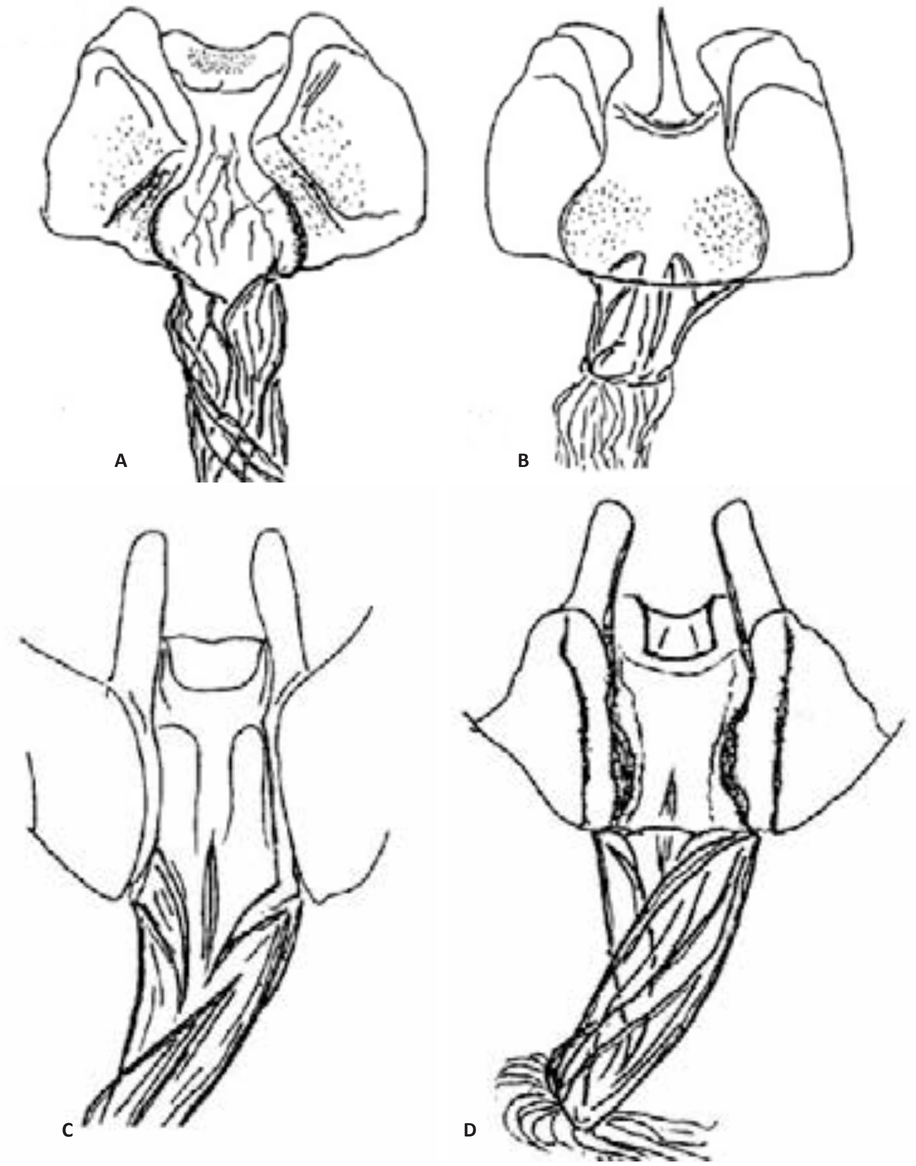


Figure 1. The female genitalia of four species of the genus *Caltoris* Swinhoe, 1893 (adapted from Devyatkin 2010): A—*Caltoris philippina* (Herrich-Schäffer, 1869) | B—*Caltoris tulsi* (de Nicéville, [1884]) | C—*Caltoris confusa* (Evans, 1932) | D—*Caltoris kumara moorei* (Evans, 1926).

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17383–17384
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
DOI: https://doi.org/10.11609/jott.6005.12.17.17383-17384
#6005 | Received 17 April 2020 | Finally accepted 22 December 2020

First photographic record of the Asiatic Brush-tailed Porcupine *Atherurus macrourus* (Linnaeus, 1758) (Mammalia: Rodentia: Hystricidae) from the Barak Valley region of Assam, India

Rejoice Gassah [1] & **Vijay Anand Ismavel** [2]

[1,2] The Makunda Christian Leprosy and General Hospital, Bazaricherra, Karimganj District, Assam 788727, India.
[1] joicesatisfy@gmail.com, [2] ivijayanand@yahoo.in (corresponding author)

An Asiatic Brush-tailed Porcupine *Atherurus macrourus* (Linnaeus, 1758) was photographed on the 25 February 2019 at 23.49h in semi-evergreen forest, close to Dosdewa Village in Karimganj District of Assam (92.405⁰N & 24.358⁰E) using a camera trap during biodiversity documentation activities. This is the first photographic record of this species from the Barak Valley region of Assam (Image 1–3). The Asiatic Brush-tailed Porcupine is a species of rodent in the Hystricidae family and is the smallest and rarest of the three species of porcupines found in southern Asia (Molur 2020). In India, this species occurs only in northeastern India and has been reported from Namdapha National Park of Arunachal Pradesh, Garampani Wildlife Sanctuary of Assam, Intanki National Park in Nagaland, Ngengpui Wildlife Sanctuary of Mizoram, and Khasi Hills of Meghalaya (Talukdar et al. 2019); there are also records from the other states (Choudhury 2013). In 2014, the species was observed from the Gedu Territorial Forest Division of western Bhutan (Dhendup & Dorji 2017). Worldwide, it has also been reported from southern China, northern Myanmar, northern Thailand, Laos, Vietnam, Malay peninsula, and adjacent islands (Molur 2020).

The species is distinguished by absence of crest, back covered with rigid spines and tail bearing scales with short spiny bristles in-between and ending in a cluster of alternately expanded and contracted papery hairs 8–10cm long giving a characteristic brush-like appearance which was clearly captured in the photographs (Agarwal 2000). Being a shy, nocturnal, and fossorial animal, it is very difficult to get diagnostic

Image 1. Asiatic Brush-tailed Porcupine *Atherurus macrourus*

Editor: Anwaruddin Choudhury, The Rhino Foundation for Nature in North East India, Guwahati, India. **Date of publication:** 26 December 2020 (online & print)

Citation: Gassah, R. & V.A. Ismavel (2020). First photographic record of the Asiatic Brush-tailed Porcupine *Atherurus macrourus* (Linnaeus, 1758) (Mammalia: Rodentia: Hystricidae) from the Barak Valley region of Assam, India. *Journal of Threatened Taxa* 12(17): 17383–17384. https://doi.org/10.11609/jott.6005.12.17.17383-17384

Funding: The equipment (camera trap) used in this observation was funded by the Makunda Christian Leprosy and General Hospital.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors wish to acknowledge with thanks the utilization of camera trap, GPS and other equipment provided by the Makunda Christian Leprosy and General Hospital for this observation.

images of this species, except through camera trapping. Porcupines are seen as a pest by farmers and are also trapped and consumed as meat. Although this species is classified as Least Concern (LC) in the IUCN Red List it is protected in India under Schedule II – Part I of the Indian Wildlife Protection Act. The presence of this species in the Barak Valley of Assam is significant as it indicates that good mammalian diversity occurs in this region, inspite of rapid degradation of the forests.


© Rejoice Gassah


© Rejoice Gassah

Image 2 & 3. Asiatic Brush-tailed Porcupine *Atherurus macrourus*

References

Agarwal V.C. (2000). Taxonomic Studies of Indian Muridae and Hystricidae Mammalia: Rodentia). Records of the Zoological Survey of India Occassional Paper No. 180, 177pp.

Choudhury A.U. (2013). *The Mammals of North East India*. Gibbon Books and The Rhino Foundation for Nature in NE India. 432pp.

Dhendup T. & R. Dorji (2017). First record of the Asiatic Brush-tailed Porcupine *Atherurus macrourus* Linnaeus 1758 (Mammalia: Rodentia: Hystricidae) from western Bhutan. *Journal of Threatened Taxa* 9(11): 10959–10960. http://doi.org/10.11609/jott.3791.9.11.10959-10960

Molur, S. (2020). *Atherurus macrourus.* (amended version of 2016 assessment) The IUCN Red List of Threatened Species 2020: e.T2354A166518819. Downloaded on 16 April 2020. https://doi.org/10.2305/IUCN.UK.2020-1.RLTS.T2354A166518819.en

Talukdar, N.R., P. Choudhury & B. Singh (2019). Current Records of porcupine in northeast India: distribution, habitat preference and conservation. *Tropical Ecology* 60: 41–51. https://doi.org/10.1007/s42965-019-00005-4

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2020 | 12(17): 17385–17386
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
DOI: https://doi.org/10.11609/jott.6906.12.17.17385-17386
#6906 | Received 18 November 2020

A look over on Red Sanders

S. Suresh Ramanan

ICAR- Central Agroforestry Research Institute, Jhansi, Uttar Pradesh 284003, India.
sureshramanan01@gmail.com

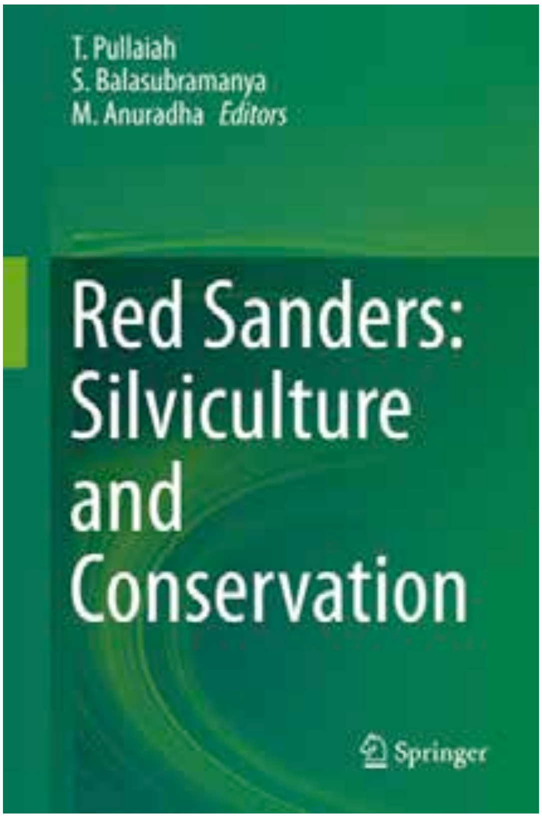
One among the rare and highly valuable timbers of the Indian sub-continent is the Red Sanders. Its natural distribution is confined to a very small region in India. Hyped as 'Pride of Eastern Ghats', its distribution is restricted to Kadapa, Chittoor, Kurnool, and Nellore districts in Andhra Pradesh and a few patches in Vellore, Tiruvannamalai, and Chengalpattu districts in Tamil Nadu.

For a deciduous tree growing up to 15m height, with round symmetrical crown architecture, the tree typically dominates other vegetation in the forest. The tree remains leafless for a short stint of time from February to March. This is followed by new green foliage and bright yellow coloured racemose inflorescence in the subsequent months. The pods mature before the next leaf fall. Red Sanders has a distinctive bark pattern concealing the bright red coloured wood beneath it. This deep red-coloured wood has a high price in the international market because of which this tree is felled rampantly, thus pushing this endemic species to the verge of extinction.

From the 2000s, the Red Sanders has captured the attention of the media due to the illicit felling and trade network, especially the social implications of its illegal trade network. It is believed that the locals and tribal men nearby the forest regions are involved in felling of the trees. Investigations, however, revealed that these men are the mere puppet of the wildlife trade kingpins. These mastermind kingpins engage the locals and tribal men as daily labour for felling the trees. Having little awareness nor any idea about the consequence of felling Red Sanders trees, these labours simply fell the trees to earn their daily wage.

There are dedicated forest staff to patrol and protect the Red Sanders and this has proven to reduce the felling but there is a dark side. Many times, the fellers get shot down by the forest officials or the forest officials get injured or killed. There was a news story published in a leading English daily; The Hindu on 07 April 2015. It was about the 20 tree fellers from Tamil Nadu gunned

Red Sanders: Silviculture and Conservation
T. Pullaiah, S. Balasubramanya & M. Anuradha (eds.)
2019.
ISBN: 9789811376269
Publisher: Springer Singapore
Pages: viii+210pp.



Date of publication: 26 December 2020 (online & print)

by the Andhra Pradesh police department. Another story published in The New Indian Express (on 24 February 2018) reports that “Between January 2015 and December 2017, 10,558 Tamil Nadu residents were arrested by Andhra Pradesh police, forest department and Red Sanders Anti-Smuggling Task Force (RSASTF)”. This led to hatred, ethnicity controversy, insulting and even name-calling of the officials. Overall, it further added to the regional dispute existing between two states, Andhra Pradesh and Tamil Nadu.

Is it a controversial tree? It is one more question in my mind when I began my quest to understand this tree. As a forestry graduate, I first encountered this species in plantations raised in our college. It did not have the appeal, nor the enchantment because it was grown outside the natural geographical zone, however, it was my first encounter with this species. Before my graduation, I did a six-month project work on the characterization of Red Sanders. It was aimed at understanding the phenotypical difference across different provenances. And personally visited some regions in Tamil Nadu where the tree was occurring naturally. More I learned about the species, the more questions popped up in my mind. Some of the questions remain a mystery to me, even today!

So, when I stumbled upon a monograph on Red Sanders, published by Springer, I was instantly curious to open the book anticipating answers to my questions. The book under review pieced together by T. Pullaiah, S. Balasubramanya, and M. Anuradha is an important addition to the literature on Red Sanders. Three editors have meticulously worked to bring out this 15-chapter book. Apart from the editors, there are other prominent researchers and scientists who have also shared their work on Red Sanders in this book.

Now begins the story of the book, with a formal introduction chapter. It is intended for any beginner, giving exposure to Red Sanders as a tree – botanically. Chapter two is all about the taxonomy, one of the core areas of botanical science, and distribution of Red Sanders. The lead author of the first two chapters, Dr. T. Pullaiah’s experience is reflected here. I am sure, even if you have not seen this tree so far, you might become curious like me to know more. On finishing chapter three, the readers might be able to comprehend the reasons – Why this tree is so valued for? Short, explicit narration about the uses of Red Sanders’ wood and its parts are there in chapter three, along with beautiful photographs. Some typical wood characteristic features are also enlisted in chapter 3. Some properties described here may not be familiar, still, they do have significance while identification of wood.

In my opinion, the chapters in this book can be grouped into four sections. The first three chapters form section I, aimed at introducing the species. Chapter four to six is more technical content on biochemistry and pharmacology of Red Sanders. This forms section II. Silviculture, the art and science of cultivating trees is the centre-hub in forestry science. Chapters seven to eleven deal with the silvicultural aspects of Red Sanders. This can be section III. The remaining chapters can be grouped as section IV dealing with a socio-economic and ecological aspect such as genetic diversity, threats, conservation and illegal trade networks. Except for chapter 15, titled as ‘Tree Improvement of Red Sanders’ can be placed after chapter 9, so that there is a coherence.

At the beginning of the article, I was narrating about the media highlighting the conflict due to Red Sanders tree felling. In Chapter 14, there is a long list of news stories published in different newspapers in India. This support my narration about the social significance of this species.

There is repetition of information and content which I believe is inevitable in an edited book, especially when it is about a single species. For instance, there is the redundancy of information on the natural distribution of Red Sanders in many chapters. This does affect the readability of the content. However, there is a specific need to mention the repetition of information even within the same chapter. In chapter three, there are two sub-sections with the same heading – ‘Fluorescence Analysis’. This is one example which indicates that the book needs to be brushed up.

If I need to recommend this book, I feel myself at conflict. For this is not a textbook, nor mere summarization of the information about Red Sanders but I feel it is a book written mainly for researchers. This monograph gives an idea about the research work carried out on Red Sanders and also points out the potential areas to work in future. More specifically, it implies understanding how certain species might be unique and need more focus.

Reference

The New Indian Express (2019). When tribals fall prey to red sanders mafia in Andhra Pradesh. Accessed on 11 May 2020. https://www.newindianexpress.com/thesundaystandard/2018/feb/24/when-tribals-fall-prey-to-red-sanders-mafia-in-andhra-pradesh-1778462.html

Dr. Kailash Chandra, Zoological Survey of India, Jabalpur, Madhya Pradesh, India
Dr. Ansie Dippenaar-Schoeman, University of Pretoria, Queenswood, South Africa
Dr. Rory Dow, National Museum of natural History Naturalis, The Netherlands
Dr. Brian Fisher, California Academy of Sciences, USA
Dr. Richard Gallon, llandudno, North Wales, LL30 1UP
Dr. Hemant V. Ghate, Modern College, Pune, India
Dr. M. Monwar Hossain, Jahangirnagar University, Dhaka, Bangladesh
Mr. Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic.
Dr. Ian J. Kitching, Natural History Museum, Cromwell Road, UK
Dr. George Mathew, Kerala Forest Research Institute, Peechi, India
Dr. John Noyes, Natural History Museum, London, UK
Dr. Albert G. Orr, Griffith University, Nathan, Australia
Dr. Sameer Padhye, Katholieke Universiteit Leuven, Belgium
Dr. Nancy van der Poorten, Toronto, Canada
Dr. Kareen Schnabel, NIWA, Wellington, New Zealand
Dr. R.M. Sharma, (Retd.) Scientist, Zoological Survey of India, Pune, India
Dr. Manju Siliwal, WILD, Coimbatore, Tamil Nadu, India
Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India
Dr. K.A. Subramanian, Zoological Survey of India, New Alipore, Kolkata, India
Dr. P.M. Sureshan, Zoological Survey of India, Kozhikode, Kerala, India
Dr. R. Varatharajan, Manipur University, Imphal, Manipur, India
Dr. Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain
Dr. James Young, Hong Kong Lepidopterists' Society, Hong Kong
Dr. R. Sundararaj, Institute of Wood Science & Technology, Bengaluru, India
Dr. M. Nithyanandan, Environmental Department, La Ala Al Kuwait Real Estate. Co. K.S.C., Kuwait
Dr. Himender Bharti, Punjabi University, Punjab, India
Mr. Purnendu Roy, London, UK
Dr. Saito Motoki, The Butterfly Society of Japan, Tokyo, Japan
Dr. Sanjay Sondhi, TITLI TRUST, Kalpavriksh, Dehradun, India
Dr. Nguyen Thi Phuong Lien, Vietnam Academy of Science and Technology, Hanoi, Vietnam
Dr. Nitin Kulkarni, Tropical Research Institute, Jabalpur, India
Dr. Robin Wen Jiang Ngiam, National Parks Board, Singapore
Dr. Lional Monod, Natural History Museum of Geneva, Genève, Switzerland.
Dr. Asheesh Shivam, Nehru Gram Bharti University, Allahabad, India
Dr. Rosana Moreira da Rocha, Universidade Federal do Paraná, Curitiba, Brasil
Dr. Kurt R. Arnold, North Dakota State University, Saxony, Germany
Dr. James M. Carpenter, American Museum of Natural History, New York, USA
Dr. David M. Claborn, Missouri State University, Springfield, USA
Dr. Kareen Schnabel, Marine Biologist, Wellington, New Zealand
Dr. Amazonas Chagas Júnior, Universidade Federal de Mato Grosso, Cuiabá, Brasil
Mr. Monsoon Jyoti Gogoi, Assam University, Silchar, Assam, India
Dr. Heo Chong Chin, Universiti Teknologi MARA (UiTM), Selangor, Malaysia
Dr. R.J. Shiel, University of Adelaide, SA 5005, Australia
Dr. Siddharth Kulkarni, The George Washington University, Washington, USA
Dr. Priyadarsanan Dharma Rajan, ATREE, Bengaluru, India
Dr. Phil Alderslade, CSIRO Marine And Atmospheric Research, Hobart, Australia
Dr. John E.N. Veron, Coral Reef Research, Townsville, Australia
Dr. Daniel Whitmore, State Museum of Natural History Stuttgart, Rosenstein, Germany.

Fishes

Dr. Neelesh Dahanukar, IISER, Pune, Maharashtra, India
Dr. Topiltzin Contreras MacBeath, Universidad Autónoma del estado de Morelos, México
Dr. Heok Hee Ng, National University of Singapore, Science Drive, Singapore
Dr. Rajeev Raghavan, St. Albert's College, Kochi, Kerala, India
Dr. Robert D. Sluka, Chiltern Gateway Project, A Rocha UK, Southall, Middlesex, UK
Dr. E. Vivekanandan, Central Marine Fisheries Research Institute, Chennai, India
Dr. Davor Zanella, University of Zagreb, Zagreb, Croatia
Dr. A. Biju Kumar, University of Kerala, Thiruvananthapuram, Kerala, India

Amphibians

Dr. Sushil K. Dutta, Indian Institute of Science, Bengaluru, Karnataka, India
Dr. Annemarie Ohler, Muséum national d'Histoire naturelle, Paris, France

Reptiles

Dr. Gernot Vogel, Heidelberg, Germany
Dr. Raju Vyas, Vadodara, Gujarat, India
Dr. Pritpal S. Soorae, Environment Agency, Abu Dubai, UAE.
Prof. Dr. Wayne J. Fuller, Near East University, Mersin, Turkey
Prof. Chandrashekher U. Rivonker, Goa University, Taleigao Plateau, Goa. India

Birds

Dr. Hem Sagar Baral, Charles Sturt University, NSW Australia
Dr. Chris Bowden, Royal Society for the Protection of Birds, Sandy, UK
Dr. Priya Davidar, Pondicherry University, Kalapet, Puducherry, India
Dr. J.W. Duckworth, IUCN SSC, Bath, UK
Dr. Rajah Jayapal, SACON, Coimbatore, Tamil Nadu, India
Dr. Rajiv S. Kalsi, M.L.N. College, Yamuna Nagar, Haryana, India
Dr. V. Santharam, Rishi Valley Education Centre, Chittoor Dt., Andhra Pradesh, India
Dr. S. Balachandran, Bombay Natural History Society, Mumbai, India
Mr. J. Praveen, Bengaluru, India
Dr. C. Srinivasulu, Osmania University, Hyderabad, India
Dr. K.S. Gopi Sundar, International Crane Foundation, Baraboo, USA
Dr. Gombobaatar Sundev, Professor of Ornithology, Ulaanbaatar, Mongolia
Prof. Reuven Yosef, International Birding & Research Centre, Eilat, Israel
Dr. Taej Mundkur, Wetlands International, Wageningen, The Netherlands
Dr. Carol Inskipp, Bishop Auckland Co., Durham, UK
Dr. Tim Inskipp, Bishop Auckland Co., Durham, UK
Dr. V. Gokula, National College, Tiruchirappalli, Tamil Nadu, India
Dr. Arkady Lelej, Russian Academy of Sciences, Vladivostok, Russia

Mammals

Dr. Giovanni Amori, CNR - Institute of Ecosystem Studies, Rome, Italy
Dr. Anwaruddin Chowdhury, Guwahati, India
Dr. David Mallon, Zoological Society of London, UK
Dr. Shomita Mukherjee, SACON, Coimbatore, Tamil Nadu, India
Dr. Angie Appel, Wild Cat Network, Germany
Dr. P.O. Nameer, Kerala Agricultural University, Thrissur, Kerala, India
Dr. Ian Redmond, UNEP Convention on Migratory Species, Lansdown, UK
Dr. Heidi S. Riddle, Riddle's Elephant and Wildlife Sanctuary, Arkansas, USA
Dr. Karin Schwartz, George Mason University, Fairfax, Virginia.
Dr. Lala A.K. Singh, Bhubaneswar, Orissa, India
Dr. Mewa Singh, Mysore University, Mysore, India
Dr. Paul Racey, University of Exeter, Devon, UK
Dr. Honnavalli N. Kumara, SACON, Anaikatty P.O., Coimbatore, Tamil Nadu, India
Dr. Nishith Dharaiya, HNG University, Patan, Gujarat, India
Dr. Spartaco Gippoliti, Socio Onorario Società Italiana per la Storia della Fauna "Giuseppe Altobello", Rome, Italy
Dr. Justus Joshua, Green Future Foundation, Tiruchirapalli, Tamil Nadu, India
Dr. H. Raghuram, The American College, Madurai, Tamil Nadu, India
Dr. Paul Bates, Harison Institute, Kent, UK
Dr. Jim Sanderson, Small Wild Cat Conservation Foundation, Hartford, USA
Dr. Dan Challender, University of Kent, Canterbury, UK
Dr. David Mallon, Manchester Metropolitan University, Derbyshire, UK
Dr. Brian L. Cypher, California State University-Stanislaus, Bakersfield, CA
Dr. S.S. Talmale, Zoological Survey of India, Pune, Maharashtra, India
Prof. Karan Bahadur Shah, Budhanilakantha Municipality, Okhalgaon, Kathmandu, Nepal

Other Disciplines

Dr. Aniruddha Belsare, Columbia MO 65203, USA (Veterinary)
Dr. Mandar S. Paingankar, University of Pune, Pune, Maharashtra, India (Molecular)
Dr. Jack Tordoff, Critical Ecosystem Partnership Fund, Arlington, USA (Communities)
Dr. Ulrike Streicher, University of Oregon, Eugene, USA (Veterinary)
Dr. Hari Balasubramanian, EcoAdvisors, Nova Scotia, Canada (Communities)
Dr. Rayanna Hellem Santos Bezerra, Universidade Federal de Sergipe, São Cristóvão, Brazil
Dr. Jamie R. Wood, Landcare Research, Canterbury, New Zealand
Dr. Wendy Collinson-Jonker, Endangered Wildlife Trust, Gauteng, South Africa

Reviewers 2017–2019
Due to pausity of space, the list of reviewers for 2017–2019 is available online.

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.10

The opinions expressed by the authors do not reflect the views of the Journal of Threatened Taxa, Wildlife Information Liaison Development Society, Zoo Outreach Organization, or any of the partners. The journal, the publisher, the host, and the partners are not responsible for the accuracy of the political boundaries shown in the maps by the authors.

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road,
Saravanampatti, Coimbatore, Tamil Nadu 641035, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa
www.threatenedtaxa.org

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

December 2020 | Vol. 12 | No. 17 | Pages: 17263–17386
Date of Publication: 26 December 2020 (Online & Print)
DOI: 10.11609/jott.2020.12.17.17263-17386

Article

Review

Communications

Short Communications

Notes

Book Review

Publisher & Host
WILD
ZOOREACH
Threatened Taxa

Member
FJN