Building evidence for conservation globally

JoTT

Journal of Threatened Taxa

PLATINUM
OPEN
ACCESS

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

26 November 2019 (Online & Print)
Vol. 11 | No. 14 | 14787–14926

10.11609/jott.2019.11.14.14787-14926
www.threatenedtaxa.org

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

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

Host
Zoo Outreach Organization
www.zooreach.org

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

continued on the back inside cover

Cover: Northern Tamandua *Tamandua mexicana* at Aranjuez, Pitahaya, Puntarenas Province, Costa Rica. © Rodolfo Orozco-Vega.

The Sally Walker Conservation Fund

Wildlife's Wonder Woman

An appeal for support

https://zooreach.org/sally-walker-conservation-fund/

Sally Walker spent 40 years of her life volunteering for wildlife conservation and better zoo management; most of that time living in India and working selflessly for the cause.

She initiated and established several key actions and contributed immensely to the objectives of conservation. In honour of her innumerable and tremendous service to zoos, wildlife, India, South Asia, and the world, we announce the **Sally Walker Conservation Fund** at Zoo Outreach Organization to continue key areas of her interest.

We seek your support and contribution to keep her dreams alive and to continue the long-standing commitments she made for the cause of wildlife conservation and zoos.

Here are the key areas where your financial contributions will impact:

In situ & ex situ
(i) The **Sally Walker Lifetime Award for Conservation** (in situ &/or ex situ).
(ii) The Sally Walker Training Programme in Conservation Biology and Application.
(iii) Communicating Science for Conservation through Zoo's Print and through innovative education programs.

Ex situ
(iv) Recognize zoos in South Asia that excel in zoo education.
(v) Support zoos in India through active training and exposure tours to zoo personnel.
(vi) Plan and support long-term conservation breeding programmes in South Asian Zoos.

In situ
(vii) Promote Conservation Engineering for building holistic conservation efforts.
(viii) Assess, plan, and act for wildlife conservation.
(ix) Small Grants for the conservation of lesser-known species and habitats.

Visit https://zooreach.org/sally-walker-conservation-fund/ and donate generously.

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14788–14801

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

PLATINUM OPEN ACCESS

Complementary bat (Mammalia: Chiroptera) survey techniques uncover two new country records for Nigeria

Iroro Tanshi [1], Anthony Ekata Ogbeibu [2] & Paul Jeremy James Bates [3]

[1,2] Department of Animal and Environmental Biology, Faculty of Life Sciences, University of Benin, PMB 1154 Benin City, Nigeria.
[1] Department of Biological Sciences, Texas Tech University, Lubbock, Texas 79409 USA.
[1,3] Harrison Institute, 15, St Botolph's Road, Sevenoaks, Kent TN13 3AQ, United Kingdom.
[1] iroro.tanshi@uniben.edu (corresponding author), [2] ogbeibu.anthony@uniben.edu, [3] pjjbates2@hotmail.com

Abstract: Knowledge of the bat fauna in Nigeria is limited due to use of outdated collection techniques, and infrequent sampling effort. To advance knowledge of bat diversity in the country, a survey of bats from three localities:—Emu, Okomu National Park (ONP), and Ososo—in southern Nigeria was conducted using mist nets set at canopy and at ground level from February–September 2011. During 28 capture nights involving a total of 202.7 mist net/nights, 239 individuals belonging to 27 bat species in eight families (Emballonuridae, Hipposideridae, Megadermatidae, Molossidae, Nycteridae, Pteropodidae, Rhinolophidae, and Vespertilionidae) were recorded. A total of 130, 64, 45 individuals of 8, 13 and 11 species were recorded from Emu, Okomu, and Ososo, respectively. Two new country records, *Casinycteris campomaanensis* and *Chaerephon aloysiisabaudiae,* both collected from Okomu National Park, are reported for Nigeria. Whereas the former species was collected in a canopy high stacked mist net setup, the latter was collected in a ground level mist net, demonstrating the value of employing contemporary and complementary sampling techniques especially in such understudied regions of Africa.

Keywords: Bats, *Casinycteris campomaanensis, Chaerephon aloysiisabaudiae*, Guinean Forest of western Africa.

DOI: https://doi.org/10.11609/jott.5294.11.14.14788-14801

Editor: Paul A. Racey, University of Exeter, Cornwall, UK.

Date of publication: 26 November 2019 (online & print)

Manuscript details: #5294 | Received 31 July 2019 | Final received 07 November 2019 | Finally accepted 11 November 2019

Citation: Tanshi, I., A.E. Ogbeibu & P.J.J. Bates (2019). Complementary bat (Mammalia: Chiroptera) survey techniques uncover two new country records for Nigeria. *Journal of Threatened Taxa* 11(14): 14788–14801. https://doi.org/10.11609/jott.5294.11.14.14788-14801

Funding: Bat Conservation International; University of Benin; Idea Wild.

Competing interests: The authors declare no competing interests.

Author details: Iroro Tanshi is interested in Afrotropical bat diversity patterns across the Lower Guinean Forest of West Africa and assemblage structure along elevational gradients. She is keen to develop mammal conservation infrastructure of the Afrotropics. Iroro also co-founded and runs a non-profit Small Mammal Conservation Organisation, that is focused on evidence-based conservation of small and medium sized mammals, ecological research and capacity building of local students in Nigeria and across West Africa. Anthony Ekata Ogbeibu is a Hydrobiologist working at the interface of biodiversity, ecology and human disturbance across fresh and brackish water systems across Nigeria. Dedicated to capacity building over the past three decades, he has trained several postgraduate students, with a publication record on the ecology of aquatic fauna and the impact of pollution on aquatic and terrestrial systems. Paul J.J. Bates trained as a small mammal/bat taxonomist. He has published extensively on the diversity, distribution and ecology of bats and rodents in Asia, Arabia and Africa. Through a series of internationally funded projects, he has promoted capacity building, academic supervision and postgraduate training of young scientists and conservationists in the Old World tropics. Today, he works with a new generation of in-country staff and students to preserve and protect wildlife and the environment in Africa and Asia.

Author contribution: IT conducted the field survey, preliminary identification (for some members of Pteropodidae) and wrote the manuscript. AEB supervised the project and contributed to manuscript writing. PJJB contributed to taxonomic notes and manuscript writing.

Ethics statement: The authors affirm that animals were handled following the guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes et al 2011).

Acknowledgements: We are grateful to Dr. Stefan Pettersson for donating equipment and providing field-based training on bat sampling techniques and to Dr. Jakob Fahr for help with project design, species identification and donation of mist nets. Funding for this project was provided by the University of Benin, Bat Conservation International (BCI), and Idea Wild. The National Park Service granted the research permit to survey Okomu National Park, and land owners and community leaders facilitated access to private and communal land in Emu and Ososo.

INTRODUCTION

Africa holds over a fifth of the global diversity of 1,411 bat species (Simmons & Cirranello 2019), but many countries on the continent remain relatively under-surveyed. A recent species distribution model of bats across Africa detected a huge Wallacean shortfall—limited occurrence data primarily due to inadequate sampling (Herkt et al. 2016). To effectively document bat species occurrence and distribution patterns, intensive sampling across multiple localities and habitat types have been suggested (Fahr & Kalko 2011). Over 90% of bat captures in Nigeria were reported prior to the 1980s, showing limited sampling effort in the last four decades (I. Tanshi unpubl. data). Similar reports of limited surveys in recent decades are known from other countries in Africa (Bates et al. 2013; Kangoyé et al. 2015).

Beyond sampling effort, limited knowledge of the fauna in Nigeria is due to inadequate capture techniques employed in previous studies. Elsewhere in the tropics, improvement and implementation of contemporary capture techniques has led to an increase in species discoveries and new distributional records (Francis 1989; Kingston 2010). Employing appropriate sampling techniques in bat surveys is important for local checklists because different trapping methods are optimized for each of the three major bat foraging groups: clutter, edge and aerial, including pteropodids (Kingston 2016). Therefore, inventory completeness relies on appropriate, contemporary and complementary sampling techniques (Meyer et al. 2011). In Nigeria, most bats have been collected by employing inappropriate methods, such as shotguns that are ineffective relative to contemporary techniques like mist nets (Bradley & Dowler 2019) in providing a true insight into a country's bat diversity.

The largest diversity hotspot for bats in Africa is predicted to occur on the easternmost part of the Guinean Forests of West Africa (GFWA) (Herkt et al. 2016). The GFWA is comprised of two blocks – Upper and Lower GFWA, which are separated by the Dahomey gap (Bakarr et al. 2004). Furthermore, the Lower GFWA spans eastern Benin Republic, through southern Nigeria to southwestern Cameroon, with Nigeria holding the largest portion of this forest block. In southern Nigeria the two largest ecoregions are the Nigerian lowland forests and Guinean forest-savanna mosaic. This Guinea savanna area, a heterogeneous transition between forest and savanna, has been demonstrated as a center for high bat diversity in Africa (Fahr & Kalko 2011), making it an important target for bat surveys. Moreover, Nigeria holds 12 terrestrial ecoregions, making it the most ecologically diverse country in western Africa (Olson et al. 2001). Despite being ecologically diverse, the bat fauna of ecoregions across Nigeria is poorly understood, primarily due to limited sampling efforts and the use of outdated sampling techniques.

To improve knowledge of the bat fauna in Nigeria, bat surveys were conducted at three localities across two ecoregions using mist nets installed at ground and canopy level. We report new records for Okomu National Park (ONP) and Nigeria. This is the first study to employ a contemporary survey technique (stacked canopy nets), complemented by ground mist netting in Nigeria.

MATERIALS AND METHODS

Study localities

Three localities were surveyed, Emu, Okomu National Park (ONP), and Ososo (Figure 1), all within Edo State, a landlocked area in southern Nigeria. The Nigerian National Park Service granted permission to conduct surveys in ONP. Community members and individual land owners granted permission for surveys in Emu and Ososo. Vegetation in the state spans lowland rainforest to the south and Guinea savanna to its northern most point. At each locality, bat trapping was conducted at two sites. Sites were selected to represent different vegetation structures or presence of water, in order to capture variability within localities.

Site description

Emu Village

This is a predominantly agricultural landscape with patches of regenerating or degraded forest and farm/bushland fallows. Although on the edge of the lowland forest zone, large scale clearings for farmlands together with the use of fire to clear ground for agriculture have led to the development of a savanna-like landscape. The presence of single-standing tall rainforest tree species, however, indicates a historic lowland forest vegetation in the area.

Site A1: Lat/long (6.558, 6.470): The dominant rainforest tree was *Irvingia gabonensis*, harvested for its edible fruits and nuts, this tree is often left untouched during forest clearing for farming. Other trees include *Hevea brasiliensis* (rubber) and *Bambusa* sp. (bamboo) in addition to *Musa* sp. (banana) and several unidentified grass species.

Site A2: Lat/long (6.559, 6.476): This site was a hilltop with a few tall trees and shrubs interspersed by grasses.

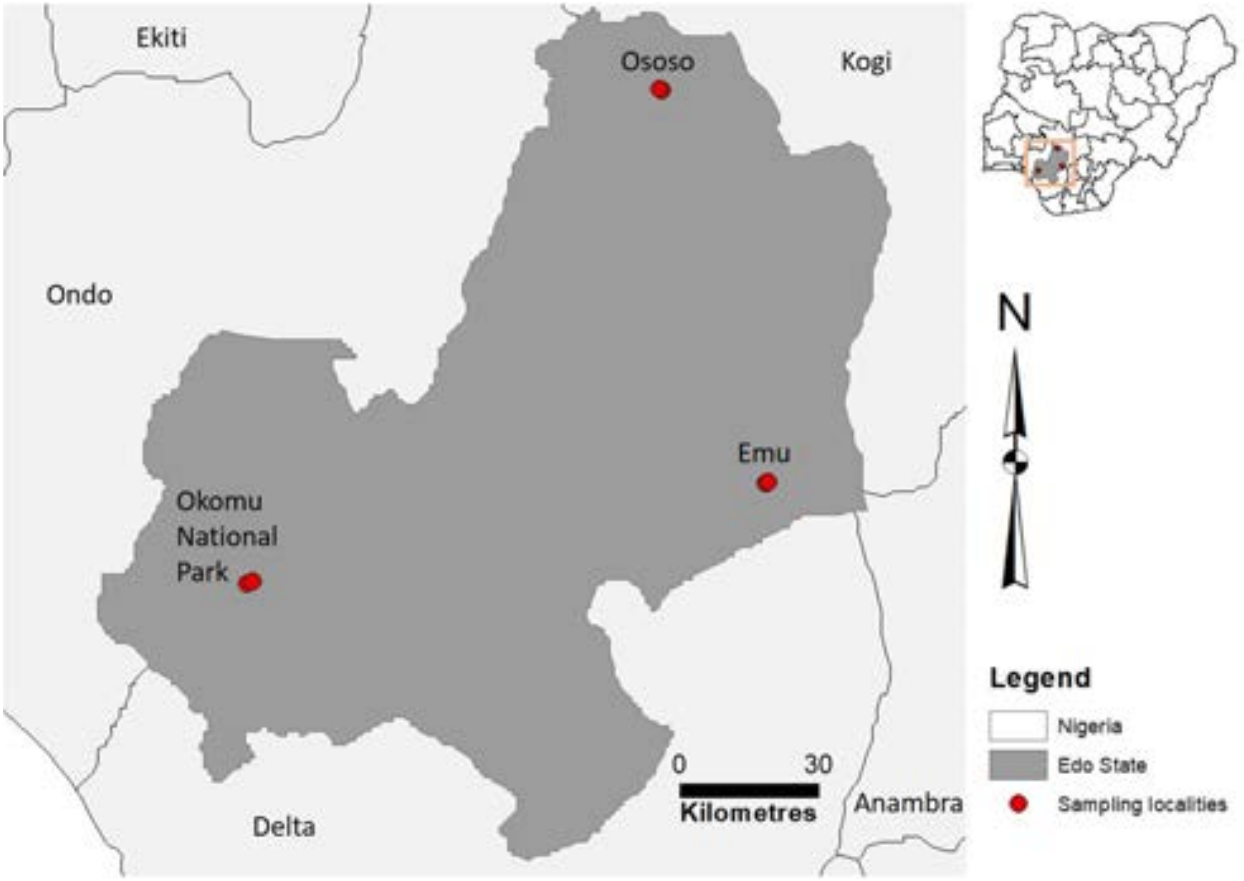

Figure 1. Study localities. Insert: Nigeria, showing spatial extent of surveyed sites.

Okomu National Park

ONP lies 45km west of Benin City adjacent to the larger Okomu Forest Reserve where timber is selectively logged. Annual rainfall ranges 1,524–2,540 mm (Aremu et al. 2012). It falls within the Nigerian Lowland Forest ecoregion (Olson et al. 2001), which is part of the Lower Guinean Forest (Bakarr et al. 2004). Previously known as Okomu Wildlife Sanctuary, ONP is the smallest of the seven national parks in the country with an approximate size of 181km^2. It, however, holds one of the country's last remaining stands of mature lowland forest west of the river Niger. The park is protected for its unique wildlife including the endangered *Cercopithecus erythrogaster* (White-throated Monkey).

Site C1: Lat/long (6.340, 5.345): This site is a seasonal lake (Lake 54), with the dominant tree being *Ceiba pentadra* (Silk cotton tree). During the rainy season, the lake overflows, but is dry in the dry season, during which the lake bed is covered by forbs, tree saplings and grasses, growing up to 0.5m height.

Site C2: Lat/long (6.345, 5.358): This site is just by a vehicle track, next to the park generator house. With the exception of a single individual of *Tectona* sp. the vegetation is closed forest.

Ososo Town

Characteristic of the Guinean forest-savanna mosaic, this is a transition zone between forest to the south and Sahel savanna to the north. The landscape is a wooded savanna vegetation, gallery forests, bare rock surfaces and farms. The terrain is hilly with a network of cave-like habitats formed from granitic boulders. The village is set within the valley of the surrounding Ososo Hills, some of which still hold patches of native vegetation, fragmented by farmland on gentle slopes and at the foot of hills.

Site B1: Lat/long (7.410, 6.244): This site is a fallow farmland vegetation with the dominant tree being few *Parkia biglobosa* surrounded by grasses.

Site B2: Lat/long (7.414, 6.240): This site is a hilltop, forested with dense understory clutter. In addition to *Parkia biglobosa*, other dominant trees were *Cola nitida* (cola nut).

Bat capturing

Bats were captured bimonthly in two 100m^2 plots (sites) per locality between February–September 2011 using 12 x 3 m mist nets with four or five shelves, 16mm mesh, 2 x 70 denier netting. Each sampling plot included eight ground nets and one canopy net. Ground nets were erected using bamboo poles with the lowest point of each net reaching the forest floor or grass layer. Canopy nets comprised of three or four mist nets stacked one above the other and attached to a rope pulley system, which was hoisted between two trees. Canopy net height varied depending on the height of trees at a given plot. Capture efforts varied between localities (Table 1).

Bats were captured between 18.30–06.00 h, and nets checked regularly throughout the night. Bats were retrieved from nets and placed in individual holding bags prior to processing. Routine biometric data were collected from each individual; forearm length (mm) using a Vernier caliper 0.05 precision, body mass (g) using a Pesola spring scale, sex, age and reproductive status (Brunet-Rossinni & Wilkinson 2009; Racey 2009). Identified individuals were released immediately after measurements. We followed Hayman & Hill (1971) and Rosevear (1965) in the identification of captured bats. Handling of captured animals followed Gannon & Sikes (2007). Taxonomy followed Simmons (2005) and where required, supported, by recent revisions. Voucher specimens were collected for all bat species. Skull extraction and measurements used in identification and confirmation of field IDs was performed by Jakob Fahr prior to deposition at the Professor A.B.M. Egborge Museum of the University of Benin City. A handheld GPS (Garmin Etrex) was used to obtain geographical coordinates of sample plots.

RESULTS

We report two new country records *Casinycteris campomaanensis* and *Chaerephon aloysiisabaudiae*. A total of 239 individuals belonging to 27 species and eight families (Emballonuridae, Hipposideridae, Megadermatidae, Molossidae, Nycteridae, Pteropodidae, Rhinolophidae and Vespertillionidae) were recorded from the three localities (Table 1). Of the 27 species, 11 were fruit bats belonging to the single family Pteropodidae with 189 individuals, while 16 were insectivorous bats belonging to seven families of which a total of 50 individuals were captured. Each locality had a unique species composition with only two species (*Eidolon helvum* and *Micropteropus pusillus*) shared between Ososo and Emu, while three species (*Epomops franqueti*, *Megaloglossus woermanni* and *Mops condylurus)* were shared between Emu and Okomu. Table 2 displays forearm length and body mass of species captured during the survey.

Species accounts

New records and material (voucher specimens) are presented, and previous localities for captured species were extracted from published literature. The current IUCN Red List category for each species is also provided (IUCN 2019). Where available, noteworthy ecological or taxonomic details are discussed under notes.

Pteropodidae

***Eidolon helvum* (Kerr, 1792)**

Near Threatened

New records: Emu and Ososo.

Previous records from Nigeria: Yola (Dollman 1908), Panyam (Thomas 1911), Abuehi, Asaba and Gombi (Andersen 1912), Lagos Island (Boulger & Porterfield 1958), University of Ile Ife (Halstead 1977; Okon 1974; Ogunbiyi & Okon 1976; Caxton-Martins 1977; Okon 1980; Aladetuyi 1984; Cole & Marquis 1985; Okon & Ogunbiyi 1997; Nwoha 2000; Agboola et al. 2003; Oke 2004), Abuja (Monath et al. 1974), Ijan Ekiti, Iyin Ekiti, Idanre, Oyo, Okitipukpa (Funmilayo 1978), Ibadan (Funmilayo 1978; Happold & Happold 1978b), Otari and Buguma (Angelici et al. 2000), northern Nigeria (Dzikwi et al. 2010), Oshogbo and New Bussa (Happold & Happold 1978b). The closest reported locality is near Benin by Rosevear (1953).

***Epomops franqueti* (Tomes, 1860)**

Least Concern

New records: Emu and Okomu National Park (Image 1).

New material: Two individuals were collected from Emu Village (F-N^o 62, 73).

Previous records from Nigeria: Old Calabar (Thomas 1880), Asaba (Andersen 1912; Rosevear 1965), Abonuema, Lagos, Oban (Andersen 1912), Umuahia (Rosevear 1965), Ibadan (Caxton-Martins 1977; Happold & Happold 1978b; Bergmans 1982), Olokomeji Forest Reserve, Nikrowa, Sapoba Forest Reserve, Igbo-Oloyin, Omo Forest Reserve (Happold & Happold 1978b), Agege, Calabar, Ife, Odukpani (Bergmans 1982), Leinde Fadali (Hutterer et al. 1992), Otari, Buguma, Orashi and Peterside (Angelici et al. 2000), northern Nigeria (Odebiyi et al. 2004).

Notes: This is a new record for Okomu National Park.

Table 1. Capture effort and the number of individuals of the 27 bat species captured from the three survey localities

		Emu		Okomu		Ososo		
		A1	A2	C1	C2	B1	B2	Total
		Canopy mist net/nights						
		27.4	5	8	17.3	22	1.5	81.2
		Ground mist net/nights						
Family/Species		42.5	-	34	20	25	-	121.5
Pteropodidae	*Eidolon helvum*	19	2			7		28
	Epomophorus gambianus	-	-			1		1
	Epomops franqueti	17	1	4				22
	Hypsignathus monstrosus	-	-	3				3
	Myonycteris angolensis smithii	-	-			4	3	7
	Megaloglossus cf. *woermanni*	1	1	9	1			12
	Micropteropus pusillus	51	4			15		70
	Myonycteris leptodon			29	3			32
	Rousettus aegyptiacus					7	1	8
	Casinycteris campomaanensis				1			1
	Scotonycteris cf. *zenkeri*			4	1			5
Hipposideridae	*Hipposideros* cf. *ruber*					1		1
Rhinolophidae	*Rhinolophus aff. darlingi*					2		2
Megadermatidae	*Lavia frons*			1				1
Nycteridae	*Nycteris arge*				1			1
	Nycteris grandis				2			2
	Nycteris macrotis					1		1
Vespertilionidae	*Glauconycteris beatrix*			1				1
	Mimetillus moloneyi	1						1
	Scotophilus dinganii					1		1
	Scotophilus leucogaster	2						2
	Scotophilus nigrita					1		1
Molossidae	*Chaerephon aloysiisabaudiae*				2			2
	Chaerephon pumilus	1						1
	Mops condylurus	30			1			31
Emballonuridae	*Saccolaimus peli*				1			1
	Taphozous nudiventris					1		1

***Epomophorus gambianus* (Ogilby, 1835)**

Least Concern

New record: Ososo (Image 2).

Previous records from Nigeria: Benin, Gombe (Andersen, 1912), Kabwir (Thomas 1912), Jebba (Andersen 1912; Bræ strup 1933), Nupeko (Monath et al. 1974), Otari, Buguma, Orashi and Peterside (Angelici et al. 2000), northern Nigeria (Dzikwi et al. 2010), near Jebba (Rosevear 1953), Ibadan, Shaffini, Ejigbo, Upper Ogun Game Reserve, Borgu Game Reserve (Oli river), Shagunu (Happold & Happold 1978b).

***Hypsignathus monstrosus* Allen, 1862**

Least Concern

New record: Okomu National Park.

New material: One individual was collected from Okomu NP (F-N^{o} 209).

Previous records from Nigeria: Old Calabar (Murray 1862; Andersen 1912), Kwa and Oban (Andersen 1912), Ibadan and Topo Island (Happold & Happold 1978b), Buguma and Orashi (Angelici et al. 2000), Calabar (Lameed & Ayodele 2008). The closest reported locality is Benin (Rosevear 1953).

Image 1. *Epomops franqueti* (Tomes, 1860).

Notes: This is a new record for Okomu National Park.

***Megaloglossus* cf. *woermanni* Pagenstecher, 1885**

Least Concern

New records: Emu village and Okomu NP.

Previous records from Nigeria: Okomu National Park (Nikrowa), Shasha Forest Reserve, Gambari Forest Reserve, Sapoba Forest Reserve, Ibadan - International Institute for Tropical Agriculture (Happold & Happold 1978), southeastern Nigeria (Luiselli & Angelici 1998), Orashi and Peterside (Angelici et al. 2000).

Notes: Based on molecular data, Nesi et al. (2013) separated eastern populations of *Megaloglossus* from western African ones, and the taxonomic status of specimens Nigeria remain unresolved. Therefore, the status of our collection remains unclear.

***Micropteropus pusillus* (Peters, 1868)**

Least Concern

New record: Emu village (Image 3).

New material: One individual was collected from Ososo (F-N° 58).

Previous records from Nigeria: Nupeko (Monath et al. 1974), Borgu Game Reserve (Oli river), Shaffini, Egbe, Olokomeji Forest Reserve, Upper Ogun Game Reserve, Ibadan (Happold & Happold 1978b), Calabar (Lameed & Ayodele 2008), northern Nigeria (Dzikwi et al. 2010).

Image 2. *Epomophorus gambianus* (Ogilby, 1835) with pup.

Rosevear 1953 lists the species, but no specific localities are provided.

***Myonycteris angolensis smithii* (Bocage, 1898)**

Least Concern

New record: Ososo Town.

New material: One specimen was collected from Ososo Town (F-N° 174)

Previous records from Nigeria: Ipole near Illesha (Happold & Happold 1978b), Filele (GBIF 2018), Idere (HZM), Igbo-Ora (GBIF 2018), Obudu (BM), Odukpani (GBIF 2018), Sapoba, Kagoro (Happold 1987), and Leinde Fadali (Hutterer et al. 1992).

Notes: We follow the suggestion of Nesi et al. (2013) to treat the taxon as a subspecies, with populations in western Nigeria now referred to *M. a. smithii*.

Image 3. *Micropteropus pusillus* (Peters, 1868).

Image 4. *Rousettus aegyptiacus* (Geoffrey 1810).

***Myonycteris leptodon* Dobson, 1878**

Least Concern

New record: Okomu National Park.

New material: Three specimens were collected from Okomu NP (F-N° 98, 104, 120).

Previous records from Nigeria: Ibadan (Bergmans 1976) and Sapoba FR (Happold 1987).

Notes: This is a new record for Okomu National Park. Specimens from both localities were previously identified as *M. torquata*. Specimens west of the river Niger, however, have been assigned to *M. leptodon* that was recently elevated to species rank, with *M. torquata* now restricted to localities east of the river (Nesi et al. 2013).

***Rousettus aegyptiacus* (Geoffrey, 1810)**

Least Concern

New record: Ososo Town (Image 4).

Previous records from Nigeria: Oban (Rosevear 1965), Jos, Kagaro and Kano (Bergmans 1994), Otari, Orashi and Peterside (Angelici et al. 2000).

***Casinycteris campomaanensis* Hassanin, 2014**

Data Deficient

New record: Okomu National Park (Image 5).

New material: One sexually immature individual was collected from Okomu NP (F-N° 103).

Previous localities: The species is not previously known from Nigeria.

Notes: This individual was captured in a ground net at about 1.2m from ground level, and close to a dry seasonal lake. This specimen represents the first record of the species for the country. The species was only recently described from a specimen caught in 2007 from its type locality - Village of Nkoe´lon-Mvini, Campo-Ma'an area, South Region, Cameroon (Hassanin 2014). The current specimen is only the second collection known for the species and is deposited in the personal collection of Jakob Fahr, awaiting transfer to the Prof. A.BM. Egborge Zoological Museum, University of Benin, Benin City.

***Scotonycteris* cf. *zenkeri* Matschie, 1894**

Unassessed

New record: Okomu National Park (Image 6).

New material: One individual was collected at Okomu NP (F-N° 102).

Previous localities: Gambari, Oban, Omo Forest Reserve, Shasha and Sapoba Forest Reserves (Happold & Happold 1978b), Orashi and Peterside (Angelici et al. 2000).

Notes: Based on molecular data, this cryptic species complex was recently resolved across the Guineo-Congolian forest range, but specimens from southwestern Nigeria remain unassessed (Hassanin et al. 2015). Therefore, pending the taxonomic resolution of specimens from southwestern Nigerian, the taxonomic status of our specimen remains unclear and awaits

Image 5. *Casinycteris campomaanensis* Hassanin, 2014, a new record for Nigeria.

Image 6. *Scotonycteris* cf. *zenkeri* Matschie, 1894.

molecular analysis. *Scotonycteris zenkeri* is suggested to occur in Okomu National Park (Anonymous, Okomu NP mammal list). This specimen confirms the presence of a *Scotonycteris* sp. in the park.

Rhinolophidae

***Rhinolophus* aff. *darlingi* Andersen, 1905**

Least Concern

New record: Ososo.

New material: Two individuals were collected at Ososo (F-N° 90, 175).

Previous localities: Kagoro (Hill et al. 1988), specimens reported for Chappal Waddi, Gangirwal as *R. simulator* by Hutterer et al. (1992) have been reidentified by Jakob Fahr (unpubl. data, January 2014).

Hipposideridae

***Hipposideros* cf. *ruber* (Noack, 1893)**

Least Concern

New records: Ososo.

New material: One individual was collected from Ososo (F-N° 89).

Previous localities: Umuahia (Cozens & Marchant 1952), Calabar, Ibadan, Kagoro, Kamuku Game Reserve, Naraguta Forest Reserve, Yankari Game Reserve (Happold 1987), Chappal Waddi, Gangirwal, (Hutterer et al. 1992).

Notes: Based on molecular analysis supported by echolocation data, Vallo et al. (2008) and Monadjem et al. (2013) demonstrated that *H.* cf. *ruber* contained at least eight lineages. As no specimens were examined from Nigeria by both of these studies, the taxonomic status of our specimen remains unclear. Similarly, the taxonomic status of other specimens reported from previous localities in Nigeria remain unclear. Based on echolocation data obtained from specimens collected recently in southeastern Nigeria (I. Tanshi unpubl. data), specimens from the country may belong to C1 and E1 lineages after Monadjem et al. (2013).

Emballonuridae

***Saccolaimus peli* (Temminck, 1853)**

Least Concern

New records: Okomu National Park

New material: One individual was collected from Okomu NP (F-N° 105).

Previous localities: Lagos (Rosevear 1953) as *Taphozous peli*, Oban (Happold 1987) as *Taphozous peli*, Orashi (Angelici et al. 2000).

Notes: This is a new record for Okomu National Park.

***Taphozous nudiventris* Cretzschmar, 1830**

Least Concern

New records: Ososo.

New material: One specimen was collected from

Table 2. Forearm length and body mass of 27 bat species captured during the survey. Values represent mean, range, standard deviation, and count.

Family	Species	Forearm (mm)	Body mass (g)
Pteropodidae	*Eidolon helvum*	118.43,96.2–131,8.7,28	242.96,135–380,55.1,28
	Epomophorus gambianus	86.9,1	148,1
	Epomops franqueti	87.08,77–96.4,4.7,22	101.05,68–143,22.3,22
	Hypsignathus monstrosus	112.87,106.1–122.2,8.4,3	148.33,102–182,41.5,3
	Myonycteris angolensis smithii	50.36,37.6–58,3.3,70	25.21,13–47,6.1,71
	Megaloglossus cf. *woermanni*	73.31,69.8–78.1,3.2,7	61.71,54–72,6.2,7
	Micropteropus pusillus	41.97,39.8–44.3,1.4,12	16.08,11–26,4.5,12
	Myonycteris leptodon	58.5,51.1–64.6,3.5,33	35.63,20–47,7.1,33
	Rousettus aegyptiacus	93.54,80.3–101.8,7.5,8	135.25,85–166,32.1,8
	Casinycteris campomaanensis	67.8,1	36,1
	Scotonycteris cf. *zenkeri*	51.58,48.8–55,2.4,5	24.6,19–35,6.4,5
Hipposideridae	*Hipposideros* cf. *ruber*	51.1,1	12,1
Rhinolophidae	*Rhinolophus* aff. *darlingi*	47.55,47.3–47.8,0.4,2	12.5,12–13,0.7,2
Megadermatidae	*Lavia frons*	54.2,1	22,1
Nycteridae	*Nycteris arge*	38.6,1	8,1
	Nycteris grandis	62.8,61.5–64.1,1.8,2	32.5,31–34,2.1,2
	Nycteris macrotis	49.9,1	15,1
Vespertilionidae	*Glauconycteris* spp.	37.2,1	6,1
	Mimetillus moloneyi	28.4,1	8.5,1
	Scotophilus dinganii	56.6,1	23,1
	Scotophilus leucogaster	52.9,52–53.8,1.3,2	19.5,18–21,2.1,2
	Scotophilus nigrita	89.2,1	79,1
Molossidae	*Chaerephon aloysiisabaudiae*	51.3,51.3–51.3,0,2	25,25–25,0,2
	Chaerephon pumilus	35.6,1	9,1
	Mops condylurus	48.5,45.9–51,1.3,31	23.03,18–35,4.5,31
Emballonuridae	*Saccolaimus peli*	88.4,1	90,1
	Taphozous nudiventris	71.3,1	44,1

Ososo (F-N° 94)

Previous localities: Gomlar, Kabwir (Rosevear 1965), Wase Rock (Dunger 1965).

Nycteridae

***Nycteris arge* Thomas, 1903**

Least Concern

New records: Okomu National Park.

New material: One individual was collected from Okomu NP (F-N° 96).

Previous localities: Akpada, Afon, Kudu (Happold 1987), Orashi (Angelici et al. 2000) Umuahia (Cozens & Marchant 1952), Akpaka Forest Reserve (Bergmans 1977), Calabar (Lameed & Ayodele 2008).

Notes: Unpublished records suggest that this species occurs in Oban (ACR 2017), Nikrowa Forest Reserve (GBIF 2018), Okomu Forest Reserve (GBIF 2018).

***Nycteris macrotis* Dobson 1876**

Least Concern

New records: Ososo (Image 7).

New records: One individual was collected from Ososo (F-N° 55).

Previous localities: Umuahia (Cozens & Marchant 1952), Nasarawa (Rosevear 1965), Akpaka Forest Reserve, Dada, Fanisau (Happold 1987), Shaguna (Bergmans 1977).

***Nycteris grandis* Peters, 1865**

Least Concern

New records : Okomu National Park (Image 8).

New material: Two individuals were collected from Okomu NP (F-N° 241, 243).

Previous localities: Calabar (Thomas 1880), Kagoro, Nikrowa, (Bergmans 1977; Happold 1987).

Image 7. *Nycteris macrotis* Dobson, 1876.

Image 8. *Nycteris grandis* Peters, 1865.

Notes: Nikrowa refers to a village near Okomu National Park. A section of the park is also referred to as Nikrowa by the park rangers. Thus, it is unclear whether the previous record for Nikrowa falls within Okomu NP in the absence of geographical coordinates for this record.

Megadermatidae

***Lavia frons* (Geoffroy, 1810)**

Least Concern

New record: Okomu National Park.

New material: One individual was collected from Okomu NP (F-N° 118).

Previous localities: Yola (Dollman 1908), Ilorin (Rosevear 1953), Pandam (Bergmans 1977), Dikwa, Kainji Lake National Park, Malamfatori, Shaguna (Happold 1987). Omo Forest Reserve is not listed here as a previous locality, because the only known report of the species from that forest represents an incorrect identification (I. Tanshi, pers. obs.) and reported on a bogus species list (Tanshi, 2019).

Vespertilionidae

***Glauconycteris beatrix* Thomas, 1901**

Least Concern

New records: Okomu National Park.

New material: One specimen was collected from Okomu NP (F-N° 240).

Previous localities: The specimen is suspected to be *G. beatrix*, which is listed for Okomu Forest Reserve (Happold 1987). Rosevear (1953) includes *Chalinolobus beatrix*, but no localities are listed.

***Mimetillus moloneyi* (Thomas, 1891)**

Least Concern

New record: Emu (Image 9).

New material: One individual was collected from Emu (F-N° 122).

Previous localities: Lagos as *Vesperugo moloneyi* (Thomas, 1891), as *Eptesicus moloneyi* reported for Lagos (Rosevear 1953; Happold 1987).

***Scotophilus leucogaster* (Cretzschmar, 1830)**

Least Concern

New record: Emu.

New materials: Two individuals were collected from Emu (F-N° 1, 16)

Previously localities: Fika (Happold 1987), Pandam Game Reserve (Bergmans 1977), Maiduguri (Harrison & Brownlow 1978), Bichi, Ibadan, Illorin, Kaduna, Kainji Lake National Park, Kamuku Game Reserve, Mokwa, Panyam, Samaru, Yankari Game Reserve, Zaria (Happold 1987).

Image 9. *Mimetillus moloneyi* (Thomas, 1891).

Image 10. *Chaerephon aloysiisabaudiae* (Festa, 1907), a new record for Nigeria.

***Scotophilus dinganii* (Smith, 1833)**

Least Concern

New record: Ososo.

New material: One individual was collected from Ososo (F-N° 176).

Previous localities: Zaria (Happold 1987), Agege, Darazo, Ibadan, Ife, Jos, Pandam Game Reserve (Bergmans 1977), Kainji Lake National Park, Kamuku Game Reserve, Lagos, Panyam and Shagunu (Happold 1987).

Molossidae

***Chaerephon aloysiisabaudiae* (Festa, 1907)**

Least Concern

New record: Okomu National Park (Image 10).

New material: Two individuals were collected from Okomu NP (F-N° 97, 101).

Previous localities: The species is not previously known from Nigeria.

Notes: This is the first record for the country. Both specimens were caught in canopy nets over a dry seasonal lake (often flooded in the rainy season). One was a lactating female. It is unsurprising that the species occurs in Nigeria, as it is previously known from countries to the east (Cameroon) and west (Ghana). Other countries include Côte d'Ivoire, Gabon, Central African Republic, Democratic Republic of Congo, Sudan, and Uganda (Fahr 2013).

***Chaerephon pumilus* (Cetzschmar, 1830)**

Least Concern

New record: Emu.

New material: One individual was collected from Emu.

Previous localities: Yola as *Chaerephon websteri* (Dollman 1908) *Tadarida websteri* (Rosevear 1953), Maiduguri (Harrison 1958), Pandam, Zawan as *T. gambiana* (Bergmans 1977), Ogbunike cave (Gugnani et al. 1994), Nguru as *T. gambiana* (Lekunze et al. 2001) Calabar as *T. pumila* (Lameed & Ayodele 2008)

Notes: *T. gambiana* was treated as a junior synonym of *Mops pumilus* by Hayman & Hill (1971).

***Mops condylurus* (Smith, 1833)**

Least Concern

New records: Emu and Okomu National Park.

New material: Four individuals were collected from Emu (F-N° 9, 23 and 29) and Okomu NP (F-N° 100)

Previous localities: Umuahia (Cozens & Marchant 1952), Lagos (Rosevear 1953) as *Tadarida angolensis*, Aguleri, Ajaokuta Forest Reserve, Asaba, Enugu, Igbetti, Lokoja, Oyo, Shagunu, Yankari Game Reserve, Zungeru (Happold 1987), Okene, Ajaokuta Forest Reserve, Lokoja, Shaguna (Bergmans 1977), Calabar (Lameed & Ayodele 2008).

Notes: This is a new record for Okomu National Park.

DISCUSSION AND CONCLUSION

This study recorded 239 individuals of 27 bat species belonging to eight families. Of the three sampled localities, only ONP had been previously reported in the literature (Happold 1987), making these first locality records for Emu and Ososo. In addition, at ONP nine species were first time records. Of these, five species (*Chaerephon aloysiisabaudiae, Hypsignathus monstrosus, Lavia frons*, *Mops condylurus*, and *Saccolaimus peli*), all of which are known edge bats or known to forage in the forest canopy, were collected exclusively in canopy net installations. Thus, a survey based on only ground mist nets will likely miss these species, demonstrating the value of complementary capture techniques. Furthermore, the new park records are important because ONP is the last remaining federally protected area holding mature secondary forest west of the river Niger in southern Nigeria. Unlike state-protected forest and game reserves, federal protection for national parks allows paramilitary trained ranger patrols that minimize poaching and encroachment. Recognized as part of the Key Biodiversity Areas (KBA) network, this park is home to some endemic species like the white throated monkey *Cercopithecus erythrogaster* and the site of recent records (across taxa) new to the country and science. It is therefore not surprising that the new country records reported from this survey were both collected at ONP.

Our capture results are similar to findings of other comparable surveys reported elsewhere in West Africa (Decher et al. 2015; Fahr & Ebigbo 2003). Decher et al. (2015) reported 312 individuals of 26 species belonging to eight families, whereas Fahr & Ebigbo (2003) reported 276 bats of 21 species belonging to six families. On the other hand, surveys with fewer captures report fewer bat species (Angelici et al. 2000; Decher & Fahr 2007; Monadjem, Fahr & Allee 2007; Denys et al. 2013). Surveys with higher sampling effort, however, report greater number of species (Fahr & Kalko 2011; Monadjem et al. 2016). Both studies in West Africa that reported higher species richness than the current study employed complementary and contemporary capture techniques (harp traps, canopy and ground mist nets and roost search) over a longer time span. Given the differential detectability of different bat ensembles, this disparity in our captures versus previous reports demonstrates the value of employing diverse capture techniques in bat survey, supporting previous recommendations (Meyer et al. 2011).

In conclusion, our survey improves knowledge of species distribution in this poorly studied part of Africa, by filling geographical gaps. Furthermore, we report new records for a Key Biodiversity Area in southern Nigeria and our capture of two new country records suggests the potential for more species discoveries in this poorly studied but ecologically diverse region of Africa.

REFERENCES

ACR (2017). African Chiroptera Report. AfricanBats NPC Pretoria, 7380pp.

Agboola, F.K., A. Thomson & A. Afolayan (2003). Isolation and properties of cytoplasmic α-glycerol 3-phosphate dehydrogenase from the pectoral muscle of the fruit bat, *Eidolon helvum*. *Biochemistry and Molecular Biology Reports* 36(2): 159–166.

Aladetuyi, S.A. (1984). Roosting and Feeding Behaviour of the Straw-coloured Bats *Eidolon helvum* of University of Ife Campus. BSc Thesis, Dep. of Zoology, University of Ile-Ife.

Andersen, K. (1912). Catalogue of the Chiroptera in the collection of the British Museum: Megachiroptera. 854pp.

Angelici, F.M., S.M., Wariboko, L. Luiselli & E. Politano (2000). A long-term ecological survey of bats (Mammalia, Chiroptera) in the Eastern Niger Delta (Nigeria). *Italian Journal of Zoology* 67(2): 169–174. https://www.tandfonline.com/doi/pdf/10.1080/11250000009356311

Aremu, O.T., G.U. Emelue, F.E. Osayimwen & F.O. Obasogie (2012). Estimate of habitat quality of white throated monkey (*Ceropithecus erythrogaster*) in Okomu National Park, Nigeria. *Nigerian Journal of Agriculture Food and Environment* 8(1): 47–51.

Bakarr, M.I., J.F. Oates, J. Fahr, M.P.E. Parren, M.O. Rödel & R. Demey (2004). *Guinean* forests of West Africa 123–130pp. In: *Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions* CEMEX & Conservation International.

Bates, P.J., K. Cameron, M.J. Pearch & B. Hayes (2013). A review of the bats (Chiroptera) of the Republic of Congo, including eight species new to the country. *Acta Chiropterologica* 15(2): 313–340. https://doi.org/103161/150811013X678955

Bergmans, W. (1976). A revision of the African genus *Myonycteris* Matschie, 1899 (Mammalia, Megachiroptera). *Beaufortia* 24(317): 189–216.

Bergmans, W. (1977). Annotated inventory of 3 small collections of Nigerian Microchiroptera (Mammalia, Chiroptera). *Zeitschrift fur Saugetierkunde-International Journal of Mammalian Biology* 42(5): 279–289.

Bergmans, W. (1982). Noteworthy extensions of known ranges of three African Fruit Bat species (Mammalia, Megachiroptera). *Bulletin Zoologisch Museum* 8(19): 157–163.

Bergmans, W. (1994). Taxonomy and biogeography of African fruit bats (Mammalia, Megachiroptera). 4. The genus *Rousettus* Gray, 1821. *Beaufortia* 44(4): 79–126.

Boulger, L.R. & J.S. Porterfield (1958). Isolation of a virus from Nigerian fruit bats. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 52(5): 269–274.

Bræstrup, F.W. (1933). On the taxonomic value of the subgenus *Lophomops* (Nyctinomine bats), with remarks on the breeding times of African Bats. *Journal of Natural History* 11(63): 269–274.

Bradley, R.D. & R.C. Dowler (2019). A century of mammal research: changes in research paradigms and emphases. *Journal of Mammalogy* 100.3: 719–732.

Brunet-Rossinni, A. K. & G. S. Wilkinson (2009). Methods for age estimation and the study of senescence in bats, pp. 315–325. In: Kunz, T.H. & S. Parsons (eds) *Ecological and Behavioral Methods for*

the Study of Bats. John Hopkins University Press, Baltimore, 901pp.

Caxton-Martins, A.E. (1977). Histochemistry of blood and bone marrow smears of the straw-coloured fruit-eating bat, *Eidolon helvum*. *Journal of anatomy 124*(Pt 1): 31.

Cole, O.F. & V.O. Marquis (1985). A pharmacological analysis of the responses of the gastrointestinal smooth muscle of the bat to transmural and periarterial nerve stimulation. *British Journal of Pharmacology* 84(3): 587–593.

Cozens, A.B. & S. Marchant (1952). A contribution to the fauna of Owerri Province. *Nigerian Field*, 17: 70–79.

Decher, J. & J. Fahr (2007). A conservation assessment of bats (Chiroptera) of Draw River, Boi-Tano, and Krokosua Hills Forest Reserves in the western region of Ghana. *Myotis* 43: 5–30.

Decher, J., A. Hoffmann, J. Schaer, R.W. Norris, B. Kadjo, J. Astrin, A. Monadjem, & R. Hutterer (2015). Bat diversity in the Simandou Mountain Range of Guinea, with the description of a new white-winged vespertilionid. *Acta Chiropterologica* 17(2): 255–282. https://doi.org/10.3161/15081109ACC2015.17.2.003

Denys, C., B. Kadjo, A.D. Missoup, A. Monadjem, & V. Aniskine (2013). New records of bats (Mammalia: Chiroptera) and karyotypes from Guinean Mount Nimba (West Africa). *Italian Journal of Zoology* 80(2): 279–290. https://doi.org/10.1080/11250003.2013.775367

Dollman, G. (1908). On a collection of bats from Yola, northern Nigeria, collected by Mr. G. W. Webster. Annals and Magazine of Natural History (8) 2: 545–547.

Dunger, G.T. (1965). Wase Rock – its history, geology, fauna and climbs. *Nigerian Field* 30: 148–184.

Dzikwi, A.A., I.I. Kuzmin, J.U. Umoh, J.K. Kwaga, A.A. Ahmad, & C.E. Rupprecht (2010). Evidence of Lagos bat virus circulation among Nigerian fruit bats. *Journal of Wildlife Diseases* 46(1): 267–271. https://www.jwildlifedis.org/doi/pdf/10.7589/0090-3558-46.1.267

Fahr, J. (2013). *Tadarida aloysiisabaudiae* Duke of Abruzzi free-tailed bat. In *Mammals of Africa, Vol. IV: Hedgehogs, Shrews and Bats* Bloomsbury 493–495pp.

Fahr, J. & N.M. Ebigbo (2003). A conservation assessment of the bats of the Simandou Range, Guinea, with the first record of *Myotis welwitschii* (Gray, 1866) from West Africa. *Acta Chiropterologica* 5(1): 125–141. https://doi.org/10.3161/001.005.0116

Fahr, J. & E.K. Kalko (2011). Biome transitions as centres of diversity: habitat heterogeneity and diversity patterns of West African bat assemblages across spatial scales. *Ecography* 34(2): 177–195. https://doi.org/10.1111/j.1600-0587.2010.05510.x

Francis, C.M. (1989). A comparison of mist nets and two designs of harp traps for capturing bats. *Journal of Mammalogy* 70(4): 865–870.

Funmilayo, O. (1978). Fruit bats for meat: are too many taken? *Oryx* 14(4): 377–378.

Gannon , W.L., & R.S. Sikes (2007). Guidelines of the American Society of Mammalogists for the use of wild mammals in research. *Journal of Mammalogy* 88(3): 809–823. https://doi.org/10.1644/06-MAMM-F-185R1.1

GBIF (2018). Global Biodiversity Information Facility (GBIF) Occurrence accessed on 03 October 2018. Available for download at https://doi.org/10.15468/dl.slnh4r

Gugnani, H.C., F.A. Muotoe-Okafor, L. Kaufman & B. Dupont (1994). A natural focus of *Histoplasma capsulatum* var. duboisii in a bat cave. *Mycopathologia* 127(3): 151–157.

Halstead, L.B. (1977). Fruit bats - an example of wildlife management. *Nigerian Field* 42(2): 50-56.

Happold, D.C.D. (1987). *The Mammals of Nigeria.* The Clarendon Press, Oxford University Press, New York, xvii+402pp.

Happold, D.C.D. & M. Happold (1978a). The fruit bats of western Nigeria. *Nigerian Field* 43(1): 30–37.

Happold, D.C.D. & M. Happold (1978b). The fruit bats of western Nigeria. *Nigerian Field* 43(2): 72–77.

Harrison, D.L. (1958). A note on successive pregnancies in an African bat (*Tadarida pumila websteri* Dollman). *Mammalia* 22: 592–595.

Harrison, D.L. & I.P. Brownlow (1978). A comparative study of the baculum in bats of the genus *Scotophilus* (Chiroptera: Vespertilionidae). *Mammalia* 42(1): 123–130.

Hassanin, A. (2014). Description of a new bat species of the tribe Scotonycterini (Chiroptera, Pteropodidae) from southwestern Cameroon. *Comptes Rendus Biologies* 337(2): 34–142. https://doi.org/10.1016/j.crvi.2013.12.006

Hassanin, A., S. Khouider, G.C. Gembu, S.M. Goodman, B. Kadjo, N. Nesi, X. Pourrut, E. Nakoune & C. Bonillo (2015). The comparative phylogeography of fruit bats of the tribe Scotonycterini (Chiroptera, Pteropodidae) reveals cryptic species diversity related to African Pleistocene forest refugia. *Comptes Rendus Biologies 338*(3): 197–211. https://doi.org/10.1016/j.crvi.2014.12.003

Hayman, E. & J.E. Hill (1971). Order Chiroptera, pp 1–73. In: Meester, J. & H.W. Setzer (eds.). *The Mammals of Africa, An Identification Manual*. Smithsonian Institution, Washington, DC, USA, 73pp.

Herkt, K.M.B., G. Barnikel, A.K. Skidmore & J. Fahr (2016). A high-resolution model of bat diversity and endemism for continental Africa. *Ecological Modelling* 320: 9–28. https://doi.org/10.1016/j.ecolmodel.2015.09.009

Hill, J.E., D.L. Harrison & T.S. Jones (1988). New records of bats (Microchiroptera) from Nigeria. *Mammalia*, *52*(4): 590–592.

Hutterer, R., F. Dieterlen, & G. Nikolaus (1992). Small mammals from forest islands of eastern Nigeria. *Bonner zoologische Beiträge* 43: 393–414.

IUCN (2019). The IUCN Red List of Threatened Species. Version 2019-2. Available at https://www.iucnredlist.org

Kangoyé, N.M., A. Ouéda, L. Granjon, A. Thiombiano, W. Guenda & J. Fahr (2015). Diversity and distribution of bats (Mammalia Chiroptera) in Burkina Faso. *Biodiversity Journal* 6: 597–632.

Kingston, T. (2010). Research priorities for bat conservation in Southeast Asia: a consensus approach. *Biodiversity and Conservation* 19(2): 471–484.

Kingston, T. (2016). Bats, 59–82pp. In: Larsen, T.H. (Ed.). *Core Standardized Methods for Rapid Biological Field Assessment*. Conservation International, 207pp.

Lameed, G.A. & A.E. Ayodele (2008). Environmental impact assessment of cement factory production on biodiversity: a case study of UNICEM, Calabar Nigeria. *World Journal of Biological Research* 1(1): 1–7.

Lekunze, L.M., A.U. Ezealor & T. Aken'Ova (2001). Prey groups in the pellets of the barn owl *Tyto alba* (Scopoli) in the Nigerian savanna. *African Journal of Ecology* 39(1): 38–44.

Luiselli, L. & F.M. Angelici (1998). Sexual size dimorphism and natural history traits are correlated with intersexual dietary divergence in royal pythons (*Python regius*) from the rainforests of southeastern Nigeria. *Italian Journal of Zoology* 65(2): 183–185. https:doi.org/10.1080/11250009809386744

Meyer, C.F., L.M. Aguiar, L.F. Aguirre, J. Baumgarten, F.M. Clarke, J.F. Cosson, S.E. Villegas, J. Fahr, D. Faria, N. Furey, M. Henry, R. Hodgkison, R.K.B. Jenkins, K.G. Jung, T. Kingston, T.H. Kunz, M.C.M. Gonzalez, I. Moya, B.D. Patterson, J-M. Pons, P.A. Racey, K. Rex, E.M. Sampaio, S. Solari, S., K.E. Stoner, C.C. Voigt, D. von Staden, C.D. Weisse & E.K.V. Kalko (2011). Accounting for detectability improves estimates of species richness in tropical bat surveys. *Journal of Applied Ecology* 48(3): 777–787. https://doi.org/10.1111/j.1365-2664.2011.01976.x

Monadjem, A., J. Fahr & A.E. Allee (2007). Rapid survey of bats of North Lorma, Gola and Grebo National Forests, with notes on shrews and rodents, pp. 49–58. In: Hoke, P., R. Demey & A. Peal (eds.). *A Rapid Biological Assessment of North Lorma, Gola and Grebo National Forests, Liberia*. RAP Bulletin of Biological Assessment 44. Conservation International, Arlington, 109pp.

Monadjem, A., L. Richards & C. Denys (2016). An African bat hotspot: the exceptional importance of Mount Nimba for bat diversity. *Acta chiropterologica* 18(2): 359–375. https://doi.org/10.3161/15081009ACC2016.18.2.005

Monadjem, A., L. Richards, P.J. Taylor, C. Denys, A. Dower, & S. Stoffberg (2013). Diversity of Hipposideridae in the Mount Nimba massif, West Africa, and the taxonomic status of Hipposideros lamottei. *Acta Chiropterologica* 15(2): 341–352.

Monath, T.P., V.H. Lee, D.C. Wilson, A. Fagbami & O. Tomori (1974). Arbovirus studies in Nupeko forest, a possible natural focus of yellow fever virus in Nigeria I. Description of the area and serological survey of humans and other vertebrate hosts. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 68(1): 30–38.

Murray, A. (1862). Description of *Sphyrocephalus labrosus*, a new bat from Old Calabar River, western Africa. *Proceedings of the Zoological Society of London* 1862: 8–11.

Nesi, N., B. Kadjo, X. Pourrut, E. Leroy, C. P. Shongo, C. Cruaud & A. Hassanin (2013). Molecular systematics and phylogeography of the tribe Myonycterini (Mammalia, Pteropodidae) inferred from mitochondrial and nuclear markers. *Molecular Phylogenetics and Evolution* 66(1): 126–137.

Nwoha, P.U. (2000). Sex differences in the bony pelvis of the fruit-eating bat, *Eidolon helvum*. *Folia Morphologica* 59(4): 291–295.

Odebiyi, J.A., S.O. Bada, A.A. Omoloye, R.O. Awodoyin & P.I. Oni (2004). Vertebrate and insect pests and hemi-parasitic plants of Parkia biglobosa and Vitellaria paradoxa in Nigeria. *Agroforestry Systems* 60(1): 51–59. https://doi.org/10.1023/B:AGFO.0000009404.96034.58

Ogunbiyi, O.A. & E.E. Okon (1976). Studies on the digestive enzymes of the African fruit bat *Eidolon helvum* (Kerr). *Comparative Biochemistry and Physiology Part A: Physiology* 55(4): 359–361.

Oke, J.T.O. (2004). The impact of population explosion of the straw-coloured fruit bat (*Eidolon helvum*) on host trees in a park at the Obafemi Awolowo University Campus, Ile-Ife. *Environtropica* 1: 88–94.

Okon, E.E. (1974). Fruit bats at Ife: their roosting and food preferences (Ife fruit bat project no. 2). *Nigerian Field* 39: 33–40.

Okon, E.E. (1980). Histological changes of the interscapular brown adipose tissue in *Eidolon helvum* in relation to diurnal activities of the bats. In: Wilson, D.E. & A.L. Gardner (eds.). Proceedings Fifth International Bat Research Conference. Texas Tech Press, Lubbock, pp. 91–93.

Okon, E.E. & O.A. Ogunbiyi (1997). Further studies on the digestive enzymes of the African fruit bat, *Eidolon helvum* (Kerr.). *Sinet* 2(1):55–62.

Olson, D.M., E. Dinerstein, E.D. Wikramanayake, N.D. Burgess, G.V. Powell, E.C. Underwood, J.A. D'amico, I. Itoua, H.E. Strand, J.C. Morrison, C.J. Loucks, T.F. Allnutt, T.H. Ricketts, Y. Kura, J.F. Lamoreux, W.W. Wettengel, P. Hedao, & K.R. Kassem (2001). Terrestrial Ecoregions of the World: A New Map of Life on Earth: A new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *BioScience* 51(11): 933–938. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

Racey, P.A. (2009). Reproductive assessment of bats. *Ecological and behavioural methods in the study of bats*, pp. 249–264. In: Kunz, T.H. & S. Parsons (eds.). *Ecological and Behavioral Methods for the Study of Bats*. John Hopkins University Press, Baltimore, 901pp.

Rosevear, D.R. (1953). *Checklist and atlas of Nigerian mammals, with a foreword on vegetation.* Government Printer, Lagos. 131pp.

Rosevear, D.R. (1965). *The Bats of West Africa.* British Museum (Natural History), London, 418pp.

Simmons, N.B. (2005). Order Chiroptera, pp. 312–529. In: Wilson, D.E. & D.M. Reeder (eds.). *Mammal Species of the World: A Taxonomic and Geographic Reference.* John Hopkins University Press, volume 1, 2000pp.

Simmons, N.B. & A.L. Cirranello (2019). Bat Species of the World: A taxonomic and geographic database. Accessed on 11/1/2019. Available at www.batnames.org

Tanshi, I. (2019). Capacity building and not expert endorsements overcomes limited taxonomic expertise: Adeyanju et al. (2017) revisited. *Journal of Research in Forestry, Wildlife and Environment* 11(2): 176–177.

Thomas, O. (1880). XXII. On bats from Old Calabar. *Annals and Magazines of Natural History* series 5, 6(32): 164–167.

Thomas, O. (1891). LXII. Descriptions of three new bats in the British Museum collection. *Annals and Magazines of Natural History*, series 6, 7(42): 527–530.

Thomas, O. (1911). LIII.—On mammals collected by the Rev. GT Fox in Northern Nigeria. *Annals and Magazine of Natural History* 7(41): 457–463.

Thomas, O. (1912). Mammals of the Panyam plateau, Northern Nigeria. *Annals and Magazine of Natural History, series–8*, 9: 269 –274.

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14802–14807

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

PLATINUM
OPEN ACCESS

Bone fractures in roadkill Northern Tamandua *Tamandua mexicana* (Mammalia: Pilosa: Myrmecophagidae) in Costa Rica

Randall Arguedas [1], Elisa C. López [2] & Lizbeth Ovares [3]

[1,3] Zoológico Nacional Simón Bolívar, Barrio Amón, Calle 13, San José 11594-1000, Costa Rica.
[2] Parque Ecológico Totláli, Guerrero s/n, San Pablo Tejalpa, Zumpahuacán, Estado de México 51986, México.
[1] ranarg@gmail.com (corresponding author), [2] mvz.elisa.lopez@totlali.com, [3] liz.ovares@gmail.com

Abstract: Northern Tamandua *Tamandua mexicana* is one of the most common roadkill species encountered on Costa Rican highways. Ten roadkill Northern Tamanduas were collected along different roads in Costa Rica and moved to a veterinary facility where appendicular radiologic studies were undertaken. The number of fractures present in each individual varied from zero to five (mean=2.6), with only one animal sustaining no fractures at all. Most fractures were present in the humerus (31%), followed by the ulna and ilium (both 19%), whilst the cranial portion of the body represented the highest number of fractures (61%). These data can contribute, not only to establishing causes of animal-road-mortalities, but also to the future understanding and decision-making of clinical actions for animals injured on the roads.

Keywords: Anteater, car accidents, radiology, roadways, wildlife mortality.

Resume: El tamandúa norteño *Tamandua mexicana* es una de las especies que más comunes que se encuentran atropelladas en las carreteras de Costa Rica. Se recolectaron diez tamandúas atropellados a lo largo de diferentes caminos en Costa Rica y se trasladaron a una clínica veterinaria donde se realizaron estudios radiológicos apendiculares. El número de fracturas presentes en cada individuo varió de cero a cinco (media = 2.6), y solo un animal no sufrió fracturas del todo. La mayoría de las fracturas estaban presentes en el húmero (31%), seguidas por la ulna y el ilion (ambos 19%); la porción craneal del cuerpo representaba el mayor número de fracturas (61%). Estos datos pueden contribuir, no solo al establecimiento de causas de mortalidad de animales en el camino, sino también a la comprensión y toma de decisiones futuras de acciones médicas para animales que son heridos en carreteras

DOI: https://doi.org/10.11609/jott.4956.11.14.14802-14807

Editor: Wendy Collinson-Jonker, Endangered Wildlife Trust, Gauteng, South Africa. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4956 | Received 18 March 2019 | Final received 02 November 2019 | Finally accepted 05 November 2019

Citation: Arguedas, R., E.C. Lopez & L. Ovares (2019). Bone fractures in roadkill Northern Tamandua *Tamandua mexicana* (Mammalia: Pilosa: Myrmecophagidae) in Costa Rica. *Journal of Threatened Taxa* 11(14): 14802–14807. https://doi.org/10.11609/jott.4956.11.14.14802-14807

Funding: Authors used their own resources for this project.

Competing interests: The authors declare no competing interests.

Author details: Randall Arguedas—Zoo and wildlife veterinarian and Master of Science degree on Conservation Medicine. Head veterinarian at the Zoológico Nacional Simón Bolívar. Professor of Zoo and wildlife medicine and surgery at Universidad Técnica Nacional. Research interests are mainly on baseline physiology, anatomy and diseases of wild vertebrates. Elisa C. López—Veterinarian and general manager at Totláli Ecological Park and legal representative of the National Registry of Scientific and Technological Institutions and Companies (RENIECYT). Currently working on the "Etnobiological Garden" research at the Totláli Ecological Park. Lizbeth Ovares—Tropical biologist. Head of the Environmental Education Department at the Zoológico Nacional Simón Bolívar. Research interests are in wildlife urban ecology and human interactions with wildlife.

Author contribution: RA—conceived and designed the study, took the X-rays, analyzed and interpreted data and wrote the paper. ECL—helped in the study design, field, took the X-rays, edited the X-ray images. LO—analyzed and interpreted data, wrote the paper.

Acknowledgements: Dr. Alejandro Gómez, Dr. Ricardo García, and Dr. Natalia Pérez, for facilitating all the x-rays. All the staff from Vías Amigables con la Vida Silvestre Costa Rica.

INTRODUCTION

Highways are significant factors of wildlife mortality; they interfere with natural migration routes and are responsible for habitat fragmentation, which is one of the main causes of biodiversity loss (De la Ossa-V & Galván-Guevara 2015). A further negative impact of roads is the resulting collision with a vehicle, namely, roadkill.

Studies have shown that roadkill seriously decreases animal populations and can even result in local extinctions creating a risk factor for xenarthran persistence, even to non-threatened species (Ribeiro et al. 2017). Among Costa Rican wildlife species, the Common Opossum *Didelphis marsupialis* and a species of anteater *Tamandua mexicana* (Image 1) dominate roadkill numbers (Monge-Nágera 2018b).

Monge-Nágera (2018a) found that *T. mexicana* was the most common roadkill species (n=73), followed by the Common Oppossum (n=66) from data gathered over a four year period (2014–2018). Furthermore, 13 additional *T. mexicana* individuals were detected as roadkill over a one-year period (48 sample efforts) on a 94.9km road (n=7.3 anteater/km) (Artavia et al. 2015) whilst a further seven individuals of *T. mexicana* were found on a 100-km section of road over an eight-month period in 2008 (Carvajal Alfaro & Díaz Quesada 2016).

T. mexicana had higher numbers of roadkill during the dry season (December to April) than the wet season (May to November) in Costa Rica and Colombia (Nadjar & De la Ossa 2013; Monge-Nágera 2018a) possibly because ants are scarcer in dryer habitats than when it is wet, causing anteater species to travel further in search of food. This may result in them crossing roads more frequently and becoming roadkill although this is just speculation since the seasonal behavior of *T. mexicana* is poorly known (Nadjar & De la Ossa 2013; Monge-Nágera 2018a) and further study of their behaviour is needed (Monge-Nágera 2017, 2018a).

Descriptive epidemiological studies of wildlife are an important source of information about natural and non-natural hazards to wildlife populations (Molina-López et al. 2011) and consequently, studies that investigate the causes of mortality have become an important source for ecosystem health monitoring (Molina-López et al. 2011). One of the most common findings in animals hit by automobiles is the appendicular fractures (Minar et al. 2013) which can be surgically treated if an injured animal is taken to a rescue center. Understanding the normal

Image 1. Northern Tamandua *Tamandua mexicana* at Aranjuez, Pitahaya, Puntarenas Province, Costa Rica.

bone radiographic appearance as well as the location of the fracture is vital in assisting the treatment of injured animals. Furthermore, increased public awareness of the number of wildlife injured or killed on Costa Rican roads may have contributed to the mitigation methods being applied.

T. mexicana is a species of a medium-sized anteater ranging from southern Mexico to northwestern Andes in South America and lives in diverse forest ecosystems (Navarrete & Ortega 2011). It is classified as "Least Concern" by the IUCN due to its wide distribution, and presumably, large population, however, the current population trend is unknown (Ortega et al. 2014), although it is represented in protected areas, as well as in anthropogenic ecosystems (Navarrete & Ortega. 2011). Usually solitary by nature, *T. mexicana* ranges often overlap with that of neighboring *T. mexicana*. Females give birth to a single offspring once a year, with the pups becoming independent after one year (Wainwright 2007; Navarrete & Ortega. 2011). Head and body length ranges from between 470–770 mm, with a tail length between 402–672 mm; weight ranges from 2–7 kg (Nowak 1991; Wainwright 2007). *T. mexicana* is both diurnal and nocturnal foraging in trees and on the ground, feeding predominantly on termite genera: (*Armitermes, Calcaritermes, Coptotermes, Leucotermes, Microcerotermes*, and *Nasutitermes;* Navarrete & Ortega 2011) and ant genera (*Camponotus, Azteca*, and *Crematogaster;* Navarrete & Ortega 2011)

The purpose of this communication is to use roadkill *T. mexicana* as tools to demonstrate the location and frequency of bone fractures resulting from an impact with a vehicle. This information can be a valuable reference in future medical and surgical procedures at rescue centers.

METHODS

Ten roadkill of *T. mexicana* were collected between April to July 2016, on different roads in Costa Rica. For each individual, the date and time of collection, geographic coordinates and the person responsible for collecting them were recorded. We believe that two of the animals were at least one year old. The remaining eight individuals consisted of mature animals based on closed epiphyseal growth plates. Based on the presence of the reproductive organs, we were able to sex three of the *T. Mexicana* confirming there were two females and one male; three of the carcasses had no organs, whilst the remaining four individuals were unclear due to damage to the abdominal cavitiy.

The 10 *T. Mexicana* (all deceased) were transferred to a veterinary establishments where appendicular radiology studies were carried out using an Ultra 12040HF (Diagnostic Imaging Systems®) X-ray unit with a CR2000 Plus Scanner and CR200 Navigator Software (Diagnostic Imaging Systems®). Lateral (L) and anteroposterior (AP) orthogonal views of the four extremities were taken. Each animal received six radiographs, with AP projections of the forelimbs and hind limbs performed on both limbs at the same time. Each affected bone, in all animals, had only one fracture, which made further classification easier. For two of the animals, x-rays of the hind legs could not be done due to extensive damage to the legs. For the remaining eight, x-rays of the forelimbs (including the scapula, humerus, radius/ulna, carpus, metacarpals, and phalanges) and x-rays of the hind limbs (including the ilium, ischium, pubis, femur, tibia and fibula, tarsals, metatarsals and phalanges) were all taken.

RESULTS

Of the 10 roadkill, a total of 54 radiographs were taken (Figures 1 & 2). Two individuals had open epiphyseal growth lines indicating that they were juveniles and still growing. The number of fractures present in each individual varied from zero to five (mean=2.6); only one animal did not present any fractures, while three of them had a total of five fractures in different bones (Table 1). Sixty-one percent of the fractures occurred in the cranial portion of the body with the majority observed in the humerus (31%) followed by the ulna (19%) and then the radius (11%). The remaining 39% were present in the caudal portion of the body with the majority observed in the ilial (19%), followed by the femur (12%) and then tibia/fibula (8%); no fractures were observed in the scapula, ischium, pubis, carpal/tarsal, metacarpal/tarsal and phalanges.

DISCUSSION

There are few studies that utilize road-killed animals as a beneficial tool for learning, specifically for evaluating fractures on animal-roadkill species. Most studies that evaluate roadkill-animal-fractures mainly focus on domestic animals (for example, dogs and cats) (Minar et al. 2013; Martínez-Hernández et al. 2017). Despite cats having a similar head and body length (that is, ~460mm) as the *T. mexicana*, our study observed that a higher

Figure 1. Selected x-rays of fractures in different bones from the ten roadkill *T. mexicana* collected between April and July 2016, on different roads in Costa Rica. Anteroposterior and lateral projections are represented. a—diaphyseal radio-ulnar fracture | b—distal ilial fracture | c—distal humeral fracture | d—distal humeral fracture | e—diaphyseal femoral fracture | f—diaphyseal tibial fracture

Table 1. Fractures per individual of the ten roadkill *T. mexicana* collected between April to July 2016, on different roads in Costa Rica.

Individual	Affected bone												
	LH	RH	LR	RR	LU	RU	LF	RF	LT	RT	LI	RI	Total
T1	-	-	-	-	-	-	-	-	-	-	-	-	0
T2	-	1		1	-	1	-	-	-	1	-	1	5
T3	1	-	-	-	-	-	-	-	-	-	-	-	1
T4	-	-	-	-	-	1	-	-	-	1	1	-	3
T5	1	1	1	1	1	-	x	x	x	x	x	x	5
T6	-	-	-	-	-	1	-	1	-	-	-	-	2
T7	-	-	-	-	-	-	-	-	-	-	1	-	1
T8	-	1	-	-	1	-	x	x	x	x	x	x	2
T9	1	1	-	-	-	-	-	1	-	-	1	1	5
T10	-	1	-	-	-	-	-	1	-	-	-	-	2
Total overall	**3**	**5**	**1**	**2**	**2**	**3**	**0**	**3**	**0**	**2**	**3**	**2**	**25**

Key: L—left | R—right | H—humerus | R—radius | U—ulna | F—femur | T—tibia | I—ilium. Individuals T5 and T8 have no hind limb x-rays (x) | -—means no fractures | X—means the individuals did not have the limb.

Figure 2. Four X-rays of complete *T. mexicana* normal extremities. Anteroposterior (AP) and lateral projections (L) are represented. a—AP projection of the pelvic limb | b—AP projection of the thoracic limb | c—L projection of the thoracic limb | d—L projection of the pelvic limb.

percentage of fractures were found in the cranial portion of the *T. mexicana* whilst the most commonly affected bones in cats were found in the caudal portion (such as, the femur (28.2%) and pelvis (24.8%). The same contrast was also noticed with dogs with more fractures observed in the pelvis (15.8%), the femur (14.8%) and the tibia (14.8%) (Phillips 1979). Reasons for a higher percentage of fractures found in the cranial portion of the *T. mexicana* is likely due to a combination of dense roadside habitat and the anatomy of xenarthrans whose plantigrade locomotion, coupled with short limbs, provides low agility and relatively slow locomotion (Ribeiro et al. 2017). They emerge from the forest onto the road, providing a driver with limited visibility ad reaction time, and are often immediately hit by a vehicle in the frontal lateral position (Ribeiro et al. 2017).

Other reasons for xenarthrans being vulnerable to roadkill are their poor vision, which may mean they simply do not see approaching vehicles (Ribeiro et al. 2017). Furthermore, speeding vehicles and poor driver visibility (particularly in areas with dense roadside vegetation) may also influence roadkill occurrence (Collinson et al. 2019).

Similar findings for fractures found on roadkill and comparable with *T. mexicana* is a study undertaken in North America, where an average of four fractures per individual in Virginia opossums *Didelphis virginuanus* were observed (Mead & Patterson 2009). This species is a medium-sized mammal, with head and body length ranging from 325 to 500 mm, weighing between 2–5.5 kg (Novakl 1991) and thus similar to the *T. mexicana*. Mead & Patterson (2009) reported several findings for opossums collected on roads, where the majority of skeletal injuries occurred in the cranial portion of the skeleton (for example, 54% rib fractures and 23% scapular fractures). Similar to the findings of Mead & Patterson (2009) on opossums, we also observed more than one fracture per individual in *T. mexicana*; this is likely due to them being of medium-sized resulting in multiple fractures when colliding with a vehicle (Cross 2012).

CONCLUSION

We found little literature evaluating long bone radiology in *T. mexicana*, therefore the data from our study which provides examples (and images) of normal appendicular x-rays plus the anatomic bone fracture location of trauma, can be used as a reference for further medical or biological studies, specifically at rescue and rehabilitation centers. Veterinarians can use epidemiological information to better understand surgical treatment of *T. mexicana* (and other species of similar size and behaviour), particularly for injured individuals that can then be rehabilitated and released back into the wild.

REFERENCES

Alfaro, V.C. & F.D. Quesada (2016). Registro de mamíferos silvestres atropellados y hábitat asociados en el cantón de La Fortuna, San Carlos, Costa Rica. *Biocenosis* May 17(1–2): 30.

Artavia, A., M. Jiménez, A. Martínez-Salinas, E. Pomareda, D. Araya-Gamboa & E. Arévalo-Huezo (2015). Registro de mamíferos silvestres en la sección de la ampliación de la Ruta 32, Limón, Costa Rica. *Brenesia* 83(84): 37–46.

Collinson, W.J., D.M. Parker,R.T. Bernard,B.K. Reilly & H.T. Davies-Mostert (2019). Factors influencing the spatial patterns of vertebrate roadkill in South Africa: The Greater Mapungubwe Transfrontier Conservation Area as a case study. *African Journal of Ecology* May: 1–13. https://doi.org/10.1111/aje.12628

Cross, A.R. (2012). Fracture biology and biomechanics, pp. 595–571. In: Tobias K. & S. Johnston (eds). *Veterinary Surgery Small Animal, Vol 1*. Saunders, Missouri, 1196pp.

De La Ossa, J. & S. Galván-Guevara (2015). Registro de mortalidad de fauna silvestre por colisión vehicular en la carretera Toluviejo–ciénaga La Caimanera, Sucre, Colombia. *Biota Colombiana* 16(1): 67–77. https://doi.org/10.15517/rbt.v66i2.33404

Martínez-Hernández, A.G., I.A. Quijano-Hernández, J. Del-Ángel-Caraza & M.A. Barbosa-Mireles (2017). Análisis de 71 casos de traumatismo en perros. *Revista Electrónica de Veterinaria* 18(2): 1–7.

Mead, A.J. & D.B. Patterson (2009). Skeletal lesions in a population of Virginia opossums (*Didelphis virginiana*) from Baldwin county, Georgia**.** *Journal of Wildlife Diseases* 45(2): 325–32. https://doi.org/10.7589/0090-3558-45.2.325

Minar, M., Y. Hwang, M. Park, S. Kim, C. Oh, S. Choi & G. Kim (2013). Retrospective study on fractures in dogs. *Journal of Biomedical Research* 14(3): 140–4. https://doi.org/10.12729/jbr.2013.14.3.140

Molina-López, R.A, J. Casal & L. Darwich (2011). Causes of morbidity in wild raptor populations admitted at a wildlife rehabilitation centre in Spain from 1995–2007: a long term retrospective study *PLoS One* 6(9): e24603. https://doi.org/10.1371/journal.pone.0024603

Monge-Nájera J. (2018a). What can we learn about wildlife killed by vehicles from a citizen science project?. A comparison of scientific and amateur tropical roadkill records. *UNED Research Journal* 10(1): 57–60. https://doi.org/10.22458/urj.v10i1.2041

Monge-Nájera J. (2018b). Road kills in tropical ecosystems: a review with recommendations for mitigation and for new research. *Revista de Biología Tropical* 66(2): 722–738. https://doi.org/10.15517/RBT.V66I2.33404

Navarrete, D. & J. Ortega (2011). *Tamandua mexicana* (Pilosa: Myrmecophagidae). *Mammalian Species* 43(1): 56–63. https://doi.org/10.1644/874.1

Novak, R.M. (1991). *Walker´s Mammals of the World, 5th Edition, Vol. I & II*. The John Hopkins University Press, Baltimore, 642pp & 1629pp.

Ortega Reyes, J., D.G. Tirira, M. Arteaga & F. Miranda (2014). *Tamandua mexicana*. The IUCN Red List of Threatened Species 2014:e. T21349A47442649. Downloaded on 11 September 2019. https://doi.org/10.2305/IUCN.UK.20141.RLTS.T21349A47442649.en

Phillips, I.R. (1979). A survey of bone fractures in the dog and cat. *Journal of Small Animal Practice* 20(11): 661–74. https://doi.org/10.1111/j.1748-5827.1979.tb06679.x

Ribeiro, P., J.E. Silveira Miranda & D. Rodrigues de Araújo (2017). The effect of roadkills on the persistence of xenarthran populations: the case of the Brazilian Cerrado. *Edentata* 18: 51–61.

Wainwright, M. (2007). *The Mammals of Costa Rica: A Natural History and Field Guide*. Cornell University Press, Ithaca, New York, 454pp.

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14808–14815

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

PLATINUM OPEN ACCESS

Barilius torsai (Teleostei: Cypriniformes: Cyprinidae), a new freshwater fish from the Brahmaputra drainage, India

Kavita Kumari [1], Manas Hoshalli Munivenkatappa [2], Archana Sinha [3], Simanku Borah [4] & Basanta Kumar Das [5]

[1,2,3,5] ICAR-Central Inland Fisheries Research Institute, Monirampur (Post), Barrackpore, Kolkata, West Bengal 700120, India.
[2] ICAR-Central Marine Fisheries Research Institute Regional Centre, Andhra University (Post), Opposite SBI Kohinoor Branch, Vishakapatnam, Andhra Pradesh 530003, India.
[4] ICAR-CIFRI Centre, HOUSEFEED Complex, Dispur (Last gate), Guwahati, Assam 781006, India.
[1] kavitacof@gmail.com, [2] manas2u@gmail.com, [3] sinhaarchana@yahoo.com, [4] simankuborah@gmail.com (corresponding author), [5] basantakumard@gmail.com

Abstract: *Barilius torsai* is described from the Torsa, a tributary of Brahmaputra River system in West Bengal, India. The new species is distinguished from all its congeners by the presence of a complete lateral line with 52–53 scales, 29 pre-dorsal scales, pectoral fin notched, two well-developed pairs of barbels (rostral and maxillary), length of rostral barbel slightly larger than maxillary, which reaches the orbit. Tubercles on snout and lower jaw absent, 9–11 blue vertical bars along the body, dorsal fin hyaline with dark pigment concentrated along lower two-third of the dorsal-fin rays.

Keywords: Chedrini, Danioninae, taxonomy, Torsa, West Bengal.

Abstract (Hindi): बरीलयिस तोरसाई का वर्णन भारत के पश्चमि बंगाल में ब्रह्मपुत्र नदी प्रणाली की सहायक नदी, तोरसा से कयिा गया। नयी प्रजातकि इसके सजातीय प्रजातयिों से भन्नि होने के लक्षण हैं-52-53 शल्कयुक्त संपूर्ण पाश्र्व रेखा, 29 पूर्व पृष्ठीय शल्क, वक्षीय पख खाँचेदार, दो जोड़े पूर्ण वकिसति बारबेल (रोस्ट्रल एवं मैक्सलिरी), रोस्ट्रल बारबेल की लम्बाई मैक्सलिरी बारबेल से थोड़ा अधकि, जो नेत्र गुहा तक पहुँचती हैं। स्नाउट एवं नचिला जबड़ा पर गाँठ अनुपस्थति, शरीर पर 9-11 नीली उध्र्वाधर लकीर, पारदर्शी पृष्ठीय पंख जसिके नचिले दो- तहिाई भाग पर गहरे रंग के वर्णक की अधकिता है ।

DOI: https://doi.org/10.11609/jott.4746.11.14.14808-14815 | **ZooBank:** urn:lsid:zoobank.org:pub:591E7FA3-82AC-48DE-B249-F09BBC477BE2

Editor: Rajeev Raghavan, Kerala University of Fisheries and Ocean studies (KUFOS), Cochin, India. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4746 | Received 05 December 2018 | Final received 09 September 2019 | Finally accepted 12 November 2019

Citation: Kumari, K., M.H. Munivenkatappa, A. Sinha, S. Borah & B.K. Das (2019). *Barilius torsai* (Teleostei: Cypriniformes: Cyprinidae), a new freshwater fish from the Brahmaputra drainage, India. *Journal of Threatened Taxa* 11(14): 14808–14815. https://doi.org/10.11609/jott.4746.11.14.14808-14815

Funding: Indian Council of Agricultural Research under the Project-REF/ER/12/01/02.

Competing interests: The authors declare no competing interests.

Author details: Kavita Kumari is scientist, Fish Genetics and Breeding at ICAR-CIFRI, Barrackpore and working on taxonomy, systematics and stock characterisation of fish along with assessment of ecosystem health using molecular tools. Manas Hoshalli Munivenkatappa is scientist at ICAR-CMFRI and working on marine fisheries management, stock assessment, fish biology and Fisheries policy. Archana Sinha is Principal scientist at ICAR-CIFRI and working on various aspects of small indigenous fish culture and conservation. Simanku Borah is scientist at ICAR-CIFRI Regional Centre, Guwahati and working in the field of Fishery Biology. He is also involved in research related to ecology and habitat characterization of rivers and wetlands. Basanta Kumar Das is Director, ICAR-CIFRI, Barrackpore and working on the aspects of Inland Fisheries Management.

Author contribution: KK—collected and analyzed specimens, examined the museum specimens, wrote final version of manuscript. MHM— analyzed specimens and helped in the manuscript preparation. AS—supervised study, helped in the revision of the manuscript, SB—examined the museum specimens, helped in revision of the manuscript. BKD—supervised study, helped in the revision of the manuscript.

Acknowledgements: The authors are very grateful to Prof. A. P. Sharma, Former Director, ICAR-CIFRI and Dr. V. R. Suresh, Head of Division, Riverine Ecology and Fisheries for providing facilities for the work. We also thank Director, ZSI, Kolkata, Dr. L. Kosygin Singh, In-charge Freshwater Fish Section, Indian Museum, ZSI, Kolkata, Dr. Bikramjit Sinha, Officer-in-Charge, ZSI, Arunachal Pradesh, Dr. W. Vishwanath Singh, Professor, Department of Life Science, Manipur University and Dr Rameshori Yumnam, Assistant Professor, Department of Life Science, Manipur University for necessary permission and help to examine comparative material. The authors also acknowledge Dr. M.K. Mukhopadhyay retired scientist, ICAR-CIFRI for his guidance for the study.

INTRODUCTION

Fishes of the genus *Barilius* Hamilton (Cyprinidae:Danioninae: Chedrini) are one of the dominant small-sized fishes occurring in hill streams and upland rivers throughout India, Bangladesh, Myanmar, Nepal, Sri Lanka, China, Iraq, and Thailand (Selim & Vishwanath 2002; Jayram 2010; Tejavej 2012; Qin et al. 2019). *Barilius* was erected as a subgenus of *Cyprinus* with *Cyprinus barila* Hamilton, as the type (Qin et al. 2019). Howes (1980) identified two groups within *Barilius* (sensu lato), corresponding to the genera *Barilius* and *Opsarius* (Rainboth 1991). These bariliine fishes are characterised by their relatively elongate, compressed bodies with round belly, vertical bars on the flanks, 9–17 anal-fin rays and sub-laterally placed lateral line (Hamilton 1822; Howes 1980; Talwar & Jhingran 1991; Tejavej 2012). Of the 36 valid species of bariliine fishes, 24 have been recorded in India (Fricke et al. 2019; Qin et al. 2019). Currently, most bariliine fishes, including all southeastern Asian species are assigned to the genus *Opsarius* (Howes 1983; Rainboth 1991; Qin et al. 2019) and the genus *Barilius* is restricted to five species characterized by an extremely shallow body: *B. barila* (Hamilton, 1822), *B. evezardi* Day, 1872, *B. modestus* Day, 1872 and *B. vagra* (Hamilton, 1822) from India, and *B. mesopotamicus* Berg, 1932 from the Tigris-Euphrates basin, based on the diagnosis of *Barilius* sensu by Howes (1980), as well as morphological (Howes 1980; 1983) and molecular phylogenetic evidence (Tang et al. 2010; Liao et al. 2011; Qin et al. 2019).

During an ichthyological survey in the Torsa, a tributary of the Brahmaputra River during July and November 2015, a total of 83 individuals of a *Barilius* species were caught by cast net of mesh size 15–20 mm at Jaldapara, Alipurduar District, West Bengal, India. Examination of the collected specimens in July 2015 and detailed re-examination in November 2015 following standard literature (Jayaram 2010; Arunkumar & Singh 2000; Nath et al. 2010; Dishma & Vishwanath 2012; Knight et al. 2015) revealed that 11 of the 83 specimens could not be assigned to any of the known species. The new species is described herein as *Barilius torsai*.

MATERIALS AND METHODS

Measurements were made with digital caliper with an accuracy of 0.1mm. Counts and measurements were made on the left side of the specimens wherever possible and based on standard methods following Dishma & Vishwanath (2012). Colour pattern was recorded from fresh and preserved (10% formalin) specimens. Voucher specimens are deposited in the Museum of the Zoological Survey of India (ZSI), Kolkata and at the ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore.

Barilius torsai sp. nov.
(Image 1)

urn:lsid:zoobank.org:act:79FEC835-A4FA-4D27-8EC1-2EDD65616A31

Type material

Holotype: ZSI FF5542, 12.xi.2015, 26.729^{0}N & 89.325^{0}E, 71.41mm SL, Torsa River, Jaldapara, Alipurduar District, West Bengal, India, coll. A. Roy Chaudhary.

Paratype: ZSI FF5543, 26.vii.2015, 26.729^{0}N & 89.325^{0}E, 74.56mm SL, data same as for holotype, coll. A. Mitra; CIFRI F10003-10010, 8 ex., 26.vii.2015, 71.46–74.23 mm SL, data same as for holotype, coll. A. Mitra; CIFRI F10011, 12.xi.2015, 71.46mm SL, data same as for holotype, coll. A. Roy Chaudhary.

Diagnosis

Barilius torsai is distinguished from all other species of *Barilius* by a combination of the following characters: lateral line complete with 52–53 scales, 29 pre-dorsal scales, pectoral fin notched, two well-developed pairs of barbels (rostral and maxillary), body with 9–11 blue vertical bars, dorsal fin hyaline with dark pigment concentrated along lower 2/3rd of dorsal-fin rays.

Description

See Table 1 and Supplementary 1 for morphometric characters and image 1 for general appearance. Body shallow, its depth about one-fourth standard length (SL), laterally compressed with ventral profile more convex than the dorsal profile. Caudal peduncle long, narrower near the caudal base. Head small and compressed, length about one-fourth SL, snout slightly blunt. Mouth oblique, angle of gape not reaching vertical from the anterior margin of the orbit. No symphysial process in the lower jaw. Eyes large, situated in the anterior half of the head, diameter about one-fourth head length (HL). Nostrils closer to anterior margin of eye than the snout tip. Two pairs of well-developed barbels (rostral and maxillary), length of rostral barbel slightly larger than maxillary, which reaches the orbit. Tubercles on snout and lower jaw absent.

Dorsal fin with two simple and seven branched rays, its origin posterior to the pelvic-fin origin, and closer to the caudal-fin base than tip of the snout. Pectoral fin

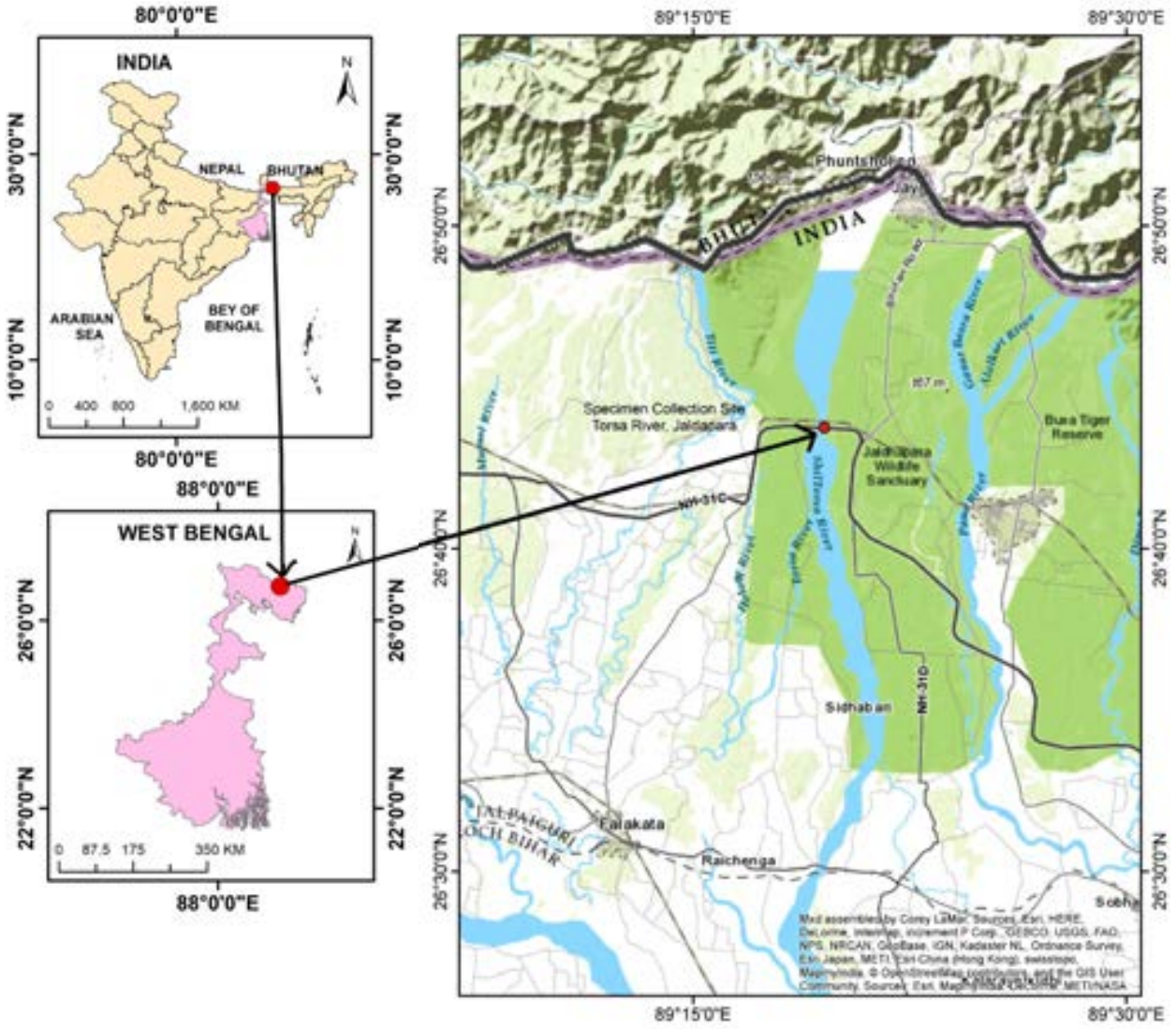

Figure 1. Type locality of *Barilius torsai* sp. nov. indicated in red.

with two simple and 11 branched rays, not reaching the pelvic-fin base, notched after third (between third and sixth ray). Pelvic fin with two simple and seven branched rays, its origin closer to the anal-fin than pectoral-fin origin, posterior tip not reaching anus/anal fin origin, muscular pad at base present. Anal fin with two simple and eight branched rays, its origin just below base of the last dorsal fin ray. Caudal fin deeply forked, lobes equal, with 17 principal rays. Scales cycloid and small. Lateral line complete, slightly curved, running along lower half of the body and passing almost through middle of the caudal base, with 52–53 scales in the lateral-line row up to the end of the caudal base. Scales in transverse line on body 11/1/5 between dorsal fin origin and pelvic fin base. 29 pre-dorsal scales.

Colour

In live and fresh specimens, dorsum appears greyish, sides and belly silvery. Body with 9–11 blue vertical bars, three to five anterior bars almost reaching lateral line, number of bars on either side of the body unequal. Pectoral, pelvic and anal fin hyaline. Caudal fin hyaline, with black margin on fork edges. Dorsal fin hyaline with dark pigment on rays, concentrated along lower two-third of dorsal-fin rays. In preserved specimens, silvery colouration disappears and all dark pigment in fins and body bar turns black. Dorsum appears black and ventral areas creamy.

Image 1. Holotype of *Barilius torsai* sp. nov. (ZSI FF5542; 71.41mm SL): A—lateral view | B—dorsal view. © Sujit Choudhury, ICAR-CIFRI, Barrackpore.

Image 2. Torsa River, Jaldapara, West Bengal, habitat of *Barilius torsai* sp. nov. © Sanjoy Kumar Das, ICAR-CIFRI, Barrackpore.

Etymology

The specific name refers to the Torsa, type locality of the species, and a tributary of the Brahmaputra River System. An adjective.

Distribution

Presently known only from the Torsa River in West Bengal, India (Figure 1, Image 2).

DISCUSSION

Fifteen species of bariliine fish are found in the Brahmaputra basin, and the larger northeastern Indian region. They are *Barilius vagra* (Hamilton, 1822); *B. barila* (Hamilton, 1822); *Opsarius arunachalensis* (Nath et al., 2010); *O. bendelisis* (Hamilton, 1807); *O. howesi* (Barman, 1986); *O. lairokensis* (Arunkumar & T. Singh, 2000); *O. profundus* (Mayanglambam & Vishwanath, 2012); *O. radiolatus* (Gunther, 1868); *O. Shacra* (Hamilton, 1822); *O. barna* (Hamilton, 1822); *O. chatricensis* (Selim & Vishwanath, 2002); *O. dimorphicus* (Tilak & Husain, 1990); *O. dogarsinghi* (Hora, 1921); *O. ngawa* (Vishwanath & Manojkumar, 2002), and *O. tileo* (Hamilton, 1822). *Barilius torsai* sp. nov. is a member of *Barilius*. It can be distinguished from members of *Opsarius* sensu Howes (1980; 1983) in having a shallow body (vs. deep), two pairs of barbels (vs. a single pair or absent), elongated pelvic axial scales (vs. lobate or fleshy), and absence of parallel rows of tubercles on the dentary (vs. presence). *Barilius torsai* can be distinguished from all other congeners by the presence of notched pectoral fin, and from its northeastern Indian congeners by the presence of a complete lateral line with 52–53 scales, greater number of pre-dorsal scales and

Table 1. Morphometric data of *Barilius torsai* sp. nov.

Parameter	Holotype	Paratype(s)
Standard length (SL; mm)	71.41	71.46–74.56
% SL		
Body depth at dorsal-fin origin	23.89	22.17–23.61
Body depth at anal-fin origin	17.74	17.79–18.24
Head length (HL)	26.58	26.66–26.84
Caudal-peduncle length	18.34	15.77–18.24
Caudal-peduncle depth	10.05	10.12–10.68
Pre-dorsal length	55.16	55.19–55.30
Pre-pelvic length	48.34	47.25–47.98
Pre-anus length	68.97	64.67–68.06
Pre-anal length	70.55	66.87–70.47
Dorsal-fin base length	13.98	13.99–14.48
Anal-fin base length	12.03	12.33–13.41
Dorsal-fin height	18.75	18.78–19.54
Pelvic-fin length	12.81	13.00–13.29
Anal fin height	14.33	14.30–14.31
Pectoral-fin length	18.13	17.18–18.10
Caudal-fin length	23.02	23.43–24.14
Body width at anal-fin origin	9.94	9.54–9.89
Body width at dorsal-fin origin	11.47	11.47–12.82
% HL		
Snout length	29.19	23.64–28.69
Interorbital width	31.51	29.69–31.03
Eye orbit diameter	23.5	23.78–25.59
Mouth gape width	20.02	21.11–28.04
Head-depth at eye	56.95	58.13–66.27
Head-depth at nape	67.12	68.96–73.06
Maximum head width	47.26	47.24–47.36
Head-width at eye	44.89	44.86–44.91
Maxillary barbel length	22.23	22.65–25.94
Rostral barbel length	23.97	23.99–29.74

hyaline dorsal fin with dark pigment concentrated along lower two-third of the dorsal-fin rays and lesser body depth at dorsal-fin origin except *B. barila*, *O. shacra*, *O. bendelisis*, *O. chatricensis* (Table 2). *Barilius torsai* further differs from species of *B. vagra* and *B. barila* in having greater number of predorsal scales (29 vs. 21–22 in *B. vagra* and 22 in *B. barila*), lateral line scales (52–53 vs. 40–45 in *B. vagra* and *B. barila*) and lesser number of branched pectoral fin rays (11 vs. 14–15 in *B. vagra* and 12 in *B. barila*).

In comparison to the species currently included within *Opsarius* sensu Howes (1980; 1983) *Barilius torsai* is similar to *O. shacra* and *O. arunachalensis* in its dorsal and anal fin ray counts, but differs from *O. shacra* in having lesser number of lateral line scales (52–53 vs. 59–70), greater number of pre-dorsal scales (29 vs. 22–25), branched pectoral fin rays (11 vs. 14) and the dorsal fin with dark pigment along lower the two-third margin (vs. upper third). It differs from *O. arunachalensis* in having a greater body depth at dorsal-fin origin (22.17–23.89% SL vs. 20.21–20.83% SL), greater number of lateral line scales (52–53 vs. 40–45) and presence (vs. absence) of barbels and vertical bars on body.

Barilius torsai differs from *O. profundus* and *O. lairokensis* in having lesser body depth (22.17–23.89% SL vs. 32.1–37.4% SL in *O. profundus* and 25.54% SL in *O. lairokensis*), greater number of lateral line scales (52–53 vs. 30–35 in *O. profundus* and 41–44 in *O. lairokensis)* and greater number of predorsal scales (29 vs. 17–18 in *O. profundus* and 21 in *O. lairokensis*). *Barilius torsai* further differs from *O. bendelisis, O. howesi* and *O. radiolatus* in having greater number of predorsal scales (29 vs. 18–20 in *O. bendelisis*, 17–18 in *O. howesi* and 24-25 in *O. radiolatus*), lateral line scales (52–53 vs. 39–46 in *O. bendelisis*, 42–43 in *O. howesi* and 56–62 in *O. radiolatus*) and lesser number of branched pectoral fin rays (11 vs. 14 in *O. bendelisis*, 13 in *O. howesi* and 16 in *O. radiolatus)*.

Barilius torsai differs from *O. barna*, *O. chatricensis*, *O. dimorphicus, O. dogarsinghi, O. ngawa*, and *O. tileo* in having greater number of predorsal scales (29 vs. 15–16 in *O. barna*, 15 in *O. chatricensis*, 25–27 in *O. dimorphicus,* 20 in *O. dogarsinghi,* 21–22 in *O. ngawa*, and 28 in *O. tileo*), lateral line scales (52–53 vs. 36–42 in *O. barna*, 38 in *O. chatricensis*, 60–66 in *O. dimorphicus,* 37–40 in *O. dogarsinghi,* 40–43 in *O. ngawa*, and 59+4 in *O. tileo*) and lesser number of branched anal fin rays (8 vs. 10–11 in *O. barna*, *O. dimorphicus* and *O. ngawa*, 10 in *O. chatricensis* and *O. tileo*, and 9 in *O. dogarsinghi*).

A new species of *Barilius* adds to our understanding of the diversity of freshwater fishes of the Torsa River and the eastern Himalayan ecoregion. New discoveries such as this also shows that our understanding of diversity and conservation of freshwater fishes of this region needs to be improved and more exploratory surveys are required.

Comparative material

Barilius barila: ZSI 54500, 85.31mm SL, Jammu, India; ZSI F2549/2, 51.71mm SL, Belsari River (tributary of Brahmaputra River), Assam, India; ZSI F4307/2, 51.79–84.80 mm SL, Barak River, Karong, Manipur, India; MUMF 5049, 5051, 83.22–89.53 mm SL, Khuga River, Churchandpur, Manipur, India.

Table 2. Comparative measurements of body depth, vertical bars on body and meristic counts of *Barilius torsai* sp. nov. with related species of *Barilius* and *Opsarius*.

Species	Body depth (% SL; mm)	Barbels (in pair)	Lateral line scales	Pre-dorsal scales	Vertical bars on body	Anal fin branched rays	Pectoral fin branched rays
B. torsai	22.17–23.89	2	52–53	29	9–11	8	11
B. vagra	25.22–26.71	2	40–45	21–22	10–14	10–12	14-15
B. barila	23.42–24.1	2	40–45	22	14–15	10–11	12
O. shacra	22.24–23.23	2	59–70	22–25	12–13	8	14
O. bendelisis	22.12–26.13	2	39–46	18–20	8–12	7–8	14
O. profundus	32.1–37.4	2	30–35	17–18	7–10	10 1/2	11
O. howesi	30.03–31.73	2	42–43	17–18	14–15	7–8	13
O. radiolatus	-	2	56–62	24–25	Absent	10–11	16
O. lairokensis	25.54	2	41–44	21	14–16	11	13
O. arunachalensis	20.21–20.83	0	40-45	21	Absent	8	11
O. barna	29.0–30.8	0	36–42	15–16	9–11	10–11	12
O. chatricensis	23.2	0	38	15	7–8	10	11
O. dimorphicus	24.9–28.8	1	60–66	25–27	Sopts	10–11	12–13
O. dogarsinghi	24.8–30.0	2	37–40	20	8–9	9	12
O. ngawa	24.8–28.3	2	40–43	21–22	13–14	10–11	12–13
O. tileo	29.9	1	59–4	28	Spots	10	13

Barilius vagra: MUMF Uncat, 41.67–55.69 mm SL, Arunachal Pradesh, India.

Opsarius arunachalensis: APFS/ZSI/P-502, P-503, 110–140 mm SL, Agari River mouth, Pasighat, East Siang District, Arunachal Pradesh, India.

Opsarius barna: MUMF 27061–27064, 73.1–83.21 mm SL, Dikrong River, Arunachal Pradesh, India.

Opsarius bendelisis: ZSI FF1357, 79.71mm SL, Cauvery River, India; ZSI FF4269, 120mm SL, Torsa River, Cooch Behar, northern Bengal, India; ZSI FF4270, 37.21–78.34 mm SL, Lataguri, Jalpaiguri District, northern Bengal, India.

Opsarius chatricensis: MUMF 503/1 (holotype), 86.43mm SL, Chatrickong River, 150km from Imphal, Ukhrul District, Manipur, India. Additional data from Selim & Vishwanath (2002).

Opsarius dimorphicus: Data from Tilak & Husain (1990).

Opsarius dogarsinghi: MUMF 207–210, 52.89–72.26 mm SL, Chakpi Stream, Manipur, India.

Opsarius howesi: ZSI FF2235, FF2236 61–70 mm SL, Jalpaiguri District, northern Bengal, India.

Opsarius lairokensis: MUMF 27075, 108.45mm SL, Moreh Bazar, Moreh, Chandel District, Manipur, India.

Opsarius ngawa: MUMF 149 (holotype), 96.56mm SL, Sherou River (tributary of Manipur river), 83km south of Imphal, Manipur, India; MUMF 27056–27058, 80.1–82.96 mm SL, Singda, Manipur, India.

Opsarius profundus: MUMF 27001 (holotype), 71.21mm SL, Koladyne River, Kolchaw, Lawntlai District, Mizoram, India.

Opsarius radiolatus: Data from Gunther (1868) and Nath et al. (2010).

Opsarius shacra: ZSI F12269, 51.15mm SL, Tribeni, Nepal; ZSI F13405/1, 38.78–73.19 mm SL, Teesta River drainage, Kalimpong Duars & Siliguri Terai, West Bengal, India; CIFRI F10001, 72.53–73.91 mm SL; Siang River, Pasighat, East Siang District, Arunachal Pradesh, India.

Opsarius tileo: MUMF 27076, 128.16mm SL, Umtrao River, Byrnihat, Norbong, Ribhoi District, Meghalaya, India.

REFERENCES

Arunkumar, L. & H.T. Singh (2000). Bariline fishes of Manipur, India, with the description of a new species: *Barilius lairokensis*. *Journal of the Bombay Natural History Society* 97(2): 247–252.

Dishma, M. & W. Vishwanath (2012). *Barilius profundus*, a new cyprinid fish (Teleostei: Cyprinidae) from the Koladyne basin, India. *Journal of Threatened Taxa* 4(2): 2363–2369. https://doi.org/10.11609/JoTT.o2838.2363-9

Fricke, R., W.N. Eschmeyer & R. van der Laan (2019). Catalog of Fishes: Genera, Species, References. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp Electronic version accessed 5 September 2019.

Günther, A. (1868). *Catalogue of The Fishes in The British Museum, Vol. 7*. Department of Zoology, British Museum (Natural History), London, 512pp.

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

Howes, G.J. (1980). The anatomy, phylogeny and classification of bariliine cyprinid fishes. *Bulletin of the British Museum (Natural History) Zoology* 37: 129–198.

Howes, G.J. (1983). Additinal notes on Bariliine cyprinid fishes. *Bulletin of the British Museum (Natural History) Zoology* 45: 95–101.

Jayaram, K.C. (2010). *The Fresh Water Fishes of the Indian Region, 2nd Edition*. Narendra Publishing House, New Delhi, 616pp.

Knight, J.D.M., A. Rai, R.K.P. D'Souza & B. Vijaykrishnan (2015). *Barilius ardens* (Teleostei: Cyprinidae), a new species from the Western Ghats, India, with redescription of *B. malabaricus* and *B. canarensis*. *Zootaxa* 3926(3): 396–412. https://doi.org/10.11646/zootaxa.3926.3.5

Liao, T.Y., E. Ünlü & S.O. Kullander (2011). Western boundary of the subfamily Danioninae in Asia (Teleostei, Cyprinidae): derived from the systematic position of *Barilius mesopotamicus* based on molecular and morphological data. *Zootaxa* 2880(1): 31–40. https://doi.org/10.11646/zootaxa.2880.1.3

Nath, P., D. Dam & A. Kumar (2010). A new fish species of the genus *Barilius* (Cyprinidae: Rasborinae), from river Siang, D'ering memorial wildlife sanctuary, Arunachal Pradesh, India. *Records of the Zoological Survey of India* 110(3): 19–33.

Rainboth, W.J. (1991). Cyprinids of South East Asia, pp. 156–210. In: Winfield, I. & J.S. Nelson (eds.). *Cyprinid Fishes: Systematics, Biology and Exploitation.* Chapman & Hall, London, 667pp.

Selim, K. & W. Vishwanath (2002). A new cyprinid fish species of *Barilius* Hamilton from the Chatrickong River, Manipur, India. *Journal of the Bombay Natural History Society* 99(2): 267–270.

Talwar, P.K. & A.G. Jhingran (1991). *Inland Fishes of India and Adjacent Countries, Vol. 1*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, 541pp.

Tang, K.L., M.K. Agnew, M.V. Hirt, T. Sado, L.M. Schneider, J. Freyhof, Z. Sulaiman, E. Swartz, C. Vidthayanon, M. Miya, K. Saitoh, A.M. Simons, R.M. Wood & R.L. Mayden (2010). Systematics of the subfamily Danioninae (Teleostei: Cypriniformes: Cyprinidae). *Molecular Phylogenetics and Evolution* 57: 189–214. https://doi.org/10.1016/j.ympev.2010.05.021

Qin, T., K.W. Maung & X.Y. Chen (2019). *Opsarius putaoensis*, a new species of subfamily Danioninae (Actinopterygii, Cyprinidae) from the Irrawaddy River basin in northern Myanmar. *Zootaxa* 4615(3): 585–593. https://doi.org/10.11646/zootaxa.4615.3.11

Tejavej, A. (2012). *Barilius signicaudas*, a new species of cyprinid fish from Maeklong Basin, western Thailand (Cypriniformes: Cyprinidae). *Zootaxa* 3586: 138–147. https://doi.org/10.11646/zootaxa.3586.1.13

Supplementary 1. Biometric data of *Barilius torsai* sp. nov.

Measurements	Holotype	Paratype (s)									
	ZSI FF5542	ZSI FF5543	CIFRI F10003	CIFRI F10004	CIFRI F10005	CIFRI F10006	CIFRI F10007	CIFRI F10008	CIFRI F10009	CIFRI F10010	CIFRI F10011
Standard length (mm)	71.41	74.56	71.46	71.67	71.89	72.15	72.17	72.98	73.17	74.23	71.46
Body depth at dorsal-fin origin	17.06	16.53	16.07	16.92	16.95	17.03	16.6	16.59	16.58	16.59	16.04
Body depth at anal-fin origin	12.67	13.6	12.71	12.91	12.81	12.89	12.97	12.99	13.1	13.4	12.98
Head length (HL)	18.98	20.01	19.1	19.17	19.21	19.24	19.31	19.51	19.57	19.89	19.18
Caudal-peduncle length	13.1	11.76	12.96	12.91	13.07	12.46	12.49	12.79	12.87	13.54	12.89
Caudal-peduncle depth	7.18	7.96	7.62	7.39	7.28	7.33	7.34	7.57	7.66	7.56	7.26
Pre-dorsal length	39.39	41.23	39.48	39.57	39.73	39.87	39.88	40.33	40.41	41.02	39.44
Pre-pelvic length	34.52	35.23	34.12	34.17	34.12	34.56	34.19	34.65	34.67	35.17	34.29
Pre-anus length	49.25	48.22	48.23	48.27	48.93	49.11	48.63	48.72	48.57	49.19	48.64
Pre-anal length	50.38	49.86	49.89	49.79	49.32	50.39	49.89	49.87	49.98	50.84	50.36
Dorsal-fin base length	9.98	10.8	10.01	10.17	10.06	10.2	10.43	10.31	10.27	10.53	10.02
Anal-fin base length	8.59	10	8.91	8.97	8.87	9.27	9.37	9.67	9.81	9.92	8.95
Dorsal-fin height	13.39	14.57	13.57	13.78	13.5	13.67	13.58	13.89	14.2	14.46	13.58
Pelvic-fin length	9.15	9.91	9.29	9.42	9.47	9.39	9.43	9.57	9.71	9.79	9.34
Anal-fin height	10.23	10.67	10.22	10.25	10.28	10.32	10.32	10.44	10.47	10.62	10.22
Pectoral-fin length	12.95	12.81	12.35	12.81	13.01	12.84	12.79	12.91	12.88	12.87	12.4
Cauda- fin length	16.44	18	16.74	16.83	16.97	17.31	17.29	17.57	17.54	17.88	16.94
Body width at anal-fin origin	7.1	7.11	6.99	6.98	6.95	6.97	6.98	6.97	7.01	7.34	7
Body width at dorsal-fin origin	8.19	9.56	8.2	8.89	8.39	8.78	9.14	9.27	8.74	9.5	8.25
Snout length	5.54	4.73	4.87	4.77	4.78	4.79	4.76	5.6	4.98	5.53	5.5
Interorbital distance	5.98	5.94	5.78	5.7	5.96	5.78	5.89	5.86	5.91	5.91	5.82
Eye orbit diameter	4.46	5.12	4.68	4.56	4.72	4.65	4.9	4.65	4.98	4.97	4.9
Mouth gape width	3.8	5.61	4.04	4.21	4.73	5.17	5.35	5.28	5.38	5.47	4.05
Head depth at eye	10.81	13.26	12.31	12.15	11.17	12.37	11.23	11.35	12.31	11.94	11.24
Head depth at nape	12.74	14.62	13.69	13.52	13.25	13.42	14.02	14.13	13.79	13.72	13.7
Maximum head width	8.97	9.46	9.03	9.08	9.08	9.09	9.146	9.24	9.25	9.4	9.06
Head width at eye	8.52	8.98	8.57	8.61	8.62	8.64	8.67	8.76	8.78	8.93	8.61
Maxillary barbel length	4.22	5.19	4.33	4.97	4.69	4.74	5.01	5.02	4.98	5.11	4.35
Rostral barbel length	4.55	5.95	4.59	4.6	4.7	5.12	5.32	4.79	4.89	5.39	4.62

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14816–14826

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

PLATINUM
OPEN ACCESS

Butterfly diversity throughout Midnapore urban area in West Bengal, India

Surjyo Jyoti Biswas [1], Debarun Patra [2], Soumyajit Roy [3], Santosh Kumar Giri [4], Suman Paul [5] & Asif Hossain [6]

[1,4,6] Department of Zoology, Sidho-Kanho-Birsha University (SKBU), Ranchi Road, Purulia, West Bengal 723104, India.
[2,3] Centre for Biomedical Engineering, IIT Ropar, Rupnagar, Punjab 140001, India.
[5] Department of Geography, Sidho-Kanho-Birsha University, Ranchi Road, Purulia, West Bengal 723104, India.
[1] surjyo@rediffmail.com, [2] patradebarun@gmail.com, [3] s20roy1994@gmail.com, [4] girisantoshkumar7@gmail.com, [5] suman.krish.2007@gmail.com, [6] asifhossain.bu@gmail.com (corresponding author)

Abstract: Butterflies have always attracted attention due to their unique colourations. As most butterflies are highly specific in their niche utilisation, abundance of the species in a locality may advocate status of ecosystem functioning and environmental health. In recent times, different anthropogenic activities and unscientific management of nature have resulted in a decline of butterfly communities at a rapid rate. The objective of the present study is to study butterfly diversity in and around Midnapore Town, West Bengal, India. A total of 82 butterfly species belonging to six families were recorded during the two years of the study period. Of the six families Nymphalidae is the most abundant family comprising 42.54% of the total population followed by Lycaenidae (22.5%), Pieridae (19.03%), Papilionidae (8.58%), Hesperiidae (7.24%), and Riodinidae (0.11%). Different diversity indices, Lorenz curve, Whittaker plot, and Gini index show high diversity in the butterfly community structure. As Midnapore Town is the connecting area between the plains of Bengal and Chota Nagpur Plateau, the present study may be the baseline for further ecological, environmental, and conservation studies.

Keywords: Chota Nagpur Plateau, diversity indices, Lepidoptera, Lorenz curve, Nymphalidae, plains of Bengal.

DOI: https://doi.org/10.11609/jott.4587.11.14.14816-14826

Editor: Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4587 | Received 25 September 2018 | Final received 16 October 2019 | Finally accepted 28 October 2019

Citation: 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

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Surjyo Jyoti Biswas is currently working in Department of Zoology as Professor, SKBU and works in the area of ethnobotany, Debarun Patra and Soumyajit Roy are PhD fellow and works at IIT Ropar, Santosh Kumar Giri currently works as Assistant Teacher, Govt of West Bengal, Suman Paul is a Professor in Department of Geography at SKBU and works in the area of urban Geography, Asif Hossain is working as Assistant Professor in Zoology, SKBU and works in the field of Bioremediation and Biodiversity.

Author contributions: DP, SR, SKG collected the field data, SP prepared the map of study area, SJB and AH participated in planning and guiding the study, evaluation of results and performed statistical analysis. All authors participated in preparing the final version of the manuscript.

Acknowledgements: SJB and AH thankfully acknowledge Head, Department of Zoology, SKB university for providing necessary facilities and DBT-BOOST, Government of West Bengal for infrastructural support.

INTRODUCTION

Butterflies play a pivotal roles for stability in food webs as: herbivores (Rusman et al. 2016), pollinators (Atmowidi et al. 2007; Mukherjee et al. 2015), host of parasitoids (van Nouhuys & Hanski 2002), and prey of predators (Hammond & Miller 1998; Rusman et al. 2016). Numerous butterfly species act as biological indicators of environmental health and ecological changes (Hill 1999; Kocher & Williams 2000; Koh & Sodhi 2004; Thomas 2005; Posha & Sodhi 2006; Koh 2007) as they can be very sensitive to habitat fragmentation and climate change (Kunte 2000). Butterflies contribute to a large extent in maintaining the community structure of flora in the tropical regions (Bonebrake et al. 2010; Samanta et al. 2017).

Empirical studies show that the Indian subcontinent hosts about 1,318 species of butterflies (Varshney & Smetacek 2015). Over the last few decades, however, various anthropogenic activities and sudden climatic change conditions have led to modification of the habitat structure and function which in turn negatively influenced butterfly diversity (Clark et al. 2007; Di Mauro et al. 2007). Therefore, the diversity studies of butterflies are critical to determine the effects of urbanization on butterfly communities and other aspects of biodiversity conservation (Blair 1999; Singh & Pandey 2004; Clark et al. 2007; Di Mauro et al. 2007; Saikia et al. 2009; Mukherjee et al. 2015). Butterfly diversity indirectly also reflects the diversity of various plant communities (Murugesan et al. 2013; Mukherjee et al. 2016). Pollard (1988) reported that biotic and abiotic factors also influence butterfly populations, indicating the bio-indication potential of the group. There are numerous reports by various investigators on butterfly diversity from different parts of India (Bhaskaran & Eswaran 2005; Eswaran & Pramod 2005; Tiple & Khurad 2009; Nimbalkar et al. 2011; Tiple 2011; Kunte et al. 2012; Majumder et al. 2012; Tiple 2012; Harsh 2014).

Midnapore is the headquarters of the district West Midnapore of the state of West Bengal in India. It is in the junction of the plains of Bengal and Chota Nagpur Plateau. The plains of Bengal are enriched mostly with agricultural fields where as the Chota Nagpur Plateau is mostly tropical deciduous forestland. Since no systematic study of diversity of butterfly fauna was ever conducted in and around Midnapore Municipality area there is no documentation, the present investigation was carried out to explore the status of butterfly fauna in Midnapore Municipal area.

MATERIALS AND METHODS

Study Area

The study was conducted in and around Midnapore Municipality area of West Midnapore District of West Bengal, India. The study area (22.262^{0}N & 87.654^{0}E; elevation about 1,035m) is situated on the banks of river Kangasabati on one side and the other side consists of sparse to highly dense forest, chiefly of *Shorea robusta*, which connects with Dalma Hills and is the entry point of Bengal-Jharkhand hill range of Chota Nagpur Plateau. This range is often used as an elephant corridor, though the town is not affected by elephants. Several adjacent areas like Gopegarh Heritage Park, Banks of Kasai River adjacent to the railway track, Vidyasagar Park, Khudiram Park, area adjacent to Aniket Bandh, Pakhibagan, Vidyasagar University Campus, area adjacent to government Silkworm Centre, Police Line field, and Ramakrishna Ashram field were the main points of study area (Figure 1).

Methods

The survey of butterflies was done using Pollard walk method (Pollard et al. 1975; Pollard 1977). The surveys of butterflies were carried out in most of the designated areas during day time mostly on sunny days (07.00 to 10.00 h). Occasional surveys were also undertaken during early morning and even after 16.00h in search of the butterflies that love shadows during summer months. The study areas were mainly divided into 12 sites and conducted on regular basis through random visit and photographs of most of the species were taken all over the year. The line transect method was used principally for assessing the butterfly communities (Hossain & Aditya 2016). We refrained from collection of live specimens or use of nets so as not to put these insects under stress or harm them accidentally during the investigation. Most of the species were identified through photographs taken from different angle so as to make a positive identification. Photographs were taken using Canon 600D +(55-250) mm f/4-5.6 lens and a Nikon L820 point & shoot camera. Identification of specimen was done following the keys of Evans (1932), Wynter-Blyth (1957), Kehimkar (2008), and Kunte (2012). Further, help was also taken from www.ifoundbutterflies.org.

Biodiversity indices

Different dominance indices and information statistic indices were analysed with the help of Microsoft Excel 2010 software to understand the community structure

Figure 1. Satellite view of twelve sites of the study area. The sites are as follows: Banks of Kasai river adjacent to railway track (P1), Vidyasagar park (P2), Midnapore College campus (P3) Khudiram park (P4), area adjacent to Aniket Bandh (P5), Policeline Field (P6), Pakhibagan (P7), Ramakrishna ashram field (P8), Vidyasagar University Campus (P9), area adjacent to government Silkworm Centre (P10) and Gopegarh Heritage Park (P11 and P12).

of the butterflies in the study area. Species richness was analysed through Shanon index (Shannon & Weaver 1963) whereas, species abundance was analysed through Simpson index (Simpson 1964) and evenness was studied through Pielou index (Mulder et al. 2004). A rank abundance curve or Whittaker plot was used to show relative abundance of different species. The plot simultaneously represents species richness and species evenness. Lorenz curve was used to show inequality in the population distribution of different species in the community (Damgaard & Weiner 2000).

Species Richness

Shanon index is an important information-statistic index, used in measuring species richness in a community. Rare species with very few individuals can contribute some value to this biodiversity index. The index is calculated through the following equation:

$H_s = -\Sigma\, p_i \ln p_i$

where, H_s is the value of Shanon index and pi is the proportion of i^{th} species in the community.

Species Abundance

Simpson's index is the measures of probability that two individuals randomly selected from a community will belong to the same species. Simpson's index was calculated using the protocol given by Simpson 1964 (Simpson 1964):

$\lambda = \Sigma\, p_i^2$

where, λ is the value of Simpson index and p_i is the proportion of i^{th} species in the community.

Species Evenness

Species evenness denotes how close the species are in a community numerically. Statistically it is well-defined as a degree of species diversity which quantifies how equal the community is. Evenness of species in a community can be represented by Pielou's index (Pielou

1969), as follows:

$E = H_s / H_{max}$ where, E is the evenness, H_s is the value of Shanon index and H_{max} is equal to ln(s) (Where, S=number of species in the community)

Whittaker plot and Lorenz curve

Whittaker plot or rank-abundance curve is a graphical representation used in ecology to display relative species abundance. In the rank abundance curve, the X-axis is denoted as abundance rank and Y-axis is denoted as relative abundance. Further, it is used to visualize species richness and evenness simultaneously (Whittaker 1965). Lorenz curves were used to demonstrate phenomena such as disproportionate distribution of species abundance in a community. This curve was also used to demonstrate degree of inequality in abundance in a community. Quantitative comparison of rank abundance curves of different families of butterflies can demonstrate the unequal distribution of species.

SHE analysis

SHE analysis scrutinizes the relationship between species richness (S), diversity as measured by Shanon index or the information (H) and evenness (E) in the samples. The most obvious advantage of this analysis is that it allows to interpret variations in the diversity (Magurran 1988). SHE analysis fundamentally can shed light on the species abundance and distribution (Buzas & Hayek 1998). The SHE analysis (McAleece et al. 1997) provides the variations in the species richness, abundance and evenness in the sample size (N) or throughout the months (N, over time) abundance for an area (Mukherjee et al. 2015) in a nutshell. The analysis for SHE was conducted using PAST software (Hammer et al. 2001).

RESULTS AND DISCUSSION

During the present study period overall 82 species of butterflies were recorded in the field with a total of 5,107 individuals belonging to six families. The list of the butterflies along with their occurrence and time of appearance has been listed in Table 1. Of the butterfly species recorded, most are 'common' and 'generalist' species (Sarma et al. 2012), and not a single species is threatened globally as per the IUCN Red List 2018, however, there are many species which were declared legally protected, viz., Gram Blue *Euchrysops cnejus*, Pointed Ciliate Blue *Anthene lycaenina*, Common Gull *Cepora nerissa* under Schedule II, and Striped Albatross *Appias libythea* under Schedule IV of the Wildlife Protection Act, 1972. The study shows higher species richness when compared with other empirical studies (Jana et al. 2013; Samanta et al. 2017; Pahari et al. 2018) on butterfly diversity in the nearby urban and forested areas except Kolkata's suburban areas which shows 91 species (Mukherjee et al. 2015).

Satellite overview of the marked study area have been represented in Figure 1. During the study period we found that family Nymphalidae is the dominant species comprising 2,173 number of individuals which constitutes 42.54% of the total population followed by Lycaenidae comprising 1,153 numbers of individuals and 22.5%, followed by Pieridae (971 individuals and 19.03%), Papilionidae (438 and 8.58%), Hesperiidae (370 and 7.24%), and Riodinidae (2 and 0.11%) (Figure 2). Previous study support Nymphalidae as the most dominant family in the semi-urban areas of Howrah and Haldia (Pahari et al. 2018) whereas, Lycaenidae as the most dominant family in the suburban areas of Kolkata, West Bengal (Mukherjee et al. 2015).

Papilio polytes which belongs to family Papilionidae was found to be the most abundant while *Papilio crino* was the least. In the family Pieridae, *Catopsilia pomona* was more predominant than other species but we found only a single species of *Ixias marianne*. In the family Nymphalidae we found that *Danais chrysippus* was the most common species while *Lethe europa* was the least.

The Shanon-Weaver index for the studied community with a value of 4.01 shows that the community is a natural one with high species richness. As the value of Simpson index increases, the species abundance decreases. The value of Simpson's index ranges between 0 and 1 and the more the index value inclined to 0 the more the species abundance in the community. The value of Simpson's

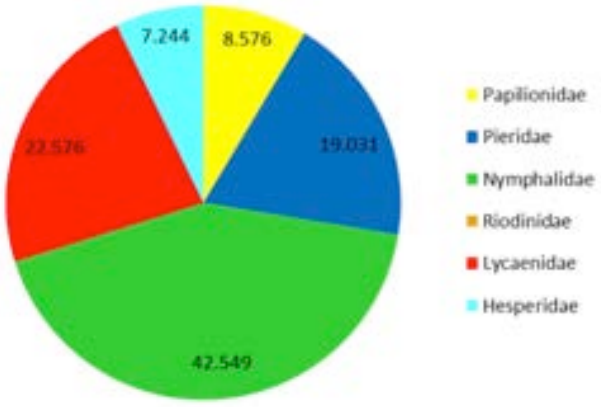

Figure 2. Family wise composition (%) of Butterfly species in the study area.

Table1. Butterfly species, their abundance and season of occurrence in the study area.

	Common name	Scientific name	Total number of species found during study period (2013–2015)	Season	Observed time (M/N/A)
Family: Papilionidae					
1	Common Rose	*Atrophaneura aristolochiae* (Fabricius)	78	Feb–Nov	M, N
2	Common Mormon	*Papilio polytes* (Linnaeus)	126	Jan-Dec	M, N
3	Blue Mormon	*Papilio polymnestor* (Cramer)	12	Aug-Nov	M, N
4	Common Jay	*Graphium doson* (Felder)	63	Jan-Dec	N
5	Tailed Jay	*Graphium agamemnon* (Linnaeus)	44	May-Nov	N
6	Lime Butterfly or Common Lime	*Papilio demoleus* (Linnaeus)	81	Jan-Dec	M, N, A
7	Common Mime	*Chilasa clytia* (Linnaeus)	19	Aug-Oct	N, A
9	Common-banded Peacock	*Papilio crino* (Fabricius)	4	Jul-Aug	A
10	Spot bar Swordtail	*Graphium nomius* (Esper)	11	Jun-Oct	M, A
Family: Pieridae					
11	Common Albatross	*Appias albino* (Boisduval)	59	Mar-Nov	M
12	Common Emigrant	*Catopsilia pomona* (Fabricius)	196	Jan-Dec	M, N, A
13	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus)	171	Jan-Dec	M, A
14	Common Grass Yellow	*Eurema hecabe* (Linnaeus)	124	Jan-Dec	M, N, A
15	Small Grass Yellow	*Eurema brigitta* (Cramer)	49	Jun-Oct	
16	Pioneer	*Belenois aurota* (Fabricius)	6	Jul-Aug	A
17	Common Gull	*Cepora nerissa* (Fabricius)	63	Mar-Dec	M, N
18	Common Jezebel	*Delias eucharis* (Drury)	97	Jan-Dec	M, A
19	White Orange tip	*Ixias marianne* (Cramer)	1	Sept	M,A
20	Yellow Orange tip	*Ixias pyrene* (Linnaeus)	15	Apr-Oct	M, A
21	Psyche	*Leptosia nina* (Fabricius)	104	Jan-Dec	M, N, A
22	Common Wanderer	*Pareronia valeria* (Cramer)	86	Jun-Dec	N
Family: Nymphalidae					
23	Common Castor	*Ariadne merione* (Cramer)	43	Mar-Oct	M, A
24	Angled Castor	*Ariadne ariadne* (Moore)	119	Jan-Dec	M, N, A
25	Tawny Coster	*Acraea violae* (Fabricius)	143	Feb-Nov	M, A
26	Plain Tiger	*Danais chrysippus* (Linnaeus)	211	Jan-Dec	M, N, A
27	Stripped Tiger	*Danais genutia* (Cramer)	82	Feb-Nov	M, N, A
28	Common Crow	*Euploea core* (Cramer)	131	Jan-Dec	M, N, A
29	Blue Tiger	*Tirumala limniace* (Cramer)	64	Mar-Nov	M, A
30	Common Leopard	*Phalanta phalantha* (Drury)	37	Mar-Dec	N
31	Baronet	*Symphaedra nais* (Forster)	34	Mar-Sept	M, A
32	Common Baron	*Euthalia aconthea* (Cramer)	27	Mar-Oct	A
33	Common Sailor	*Neptis hylas* (Linnaeus)	18	Feb-Nov	M, N
34	Chestnut-streaked Sailor	*Neptis jumbah* (Moore)	19	Feb-Nov	M, N, A
35	Great Eggfly	*Hypolimnas bolina* (Linnaeus)	49	Jan-Dec	N, A
36	Peacock Pansy	*Junonia almanac* (Linnaeus)	94	Jan-Dec	N, A
37	Blue Pansy	*Junonia orithya* (Linnaeus)	66	Mar-Oct	M, N, A
38	Yellow Pansy	*Junonia hierta* (Fabricius)	47	Jan-May	M, A
39	Lemon Pansy	*Junonia lemonias* (Linnaeus)	138	Jan-Dec	N, A
40	Grey Pansy	*Junonia atlites* (Linnaeus)	161	Jan-Dec	N, A
41	Chocolate Pansy	*Junonia iphita* (Cramer)	39	Apr, Oct	N
42	Common Palmfly	*Elymnias hypermnestra* (Linnaeus)	50	Dec- May	N, A

	Common name	Scientific name	Total number of species found during study period (2013–2015)	Season	Observed time (M/N/A)
43	Common Evening brown	*Melanitis leda* (Linnaeus)	182	Jan-Dec	M, A
44	Common Bush Brown	*Mycalesis perseus* (Fabricus)	163	Jan-Dec	A
45	Dark Branded Bushbrown	*Mycalesis mineus* (Linnaeus)	43	Oct-Mar	N, A
46	Common Fourring	*Ypthima huebneri* (Kirby)	121	Jan-Deb	M, A
47	Common Fivering	*Ypthima baldus* (Fabricus)	33	May-Oct	N
48	Bamboo Tree brown	*Lethe europa* (Fabricus)	3	Mar	M
49	Commander	*Moduza procris* (Cramer)	56	Jun-Nov	M, N
Family: Riodinidae					
50	Double-banded Judy	*Abisara bifasciata* (Moore)	2	Dec-Mar	N
Family: Lycaenidae					
51	Ape Fly	*Spalgis epius* (Westwood)	9	Mar-Nov	M, N
52	Common Pierrot	*Castalius rosimon* (Fabricius)	144	Jan-Dec	M, N
53	Common Cerulean	*Jamides celens* (Cramer)	49	Jul-Oct	M, N
54	Common Lineblue	*Prosotas nora* (Felder)	33	Jan-Oct	M, N
55	Common Quacker	*Neopithecops zalmora* (Butler)	31	Jul-Nov	N, A
56	Common Silverline	*Spindasis vulcanus* (Fabricius)	67	Jun-Nov	M, N
57	Dark Cerulean	*Jamides bochus* (Stoll)	5	Mar-Apr	A
58	Dark Grassblue	*Zizeeria karsandra* (Moore)	167	Jan-Dec	M, N, A
59	Falcate Oakblue	*Mahathala ameria* (Hewitson)	8	Apr-Nov	M, N
60	Gram Blue	*Euchrysops cnejus* (Fabricius)	96	Jan-Dec	M, N, A
61	Indian oakblue	*Arhopala atrax* (Hewitson)	12	Jun-Jul	
62	Lesser Grassblue	*Zizina otis* (Fabricius)	17	Jul-Oct	M, N
63	Lime Blue	*Chilades lajus* (Stoll)	121	Feb-Nov	M, N, A
64	Tailless Lineblue	*Prosotas dubiosa indica* (Evans)	5	Jul	N
65	Oriental Grass Jewel	*Freyeria putli* (Stoll)	4	Mar-Aug	
66	Pale Grass Blue	*Pseudozizeeria maha* (Kollar)	109	Mar-Oct	
67	Plains Cupid	*Chilades pandava* (Horsfield)	38	May-Sep	M, N, A
68	Rounded Pierrot	*Tarucus nara* (Kollar)	146	Mar-Oct	N, A
69	Slate Flash	*Rapala manea* (Hewitson)	64	Mar-Dec	M
70	Zebra Blue	*Leptotes plinius* (Fabricius)	17	May-Jul	M, A
71	Pea Blue	*Lampides boeticus* (Linnaeus)	11	Oct-Nov	N
Family: Hesperiidae					
72	Brown Awl	*Badamia exclamationis* (Fabricius)	14	Jun-Aug	N, A
73	Chestnut Bob	*Lambrix salsala* (Moore)	78	Jan-Dec	M, N
74	Common branded Awl	*Hasora chromus* (Cramer)	2	Aug	M
75	Common snow Flat	*Tagiades japetus* (Stoll)	13	Nov-Jan	M
76	Forest Hopper	*Astictopterus jama* (Felder and Felder)	1	Oct	M
77	Indian Grizzle Skipper	*Spialia galba* (Fabricius)	29	May-Jul	M, A
78	Moore Ace	*Halpe porus* (Mabille)	2	Jul-Aug	N
79	Indian Palm Bob	*Suastus gremius* (Fabricius)	74	Jan-Dec	M, N
80	Tree Flitter	*Hyarotis adrastus* (Stoll)	52	Sep-Feb	M
81	Common Redeye	*Matapa aria* (Moore)	82	Feb-Nov	M, N, A
82	Grass Demon	*Udaspes tolus* (Cramer)	23	Aug-Dec	M, N, A

M—morning (05.00–10.59) | N—noon (11.00–15.59) | A—afternoon: (16.00–19.00).

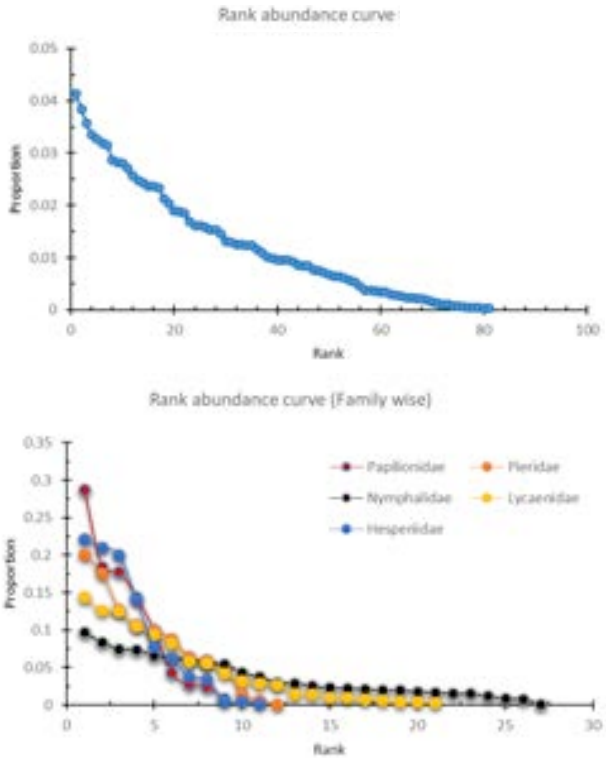

Figure 3. A. Whittaker plot of rank-abundance of the butterfly community B. Family wise rank-abundance curve

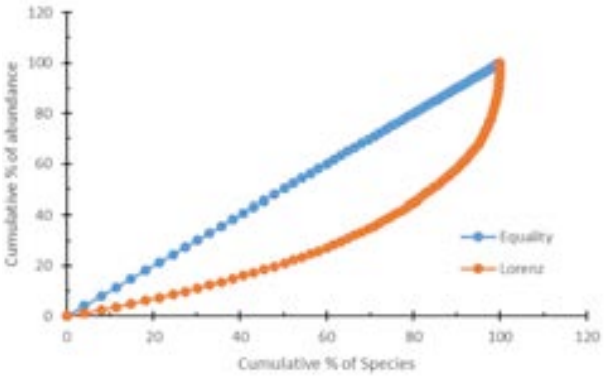

Figure 4. Lorenz curve showing inequality in species richness and abundance.

Table 2. Values of different biodiversity indices.

Shanon Index	Simpson Index	Pielou Index	Lorenz Curve	
4.01	0.02	0.91	Lorenz Area	Gini Index
			13.46	0.2692

index in this study is 0.021 that shows an intuitive high proportion to species abundance. As we know the value of Pielou's index ranges between 0 and 1 and the more the index value reaches 1 the more the evenness in the community. The species evenness (E=0.91) calculated for the studied community shows high evenness (Table 2).

The rank abundance curve for the community has a relatively low steep inclination in Whittaker plot showing high evenness as the high-ranking species have much lower abundances than the low-ranking species. A low gradient dictates high evenness among the different species (Figure 3 A). The rank-abundance curve when compared family wise (Figure 3 B) shows that family Nymphalidae has the highest species evenness, whereas family Papilionidae has the lowest species evenness. In Lorenz curve (Figure 4) a perfectly equal species abundance would be one in which every species has the same population size. The Gini coefficient is the ratio of the area between the line of equality and Lorenz curve. It ranges between 0 and 1. The higher the Gini coefficient, the more unequal the population distribution (Gini 1936). In the present study (Table 2) the Gini coefficient value is 0.269 that supports the species richness and species abundance demonstrated through the Shanon and Simpson index.

Observations on SHE graphs of monthly variations in richness and abundance of butterfly species clearly indicate log series pattern of distribution, where S will increase, H will remain constant and E will decrease (Figure 5) (Hayek & Buzas 1997; Buzas & Hayek 2005; Magurran 2004). It seems that the butterfly abundance increased in winter and post monsoon and decreased in summer and monsoon. This may be due to the changes in the temperature in this lateritic soil area and high precipitation in the monsoon may cause destruction of the habitats as well as food supply of most of the species concerned.

CONCLUSION

The present report on the butterflies in and around Midnapore Municipality area is the first of its kind. There are no such records on the studies of butterflies earlier from the region. Butterflies are susceptible to subtle changes in landscape, land use patterns and vegetation loss, therefore, utmost care should be taken to preserve not only butterflies but also the species that support them. Percentage-wise distribution of the family Riodinidae was the lowest so it might be that the habitat of the study areas and climate of the region was not suitable for the family in the present investigation

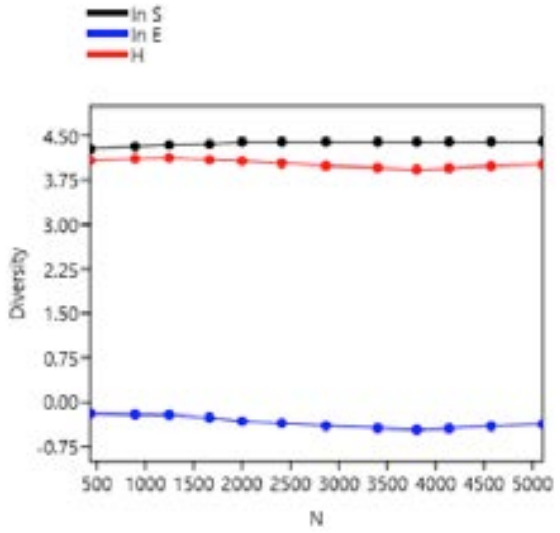

Figure 5. Graphical representation of SHE analysis, obtained from PAST 3.20 software, calculated from the data of relative abundances of 82 butterfly species in 12 months (samples) of two consecutive years in and around Midnapore urban area.

which warrants independent investigations. During our study we encountered that butterflies were abundant during post monsoon and monsoon while at other times (winter and summer) their population dwindled which may be due to less rainfall in winter, scorching heat and long dry spells during summer. The Shanon-Weaver index for the studied community shows high species richness. Simpson's index shows an intuitive high proportion to species abundance. The species evenness (E=0.91) calculated through Pielou's index shows high evenness. A low gradient in rank-abundance curve dictates high evenness among the different species. Gini coefficient (0.269) in the present study supports well about the species richness and species abundance demonstrated through the Shanon and Simpson index. SHE analysis indicate log series distribution of the butterfly species throughout the year in the studied area. Such studies can generate or inculcate interest among students, locals and authorities to save or conserve these pollinators and their habitat, also its conservation is essential for sustainable development.

REFERENCES

Atmowidi, T., D. Buchori, S. Manuwoto, B. Suryobroto & P. Hidayat (2007). Diversity of pollinator insects in relation of seed set of Mustard (*Brassica rapa* L.: Cruciferae). *HAYATI Journal of Bioscience* 14: 155–161. https://doi.org/10.4308/hjb.14.4.155

Blair, R.B. (1999). Birds and butterflies along an urban gradient: surrogate taxa for assessing biodiversity? *Ecological Applications* 9(1): 164–70. https://doi.org/10.1890/1051-0761(1999)009[0164:BABAAU]2.0.CO;2

Bonebrake, T.C., L.C. Ponisio, C.L. Boggs & P.R. Ehrlich (2010). More than just indicators: a review of tropical butterfly ecology and conservation. *Biological conservation* 143(8): 1831–41. https://doi.org/10.1016/j.biocon.2010.04.044

Bhaskaran, S. & R. Eswaran (2005). Status and distribution of butterfly species in Sivakasi Taluk, Tamilnadu. *Journal of Insect science* 18(1): 134–136.

Buzas, M.A., & L.A.C. Hayek (1998). SHE analysis for biofacies identification. *Journal of Foraminiferal Research* 28: 233–239.

Buzas, M.A., & L.A.C Hayek (2005). On richness and evenness within and between communities. *Paleobiology* 31: 199–220. https://doi.org/10.1666/0094-8373(2005)031[0199:ORAEWA]2.0.CO;2

Clark, P.J., J.M. Reed & F.S. Chew (2007). Effects of urbanization on butterfly species richness, guild structure, and rarity. *Urban Ecosystems* 10(3): 321–37. https://doi.org/10.1007/s11252-007-0029-4

Damgaard, C., & J. Weiner (2000). Describing inequality in plant size or fecundity. *Ecology* 81(4):1139–1142. https://doi.org/10.1890/0012-9658(2000)081[1139:DIIPSO]2.0.CO;2

Di Mauro, D., T. Dietz & L. Rockwood (2007). Determining the effect of urbanization on generalist butterfly species diversity in butterfly gardens. *Urban ecosystems* 10(4): 427–39. https://doi.org/10.1007/s11252-007-0039-2

Eswaran, R. & P. Pramod (2005). Structure of butterfly community of Anaikaty Hills, Western Ghats. *Zoos' Print Journal* 20(8): 1939–1942. https://doi.org/10.11609/JoTT.ZPJ.1330.1939-42

Evans, W.H. (1932). *The Identification of Indian Butterflies*. Bombay Natural History Society, Bombay, 464pp.

Gini, C. (1936). On the measure of concentration with special reference to income and statistics. Colorado College Publication, *General Series No*. 208: 73–79.

Hammer, Ø., D.A.T. Harper & P.D. Ryan (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Paleontologia Electronica* 4(1): 9.

Hammond, P.C. & J.C. Miller (1998). Comparison of the biodiversity of Lepidoptera within three forested ecosystems. *Annals of the Entomological Society of America* 91: 323–328. https://doi.org/10.1093/aesa/91.3.323

Harsh, S. (2014). Butterfly Diversity of Indian Institute of Forest Management, Bhopal, Madhya Pradesh, India. *Journal of Insects* 2014. 1–4. https://doi.org/10.1155/2014/254972

Hayek, L.A.C. & M.A. Buzas (1997). *Surveying Natural Populations*. Columbia University Press, New York, 347–389.

Hill, J.K. (1999). Butterfly spatial distribution and habitat requirements in a tropical forest: impacts of selective logging. *Journal of Applied Ecology* 36: 564–572. https://doi.org/10.1046/j.1365-2664.1999.00424.x

Hossain, A. & G. Aditya (2016). Avian Diversity in Agricultural Landscape: Records from Burdwan, West Bengal, India. *Proceedings of the Zoological Society* 69(1): 38–51. https://doi.org/10.1007/s12595-014-0118-3

Jana, D., S. Giri, D.K. Tamili & S.K. Chakraborty (2013). Diversity of lepidopteran insects in the coastal regions of Midnapur (East), West Bengal, India. *Indian Journal of Biological Sciences* 19: 32–41.

Kehimkar, I. (2008). *The Book of Indian Butterflies*. *Bombay natural History Society and Oxford University Press*, Mumbai, 497pp.

Kocher, S.D., & E.H. Williams (2000). The diversity and abundance of North American butterflies vary with habitat disturbance and geography. *Journal of Biogeography* 27(4): 785–94. https://doi.org/10.1046/j.1365-2699.2000.00454.x

Koh, L.P. (2007). Impacts of land use change on Southeast Asian forest butterflies: a review. *Journal of Applied Ecology* 44: 703–213. https://doi.org/10.1111/j.1365-2664.2007.01324.x

Koh, L.P. & N.S. Sodhi (2004). Importance of reserves, fragments, and parks for butterfly conservation in a tropical urban landscape. *Ecological Applications* 14(6): 1695–708. https://doi.org/10.1890/03-5269

Kunte, K. (2000). *Butterflies of Peninsular India.* Universities Press

Images 1–18. Photographs of some representative butterfly species in their habitats. © Debarun Patra and Soumyajit Roy.
1—*Pachliopta aristolochiae* | 2—*Papilio polytes* | 3—*Delias eucharis* | 4—*Graphium agamemnon* | 5—*Papilio demoleus* | 6—*Papilio clytia* | 7—*Euthalia nais* | 8—*Papilio crino* | 9—*Graphium nomius* | 10—*Neptis hylas* | 11—*Neptis jumbah* | 12—*Belenois aurota* | 13—*Hypolimnas bolina* | 14—*Junonia iphita* | 15—*Junonia lemonias* | 16—*Junonia orithya* | 17—*Junonia almanac* | 18—*Junonia hierta*.

Images 19–36. Photographs of some representative butterfly species in their habitats. © Debarun Patra and Soumyajit Roy.
19–*Spalgis epius* | 20—*Badamia exclamationis* | 21—*Lambrix salsala* | 22—*Jamides celens* | 23—*Prosotas nora* | 24—*Castalius rosimon* | 25—*Neopithecops zalmora* | 26—*Matapa aria* | 27—*Tagiades japetus* | 28—*Zizina labradus* | 29—*Mahathala ameria* | 30—*Euchrysops cnejus* | 31—*Udaspes tolus* | 32—*Spialia galba* | 33—*Zizina otis* | 34—*Chilades lajus* | 35—*Suastus gremius* | 36—*Chilades pandava.*

(India) Limited, Hyderabad, 254pp.

Kunte, K., S. Sondhi, B.M. Sangma, R. Lovalekar, K. Tokekar & G. Agavekar (2012). Butterflies of the Garo Hills of Meghalaya, northeastern India: their diversity and conservation. *Journal of Threatened Taxa* 4(10): 2933–2992. https://doi.org/10.11609/JoTT.o2945.2933-92

Magurran, A.E. (1988). *Ecological Diversity and its Measurement*. Chapman & Hall, London, 192pp.

Magurran, A.E. (2004). *Measuring Biological Diversity*. Blackwell Publishing, Oxford, 256pp.

Majumder, J., R. Lodh & B.K. Agarwala (2012). Variation in butterfly diversity and unique species richness along different habitats in Trishna Wildlife Sanctuary, Tripura, northeast India. *Check List* 8(3): 432–436. https://doi.org/10.15560/8.3.432

McAleece, N., P.J.D. Lambshead, G.L.J. Paterson & J.D. Gage (1997). "Biodiversity Pro: free statistics software for ecology." The Natural History Museum and the Scottish Association for Marine Science, UK. https://www.sams.ac.uk/research/software, accessed October 24, 2018

Mukherjee, S., S. Banerjee, G.K. Saha, P. Basu & G. Aditya (2015). Butterfly diversity in Kolkata, India: An appraisal for conservation management. *Journal of Asia-Pacific Biodiversity* 8(3): 210–221. https://doi.org/10.1016/j.japb.2015.08.001

Mukherjee, S., G. Aditya, P. Basu & G.K. Saha (2016). Butterfly diversity in Kolkata metropolis: a synoptic check list. *Check List* 12(2): 1858. https://doi.org/10.15560/12.2.1858

Mulder, C.P.H., E. Bazeley-White, P.G. Dimitrakopoulos, A. Hector, M. Scherer-Lorenzen & B. Schmid (2004). Species evenness and productivity in experimental plant communities. *Oikos* 107: 50–63. https://doi.org/10.1111/j.0030-1299.2004.13110.x

Murugesan, M., P.R. Arun & B.A.K. Prusty (2013). The butterfly community of an urban wetland system - a case study of Oussudu Bird Sanctuary, Puducherry, India. *Journal of Threatened Taxa* 5(12): 4672–4678. https://doi.org/10.11609/JoTT.o3056.4672-8

Nimbalkar, R.K., S.K. Chandekar & S.P. Khunte (2011). Butterfly diversity in relation to nectar food plants from Bhor Tahsil, Pune District, Maharashtra, India. *Journal of Threatened Taxa* 3(3): 1601–1609. https://doi.org/10.11609/JoTT.o2612.1601-9

Pahari, P.R., N.P. Mishra, A. Sahoo & T. Bhattacharya (2018). A study on the butterfly diversity of Haldia industrial belt and adjacent rural area in Purba Medinipur District, West Bengal, India. *World Scientific News* 97: 207–224.

Pielou, E.C. (1969). *An Introduction to Mathematical Ecology*, John Wiley, New York, NY, USA, viii+286pp.

Pollard, E. (1977). A method for assessing changes in the abundance of butterflies. *Biological Conservation* 12(2): 115–134. https://doi.org/10.1016/0006-3207(77)90065-9

Pollard, E. (1988). Temperature, rainfall and butterfly numbers. *Journal of Applied Ecology* 1: 819–828. https://doi.org/10.2307/2403748

Pollard, E., D.O. Elias, M.J. Skelton & J.A. Thomas (1975). A Method of Assessing the Abundance of Butterflies in Monk's Wood National Nature Research in 1973. *Entomologist's Gazette* 26: 79–87.

Posa, R.M.C. & N.S. Sodhi (2006). Effects of anthropogenic land use on forest birds and butterflies in Subic Bay, Philippines. *Biological Conservation* 129: 256–270. https://doi.org/10.1016/j.biocon.2005.10.041

Rusman, R., T. Atmowidi & D. Peggie (2016). Butterflies (Lepidoptera: Papilionoidea) of Mount Sago, West Sumatra: Diversity and Flower Preference. *HAYATI Journal of Biosciences* 23(3): 132–7. https://doi.org/10.1016/j.hjb.2016.12.001

Saikia, M.K., J. Kalita & P.K. Saikia (2009). Ecology and conservation needs of nymphalid butterflies in disturbed tropical forest of eastern Himalayan biodiversity hotspot, Assam, India. *International Journal of Biodiversity Conservation* 1(8): 231–250.

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

Shannon, C.E. & W. Weaver (1963). *The Mathematical Theory of Communication*. The University of Illinois Press, Urbana, 117pp.

Sarma, K., A. Kumar, A. Devi, K. Mazumdar, M. Krishna, P. Mudoi & N. Das (2012). Diversity and habitat association of butterfly species in foothills of Itanagar, Arunachal Pradesh, India. *Cibtech Journal of Zoology* 1(2): 67–77.

Simpson, G.G. (1964). Species density in North American recent mammals. *Systemetic Zoology* 13: 57–73.

Singh, A.P. & R. Pandey (2004). A model for estimating butterfly species richness of areas across the Indian subcontinent: species proportion of family Papilionidae as an indicator. *Journal of the Bombay Natural History Society* 101: 79–89.

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 of London B: Biological Sciences* 360(1454): 339–57. https://doi.org/10.1098/rstb.2004.1585

Tiple, A.D. (2011). Butterflies of Vidarbha region, Maharashtra State, central India. *Journal of Threatened Taxa* 3(1): 1469–1477. https://doi.org/10.11609/JoTT.o2397.1469-77

Tiple, A.D. (2012). Butterfly species diversity, relative abundance and status in Tropical Forest Research Institute, Jabalpur, Madhya Pradesh, central India. *Journal of Threatened Taxa* 4(7): 2713–2717.

Tiple, A.D. & A.M. Khurad (2009). Butterfly species diversity, habitats and seasonal distribution in and around Nagpur City, central India. *World Journal of Zoology* 4(3): 153–62. https://doi.org/10.11609/JoTT.o2656.2713-7

Van Nouhuys, S. & I. Hanski (2002). Colonization rates and distances of a host butterfly and two specific parasitoids in a fragmented landscape. *Journal of Animal Ecology* 71(4): 639–50. https://doi.org/10.1046/j.1365-2656.2002.00627.x

Varshney, R.K. & P. Smetacek (eds.) (2015). *A Synoptic Catalogue of the Butterflies of India*. Indinov Publishing, NewDelhi, 261pp.

Whittaker, R.H. (1965). Dominance and diversity in land plant communities: numerical relations of species express the importance of competition in community function and evolution. *Science*. 147(3655): 250–60. https://doi.org/10.1126/science.147.3655.250

Wynter-Blyth, M.A. (1957). *Butterflies of the Indian Region*. Bombay Natural History Society, xx+523pp+72pl.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14827–14844

COMMUNICATION

Plant and fungi diversity of Devi Pindiyan Valley in Trikuta Hills of northwestern Himalaya, India

Sajan Thakur [1], Harish Chander Dutt [2], Bikarma Singh [3], Yash Pal Sharma [4], Nawang Tashi [5], Rajender Singh Charak [6], Geeta Sharma [7], Om Prakash Vidyarthi [8], Tasir Iqbal [9], Bishander Singh [10] & Kewal Kumar [11]

[1,2,4,5,7,9] Department of Botany, [6] Department of Geography, University of Jammu, Jammu, Jammu & Kashmir 180006, India.
[3] Plant Sciences (Biodiversity and Applied Botany Division), CSIR-Indian Institute of Integrative Medicine, Canal Road, Jammu, Jammu & Kashmir 180001, India.
[8] State Forest Research Institute, Jammu, Jammu & Kashmir 180007, India.
[10] Department of Botany, Veer Kunwar Singh University, Arrah, Bihar 802301, India.
[11] Department of Botany, Government Degree College for Women, Udhampur, Jammu & Kashmir 182101, India.
[1] sajan0007thakur@gmail.com, [2] hcdutt@rediffmail.com, [3] drbikarma@iiim.ac.in (corresponding author),
[4] yashdbm3@yahoo.co.in, [5] nawang7786@gmail.com, [6] rajsinghju@gmail.com, [7] geetaji@yahoo.com,
[8] opsfrijk@gmail.com, [9] taseer83@gmail.com, [10] bishander85@gmail.com, [11] kewalkumar0@gmail.com

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

PLATINUM OPEN ACCESS

Abstract: The Devi Pindiyan Valley, an abode of Goddess Vaishno Devi, in Trikuta Hills (western Himalaya) is a unique hill-top land ecosystem with a diverse regional mixed subtropical and temperate flora. Because of its suitable geographic location, specific and unique habitat conditions, this mountainous belt of Shivalik Himalaya has a large number of endemic and threatened plant species. This study presents information on the plant diversity of Devi Pindiyan Valley of Trikuta Hills. Several line-transect (100m N-S and 100 E-W) surveys were conducted in which nested quadrats of 10m × 10m were laid for trees, within which interspersed two 5m × 5m sub-quadrats for shrubs and five 1m × 1m sub-quadrants for herbs at different places for determination of floristic composition. In the diverse habitats of this valley, we recorded 213 vascular plant species belonging to 164 genera under 71 families. This study area also harbors rich diversity of fungi, where the most visible 7 species of macrofungi belongs to 7 genera and 4 families were documented. Out of the documented species, 35 species have been categorized as threatened based on the latest IUCN Red list criteria, while 178 species are included in the catalogue of world life. *Engelhardtia spicata* Lechen ex Blume var. *integra* (Kurz) Manning ex Steenis has been categorized as Least Concerned (LC) by IUCN Red List site. The species diversity indicates the high conservation value of this area and documenting such an ecologically rich ecosystem becomes a prerequisite for developing and formulating conservation-cum-management strategies. Therefore, we recommend there is need for ecological research in terms of biodiversity conservation on Devi Pindiyan Valley and similar ecosystems.

Keywords: Conservation status, Devi Pindiyan Valley, floristic composition, Shivalik Himalaya.

DOI: https://doi.org/10.11609/jott.4792.11.14.14827-14844

Editor: P. Lakshminarasimhan, Botanical Survey of India, Pune, India. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4792 | Received 02 January 2019 | Final received 22 October 2019 | Finally accepted 31 October 2019

Citation: Thakur, S., H.C. Dutt, B. Singh, Y.P. Sharma, N. Tashi, R.S. Charak, G. Sharma, O.P. Vidyarthi, T. Iqbal, B. Singh & K. Kumar (2019). Plant and fungi diversity of Devi Pindiyan Valley in Trikuta Hills of northwestern Himalaya, India. *Journal of Threatened Taxa* 11(14): 14827–14844. https://doi.org/10.11609/jott.4792.11.14.14827-14844

Funding: Financial assistance received from UGC-SAP DRS-II and CSIR.

Competing interests: The authors declare no competing interests.

Author details: Mr. Sajan Thakur, Mr. Nawang Tashi, Mr. Bishander Singh and Mr. Tasir Iqbal are PhD research scholars. Dr. Harish Chander Dutt works extensively in the area of plant ecology and taxonomy. Dr. Bikarma Singh is a higher plant taxonomist in the area of systematics, ecology, ethnobotany, and plant natural products for value addition. Prof. Yash Pal Sharma has expertise in mushrooms of Himalaya. Dr. Rajender Singh Charak is a Cartographer and an expert in Cartography, Remote Sensing and GIS. Prof. Geeta Sharma is an expert in botany. Mr. Om Prakash Vidyarthi is a chief conservator of forest and is known for tree talk. Dr. Kewal Kumar works in GDC Udhampur and possesses expertise in botany.

Author contribution: BS, HCD and YPS conceived the idea. ST, HCD, BS, YPS, NT, TQ, RSC, GS, KK and OPV collected, identified, compiled and prepared the manuscript. BS provided the native and non-native status of the species presented in the manuscript.

Acknowledgements: We thank the headman and local people of various localities of the region for their help in various ways. The help received from Department of Forest, Government of J&K is also acknowledged. This publication bears publication number CSIR-IIIM/IPR/0078.




INTRODUCTION

Himalayan eco-terrains are globally recognized as a hub and repository of unique biological diversity in Asia, and their distribution differs from tropical to alpine climate (Nayar & Shastry 1987; Singh 2019). The species composition of the Himalayan hills and mountains varies from place to place and these variations depend mainly on different climatic factors coupled with differences in latitude, longitude, and altitude (Singh 2015).The Indian Himalaya are home to more than 8,000 species of vascular plants, of which 4,000 species are endemic and 1,748 are known for their medicinal properties (Samant et al. 1998; Singh 2019a). The western Himalayan geographic region extends from Jammu & Kashmir to the Kumaon belt of Uttarakhand State. The Shivalik region of Jammu division is known for unique and endemic species whose occurrence is due to favorable climatic conditions required for the growth and dissemination of plant species (Singh 2019b). Review of literature reveals that Jammu & Kashmir is home to about 4,439 species of plants (Singh et al. 1999), and out of these, 948 species are published to have medicinal and aromatic value (Gairola et al. 2014). It is evident from the published work that a lot of research has been carried out in this region by different plant scientists to study biodiversity, ethnobotany, ecology, and data up-gradation on environmental parameters (Sharma & Kachroo 1983; Kapur & Sarin 1990; Swami & Gupta 1998; Kirn 2000; Kumar & Hamal 2009; Kumar et al. 2009, 2015; Kumar & Sharma 2011; Bhellum & Magotra 2012; Bhatia et al. 2013, 2014; Dar et al. 2014; Dutt et al. 2015; Kour et al. 2017; Pandita & Dutt 2017; Singh et al. 2016, 2019).

Trikuta Hills in the Himalaya are known for the holy pilgrimage of the shrine of Shri Mata Vaishno Devi and more than 1.5 lakh people visit this place of worship every year from different parts of the globe. This shrine mountain ecosystem has several steep slopes, deep gorges and valleys, rich in different types of vegetation. Ecologically, these hills can be characterized as sub-tropical to temperate mixed vegetation, rich in *Pinus, Quercus, Engelhardtia*, and *Cedrus* as dominant tree species. The elevation of this mountain ranges from 750 to 2,706m. Many sacred rivers and small streams originate from these hills, and the higher reaches of these hills are occasionally covered with snow during winter months. There are several unexplored regions due to sacred beliefs and tough terrain in the hills. In this study, we present the floral and fungal diversity of Devi Pindiyan Valley with an aim to conserve species in this valley.

MATERIALS AND METHODS

Study Area

Devi Pindiyan Valley of Trikuta Hill is situated 36km from Jammu Town and 13km from Katra City (Reasi District) in Panthal forest area. It lies between latitudes of 32.892 to 33.010N and longitudes of 74.986 to 74.995E and the elevation range of 860–1,360m (Figure 1). It covers approximately an area of 17.3 km^2. The study area is part of district Reasi of Jammu & Kashmir. This mountainous belt falls in the Palaearctic Realm and the forest terrains are rugged and the hills are characterized by moderate to steep slopes. The vegetation components are characterized by typical subtropical and temperate forests. The forest components as a whole are regarded as a sacred grove and named Devi Pindiyan Shakti Pith. The upper ridges of Trikuta Hill experiences winter snowfall which is responsible for the moderate temperature in summer and cool weather in winter. December–January are the coldest months of the year when minimum temperatures reach minus 4°C. The mean temperature in January is about 8°C, and in May, the temperature rises between 35°C and 40°C. The annual rainfall ranges between 3,200mm and 3,472mm, distributed over 60–90 rain days. A number of seasonal streams that provide water to the local community for domestic purposes originate from the forest reserve. River Jhajjar is one of the important sacred perennial water system originating from Trikuta Hill which runs through the valley. There are only four villages where an indigenous Dogri speaking community of Duggar resides. Due to the remote location, typical physiography and climate, the local people derive much of their livelihood from agriculture, horticulture and floriculture. They mostly depend on forest resources for food, shelter and medicine. Since the region is known as a sacred place, some of them cultivate marigolds for sale in the market which adds to their earnings.

Field Survey, Data Collection and Identification

Four field exploration tours were undertaken for survey, collection and mapping of plant samples from six study sites in Devi Pindiyan Valley from March 2017 till September 2018 with the help of experts from the J&K Forest Department, CSIR-IIIM Jammu, and the University of Jammu (Image 1). Several line-transect (100m N-S and 100m E-W) surveys were conducted at different places for determination of floristic composition. Nested quadrats of 10 × 10m were laid for trees, within which were interspersed two 5 × 5m sub-quadrats for shrubs and five 1 × 1m sub-quadrats for herbs in different

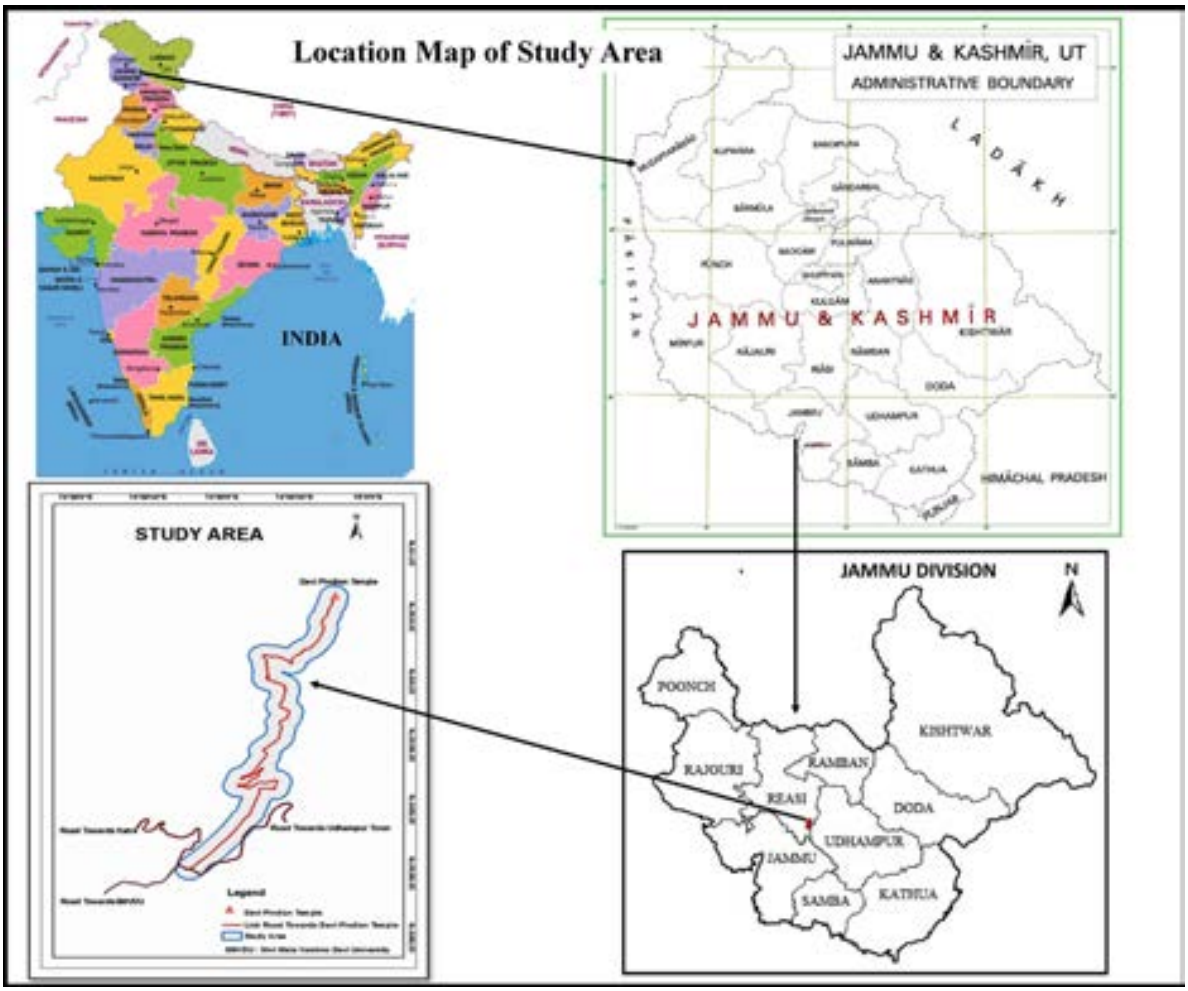

Figure 1. Devi Pindiyan Valley and main sampling plots (details information of each plot is given in Table 1).

Table1. Characterization of collecting sites from Devi Pindiyan Valley of Trikuta Hill, Shivalik Himalaya.

Survey sites (Date of collection)	Geographical coordinates			Habitat characterized
	Latitude	Longitude	Elevation (m)	
Site 1 (14 March 2017)	32.982° N	74.986° E	860	Tropical forests
Site 2 (19 August 2017)	32.987° N	74.987° E	1020	Mixed tropical and subtropical forests
Site 3 (19 August 2017)	32.994° N	74.990° E	1149	Mixed tropical and subtropical forests
Site 4 (28 April 2018)	32.999° N	74.989° E	1135	Mixed tropical and subtropical forests
Site 5 (28 April 2018)	33.004° N	74.993° E	1089	Mixed tropical and subtropical forests
Site 6 (14 September 2018)	33.010° N	74.995° E	1360	Mixed subtropical and temperate forests

growing seasons. GPS coordinates were recorded by using Garmin Oregon 650 GPS navigation device (Table 1). Data on habit, phenological characters and associated species of plants were collected along with digital photographs. Macro-fungi present in the area were also systematically collected, photographed and preserved. Laboratory studies were conducted in the Department of Botany, University of Jammu and RRLH Janaki Ammal Herbarium at CSIR-Indian Institute of Integrative Medicine, Jammu (CSIR-IIIM). Conventional herbarium techniques proposed by Jain & Rao (1977) and Rao & Sharma (1990) were followed. The accurate identification and authentication of plants was based on the collected herbarium vouchers and photographs, which were used as unique evidence and reference material for regional distribution. Proper identification and naming of macro-fungi species was done through individual expertise and online databases such as Index

Image 1. Vegetation survey, data collection and identification of plants of Devi Pindiyan Valley. © S. Thakur, B. Singh & O.P. Vidyarthi.

fungorum (www.indexfungorum.org) and Mycobank (www.mycobank.org).

The species were enumerated and photographed through non-invasive methods. The vouchers of the collected plants were identified by comparing them physically with existing preserved specimens at the Herbarium of the University of Jammu (HBJU) and Janaki Ammal Herbarium (RRLH) Jammu. Later, all taxa were authenticated by using taxonomic keys and published floras (Sharma & Kachroo 1983; Kapur & Sarin 1990; Swami & Gupta 1998). The prepared herbarium sheets were deposited at the Herbarium of University of Jammu (HBJU).

Systematization and Presentation

All plant species of Devi Pindiyan were systematically arranged. Families were arranged as per Bentham and Hooker's System of Classification (Bentham & Hooker 1876). Habit of each plant species were categorized as trees, shrubs, herbs and lianas. The correct ICN names of each plant and macro-fungi species were carried out using web-based databases (www.theplantlist.org, www.indexfungorum.org and www.mycobank.org). The threat status of each species was determined using the online database of IUCN Red List (www.iucnredlist.org) and presented as Critically Endangered, Endangered, Vulnerable, Least Concern, Data Deficient and if

similar information was not available, then they were designated as NA.

RESULTS

Forest Characterization

The intermediate climate between the subtropical and the temperate vegetation along with the topography of the Devi Pindiyan Valley is responsible for its unusual mixed type of vegetation. The forest belts possess different types of very unique plant associations such as mixed deciduous broad-leaved forests, lower pine association coupled with secondary scrub parameters. This valley is dominated by species such as *Sapium sebiferum*, *Grewia optiva* and *Toona ciliata* in mixed broad-leaved areas. *Pinus roxburghii*, *Phoenix dactylifera*, *Trema politoria*, and *Debregeasia longifolia* at the upper hills mixed with pine vegetation. The secondary scrubby layers are dominated by *Woodfordia fruticosa*, *Justicia adhatoda*, *Euphorbia royleana* and *Ehretia acuminata*.

Floristic Composition and Analysis

A total of 213 plant species belonging to 165 genera and 71 vascular plant families were collected from the Devi Pindiyan and associated hills of Trikuta Mountain (Appendix 1). Out of a total of 213 plant species, 204 were angiosperms (166 dicots and 38 monocots), one was gymnosperm and the remaining eight were pteridophytes (Table 2). The highly represented families were Poaceae (19 species), Lamiaceae (14 species), Fabaceae (13 species), Asteraceae & Moraceae (12 species each), Solanaceae (9 species), Euphorbiaceae (8 species), Rosaceae (7 species), Ranunculaceae (6 species) & Malvaceae, Pinaceae and Pteridaceae (5 species each). Highly represented genera in the valley were *Ficus* (10 species), *Euphorbia* & *Solanum* (5 species each), *Rubus* (4 species), and *Acacia* & *Datura* (3 species each). A total of 95 plant species were herbaceous in habit, 48 were shrubby bushes, 54 were trees and 16 were climbers. Some snapshots of species diversity are given in Images 2 and 3.

Besides vascular plant diversity, this region also exhibits macrofungal diversity, of which some are used as food or medicine by the local inhabitants of the study area. While investigating, seven macro-fungi were documented from the study area that include *Ganoderma lucidum* (Curtis) P.Karst. (Ganodermataceae), *Schizophyllum commune* Fr. (Schizophyllaceae), *Termitomyces heimii* Natarajan (Lyophyllaceae), *Macrolepiota procera* Scop., *Agaricus arvensis* Schaeff., *Calvatia gigantea* (Batsch) Lloyd, and *Bovista minor* Morgan (all Agaricaceae members). The first two macro-fungi (*Ganoderma lucidum* and *Schizophyllum commune*) are used as medicine by the local people, whereas the remaining were recorded as being used as wild edible macro-fungi (Image 4).

Table 2. Classification of vascular plants distribution in Devi Pindiyan Valley.

Taxon	Family	Genus	Species	Total
I. Lycophytes and Ferns	**5**	**6**	**8**	**8**
II. Gymnosperms	**1**	**1**	**1**	**1**
III. Angiosperms	**65**	**158**	**204**	**204**
Monocotyledons	12	33	38	38
Dicotyledons	53	125	166	166
Total	**71**	**165**	**213**	**213**

Economically Valued Plants

Out of a total of 213 plant species collected from the area, 76.05% (162 spp.) are reported in literature as high valued medicinal plants (Samant et al. 1998; Bhatia et al. 2013, 2014; Gairola et al. 2014; Dutt et al. 2015). Some abundantly growing medicinal plants of Devi Pindiyan Valley and its associated mountain ranges include *Achyranthes bidentata, Acacia modesta, Artemisia nilagirica, Berberis lycium*, *Bergenia pacumbis*, *Cissampelos pareira, Colebrookea oppositifolia, Colchicum luteum, Cryptolepis dubia, Datura innoxia, Holarrhena pubescens, Micromeria biflora, Mentha longifolia, Ocimum americanum, Plantago lanceolata, Sida rhombifolia, Valeriana jatamansi, Verbascum thapsus, Viola canescens*,and *Zanthoxylum armatum*.

While gathering oral information from local people, 26 species were recorded as edible and consumed as wild leafy vegetables, wild fruits or seeds. Most abundantly growing plants under this category are *Colocasia esculenta, Debregeasia longifolia, Ficus spicata, Mentha spicata, Morus alba, Murraya koenigii, Rubus ellipticus, Rubus niveus, Rumex hastatus, Zanthoxylum armatum* and *Ziziphus jujuba*. The study area is composed of nearly 55 timber yielding plants, with *Engelhardtia spicata, Ficus semicordata, Ficus racemosa, Mallotus philippensis, Kigelia africana, Melia azedarach*, and *Pinus roxburghii* being the most dominant tree species. We also recorded 10 plants from the area as a source of dye such as *Impatiens balsamina, Impatiens bicolor, Geranium nepalensis, Acacia catechu*, and *Pistacia chinensis* (Figure 2).

Image 2. Plant diversity found in Devi Pindiyan Valley and adjoining areas: A—*Engelhardtia spicata* Lechen ex Blume var. *integra* (Kurz) Manning ex Steenis | B—*Woodwardia radicans* (L.) Sm. | C—*Euphorbia royleana* Boiss. | D—*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda | E—*Adiantum recurvatum* (D.Don) Fraser-Jenk. | F—*Pteris vittata* L. | G—*Toona sinensis* (A.Juss.) M.Roem. | H—*Vitex altissima* L.f. | I—*Rubus ellipticus* Sm. | J—*Senna occidentalis* (L.) Link | K—*Bauhinia variegata* L. | L—*Dendrocalamus strictus* (Roxb.) Nees. © S. Thakur, B. Singh & O.P. Vidyarthi.

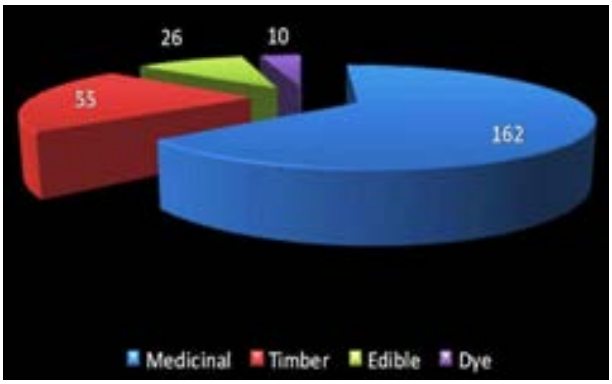

Figure 2. Economically valued plants of Devi Pindiyan Valley.

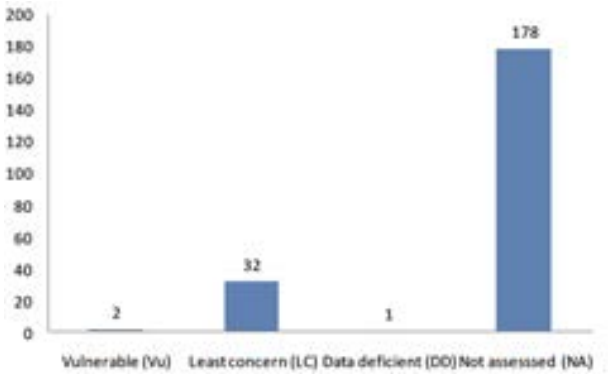

Figure 3. Graphical representation of species of Devi Pindiyan Valley as per IUCN.

Native and Non-Native Status

Of the total 213 investigated species, 124 species representing 58.22% are native to the Palaearctic Realm and remaining 89 species (41.78%) are non-native to India and adjoining areas (Appendix 1). They are either introduced, alien (invasive) or recorded from other regions as native plants. They are European, African, Australian, or tropical American origin plants escaped to have distribution in the study area (India) as invasive or were introduced sometime in history. A total of 32 species (15.02%) are native to India or are exclusively endemic to the Himalayan regions. Common endemic species to Himalaya include *Mimosa himalayana*, *Valeriana jatamansi, Neolitsea umbrosa, Engelhardtia spicata, Colchicum luteum, Isachne himalaica, Colebrookea oppositifolia, Ficus semicordata, Delphinium denudatum, Grewia optiva, Acacia modesta, Begonia picta, Heracleum candicans, Selinum vaginatum,* and *Euphorbia royleana*. About 0.93% species have nativity in Indo-Malayan regions. There are several species which are of Chinese origin and have abundant growth in the study area includes *Ficus sarmentosa, Hedychium spicatum, Pteris vittata,* and *Pistacia chinensis.*

Threats and Conservation Perspectives

Human disturbance coupled with habitat fragmentation have been identified as a major cause of biodiversity loss in many hotspots. Destruction of forests has resulted in the degradation of the environment and habitat of native species of the state. The rich genetic diversity has been depleted and many plant species are facing the threat of extinction in their natural habitats. Expansion of developmental activities (road/dam/city construction), logging, mining and similar associated activities are major threats to plant and animal species. The conservation status of all collected and authenticated species were worked out following IUCN Red List website (www.iucnredlist.org), and out of a total of 213 species, 34 species have been categorized under one or other threat concern. Total 32 species were listed as Least Concern (LC) species, 1 species each were categorized under Vulnerable (V) category and Data Deficient (DD) and remaining 178 species were not assessed as per IUCN classification (Figure 3)

DISCUSSION

The endemic species with limited geographical ranges are susceptible to extinction as they are extremely vulnerable to environmental changes, while widely distributed species can cope with the changing environment and anthropogenic disturbances (Rao et al. 2003). In this study, we reviewed for the first time, and presented the plant diversity of unexplored Devi Pindiyan Valley of Trikuta Hills in Shivalik Himalaya. In the diverse habitats of this valley, we recorded 213 vascular plants of 164 genera under 71 families, and seven macro-fungal genera belonging to four families, indicating that the flora of the surveyed region shows high diversity. In fact, while surveying and exploring the interior belts, we often found a large number of plant species from a certain small area, which were very different in habitat condition from their surroundings. In addition to these, we were able to mark wide variations in ecological conditions found within the explored area along with variations in altitudes. According to the Botanical Survey of India, Jammu & Kashmir in the western Himalaya is one such region which has been floristically under-explored (Dar et al. 2012), and the present finding helps to fill the data gap. Few research projects were previously conducted in the area, and one of them was of Kapur (1982),

Image 3. Plant diversity found in Devi Pindiyan Valley and adjoining areas: A—*Toona ciliata* M.Roem. | B—*Mimosa himalayana* Gamble | C—*Neolamarckia cadamba* (Roxb.) Bosser | D—*Cotinus coggygria* Scop. | E—*Rhamnus triquetra* (Wall.) Brandis | F—*Sauromatum venosum* (Aiton) Kunth | G—*Cissampelos pareira* L. | H—*Leucas lanata* Benth. | I—*Boehmeria macrophylla* Hornem. | J—*Impatiens balsamina* L. | K—*Impatiens bicolor* Royle | L—*Viola canescens* Wall. | M—*Pinus roxburghii* Sarg. | N—*Olea paniculata* R.Br. | O—*Thalictrum foliolosum* | P—*Saccharum spontaneum* L. | Q—*Zanthoxylum armatum* DC. © S. Thakur, B. Singh & O.P. Vidyarthi.

Image 4. Macro-fungal diversity found in Devi Pindiyan Valley and adjoining areas: A—*Ganoderma lucidum* (Curtis) P.Karst. | B—*Schizophyllum commune* Fr. | C—*Termitomyces heimii* Natrajan | D—*Macrolepiota procera* Scop. | E—*Agaricus arvensis* Schaeff. | F—*Calvatia gigantea* (Batsch) Lloyd | G—*Bovista minor* Morgan. © Y.P. Sharma.

who studied the phytoecology and forest associations, but very little data on ecology was presented. Lesser known species outside their natural habitat are facing threats of existence seeing in vulnerable category and may slowly move towards the verge of extinction due to unabated anthropogenic activities such as deforestation and illicit extraction of valuable medicinal plants. Hence, such species need immediate conservation measures and research on ecological restoration. Owing to our extensive study efforts in the Devi Pindiyan, this documented research will provide a good notion of the plant diversity and reasons for conservation of this sacred place for the future.

REFERENCES

Bentham, G. & J.D. Hooker (1876). *Genera Plantarum*. Published by L. Reeve & Co., London, 1040pp.

Bhatia, H., Y.P. Sharma, R.K. Manhas & K. Kumar (2013). Ethnobotanical plants used by the villagers of district Udhampur, J&K, India. *Journal of Ethnopharmacology* 151: 1005–1018.

Bhatia, H., Y.P. Sharma, R.K. Manhas & K. Kumar (2014). Traditional phytoremedies for the treatment of menstrual disorders in district Udhampur, J&K, India. *Journal of Ethnopharmacology* 160: 202–210.https://doi.org/10.1016/j.jep.2014.11.041

Bhellum, B.L. & R. Magotra (2012). *A catalogue of flowering plants of Doda, Kishtwar and Ramban Districts (Kashmir Himalayas).* Bishen Singh Mahendra Pal Singh, Dehradun, India, 286pp.

Dar, G.H., A.A. Khuroo, C.S. Reddy & A.H. Malik (2012). Impediment to taxonomy and its impact on biodiversity science: an Indian perspective. *Proceedings of the National Academy of Sciences, India, Section B. Biological Sciences* 82: 235–240.

Dar, G.H., A.H. Malik & A.A. Khuroo (2014). A contribution to the flora of Rajouri and Poonch Districts in the PirPanjal Himalaya (Jammu & Kashmir), India. *Check List* 10: 317–328.

Dutt, H.C., N. Bhagat & S. Pandita (2015). Oral traditional knowledge on medicinal plants in jeopardy among Gaddi shepherds in hills of Northwestern Himalaya, J&K, India. *Journal of Ethnopharmacology* 168: 337–348.

Gairola, S., J. Sharma & Y.S. Bedi (2014). A cross-cultural analysis of Jammu, Kashmir and Ladakh (India) medicinal plant use. *Journal of Ethnopharmacology* 155:925–986.

Jain, S.K. & R.R. Rao (1977). *A Handbook of Field and Herbarium Methods*. Today and Tomorrow Printers and Publishers, New Delhi, India, 157pp.

Kapur, S.K. (1982). *Phyto-ecological studies in Trikuta Hills with special reference to the distribution pattern of economic plant products*. PhD Thesis, Regional Research Laboratory, Jammu (unpublished).

Kapur, S.K. & Y.K. Sarin (1990). *Flora of Trikuta Hills*. Bishen Singh Mahendra Pal Singh, Dehradun, India, 267pp.

Kirn, H.S. (2000). Pteridophytic flora of Poonch District of Jammu and Kashmir State, north-west Himalayas. *Indian Fern Journal* 17: 92–105.

Kour, S., R. Yangdol, S. Kumar & Y.P. Sharma (2017). Reports on family Psathyrellaceae from Jammu and Kashmir, India. *Indian Journal of Forestry* 40:303–311.

Kumar, K., Y.P. Sharma, R.K. Manhas & H. Bhatia (2015). Ethnobotanical plants of Shankaracharya Hill, Srinagar, J&K, India. *Journal of Ethnopharmacology* 170: 255–274.

Kumar, M., Y. Paul & V.K. Anand (2009). An Ethnobotanical study of medicinal plants used by the locals in Kishtwar, Jammu and Kashmir, India. *Ethnobotanical Leaflets* 13: 1240–56.

Kumar, S. & I.A. Hamal (2009). Wild edibles of Kishtwar high altitude national park in Northwest Himalaya, Jammu and Kashmir (India). *Ethnobotanical Leaflets* 13: 195–202.

Kumar, S. & Y.P. Sharma (2011). Diversity of wild mushroom from Jammu and Kashmir, India, pp. 568–579. Proceedings of the 7th International Conference on Mushroom biology and Mushroom Products (ICMBMP).

Nayar, M.P. & A.R.K. Shastry (1987-1990). *Red Data Book of Indian Plants, 3 Vols*. Botanical Survey of India, Calcutta, India.

Pandita, S. & H.C. Dutt (2017). Herbaceous species in structuring the ecotone between forest-grassland in lesser stratum of North-West (NW) Himalaya. *NeBIO* 8: 287–293.

Rao, C.K., B.L. Geetha & G. Suresh (2003). *Red list of Threatened Vascular Plant Species in India*. Published by ENVIS, Botanical Survey of India, MoEF, Howrah, India, 144pp.

Rao, R.R. & B.D. Sharma (1990). *A Manual for Herbarium Collections*. Botanical Survey of India, Calcutta, India, 20pp.

Reddy, C.S., G. Bagyanarayana, K.N. Reddy & V.S. Reddy (2008). *Invasive Alien Flora of India*. Published by National Biological Information Infrastructure, US Geological Survey, USA, 130pp.

Samant, S.S., U. Dhar & L.M.S. Palni (1998). *Medicinal Plants of Indian Himalaya: Diversity Distribution Potential Values*. G.B. Pant Institute of Himalayan Environment and Development: Almora, India, 161pp.

Sharma, B.M. & P. Kachroo (1983). *Flora of Jammu and Plants of Neighbourhood (Vol. I-II)*. Bishen Singh Mahendra Pal Singh, Dehradun, India, 407pp.

Singh, B. (2015). *Himalayan Orchids- Distribution and Taxonomy*. Write and Print Publications, New Delhi, India, 224pp.

Singh, B. (2019a). *Plants for Human Survival and Medicine*. New India Publishing Agency, New Delhi, India, 592pp.

Singh, B. (2019b). *Plants of Commercial Values*. New India Publishing Agency, New Delhi, India, 450pp.

Singh, B., B. Singh, S.K. Borthakur & S.J. Phukan (2018). Contribution to biodiversity hotspot: assessment of forest types, floristic composition and economic wealth of Nokrek Biosphere Reserve in northeast India. *Indian Forester* 144: 734–741.

Singh B., S. Singh, B. Singh, S. Kitchlu & B. Babu (2019). Assessing ethnic traditional knowledge, biology and chemistry of *Lepidium didymum* L., lesser-known wild plants of western Himalaya. *Proceedings of the National Academy of Sciences, India Section B. Biological Sciences* 89(3): 1087–1094. https://doi.org/10.1007/s40011-018-1027-4

Singh B., P. Sultan, Q.P. Hassan, S. Gairola & Y.S. Bedi (2016) Ethnobotany, traditional knowledge, and diversity of wild edible plants and fungi: a case study in the Bandipora district of Kashmir Himalaya, India. *Journal of Herbs Spices and Medicinal Plants* 22(3): 247–278.

Singh, D.K., B.P. Uniyal & R. Mathu (1999). Jammu and Kashmir, pp. 905–974. In: Mudgal, V. & P.K. Hajra (eds.). *Floristic Diversity and Conservation Strategies in India*, *Vol. 2*. Botanical Survey of India, Ministry of Environment and Forests, Dehradun, India.

Swami, A. & B.K. Gupta (1998). *Flora of Udhampur*. Bishen Singh Mahendra Pal Singh, Dehradun, India, 455pp.

Appendix 1. List of plants in Devi Pindiyan Valley of Trikuta Hills, Shivalik Himalaya.

	Botanical name	Phenology period	Habit	IUCN status	Nativity status	Voucher no.
	DICOTS					
	Ranunculaceae					
1.	*Clematis barbellata* Edgew.	June–August	Climber	NA	Native to Palaearctic realm and in Himalaya	HBJU125
2.	*Clematis gouriana* Roxb. ex DC.	September–December	Climber	NA	Native to Palaearctic realm	HBJU126
3.	*Delphinium denudatum* Wall. ex Hook.f. & Thomson	May–September	Herb	NA	Native to Himalaya	HBJU151
4.	*Ranunculus distans* Royle	June–August	Herb	NA	Native to Himalaya	HBJU206
5.	*Ranunculus muricatus* L.	March–July	Herb	NA	Non-native to India, and native of Europe	HBJU276
6.	*Thalictrum foliolosum* DC.	August–December	Herb	NA	Native to Himalaya	HBJU226
	Menispermaceae					
7.	*Cissampelos pareira* L.	March–October	Climber	NA	Native to India	HBJU124
8.	*Cocculus laurifolius* DC.	March–August	Climber	NA	Native to Himalaya	HBJU127
	Berberidaceae					
9.	*Berberis lycium* Royle	April–June	Shrub	NA	Native to Palaearctic realm	HBJU112
	Papaveraceae					
10.	*Fumaria indica* Pugsley	March–July	Herb	NA	Native to Palaearctic realm	HBJU178
	Violaceae					
11.	*Viola odorata* L.	April–September	Herb	NA	Non-native, introduced from Europe	HBJU290
12.	*Viola canescens* Wall.	March–July	Herb	NA	Native to Himalaya	HBJU288
	Malvaceae					
13.	*Bombax ceiba* L.	November–March	Tree	NA	Non-native to India and introduced	HBJU115
14.	*Grewia asiatica* L.	March–September	Tree	NA	Non-native to India	HBJU159
15.	*Grewia optiva* (Buch.-Ham. ex Roxb.) J.R.Drumm. ex Burret	April–Septmber	Tree	NA	Native to Himalaya	HBJU184
16.	*Pterospermum acerifolium* (L.) Willd.	December–July	Tree	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU203
17.	*Sida rhombifolia* L.	September–January	Shrub	NA	Non-native to India, and native to New World (America & Oceania)	HBJU263
	Linaceae					
18.	*Reinwardtia indica* Dumort.	April–January	Shrub	NA	Native to Himalaya	HBJU246
	Geraniaceae					
19.	*Geranium nepalense* Sweet	April–October	Herb	NA	Native to Himalaya	HBJU156
20.	*Geranium mascatense* Boiss.	February–May	Herb	NA	Native to Palaearctic realm (Himalaya)	HBJU277
	Balsaminaceae					
21.	*Impatiens balsamina* L.	July–October	Herb	NA	Non-native to India, and native to tropical America	HBJU190
22.	*Impatiens bicolor* Royle	May–October	Herb	NA	Non-native to India	HBJU191
	Oxalidaceae					
23.	*Oxalis corniculata* L.	February–October	Herb	NA	Non-native to India, and native of Europe	HBJU228
	Rutaceae					
24.	*Aegle marmelos* (L.) Corrêa	October–January	Tree	NA	Non-native to India and introduced	HBJU107
25.	*Murraya koenigii* (L.) Spreng.	March–August	Tree	NA	Native to Palaearctic realm	HBJU187
26.	*Zanthoxylum armatum* DC.	April–October	Shrub	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU239

	Botanical name	Phenology period	Habit	IUCN status	Nativity status	Voucher no.
	Meliaceae					
27.	*Melia azedarach* L.	March–October	Tree	LC	Non-native to India, and native of Bangladesh	HBJU180
28.	*Toona ciliata* M.Roem.	January–August	Tree	LC	Non-native to India	HBJU229
29.	*Toona sinensis* (AJuss.) M.Roem.	May–January	Tree	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU281
	Rhamnaceae					
30.	*Rhamnus triquetra* (Wall.) Brandis	July–September	Tree	NA	Native to Palaearctic realm	HBJU247
31.	*Ziziphus jujuba* Mill.	May–October	Tree	LC	Native to Palaearctic realm (Southeastern Asia)	HBJU294
32.	*Ziziphus oenopolia* (L.) Mill.	August–December	Shrub	NA	Native to Palaearctic realm	HBJU295
	Sapindaceae					
33.	*Cardiospermum halicacabum* L.	June–October	Climber	NA	Non-native to India and invasive	HBJU149
34.	*Dodonaea viscosa* (L.) Jacq.	January–August	Shrub	NA	Non-native to India	HBJU160
	Anacardiaceae					
35.	*Cotinus coggygria* Scop.	February–November	Shrub	LC	Non-native to India, and native of Southern Europe	HBJU140
36.	*Lannea coromandelica* (Houtt.) Merr.	March–September	Tree	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU202
37.	*Mangifera indica* L.	March–September	Tree	DD	Native of Indo-Malaya region, planted	HBJU212
38.	*Pistacia chinensis* Bunge	March–November	Tree	NA	Native to Palaearctic realm (Western China)	HBJU233
	Fabaceae					
39.	*Acacia catechu* (L.f.) Willd.	April–September	Tree	NA	Native to Palaearctic realm	HBJU101
40.	*Acacia modesta* Wall.	May–October	Tree	NA	Native to Himalaya	HBJU102
41.	*Acacia nilotica* (L.) Delile	March–August	Tree	LC	Non-native to India and native of Tropical America	HBJU103
42.	*Bauhinia vahlii* Wight & Arn.	April–August	Climber	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU110
43.	*Bauhinia variegata* L.	February–July	Tree	LC	Native to Palaearctic realm (Southeastern Asia)	HBJU111
44.	*Cassia fistula* L.	April–July	Tree	NA	Native to Palaearctic realm	HBJU119
45.	*Indigofera cassioides* DC.	January–June	Shrub	NA	Native to Palaearctic realm	HBJU163
46.	*Indigofera heterantha* Wall. ex Brandis	May–October	Shrub	NA	Native to Palaearctic realm	HBJU193
47.	*Lespedeza gerardiana* Wall. Ex Maxim.	September–December	Shrub	NA	Native to Palaearctic realm	HBJU175
48.	*Mimosa himalayana* Gamble	June–December	Shrub	NA	Endemic to Himalaya	HBJU183
49.	*Pueraria tuberosa* (Willd.) DC.	March–August	Climber	NA	Native to Palaearctic realm (India)	HBJU204
50.	*Senna occidentalis* (L.) Link	October–March	Shrub	NA	Non-native to India, and native to tropical South America	HBJU217
51.	*Senna tora* (L.) Roxb.	November–February	Shrub	NA	Non-native to India, and native to tropical South America	HBJU218
	Rosaceae					
52.	*Cotoneaster nummularius* Fisch. & C.A.Mey.	May–October	Shrub	NA	Native to Palaearctic realm (Southeastern Asia, Himalaya)	HBJU132
53.	*Prunus cerasoides* Buch.-Ham. ex D.Don	October–March	Tree	LC	Native to Palaearctic realm (Southeastern Asia)	HBJU199
54.	*Rubus ellipticus* Sm.	March–May	Shrub	NA	Native to Palaearctic realm (Southeastern Asia, India)	HBJU210
55.	*Rubus niveus* Thunb.	May–September	Shrub	NA	Native to Palaearctic realm	HBJU250
56.	*Rubus paniculatus* Sm.	June–October	Shrub	NA	Native to Palaearctic realm	HBJU251
57.	*Rubus rosifolius* Sm.	March–July	Shrub	NA	Native to Himalaya	HBJU211
58.	*Spiraea bella* Sims	May–September	Shrub	NA	Native to Himalaya	HBJU224

	Botanical name	Phenology period	Habit	IUCN status	Nativity status	Voucher no.
	Saxifragaceae					
59.	*Bergenia pacumbis* (Buch.-Ham. ex D.Don) C.Y.Wu & J.T.Pan	June–August	Herb	NA	Native to Palaearctic realm (Himalaya)	HBJU146
	Myrtaceae					
60.	*Psidium guajava* L.	May–September	Tree	NA	Non-native, introduced from Europe	HBJU200
	Lythraceae					
61.	*Woodfordia fruticosa* (L.) Kurz	January–May	Shrub	LC	Native to Asia (Himalaya)	HBJU292
	Onagraceae					
62.	*Oenothera rosea* L'Hér. ex Aiton	May–December	Herb	NA	Native to Palaearctic realm	HBJU225
	Begoniaceae					
63.	*Begonia picta* Sm.	July–September	Herb	NA	Native to Himalaya	HBJU278
	Apiaceae					
64.	*Heracleum candicans* Wall. ex DC.	May–September	Herb	NA	Native to Himalaya	HBJU244
65.	*Ligusticum elatum* (Edgew.) C.B.Clarke	July–September	Herb	NA	Native to Himalaya	HBJU209
66.	*Selinum vaginatum* C.B.Clarke	June–October	Herb	NA	Native to Himalaya	HBJU260
	Araliaceae					
67.	*Hedera helix* L.	September–May	Climber	NA	Non-native to India, and native of Europe	HBJU185
	Caprifoliaceae					
68.	*Valeriana jatamansi* Jones	April–September	Herb	NA	Endemic to Himalaya	HBJU232
	Adoxaceae					
69.	*Viburnum nervosum* D.Don	April–October	Shrub	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU286
	Rubiaceae					
70.	*Catunaregam spinosa* (Thunb.) Tirveng.	March–June	Tree	NA	Native to Palaearctic realm	HBJU120
71.	*Neolamarckia cadamba* (Roxb.) Bosser	June–November	Tree	NA	Non-native to India	HBJU312
72.	*Spermadictyon suaveolens* Roxb.	September–March	Shrub	NA	Non-native to India, Native of Tropical America	HBJU223
73.	*Wendlandia heynei* (Schult.) Santapau & Merchant	March–August	Tree	NA	Native to Palaearctic realm	HBJU236
	Asteraceae					
74.	*Ageratum conyzoides* (L.) L.	January–December	Herb	NA	Non-native, invasive to India and native from tropical America	HBJU105
75.	*Artemisia nilagirica* (C.B.Clarke) Pamp.	July–October	Herb	NA	Native to Palaearctic realm	HBJU131
76.	*Bidens biternata* (Lour.) Merr. & Sherff	January–December	Herb	NA	Non-native, invasive to India and native to tropical America	HBJU113
77.	*Cirsium arvense* (L.) Scop.	June–October	Herb	NA	Non-native, invasive to India	HBJU123
78.	*Erigeron bonariensis* L.	May–October	Herb	NA	Non-native, invasive to India	HBJU144
79.	*Inula cuspidata* (Wall. ex DC.) C.B. Clarke	June–August	Shrub	NA	Native to Himalaya	HBJU164
80.	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	June–October	Herb	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU172
81.	*Parthenium hyterophorus* L.	April–August	Herb	NA	Non-native and invasive to India, and native of Tropical America	HBJU253
82.	*Silybum marianum* (L.) Gaertn.	February–September	Herb	NA	Non-native, Mediterranean and Africa	HBJU264
83.	*Sonchus arvensis* L.	July–September	Herb	NA	Non-native to India, and native of Europe	HBJU272
84.	*Sonchus oleraceus* (L.) L.	May–December	Herb	NA	Non-native to Palaearctic realm	HBJU273
85.	*Taraxacum campylodes* G.E. Haglund	September–March	Herb	NA	Non-native, introduced from Mediterranean and Africa	HBJU268
	Oleaceae					
86.	*Jasminum grandiflorum* L.	August–January	Shrub	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU168

	Botanical name	Phenology period	Habit	IUCN status	Nativity status	Voucher no.
87.	*Ligustrum nepalense* Wall.	April–July	Tree	NA	Native to Palaearctic realm	HBJU177
88.	*Olea paniculata* R.Br.	April–November	Tree	NA	Native to Palaearctic realm (Himalaya)	HBJU313
	Apocyanaceae					
89.	*Carissa spinarum* L.	April–June	Shrub	NA	Non-native to India, probably native of South Africa	HBJU118
90.	*Cryptolepis dubia* (Burm.f.) M.R.Almeida	March–November	Climber	NA	Native to Palaearctic realm	HBJU133
91.	*Holarrhena pubescens* Wall. ex G.Don	April–December	Tree	LC	Non-native to India, and native of Africa	HBJU188
	Boraginaceae					
92.	*Cynoglossum wallichii* G.Don	May–August	Herb	NA	Native to Palaearctic realm	HBJU135
93.	*Cynoglossum zeylanicum* (Vahl ex Hornem.) Thunb. ex Lehm.	April–October	Herb	NA	Native to Palaearctic realm	HBJU136
94.	*Ehretia acuminata* R.Br.	March–May	Tree	NA	Native to Palaearctic realm	HBJU157
	Convolvulaceae					
95.	*Ipomoea purpurea* (L.) Roth	June–September	Climber	NA	Non-native and invasive to India	HBJU165
96.	*Ipomoea calophylla* Fenzl	August–November	Climber	NA	Non-native to India	HBJU279
	Solanaceae					
97.	*Datura innoxia* Mill.	May–October	Shrub	NA	Non-native to India, and native to tropical America	HBJU280
98.	*Datura metel* L.	March–December	Shrub	NA	Non-native to India, and native to tropical America	HBJU283
99.	*Datura stramonium* L.	June–November	Shrub	NA	Non-native, introduced from Europe	HBJU148
100.	*Physalis minima* L.	August–October	Herb	LC	Native to Palaearctic realm	HBJU195
101.	*Solanum americanum* Mill.	June–January	Herb	NA	Non-native to India, and native of tropical America	HBJU220
102.	*Solanum hazenii* Britton	January–December	Shrub	NA	Native to Palaearctic realm	HBJU221
103.	*Solanum torvum* Sw.	April–July	Shrub	NA	Non-native to India, and native of West Indies	HBJU222
104.	*Solanum villosum* Mill.	July–November	Herb	NA	Non-native to India	HBJU284
105.	*Solanum virginianum* L.	May–November	Herb	NA	Non-native to India	HBJU271
	Scrophulariaceae					
106.	*Buddleja crispa* Benth.	February–August	Shrub	NA	Native to Palaearctic realm	HBJU116
107.	*Verbascum thapsus* L.	June–October	Herb	NA	Non-native to India, native of Europe	HBJU274
	Bignoniaceae					
108.	*Jacaranda mimosifolia* D.Don	May–August	Tree	Vu	Non-native, introduced from America	HBJU167
109.	*Kigelia africana* (Lam.) Benth.	April–October	Tree	LC	Non-native, introduced from Europe	HBJU170
	Acanthaceae					
110.	*Dicliptera bupleuroides* Nees	May–July	Herb	NA	Native to Palaearctic realm	HBJU139
111.	*Justicia adhatoda* L.	June–September	Shrub	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU169
112.	*Lepidagathis incurva* Buch.-Ham. ex D.Don	October–May	Herb	NA	Native to Palaearctic realm	HBJU173
	Verbenaceae					
113.	*Lantana camara* L.	January–October	Shrub	NA	Non-native and invasive to India, and native of tropical America	HBJU171
	Lamiaceae					
114.	*Ajuga macrosperma* Wall. ex Benth.	January–November	Herb	NA	Native to Palaearctic realm (Himalaya)	HBJU106
115.	*Colebrookea oppositifolia* Sm.	January–March	Shrub	NA	Native to Palaearctic realm (Himalaya)	HBJU128

	Botanical name	Phenology period	Habit	IUCN status	Nativity status	Voucher no.
116.	*Elsholtzia fruticosa* (D.Don) Rehder	August–October	Shrub	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU158
117.	*Isodon rugosus* (Wall. ex Benth.) Codd	July–October	Shrub	NA	Native to Palaearctic realm	HBJU166
118.	*Leucas lanata* Benth.	August–September	Herb	NA	Non-native to India	HBJU176
119.	*Mentha longifolia* (L.) L.	May–November	Herb	LC	Non-native to India, native to Europe	HBJU181
120.	*Mentha spicata* L.	July–November	Herb	LC	Non-native to India, native to Europe	HBJU285
121.	*Micromeria biflora* (Buch.-Ham. ex D.Don) Benth.	January–December	Herb	NA	Native to Himalaya	HBJU182
122.	*Nepeta graciliflora* Benth.	June–August	Herb	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU245
123.	*Ocimum americanum* L.	January–December	Shrub	NA	Non-native to India, and native of tropical America	HBJU287
124.	*Origanum vulgare* L.	July–December	Herb	NA	Non-native to India, and native of Europe	HBJU252
125.	*Scutellaria scandens* D.Don	April–August	Herb	NA	Native to Palaearctic realm	HBJU215
126.	*Thymus vulgaris* L.	August–November	Herb	LC	Non-native to India, native to southern Europe	HBJU227
127.	*Vitex altissima* L.f.	June–November	Shrub	NA	Native to Palaearctic realm	HBJU235
	Plantaginaceae					
128.	*Plantago major* L.	June–September	Herb	LC	Non-native, introduced from Mediterranean and Africa	HBJU289
129.	*Plantago lanceolata* L.	May–August	Herb	Vu	Native to Palaearctic realm	HBJU198
	Nyctaginaceae					
130.	*Mirabilis jalapa* L.	June–November	Shrub	NA	Non-native to India, and introduced	HBJU242
	Amaranthaceae					
131.	*Achyranthes bidentata* Blume	July–October	Herb	NA	Non-native to India, and native to tropical Africa	HBJU109
132.	*Chenopodium album* L.	May–November	Herb	NA	Non-native, Introduced species from Mediterranean and Africa	HBJU122
	Polygonaceae					
133.	*Rumex hastatus* D.Don	April–June	Herb	NA	Native to Himalaya	HBJU261
	Lauraceae					
134.	*Neolitsea umbrosa* (Nees) Gamble	March–May	Tree	NA	Endemic to Himalaya	HBJU267
	Proteaceae					
135.	*Grevillea robusta* A.Cunn. ex R.Br.	March–August	Tree	NA	Non-native to India, and native of South Wales	HBJU241
	Euphorbiaceae					
136.	*Euphorbia helioscopia* L.	January–July	Herb	NA	Non-native to India	HBJU161
137.	*Euphorbia hirta* L.	June–December	Herb	NA	Non-native to India, and native to tropical America	HBJU162
138.	*Euphorbia neriifolia* L.	June–September	Shrub	NA	Non-native to India	HBJU179
139.	*Euphorbia prostrata* Aiton	April–October	Herb	NA	Non-native to India	HBJU192
140.	*Euphorbia royleana* Boiss.	May–July	Shrub	NA	Native to Himalaya	HBJU194
141.	*Mallotus philippensis* (Lam.) Müll. Arg.	March–August	Tree	NA	Native to Palaearctic realm	HBJU258
142.	*Ricinus communis* L.	June–December	Shrub	NA	Non-native to India	HBJU248
143.	*Sapium sebiferum* (L.) Roxb.	May–October	Tree	NA	Native to Himalaya	HBJU256
	Phyllanthaceae					
144.	*Glochidion heyneanum* (Wight & Arn.) Wight	June–November	Tree	NA	Native to Palaearctic realm	HBJU240
145.	*Leptopus cordifolius* Decne	May–August	Shrub	NA	Non-native to India	HBJU254

	Botanical name	Phenology period	Habit	IUCN status	Nativity status	Voucher no.
	Urticaceae					
146.	*Boehmeria macrophylla* Hornem.	June–January	Shrub	NA	Native to Palaearctic realm	HBJU114
147.	*Debregeasia longifolia* (Burm.f.) Wedd.	August–February	Shrub	NA	Native to Himalaya	HBJU137
148.	*Debregeasia saeneb* (Forssk.) Hepper & J.R.I.Wood	March–July	Shrub	NA	Non-native to India, and native of South America	HBJU150
149.	*Urtica dioica* L.	June–September	Herb	LC	Non-native to India	HBJU231
	Cannabaceae					
150.	*Trema politoria* (Planch.) Blume	May–October	Tree	NA	Native to Palaearctic realm	HBJU282
	Moraceae					
151.	*Ficus arnottiana* (Miq.) Miq.	March–November	Tree	NA	Native to Palaearctic realm	HBJU196
152.	*Ficus auriculata* Lour.	March–August	Tree	NA	Native to Palaearctic realm	HBJU197
153.	*Ficus benghalensis* L.	April–October	Tree	NA	Native to Palaearctic realm (India)	HBJU201
154.	*Ficus hispida* L.f.	June–October	Tree	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU207
155.	*Ficus palmata* Forssk.	June–November	Tree	NA	Native to Himalaya	HBJU208
156.	*Ficus pumila* L.	May–November	Tree	NA	Native to Palaearctic realm	HBJU213
157.	*Ficus racemosa* L.	June–November	Tree	NA	Native to Palaearctic realm	HBJU214
158.	*Ficus religiosa* L.	May–August	Tree	NA	Native to Palaearctic realm	HBJU216
159.	*Ficus sarmentosa* Buch.-Ham. ex Sm.	May–September	Shrub	NA	Native to Palaearctic realm (China)	HBJU174
160.	*Ficus semicordata* Buch.-Ham. ex Sm.	May–October	Tree	NA	Native to Palaearctic realm (Himalaya)	HBJU234
161.	*Morus alba* L.	April–August	Tree	NA	Non-native to India	HBJU219
162.	*Morus macroura* Miq.	March–May	Tree	NA	Native to Palaearctic realm (Himalaya)	HBJU266
	Ulmaceae					
163.	*Holoptelea integrifolia* (Roxb.) Planch.	May–October	Tree	NA	Native to Palaearctic realm	HBJU189
	Juglandaceae					
164.	*Engelhardtia spicata* Lechen ex Blume var. *integra* (Kurz) Manning ex Steenis	January–December	Tree	LC	Endemic to Himalaya	HBJU143
	Fagaceae					
165.	*Quercus oblongata* D.Don	March–October	Tree	NA	Native to Himalaya	HBJU243
	Salicaceae					
166.	*Flacourtia indica* (Burm.f.) Merr.	January–July	Tree	NA	Native to Palaearctic realm	HBJU237
	GYMNOSPERMS					
	Pinaceae					
167.	*Pinus roxburghii* Sarg.	October–November	Tree	LC	Native to Himalaya	HBJU270
	MONOCOTS					
	Cannaceae					
168.	*Canna indica* L.	September–October	Herb	NA	Non-native to India	HBJU147
	Zingiberaceae					
169.	*Hedychium spicatum* Sm.	June–November	Herb	NA	Native to Palaearctic realm (China)	HBJU186
	Dioscoreaceae					
170.	*Dioscorea biloba* (Phil.) Caddick & Wilkin	August–November	Climber	NA	Native to Palaearctic realm (Southeast India)	HBJU154
171.	*Dioscorea bulbifera* L.	July–November	Climber	NA	Native to Himalaya	HBJU141
	Smilaceae					
172.	*Smilax aspera* L.	June–November	Climber	NA	Native to Palaearctic realm	HBJU262

	Botanical name	Phenology period	Habit	IUCN status	Nativity status	Voucher no.
	Asparagaceae					
173.	*Agave americana* L.	April–October	Shrub	NA	Non-native, introduced from Mexico	HBJU104
174.	*Asparagus adscendens* Roxb.	October–December	Climber	NA	Native to Palaearctic realm	HBJU142
175.	*Asparagus racemosus* Willd.	October–January	Climber	NA	Native to Palaearctic realm (Himalaya)	HBJU108
	Colchicaceae					
176.	*Colchicum luteum* Baker	February–May	Herb	NA	Endemic to Himalaya	HBJU152
	Commelinaceae					
177.	*Commelina benghalensis* L.	May–October	Herb	LC	Native to Palaearctic realm (Southeastern Asia)	HBJU130
178.	*Floscopa scandens* Lour.	March–May	Herb	LC	Native to Palaearctic realm	HBJU155
	Arecaceae					
179.	*Phoenix dactylifera* L.	June–September	Tree	NA	Non-native to India, native of northern Africa	HBJU230
	Araceae					
180.	*Colocasia esculenta* (L.) Schott	February–September	Herb	LC	Native to Palaearctic realm	HBJU138
181.	*Sauromatum venosum* (Dryand. ex Aiton) Kunth	Apil–July	Herb	LC	Non-native to India, native of Africa	HBJU257
	Alismataceae					
182.	*Sagittaria graminea* Michx.	June–November	Herb	LC	Native to Palaearctic realm	HBJU255
	Cyperaceae					
183.	*Cyperus cyperoides* (L.) Kuntze	April–December	Herb	LC	Non-native to India, native of southeastern Australia	HBJU310
184.	*Fimbristylis quinquangularis* (Vahl) Kunth	August–October	Herb	LC	Non-native to India	HBJU312
185.	*Fimbristylis schoenoides* (Retz.) Vahl	January–December	Herb	LC	Non-native to India, native of Australia	HBJU311
186.	*Cyperus sanguinolentus Vahl* [=*Pycreus sanguinolentus* (Vahl) Nees]	July–December	Herb	NA	Non-native to India, and native to tropical Africa	HBJU205
	Poaceae					
187.	*Arundinella pumila* (Hochst. ex A.Rich.) Steud.	May–July	Herb	NA	Non-native to India, and native to western Africa	HBJU300
188.	*Brachiaria ramosa* (L.) Stapf	May–October	Herb	LC	Non-native to India	HBJU305
189.	*Capillipedium assimile* (Steud.) A.Camus	August–December	Herb	NA	Non-native to India	HBJU307
190.	*Chrysopogon fulvus* (Spreng.) Chiov.	June–October	Herb	NA	Non-native to India, and native to central Africa	HBJU303
191.	*Cynodon dactylon* (L.) Pers.	January–December	Herb	NA	Non-native to India, and invasive	HBJU134
192.	*Dactyloctenium aegyptium* (L.) Willd.	May–October	Herb	NA	Non-native to India, and native to South Africa	HBJU309
193.	*Dendrocalamus strictus* (Roxb.) Nees	November–June	Tree	NA	Native to Palaearctic realm (Southeastern Asia)	HBJU153
194.	*Eragrostis atrovirens* (Desf.) Trin. ex Steud.	May–September	Herb	NA	Native to Palaearctic realm	HBJU298
195.	*Imperata cylindrica* (L.) Raeusch.	April–August	Herb	NA	Non-native to India, and native to tropical America	HBJU306
196.	*Isachne himalaica* Hook.f.	June–December	Herb	NA	Endemic to Himalaya	HBJU301
197.	*Oplismenus burmanni* (Retz.) P.Beauv.	July–October	Herb	NA	Native to Palaearctic realm	HBJU249
198.	*Oplismenus composites* (L.) P.Beauv.	September–November	Herb	NA	Non-native to India, and native of North America	HBJU304
199.	*Paspalum scrobiculatum* L.	May–December	Herb	LC	Non-native to India	HBJU302
200.	*Paspalum vaginatum* Sw.	June–September	Herb	LC	Non-native to India, and native of western Australia	HBJU296
201.	*Cenchrus sieberianus* (Schltdl.) Verloove	July–September	Herb	LC	Non-native to India	HBJU297
202.	*Pogonatherum crinitum* (Thunb.) Kunth	May–September	Herb	NA	Non-native to India	HBJU308

	Botanical name	Phenology period	Habit	IUCN status	Nativity status	Voucher no.
203.	*Saccharum spontaneum* L.	July–September	Herb	LC	Native to Palaearctic realm (India)	HBJU291
204.	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	March–June	Herb	NA	Non-native to India and American origin	HBJU269
205.	*Brachiaria setigera* (Retz.) C.E.Hubb. [=*Urochloa setigera*(Retz.) Stapf]	July–September	Herb	NA	Non-native to India	HBJU299
	PTERIDOPHYTES					
	Selaginellaceae					
206.	*Selaginella* sp.	November–January	Herb	NA	-	HBJU259
	Adiantaceae					
207.	*Adiantum lunulatum* Burm.f.	January–April	Herb	NA	Native to Palaearctic realm (India)	HBJU117
208.	*Adiantum recurvatum* (D.Don) Fraser-Jenk.	December–April	Herb	NA	Native to Himalaya	HBJU121
	Pteridaceae					
209.	*Cheilanthes argentea* (S.G.Gmel.) Kunze	August–October	Herb	NA	Native to Palaearctic realm	HBJU129
210.	*Pteris linearis* Poir.	March–June	Herb	NA	Non-native to India, and native of Europe	HBJU238
211.	*Pteris vittata* L.	January–April	Herb	LC	Native to Palaearctic realm (China)	HBJU275
	Blechnaceae					
212.	*Woodwardia radicans* (L.) Sm.	July–September	Herb	NA	Non-native to India and native of Europe	HBJU293
	Aspleniaceae					
213.	*Asplenium dalhousiae* Hook.	August–November	Herb	NA	Native to Palaearctic realm	HBJU145

Note: NA–IUCN status not assessed | LC—Least Concern | Vu—Vulnerable | DD—Data Deficient | Native status worked out from Reddy et al. (2008).

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14845–14861

A checklist of rust fungi from Himachal Pradesh, India

Ajay Kumar Gautam [1] & **Shubhi Avasthi** [2]

[1] School of Agriculture, Abhilashi University, Chail Chowk, Tehsil Chachyot, Mandi, Himachal Pradesh 175028, India.
[2] School of Studies in Botany, Jiwaji University, Gwalior, Madhya Pradesh 474001, India.
[1] a2gautam2006@gmail.com (corresponding author), [2] shubh.avasth@gmail.com

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

PLATINUM
OPEN ACCESS

Abstract: An updated analysis of the diversity of rust fungi in Himachal Pradesh is provided herein as a product of field surveys, of mycological analysis, and of all forms of published documentation and literature. The results of all forms of analysis revealed that Himachal Pradesh has 167 species of rust fungi belonging to the class Pucciniomycetes. The class is represented by 11 families, 23 genera with 167 species. The *Pucciniaceae* (96 species) followed by *Phragmidiaceae* (14 species) are the largest families of rust fungi reported from the state. Rest of the families were found associated with 1–10 species of rust fungi. The rust fungi (19 species) with uncertain placement are placed in incertae sedis. The rust genera reported from Himachal Pradesh so far are *Aecidium*, *Chrysomyxa*, *Coleosporium*, *Frommea*, *Gymnosporangium*, *Kuehneola*, *Kweilingia*, *Melampsora*, *Monosporidium*, *Ochrospora*, *Peridermium*, *Phakopsora*, *Phragmidium*, *Pileolaria*, *Puccinia*, *Pucciniastrum*, *Pucciniostele*, *Ravenelia*, *Skierka*, *Uredinopsis*, *Uredo*, *Urocystis,* and *Uromyces*.

Keywords: Basidiomycota, checklist, Himachal Pradesh, Pucciniales, Pucciniomycetes.

DOI: https://doi.org/10.11609/jott.4238.11.14.14845-14861

Editor: R.K. Verma, Tropical Forest Research Institute, Jabalpur, India.

Date of publication: 26 November 2019 (online & print)

Manuscript details: #4238 | Received 07 May 2018 | Final received 18 October 2019 | Finally accepted 27 October 2019

Citation: Gautam, A.K. & S. Avasthi (2019). A checklist of rust fungi from Himachal Pradesh, India. *Journal of Threatened Taxa* 11(14): 14845–14861. https://doi.org/10.11609/jott.4238.11.14.14845-14861

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Dr. Ajay Kumar Gautam PhD, is serving at School of Agriculture, Abhilashi University Mandi (H.P.). His research is focused on fungal diversity of north-western Himalaya. Dr. Shubhi Avasthi has obtained her PhD from Jiwaji University Gwalior. Presently she is working as guest Faculty at School of Studies in Botany, Jiwaji University Gwalior.

Author contribution: AKG performed the survey, data collection and finalized the manuscript. SA compiled the published literature and contributed in manuscript writing.

Acknowledgements: Authors are grateful to their respective organizations for providing the necessary laboratory facilities and valuable support during the study. We thank the anonymous reviewers for their critical comments and suggestions.

INTRODUCTION

Rust fungi are highly specialized obligate plant parasites having several unique morphological and microscopic features. These fungi commonly appear as yellow orange or brown powder on a variety of host plants and plant parts. Unlike other plant pathogens, rusts usually affect healthy and vigorously growing plants; the infection is limited to plant parts, such as leaves, petioles, tender shoots, stem, and fruits. The group is considered as one of the most harmful plant pathogens in agriculture, horticulture and forestry. These fungi are of major concern because they act as limiting factors for the successful cultivation, plantation and growth of agricultural crops and forestry plants. A wider diversity and broader host range is exhibited by this fungal group and their infection is not only limited to agricultural crops but also non-agricultural plants including medicinal herbs, shrubs, trees, and even weeds. An estimated 168 rust genera and approximately 7,000 species exist on various plant hosts, more than half of which belong to the genus *Puccinia* (Mohanan 2010).

Rust fungi show unique systematic characteristics among all fungal groups. A single species may produce up to five morphologically and cytologically distinct spore-producing structures, viz., spermagonia, aecia, uredinia, telia, and basidia, in successive stages of reproduction during the infection process. The presence of these successive stages may vary from species to species. To initiate and develop infection, rusts require an average temperature up to 35°C along with 50–60 % relative humidity. The rust infected plants may appear stunted, chlorotic (yellowed), or otherwise discoloured, whereas, disease symptoms includes coloured pustules, witches brooms, stem canker, hypertrophy of the affected tissues or formation of galls (Cummins & Hiratsuka 2003). Unlike other fungi, rusts exhibit one of the most important characteristics of their exceptionally high degree of host specificity.

Among all reported rust fungi, some are among agriculture's most destructive and devastating pathogens, causing diseases such as wheat stem rust, wheat yellow (stripe) rust, Asian soybean rust, coffee rust and many more. These rust fungi cause annual crop losses in billions every year worldwide. This loss can be greater in developing world where growers are not aware about diseases caused by rust fungi and often cannot afford fungicides. Owing to their economic importance, the rusts have been studied extensively in regular mycological surveys in Himachal Pradesh, but no single-source compiled literature is available. Therefore, this study facilitates the access to scattered Himalayan literature with reference to rust fungi to the students and plant pathologists of national and international community.

STUDY AREA

Himachal Pradesh is one of the northern states of India that lies between 30.377– 32.21 North and 75.74 – 79.07 East. It is a mountainous state with very high mountains to grasslands in plain (Figure 1). Great variations in elevation ranging from about 350m (1,148 ft) to 7,000m (22,966 ft) are found in the state. The variations are also observed in the climatic conditions. Hot and sub-humid tropical conditions were found in the southern tracts while, cold, alpine and glacial conditions in the northern and eastern mountain ranges with more elevation. The variability in rainfall was observed in the range of 1,500–3,000 mm. These variations in geo-climatic conditions of the state lead to greater biodiversity in the state. A total 66.52% of the area is covered with very dense evergreen to deciduous forests types. While, alpine shrub and meadows are found distributed in the west and northeastern Himalaya; alders, birches, rhododendrons, and moist alpine shrubs are regional vegetation. The plant pathogens including bacteria, fungi and viruses are also found due to these changeable geographical and climatic conditions of the state which are quite favourable for their growth and development.

MATERIALS AND METHODS

The information on rust fungi was gathered by investigating the following data sources: (1) mycological survey conducted on rust fungi from Himachal Pradesh during the years 2014 to 2018, and (2) all forms of published documentation and literature (Bilgrami et al. 1991; Jamaluddin et al. 2004). The names of some taxon in the obtained data have been replaced by currently accepted names as they were of out-of-date. The current usage of names was checked using the Index Fungorum (http://www.indexfungorum.org/) to adopt the generic and specific taxonomy in Species Fungorum (http://www.speciesfungorum.org/).

The plant samples found infected with rust fungi were collected during a mycological survey of various localities of Himachal Pradesh. Field observations of rust fungi on host plants and their photographs were

Figure 1. Himachal Pradesh showing district wise number of reports of rust fungi.

taken in natural conditions. Collected specimens were packed in paper bags and taken to the laboratory for further analysis. A few disease samples were used for morphological analysis of the rust fungi and the rest of the materials were dried for future microscopic studies. The air dried specimens were preserved in standard size herbarium packets and deposited at the Abhilashi University Mycological Herbarium (AUMH).

The microscopic mounts were prepared from fresh samples by brushing the rust powder into a drop of distilled water and lactophenol on microscopic slides, which were covered with cover slip and gently heated. The microscopic slides were analysed for spore dimensions like size, shape and ornamentations.

Both macro- and micro-morphological characters obtained from the laboratory were only used for taxonomic studies of the collected fungi. The fungal specimens were identified and their distribution records were checked by using standard literature (Cummins & Hiratsuka 2003; Mukerji & Manoharachary 2010). Illustrations are photographed under microscope equipped with digital camera.

RESULTS

As per the results obtained in the present study and from all sources of information, Himachal Pradesh has 167 species of rust fungi belonging to 23 genera and 11 families (Table 1). The largest family is Pucciniaceae (95 species) followed by *Phragmidiaceae* (14 species). Other families were reported to have species of rust fungi up to ten. However, 19 species of rust fungi with uncertain placement are placed in taxonomic group incertae sedis. *Aecidium*, *Chrysomyxa*, *Coleosporium*, *Frommea*, *Gymnosporangium*, *Kuehneola*, *Kweilingia, Melampsora*, *Monosporidium*, *Ochrospora*, *Peridermium*, *Phakopsora*, *Phragmidium*, *Pileolaria*, *Puccinia*, *Pucciniastrum*, *Pucciniostele*, *Ravenelia*, *Skierka*, *Uredinopsis*, *Uredo*, *Urocystis*, and *Uromyces* are the rust genera reported so far from Himachal Pradesh.

Present studies revealed that 170 plant species belonging to 52 families were found infected with rust fungi throughout the state. Thirty-five hosts of family Poaceae were highest to be found infected with these fungi followed by Ranunculaceae (16), Rosaceae (15), Asteraceae (11), Polygonaceae (7), Fabaceae, Salicaceae, Acanthaceae & Lamicaeae (6 each), Pinnaceae & Apiaceae (5 each), Rubiaceae (4), Saxifragaceae, Cyperaceae & Euphorbiaceae (3 each), and Berberidiaceae, Geraniaceae, Linaceae & Zinziberaceae

Table 1. Number of species of rust fungi in the families and genera in Himachal Pradesh.

Family	Genera	Number of species
Coleosporiaceae	*Chrysomyxa*	03
	Coleosporium	06
Cronartiaceae	*Peridermium*	06
	Uredo	07
Melampsoraceae	*Melampsora*	08
	Ochrospora	01
Phakopsoraceae	*Monosporidium*	02
	Phakopsora	02
	Pucciniostele	01
	Kweilingia	01
Phragmidiaceae	*Frommea*	01
	Kuehneola	01
	Phragmidium	09
Pileolariaceae	*Pileolaria*	02
	Skierka	01
Pucciniaceae	*Gymnosporangium*	01
	Puccinia	80
	Uromyces	16
Pucciniastraceae	*Pucciniastrum*	01
	Uredinopsis	01
Raveneliaceae	*Ravenelia*	02
Urocystidaceae	*Urocystis*	01
Total (10)	**21**	**148**
Incertae sedis	*Aecidium*	12
	Uredo	07
Grand Total (11)	**23**	**167**

(2 each). The rest of the plant species were reported to be infected with a single rust fungus. The area-wise results revealed that most of the rust fungi (about 127) were reported from Shimla and nearby regions followed by Solan (22), Kullu (18), Kangra (9), Chamba & Mandi (7 each), Lahul & Spiti (4), and Kinnaur & Bilaspur (1 each).

The checklist of rust fungi from Himachal Pradesh, a hilly state of northern India.

Fungi

Basidiomycota Whittaker ex Moore

Pucciniomycetes Pucciniomycetes R. Bauer, Begerow, J.P. Samp., M. Weiss & Oberw.

Pucciniales Clem. & Shear

1. Family: *Coleosporiaceae* Dietel.

Genus: *Chrysomyxa* Unger., Beitr. vergleich. Pathologie: 24 (1840)

Type species: *Chrysomyxa abietis* (Wallr.) Unger (1840)

Chrysomyxa deformans (Diet.) Jacz., (Dietal 1890)

On *Pinaceae*—leaves of *Picea morinda*

Distribution: Shimla & Dalhausie

Chrysomyxa piceae Barclay, (Barclay 1890)

On *Pinaceae*—leaves of *Picea morinda*

Distribution: Narkanda & Mashobra

Chrysomyxa himalensis Barclay, (Butler 1905)

On *Ericaceae*—leaves of *Rhododendron arboreum*

Distribution: Shimla

Genus: *Coleosporium* Lév., Annls Sci. Nat., Bot., sér. 3 8: 373 (1847)

Type species: *Coleosporium tussilaginis* (Pers.) Lév. (1849)

Coleosporium barclayense Bagchee, (Bagchee 1950; Sehgal et al. 1989; Puri 1955)

On *Pinaceae*—Fallen needles of *Pinus roxburghii* and *Pinus excelsa*

Distribution: Kullu and Shimla

Coleosporium campanulae (Pers.) Tul., (Barclay 1890; Sehgal et al. 1989)

On *Campanulaceae*—Leaves of *Campanula colorata*, needles of *Pinus roxburghii*

Distribution: Kasauli and Shimla

Coleosporium clematidis Barclay, (Barkley 1856; Sydow & Butler 1912)

On *Ranunculaceae*—leaves of *Clematis montana* and *Clematis buchnania*

Distribution: Shimla

Coleosporium leptodermidis (Barclay) P. Syd. & Syd., (Sydow & Butler 1912)

On *Ranunculaceae*—leaves of *Clematismontana*

Distribution: Shimla

Coleosporium plectranthi Barclay, (Cummins 1943)

On *Lamiaceae*—leaves of *Plectranthus geradianus*

Distribution: Shimla

Coleosporium senecionis (Pers.) Fr., (Sydow & Mitter 1933)

On *Asteraceae*—leaves of *Senecio graciliforus*

Distribution: Shimla

2. Family: *Cronartiaceae* Dietel.

Genus: *Peridermium* (Link) J.C. Schmidt & Kunze,

Type species: *Peridermium californicum* Arthur & F. Kern (1914)

Peridermium brevius (Barclay) Sacc., (Barclay 1890)

On *Pinaceae*—Neeles of *Pinus excelsa*

Distribution: Shimla

Peridermium cedri (Barclay) Sacc., (Barclay 1890)

On *Pinaceae*—neeles of *Cedrus libani* var. *deodar*

Distribution: Shimla

Peridermium malayense Bagchee**,** (Sydow & Butler 1901)

On *Pinaceae*—branches of *Pinuslongifolia*

Distribution: Shimla

Peridermium orientale Cooke., (Sydow & Butler 1901)
On *Pinaceae*—Needles of *Pinus longofolia*
Distribution: Shimla, Kangra, Kasauli (Solan)
Peridermium piceae (Barclay) Sacc., (Sydow & Butler 1901)
On *Pinaceae*—leaves of *Picea morinda*
Distribution: Shimla
Peridermium thomsonii (Berk.) Berk.., (Cooke 1878)
On *Pinaceae*—leaves of *Picea morinda*
Distribution: Mahasu (Shimla), Kullu

3. Family: *Melampsoraceae* Dietel.
Genus: *Melampsora* Castagne (Image 1)
Type species: *Melampsora euphorbiae* (Ficinus & C. Schub.) Castagne (1843)

Melampsora ciliata Barclay, (Barclay 1891, Khan et al. 2004)
On *Salicaceae*—on leaves of *Populus ciliata*
Distribution: Shimla
Melampsora populnea (Pers.) P. Karst., (Syn. *Melampsora aecidioides* (DC) Schroet., *Melampsora rostrupii* G. Wagner) (Barclay 1891; Butler & Bisby 1931; Cummins 1943; Sharma & Sharma 2000)
On *Salicaceae*—on leaves of *Populus alba*, *Populus ciliata*
Distribution: Shimla
Melampsora euphorbiae (Ficinus & C. Schub.) Castagne, (Syn. *Melampsora helioscopiae* (Pers.) Vint.) (Sydow & Butler 1901)
On *Euphorbiaceae—Euphorbia pulcherrima* Wild. Ex. Klotz. and *Euphorbia helioscopia*
Distribution: Kangra
Melampsora hypericorum (DC.) J. Schröt., (Patil & Nayar 1936)
On *Hypericaceae*—leaves of *Hypericum* sp.
Distribution: Shimla
Melampsora caprearum Thüm., (syn. *Melampsora laricis-caprearum* Kleb.) (Sydow & Butler 1907)
On *Salicaceae*—leaves of *Salix daphnoides* and *Salix elegans*
Distribution: Dalhausie (Chamba) and Shimla
Melampsora lini (Ehrenb.) Lév., (Mishra 1963b, Mishra & Prasada 1966)
on *Linaceae*—leaves and stem of *Linum mysorense* and *Linum grandiflorum*.
Distribution: Flowerdale, Shimla
Melampsora medusae Thum., (Paul et al. 2004).
On *Salicaceae*—leaves of *Populus deltoids*
Distribution: Kangra
Melampsora oblonga Bagchee, (Ranadive et al. 2012).
On *Pinaceae—leaves of Pinus excelsa*
Distribution: Mandi (Central H.P.)
Melampsora salicis-albae Kleb., (Sydow & Butler 1901)
On *Salicaceae*—Leaves of *Salix alba*
Distribution: Suket, Mandi
Melampsora rostrupii G. H. Wagner, (Syn. *M. accidioides*, *M. populnea*) (Rehill & Puri 1980)
On *Salicaceae*—leaves of *Populus alba*
Distribution: Shimla.

Genus: *Ochrospora* Diet.
Type species: *Ochrospora sorbi* (G. Winter) Dietel (
Ochrospora sorbi (Oudem) Diet., (Arthur & Cummins 1933)
On *Ranunculaceae—Anemone* sp.
Distribution: Alwas (Chamba)

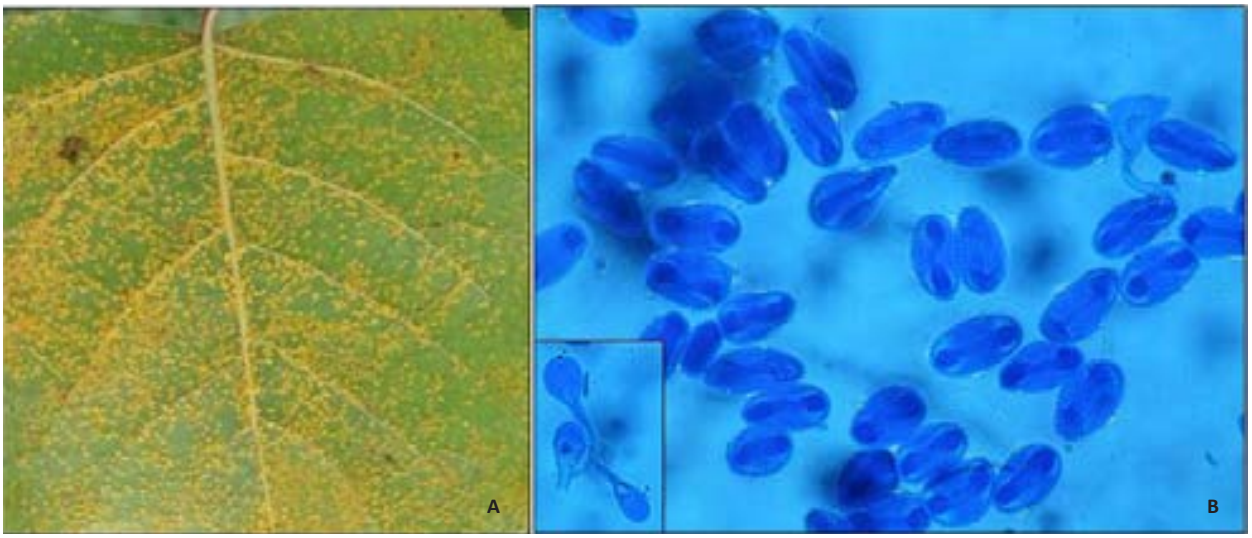

Image 1. *Melampsora populnea* on *Populus alba*: A—symptoms | B—urediniospore with paraphyses. © Ajay Kumar Gautam.

4. Family: *Phakopsoraceae* Cummins & Y. Hirats. f.,
Genus: *Monosporidium* Barclay
Type species: *Monosporidium euphorbiae* Barclay ex Sacc. (1891)
Monosporidium andrachnes Barclay, (Barclay1890)
On *Phyllanthaceae*—leaves of *Andrachne cordifolia*,
Distribution: Shimla & Kasuli (Solan)
Monosporidium euphorbiae Barclay ex Sacc., (Barclay 1890)
On *Euphorbiaceae*—leaves of *Euphorbia pilosa*
Distribution: Shimla

Genus: *Kweilingia* Teng
Type species: *Kweilingia bambusae* (Teng) Teng (1940)
Kweilingia divina (Syd.) Buriticá (Gautam & Avasthi 2018)
On *Poaceae*—leaves of *Dendroclamus strictus*
Distribution: Bilaspur

Genus: *Phakopsora* Dietel
Type species: *Phakopsora punctiformis* (Barclay & Dietel) Dietel (1898)
Phakopsora cronartiiformis Dietel, (Butler 1912)
On *Vitaceae*—leaves of *Vitis himalayana*
Distribution: Nachar, bashahr (Shimla)
Phakopsora punctiformis (Barclay & Dietel) Dietel, (Dietal 1890)
On *Rubiaceae*—leaves of *Galium aparine*
Distribution: Shimla

Genus: *Pucciniostele* Tranzschel & K.L. Kom.
Type species: *Pucciniostele clarkiana* (Barclay) Tranzschel & K.L. Kom. (1899)
Pucciniostele clarkiana (Barclay) Tranzschel & K.L. Kom., (Barclay 1890)
On *Saxifragaceae*—leaves of *Astilbe rivularis*
Distribution: Shimla

5. Family: *Phragmidiaceae* Corda
Genus: *Frommea* Arthur
Type species: *Frommea obtusa* (F. Strauss) Arthur (1917)
Frommeella tormentillae (Fuckel) U. Braun, (syn. *Frommea obtusa* (Str.) Arth.)
(Godre & Patwardhan 1965)
On *Rosaceae*—leaves of *Potentilla fragariae*
Distribution: Shimla

Genus: *Kuehneola* Magnus
Type species: *Kuehneola albida* (J.G. Kühn) Magnus (1898)
Kuehneola loeseneriana (Henn.) H.S. Jacks. & Holw., (syn. *Puccinia arthraxonis* (P. Henn.) Syd., P. Syd. & E.J. Butler, (Golatkar 1976; Sharma & Sachan 1994)
On *Poaceae—Arthraxon prionodes*
Distribution: Kasauli Solan (H.P.).

Genus: *Phragmidium* Link (Image 2)
Type species: *Phragmidium mucronatum* (Pers.) Schltdl. (1824)
Phragmidium kamtschatkae (H.W. Anderson) Arthur & Cummins, (syn. *Pucciniaroseae* Barclay; *Trolliomyces rosae* (Barclay) Ulbrich, *Teloconia rosae* (Barclay) Syd.) (Mundkar 1938; Pandotra & Ganguly 1964; Ulbrich 1939)
On *Rosaceae*—leaves and branches of *Rosa macrophylla*
Distribution: Shimla
Phragmidium barclayi Dietel, (Sydow & Butler 1907)
On *Rosaceae—leaves* of *Rubus lasiocarpus*
Distribution: Shimla
Phragmidium mucronatum (Pers.) Schltdl., (syn. *Phragmidium disciflorum* (Tode) James.)(Cooke 1978)
On *Rosaceae—Rosa* sp.
Distribution: Kalatop forest, Chamba
Phragmidium incompletum Barclay, (Sydow & Butler 1901)
On *Rosaceae*—leaves of *Rubus paniculatus*
Distribution: Shimla
Phragmidium kamtschatke (Anders.) Arthur & Cummins, (Pandotra & Gaungly 1964)
On *Rosaceae*—leaves of *Rosa macrophylla*
Distribution: Narkanda, Shimla
Phragmidium laceianum Barclay, (Barclay 1891)
On *Rosaceae*—leaves of *Potentilla argyrophylla*
Distribution: Narkanda, Bushahr (Shimla), Kullu
Phragmidium nepalense Barclay (Barclay 1891)
On *Rosaceae*—on leaves of *Potentilla nepalensis*,
Distribution: Mathiana, Shimla
Phragmidium octoloculare Barclay, (Barclay 1891)
On *Rosaceae*—leaves of *Rubus rosaefolius*
Distribution: Shimla
Phragmidium quinqueloculare Barclay, (Barclay 1890)
On *Rosaceae*—leaves of *Rubus biflorus*
Distribution: Shimla
Phragmidium rose-moschatae Dietel, (Mitter & Tandon 1938)
On *Rosaceae*—leaves of *Rosa moschata*
Distribution: Shimla & Kasauli

6. Family: *Pileolariaceae* Cummins & Y. Hirats.
Genus: *Pileolaria* Castagne (Image 3)
Type species: *Pileolaria terebinthi* (DC.) Castagne (1842)
Pileolaria indica Syd., (Sydow 1938)
On *Anacardiaceae*—leaves of *Pistacia integerrima*

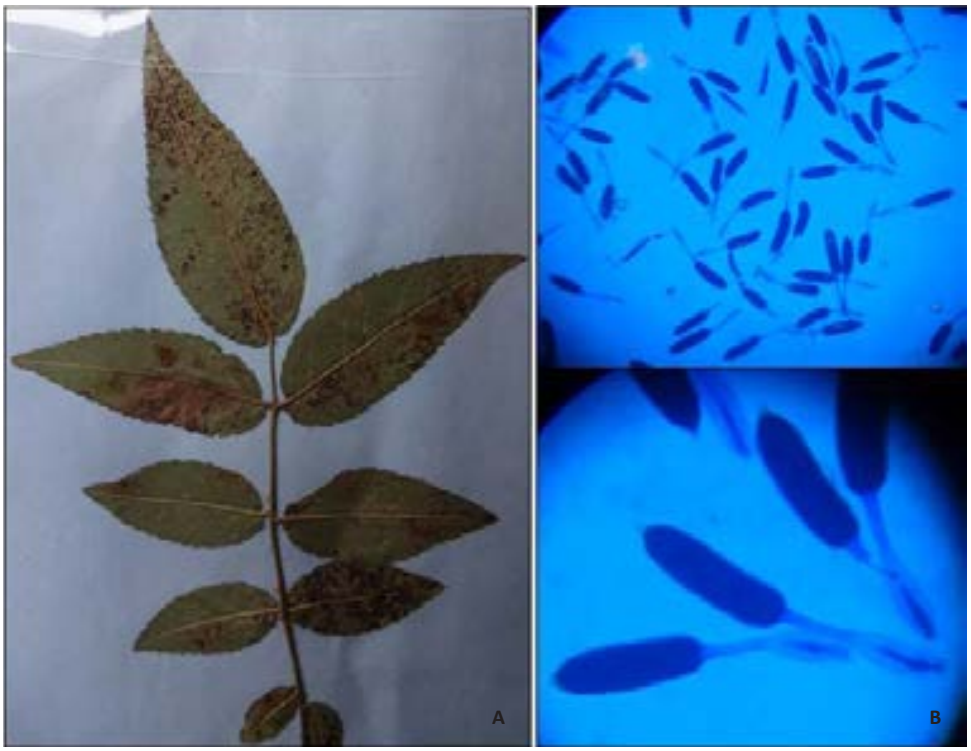

Image 2. *Phragmidium* sp. on *Rosa* sp.: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

Distribution: Wangtu, Bushahr (Shimla)
Pileolaria pistaciae F. L. Tai & C. T. Wei, (Gautam & Avasthi 2017b)
On *Anacardiaceae*—leaves of *Pistacia integerrima*
Distribution: Balt (Mandi)

Genus: *Skierka* Racib. (Image 4)
Type species**:** *Skierka canarii* Racib. (1900)
Skierka himalayensis A. K. Gautam & S. Avasthi, (Gautam & Avasthi 2017b)
On Anacardiaceae—leaves of *Pistacia integerrima*
Distribution: Mandi

7. Family: *Pucciniaceae* Chevall.
Genus: *Gymnosporangium* R. Hedw. ex DC.,
Type species: *Gymnosporangium fuscum* DC. (1805)
Gymnosporangium cunninghamianum Barclay, (Barclay 1890)
On *Rosaceae*—leaves of *Pyrus pashia* and *Pyrus vasiocola*
On *Cupressaceae—Cupressus torulosa*
Distribution: Shimla

Genus: *Puccinia* Pers. (Images 5–11)
Type species: *Puccinia graminis* Pers. (1794)
Puccinia agrostidis Plowr., (Barclay 1891)
On *Ranunculaceae—Aquilegia vulgaris*
Distribution: Shimla
Puccinia ahmadiana Syd., (Sydow 1938)
On *Asteraceae—Pterotheca falconeri*
Distribution: Puti Ruhi, Lahul, Kullu Valley of Himachal Pradesh.
Puccinia porri (Sowerby) G. Winter, (syn. *Puccinia allii* (DC.) F. Rud.) (Butler & Bisby 1931; Singh & Sharma 1977, Bharat & Gupta 2011)
On *Amaryllidaceae—Allium sativum*
Distribution: Kullu, Shimla
Puccinia andropogonis Schwein., (Barclay 1890)
On *Poaceae—Andropogon tristis*
Distribution: Shimla
Puccinia graminis Pers., (syn. *Puccinia anthistiriae* Barclay) (Sydow & Butler 1912)
On *Poaceae—Anthistiria anathera*
Distribution: Shimla
Puccinia apii Desm., (Barclay 1890)
On *Apiaceae—Apium graveolens*
Distribution: Shimla
Puccinia arenariae (Schumacher) J. Schröt., (Barclay 1891)
On *Caryophyllaceae—Stellaria paniculata*
Distribution: Narkanda (Shimla)
Puccinia atropuncta Peck & Clint., (Chona et al. 1956)
On *Asteraceae—Prenanthes brunoniana*

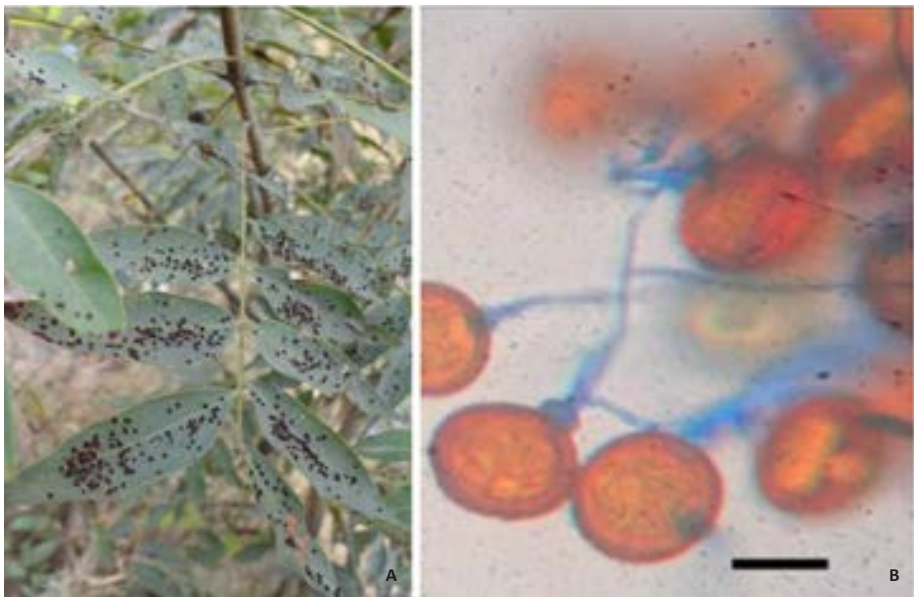

Image 3. *Pileolaria pistaciae*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

Image 4. *Skierka himalayensis*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

Distribution: Shimla

Puccinia bulbocastani (A. Cumino) Fuckel., (Bhardwaj & Sharma 1990)

On *Apiaceae*—on *Bunium persicum*

Distribution: Solan

Puccinia bistortae (F. Strauss.) DC., (Sydow 1938)

On *Polygonaceae*—*Polygonum viviparum*

Distribution: Losar, Spiti (Lahul & Spiti)

Puccinia brachypodii G.H. Otth., (Payak 1965)

On *Berberidaceae*—*Berberis aristata*

Distribution: Shimla

Puccinia bupleuri (Opiz) Rudolphi, (syn. *Pucciniabupleuri-falcati* (DC.) G. Wint. (Barclay 1890)

On *Apiaceae*—*Bupleurum falcatum*

Distribution: Shimla

Puccinia calthae Link, (Arthur & Cummins 1933; Chona et al. 1956)

On *Ranunculaceae*—*Caltha palustris* var. *alba*

Distribution: Dhramshala (Kangra); Rohtang pass (Kullu)

Puccinia caricis var. *himalayensis* Barclay,(Butler & Bisby 1931; Padwick & Khan 1944)

On *Cyperaceae*—*Carex setigera*

Distribution: Shimla

Puccinia caricis-filicinae Barclay, (Mitter & Tandon 1938)

On *Cyperaceae*—*Carex filicina*

Distribution: Shimla

Puccinia caricis-nubigenae Padwick & A. Khan, (Mitter & Tandon 1938)

On *Cyperaceae*—*Carex nubigena*

Distribution: Kufri, Shimla

Puccinia carthami Corda, (Sydow & Butler 1901)

On *Asteraceae*—*Carthamus oxycantha*

Distribution: Kangra

Puccinia chrysopogoni Barclay, (Barclay 1890; Sydow &

Butler 1907)
Oleaceae—*Jasminum humile*
Poaceae—*Chrysopogon gryllus*
Distribution: Shimla
Puccinia circaeae Pers., (Barclay 1890)
On *Onagraceae—Circaea alpine*
Distribution: Shimla
Puccinia collettiana Barclay, (Barclay 1890; Ganguly & Pandotra 1963)
On *Rubiaceae—Rubia cordifolia*
Distribution Shimla, Kasauli (Solan), Naggar (Kullu)
Puccinia coronata Corda, (syn. *Puccinia coronata* var. avenae P. Syd. & Syd.) (Mishra et al. 1964)
On *Poaceae—Avena sativa*
Distribution: Shimla
Puccinia cousiniae P. Syd. & Syd., (Padwick 1945)
On *Poaceae—Coursinia thomsoni*
Distribution: Spiti (Lahul & Spiti)
Puccinia cynodontis Lacroix ex Desm., (Sharma & Sachan 1994)
On *Poaceae—Cynodon dactylon*
Distribution: Solan
Puccinia dactylidina Bubák, (Sydow & Butler 1912)
On *Poaceae—Dactylis glomerata*
Distribution: Shimla
Puccinia dioscoreae Kom., (Pandotra & Ganguly 1962)
On *Dioscoreaceae—Dioscorea deltoidea*
Distribution: Manali
Puccinia duthiei Ellis & Tracy, (Sydow & Butler 1911)
On *Poaceae—Andropogon pertusus*
Distribution: Kasauli (Solan)
Puccinia ellisii De Toni, (Barclay 1891)
On *Apiaceae—Angelica glauca*
Distribution: Phagu, Shimla
Puccinia eremuri Kom., (Barclay 1891)
On *Xanthorrhoeaceae—Eremurus himalaicus*
Distribution: Kullu
Puccinia erianthi Padwick & A. Khan, (Padwick & Khan 1944)
On *Poaceae—Erianthus fulvus*
Distribution: Shimla
Puccinia eulaliae Barclay, (Butler & Bisby 1960)
On *Poaceae—Pollinia japonica*
Distribution: Reported from Shimla (H.P.) only.
Puccinia excelsa Barclay, (Barclay 1891)
On *Lamiaceae—Phlomis bracteosa*
Distribution: Mahasu & Huttoo Peak, Shimla
Puccinia fagopyri Barclay, (Barclay 1890)
On *Polygonaceae—Fagopyrum esculentum*
Distribution: Shimla, Sangla valley (Kinnaur)
Puccinia flavipes Syd. & P. Syd., (Barclay 1890)
On *Rosaceae—Fragaria vesca*
Distribution: Shimla
Puccinia gentianae (F. Strauss.) Link, (Barclay 1890)
On *Gentianaceae—Gentiana kurroo*
Distribution: Shimla
Puccinia geranii-silvatici P. Karst., (Barclay 1890)
On *Geraniaceae—Geranium nepalense*
Distribution: Shimla
Puccinia striiformis Westend, (syn. *Puccinia glumarum* (Schw.) Eriks & P. Henn.) (Prasada 1948)
On *Poaceae—Brachypodium sylvaticum*
Distribution: Shimla
Puccinia graminis Pers., (Barclay 1890a)
On *Poaceae—Festuca gigentia*
Distribution: Shimla, Kullu
Puccinia graminis-agropyri P.R. Mehta & R. Prasad, (Prasada 1948)
On *Poaceae—Agropyron semicostatum*
Distribution: Shimla
Puccinia graminis-poae Erikss. & Henning, (Prasada 1948)
On *Poaceae—Poa nemoralis*
Distribution: Shimla
Puccinia himalensis (Barclay) Dietel, (Padwick 1946; Sydow & Butler 1906 & 1907)
On *Poaceae—Festuca gigentia*
Distribution: Shimla
Puccinia himachalensis A.K. Gautam and S. Avasthi, (Gautam & Avasthi 2016a)
On *Ranunculaceae—Clematis grata*
Distribution: Mandi
Puccinia invenusta Syd. & P. Syd., (Sharma & Sachan 1994)
On *Poaceae—Phramites karka*
Distribution: Solan
Puccinia iridis Wallr., (Sydow & Butler 1912)
On *Iridaceae—Iris florentina*
Distribution: Shimla
Puccinia komarovii Tranzschel ex P. Syd. & Syd., (Khanna 1961)
On *Balsaminaceae—Impatiens amphorata*
Distribution: Shimla
Puccinia leptodermidis Barclay, (Barclay 1890; Sydow & Butler 1912)
On *Rubiaceae—Leptodermis lenceolata*
Distribution: Shimla, Kasauli (Solan)
Puccinia menthae Pers., (Pandotra & Ganguly 1964; Sydow & Butler 1912; Sydow 1938)
On *Lamiaceae—Mentha longifolia*
Distribution: Busher, Shimla, Kasauli, Kullu
Puccinia minutissima Arthur, (Munjal & Gill 1962)

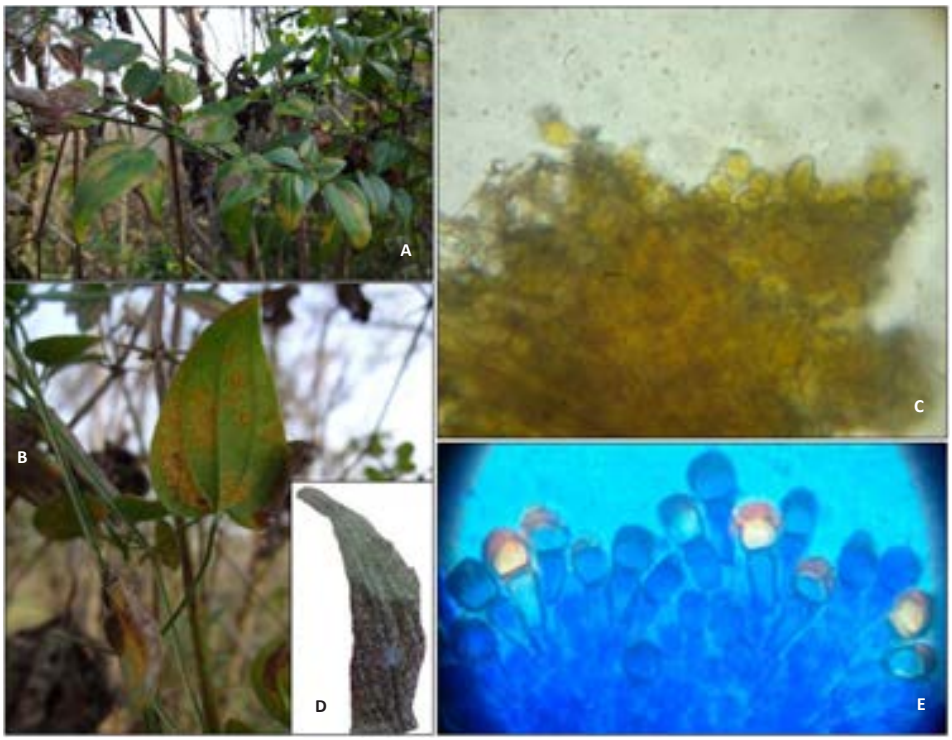

Image 5. *Puccinia collettiana*: A—habitat of host | B, C—symptoms |D—urediniospores | E—teliospores. © Ajay Kumar Gautam.

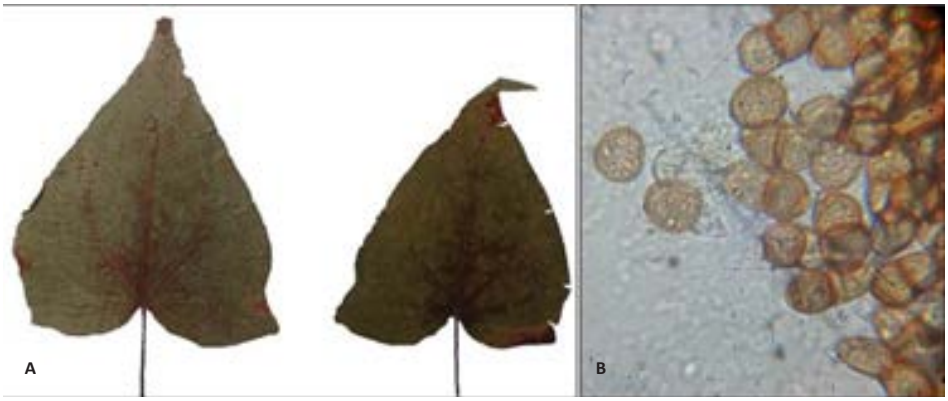

Image 6. *Puccinia fagopyri*: A—symptoms | B—urediniospores & teliospores. © Ajay Kumar Gautam.

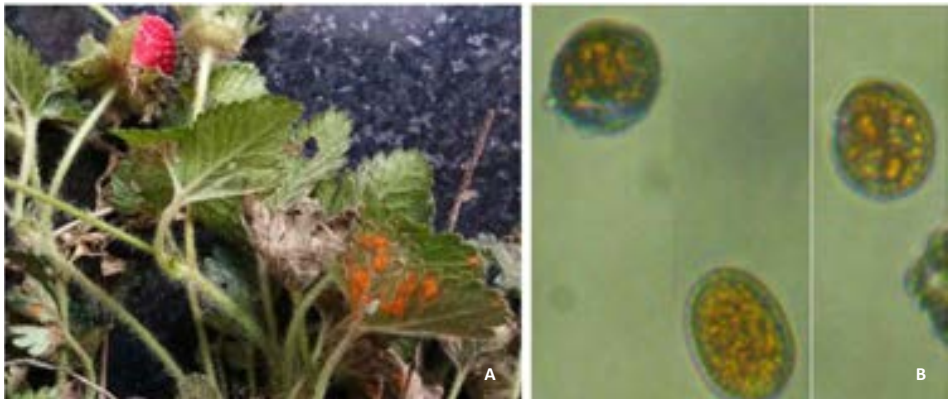

Image 7. *Puccinia flavipes*: A—symptoms | B—urediniospores. © Ajay Kumar Gautam.

On *Poaceae—Saccharum officinarum*
Distribution: Manali
Puccinia nepalensis Barclay & Dietel, (Barclay 1890; Ramakrishanan 1952)
On *Polygonaceae—Rumex nepalensis*
Distribution: Shimla and Kasauli
Puccinia neyraudiae Syd. & P. Syd., (Sharma & Sachan 1994)
On *Poaceae—Neyraudia arundinacea*
Distribution: Solan
Puccinia nitida (F. Strauss) Barclay, (Sydow & Butler 1912)
On *Polygonaceae—Polygonum ampelexicaule*
Distribution: Mashobra, Shimla, Rohtaang Pass
Puccinia opizii Bubák, (Arthur & Cunmins 1933)
On *Asteraceae—Lactuca decipiens*
Distribution: Alwas (Chamba)
Puccinia pacifica Blasdale ex Arthur, (Chona et al. 1956)
On *Plantaginaceae—Plantago tibetica*
Distribution: Shimla
Puccinia recondita Roberge ex Desm., (syn. *Pucciniapersistens* Plowr., *Pucciniarubigo-vera* (DC.) G. Winter) (Arthur & Cummins 1933; Barclay 1890; Jain et al. 1966)
On *Ranunculaceae—Aquilegia vulgaris*, *Thalictrum javanicum*, *Thalictrum minus*
Distribution: Shimla, Dharamshala, Chamba, Kote, Keylog, Kullu
Puccinia pimpinellae (F. Strauss) Link, (Barclay 1890)
On *Apiaceae—Pimpinella diversifolia*
Distribution: Shimla
Puccinia polliniae Barclay, (Barclay 1890)
On *Acanthaceae—Pollinia nuda*
Distribution: Shimla
Puccinia pogonatheri Petch, (Sharma & Sachan 1994)
On *Poaceae—Pogonatherum paniceum*
Distribution: Solan
Puccinia polygoni-amphibii Pers., (Syn. *Pucciniapolygone* Alb. & Schw.)(Ganguly & Pandotra 1963, Mishra & Sharma 1964)
On *Polygonaceae—Polygonum orientale*
Distribution: Shimla, Katrain (Kullu)
Puccinia prainiana Barclay, (Barclay 1890)
On *Smilacaceae—Smilax aspera*
Distribution: Shimla
Puccinia punctata Link, (Barclay 1890)
On *Rubiaceae—Galium aparnie*
Distribution: Shimla
Puccinia purpurea Cooke, (Sharma & Sachan 1994)
On *Poaceae—Sorgham halepense*
Distribution: Solan
Puccinia pusilla Syd. & P. Syd., (Sharma & Sachan 1994)
On *Poaceae—Cappilipedium assimite*
Distribution: Solan
Puccinia recondita var. *simlensis* A.P. Misra, S.T. Ahmad & Sheodh. Singh, (Gupta 1977)
On *Ranunculaceae—Thalictrum javanicum,*
On *Poaceae—Helicotrichon virens*
Distribution: Shimla
Puccinia roscoeae Barclay, (Gupta 1977)
On *Zingiberaceae—Roscoea alpina*, *Roscoea procera*
Distribution: Shimla
Puccinia saviculae Grev., (Barclay 1890)
On *Apiaceae—Savicula europea*
Distribution: Shimla
Puccinia saxifragae-cilliatae Barclay, (Barclay 1890)
On *Saxifragaceae—Saxifrega ligulata*
Distribution: Shimla
Puccinia heucherae (Schweinitz) Dietel, (syn. *Puccinia saxifragae-micranthae* Barclay) (Barclay 1891)
On *Saxifragaceae*—leaves of *Saxifrega micrantha*
Distribution: Bushar & Shimla
Puccinia sonchi Roberge ex Desm., (Sydow 1938)
On *Asteraceae—Sonchus* sp.
Distribution: Kullu
Puccinia sorghi Schwein., (Annonymous 1950; Mishra 1963a)
On *Poaceae—Zea maize*
On *Oxalidaceae—Oxalis conriculata*
Distribution: Mashobra & Shimla
Puccinia striiformis Westend., (Vasudeva 1958; Joshi & Merchand 1963; Mishra et al. 1965, 1975; Ahmad et al. 1969)
On Poaceae—*Muehlenbergia huegelii*; *Bromusjaponicas* and *Loliumperenne*
Distribution: Shimla
Puccinia striiformis f. *muehlenbergii* Misra & Lele., (Mishra & Lele 1963)
On *Poaceae—Muehlenbergia huegelii*
Distribution: Shimla
Puccinia tanaceti DC., (Sharma & Sachan 1994; Bharat 2008)
On *Asteraceae—Artemisia nilogirica*
Distribution: Solan
Puccinia thlaspeos Ficinus & C. Schub., (Arthur 1934; Arthur & Cummins 1933)
On *Brassicaceae—Draba lanceolata*
Distribution: Hunan Nallah, Pangi & Chamba
Puccinia tiliaefolia T.S. Ramakr. & Sundaram, (Gautam & Avasthi 2017c)
On *Malvaceae—Grewia tiliifolia*
Distribution: Mandi
Puccinia tricholepidis Syd., (Sydow 1938)

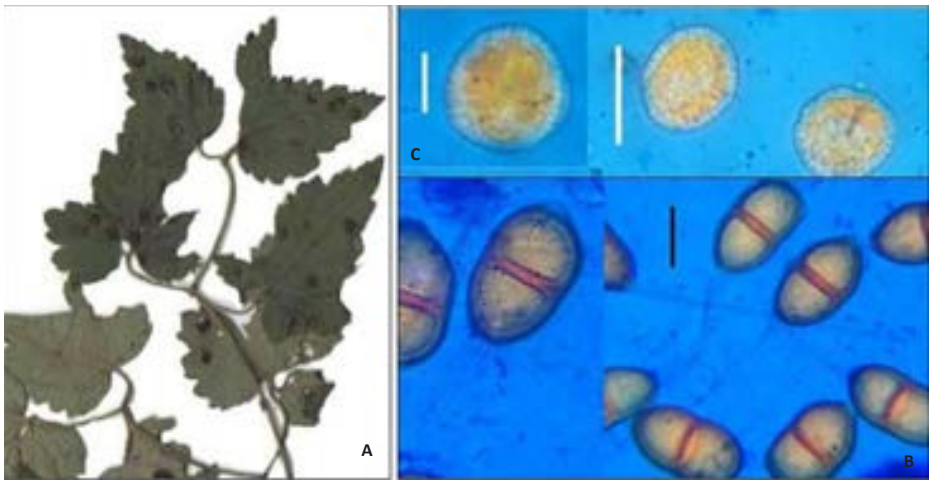

Image 8. *Puccinia himachalensis*: A—symptoms | B—teliospores | C—urediniospores. © Ajay Kumar Gautam.

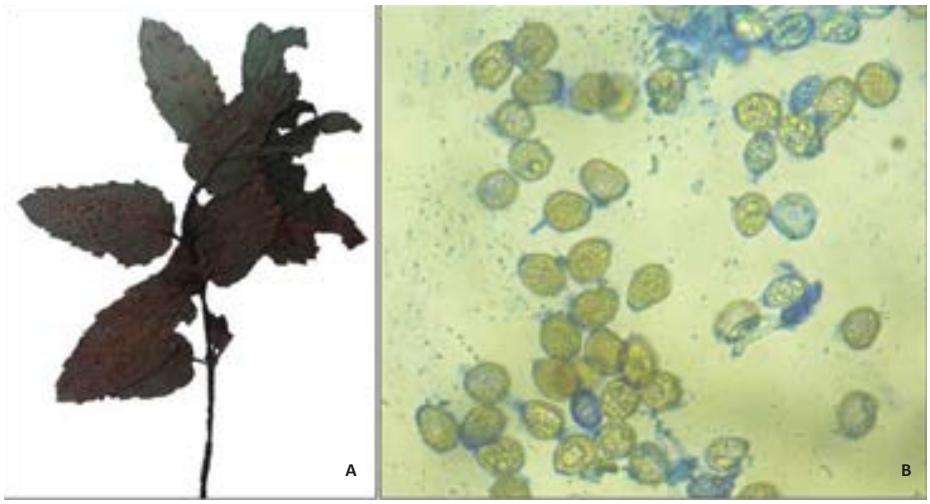

Image 9. *Puccinia menthae*: A—symptoms | B—urediniospores. © Ajay Kumar Gautam.

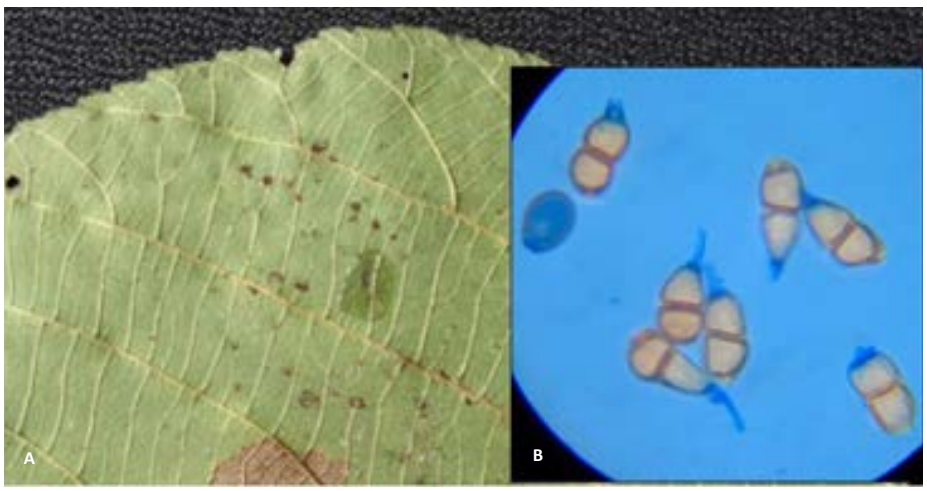

Image 10. *Puccinia tiliaefolia*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

On *Asteraceae—Tricholepis elongata*
Distribution: Saharan & Bushar
Puccinia trifolii R. Hedw., (Arthur & Cummins 1933)
On *Ranunculaceae—Anemone polyanthes*
Distribution: Alwas, Chamba
Puccinia tweediana T.S. Ramakr. & K. Ramakr., (Chona & Munjal 1955;
Ramakrishnan & Ramakrishnan 1948)
On *Acanthaceae—Dicliptera* sp., *D. bupleuroides*
Distribution: Kullu, Shimla
Puccinia urticae Barclay, (Barclay 1890)
On *Urticaceae—Urtica parviflora*
Distribution: Shimla & Kasauli
Puccinia ustalis Berk., (Berkeley 1856)
On *Ranunculaceae*—leaves of *Ranunculus hirtellus*
Distribution: Mathana, Shimla
Puccinia violae (Schumach.) DC., (Bilgrami 1963)
On *Violaceae—Viola serpens*.
Distribution: Shimla
Puccinia wattiana Barclay, (Sharma & Sachan 1994)
On *Ranunculaceae—Clematis gouriana*
Distribution: Shimla

Genus: *Uromyces* (Link) Unger (Image 12)
Type species: *Uredo appendiculata* Pers. (1796)
Uromyces trifolii (R. Hedw.) Lév., (Syn. *Uromyces flectens* Lagerh., *Uromycesnerviphilus* (Grognot) Hotson) (Gautam & avasthi 2017a)
On *Fabaceae*—leaves of *Trifolium repens* L.,
Distribution: Chail Chowk, Mandi
Uromyces viciae-fabae (Pers.) J. Schröt. (syn. *Uromyces fabae* (Pers.) de Barry. (Kulshreshtha et al. 1998)
On *Fabaceae*—leaves of *Vigna radiata* (L.)
Distribution: Shimla
Uromyces agropyri Barclay, (Barclay 1891)
On *Poaceae —Agropyron* sp.
Distribution: Bushahr (Shimla)
Uromyces dactylidis G.H. Otth (Syn. *Puccinia lycoctoni* Fuckel) (Sydow & Butler 1907)
On *Ranunculaceae—Aconitum lycoctonum*
Distribution: Shimla
Uromyces ciceris-arietini (Grognot.) Jacz. & G. Boyer, (Payak 1962)
On *Fabaceae—Trigonella polyerata*
Distribution: Shimla
Uromyces appendiculatus (Pers.) Link, (Sydow & Butler 1912)
On *Fabaceae—Vigna vexillata*
Distribution: Dhramshala
Uromyces macintirianus Barclay, (Sydow & Butler 1938)
On *Acanthaceae*—leaves of *Hemigraphis latebrosa*

Image 11. *Puccinia wattiana*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

Distribution: Shimla
Uromyces hobsonii Vize, (Sydow & Butler 1907)
On *Oleaceae*—leaves of *Jasminum grandiflorum*
Distribution: Shimla
Uromyces polygoni-avicularis var. *polygoni-avicularis* (Pers.) P. Karst., (Sydow 1938)
On *Polygonaceae*—leaves of *Polygonum cogatum*
Distribution: Lahul Valley (L&S), Kullu
Uromyces rottboelliae Arthur, (Sydow & Butler 1938)
On *Poaceae—Rottboellia speciosa*
Distribution: Shimla
Uromyces sommerfeltii Hyl., Jorst. & Nannf., (Barclay 1890)
On *Asteraceae—Solidago virgaurea*
Distribution: Shimla
Uromyces strobilanthis Barclay, (Mitter & Tandon 1938)
On *Acanthaceae—Strobilanthes dalhausianus*
Distribution: Shimla
Uromyces valerianae- wallichii (Dietel) Arthur & Cummins, (Arthur & Cummins 1933)

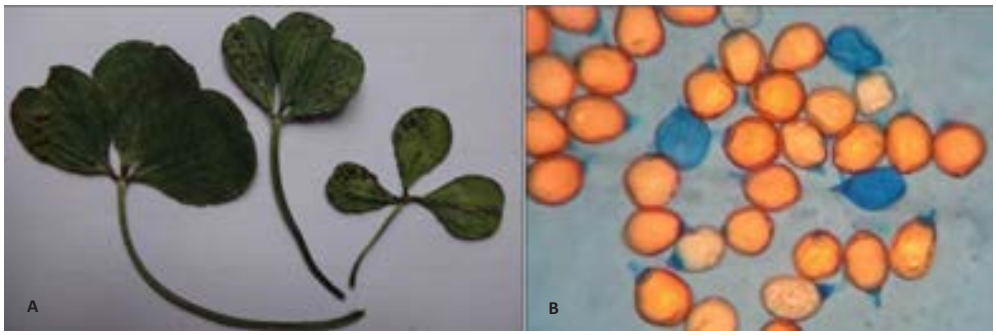

Image 12. *Uromyces trifolii*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

On *Caprifoliaceae*—leaves of *Valeria nawallichii*,
Distribution: Shimla
Uromyces vignae Barclay, (Barclay 1891)
On *Fabaceae—Vigna vexillata*
Distribution: Shimla
Uromyces vossiae Barclay, (Barclay 1890)
On *Poaceae —Vossia speciosa*
Distribution: Shimla

Genus: *Haplotelium* Syd.
Type species: *Haplotelium amoenum* (Syd. & P. Syd.) Syd. (1922)
Haplotelium ambiens (Cooke) Syd., (syn. *Uromyces ambiens* Cooke) (Barclay 1891, Sydow 1913)
On *Buxaceae—Buxus sempervirens*
Distribution: Bushahr (Shimla)

8. *Pucciniastraceae* Gäum. ex Leppik 1972
Genus: *Pucciniastrum* G.H. Otth
Type species**:** *Pucciniastrum epilobii* (Pers.) G.H. Otth (1861)
Pucciniastrum agrimoniae (Dietel) Tranzschel, (Sydow & Butler 1901; Sydow & Butler 1912)
On *Rosaceae*—leaves of *Agrimonia eupatoria*
Distribution: Shimla

Genus: *Uredinopsis* Magnus
Type species: *Uredinopsis filicina* (Niessl) Magnus (1893)
Uredinopsis syngrammes Munjal & J.N. Kapoor., (Munjal & Kapoor 1961)
On *Pteridaceae*—Leaves of *Syngramme fraxiana* Bedd.
Distribution: Narkanda

9. *Urocystidaceae* Begerow, R. Bauer & Oberw.
Genus: *Urocystis* Rabenh. ex Fuckel
Type species: *Urocystis occulta* (Wallr.) Rabenh. (1867)
Urocystis sorosporioides Körn. ex Fuckel, (Mundkar & Thirumalachar 1952)
On *Ranunculaceae*—leaves and stem of *Delphinium denudatum*
Distribution: Shimla

10. *Raveneliaceae* Leppik
Genus: *Ravenelia* Bark.
Type species: *Ravenelia glanduliformis* Berk. & M.A. Curtis (1874)
Ravenelia mitis Syd. & P. Syd. (Sydow & Sydow 1904-21)
On *Fabaceae*—leaves of *Tephrosia purpurea*
Distribution: Solan
Ravenelia tandonii Syd. (Bakshi & Singh)
On *Fabaceae*—leaves of *Acacia catechu*
Distribution: Solan.

Incertae sedis
Genus: *Aecidium* Pers.
Type species: *Aecidium berberidis* Pers. ex J.F. Gmel. (1792)
Aecidium cunninghamianum Barclay, (Barclay 1891)
on *Rosaceae*—leaves of *Cotoneaster bacillaris* Wall.
Distribution: Shimla
Aecidium flavescens Barclay, (Barclay 1891)
on *Asteraceae* —leaves of *Senecio rufinervis* DC.
Distribution: Mashobra, Shimla
Aecidium infrequens Barclay, (Sydow & Butler 1912)
on *Geraniaceae* —leaves of *Geranium nepalense*
Distribution: Shimla
Aecidium leucospermum DC., (Barclay 1890)
on *Ranunculaceae*—leaves of *Anemone rivularis*
Distribution: Shimla
Aecidium lophanthi P. Henn., (Arthur & Cummins 1933)
on *Lamiaceae*—leaves of *Mentha* sp.
Distribution: Chamba
Aecidium montanum E.J. Butler, (Arthur & Cimmins 1933)
On *Berberidaceae*—leaves of *Berberis lyceum*
Distribution: Kangra

Aecidium mori Barclay, (Barclay 1890)
On*Moraceae*—leaves of *Morusalba*
Distribution: Shimla
Aecidium myriactidis (Barclay) Syd. & P.Syd., (Barclay 1890)
On *Asteraceae*—leaves of *Myriactis nepalensis*
Distribution: Mashobra (Shimla)
Aecidium orbiculare Barclay, (Barclay 1891)
On *Ranunculaceae*—leaves of *Clematisgrata*
Distribution: Shimla
Aecidium peristrophes Syd. & P. Syd., (Sydow & Butler 1912)
On *Acanthaceae*—leaves of *Peristrophe* sp.
Distribution: Kangra
Aecidium plectranthi Barclay, (Barclay 1890)
On *Lamiaceae*—leaves of *Plectranthuscoetsa*
Distribution: Shimla
Aecidium wthaniae Thuem., (Sydow & Butler 1912)
On *Solanaceae*—leaves of *Withania coagulans*
Distribution: Shimla

Genus: *Uredo* Pers.
Type species: *Uredo betae* Pers. (1801)
Uredo apludae Barclay, (Barclay 1890)
On *Poaceae*—leaves of *Apluda aristata*
Distribution: Shimla
Uredo duetziae Barclay, (Butler & Bisby 1960)
On *Hydrangeaceae*—leaves of *Deutzia corymbosa*
Distribution: Shimla
Uredo lebrookiana Barclay, (Watt), (Butler & Bisby 1960)
On *Lamiaceae*—leaves of *Colebrookea oppositifolia*,
Distribution: Suni, near Simla
Uredo gomphrenae Barclay, (Sydow & Butler 1907)
On *Amaranthaceae*—leaves & stem of *Gomphrena globosa*
Distribution: Shimla
Uredo ignobilis Syd. & P. Syd., (Pedwick & Khan 1944)
On *Poaceae*—leaves of *Sporobolus indicus*
Distribution: Shimla
Uredo pileae Barclay, (Barclay 1891)
On *Poaceae*—leaves of *Sporobulus trinervia*
Distribution: Shimla
Uredo valerianae-wallichii Dietel, (Barclay 1891)
On *Caprifoliaceae*—leaves of *Valeriana wallichii*,
Distribution: Shimla

DISCUSSION

The present study provides the checklist of rust fungi from Himachal Pradesh, a northwestern Himalayan State of India. A remarkable diversity of rust fungi have been reported from the state which has an area of 55,673km^2. The state exhibits marked variations in climate and vegetation and so far in fungal diversity. The available information about rust fungi from the state is in general meager and there is much scope for exploratory work on the taxonomy, diversity and ecological aspects of these fungi. There are about 167 species, 23 genera belonging to 11 families recorded from this hilly Himalayan state, with great variations in host infected (about 171 plant species belonging to 121 genera and 52 families). This distinguished diversity of rust fungi may be due to the fact that rust fungi tend to prefer humid habitats, which is one of the major characteristic features of the state. Being obligate parasites, rust fungi are associated with spreading and development of nutrient plants and are found in many belts, both on herbaceous plants, and on trees and shrubs.

After compilation of literature it is observed that most of the rust fungi were reported from Shimla and nearby regions. Although, these fungi are also reported from other districts of the state but the scope of exploration of these fungi and their host range is still there.

Two checklists on two major rust genera namely, *Puccinia* (Gautam & Avasthi 2016b) *Uromyces* (Gautam & Avasthi 2017a) have recently been published from this hilly state. Two new species of rust fungi namely *Puccinia himachalensis* (Gautam & Avasthi 2016a) and *Skierka himalayensis* (Gautam & Avasthi 2017b) have been reported from the state which are new to science. Whereas, *Pileolaria pistaciae* (Gautam & Avasthi 2017b), *Kweilingia divina* (Gautam & Avasthi 2018) are the new additions to the mycobiota of the state while, *Puccinia tiliaefolia* (Gautam & Avasthi 2017c) has been rediscovered after 46 years from India. During the literature survey we did not come across any molecular studies conducted on rust fungi from the state. As per greater phytodiversity of the state, studies on the rust fungi are inadequate and there is vast scope to conduct studies and fill the data gaps. Molecular studies of rust fungi are still required besides morphological taxonomy, which will not only help in revision and reassessment of the existing fungal species, but also to find their correct taxonomic position. The knowledge generated by the work is of immense utility as it is a key to revealing the diversity and ecology of rust fungi from Himachal Pradesh Himalaya.

REFERENCES

Ahmad, S.T., H.S. Singh & D.P. Mishra (1969). Additions to wheat rusts races in India race 14 & 38 of *Puccinia striformis* identified during 1965. *Indian Phytopathology* 22: 525–526.

Annonymous (1950). List of common names of Indian plant diseases. *Indian Journal of Agricultural Research* 20: 107–142.

Arthur J.C. (1934). *Manual of Rusts in United States and Canada*. Lafayette, Indiana. 438pp.

Arthur, J.C. & G.D. Cummins (1933). Rusts of North West Himalayas. *Mycologia* 25: 397–406.

Bagchee (1950). *Coleosporium barclayense* Bagchee. *Indian Forest Records* 4(2): 53.

Bakshi, B.K. & S. Singh (1967). Rusts on Indian Forest Trees. Indian Forest Records (NS), *Forest Pathology* 2: 139–198.

Barclay A. (1890). Descriptive list of Uredineae occurring in the neighborhood of Shimla. *Journal Asiatic Society of Bangal* 56: 161–165, 350–375.

Barclay A. (1891). Additional Uredineae from the neighborhood of Shimla. *Journal Asiatic Society of Bangal* 60: 211–230.

Berkeley M.J. (1856). Decades of fungi; Decas 1–62 nos 1–620. *Hooker's London Journal of Botany* 3–8: 844–1856.

Bharat N.K. (2008). Occurrence of rust on *Artemisia dracunculus* L. in Himachal Pradesh. *Indian Forester* 134: 140.

Bharat, N.K. & S.K. Gupta (2011). Outbreak of garlic rust in Shimla district of Himachal Pradesh. *Journal of Mycology and Plant Pathology* 41: 132–133.

Bhardwaj, L.N. & P.N. Sharma (1990). Occurrence of rust on black zira in Himachal Pradesh. *Indian Journal of Mycology and Plant Pathology* 20(3): 270.

Bilgrami K.S. (1963). A new species of *Periconia* on the leaves of *Typhalatifolia*. *Science and Culture* 29: 47–48.

Bilgrami K.S., Jamaluddin & Rizwi MA (1991). Fungi of India: List and references. Today and Tomorrow's Printers & Publishers, New Delhi, India.

Butler E.J. (1918). Uredinales from North Western Himalaya. *Mycologia* 35: 446–458.

Butler, E.J. (1912). The rusts of wildvines in India. *Annals of Mycology* 10: 153–158.

Butler, E.J. (1905). Pilzkrankheiten in Indien in Jahre 1903. *Zeitschrift für Pflanzenkunde* 15: 44–48.

Butler, E.J. & G.R. Bisby (Revised by Vasudeva RS.) (1960). *The fungi of India*. ICAR Publications New Delhi, India, 552pp.

Butler, E.J. & G.R. Bisby (1931). *The fungi of India*. Imperial Council of Agricultural Research India. Science Monograph I XVIII+237pp.

Chona, B.L. & R.L. Munjal (1955). Notes on miscellaneous fungi-II. *Indian Phytopathology* 8: 184–198.

Chona, B.L. & R.L. Munjal (1956). Notes on miscellaneous fungi-III. *Indian Phytopathology* 9: 53–56.

Chona, B.L., R.L. Munjal & J.N. Kapoor (1956). Notes on miscellaneous Indian fungi-IV. Indian Phytopathology 9: 125–132.

Cooke, M.C. (1878). Some Himalayan fungi. Grevillea 7: 94–96.

Cummins, G.B. (1943). Uredinales from the North Western Himalayas. *Mycologia* 35: 446–458.

Cummins, G.B. & N. Hiratsuka (2003). *Illustrated Genera of Rust Fungi*, *3rd ed*. American Phytopathological Society, St. Paul, Minnesota 240pp.

Dietal, P. (1890). Uredineen aus dem Himalaya. *Hedwegia* 29: 259–270.

Ganguly, D. & V.R. Pandotra (1963). Fungi on medicinal and aromatic plants in North West Himalays – I. Mycopathologia et Mycologia Applicata 20: 39–40.

Gautam, A.K. & S. Avasthi (2016a). *Puccinia himachalensis* – a new rust fungus from Himachal Pradesh, India. *Plant Pathology & Quarantine* 6(2): 220–223.

Gautam, A.K. & S. Avasthi (2016b). First checklist of rust fungi in the genus *Puccinia* from Himachal Pradesh, India. *Plant Pathology & Quarantine* 6(2): 106–120.

Gautam, A.K. & S. Avasthi (2017a). *Uromyces trifolii*, a new addition to rust fungi of Himachal Pradesh, India with a checklist of *Uromyces* in India. *Plant Pathology & Quarantine* 7(1): 1–14.

Gautam, A.K. & S. Avasthi (2017b). Fungi associated with *Pistacia integerrima* with a description of a new species and one new record from India. *Acta Mycologica* 52(2): 1100. https://doi.org/10.5586/am.1100

Gautam, A.K. & S. Avasthi (2017c). Discovery of *Puccinia tiliaefolia* (Pucciniales) in northwestern Himalayas, India. *Polish Botanical Journal* 62(1): 135-137.

Gautam, A.K. & S. Avasthi (2018). A new record to rust fungi of North Western Himalayas (Himachal Pradesh), India. *Studies in Fungi* 3(1): 234–240.

Godre, W.Y. & P.G. Patwardhan (1965). Occurrence of *Erysiphe graminis* var. *tritici* in Bombay, Maharashtra. *Current Science* 34: 89.

Golatkar, V.V. (1976). *Harknessia*: a new generic record to India. *Current Science* 45: 269–270.

Gupta, S.C. (1977). New diseases of sugarcane in U.P. India. *Current Science* 46: 27.

Jain, A.C., B.G. Nikam, S.N. Kulkarni & O.P. Sharma (1966). Fungi of Gwalior and Indore region. *The Vikram* 4: 181–187.

Jamaluddin, S., M.G. Goswami & B.M. Ojha (2004). *Fungi of India (1989–2001)*. Scientific Publishers (India), Jodhpur, 326 pp.

Joshi, L.M. & W.C. Merchand (1963). *Bromus japonicas* Thunb. susceptible to wheat rust under normal conditions. *Indian Phytopathology* 16: 312–313.

Khan, Y., R.C. Sharma, R.C. & S. Sharma (2004). Incidence and severity of leaf rust (*Melampsora ciliata*) of Poplar in Himachal Pradesh. *Indian Forester* 130(6): 673–679.

Khanna, P.K. (1961). A new report of a new host of *Puccinia kanmorensis* Cummins from India. Proceedings from National Academy of Sciences India 31B: 113.

Kulshreshtha, M., A. Gulabani, D.K. Agarwal & A.K. Sarbhoy (1998). Some new additions to fungi of India. *Indian Phytopathology* 51(1): 104.

Mishra, D.P. (1963a). Natural occurrence of the aecial stage of *Puccinia sorghi* Schw. *Oxalis corniculata* Linn. in Nepal. *Indian Phytopathology* 16: 8–9.

Mishra, D.P. (1963b). A new physiologic race of linseed rust in India. Indian Phytopathology 16: 102–103.

Mishra, D.P. & R. Prasada (1966). Status of linseed rust races in India and sources ofresistance. *Indian Phytopathology* 19: 184–188.

Mishra, D.P. & S.K. Sharma (1964). Natural infection of *Oxalis corniculata*, the alternate host of *Puccinia sorghi* in India. *Indian Phytopathology* 17: 138–141.

Mishra, D.P. & V.C. Lele (1963). *Choanephora cucubitarum* on *Cajanus cajan* in India. *Indian Phytopathology* 22: 515–517.

Mishra, D.P., S.K. Sharma, P.C. Joshi & S. Singh (1964). Further studies in the crown rust of oat in India. *Indian Phytopathology* 17: 142–145.

Mishra, D.P., S. Singh & S. Ahmad (1975). Notes on some rusts from Shimla Hills. *Indian Phytopathology* 28: 256–260.

Mishra, D.P., S.T. Ahmad & H.S. Singh (1965). Natural occurrence of specialized forms of *Puccinia graminis* and *Puccinias triiformis* on *Loliumperenne*. *Indian Phytopathology* 18: 214–215.

Mitter, J.H. & R.N. Tandon (1938). Fungi of Nainital Part-II. *Journal of Indian Botanical Society* 17: 177–182.

Mohanan, C. (2010). *Rust Fungi of Kerala. Kerala, India.* Kerala Forest Research Institute, Peechi, 148pp.

Mukerji, K.G. & C. Manoharachary (2010).*Taxonomy and Ecology of Indian Fungi*. I. K. International Pvt Ltd. New Delhi, India, 304pp.

Mundkar, B.B. (1938). Fungi of India- supplement I, ICAR Sci. Monograph 12:54pp.

Mundkar, B.B. & M.J. Thirumalachar (1952). Ustilaginales of India. Commonwealth Mycological Institute, Kew 84pp.

Munjal, R.L. & H.S. Gill (1962). Some dematiaceous fungi from India-I. *Indian Phytopathology* 15: 269–279.

Munjal, R.L. & J.N. Kapoor (1961). Two fern rusts from India. *Current science* 30: 308–310.

Padwick, G.W. (1945). Notes on Indian fungi-III. *Mycological Papers*

12: 15 pp.
Padwick, G.W. (1946) Notes on Indian fungi-IV. *Mycological Papers* 17: 12 pp.
Padwick, G.W. & A. Khan (1944). Notes on Indian fungi-II. *Mycological Papers* 10: 17 pp
Pandotra, V.R. & D. Ganguly (1962). Notes on two fungi collected from Kullu Valley, Punjab. *Indian Phytopathology* 15: 216–217.
Pandotra, V.R. & D. Ganguly (1964). Fungi on medicinal and aromatic plants in North West Himalayas Mycopathology et Mycological Applicata 22: 59–68, 106–116.
Patil, J.S. & A.P.B. Nayar (1936). Natural and Induced resistance to shoot rot in the coconut. *Proccedings of Indian Academic of Sciences* 3(B): 432–437.
Paul, Y.S., V.K. Thakur & C. Gopi (2004). Occurrence of *Melampsoramedusae* Thum in India. *Journal of Mycology and Plant Pathology* 34: 850–851.
Payak, M.M. (1962). Natural occurrence of gram rusty in uredial stage on *Trigonella polycerata* L. in Shimla hills. *Current Science* 31: 433–434.
Payak, M.M. (1965). *Berberis* as the aecial host of *Puccinia brachypodii* in Shimla Hills, India. *Phytopathology* 52: 49–54.
Prasada, R. (1948). Studies on rusts on some of the wild grasses occurring in the neighborhood of Shimla. *Indian Journal of Agricultural Science* 18: 165–176.
Puri, Y.N. (1955). *Rust and wood rotting fungi on some of the Indian Conifers*. Forest Bulletin Dehradun 179. Manager of Publication, Government of India Press, Calcutta.
Ramakrishanan, T.S. (1952). Additions to fungi of Madras-XII. *Proceeings of Indian Academy of Sciences* 35(B): 11–121.
Ramakrishanan, T.S. & K. Ramakrishanan (1948). Additions to fungi of Madras- V. *Proceedings of Indian Academy of Sciences* 28(B): 50–70.
Ranadive, K., S. Kadbane, S. Mandal, H. Wasesa, P. Jite, V. Ranade & J. Vaidya (2012). Host distribution of *Melampsora* Cast from India. *Journal of Scientific Information* (Special issue) 4: 33–40.
Rehill, P.S. & Y.N. Puri (1980). Some important diseases of *Populus*. *Indian Journal of Foresrty* 3(2): 176–183.
Sehgal, H.S., R.K. Tiwari, S.N. Khan & B.M. Misra (1989). New records of fungi and new host records from India. *Indian Forester* 115: 228–234.
Sharma, R.C., & S. Sharma (2000). Status and distribution of foliar diseases of poplar in Himachal Pradesh. *Indian Phytopathology* 53: 57–60.
Sharma, R.K. & S.N. Sachan (1994). New host of rust fungi from Himachal Pradesh. *Advances in Plant Sciences* 7: 154–158.
Sharma, S., & R.C. Sharma (2002). Prevalence of poplar leaf rust in Himachal Pradesh. *Indian Phytopath* 55: 81–83.
Singh, V.M. & Y.R. Sharma (1977). Rust on Garlic FAO. *Plant Protection Bulletin* 25: 41–42.
Sydow, H (1913). Mycotheca Germanica. Fasc. XXIV: 1151-1200. *Annals of Mycology* 11: 364–366.
Sydow, H. (1938). Fungi Himalayensis. *Annals of Mycology* 36: 437–442.
Sydow, H. & E.J. Butler (1901). Fungi Indiae Orientalis Pars. I. *Annals of Mycology* 4: 424–445.
Sydow, H. & E.J. Butler (1906). Fungi Indiae Orientalis Pars. I. *Annales Mycologici* 4: 424–445.
Sydow, H. & E.J. Butler (1907). Fungi Indiae Orientalis II. *Annales Mycologici* 5: 485–515.
Sydow, H. & E.J. Butler (1911). Fungi Indiae Orientalis part III. *Annales Mycologici* 9: 372–421.
Sydow, H. & E.J. Butler (1912). Fungi Indiae Orientalis IV. *Annales Mycologici* 10: 243–280.
Sydow, H. & J.H. Mitter (1933). Fungi Indici I. *Annals of Mycology* 31:84–97.
Sydow, H. & P. Sydow (1904–21). Novae fungorum species-I. *Annals of Mycology* 2: 162–174.
Ulbrich, E. (1939). New species from Nanga Parbat collected by C. Troll. Fungi. Addendum to Pucciniaceae. *Notizbl. hot. Gart. Bed.* 14: 124, 343–344.
Vasudeva, R.S. (1958). Report of the division of Mycology and Plant Pathology. Science Report of Agricultural Research Institute, New Delhi, pp. 87–101 & 1954–55.

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14862–14869

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

PLATINUM
OPEN ACCESS

The distribution of blue-green algae (Cyanobacteria) from the paddy fields of Patan and Karad tehsils of Satara District, Maharashtra, India

Sharada Jagannath Ghadage [1] & **Vaneeta Chandrashekhar Karande** [2]

[1,2] Department of Botany, Yashwantrao Chavan Institute of Science, Tal Karad, Satara District, Maharashtra 415001, India.
[1] ssharada1980@gmail.com (corresponding author), [2] vaneetachandra@gmail.com

Abstract: The distribution pattern of blue-green algae was studied from paddy fields of Patan and Karad tehsils in relation to physico-chemical properties of soil, viz., pH, electrical conductivity, organic carbon %, available N, P, and K. Paddy field soil samples of 38 localities from Patan and 28 localities from Karad were analysed. One-hundred-and-thirty-seven species belonging to 35 genera of 10 families from three orders were encountered from paddy field soils of both the tehsils. Out of 66 soil samples 93.65% samples showed occurrence of unicellular, heterocystous and non heterocystous forms while 6.34% soil samples showed only non heterocystous forms. *Anabaena* and *Oscillatoria* were found to be of common occurrence. Significant variation was not observed in distribution pattern of blue-green algal forms in relation to physico-chemical properties during successive surveys.

Keywords: Cyanobacteria, heterocystous, physico-chemical parameters, soil samples.

DOI: https://doi.org/10.11609/jott.4891.11.14.14862-14869

Editor: Asheesh Shivam, Nehru Gram Bharati (Deemed to be University), Prayagraj, India. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4891 | Received 14 February 2019 | Final received 10 October 2019 | Finally accepted 12 November 2019

Citation: Ghadage, S.J. & V.C. Karande. (2019). The distribution of blue-green algae (Cyanobacteria) from the paddy fields of Patan and Karad tehsils of Satara District, Maharashtra, India. *Journal of Threatened Taxa* 11(14): 14862–14869. https://doi.org/10.11609/jott.4891.11.14.14862-14869

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Sharada J. Ghadage graduated from the University of Kolhapur and is currently a research scholar with center for Yashwantrao Chavan Institute of Science, Satara. She is working as a senior assistant professor in S.G.M. college, Karad. She is currently working on one minor project - Effect of Azolla biofertilizer on soil quality and developmental stages of various crops, fnded by RUSA. Dr. Mrs. V. C. Karande has 36 years experience as a professor for PG and UG department in Botany subject Yashwantrao Chavan Institute of Science, Satara. She is working as a Head of Botany department as well as Vice Principal in Y.C. Institute of Science, Satara and is a BOS member in Shivaji University, Kolhapur. Also she worked as a science faculty Dean in Shivaji University, Kolhapur. She had completed two minor projects on biodiversity of blue green algae.

Author contribution: SJG - Conconceptualized study, collected and analyzed data, wrote final version of manuscript translated in the field, VCK - supervised study, helped in the revision of the manuscript.

Acknowledgements: We are thankful to Dr. K.G. Kanade, principal, Y.C. Institute. of Science, Satara for the encouragement during the work. Thanks are also due to the head Department of Botany Y.C. Institute of Science, Satara for the facilities. We are thankful to staff members and colleagues and friends for the keen interest and suggestions during this work.

INTRODUCTION

Blue-green algae are the first photosynthetic prokaryotes which emit oxygen in the atmosphere. Cyanobacteria are the connecting link between bacteria, eukaryotic algae, and higher plants. They resemble bacteria in the lack of membrane bound organelles like true nucleus, chloroplast, and mitochondria (Feldgarden & Cohn 2003); and they contain a photosynthetic system like that of eukaryotic algae and green plants (Castenholz & Waterbury 1989).

They contain bluish-green colored pigment phycocyanin where 'cyan' means dark blue, hence the name 'Cyanobacteria' and this pigment in conjunction with green chlorophyll, hence the common name is 'Blue-green algae'. Besides chlorophyll, other pigments also present and giving different coloration to them are carotenoids, phycobilins (phycocyanin, phycoerythrin). They also appear bluish, purple, brown, black and green in color (Kondo & Yasuda 2003).

Blue-green algae are important components of soil microflora in the paddy field. They play an important role in maintaining and improving soil fertility as they have the ability to fix nitrogen. Rice fields provide ideal environment for luxuriant growth of blue-green algae. They are found in paddy field soil throughout the year at various growth stages of the rice crop. The occurrence, distribution and proliferation of those blue-green algae is controlled by the physical and chemical nature of the paddy field soil. These parameters of soil show profound effect on the distribution of blue-green algae (Nayak et al. 2004).

Extensive work on the blue-green algae of paddy fields has been carried out in various regions of India, viz., West Bengal, Kerala, Chattisgarh, Manipur, Mizoram, Uttar Pradesh, Madhya Pradesh, Odisha, Tamil Nadu, and Maharashtra, and in Bangladesh (Banarjee 1935; Goyal et al. 1984; Anand & Revati 1987; Anand et al. 1987, 1995; Sahu et al. 1997; Ahmed 2001; Nayak et al. 2001). There have been some reports on the growth and nitrogen fixation potentials of blue-green algae (Gupta 1964; Prasad & Mehrotra 1980; Santra 1991). Marked variations among the species of blue-green algae from rice field soils of different regions of India have been recorded by Tiwari (1972), Sinha & Mukherjee (1975a,b; 1984), and Anand (1990). The effect of soil pH on the blue-green algal diversity in rice field soils was studied by Singh (1978), Sardeshpande & Goyal (1981b), and Nayak & Prasanna (2007).

Studies on blue-green algal flora from the paddy fields of Maharashtra were undertaken by Gonzalves & Gangla (1949), Sardeshpande & Goyal (1981a); Kolte & Goyal (1985), Patil & Satav (1986), Madane & Shinde (1993), and Patil & Chougule (2009). Biodiversity of blue-green algae from the paddy fields of Satara District was studied by Karande (2009); and Kamble (2010, 2017). Blue-green algal diversity other than paddy was studied by Kamat (1962, 1963, 1964, 1974); Jawale & Kumawat (2004); Auti & Pingle (2006), and Nikam et al. (2013). There is, however, no report on the blue-green algal distribution pattern in relation to physicochemical properties of paddy soil from Patan and Karad tehsils of Satara District, hence the present work.

MATERIALS AND METHODS

Study Area

For the present work paddy fields were selected from Patan and Karad tehsils of Satara, Maharashtra. Patan is 65km away to the south-west of Satara. It is located at 17.370^{0}N and 73.900^{0}E. Most of Patan Tehsil is hilly with deep valleys while some part is plains. It receives heavy rainfall. Common soil is red lateritic soil, in plains it is black cottony soil while at elevations it is of basaltic and lateritic type. This tehsil is famous for cultivation of local varieties of paddy, viz.: Dombya, Dodkya, Kolambya, Bhados, Panwel, Indrayani, Champakali, Ghansal, Jiresal, Teliansh 6444, Kaveri 888, Krishnakusal, Basmati, and Ambemohar.

Karad is 52km away to the south-east of Satara. It is located at 17.289^{0}N and 74.181^{0}E. Karad city situated at southern part of Satara District near Agashiva, at the confluence of Koyna and Krishna rivers which is called 'Preeti sangam'. The tehsil receives moderate rainfall and the common soil type is black cottony soil. It is famous for cultivation of local varieties of rice, viz.: Indrayani, Rethare Basmati, Pusa Basmati, Hansa, Khadkil Kolhapuri, Kolhapuri R-24, and Kaveri.

Soil samples were collected from paddy fields of study area (Fig. 1). Thirty-eight soil samples from Patan and 28 soil samples from Karad were selected for physico-chemical analysis. About 250g of soil from rice fields were collected randomly from both the tehsils as per Somawanshi et al. (1999). The collected soil samples were brought in the laboratory using polythene bags, dried at room temperature in diffuse sunlight in shade, then crushed with the help of a mortar and pestle, sieved and used for physico-chemical analysis. pH, EC, organic carbon %, available Nitrogen, Phosphorous, and Pottash were analysed following standard methods (Table 2). Physico-chemical parameters of soil from both the tehsils were compared with distribution of blue-green algal flora

Figure 1. Study area—location of Karad and Patan Tahasils of Satara District. Source: Google maps.

(Tables 3 and 4).

From above sieved soil about 1g of soil transferred aseptically to BG 11 + and BG 11- medium (Rippka et al. 1979), Fogg's medium and chu 10 medium. We found good results in BG 11 **±** medium, so for further culturing and sub culturing we prefer BG 11 ± medium. These cultures were incubated at 22±2˚c with 16/8 light dark cycle under 5 Klux intensity of light, after incubation algal growth appeared in enriched cultures in laboratory. Cyanobacterial growth from enriched cultures were examined microscopically and identified with the help of standard literature (Dasikachary 1959; Santra 1993; Anand 1990; Anagnostidis & Komarek 1985). Photographs were taken by using photomicrography unit of Olympus CH20i (Photoplates II, III).

The composition of BG 11 culture media

BG-11 Medium (Allen 1968; Allen & Stainer 1968; Rippka et al. 1979)

Component	**g L $^{-1}$**
K_2HPo_4	0.04
$MgSO_4.5H_2O$	0.075
$Cacl_2.2H_2O$	0.036
Citric acid	0.006
Ferric Ammonium Citrate	0.006
EDTA	0.001
Na_2CO_3	0.002
Trace Metal Mix (A_5)	1ml

The trace metal mixture A_5 solution contained the following constituents in

Salts	g L^{-1}.
H_3BO_3	2.86
$MnCl_2.4H_2O$	1.81
$ZnSO_4.7H_2O$	0.222
$Na2MoO_4.2H_2O$	0.390
$CuSO_4.5H_2O$	0.079
$CO(NO3)_2.6H_2O$	0.049
pH was maintained in	7–7.5

RESULT AND DISCUSSION

Thorough screening of 66 paddy field soil samples collected and cultured from study area have shown occurrence of 137 species belonging to 35 genera of 10 families from three orders, viz., Chroococcales, Nostocales, and Stigonematales (Table 1). Of the 35 genera isolated from soil samples 11 are unicellular and 24 are filamentous. Among filamentous taxa; 10 were filamentous non-heterocystous and 14 are filamentous heterocystous. Filamentous heterocystous forms are found to be dominant over filamentous non-heterocystous forms. Among the heterocystous form order Nostocales found to be dominant. The abundance and distribution of heterocystous forms may be indicating the lower nitrogen status in study region. Species richness was found in the genus *Oscillatoria*. The most widespread genus from the paddy field soils of study region is *Anabaena* followed by *Oscillatoria* and *Lyngbya*. The observations of the present study do not differ much from those by Anand et al. (1995), where it was reported that the genera *Oscillatoria* and *Phormodium* were predominant in rice fields of Kerala.

Thirty-four genera and 131 species from Patan and 30 genera and 95 species from Karad were recorded (Table 1); 63.50% taxa showed common occurrence, 32.11% taxa restricted to paddy soils of Patan while 4.37% taxa found in paddy field soils of Karad. Nine forms strictly restricted to paddy field soils of Patan, viz., *Synechosystis, Westiellosis, Aulosira, Symploca, Schizothrix, Merismopedia, Trichodesmium, Cylindrospermum*, and *Dacyloccocopsis* while *Polychlamydum* is a rare form restricted to paddy field soils of Karad. Order Nostocales found to be largest order in the family Oscillatoriaceae. Genera *Oscillatoria, Lyngbya*, and *Phormidium* belonging to family Oscillatoriaceae and genera *Anabaena* and *Nostoc* belonging to the family Nostocaceae were found to be dominant from paddy soils of both the tehsils.

Analysis of paddy field soils (38 localities from Patan and 28 localities from Karad) by applying standards of soil parameters required for agriculture were conducted (Table 2). Soil analysis showed that pH and EC of majority

Table 1. Total number of species from Patan and Karad tehsils.

Family	Genera	Species in Patan Tehsil	Species in Karad Tehsil
Order Chroococcales			
1. Chroococcaceae	*Chroococcus*	5	4
	Aphanothece	3	3
	Aphanocapsa	2	2
	Gloeothece	3	2
	Gloeocapsa	6	3
	Synechosystis	1	1
	Synechococcus	2	1
	Microsystis	1	2
	Dacylococcopsis	1	-
	Merismopedia	1	-
2. Entophysalidaceae	*Chlorogloea*	2	2
Order Nostocales			
1. Oscillatoriaceae	*Lyngbya*	16	9
	Trichodesmium	1	1
	Oscillatoria	27	20
	Phormidium	12	7
	Microcoleus	2	2
	Symploca	1	-
	Schizothrix	1	-
	Polychlamydum	-	1
2. Microchaetaceae	*Microchaete*	2	2
3. Nostocaceae	*Cylindrospermum*	7	2
	Anabaena	9	10
	Nostoc	7	7
	Pseudoanabaena	2	1
	Aulosira	2	-
4. Scytonemataceae	*Plectonema*	1	1
	Scytonema	2	2
	Tolypothrix	2	1
5. Rivulariaceae	*Calothrix*	1	2
Order Stigonematales			
1. Mastigocladaceae	*Mastigocladus*	1	1
2.Nostochopsidaceae	*Nostochopsis*	1	1
3. Stigonemataceae	*Fisherella*	2	2
	Hapalosiphon	3	1
	Westiellopsis	1	1
	Westiella	1	1
10 Families	35 Genera and 137 species	34 Genera and 131 species	30 Genera and 95 Species

Table 2. Standard of soil parameters required for agriculture (Somawanshi et al. 1999).

pH	EC	Fertility category	Soil samples showing			
			Organic carbon %	N kg/ha	P kg/ha	K kg/ha
1. Acid soil < 6.0	1. Good soil < 1	1. Very low	< 0.20	< 140	< 7	< 100
2. Good soil 6.00-8.50	2. Poor 1–2	2. Low	0.21–0.40	141–280	7–14	101–150
3. Alkali soil > 8.50	3. Harmful to some crops 2–3	3. Moderate	0.41–0.60	281–420	15–20	151–200
	4. Harmful to most of crops >3	4. Moderate High	0.61–0.80	421–560	21–28	201–250
		5. High	0.81–1.00	561–700	29–35	251–300
		6. Very High	>1.00	>700	>35	>300

of the paddy soils from both the tehsils are in good range (Tables 3 and 4). Organic carbon % form paddy field soils of Patan ranged from 0.31–0.106 %; while that of Karad ranged from 0.73–0.87 % by applying standards of soil parameters; the organic carbon % from paddy field soils of Patan was higher than paddy field soils of Karad (Table 3 and 4). Blue-green algal abundance was recorded to be more in paddy soils of Patan than Karad. The total nitrogen from Patan ranged 150.5–410 kg/ha and that of Karad 61.1–323.4 kg/ha found to be favorable for the distribution of blue-green algal forms. The range of available N from both the tehsils when compared with standards (Table 2) indicated that the low to moderate nitrogen content (Tables 3 & 4) did not affect the blue-green algal abundance. Roger & Kulasooriya (1980) reported that under deficiency of nitrogen in soil condition, nitrogen fixing blue-green algae show their dominance. Our observations are in concordance with those proposed by them.

Available P in Patan ranged 62.7–168 kg/ha and Karad ranged 20.1–56 kg/ha showed blue-green algal abundance. Majority of the localities showed fertility category low to moderate (Tables 3 & 4) when compared with standards from both the tehsils and even though it did not affect blue-green algal dominance. According to Fuller & Rogers (1952), Cyanobacteria are responsible for increased soil phosphorous. Majority of the localities showed average concentrations of phosphorous. Our observations about available phosphorous of paddy soils of Karad support them, but only up to some extent. Available K from Patan paddy field soils ranged 304.6–647.3 Kg/ha and from Karad ranged 145.6–676.4 kg/ha, respectively. Majority localities showed moderate and high range of available K and blue-green algal abundance observed at this range. There is no significant correlation found in concentration of P and blue-green algal distribution from both the tehsils paddy field soils.

Among the soil properties pH is most important factor which determines growth, establishment and diversity of Cyanobacteria. Blue-green algae generally prefer neutral to slightly alkaline pH for optimum growth (Singh 1961). Our observations support this view as majority of the soil samples from the study area showed neutral to alkaline pH ranging 7–8.40 with occurrence of abundant blue-green algae. pH values of various localities showed significant positive correlation. In culture media the optimal pH for the growth of Cyanobacteria ranges 7.5–10. Abundance of blue-green algae is observed at the pH 6.5–7.5 in our experiments. Low available Nitrogen and Potassium does not affect blue-green algal dominance. Paddy field soil of Patan was rich in organic carbon % while that of Karad showed less organic carbon %. This may be the reason for blue-green algal dominance from paddy soils of Patan area. There was no remarkable role of available phosphorous noted on the blue-green algal dominance from study area.

Different unicellular, heterocystous filamentous and non-heterocystous filamentous forms were isolated, identified and maintained in unialgal culture. Blue-green algal forms were more or less evenly distributed in the rice fields of both the tehsils. Out of 66 soil samples 93.65% samples contained unicellular, heterocystous and non heterocystous forms; 6.34% contained only non heterocystous forms.

Patan is famous for paddy cultivation, traditional cropping system, use of local varieties for cultivation and favorable climatic conditions favours luxuriant growth of paddy in Patan area. Hence we recorded blue-green algal dominance from paddy field soils of Patan . Observations suggested that soil from both the tehsils is nutritionally rich. Understanding of blue-green algal flora and its correlation with soil parameters will help in applying fertilzers, it will also help in enhancing the nitrogen fixing blue-green algae and reducing non nitrogen fixers which usually compete with the all available nutrients with the nitrogen fixers.

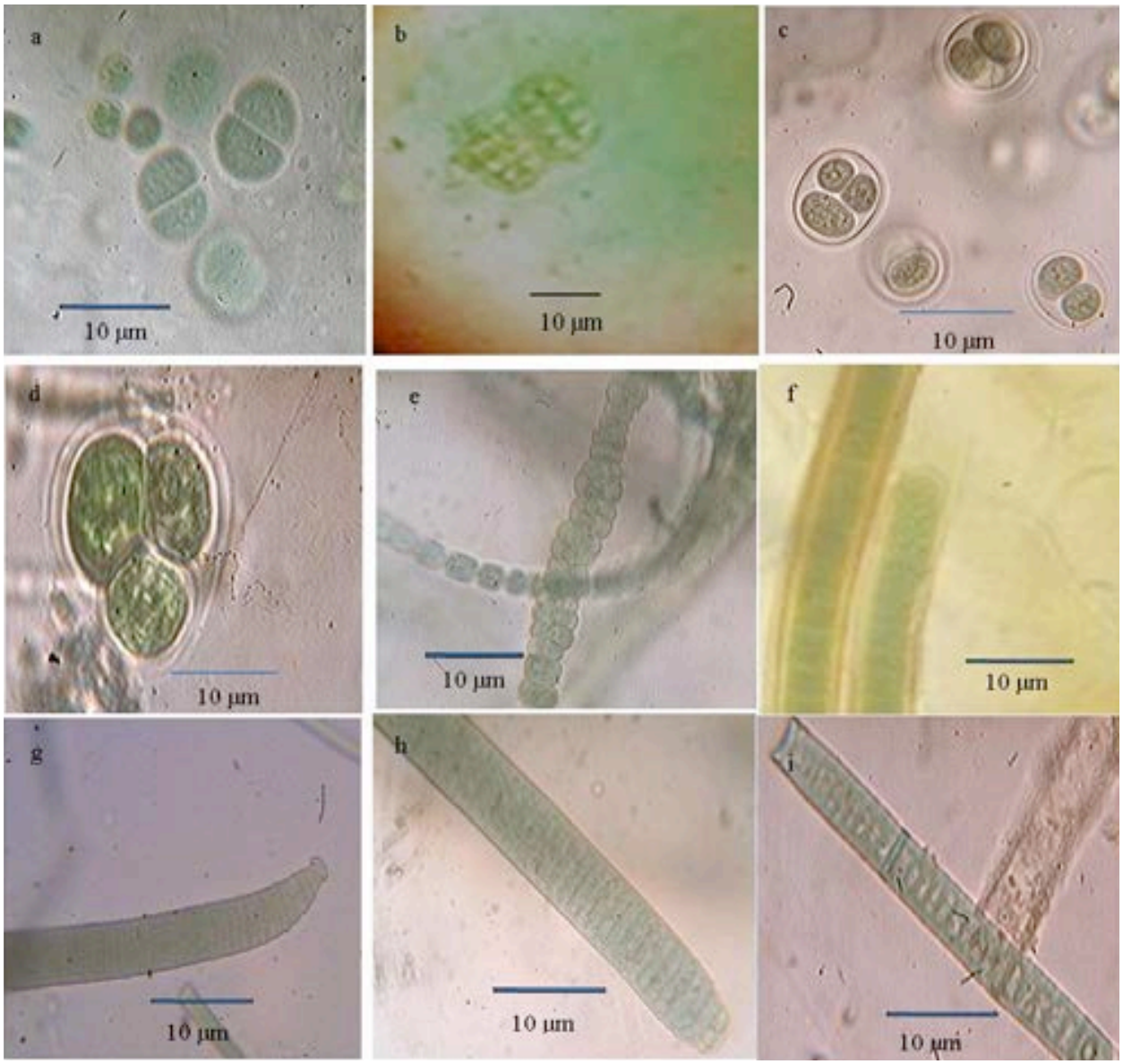

Image 1. a—*Aphanothece pallida* | b—*Merismopedia tenuissima* | c—*Gloeocapsa livida* | d—*Chroococcus turgidus* | e—*Chlorogloea fritschii* | f—*Lyngbya stagnina* | g—*Oscillatoria princeps* | h—*Oscillatoria chalybea* | i—*Symploca thermalis*.

Table 3. Numerical analysis for fertility category of soil samples from Patan Tehsil, Satara District.

	pH	EC	Fertility status	No. of soil samples showing			
				Organic carbon %	Available N kg/ha	Available P kg/ha	Available K kg/ha
1	37 soil samples with Good soil pH; except soil sample of Rasati with acidid i. e. 5.68 p H	37 soil samples have good Ec. Except Soil sample of Konjawde having 1.48 Ec; Which is not good for seed germination	Very low	02	08	-	01
2			Low	13	15	05	01
3			Moderate	04	09	03	02
4			Moderate high	04	03	06	10
5			High	06	02	04	04
6			Very high	09	01	20	20
Total	38	38		38	38	38	38

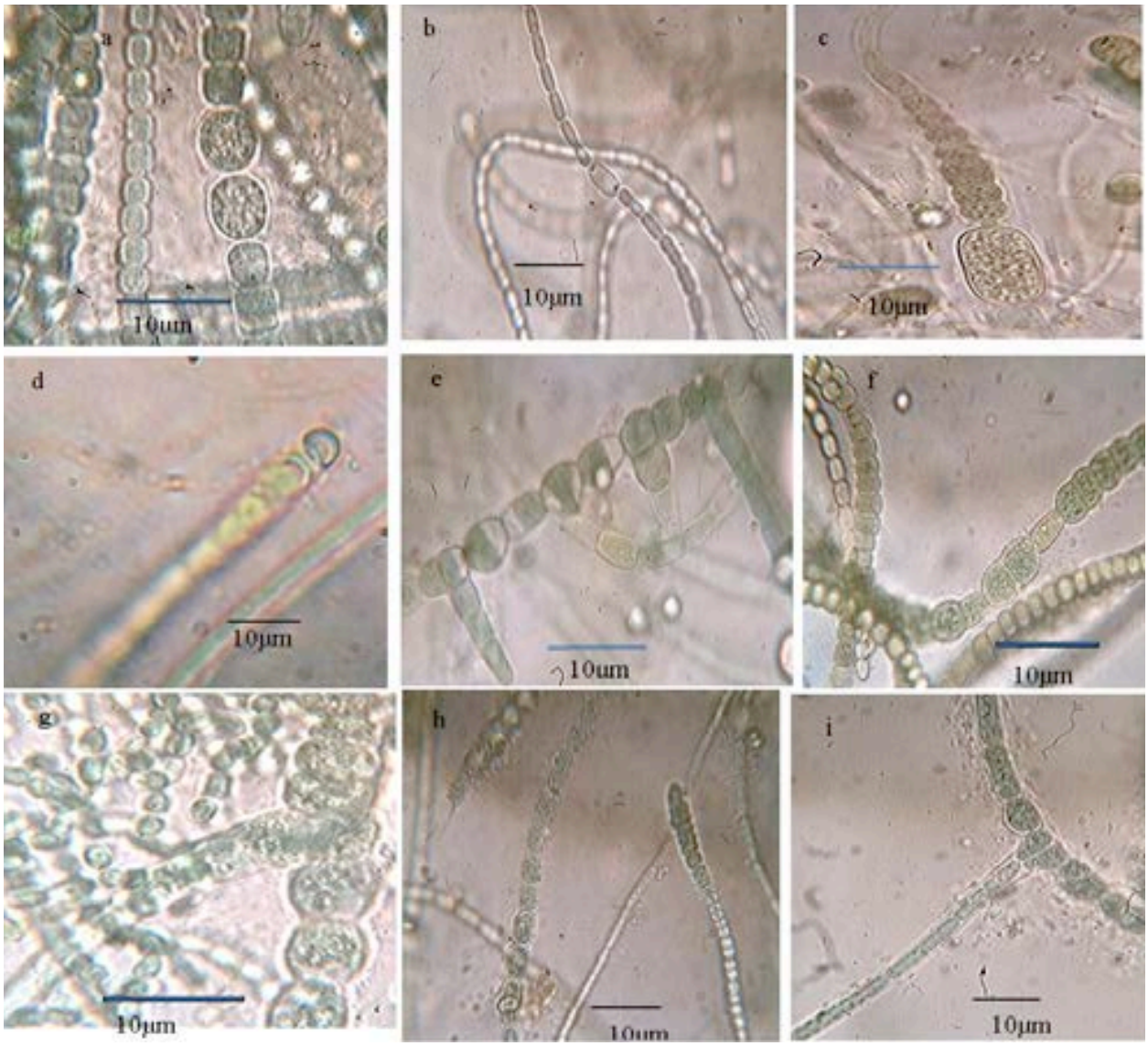

Image 2. a—*Anabaena fertilissima* | b—*Nostoc rivulare* | c—*Calothrix bharadwajae* | d—*Calothrix fusca* | e—*Nostochopsis lobatus* | f—*Fischerella mucicola* | g—*Hapalosiphon flagelliformis* | h—*Hapalosiphon baronii* | i—*Hapalosiphon intricatus*.

Table 4. Numerical analysis for fertility category of soil samples from Karad Tehsil, Satara District.

	pH	EC	Fertility status	No. of soil samples showing			
				Organic carbon %	Ava. N kg/ha	Ava. P kg/ha	Ava. K kg/ha
1	All 28 soil samples with Good soil pH	27 soil samples have good Ec.Soil sample of Talbid having 1.16 Ec; Which is not good for seed germination	Very low	07	08	01	-
2			Low	10	17	05	02
3			Moderate	04	01	05	03
4			Moderate high	06	02	02	02
5			High	-		03	03
6			Very high	01		12	18
Total	28	28		28	28	28	28

REFERENCES

Allen, M. (1968). Simple conditions for growth of unicellular blue green algae on plates. *Journal of Phycology* 4: 1–4.

Allen, M. & R. stanier (1968). Selective isolation of blue green algae from water and soil. *Journal of General Microbiology* 51: 203–209.

Anand, N. (1990). A hand book of Blue green algae. Bishen singh, Mahendra pal singh, Dehra Dun. pp.1–79.

Anand, N., R.S. Hooper & S. Kumar (1995). Distribution of blue – green algae in rice fields of Kerla state, India. *Phykos* 35: 55–64.

Anand, N., S. Kumar & R.S. Hooper (1987). Blue- green algae from rice fields in Kerala state, India. *Hydrobiologia* 144: 223–232.

Anand, N. & G. Revathi (1987). Blue green algae from rice fields of Tamil Nadu. *Phykos* 26: 17–21.

Ahmed, S.U. (2001). Distribution pattern of blue green algae in rice field soils of Hojai sub-division of Assam. *Phykos* 40 (1 and 2) : 33–38.

Anagnostidis, K. & J. Komarek (1985). Modern approach to the classification system of cyanophytes 1 - Introduction. *Arch Hydrobiology* supplement 71. *Algological studies* 38/39: 291–302.

Auti, B.K. & S.D. Pingle (2006). Nostocales from Northern circle of Ahmednagar district (M. S.) *Indian Hydrobiology* 9(2) : 147–150.

Banarjee, J.C. (1935). On algal found on soil samples from alluvial paddy field of Faridpur, Bengal, *Science Culture. Journal* : 298.

Castenholz, R.W. & J.B. Waterbury (1989). In: Staley, J.T., M. P. Bryant, N.P. fenningand & J.G. Holt (eds.). *Bergey's Mannual of Systematic Bacteriology - Vol. 3*. Williams and Wilkins, Baltimore, 1710–1727.

Desikachary, T.V. (1959). *Cyanophyta*. Indian council of Agricultural Research, New Delhi, 685pp.

Feldgarden, M.N. Byrd M. S. & F.M. Cohan (2003). Gradual evolution in bacteria: evidence from *Bacillus* systematics. *Microbiology* 149: 3565–3573.

Fuller, W.H. & R.N. Roger (1952). Utilization of the Phosphorous of the algal cells as measured by the Neubauer technique. *Soil Science* 74 : 417

Goyal, S.K., B.M. Shrama & R.S. Gupta (1984). Algal flora of rice field soils of Jammu and Kashmir states. *Phykos* 23: 59–64.

Gonzalves, E.A. & K.S. Gangla (1949). Observations on the algae of paddy field soils. *Journal of University Bombay* 18 : 51–59.

Gupta, A.B. (1964). Algal flora and its importance in the economy of rice fields. *Hydrobiologia* 38: 213–222.

Jawale, A.K. & D.A. Kumawat (2004). Some blue green algae from Maharashtra in National Symposium on Biology and Biodiversity of fresh water algae. Chennai, 37pp.

Kamat, N.D. (1962). The Cyanophyceae and Chlorophyceae of Panhala. *Journal of University Bombay* 30: 22–31.

Kamat, N.D. (1963). The Algae of Kolhapur, India. *Hydrobiologia* 22 (3 & 4): 209–305.

Kamat, N.D. (1964). The Algae of Mahabaleshwar. *Journal of University Bombay* 31: 28–41.

Kamat, N.D. (1974). Algae of Marathwada, Maharashtra. *Phykos* 13(1 & 2) : 22–32.

Karande, C.T. (2009). Cyanobacterial biodiversity in paddy fields from Satara district - A project submitted to UGC.

Kamble, P.B. (2010). Isolation purification and biochemical characterization of blue green algae from paddy field soils of Satara district - MPhil Dessertation submitted to Shivaji university, Kolhapur, 125pp.

Kamble, P.B. (2017). Studies on Filamentous blue green algae from Satara district Maharastra. PhD Thesis submitted to Shivaji University, Kolhapur, 278pp.

Kolte, S.O. & S.K. Goyal (1985). Distribution pattern of blue green algae in rice field soils of Vidarbha region of Maharashtra state. *Phykos* 24: 156–162.

Kondo, M. & M. Yasuda (2003). Seasonal changes in N_2 fixation activity and environment in paddy soils of Japan. *Japan Agricultural Research Quarterly* 37 : 105–111.

Madane, N.P. & P.A. Shinde (1993). Blue-green algae in salt affected soils of Kolhapur district (M. S.) *Journal of Maharashtra Agricultural Universities* 18: 289–290.

Nayak, S. & R. Prasanna (2007). Soil pH and its role in cyanobacterial abundance and diversity in rice field soils. *Applied ecology and environmental Research* 5(2): 103–113.

Nayak, S., R. Prassana, T.K. Dominic & P.K. Singh (2001). Floristic abundance and relative distribution of different cyanobacterial genera in rice field soil at different crop growth stages. *Phykos* 40: 14–21.

Nayak, S., R. Prasanna, T.K. Dominic & P.K. Singh (2004). Effect of BGA – *Azolla* biofertilizers on nitrogen fixation and chlorophyll accumulation at different depths in soil cores. *Biology and Fertility of Soils* 40: 67–72.

Nikam, T.D., J.N. Nehul, Y.R. Gahile, B.K. Auti, M.L. Ahire, K.M. Nitnaware, B.N. Joshi & N. Jawali (2013). Cyanobacterial diversity in Western Ghats region of Maharashtra, India. *Bioremediation, Biodiversity and Bioavailability* 7(1): 70–80.

Patil, S.R. & B.B. Chaugule (2009). Diversity of blue green algae in paddy fields of Western Maharashtra *Indian Hydrobiology* 12: 89–94.

Patil, P.L. & S.D. Satav (1986). A study of nitrogen fixing blue green algae from rice fields of Western Maharashtra *Phykos* 25(1 & 2): 113–116.

Prasad, B.N. & R.K. Mehrotra (1980). Blue green algae of paddy fields of U.P. *Phykos* 19: 121–128.

Rippka, R., J. Deruelles, J.H. Waterbury, M. Berdman & R.Y. Stanier (1979). Generic assignments and strain histories and properties of pure cultures of Cyanobacteria. *Journal of General Microbiol*ogy III: 1–61

Roger, P.A. & S.A. Kulasooriya (1980). Book of blue green algae and Rice. The International Rice Research Institute, Los Banos, Laguna, Philippines, 117pp.

Santra, S.C. (1991). Rice field blue green algae (Cyanobacteria) and its utilization prospects as biofertilizer in West Bengal, *India, Proceeding of National Symposium* On Cyanobacterial Nitrogen fixation New Delhi, 385–389pp.

Santra, S.C. (1993). *Biology of Rice Fields Blue Green Algae.* Daya Publishing House, New Delhi, 184pp.

Sardeshpande, J.S. & S.K. Goyal (1981a). Distributional pattern of blue green algae in rice field soils of Konkan region of Maharashtra State. *Phykos* 20: 102–106

Sardeshpande, J.S. & S.K. Goyal (1981b). Distribution pattern of blue green algae in rice field soils of Konkan region of Maharashtrra State. *Phykos* 20: 102–106.

Sinha, J.P. & D. Mukherjee (1975a). On Blue green algae from the paddy fields of Bankura district of West Bengal - I. *Phykos* 14(1 & 2): 117–118.

Sinha, J.P. & D. Mukherjee (1975b). On Blue green algae from the paddy fields of Bankura district of West Bengal - II. *Phykos* 14 (1 & 2): 119–120.

Sinha, J.P. & D. Mukherjee (1984). Blue green algae from the paddy fields of Bankura District of West Bengal - III. *Phykos* 23(1 & 2): 142–143.

Sahu, J. K., H. Naik & S.P. Adhikary (1997). Blue green Algae of rice field soils of Orissa state - I Distributional pattern in different agroclimatic zones. *Phykos* 35: 93–110.

Singh, R.N. (1961). *Role of blue green algae in the nitrogen economy of Indian agriculture*. Indian council of Agricultural Research, New Delhi, 175pp.

Singh, P.K. (1978). Nitrogen economy of rice soils in relation to nitrogen fixation by blue green algae and Azolla, pp. 12–23. In: Proceeding of National, Symposium On increasing rice yield in Kharif (CFRI, India).

Somawanshi, R.B., A.D. Kadlag, A.N. Deshpande, B.D. Tamboli, P.P. Kadu & B.D. Bhakare (1999). A Book of Laboratory methods for analysis of soils, irrigation water and plants. 230pp.

Tiwari, G.L. (1972). Study of blue green algae from paddy field soils of India. *Hydrobiologia* 29: 335–350.

Short Communication

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

PLATINUM
OPEN ACCESS

Cordia diffusa K.C. Jacob, the Kovai Manjack (Boraginaceae): a highly threatened steno-endemic species from Coimbatore City, Tamil Nadu, India

S. Arumugam [1], K. Sampath Kumar [2], B. Karthik [3] & V. Ravichandran [4]

[1,3,4] Botanical Survey of India, Southern Region Centre, TNAU Campus, Lawley Road P.O., Coimbatore, Tamil Nadu 641 003, India.
[2] Research & Development Centre, Bharathiar University, Coimbatore, Tamil Nadu 641046, India.
[1] grassindia11@gmail.com, [2] rksambath@gmail.com (corresponding author), [3] karthikbr1711@gmail.com, [4] ravichandran725@gmail.com

Abstract: *Cordia diffusa* K.C. Jacob, belonging to Boraginaceae, discovered in 1938 and named by K.C. Jacob in 1944, is a little-known and the only narrow endemic but neglected plant of Coimbatore City. The lectotype of the steno-endemic is determined and the current status, distribution, potential threats, bioprospecting potential, and suggestions for conservation of the species are discussed. The collection of steno-endemic plant during intensive exploration in its type locality nearly after 90 years is of phytogeographic and conservation significance. The endemic is proposed the category of Critically Endangered (CR) based on criterion D of IUCN (as per versions 3.1 & 13). *C. diffusa* can be protected by promoting awareness of the rarity of native species and mass propagation through vegetative means so as to introduce it in gardens, parks, and avenues, etc. at once in the city.

Keywords: Conservation, endemic shrub, lectotypification, status, threats.

Understanding rarity has been an important task among plant ecologists and also vital in conserving biodiversity while the process of rarity has diverse ecological consequences. Steno- or strict endemic species have a small, non-dominant, constantly sparse plant population size and are characterised by their narrow habitat specificity and geographically restricted in a specific habitat (Rabinowitz 1981). Species with narrow distribution range and/or fewer individuals are considered to be most prone to extinction due to changing climatic conditions and competition from alien species (Chitale et al. 2014). Human-induced perturbations resulting in habitat loss is identified as one of the important causes of rarity, though several intrinsic factors also govern the distribution and survival of species in their natural habitats. The conservation of narrow endemics that are threatened or endangered has become a major concern shared by governments, conservation organisations, and individuals (Kruckeberg & Rabinowitz 1985). Species not collected in herbaria for several decades have been one of the valuable yardsticks for judging the rarity status of the species (Meher-Homji 1995).

Coimbatore, the district headquarters and the third largest city of Tamil Nadu, is located between 11.016^{0}N, and 76.955^{0}E with an approximate altitude of 470m,

DOI: https://doi.org/10.11609/jott.5292.11.14.14870-14875

Editor: N.P. Balakrishnan, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #5292 | Received 31 July 2019 | Final received 06 November 2019 | Finally accepted 10 November 2019

Citation: Arumugam, S., K.S. Kumar, B. Karthik & V. Ravichandran (2019). *Cordia diffusa* K.C. Jacob, the Kovai Manjack (Boraginaceae): a highly threatened steno-endemic species from Coimbatore City, Tamil Nadu, India. *Journal of Threatened Taxa* 11(14): 14870–14875; https://doi.org/10.11609/jott.5292.11.14.14870-14875

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to the Dr. A.A. Mao, director, Botanical Survey of India, Kolkata, for his kind support and encouragement; and to Dr. C. Murugan, scientist-E, BSI-SRC, Coimbatore, for his help and cooperation in providing necessary facilities. Our thanks are also due to Dr. A. Rajasekaran, scientist-C, Institute of Forest Genetics and Tree Breeding, Coimbatore, for his cordial support and kind help to locate the plant in the IFGTB campus. KSK profoundly thanks all the timely generous favors and friendly rapport by Mr. N. Vikraman, MSc MTech, Nodal Officer, NABARD, Aizwal, Mizoram; and thanks Research & Development Centre, Bharathiar University, Coimbatore, for providing the support and resources. We wish to express our appreciation and cordial thanks to the esteemed Reviewer for the valuable comments and suggestions to improve and refine the content.

extending over an area of 105km^2, inhabited by over two million urban population (https://coimbatore.nic.in/). Coimbatore City, bounded on the west by the Western Ghats, Noyyal (Noyyil) river running to the south, while the east and the north are coverd by vast stretches of fields mainly of black cotton soil (Chandrabose 1981; Chandrabose & Nair 1988). The city limit has expanded as the metropolitan area of the city has increased from 38.28km^2 in 1973 to 62km^2 in 1981 to 274.34km^2 in 2010, owing to the rapid urbanisation and expanding population. It is also one of the most industrialised cities of Tamil Nadu (Anonymous 2015).

Coimbatore City area was botanically sporadically explored since 1826 by renowned botanists such as C.A. Barber, K.C. Jacob, Colonel Cox, J.L. Elllis, and later by M. Chandrabose, Girija Lakshmanan, T.R. Somasundaram, K. Subramanyam, H. Sundanda Kamath, and others. The Flora of Coimbatore published by Chandrabose & Nair (1988) recorded c. 850 taxa by exploring about 258km^2 over a period of 10 years in the city and its environs. Of these, three taxa (*Polygala jacobii* Chandrabose (1968), *Euphorbia hypericifolia* L. var. *coimbatorensis* Chandrabose (1988), and *Cordia diffusa* KC Jacob (1944)) were reported as endemic to the region, but *C. diffusa*, restricted to the city limits, is the only stenoendemic species as of now. *Polygala jacobii,* treated as an unresolved name in the Plant List, is a Indo-Sri Lankan rare endemic herb distributed in Karnataka, Kerala, Madhya Pradesh, Maharashtra, and Tamil Nadu in India (Kulkarni & Singh 1973; http://florakarnataka.ces.iisc.ac.in/hjcb2/herbsheet.php?id=3666&cat=1), and *E. hypericifolia* L. var. *coimbatorensis* is now synonymised under *Euphorbia indica* Lam. (Plant List 2019; POWO 2019).

Taxonomic History & Phytogeography

The genus *Cordia* L. (Boraginaceae sensu lato and Cordiaceae sensu stricto), native to tropical and subtropical regions, is diverse with c. 250–350 widespread species (Mabberley 2008; Balachandran & Rajendiran 2016). In India, the genus is represented by about 20 species, of which 13 species have been recorded so far from Tamil Nadu (Ramamurthy 1987; Balachandran & Rajendiran 2016) including three endemics, viz., *Cordia diffusa* K.C. Jacob, *C. domestica* Roth, and *C. ramanujamii* Balachandran & Rajendiran, all are shurbs or small trees. *C. domestica* is distributed in Western Ghats of Madurai and Nilgiris districts and also reported to be cultivated (Ramamurthy 1987), while *C. ramanujamii* is a recently discovered endemic species from the Pakaam Malai Reserve Forest, Ginjee, Eastern Ghats, Tamil Nadu, at an altitude of 350m (Balachandran & Rajendiran 2016).

A new *Cordia* species was discovered by Dr. K. Cherian Jacob on 02 May 1938, based on the collections from Nanjundapuram, about 8km south of Coimbatore, and was later named as *Cordia diffusa* K.C. Jacob (1944). This species was included in the enumeration of rare and threatened plants of southern India by Henry et al. (1978), and it was determined as Indeterminate on the IUCN Red List of Threatened Plants (Rao et al. 2003). Based on the specimens available at MH, it was revelaed that this rare narrow endemic species was collected by K. Subramanyam in 1959 (MH: 7784) and was last collected by Chandrabose in 1968 from nearby the type locality, as well as from the Forest College compound, R.S. Puram, Coimbatore. The steno-endemic, however, has not been collected or recorded since 1968. It was stated by Chandrabose & Nair (1988) that *Cordia diffusa*, is also on the verge of extinction due to rapid urbanisation, industrialisation and other anthropogenic activities. They further reiterated that conservation of the species in this highly disturbed area would be a challenge. In the light of these facts, we made thorough explorations in and around the type locality to determine the current status of the species. Prabhu et al. (in press) report the collection of the species from the Forest College Campus, Insitute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, in their phytochemical screening and bioactivity studies. There is, however, no extant population of the plant in the Forest College, IFGTB Compound. The bush from which the collection was reportedly made was found cleared from the garden of IFGTB. A few stem cuttings of the removed plant are being kept now for propagation of the species (Fig. 1G). Hence, the authors made intensive surveys for the plant in its type locality for about one year and could recollect the species in flowers and fruits from the dry open wastelands along the railway track, Nanjundapuram area, Coimbatore, in May 2018. A population of just 10 individuals were observed in the type locality, and the plant was straggling in the dry open wasteland with black cotton soil and almost always associated with *Capparis* sp., besides *Calotropis gigantea*, *Morinda tinctoria*, etc. The habitat of the endemic plant was highly disturbed by human interferences particularly plastics, polythene, bottles and other garbage found strewn around the habitat. From the pertinent literature, it was revealed that this species was not collected from its type locality after the type collection by K.C. Jacob in 1938. Hence, the present collection of *C. diffusa* from its type locality, nearly after 90 years is of phytogeographic and

conservation significance of this little-known species. There are, however, collections from nearby areas along Vaalankulam Lake in western Coimbatore (see specimens examined). The species was supposedly recently recorded from the Gulf of Mannar, eastern coast, by Daniel & Umamaheswari (2001). The rare occurence of the endemic species from the mainland coast as well as from the Karaichalli Island, Thoothukudi (Tuticorin) District, Gulf of Mannar Bioisphere Reserve, is intriguing and is the only record of *C. diffusa* from the coast and far away from its type locality. Nevertheless, the cited specimens in the Flora (P. Daniel & P. Umamaheswari 103325, 107301; S.A. Muthukumar 104746) could not be traced at MH. Hence, the disjunct distribution of this narrow endemic is intriguing and needs further investigations.

The reported distribution of *C. diffusa* K.C. Jacob in Chengalpattu District (Ramamurthy 1987; Nayar 1996; Singh et al. 2015), and in the Deccan (Ahmedullah & Nayar 1987) is doubtful as there are no specimens from these regions available in MH. Daniel & Umamaheswari (2001) also concluded that the endemic species was earlier reported from Coimbatore only.

Systematic Treatment

Cordia diffusa

K.C. Jacob in J. Bombay Nat. Hist. Soc. 45: 78. 1944; A.N. Henry et al. in J. Bombay Nat. Hist. Soc. 75: 692. 1978; K. Ramamurthy in A.N. Henry et al., Fl. Tamil Nadu 2: 97. 1987; M. Chandrabose & N.C. Nair in Fl. Coimbatore 190. 1988; P. Daniel & P. Umamaheswari in Fl. Gulf of Mannar 279, t.37. 2001. *Gerascanthus diffusus* (K.C. Jacob) Borhidi, Acta Bot. Hung. 34: 404. 1988 (Image 1).

Lectotype: INDIA, Tamil Nadu, Coimbatore District, near Nanjundapuram, 1,330ft (c. 400m), railwayline, 02 May 1938, K.C. Jacob 86237A, MH Acc. No. 175500! designated here; Isolectotypes: K.C. Jacob 86237 B, C, D & E, MH Acc. Nos. 175501!–175504! Paratype: Tank Road, near Railway station, c. 400m, 23 March 1942, K.C. Jacob s.n., MH 175505!

Specimens examined: India, Tamil Nadu, Coimbatore District, Vaalankulam, along railway line, 467m, K. Subramanyam 7784, 10 February 1959, MH Acc. Nos. 15269!, 15270!; Ramanathapuram, 469m, M. Chandrabose 28852, 21 November 1965, MH 55200!, 55201!; Forest College Compound, R.S. Puram, 468m, M. Chandrabose 29876, 07 May 1968, MH Acc. Nos. 57090!, 570901!; Vaalankulam side, 467m, M. Chandrabose 30292, 02 July 1968, MH Acc. Nos. 57455!, 57456!; M. Chandrabose 30577, 02 August 1968, MH Acc. Nos. 57601!, 57602!; R.S. Puram, Botanical Garden, IFGTB Campus, Gurudev Singh & C.K. Jeyachandran 17681, 13 October 1987, FRC (n.v.); Near Nanjundapuram, c. 410m, along railway line, K. Sampath Kumar 997, 29 April 2018, MH (Image 2).

Shrubs, straggling, spreading, c. 1m high; branches many, woody, spreading in all directions, lenticellate; younger parts tawny pubescent. Leaves 3–7 x 2.0–3.5 cm, simple, alternate or opposite, exstipulate, broadly elliptic-oblong, acute or obtuse at apex, shortly mucronate, rough, coriaceous, dentate, scalloped along margins, dark green above, pale beneath; midrib prominent beneath, nerves prominent, 6–8 pairs; rough hairy on both surfaces, petiole c. 0.3–0.5 cm long, pubescent. Inflorescences in terminal 8–12 flowered umbellate cymes; peduncle simple, c. 2cm long. Flowers ebracteate, pedicels 2–4 mm long. Calyx tubular, brown, tomentose, c. 5mm long; fruiting calyx saucer-shaped, margins brown, tomentose. Corolla white, tubular, c. 8mm long, lobes 4, linear-oblong, prominent and reflexed, fragrant. Stamens 4, antisepalous, epipetalous, exserted; anthers pale brownish, sagitate; filaments adnate to the base, free at the top, white, glabrous. Style terminal, simple below, bipartite, branches again bipartite, pale yellow; stigma simple, white. Ovary 4-loculed, c. 2mm long, greenish. Drupes ovoid-acute, mucronate, 1–1.5 x 0.8–1.2 cm, greenish when young, bright ornage when ripe, edible, pulp sugary, viscid, with cup-shaped, fulvous pubescent, irregularly many lobed persistent calyx; 1-seeded; seeds globose, orange, shiny, 5–8 x 4–6 mm.

Flowering and fruiting: Almost throughout the year.

Current Status

Based on the field surveys, consultation of herbarium specimens of earlier collections including types at MH, review of pertinent literature (Jacob 1944; Henry et al. 1978; Ramamurthy 1987; Ahmedullah & Nayar 1987; Chandrabose & Nair 1988; Daniel & Umamaheswari 2001), it is infered that the extant population of the steno-endemic may not exceed 50 mature individuals and the area of occupancy is very small and restricted covering less than 5km^2. Owing to the small and inferred continued declining population size, and the number of mature individuals in the extant population being less than 50, it is proposed that the species be categorized as Critically Endangered (CR) based on criterion D for restricted number of mature individuals as per the guidelines of the IUCN Red List Categories & Criteria (versions 3.1 & 13; IUCN 2001, 2017). Hence, conservation of the species requires immediate and

Image 1. *Cordia diffusa* K.C.Jacob: A—habit of the steno-endemic shrub | B—leaf morphology | C—close-up of inflorescence | D—a twig with immature and mature fruits | E—branch with flowers and fruits | F—close-up of a mature fruit and a seed (inset) | G—sapling from stem cutting. © A–F - K. Sampath Kumar | G - S. Arumugam.

inevitable actions to avoid the possible extinction in the near future.

Threat Factors and Conservation Strategies

Human interference with the environment in recent times has greatly accelerated the pace of extinction, though extinctions have also taken place in the past mainly due to natural causes. But, endangered plant species, compared with endangered animals, attract rather little public attention (Sivarajan 1991). As per the recent estimates, the extinction rate of seed-bearing plant species is 500 times faster than in other species (Ledford 2019).

The flora of Coimbatore and its environs obviously is much disturbed due to regular biotic interferences. The popluations of *C. diffusa* in its type locality are found

rare and becoming endangered, and conserving this species in such a highly disturbed area would be really a challenge (Chandrabose 1981; Chandrabose & Nair 1988). During the present survey in the type locality, it was identified that the human interference has been the major threat factor, and dumping of used polythenes, plastics, glasswares, waste materials, debris of buildings, and persistent clearing of vegetation along the tracks by the railway all leading to the habitat destruction and degradation, besides the increasing pollution, rapid urbanisation and industrialisation in the city area. The lack of awareness about the endemic plant of the city also results in the removal of the stands in the wild.

As the plant is shrubby and can be easily propagated by stem cuttings (Fig. 1G), it can be mass propagated at the earliest and introduced in city gardens and in other suitable habitats in and around the city so as to conserve the species. Awareness of the steno-endemic should be created among the public particularly among the school children and college students; and vegetative propagules may be distributed by the concerned agencies or through local 'plant protection' societies and environment / nature clubs to save the plant in peril. The micropropagation studies on the highly threatened endemic plant must be given high priority. The in vitro repository of plant propagules may be deposited at the National Bureau of Plant Genetic Resources (NBPGR) towards long-term ex situ conservation of the species.

Ex situ conservation through seed, pollen, gene and germplasm banks may also be considered to preserve the species outside its natural habitats. Reproductive biological studies may provide important perspectives to help preserve the genetic potential which are crucial for restoration and reintroduction.

Potential Uses/ Bioprospecting

There are lesser chances to collect and name the missing species before they become extinct and the information about potential uses or unique properties of such native plants need to be passed on (Sharp 1964; Raven 1976). With the scanty literature and the limited herbarium collections, *Cordia diffusa* remains a poorly known plant.

The traditional uses, phytochemistry and pharmacology of the 36 medicinal species of the genus *Cordia* have been reviewed recently (Oza & Kulkarni 2017), wherein c. 300 phytochemical compounds of various classes present in the 36 species has been documented. The traditional uses, diversity of phytochemicals, pharmacological properties, and biological activities of *C. dichotoma* discussed in the review by Jamkhande et al. (2013); and the presence of apigenin in the bark of *C. dichotoma* showed significant healing and reduction in inflammatory enzymes of ulcerative colitis (Ganjare et al. 2011). The protective effect of bark extract of *C. macleodii* against Naja venom poisoning was reported by Soni & Bodakhe (2014). The reputed use of bark from *C. rothii* in heart ailments in Gujarat has also been recorded (Chauhan & Chavan 2009). Similarly, the leaves *C. diffusa* has been studied recently for its antioxidant activity and phytochemical consitutents (Prabu et al. in press). Thus, *C. diffusa* has the potential for further bioprospection studies using vegetatively propagated materials or in vitro raised plant parts to avoid collecting from the wild.

Conclusions

Ex situ conservation measures for the narrow endemic plant of Coimbatore City, *Cordia diffusa* K.C. Jacob, must be initiated immediately. In situ conservation of the wild populations will be most challenging in the light of serious habitat loss owing to the burgeoning population, ever-increasing pollution, rapid urbanisation

Image 2. Herbarium of *Cordia diffusa* K.C.Jacob: (KSK 997).

and industrialisation, besides possible impacts of global climate change. Hence, effective steps to promote awareness of the rarity and conservation significance of the unique shrub of the city among the public and particularly students are the need of the hour. As the shrub seems to establish easily by asexual mode, multiplication through stem cuttings in nurseries and distribution of vegetatively propagated plant saplings to gardeners may be given top priority, besides introducing it in public and private gardens. Further studies on bioprospection and in vitro clonal propagation are vital. The disjunct distribution of the endemic plant in the region needs further research. Field explorations and regular monitoring of the extant populations in the fragile habitats of the city environs may reveal the current status of other native taxa.

References

Ahmedullah, M. & M.P. Nayar (1987). *Endemic Plants of the Indian Region. Peninuslar India.* Vol. 1. Botanical Survey of India, Calcutta, 261pp.

Anonymous (2015). TN Envis District Profile for Ecosensitive Areas in Tamil Nadu, Western Region: Coimbatore, Tirupur, Karur & Erode. ENVIS Centre, Dept. of Environment, Govt. of Tamil Nadu, Chennai, 164pp.

Balachandran, N. & K. Rajendiran (2016). *Cordia ramanujamii* (Cordiaceae): a new species from Tamil Nadu, India. *Taiwania* 61(2): 74–77. https://doi.org/10.6165/tai.2016.61.74

Chandrabose, M. (1967/1968). A new species of *Polygala* from South India. *Bulletin of the Botanical Survey of India* 9(1–4): 288–290.

Chandrabose, M. (1981). Florisitic Studies in Coimbatore City and its environs. *Bulletin of the Botanical Survey of India* 23(1–2): 96–99.

Chandrabose, M. & N.C. Nair (1988). *Flora of Coimbatore*. Bishen Singh Mahendra Pal Singh, Dehra Dun, 398pp.

Chauhan, M.G. & S.S. Chavan (2009). Pharmacognosy and biological activity of *Cordia rothii* Roem. & Schult. bark. *Indian Journal of Traditional Knowledge* 8(4): 598–601.

Chitale, V.S., M.D. Behera & P.S. Roy (2014). Future of Endemic Flora of Biodiversity Hotspots in India. *PLoS ONE* 9(12): e115264. https://doi.org/10.1371/journal.pone.0115264

Daniel, P. & P. Umamaheshwari (2001). *Flora of Gulf of Mannar Southern India*. Botanical Survey of India, Calcutta, 688pp.

Ganjare, A.B., S.A. Nirmal & A.N. Patil (2011). Use of apigenin from *Cordia dichotoma* in the treatment of colitis. *Fittoterpia* 82(7): 1052–1056.

Henry, A.N., K. Vivekananthan & N.C. Nair (1978). Threatened flowering plants of south India. *Journal of the Bombay Natural History Society* 75: 684–697.

IUCN (2001). IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, pp. 35.

IUCN Standards and Petitions Subcommittee (2017). Guidelines for Using the IUCN Red List Categories and Criteria. Version 13. Prepared by the Standards and Petitions Subcommittee, 108pp. Downloadable from https://cmsdocs.s3.amazonaws.com/RedListGuidelines.pdf

Jacob, K.C. (1944). A new species of *Cordia*. *Journal of the Bombay Natural History Society* 45: 77–79.

Jamkhande, P.G., S.R. Barde, S.L. Patwekar & P.S. Tidke (2013). Plant profile, phytochemistry and pharmacology of *Cordia dichotoma* (Indian cherry): A review. *Asian Pacific Journal of Tropical Biomedicine* 3(12): 1009–1012.

Kruckeberg, A.R. & D. Rabinowitz (1985). Biological Aspects of Endemism in Higher Plants. *Annual Review of Ecological Systematics* 16: 447–479.

Kulkarni, B.G. & N.P. Singh (1973). On the distribution of *Polygala jacobii* Chandr. *Current Science* 42: 359.

Ledford, H. (2019). Global plant extinctions mapped. *Nature* 570: 148–149.

Mabberley, D.J. (2008). *Mabberley's Plant-Book*. *3rd Edition*. Cambridge University Press, New York, 1040pp.

Meher-Homji, V.M. (1995). Comments on 'Endemic, rare and threatened flowering plants of South India'. *Current Science* 68: 1083–1084.

MOE (2012). The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna and Flora. Ministry of Environment, Colombo, Sri Lanka, 477pp.

Nayar, M.P. (1996). *Hotspots of Endemic Plants of India, Nepal, and Bhutan*. Tropical Botanic Garden and Research Institute, Thiruvananthapuram, pp.254.

Oza, M.J. & Y.A. Kulkarni (2017). Traditional uses, phytochemistry and pharmacology of the medicinal species of the genus *Cordia* (Boraginaceae). *Journal of Pharmacy and Pharmacology* 69(7): 755–789.

Plant List (2019). *Euphorbia indica*. http://www.theplantlist.org/tpl1.1/record/kew-80276. Accessed on 19 May 2019.

POWO (Plants of the World Online) (2019). *Euphorbia indica*. http://www.plantsoftheworldonline.org/taxon/ urn:lsid:ipni.org:names:346892-1#synonyms. Accessed on 19 May 2019.

Prabu, K., A. Rajasekaran, D. Bharathi & S. Ramalakshmi (in press). Anti-oxidant activity, phytochemical screening and HPLC profile of rare endemic *Cordia diffusa*. Journal of King Saud University Science. Corrected proof 18 April 2018 unpublished; https://doi.org/10.1016/j.jksus.2018.04.025

Rabinowitz, D. (1981). Seven forms of rarity, pp. 205–217. In: Hugh S. (ed.). *Biological Aspects of Rare Plant Conservation.* John Wiley and Sons, New York, 558pp.

Ramamurthy, K. (1987). Boraginaceae, p. 97. In: Henry, A.N., G.R. Kumari & V. Chitra (eds.). *Flora of Tamil Nadu, India*. *Vol. 2*. Botanical Survey of India, Coimbatore, 258pp.

Rao, C.K., B.L. Geetha & G. Suresh (2003). Red List of Threatened Vascular Plant Species in India. Compiled from the 1997 IUCN Red List of Threatened Plants. ENVIS, Botanical Survey of India, Ministry of Environment & Forests, Govt. of India, Howarh, 169pp.

Raven, P.H. (1976). The destruction of the tropics. *Frontiers* 40: 22–23.

Sharp, A.J. (1964). The complete botanist. *Science* 146: 745–748.

Singh, P., K. Karthikeyan, P. Lakshminarasimhan & S.S. Dash (2015). *Endemic Vascular Plants of India*. Botanical Survey of India, Kolkata, 339pp.

Sivarajan, V.V (1991). *Introduction to the Principles of Plant Taxonomy*. Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi, 292pp.

Soni, P. & S.H. Bodakhe (2014). Antivenom potential of ethanolic extract of *Cordia macleodii* bark against Naja venom. *Asian Pacific Journal Tropical Biomedicine* 4(1): 449–454.

https://indiabiodiversity.org/species/show/263922

https://sites.google.com/site/efloraofindia/species/m---z/po/polygalaceae/polygala/polygala-jacobii

Short Communication

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14876–14885

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

PLATINUM
OPEN ACCESS

New distribution records in the orchid flora of Tripura, India

Arjun Adit [1], Monika Koul [2] & Rajesh Tandon [3]

[1,3] Department of Botany, University of Delhi, Delhi 110007, India.
[2] Department of Botany, Hansraj College, University of Delhi, Delhi 110007, India.
[1] arjun.adit878@gmail.com, [2] drmkoul@gmail.com, [3] tandon.raj@gmail.com (corresponding author)

Abstract: Ten species of orchids belonging to eight genera are recorded for the first time from Tripura State of India. The taxa include *Bulbophyllum affine* Wall. ex Lindl., *Bulbophyllum lobbii* Lindl., *Coelogyne suaveolens* (Lindl.) Hook.f., *Dendrobium tortile* Lindl., *Micropera pallida* Lindl., *Mycaranthes floribunda* (D.Don) S.C.Chen & J.J.Wood, *Pinalia acervata* (Lindl.) Kuntze, *Pinalia globulifera* (Seidenf.) A.N.Rao, *Thelasis khasiana* Hook.f. and *Trichoglottis ramosa* (Lindl.) Senghas. Geographical distribution along with detailed descriptions and photographs of the recorded species are provided.

Keywords: Epiphytes, Indo-Malayan, new report, northeastern India, Orchidaceae.

Orchidaceae represents the largest angiosperm family and is known to occupy a variety of niches, with growth forms ranging from terrestrial to epiphytic and even underground (IUCN 2017). With over 1,300 species, orchids make up nearly 9% of the Indian flora and represent the largest family of flowering plants in India (ICAR-NRCO 2017). The northeastern region of India is recognized for its rich and unexplored floristic diversity due to its placement in the Indo-Malayan ecozone. The earlier record from the state, the Flora of Tripura (Deb 1983) cites 33 orchid species. The publication, however, is more than 35 years old and the vegetation (floral species composition) of the state has changed since then. There have been many new orchid records from the neighboring states in the northeastern region (Odyuo et al. 2013, 2017; Chowlu et al. 2014; Nanda et al. 2014; Panday et al. 2014; Verma & Lavania 2014), however, only a few new records are published from the state of Tripura (Das & Datta 2016; Panda et al. 2016). The present report provides records of 10 orchid species which were earlier not known from the state. The specimens were gathered during field surveys conducted during the first half of 2018 and were systematically identified using available literature (Kumar & Kumar 2005; Schuiteman et al. 2008; Chen et al. 2009; Agrawala & Chowdhery 2013; Kumar et al. 2018).

Materials and Methods

Extensive field surveys were conducted in the forests of Tripura State between March and August 2018. Orchids were photographed and morphometric data were gathered besides the GPS coordinates and details of habitat. Only one orchid specimen representing each taxon was collected due to their threatened status and low population size, and was pressed, treated with formalin and prepared using standard method (de Vogel 1987; Bridson & Forman 1992). These herbarium specimens were deposited at the Delhi University

DOI: https://doi.org/10.11609/jott.4613.11.14.14876-14885

Editor: Pankaj Kumar, Kadoorie Farm and Botanic Gardern (KFGB) Corporation, Hong Kong S.A.R., P.R. China. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4613 | Received 05 October 2018 | Final received 30 October 2019 | Finally accepted 05 November 2019

Citation: Adit, A., M. Koul & R. Tandon (2019). New distribution records in the orchid flora of Tripura, India. *Journal of Threatened Taxa* 11(14): 14876–14885; https://doi.org/10.11609/jott.4613.11.14.14876-14885

Funding: Rufford Small Grants for Nature Conservation.

Competing interests: The authors declare no competing interests.

Acknowledgements: AA is thankful for the financial assistance from the Rufford Small Grants for Nature Conservation (25610-1), United Kingdom and the Junior Research Fellowship from the Council of Scientific and Industrial Research (CSIR). We are deeply grateful to the Forest Department, Government of Tripura for providing logistics required during the project besides the permission to conduct research in the state (No.F.2-61/For/Misc/Estt-2013/23009-019).

Herbarium (DUH), India, and accession numbers were noted down. Comparisons between herbarium records were made using online portals such as the Kew Herbarium Catalogue (http://apps.kew.org/herbcat/gotoHomePage.do) and the Swiss Orchid Foundation at the Herbarium Jany Renz (https://orchid.unibas.ch/index.php/en/database-search/advanced-search).

Taxonomic Treatment

***Bulbophyllum affine* Wall. ex Lindl.**

Gen. Sp. Orchid. Pl. 48. 1830; *Sarcopodium affine* (Wall. ex Lindl.) Lindl. & Paxton, Paxton's Fl. Gard. 1: 155. 1853; *Phyllorkis affinis* (Wall. ex Lindl.) Kuntze, Revis. Gen. Pl. 2: 677. 1891; *Bulbophyllum kusukusense* Hayata, Icon. Pl. Formosan. 4: 48, f. 19. 1914. Type: Nepal, 1852, *N. Wallich 1982* (K!)

Erect epiphytic herb; rhizome sturdy, 0.5–0.8 cm in diameter; pseudobulbs erect, 6–8 cm apart, cylindrical, 2.5–3.5 cm in length, 0.8–1.2 cm in diameter; leaf solitary with entire margin, petiole 1–2 cm long, lamina 14–16 x 2–3 cm, oblong with parallel venation, retuse apex and decurrent base; inflorescence consisting of a single flower originating from the rhizome; flower pedicellate, bracteate, 2.0–2.5 cm long, zygomorphic; sepals and petals lanceolate with acute apices, 1.3–1.7 x 0.4–0.7 cm, white with longitudinal maroon stripes; lip lanceolate with acute apex, 0.4–0.5 x 0.1–0.2 cm, orange to scarlet in color; column slightly recurved, 0.5cm long, sessile; anther cap orange, pollinia 2, cream yellow (Images 1, 11).

Flowering and Fruiting: June–July.

Habitat: Found in a large population growing on a single *Balakata baccata* (Roxb.) Esser tree in moist broadleaf forest adjacent to Tlangsang Village in Jampui Hills.

Specimen examined: DUH 14443 (DUH), 7.vi.2018, Tlangsang, North District, Tripura, India, 23.906^{0}N, 92.272^{0}E, 690m, coll. Arjun Adit 2121.

Other specimen examined: K001114844 (K), 1852, Nepal, coll. N. Wallich 1982.

Distribution: Bhutan, Cambodia, India (throughout), Laos, Myanmar, Nepal, southern China, Taiwan, Thailand, and Vietnam.

***Bulbophyllum lobbii* Lindl.**

Edwards's Bot. Reg. 33: 29. 1847; *Sarcopodium lobbii* (Lindl.) Lindl. & Paxton, Paxton's Fl. Gard. 1: 155. 1850; *Sarcobodium lobbii* (Lindl.) Beer, Prakt. Stud. Orchid. 306. 1854; *Phyllorkis lobbii* (Lindl.) Kuntze, Revis. Gen. Pl. 2: 677. 1891; *Phyllorchis lobbii* (Lindl.) Kuntze, Revis. Gen. Pl. 2: 677. 1891. Type: Java, Pangerango, Lobb 312 (K-LINDL.)

Erect epiphytic herb; rhizome sturdy, 1.0–1.5 cm in diameter; pseudobulbs erect, 10–15 cm apart, globose, 1.2–1.5 cm in length, 1.2–1.5 cm in diameter; leaf solitary with entire margin, petiole 1.4–1.7 cm long, lamina 10–10.5 x 2–3 cm, oblong with parallel venation, acute apex and decurrent base; inflorescence consisting of a single flower originating from rhizome; flower pedicellate, bracteate, 4.0–4.5 cm long, zygomorphic; sepals and

Image 1. *Bulbophyllum affine* Wall. ex Lindl.

Image 2. *Bulbophyllum lobbii* Lindl.

petals lanceolate with acute apex, 2.5–3.0 x 0.7–1.1 cm, creamish-yellow with faint longitudinal maroon stripes; lip triangulate with acute apex, 1.0–1.2 x 1.2–1.4 cm, white; column slightly recurved, 0.8cm long, sessile; anther cap yellow, pollinia 2, cream yellow (Images 2, 12).

Habitat: Growing on *Cryptocarya amygdalina* Nees and *Magnolia montana* (Blume) Figlar trees in the moist broadleaf forest of Phuldungsei in Jampui Hills along with other epiphytes like *Hoya lanceolata* Wall. ex D.Don, *Mycaranthes floribunda* (D.Don) S.C.Chen and *Thelasis khasiana* Hook.f.

Flowering and Fruiting: March–April.

Specimen examined: DUH 14444 (DUH), 19.iii.2018, Phuldungsei, North District, Tripura, India, 23.810^{0}N, 92.261^{0}E, 923m, coll. Arjun Adit 2105.

Other specimen examined: K000364608 (K!), Malaya, coll. Lobb s.n.

Distribution: Bangladesh, Bhutan, Brunei, Cambodia, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura), Indonesia, Malaysia, Myanmar, Philippines, Singapore, and Thailand.

***Coelogyne suaveolens* (Lindl.) Hook.f.**

Fl. Brit. India. 5: 832. 1890; *Pholidota suaveolens* Lindl., Gard. Chron. 1856: 372. 1856; *Pleione suaveolens* (Lindl.) Kuntze, Revis. Gen. Pl. 2: 680. 1891. Type: India, 19 May 1856, Bishop Winchester s.n. (K!)

Image 3. *Coelogyne suaveolens* (Lindl.) Hook. f.

Erect epiphytic herb; rhizome sturdy, 0.8–1.0 cm in diameter; pseudobulbs erect, 7–9 cm apart, cylindrical, 5.5–6.0 cm in length, 2.0–2.5 cm in diameter; leaves two, with undulate margin, petiole 3–3.5 cm long, lamina 19–20 x 3.2–3.5 cm, oblanceolate with parallel venation, acuminate apex and decurrent base; Inflorescence synanthous, consisting of 10–14 flowers in a raceme; flowers pedicellate, bracteate, 1.5–2.0 cm long, zygomorphic, white; bract one per flower, cymbiform, brown in color; sepals and petals oblong with acute apices, 1.2 – 1.5 x 0.5 – 0.8 cm, white; lip oblong with acute apex, 1.2–1.5 x 0.5–0.8 cm; lip keel lamellae crenate to dentate, longitudinally arranged, yellow, four to five in number; column white recurved, 0.4cm long, sessile; anther cap red, pollinia 2, yellow (Images 3, 13).

Habitat: Growing on *Magnolia montana* (Blume) Figlar tree in moist broadleaf forest along with *Pinalia acervata* (Lindl.) Kuntze at Vanghmun in Jampui Hills.

Flowering and Fruiting: April–July

Specimen examined: DUH 14445 (DUH), 6.v.2018, Vanghmun, North District, Tripura, India, 23.976^{0}N, 92.278^{0}E, 633m, coll. Arjun Adit 2114.

Other specimen examined: K000079285 (K!), India, Bishop Winchester s.n.

Distribution: Bhutan, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura), Laos, Myanmar, southern China, and Thailand.

***Dendrobium tortile* Lindl.**

Gard. Chron. 1847: 797. 1847; *Dendrobium dartoisianum* De Wild., Gard. Chron. 39: 380. 1906; *Dendrobium haniffi* Ridl. ex Burkill, Gard. Bull. Straits Settlem. 3: 295. 1924. Type: June 1847, Veitch s.n. (K!)

Erect epiphytic herb; non-rhizomatous; pseudobulb in form of erect cane with nodes, cylindrical, 30–40 cm in length, 1.0–1.5 cm in diameter; leaves simple with entire margin, alternately arranged, sessile, lamina 10–13 x 1.3–1.5 cm, linear with parallel venation, acute apex and decurrent base; inflorescence terminal in groups of 2–4 flowers; flowers pedicellate, bracteate, 5–6 cm long, zygomorphic, white; bract one per flower with papery texture, transparent 0.5–0.7 x 0.4–0.5 cm; sepals and petals lanceolate with acute apices, 3.0–3.5 x 0.4–0.6 cm, twisted, white with purplish hue; lip tubular and enclosing the column with acute apex, 2.5–2.8 x 2.0–2.5 cm, white, mentum greenish white 0.5–0.8 cm long; column green, 0.3cm, sessile; anther cap green, pollinia 2, cream (Images 4, 14).

Image 4. *Dendrobium tortile* Lindl.

Habitat: Growing on *Tectona grandis* L.f., *Shorea robusta* C.F. Gaertn., *Dipterocarpus turbinatus* C.F. Gaertn., *Artocarpus chama* Buch.-Ham., and *Vitex altissima* L.f. in moist deciduous forests of Garji and Kumarghat reserve forests.

Flowering and Fruiting: February–May.

Specimen examined: DUH 14446 (DUH), 23.iii.2018, Garji Reserve Forest, Gomti District, Tripura, India, 23.438^{0}N, 91.471^{0}E, 38m, coll. Arjun Adit 2107.

Other specimen examined: K000596550 (K!), 3.ii.1926, Wangka, Kanburi, Thailand, 15.133^{0}N, 98.5^{0}E, 200m, coll. A.F.G. Kerr 0278.

Distribution: Bangladesh, India (Assam, Meghalaya, Mizoram, Manipur, Nagaland, and Tripura), Laos, Malaysia, Myanmar, Thailand, and Vietnam.

***Micropera pallida* (Roxb.) Lindl.**

Edwards's Bot. Reg. 18: 1522. 1833; *Aerides pallida* Roxb., Fl. Ind. (ed. 1832). 3: 475. 1832; *Camarotis apiculata* Rchb.f., Bonplandia. 5: 39. 1857; *Dendrocolla apiculata* Zoll. ex Rchb.f., Bonplandia. 5: 39. 1857; *Camarotis pallida* Lindl., J. Proc. Linn. Soc., Bot. 3: 37. 1859; *Sarcochilus cochinchinensis* G. Nicholson, Ill. Dict. Gard. 3: 360. 1886; *Sarcochilus roxburghii* Hook.f., Fl. Brit. India. 6: 36. 1890; *Saccolabium saxicolum* Ridl., Trans. Linn. Soc. London, Bot. 3: 374. 1893; *Sarcanthus apiculatus* (Rchb.f.) J.J. Sm., Orch. Java: 598. 1905; *Sarcanthus thorelii* Guillaumin, Bull. Soc. Bot. France. 77: 331. 1930; *Micropera apiculata* (Rchb. f.) Garay, Bot. Mus. Leafl. 23: 186. 1972. Type: Bangladesh, Comilla, 7 September 1871, C.B. Clarke 14202 (K!).

Erect or hanging epiphytic monopodial herb; non-rhizomatous; stem terete, 25–30 cm in length, 0.3–0.5 cm in diameter; leaves simple with entire margin, alternately arranged, sessile, lamina 7–10 x 0.8–1.0 cm, linear with parallel venation, obtuse apex and sheathing base; inflorescence axillary and drooping with 9–11 flowers; flowers pedicellate, bracteate, 1.0–1.5 cm long, zygomorphic, yellow; bract one per flower, brown black; sepals and petals obtuse with round apices, 0.5–0.6 x 0.2–0.3 cm, yellow; lip obtuse with acute apex, 0.3–0.4 x 0.2–0.3 cm, yellow, spur yellowish-white 0.1–0.2 cm long; column white, 0.1cm long, sessile; anther cap yellow at head and cream on tail, pollinia 2, yellow (Images 5, 15).

Habitat: Growing on *Mangifera indica* L. and *Artocarpus hirsutus* Lam. in moist deciduous forests of Garji, Maharani and Kumarghat reserve forests.

Flowering and Fruiting: June–August.

Specimen examined: DUH 14447 (DUH), 9.vi.2018, Garji Reserve Forest, Gomti District, Tripura, India,

Image 5. *Micropera pallida* Lindl.

23.395^{0}N, 91.440^{0}E, 23m, coll. Arjun Adit 2122.

Other specimen examined: K000974275 (K!), 7.ix.1871, Comilla, Bangladesh, coll. C.B. Clarke 14202.

Distribution: Bangladesh, Brunei, Cambodia, India (throughout), Indonesia, Laos, Malaysia, Myanmar, Thailand, and Vietnam.

***Mycaranthes floribunda* (D. Don) S.C. Chen & J.J. Wood**

Fl. China 25: 348. 2009; *Dendrobium floribundum* D.Don, Prodr. Fl. Nepal. 34. 1825; *Eria paniculata* Lindl. in Wallich, Pl. Asiat. Rar. 1: 32. 1830; *Pinalia paniculata* (Lindl.) Kuntze, Revis. Gen. Pl. 2: 679. 1891. *Callista floribunda* (Rchb.f.) Kuntze, Revis. Gen. Pl. 2: 654. 1891. Type: India, Sikkim, J.D. Hooker 67 (K!)

Erect epiphytic herb; stem clustered without psuedobulbs; leaves simple with entire margin, sessile, alternately arranged, lamina 12–14 x 0.4–0.5 cm, linear with parallel venation, acuminate apex and sheathing base; inflorescences 2–3 in terminal position, consisting of 35–45 flowers in raceme; flowers pedicellate, bracteate, 0.3–0.5 cm long, zygomorphic; bract one per flower, green; sepals ovate with acute apices, 0.2–0.3 x 0.1–0.2 cm, yellowish green; petals ovate with acute apices, 0.2–0.3 x 0.1–0.2 cm, white with purple spots; lip rectangular with blunt apex, 0.2–0.3 x 0.1–0.2 cm, with cream colored protrusion; column white, 0.1cm long, sessile; anther cap cream, pollinia 8, cream (Images 6, 16).

Habitat: Growing on *Cryptocarya amygdalina* Nees and *Magnolia montana* (Blume) Figlar trees in moist broadleaf forest of Phuldungsei in Jampui Hills along with other epiphytes like *Hoya lanceolata* Wall. ex D.Don, *Bulbophyllum lobbii* Lindl., and *Thelasis khasiana* Hook.f.

Flowering and Fruiting: May–June

Specimen examined: DUH 14448 (DUH), 7.v.2018, Phuldungsei, North District, Tripura, India, 23.810^{0}N, 92.261^{0}E, 923m, coll. Arjun Adit 2115.

Other specimen examined: K001114827 (K!), Pundua, Bangladesh, coll. F. De Silva 1971.

Distribution: Bangladesh, Bhutan, Cambodia, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura), Laos, Myanmar, southern China, Thailand, and Vietnam.

***Pinalia acervata* (Lindl.) Kuntze**

Revis. Gen. Pl. 2: 679. 1891; *Eria acervata* Lindl., J. Hort. Soc. London. 6: 58. 1851; *Eria poilanei* Gagnep., Bull. Mus. Natl. Hist. Nat. 23: 310. 1930; *Dendrobium seriatum* Wall. ex Hook.f., Fl. Brit. India. 5: 796. 1890. Type: Cambodia, 14 August 1928, M. Poilane 15285 (P!)

Erect epiphytic herb; arhizomatous; pseudobulbs erect, clustered, conical, 3.5–4.0 cm in length, 1.0–1.5 cm in diameter; Leaves simple with entire margin, sessile, lamina 14–18 x 1.0–1.2 cm, linear with parallel venation, acuminate apex and sheathing base; inflorescence

Image 6. *Mycaranthes floribunda* (D. Don) S.C. Chen & J.J. Wood

Image 7. *Pinalia acervata* (Lindl.) Kuntze

synanthous, consisting of 8–10 flowers in raceme; flowers pedicellate, bracteate, 1.6–1.8 cm long, zygomorphic; Bract one per flower, green; sepals and petals ovate with acuminate apices, 1.2–1.4 x 0.2–0.3 cm, white; lip broadly cuneate with acute apex, 1.2–1.5 x 0.5–0.8 cm with cream colored ornamentation, mentum 0.2–0.3 cm long; column white, 0.4 cm long, sessile; anther cap lemon yellow, pollinia 8, yellow (Images 7, 17).

Habitat: Growing on *Magnolia montana* (Blume) Figlar tree in moist broadleaf forest along with *Coelogyne suaveolens* (Lindl.) Hook.f. at Vanghmun in Jampui Hills.

Flowering and Fruiting: June–July.

Specimen examined: DUH 14449 (DUH), 6.vi.2018, Vanghmun, North District, Tripura, India, 23.976^{0}N, 92.278^{0}E, 633m, coll. Arjun Adit 2120.

Other specimen examined: K000596933 (K!), 22.vi.1915, Chiangmai, Thailand, coll. A.F.G. Kerr s.n.

Distribution: Bhutan, Cambodia, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim, and Tripura), Laos, Myanmar, Nepal, southern China, Thailand, and Vietnam.

***Pinalia globulifera* (Seidenf.) A.N.Rao**

Bull. Arunachal Forest Res. 26: 103. 2010; *Eria globulifera* Seidenf., Opera Bot. 62: 125. 1982. Type: Thailand, Doi Pae Poe, 1982, Seidenfaden GT 7317 (C!)

Erect epiphytic herb; arhizomatous; pseudobulbs erect, clustered, cylindrical, 6–7 cm in length, 1.8–2.0 cm in diameter; Leaves four, simple, with entire margin, alternately arranged with negligible internodal distance, petiole 1.5–2.0 cm long, lamina 15–17 x 2.5–2.7 cm, oblanceolate with parallel venation, acuminate apex and decurrent base; inflorescences terminal, two in number, with 70–90 flowers in each globular raceme; flowers pedicellate, bracteate, 0.5–0.6 cm long, zygomorphic; bract one per flower, white; sepals and petals ovate with acute apex, 0.2 x 0.2 cm, white; lip ovate with acute yellow apex, 0.2 x 0.2 cm; column white, 0.1cm long, sessile; anther cap yellow, pollinia 8, yellow (Images 8, 18).

Image 8. *Pinalia globulifera* (Seidenf.) A.N.Rao

Habitat: Growing on a *Syzygium cumini* (L.) Skeels tree in moist broadleaf forest along with *Coelogyne fimbriata* Lindl. at Vanghmun in Jampui Hills.

Flowering and Fruiting: July–September.

Specimen examined: DUH 14450 (DUH), 14.vii.2018, Phuldungsei, North District, Tripura, India, 23.813^{0}N, 92.259^{0}E, 845m, coll. Arjun Adit 2126.

Distribution: Bhutan, Cambodia, India (Arunachal Pradesh, Assam, Himachal Pradesh, Jammu & Kashmir, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, and Uttarakhand), Laos, Myanmar, Thailand, and Vietnam.

***Thelasis khasiana* Hook.f.**

Fl. Brit. India. 6: 87. 1890; *Thelasis pygmaea* var. *khasiana* (Hook.f.) Schltr. Mem. Herb. Boissier. 21: 71. 1900. Type: India, Khasia Mts., Lobb s.n. (K!)

Erect epiphytic herb; rhizome short; pseudobulbs erect, 0.5–1.0 cm apart, ovoid, 1.1–1.3 cm in length, 0.8–1.0 cm in diameter; leaves or sometimes with a second smaller leaf, simple with entire margin, petiole 1.2–1.5 cm long, lamina 6.5–6.9 x 1.1–1.3 cm, lanceolate with parallel venation, acute apex and decurrent base; inflorescence synanthous in form of raceme originating from the base of pseudobulb; flower pedicellate, bracteate, 0.3–0.4 cm long, zygomorphic; Sepals and petals lanceolate with acute apices, 0.1–0.2 x 0.1–0.2 cm, yellowish-green; lip ovate-lanceolate with acute apex, 0.1–0.3 x 0.1–0.2 cm, yellowish green; column slightly recurved, 0.1cm long, sessile; anther cap green; pollinia 2, yellow (Images 9, 19).

Habitat: Found on *Cryptocarya amygdalina* Nees tree in the moist broadleaf forest of Phuldungsei in Jampui Hills along with other epiphytes like *Hoya lanceolata* Wall. ex D. Don, *Bulbophyllum lobbii* Lindl. and *Mycaranthes floribunda* (D.Don) S.C. Chen.

Flowering and Fruiting: July–August.

Specimen examined: DUH 14451 (DUH), 14.vii.2018, Phuldungsei, North District, Tripura, India, 23.810^{0}N,

Image 9. *Thelasis khasiana* Hook.f.

92.261^{0}E, 923m, coll. Arjun Adit 2125.

Other specimen examined: K000891232 (K!), 18.ix.1850, Below Paurany, India, coll. J.D. Hooker and T. Thomson s.n.

Distribution: India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura), Laos, Myanmar, southern China, Thailand, and Vietnam.

***Trichoglottis ramosa* (Lindl.) Senghas**

F.R.R. Schlechter, Orchideen Beschreib. Kult. Zücht., ed. 3, 1: 1315. 1988; *Staurochilus ramosus* (Lindl.) Seidenf. Opera Bot. 95: 95. 1988; *Oeceoclades flexuosa* Lindl., Gen. Sp. Orchid. Pl.: 236. 1833; *Saccolabium ramosum* Lindl., Gen. Sp. Orchid. Pl. 224. 1833; *Saccolabium flexuosum* Lindl., J. Proc. Linn. Soc., Bot. 3: 36. 1859; *Saccolabium flexuosum* (Lindl.) Rchb.f. in W.G. Walpers, Ann. Bot. Syst. 6: 886. 1864; *Aerides ramosa* (Lindl.) Wall. ex Hook.f., Fl. Brit. India 6: 72. 1890; *Cleisostoma ramosum* Hook.f., Fl. Brit. India. 6: 72. 1890; *Gastrochilus flexuosus* (Lindl.) Kuntze, Revis. Gen. Pl. 2: 661. 1891; *Gastrochilus ramosus* (Lindl.) Kuntze, Revis. Gen. Pl. 2: 661. 1891; *Sarcanthus ramosus* (Hook.f.) J.J.Sm., Natuurw. Tijdschr. Ned.–Indië. 72: 92. 1912; *Pomatocalpa ramosum* (Lindl.) Summerh., Kew Bull. 56. 1948. Type: India, Ganges delta, Wallich Icon no. 654 (K!)

Erect or hanging monopodial epiphytic herb; leaves simple with entire margin, alternately arranged, sessile, lamina 10–17 x 0.8–1.2 cm, linear with parallel venation, emarginate apex and sheathing base; inflorescence branched, erect and terminal with 20–30 flowers on each side branch; flowers pedicellate, bracteate, 0.6–0.7 cm long, zygomorphic, brick red; bract one per flower, brown; sepals and petals oblanceolate with acute apex, 0.3–0.4 x 0.1 cm, brick red; lip rectangular with truncate apex, 0.2–0.3 x 0.1 cm, white with purple spot at the apex and yellow spot near the base, spur white 0.2–0.3 cm long; column pink, 0.1cm long, sessile; anther cap yellow, pollinia 2, yellow (Images 10, 20).

Habitat: Found growing on *Melaleuca viminalis* (Sol. ex Gaertn.) Byrnes in close association with *Acampe praemorsa* (Roxb.) Blatt. & McCann and *Rhynchostylis retusa* (L.) Blume in moist deciduous forest of Clouded Leopard National Park and Sepahijala Wildlife Sanctuary.

Flowering and Fruiting: April–July

Specimen examined: DUH 14452 (DUH), 11.v.2018, Clouded Leopard National Park, Sepahijala District, Tripura, India, 23.675^{0}N, 91.320^{0}E, 47m, coll. Arjun Adit 2117.

Other specimen examined: K000364567 (K!), Sikkim, India, coll. J.D. Hooker s.n.

Distribution: Bangladesh, Bhutan, India (except Jammu & Kashmir, Laddakh, Himachal Pradesh and Uttarakhand), Myanmar and Thailand.

Image 10. *Trichoglottis ramosa* (Lindl.) Senghas

Image 11. Herbarium record of *Bulbophyllum affine* Wall. ex Lindl.

Image 12. Herbarium record of *Bulbophyllum lobbii* Lindl.

Image 13. Herbarium record of *Coelogyne suaveolens* (Lindl.) Hook. f.

Image 14. Herbarium record of *Dendrobium tortile* Lindl.

Image 15. Herbarium record of *Micropera pallida* Lindl.

Image 16. Herbarium record of *Mycaranthes floribunda* (D. Don) S.C. Chen & J.J. Wood

Image 17. Herbarium record of *Pinalia acervata* (Lindl.) Kuntze

Image 18. Herbarium record of *Pinalia globulifera* (Seidenf.) A.N.Rao

Image 19. Herbarium record of *Thelasis khasiana* Hook.f.

Image 20. Herbarium record of *Trichoglottis ramosa* (Lindl.) Senghas

References

Agrawala, D.K. & H.J. Chowdhery (2013). Morphological diversity within the genus *Eria* (Orchidaceae) in India. *Richardiana* 13: 184–197.

Bridson, D. & L. Forman (1992). *The Herbarium Handbook*. Royal Botanic Gardens, Kew, 346pp.

Chen, S.C., Z.J. Liu, G.H. Zhu, K.Y. Lang, Z.H. Tsi, Y.B. Luo, X.H. Jin, J.C. Philip, J.J. Wood, S.W. Gale, P. Ormerod, J.J. Vermeulen, H.P. Wood, D. Clayton & A. Bell (2009). Orchidaceae, pp. 1–507. In: Wu, Z.Y., P.H. Raven & D.Y. Hong (eds.). *Flora of China. Vol. 25 (Orchidaceae)*. Science Press, Beijing and Missouri Botanical Garden Press, St. Louis, 570pp.

Chowlu, K., S.M. Kamalesh, H.B. Sharma, R. Ngapui, A.N. Rao & S.P. Vij (2014). *Bulbophyllum dickasonii* Seidenf. (Orchidaceae): a new record for India with a complete morphological description. *Kew Bulletin* 69: 1–4.

Das, D. & B.K. Datta (2016). *Spiranthes sinensis* (Persoon) Ames [Orchidaceae] – a new record for Tripura in NE India. *Pleione* 10: 396–399.

de Vogel, E.F. (1987). *Manual of Herbarium Taxonomy: Theory and Practice*. UNESCO, Jakarta, x+164pp.

Deb, D.B. (1983). *Flora of Tripura State, Volume II.* Today and Tomorrow's Printers and Publishers, New Delhi, 634pp.

ICAR-NRCO (2017). ICAR-NRCO: At a glance. ICAR-NRC for Orchids, Pakyong, Sikkim, 56pp.

IUCN (2017). 2016–2017 SSC Orchid Specialist Group Report. IUCN, 2pp.

Kumar, C.S. & P.S. Kumar (2005). An orchid digest of Manipur, northeastern India. *Rheedea* 15: 1–70.

Kumar, P., S.W. Gale, T. Phaxaysombath, S. Bouamanivong & G.A. Fischer (2018). Additions to the orchid flora of Laos and taxonomic notes on orchids of the Indo-Burma region. *Taiwania* 63: 61–83.

Nanda, Y., K. Chowlu & A.N. Rao (2014). *Dendrobium hesperis* (Seidenfaden) Schuiteman & Adams - a new orchid record to North-East India from Manipur, India. *Pleione* 8: 523–525.

Odyuo, N., D.K. Roy, C. Deori & R. Daimary (2013). *Ceratostylis radiate* (Orchidaceae) – A new record to the Indian flora. *Rheedea* 23: 43–45.

Odyuo, N., R. Daimary & C. Deori (2017). *Liparis formosana* (Orchidaceae) – A New Addition to the Orchid Flora of India. *Journal of Japanese Botany* 92: 53–56.

Panda, S.P., B.K. Singh, M.U. Sharief, S.S. Hameed & A. Pramanik (2016). The genus *Zeuxine* Lindl. (Orchidaceae) in Tripura State, India. *Journal of Threatened Taxa* 8(14): 9675–9677. https://doi.org/10.11609/jott.2843.8.14.9675-9677

Panday, S., D. Verma, S.K. Singh & B.K. Sinha (2014). Three new distributional records of orchids from Mizoram. *Nelumbo* 56: 252–254.

Schuiteman, A., P. Bonnet, B. Svengsuksa & D. Barthélémy (2008). An annotated checklist of the Orchidaceae of Laos. *Nordic Journal of Botany* 26: 257–316.

Verma, D. & S. Lavania (2014). Additions to the Orchid Flora of Meghalaya, India. *Richardiana* 15: 105–114.

Short Communication

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14886–14890

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

PLATINUM
OPEN ACCESS

Notes on the extended distribution of *Humboldtia bourdillonii* (Fabales: Fabaceae), an Endangered tree legume in the Western Ghats, India

Anoop P. Balan [1], A.J. Robi [2] & S.V. Predeep [3]

[1] KSCSTE-Malabar Botanical Garden and Institute for Plant Sciences, Kozhikode, Kerala 673014, India.
[2] Department of Botany, Bishop Abraham Memorial College, Thuruthicad, Pathanamthitta, Kerala 689597, India.
[3] Department of Botany, SVR NSS College, T.P. Puram Post, Vazhoor, Kottayam, Kerala 686505, India.
[1] anooppb01@gmail.com (corresponding author), [2] ajrobin80@gmail.com, [3]predeepsv@gmail.com

Abstract: *Humboldtia bourdillonii* is an Endangered tree legume; considered endemic to its type locality in the Periyar Tiger Reserve in Idukki District of Kerala State. A new population of this highly threatened endemic species is located in the Vagamon Hills of Kottayam District which is about 70km away from its original locality. The newly located population is drastically affected by the severe floods and landslides that occurred in Kerala state during August 2018. Urgent conservation measures are needed to protect the population from further loss.

Keywords: Adimundan, *Humboldtia*, Fabaceae, Caesalpinioideae, threatened, Vagamon Hills, Western Ghats.

Humboldtia Vahl is a small tree legume genus with seven species and two varieties, all are endemic to southern Western Ghats of Karnataka, Kerala and Tamil Nadu states, except *H. laurifolia*, the type species which is endemic to Sri Lanka. The species of *Humboldtia* inhabits the evergreen forest in the altitudinal range of 200–1,250 m and generally prefer river banks and areas between streamlets. *H. brunonis* Wall., *H. decurrens* Bedd. and *H. laurifolia* Vahl are myrmecophytes that harbour ants and many endemic invertebrate taxa such as bees and arboreal earthworms within swollen hollow internodes (Krombein et al. 1999). Most of the species of *Humboldtia* are under severe threat especially due to habitat loss and degradation of forest by anthropogenic activities. Among them, *H. unijuga* Bedd. var. *trijuga* J. Joseph & V. Chandras. is Critically Endangered, *H. unijuga* var. *unijuga* and H. *vahliana* Wight are Endangered, *H. laurifolia* is Vulnerable and *H. decurrens* is Near Threatened as per IUCN (2019). *H. bourdillonii* Prain was described by David Prain based on the collections of T.F. Bourdillon from the 'Peermade Ghats' of Idukki District in Kerala State in 1894 with no further information on the species thereafter. After a century, Sasidharan (1998) relocated the species from the Periyar Tiger Reserve of Peermade Ghats. Augustine (2000, 2002) and Ramachandran et al. (2014) also reported the species from the same region. The latter conducted a detailed study on the population status of the species and found that it has a discrete distribution with an area of occupancy of 0.06km^2 and area of occurrence of approximately 2km^2 and the population is estimated to have 1,310 individuals only. Ramachandran et al. (2014) assessed *H. bourdillonii* as Critically Endangered status

DOI: https://doi.org/10.11609/jott.5424.11.14.14886-14890

Editor: N.P. Balakrishnan, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #5424 | Received 25 September 2019 | Final received 07 November 2019 | Finally accepted 13 November 2019

Citation: Balan, A.P., A.J. Robi & S.V. Predeep (2019). Notes on the extended distribution of *Humboldtia bourdillonii* (Fabales: Fabaceae), an Endangered tree legume in the Western Ghats, India. *Journal of Threatened Taxa* 11(14): 14886–14890. https://doi.org/10.11609/jott.5424.11.14.14886-14890

Funding: Science and Engineering Research Board (SERB), Dept. of Science and Technology, Govt. of India.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are grateful to the director, KSCSTE-Malabar Botanical Garden & Institute for Plant Sciences, Kozhikode, Kerala for all the facilities provided for this work. The constant encouragement and support of Dr. N.S. Pradeep, Sr. Scientist and the help of Mrs. Liji, M., Herbarium Assistant, MBGIPS, Kozhikode is also thankfully acknowledged. First author is indebted to the Science and Engineering Research Board (SERB), Deptartment of Science and Technology, Government of India for financial assistance through the project PDF/2016/001936. The second author is thankful to the principal, Bishop Abraham Memorial College, Thuruthicad for the facilities and support.

against the Endangered status on the IUCN Red List (World Conservation Monitoring Centre 1998).

During a botanical exploration conducted to Vagamon Hills in the Kottayam-Idukki district border in June 2018, the authors accidently found a small patch of *H. bourdillonii* in the margins of a reserve forest near a tributary of Meenachil River. The species in this small patch is represented by about 20 individuals of different ages and girth classes. Few trees were with irregular flowers while majority were in fruiting stage. This is the first report of occurrence of this threatened species outside its type locality. Detailed description, illustration, images, distribution map and notes on habitat, ecology and conservation status are provided for easy identification and a better understanding of the species.

Taxonomic treatment

Humboldtia bourdillonii Prain, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 73(5): 200. 1904; Gamble, Fl. Madras 411. 1919; Sanjappa, Blumea 31: 331. 1986 & Legumes India 30. 1992; Sasidh., Higher Plants of Indian Sub-Continent 8: 209. 1998; T.S. Nayar *et al*., Fl. Pl. Kerala 319. 2006; V.S. Ramach. *et al*., Trop. Ecol. 55(1): 85. 2014; Sanjappa in G.V.S. Murthy & V.J. Nair (ed.) Flora of Kerala 2: 236. 2016 (Figure 1, Image 1)

Small to medium-sized trees, up to 15m high, bark smooth; branchlets woody. Stipules appendaged, 2–3.5 × 1–1.5 cm, ovate, acuminate, prominently parallel-veined, glabrous, persistent; appendages falcate-reniform, divergently veined, persistent. Leaves 6–8 foliolate; petioles ca 1cm long; rachis 10–16 cm long, narrowly, obcordately winged between the leaflets; petiolules 3–4 mm long, stout, glabrous; leaflets 12–25 × 3–4 cm, linear-lanceolate to narrowly ovate or elliptic, acuminate at apex, obtuse and unequal at base, thick-chartaceous, glabrous; veins prominently reticulate beneath. Flowers in 4–6 cm long corymbs on tubercles on stem and old branches, tawny velvety; pedicels 1–1.5 cm long, velvety; bracts 3–4 × 1.5 mm, ovate, brown tomentose, deciduous; bracteoles connate when young, splitting down at maturity, 5–6 x 3 mm, ovate, obtuse, brown tomentose and gland-dotted, deciduous. Calyx brown tomentose; tube ca 6mm long; lobes 4, crimson, 9–11 × 3–5 mm, subequal, ovate-oblong, obtuse-rounded at apex, tomentose. Petals 5, white, 3 larger ones 11–12 × 6–7 mm, others 8–9 × 3–4 mm, obovate, obtuse at apex, sparsely pilose inside, shortly clawed, caducous. Stamens 5, filaments 2.5–3 cm long, reddish, broad and pilose at base; anthers versatile, ca 4 × 1.5 mm, oblong. Ovary stipitate, 6–7 × 3 mm, obliquely oblong, densely pilose, 5–6–ovuled; style 1.6–1.8 cm long, narrowing towards the tip; stigma capitate. Pods 10–14 × 3–3.5 cm, dolabriform, falcate, velvety, bright red or crimson, sutures thick, prominently veined, 3–5 seeded. Seeds ca 2.5 × 2 cm, suborbicular, pale red when young and dark brown when matured.

Local name: 'Adimundan' (Malayalam)

Flowering & Fruiting: January–July.

Habitat & Ecology: Grows in steep, slippery terrain in wet evergreen forest at ca. 1,100m, in an isolated patch of about 0.5ha area. The population is located near to a stream and comprises eight mature individuals (10–70 cm gbh) and 12 seedlings (<10cm gbh). *Aglaia tomentosa* Teijsm. & Binn., *Antidesma montanum* Blume, *Aporosa acuminata* Thwaites, *Artabotrys zeylanicus* Hook. f. & Thomson, *Casearia graveolens* Dalz., *Drypetes venusta* (Wight) Pax & K. Hoffm., *Goniothalamus keralensis* E.S.S. Kumar, Shaju, Roy et Raj Kumar, *Litsea bourdillonii* Gamble, *Schefflera racemosa* (Wight) Harms, *Vernonia arborea* Buch.-Ham., etc. are the major associates of *H. bourdillonii*.

Specimens examined: Kerala, Idukki District, Peermade Ghats, 07 February 1894, *Bourdillon* 906 (CAL, MH), Peermade road, 853m (2800ft), 06 March 1907, *Bourdillon* 1614 (University College Herbarium, Thiruvananthapuram); Arjunankotta, 25 February 1994, Sasidharan & Jomy 13378 (CAL); 14 February 2007, S.V. Predeep & Anoop P.B. 20531 (MBGH); Kottayam District, Vagamon Hills, 16 June 2018, Anoop P.B. & A.J. Robi 15548 (MBGH – Image 2).

Threats and conservation

Peermade Hills and Vagamon Hills were once covered by continuous dense evergreen forests and was home to several Western Ghats endemic species. Extensive forest clearance especially for the cultivation of Cardamom and Tea during 19th century under British rule have caused serious decline in population of several threatened plants including *H. bourdillonii*. At present, the evergreen forests in Vagamon Hills are restricted to certain pockets and are under severe threat due to tourism related activities, since Vagamon is one of the major tourist destinations in Kerala state. The newly located population of *H. bourdillonii* is also facing serious threat from human intervention and natural calamities like landslides and soil erosion. Both locations of the species are in landslide prone areas identified by the Kerala State Disaster Management Authority – KSDMA (Figure 2). Between 1 June and 18 August 2018 Kerala State received 36% excess rainfall than normal levels, leading to widespread floods and the torrential rains triggered a number of landslides that devastated innumerable infrastructure

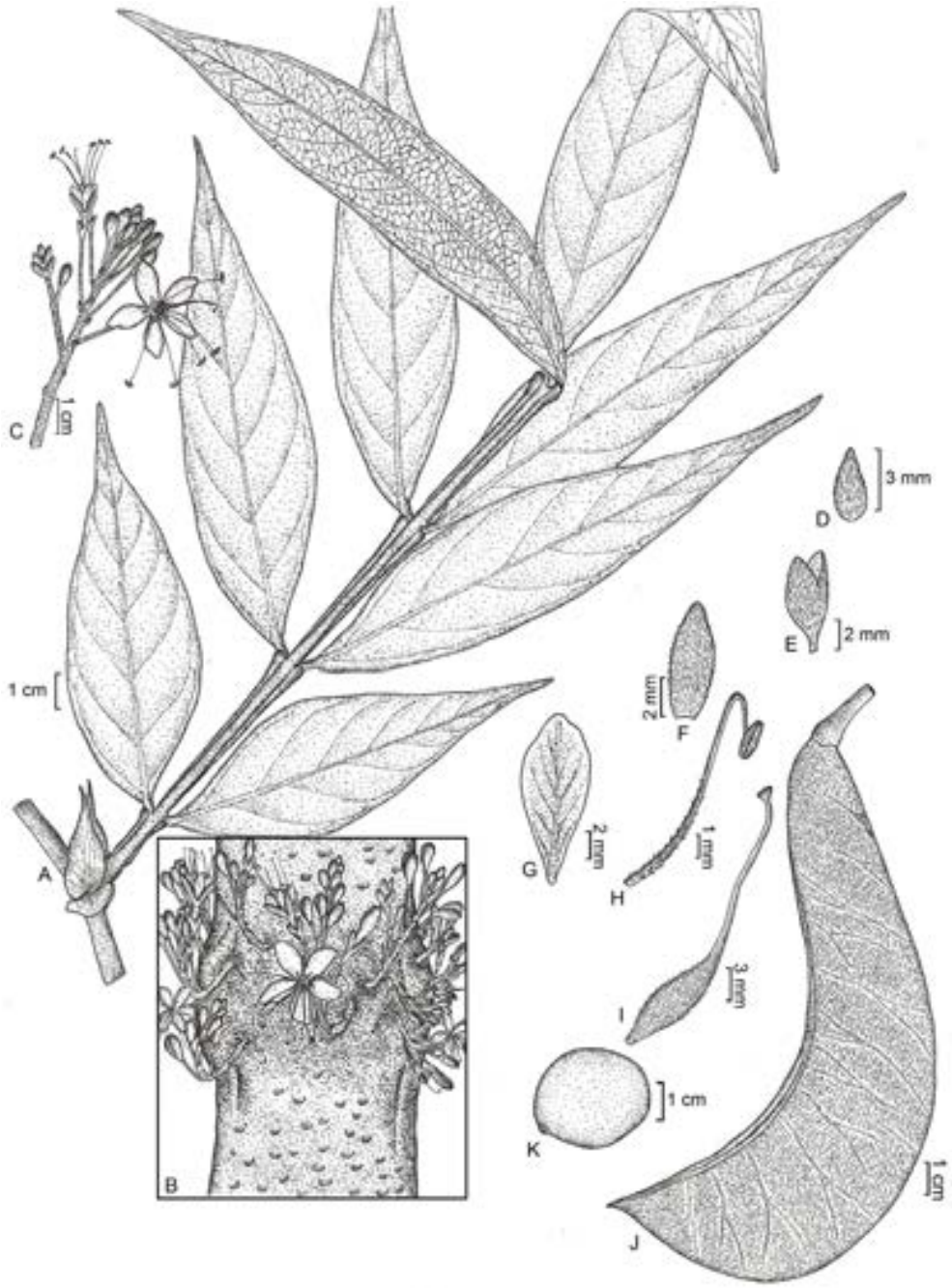

Figure 1. ***Humboldtia bourdillonii*** **Prain: A—leaf | B—cauline inflorescence | C—corymb | D—bract | E—bracteoles | F—sepal | G—petal | H—stamen | I—pistil | J—pod | K—seed. © Anoop P. Balan.**

facilities and washed away a vast variety of Biodiversity. Vagamon Hills also experienced heavy precipitation and large-scale landslides during that period and a massive landslide occurred near to the population of *H. bourdillonii*, washed away four to five mature trees of the species along with its associated endemic taxa (Image 3).

Immediate intervention is required from the forest department to protect the extant population from further damage, since the land is in their custody. Actions are also needed to raise the seedlings in nurseries (ex situ conservation) and further reintroduction to adjacent localities in Vagamon Hills. Mass multiplication through vegetative/ tissue culture techniques should also be attempted to prevent the extinction of this highly threatened species.

Image 1. *Humboldtia bourdillonii* Prain: A—tree trunk | B—stipules | C—leaves | D—pods | E—pod, split-opened | F—seed, young and matured. © Anoop P. Balan.

References

Augustine, J. (2000). *Floristic and Ethnobotanical Studies of Periyar Tiger Reserve, Kerala*. Ph.D. Thesis, University of Calicut, Kozhikode, 1204 pp.

Augustine, J. (2002). Some threatened plants collected from Sabarimala and surrounding evergreen forests, Kerala. *Indian Journal of Forestry* 25: 338–340.

IUCN (2019). The IUCN Red List of Threatened Species. Version 2019-2. <https://www.iucnredlist.org>

Krombein, K.V., B.B. Norden, M.M. Rickson & F.R. Rickson (1999). Biodiversity of the Domatia Occupants (Ants, Wasps, Bees and others) of the Sri Lankan Myrmecophyte *Humboldtia laurifolia* Vahl (Fabaceae). *Smithsonian Contributions to Zoology* 603: 1–30. https://doi.org/10.5479/si.00810282.603

Ramachandran, V.S., K. Swarupanandan & M. Sanjappa (2014). Status and distribution of *Humboldtia bourdillonii*, an endangered tree species of the Western Ghats, India. *Tropical Ecology* 55(1): 85–91.

Sasidharan, N. (1998). Rediscovery of four threatened and possibly extinct endemic tree legumes from Kerala. *Higher Plants of Indian Subcontinent* 8: 205–213.

World Conservation Monitoring Centre (1998). *Humboldtia bourdillonii*. *The IUCN Red List of Threatened Species* 1998: e.T31187A9606349. Downloaded on 17 November 2019. https://doi.org/10.2305/IUCN.UK.1998.RLTS.T31187A9606349.en

Image 2. Herbarium of *Humboldtia bourdillonii* (MBGH Acc. No. 6788).

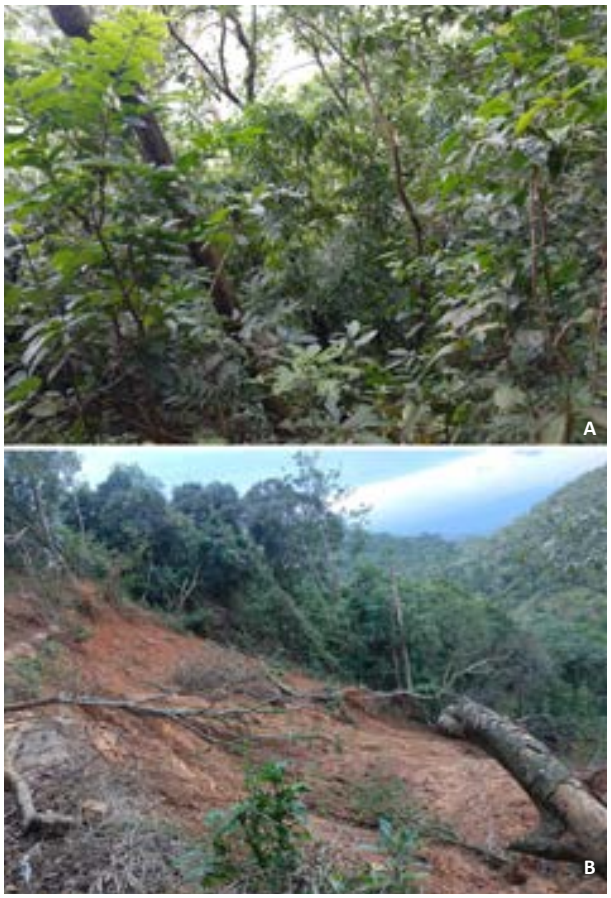

Image 3. A & B—location of *Humboldtia bourdillonii* in Vagamon Hills, before and after the landslide. © Anoop P. Balan.

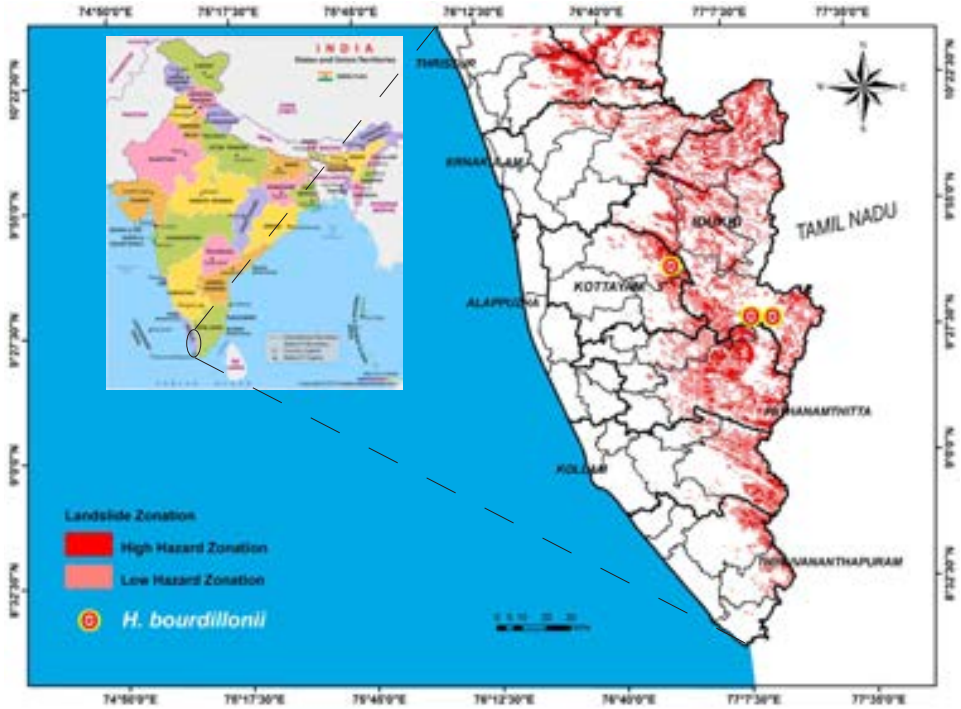

Figure 2. Location of *Humboldtia bourdillonii* in landslide prone areas of Kerala (Map courtesy Kerala State Disaster Management Authority).

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

PLATINUM
OPEN ACCESS

Vertebrate prey handling in the Indian Grey Hornbill *Ocyceros birostris* (Aves: Bucerotiformes: Bucerotidae)

James A. Fitzsimons

The Nature Conservancy, PO Box 57, Carlton South, Victoria 3053, Australia; and School of Life and Environmental Sciences, Deakin University, 221 Burwood Highway, Burwood, Victoria 3125, Australia.
jfitzsimons@tnc.org

Most hornbills (Bucerotidae) are omnivorous, but the proportions of different types of food in the diet vary during the year; mostly frugivorous species include more animal protein in their diet when nesting (Kemp 1995, 2001; Kinnaird & O'Brien 2007; Poonswad et al. 2013). Besides the larger ground-hornbills of Africa (Bucorvidae), there are few specific records of how vertebrate prey are handled by Bucerotidae hornbills, particularly in Asia. This is likely to be due to dietary studies in the breeding season (when most vertebrate prey is taken) focusing on delivery to the female and young in the nest (e.g., Santhoshkumar & Balasubramanian 2014). Santhoshkumar & Balasubramanian (2014) consider information published on the Indian Grey Hornbill *Ocyceros birostris* (one of the most common species in the Indian subcontinent) to be inadequate. This paper presents an observation of vertebrate prey handling in the Indian Grey Hornbill *Ocyceros birostris* and compares this with other accounts for this species and other hornbill species.

Three Indian Grey Hornbills (including an adult male and female) were located in a large tree in the Lodhi Gardens, New Delhi, India, at approximately 10.00h on 30 June 2018. The hornbills were observed for approximately seven minutes and photos and video were taken.

The adult male hornbill had a Garden Lizard *Calotes versicolor* in its bill by the neck with the head on one side and rest of the body on the other. The lizard was clearly dead at this stage and photographs show the head of the lizard had been crushed. The male hornbill rubbed the lizard's head on the branch 3–4 times at intervals of approximately 20 seconds (Image 1). After a few minutes, the male gave the lizard to the female perched next to the male (Image 2–4) who moved the prey in the bill while perched together, with the male calling. Further, the female 'wiped' the sides of the Garden Lizard on the branch (Image 5), before the pair flew off out of sight. It could not be determined if further manipulation of the lizard took place before consumption.

Asian hornbills are generally frugivorous but turn omnivorous in the breeding season (Poonswad et al. 1998), and this is true for the Indian Grey Hornbill (Santhoshkumar & Balasubramanian 2010, 2014; Kasambe 2011). The Garden Lizard is a common lizard in India (Das & Das 2018), and the Indian Grey Hornbill a known predator, but the proportion (and importance) of Garden Lizards in Indian Grey Hornbill diets during the breeding season varies between published studies. For example, Kasambe (2011) suggests Garden Lizards are an important source of protein for female and nestling Indian Grey Hornbills in the breeding season and both male and female hornbills hunt them. Lowther (1942) recorded Garden Lizard in their diet but Patel et al. (1997) did not. Charde et al. (2011a) observed one instance of a female bringing a Garden Lizard to the

DOI: https://doi.org/10.11609/jott.5272.11.14.14891-14894

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

Manuscript details: #5272 | Received 25 July 2019 | Finally accepted 27 October 2019

Citation: Fitzsimons, J.A. (2019). Vertebrate prey handling in the Indian Grey Hornbill *Ocyceros birostris* (Aves: Bucerotiformes: Bucerotidae). *Journal of Threatened Taxa* 11(14): 14891–14894. https://doi.org/10.11609/jott.5272.11.14.14891-14894

Funding: The Nature Conservancy.

Competing interests: The author declares no competing interests.

Acknowledgements: The author was in India courtesy of a Coda Fellowship through The Nature Conservancy.

nest but Charde et al. (2011b) observed many instances of this. Santhoshkumar & Balasubramanian (2014) found Garden Lizards constituted 0.06–0.10% of food items in the breeding season. These differences may represent differences in survey techniques, differences in availability of Garden Lizards or differences in feeding preferences between individuals or populations of Indian Grey Hornbills. Garden Lizard and other *Calotes* species are also consumed as part of the diet of congenerics, i.e., the Malabar Grey Hornbill *Ocyceros griseus* (Mudappa 2000; Paleri 2007; pers. obs. 2018) and Sri Lanka Grey Hornbill *O. gingalensis* (Wijerathne & Wickramasinghe 2018).

Most dietary studies for Indian hornbills more generally document food types being brought to the nest (e.g., Santhoshkumar & Balasubramanian 2010, 2014; Charde 2011a,b) and not the capture, killing or handling of prey which mostly occurs away from the nest. An exception is Kasambe (2011) who stated the Indian Grey Hornbill "severely crushes and kills the Garden Lizard before it is swallowed".

My observations, in late June and likely at the end of the breeding season, suggest the Garden Lizards may be further 'processed', after being killed and before consumption. This is supported by a 20-second video by Patil (2014) which shows an Indian Grey Hornbill undertaking very similar behaviour to my observations, but in that instance the lizard was still alive. The hornbill wiped the sides of the lizard on a branch but was clearly not trying to kill it with that motion.

Descriptions of other hornbill species using tree branches to process lizards before consumption clearly focus on killing or incapacitating the prey. Kannan & James (1997) noted "Larger prey [including Agamid lizards] were thrashed against the bough [by Great Hornbill *Buceros bicornis*] to incapacitate them". Li (2016) observed an Oriental Pied Hornbill *Anthracoceros albirostris* preying on *Calotes versicolor*: "flicked the animal against a branch, perhaps to knock it unconscious" before consuming it head first. Hong (2014) similarly described Oriental Pied Hornbill preying on *C. versicolor*: "The lizard was swiped against the branch until it was dead". These descriptions suggest a different, more forceful technique to purposefully kill large lizards, and are not consistent with the branch-rubbing behaviour observed in my observations or the video by Patil (2014).

An explanation for the observations described in this paper may lie in the techniques used by hornbills to process other food types. For hornbills, most food items are swallowed whole (Poonswad et al. 2013; Sivakumaran 2019) but Kemp (2001; repeated in Poonswad et al.

Image 1. Male adult Indian Grey Hornbill rubbing Garden Lizard either side of a branch.

Image 2. Male adult Indian Grey Hornbill holding Garden Lizard prior to giving it to the female bird.

Image 3. Male adult Indian Grey Hornbill holding Garden Lizard prior to giving it to the female bird.

Image 4. Female adult Indian Grey Hornbill moving the Garden Lizard through its bill.

Image 5. Female adult Indian Grey Hornbill wiping Garden Lizard on branch.

2013) stated that "Large items … may be broken up, separated into edible and inedible parts, as by removing fruit husks or insect wings, and then crushed or softened in the bill. Certain distasteful foods, such as sticky fruits or hairy caterpillars, or slimy items, may be wiped on a branch or the ground before being swallowed". Kemp (1995) provided further details: "Others are softened before swallowing, the hornbill passing them through and crushing them in the bill, which is serrated in many species, or cleaned of unwanted coverings by being wiped back and forth over a perch or along the ground, as in the case of hairy caterpillars, slimy toads, or juicy fruits".

Garden Lizards do have spines (particularly around the neck) and elongated scales in places (Zug et al. 2006). Constant wiping of the head and both sides of the Garden Lizard on a branch could serve to remove spines, or make them less rigid, before the lizard is consumed whole and head first. It may also serve to further the 'softening' process, through breaking or dislodging bones, prior to consumption.

This observation and those of Gadikar (2017) suggest we still have more to learn on the ecology of *Ocyceros* hornbills in India.

References

Charde, P., R. Kasambe & J.L. Tarar (2011a). Breeding behaviour of Indian Grey Hornbill in central India. *Raffles Bulletin of Zoology* 24(Suppl.): 59–64.

Charde, P., R. Kasambe, A. Pimplapure & J.L. Tarar (2011b). Nest sanitation in Indian Grey Hornbill in central India. *Raffles Bulletin of Zoology* 24(Suppl.): 65–67.

Das, I. & A. Das (2018). *A Naturalist's Guide to the Reptiles of India*. JB Publishing, Shipham, United Kingdom, 176pp.

Gadikar, A. (2017). Adaptations of the Indian Grey Hornbill *Ocyceros birostris* in an urban environment. *Indian Birds* 13: 167–168.

Hong, C.B. (2014). *The Oriental Pied Hornbill and the Changeable Lizard*. Bird Ecology Study Group, Singapore. Electronic version accessed 21 January 2019. https://www.besgroup.org/2014/12/13/the-oriental-pied-hornbill-and-the-changeable-lizard/

Kasambe, R. (2011). *Indian Grey Hornbill: Study of the Ecology and Breeding Behaviour Indian Grey Hornbill Ocyceros birostris in central India***.** Lambert Academic Publishing, Saarbrücken, Germany, 172pp.

Kannan, R. & D.A. James (1997). Breeding biology of the Great Pied Hornbill (*Buceros bicornis*) in the Anaimalai Hills of southern India. *Journal of the Bombay Natural History Society* 94: 451–465.

Kemp, A. (1995). *The Hornbills: Bucerotiformes*. Oxford University Press, Oxford, UK, 302pp.

Kemp, A.C. (2001). Family Bucerotidae (Hornbills), pp. 436–523. In: del Hoyo, J., A. Elliott & J. Sargatal (eds.). *Handbook of the Birds of the World. Volume 6: Mousebirds to Hornbills*. Lynx Editions, Barcelona, 589pp.

Kinnaird, M.F. & T.G. O'Brien (2007). *The Ecology* and *Conservation of Asian Hornbills*: *Farmers of the Forest*. University of Chicago Press, Chicago, 352pp.

Li, S.S. (2016). Oriental pied hornbill preying on changeable lizard. *Singapore Biodiversity Records* 2016: 88–89.

Lowther, E.H.N. (1942). Notes on some Indian birds. 7. Hornbills *Journal of the Bombay Natural History Society* 43: 389–401.

Mudappa, D. (2000). Breeding biology of the Malabar Grey Hornbill *Ocyceros griseus* in southern Western Ghats, India. *Journal of the Bombay Natural History Society* 97: 15–24.

Paleri, A. (2007). Malabar Grey Hornbill *Ocyceros griseus* nesting near human habitation. *Indian Birds* 3: 152–153.

Patel, N., N. Chaturvedi & V. Hegde (1997). Food of Common Grey Hornbill *Tockus birostris* (Scopoli). *Journal of the Bombay Natural History Society* 94: 408–411.

Patil, B. (2014). Grey Hornbill hunting a lizard. Youtube video. Available: https://www.youtube.com/watch?v=Ygvohf7eJ68. Electronic version accessed 21 January 2019.

Poonswad, P., A. Tsuji, N. Jirawatkavi & V. Chimchome (1998). Some aspects of food and feeding ecology of sympatric hornbill species in Khao Yai National Park, Thailand, pp. 137–157. In: P. Poonswad (ed.).

The Asian Hornbills: Ecology and Conservation. BIOTEC–NSTDA, Bangkok, 325pp.

Poonswad, P., A. Kemp & M. Strange (2013). *Hornbills of the World: A Photographic Guide*. Draco Publishing and Distribution, Hornbill Research Foundation, Singapore and Bangkok, 212pp.

Santhoshkumar, E. & P. Balasubramanian (2010). Breeding behaviour and nest tree use by Indian Grey Hornbill *Ocyceros birostris* in the Eastern Ghats, India. *Forktail* 26: 82–85.

Santhoshkumar, E. & P. Balasubramanian (2014). Food habits of Indian Grey Hornbill *Ocyceros birostris* in Sathyamangalam forest Division, Eastern Ghats, India. *Journal of the Bombay Natural History Society* 111: 90–97.

Sivakumaran, M.S. (2019). Predation of swiftlet *Aerodramus* sp. by Bushy-crested Hornbill *Anorrhinus galeritus* in Bornean Malaysia. *BirdingAsia* 31: 41–42.

Wijerathne, I. & S. Wickramasinghe (2018). Behavioral pattern of endemic Sri Lanka Grey Hornbill (*Ocyceros gingalensis*) within the breeding and nonbreeding seasons. *International Journal of Biodiversity* 2018: 9509785.

Zug, G.R., H.H.K. Brown, J.A. Schulte II & J.V. Vindum (2006). Systematics of the Garden Lizards, *Calotes versicolor* Group (Reptilia, Squamata, Agamidae), in Myanmar: Central dry zone populations. *Proceedings of the California Academy of Science* 57(2): 35–68.

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

PLATINUM OPEN ACCESS

Impact of cyclone Fani on the breeding success of sandbar-nesting birds along the Mahanadi River in Odisha, India

Subrat Debata

Aranya Foundation, Plot No-625/12, Mars Villa, Panchasakha Nagar, Dumduma, Bhubaneswar, Odisha 751019, India
subrat.debata007@gmail.com

Extreme weather events can have severe negative effects on animal populations (Hennicke & Flachsbarth 2009). Events such as cyclonic storms, synonymously known as typhoons, cyclones, or hurricanes are common worldwide and their occurrence can have both direct and indirect effects on bird population. Wiley & Wunderle (1993) made an extensive review on the consequences of such effects on birds. Birds those inhabit in open and exposed areas are especially susceptible to severe cyclonic effect (Cely 1991). The direct effects include decline in population due to mortality and physical injury (Nagarajan & Thiyagesan 1995; Wolfaardt et al. 2012), geographic displacement (Legrand 1985; DeBenedictis 1986), destruction of breeding sites (Reville et al. 1990; Shepherd et al. 1991), and loss of eggs and chicks (Reville et al. 1990; Hennicke & Flachsbarth 2009; Wolfaardt et al. 2012). Aftermath of cyclonic storms, the surviving population also experiences indirect effects. Due to lack of foraging site and food resource availability, the parent birds fail to provide provisioning services to their chicks leading to infant mortality from starvation (Feare 1976; Langham 1986). Information on the effect of such cyclonic storms on the birds those inhabit and breed in riverine habitats, however, is very scarce and is anecdotal. In this note I report the impact of Fani, an extremely severe cyclonic storm, on different waterbird species that breed on the sandy islands along Mahanadi River in Odisha, eastern India.

The Mahanadi River is the largest river in Odisha and different stretches of it have been identified as important waterbird congregation sites (Nair et al. 2014; Kar & Debata 2018). During summer season, a number of sandy islands in this river are also used as regular breeding sites for several waterbirds including some of the globally threatened species (Rahmani & Nair 2012; Kar & Debata 2018; Kar et al. 2018; Debata et al. 2019). I observed breeding activities of Black-bellied Tern *Sterna acuticauda* J.E. Gray, 1831, River Tern *Sterna aurantia* J.E. Gray, 1831, Little Tern *Sternula albifrons* (Pallas, 1764), Indian Skimmer *Rynchops albicollis* Swainson, 1838, River Lapwing *Vanellus duvaucelii* Lesson, 1826, Great Thick-knee *Esacus recurvirostris* Cuvier, 1829, Small Pratincole *Glareola lacteal* Temminck, 1820, and Black-winged Stilt *Himantopus himantopus* (Linnaeus, 1758) from seven different islands along the Mahanadi River during January–July 2019 (Figure 1). Among all the species, breeding activity of Black-bellied Tern was completed much earlier in April while for the other species it continued beyond April. Every day I visited every nesting site during 05.30–08.30 h to monitor the existing nests and chicks, and record new nests. I also counted the individuals of each species. As on 02 May 2019, there

DOI: https://doi.org/10.11609/jott.5480.11.14.14895-14898

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

Manuscript details: #5480 | Received 20 October 2019 | Final received 23 October 2019 | Finally accepted 05 November 2019

Citation: Debata, S. (2019). Impact of cyclone Fani on the breeding success of sandbar-nesting birds along the Mahanadi River in Odisha, India. *Journal of Threatened Taxa* 11(14): 14895–14898. https://doi.org/10.11609/jott.5480.11.14.14895-14898

Funding: Compensatory Afforestation Fund Management and Planning Authority, India.

Competing interests: The author declares no competing interests.

Acknowledgements: The present study is an outcome of the ongoing breeding activity monitoring work of Indian Skimmer along the Mahanadi River by the Odisha Forest Department and it is being financially supported by the Compensatory Afforestation Fund Management and Planning Authority, India. I would like to thank K. Swain, divisional forest officer, Chandaka Wildlife Division for his support during the study. Thanks to S.K. Dalai for his assistance in identifying nesting sites and T. Kar for preparing the map.

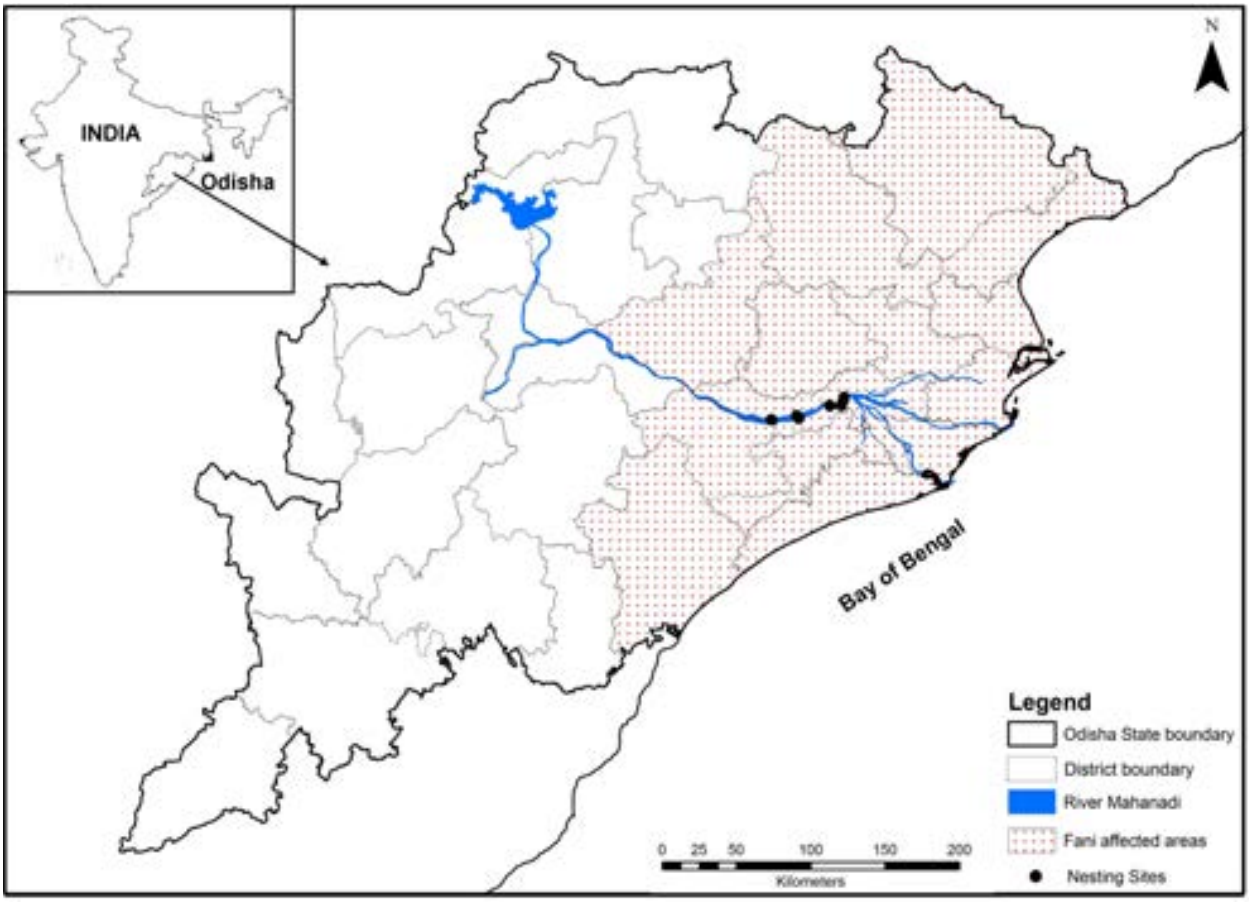

Figure 1. Map showing the cyclone Fani affected areas and location of the nesting sites of different sandbar-nesting birds along the Mahanadi River in Odisha, eastern India during the year 2019.

were a total of 269 active nests and 154 chicks. The population count, number of active nests, and chicks of each species is given in Table 1.

On 03 May 2019, at around 08.00h, cyclone Fani made a landfall in Odisha. During this period, the maximum wind speed reached up to 250km/h along with heavy rainfall, and about 13 districts were severely affected from it (Figure 1). As all the identified nesting sites in the study area are situated within the affected zone (Figure 1), they also experienced the consequences. My survey on 04 May 2019 found that Fani had major negative impacts on the population, nesting sites, nesting success, and chick survival (Image 1; Table 1). Overall, there was a relative decline of 81% in population of all the species. All the nesting sites were damaged and none of the active nests or chicks of any species survived (Table 1). Out of the 154 chicks of all species, I could only detect the carcass of 12 chicks of Indian Skimmer and seven chicks of River Tern. I could not detect any egg.

My discussion with the local people revealed that during the cyclone, there was an increase in water level and high tide in the river, which resulted in the submergence and flooding of the islands. The heavy rain and rise in water level might have resulted in flooding of the nests. Due to high tide and water current, the eggs and chicks might have drowned in water. As the wind speed was very strong during the time, there is a possibility that some of the chicks and adults might have also been blown away. Such effects from extreme weather event have also been reported in different time periods across India. During the late 80s several species of birds died due hailstorms in Karera Bustard sanctuary, Madhya Pradesh (D'Cunha & Akhtar 1987), and Jaipur in Rajasthan (Rammanohar & Rajasekaran 1989). In Pichavaram Mangrove forest of Tamil Nadu, mortality of birds has been reported on several occasions due cyclones during 1993 (Nagarajan & Thiyagesan 1995; Thiyagesan & Nagarajan 1997). In 2013, cyclone Phailin had major impacts on mass mortality and destruction of nesting sites of several species of birds in Andhra Pradesh (Anonymous 2015) and Odisha (Senapati 2015). In 2014, the impact of hailstorms resulted in the death of

Table 1. Impact of cyclone 'Fani' (Landfall date 03 May 2019) on different sandbar-nesting birds along the Mahanadi River in Odisha, eastern India during the year 2019.

Species (Common name)	IUCN Red List status	Before Fani (02.v.2019)			After Fani (04.v.2019)			Relative decline (%)		
		Population	Active nests	Chicks	Population	Active nests	Chicks	Population	Active nests	Chicks
Rynchops albicollis (Indian Skimmer)	VU	172	40	88	65	0	0	62	100	100
Sterna aurantia (River Tern)	NT	63	27	29	18	0	0	71	100	100
Sternula albifrons (Little Tern)	LC	32	35	7	6	0	0	81	100	100
Vanellus duvaucelii (River Lapwing)	NT	26	13	6	11	0	0	57	100	100
Esacus recurvirostris (Great Thick-knee)	NT	8	1	2	2	0	0	75	100	100
Glareola lacteal (Little Pratincole)	LC	>500	152	22	50	0	0	90	100	100
Himantopus himantopus (Black-winged Stilt)	LC	4	1	0	1	0	–	75	100	–

VU—Vulnerable | NT—Near Threatened | LC—Least Concern.

Image 1. Effect of Fani on breeding failure of sandbar-nesting birds along the Mahanadi River in the year 2019: A—damage of the nesting site protection fencing | B—flooding of nesting site | C—dead chick of Indian Skimmer | D—dead chick of River Tern. © Subrat Debata.

more than 50,000 birds in several areas of Maharashtra (Narwade et al. 2014). In 2018, two cyclones, Titli and Gaja also had similar impacts on mortality of several hundreds of birds in Andhra Pradesh (Babu 2018) and in Point Calimere in Tamil Nadu (Kolappan 2018).

It is predicted that changing pattern of global climate will increase the frequency and intensity of storms worldwide (IPCC 2007). So, possibilities of cyclonic effects on birds are also likely to increase. The impact can be detrimental and could even lead to local extirpation of the species that represent limited population and distribution range (Parmesan et al. 2000; Scheffer et al.

2001). Among all the eight species of birds those breed along the Mahanadi River, five are globally threatened. Apart from the ongoing threats, complete failure of breeding activity form the consequences of cyclones may lead to rapid population depletion and local extinction of these species in the long run.

References

Anonymous (2015). Cyclone Phailin aftermath: Thousands of migratory birds affected. https://www.firstpost.com/india/cyclone-phailin-aftermath-thousands-of-migratory-birds-affected-1172753.html. Electronic version accessed 23 October 2019.

Babu, G.R. (2018). Cyclone Titli leaves 2,000 migratory birds dead. www.newindianexpress.com/states/andhra-pradesh/2018/oct/15/cyclone-titli-leaves-2000-migratory-birds-dead-1885685.html. Electronic version accessed 23 October 2019.

Cely, J.E. (1991). Wildlife effects of Hurricane Hugo. *Journal of Coastal Research* 8: 319–326.

D'Cunha, E.P.E. & A. Akhtar (1987). Mortality from a hail storm at the Karera Bustard sanctuary, Madhya Pradesh. *Journal of the Bombay Natural History Society* 83: 218–219.

Debata, S., T. Kar, H.S. Palei & K.K. Swain (2019). Breeding ecology and causes of nest failure in the Indian Skimmer *Rynchops albicollis*. *Bird Study* 66: 243–250. https://doi.org/10.1080/00063657.2019.1655526

DeBenedictis, P.A. (1986). The changing seasons. *American Birds* 40: 75–82.

Feare, C.J. (1976). The breeding of the Sooty Tern, *Sterna fuscata*, in the Seychelles and the effects of experimental removal of its eggs. *Journal of Zoology (London)* 179: 317–360. https://doi.org/10.1111/j.1469-7998.1976.tb02299.x

Hennicke, J.C. & K. Flachsbarth (2009). Effects of cyclone Rosie on breeding Red-tailed Tropicbirds *Phaethon rubricauda* on Christmas island, Indian Ocean. *Marine Ornithology* 37: 175–178.

IPCC (2007). *Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, 976pp.

Kar, T. & S. Debata (2018). Assemblage of waterbird species in an anthropogenic zone along the Mahanadi River of Odisha, eastern India: Implications for management. *Proceedings of the Zoological Society* 8 December 2018. http://doi.org/doi:10.1007/s12595-018-0276-9

Kar, T., H.S. Palei & S. Debata (2018). Breeding reports and conservation implications of the Endangered Black-bellied Tern *Sterna acuticauda* J.E. Gray, 1831 (Aves: Charadriiformes: Laridae) in Odisha, eastern India. *Journal of Threatened Taxa* 10(13): 12840–12843. https://doi.org/10.11609/jott.4106.10.13.12840-12843

Kolappan, B. (2018). After Cyclone Gaja, the wildlife sanctuary looks like a deserted war zone. https://www.thehindu.com/sci-tech/energy-and-environment/cyclone-gaja-birds-flee-nagapattinams-devastated-pt-calimere/article25560716.ece. Electronic version accessed 23 October 2019.

Langham, N. (1986). The effect of cyclone "Simon" on the terns nesting on One Tree Island, Great Barrier Reef, Australia. *Emu* 86: 53–57. https://doi.org/10.1071/MU9860053

Legrand, H.E. Jr. (1985). Southern Atlantic Coast Region. *American Birds* 39: 899–902.

Nagarajan, R. & K. Thiyagesan (1995). Avian mortality caused by a cyclone at the Pichavaram Mangroves, southern India. *Pavo* 33: 117–121.

Nair, M.V., S. Panda & A.K. Pradhan (2014). Hirakud wetlands, Odisha: A little known refuge and potential IBA for wintering waterfowl, pp. 186–201. In: Gopi, G.V. & S.A. Hussain (eds.). *Waterbirds of India*. Wildlife Institute of India, Dehradun, 368pp.

Narwade, S., M.C. Gaikwad, K. Fartade, S. Pawar, M. Sawdekar & P. Ingale (2014). Mass mortality of wildlife due to hailstorms in Maharashtra, India. *Bird Populations* 13: 28–35.

Parmesan, C., T.L. Root & M.R. Willing (2000). Impacts of extreme weather and climate on terrestrial biota. *Bulletin of the American Meteorological Society* 81: 443–450. https://doi.org/10.1175/1520-0477(2000)081<0443:IOEWAC>2.3.CO;2

Rahmani, A.R. & M.V. Nair (2012). *Threatened Birds of Odisha*. Oxford University Press, New Delhi, 196pp.

Rammanohar, B. & M. Rajasekaran (1989). Additional record on mortality from a hail storm at Jaipur. *Journal of the Bombay Natural History Society* 86: 461.

Reville, B.J., J.D. Tranter & H.D. Yorkston (1990). Conservation of the Endangered Seabird Abbott's Booby on Christmas Island. 1983–1989. Occasional paper no. 20, Australian National Parks and Wildlife Service, Canberra, Australia. 18pp.

Scheffer, M., S. Carpenther, J.A. Foley, C. Folke & B. Walker (2001). Catastrophic shifts in ecosystems. *Nature* 413: 591–596. https://doi.org/10.1038/35098000

Senapati, A. (2015). Phailin keeps migratory birds away from Chilika lake. https://www.downtoearth.org.in/news/phailin-keeps-migratory-birds-away-from-chilika-lake-42887. Electronic version accessed 23 October 2019.

Shepherd, P., T. Crockett, T.L. De Santo & K.L. Bildstein (1991). The impact of Hurricane Hugo on the breeding ecology of wading birds at Pumpkinseed Island, Hobcaw Barony, South Carolina. *Colonial Waterbirds* 14: 150–157. https://doi.org/doi:10.2307/1521504

Thiyagesan, K. & R. Nagarajan (1997). Effects of a cyclone on waterbird populations at the Pichavaram mangroves, southern India. *Wader Study Group Bulletin* 84: 47–51.

Wiley, J.W. & J.M. Wunderle (1993). The effects of hurricanes on birds, with special reference to Caribbean islands. *Bird Conservation International* 3: 319–349. https://doi.org/10.1017/S0959270900002598

Wolfaardt, A.C., S. Crofts & A.M.M. Baylis (2012). Effects of a storm on colonies of seabirds breeding at the Falkland Islands. *Marine Ornithology* 40: 129–133.

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

PLATINUM OPEN ACCESS

First record of the micromoth *Ethmia lineatonotella* (Moore, 1867) (Lepidoptera: Depressariidae: Ethmiinae) from Bhutan

Jatishwor Singh Irungbam [1] & Meenakshi Jatishwor Irungbam [2]

[1,2] Faculty of Science, University of South Bohemia, Ceske Budejovice 37005, Czech Republic.
[1,2] Institute of Entomology, Czech Academy of Science, Ceske Budejovice 37005, Czech Republic.
[1] jatishwor.irungbam@gmail.com (corresponding author), [2] meenakshi.irungbam@gmail.com

Ethmia lineatonotella (Moore, 1867) is a micromoth that belongs to the family Depressariidae Meyrick, 1883, subfamily Ethmiinae Busck, 1909. The genus *Ethmia* has a cosmopolitan distribution with about 231 described species from the Palearctic region (Sattler 1967), New World (Powell 1973), southeastern Asia (Robinson et al. 1994), and Australia (Nielsen et al. 1996). In the Himalayan region, only 13 species are reported which shows that the genus is poorly studied and the data on the distribution and biology is lacking in the region (Kun 2004; Yen et al. 2009; Savela 2018). Table 1 shows the species recorded from Himalayan regions along with their range of distribution. Recent surveys in Bhutan have recorded 825 moth species but none of the *Ethmia* species were reported from Bhutan (Gielis & Wangdi 2017). The members of the genus are nocturnal and distributed at low elevation and the larvae are defoliator, skeletonizer or flower-eater on Boraginaceae (Yen et al. 2009), while some European and American species feed on plants of family Rosaceae (Powell 1973) or family Ranunculaceae (Sattler 1967). In the present paper, we report the sighting of *E. lineatonotella* (Moore, 1867) for the first time from Mendrelgang Village in Tsirang District, Bhutan.

The *E. lineatonotella* moth was recorded during the survey conducted at Mendrelgang Village (26.950^{0}N & 90.113^{0}E), Tsirang District, Bhutan as part of the moth documentation project initiated by the National Biodiversity Centre (NBC), Serbithang, Bhutan on the night of 6 May 2015, at around 20.30h. Two individuals (Image 1 & 2) were attracted to the light trap (4 x 5 m white cloth sheet hanging facing north and south directions) fitted with fluorescent bulbs (Irungbam et al. 2016). The moth was photographed and collected as voucher materials; later the specimens were curated and identified using the keys of the species provided by Robinson et al. (1994) and Kun (2004). The materials are currently stored at Invertebrate Referral Centre, NBC, Thimphu.

DOI: https://doi.org/10.11609/jott.4173.11.14.14899-14901

Editor: M. Monwar Hossain, Jahangirnagar University, Dhaka, Bangladesh. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4173 | Received 30 September 2019 | Finally accepted 24 October 2019

Citation: Irungbam, J.S. & M.J. Irungbam (2019). First record of the micromoth *Ethmia lineatonotella* (Moore, 1867) (Lepidoptera: Depressariidae: Ethmiinae) from Bhutan. *Journal of Threatened Taxa* 11(14): 14899–14901. https://doi.org/10.11609/jott.4173.11.14.14899-14901

Funding: Bhutan Trust Fund for Environment Conservation (BTFEC), Bhutan; National Biodiversity Centre (NBC), Bhutan; Grant Agency, University of South Bohemia (GA JU 038/2019/P), Czech Republic.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are grateful to the unknown reviewer/s who have help us to improve the quality of this article. We also thank the Bhutan Trust Fund for Environmental Conservation (BTFEC), Bhutan, for providing financial assistance for the field visits and equipment; the National Biodiversity Centre (NBC), Bhutan, for coordinating the entire project; the Grant Agency, University of South Bohemia (GA JU 038/2019/P), for partial support during the preparation of the manuscript. Lastly, first author would like to thank Dr. Z.F. Fric, Institute of Entomology, CAS, Czech Republic for his support and encouragement during the preparation of this article.

***Ethmia lineatonotella* (Moore, 1867) (Image 1)**

Hyponomeuta lineatonotella Moore, 1867, Proceedings of Zoological Society London 1867: 669, pl. 33, fig. 18.

Psecadia vitattopunctata Matsumura, 6000, Illustrated insects of the Japanese empire: 831.

Ethmia lineatonotella Sattler, 1967, *Microlepidoptera Palaearctica* 2: 124, pl. 8, 61, 103, fig. 63; Kun & Szabóky, 2000, Acta Zoologica Academiae Scientiarum Hungaricae 46: 55, fig. 2–3, 26, 42; Yen, Wei, & Kun, 2009. Biota Taiwanica, 17, fig. 10.

Specimens examined: BM-208, BM-209, 2 males, 05.v.2015, Bhutan, Tsirang, Mendrelgang Village, Mendrelgang Central School, 26.950^{0}N & 90.113^{0}E, 1,233m, coll. J.S. Irungbam.

Diagnosis: Wingspan with 45mm. Head with filiform antenna, scape with yellow scales, yellowish flagellum, with brown scales distally. Maxillary palp consisting of four segments and yellow in colour and Labial palp yellow in colour with a black ring on medial segment. Frons and vertex yellowish with black scales apically. Thorax yellowish with six black spots; tegulae white with a pair of black spots at base. Forewing longer than abdomen, covered with black marking on yellowish background. Basal part consists of seven spots, four characteristic long striae; two larger spots at outer edge of cell between veins Cu2 and M2. Hindwing with strong costal brushes and yellow cilia; Forelegs and midlegs

Image 1. Wingspan 45mm. An adult of *Ethmia lineatonotella* (Moore, [1868]) recorded from Mendrelgang Village, Tsirang showing the presence of four number of striae on the forewing.

Image 2. An adult of *Ethmia lineatonotella* (Moore, [1868]) recorded from Mendrelgang Village, Tsirang during light trapping on 6 May 2015.

Table 1. The checklist of Genus *Ethmia* reported from the Himalayan region.

	Species	Global distribution
1	*Ethmia ermineella* (Walsingham, 1880)	Northern India, Nepal, Myanmar, Tibet, western China.
2	*Ethmia assamensis* (Butler, 1879)	Bhutan, India, Nepal, China, Sri Lanka, Pakistan.
3	*Ethmia lineatonotella* (Moore, [1868]) *	Bhutan, India, Myanmar, Vietnam, Taiwan.
4	*Ethmia trifida* Kun, 2004	India, Myanmar, Thailand, Malaysia, Borneo, Brunei, Sabah, Brunei, Philippines, Indonesia, Sumatra.
5	*Ethmia nigroapicella* (Saalmüller, 1880)	India, Myanmar, Hawaii, Taiwan, Seychelle Islands, Kei Island, Samoa, Madagascar.
6	*Ethmia szabokyi* Kun, 2001	India, Nepal.
7	*Ethmia lapidella* (Walsingham, 1880)	India, China, Japan, Taiwan.
8	*Ethmia didyma* Kun, 2002	Nepal.
9	*Ethmia acontias* Meyrick, 1906	India, Sri Lanka.
10	*Ethmia hilarella* (Walker, 1863)	Southern India, Sri Lanka, Taiwan.
11	*Ethmia anatiformis* Kun, 2001	Nepal.
12	*Ethmia crocosoma* Meyrick, 1914	India, Nepal
13	*Ethmia pingxiangensis* Liu, 1980	Northeastern India, Myanmar, Thailand.

faint yellow with clack rings; and orange coloured abdomen. Tarsus black with light tip. Hindleg orange; abdomen similarly orange-coloured. Unfortunately, the genitalia had been destroyed due to a fungal infection and so we could not examine the genitals.

Ethmia lineatonotella can be easily distinguished from other similar species group by the presence of four striae on the forewing (Image 1) whereas *E. trifida* has three, *E. palawana* has only one while they are reduced to a single dot in *E. thomaswitti* and is lacking in *E. galactarcha* (Kun 2004). Sattler (1967) placed *E. lineatonotella* in the *E. assamensis* species group which consist of five species. Later, Kun (2004) transferred *E. lineatonotella* to *E. lineatonotella* species group which contains five species (*E. lineatonotella* Moore, 1867; *E. galactarcha* Meyrick, 1928; *E. palawana* Schultze, 1925; *E. trifida* Kun, 2004; *E. thomaswitti* Kun, 2004). *E. lineatonotella* is distributed through India (Darjeeling, Assam), Myanmar, Vietnam, and Taiwan (Kun & Szabóky 2000). Geilis & Wangdi (2017) who have surveyed moths in different localities of Bhutan also have not recorded *E. lineatonotella*. The present record of the species from Mendrelgang village, Tsirang District is a new record for Bhutan.

References

Geilis, C. & K. Wangdi (2017). *A Field Guide to the Common Moths of Bhutan*. National Biodiversity Centre (NBC), 100pp.

Irungbam, J.S., M.S. Chib & K. Wangdi (2016). Taxonomic review of the superfamily Pyraloidea in Bhutan (Lepidoptera). *Journal of Asia-Pacific Biodiversity* 9(3): 355–382.

Kun, A. (2004). A review of the *Ethmia lineatonotella* species group, with description of new Indonesian species (Lepidoptera, Elachistidae). *Acta Zoologica Academiae Scientiarum Hungaricae.* 50(4): 53–78.

Kun, A. & C. Szabóky (2000). Survey of the Taiwanese Ethmiinae (Lepidoptera, Oecophoridae) with descriptions of three new species. *Acta Zoologica Academiae Scientiarum Hungaricae,* 46: 53–78.

Nielsen, E.S., E.D. Edwards & T.V. Rangsi (eds.) (1996). Checklist of the Lepidoptera of Australia. *Monographs on Australian Lepidoptera* 4: XIV+529 pp.

Powell, J.A. (1973). A systematic monograph of new world Ethmiid moths (Lepidoptera, Gelechioidea). *Smithsonian Contributions to Zoology* 120: 1–302.

Robinson, G.S., K.R. Tuck & M. Shäffer (1994). *Smaller moths of South-East Asia.* London: The Natural History Museum, 309pp.+32pls.

Sattler, K. (1967). *Ethmiidae.* In: Amsel, H.G., F. Gregor & H. Reisser (eds.). *Microlepidoptera Palaearctica. Volume 2*. Wien: Verlag Georg Fromme & Co., 185pp+106pls.

Savela, M. (2018). Lepidoptera and some other life forms. http://ftp.funet.fi/index/Tree_of_life/insecta/lepidoptera/ditrysia/gelechioidea/depressariidae/ethmiinae/ethmia/. Accessed on 31 March 2018.

Yen, S-H., C-H. Wei & A. Kun (2009). *Biota Taiwanica. Hexapoda: Lepidoptera, Elachistidae - Ethmiinae.* National Sun Yat-Sen University & National Science Council, 55pp+11pls.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14902–14905

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

PLATINUM
OPEN ACCESS

Additional distribution records of the rare Nepal Comma *Polygonia c-album agnicula* (Moore, 1872) (Insecta: Lepidoptera: Nymphalidae) from Rara National Park, Nepal

Sanej Prasad Suwal [1], Biraj Shrestha [2], Binita Pandey [3], Bibek Shrestha [4], Prithivi Lal Nepali [5], Kaashi Chandra Rokaya [6] & Bimal Raj Shrestha [7]

[1] Butterfly Watchers Nepal, Byasi, Bhaktapur, Nepal.
[2] Coastal Science and Policy, University of California, Santa Cruz, 115 McAllister Way, California 95060, USA.
[3] Wildlife Biologist, USAID Pani Program, Resources Himalaya Foundation, Sanepa, Lalitpur, Nepal.
[4] Ranger, Non Gazetted 1st class, Rara National Park, Hutu, Mugu, Nepal.
[5] Non Gazetted Officer, 2nd class, Rara National Park, Hutu, Mugu, Nepal.
[6] Local guide, Rara Village, Mugu, Nepal.
[7] Research Director, Biodiversity Research and Conservation Society, Kathmandu, Nepal.
[1] sanej100@gmail.com (corresponding author), [2] bshrest1@ucsc.edu, [3] binita.p862@gmail.com, [4] shtbvek@gmail.com, [5] prithivilalnepali@gmail.com, [6] kaashichandra@gmail.com, [7] rajsthbimal9@gmail.com

Various geographical subspecies of the Comma butterfly, *Polygonia c-album* (Linnaeus, 1758) are distributed across Europe and Asia, reaching as far as Japan in Asia and south to Morocco (Gogoi et al. 2015). *P. c-album* is a medium-sized butterfly with wingspan of 45–50 mm and having a central silver dash or comma underside (Evans 1932) hence the name. It belongs to the family Nymphalidae. There are three subspecies of *Polygonia c-album*, namely, *P.c. kashmira* (Evans, 1932) distributed in Kashmir, Ladakh; *P.c. cognata* (Moore, 1899), distributed in northwestern Himalaya; and *P.c. agnicula* (Moore, 1872) distributed in Nepal–Bhutan (Kehimkar 2008), and Arunachal Pradesh (Gogoi et al 2015). *P.c. agnicula* is unique from other subspecies since it is uniformly fulvous red above with narrower markings with no ashy wing margins, submarginal area with red band, bordered along its inner margin by a broken dark brown post discal band (Evans 1932). The subspecies is considered to be rare in contrast to other two subspecies in Indian region (Evans 1932; Smith 1989) and uncommon locally in Bhutan (Poel &Wangchuk 2007) but still could be rare.

P.c. agnicula was first discovered in Nepal by Maj. Gen. G. Ramsey (Smith 1990). It is distributed from central to western region of the country with sighting only from five different sites including Karnali (29.386^{0}N, 82.388^{0}E, 4,314m) (Smith 1980) Manang (28.551^{0}N, 84.237^{0}E, 2,746m) (Smith 1980; Poel 2012; B.R. Shrestha pers. obs. 2018), Rasuwa (28.206^{0}N, 85.568^{0}E, 1,810m) (Poel 2017), Humla (29.966^{0}N, 81.833^{0}E) (M.S. Limbu pers. comm. 2017, N. Kusi pers. obs. 2014), and Ghurchi lek, Mugu (29.466^{0}N, 82.136^{0}E, 3,515m) (N. Kusi pers. obs. 2014).

Rara National Park (RNP) (29.511^{0}N, 82.05^{0}E) is the smallest national park of Nepal covering an area

DOI: https://doi.org/10.11609/jott.4899.11.14.14902-14905

Editor: Monsoon J. Gogoi, Bombay Natural History Society, Mumbai, India. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4899 | Received 16 February 2019 | Final received 04 November 2019 | Finally accepted 10 November 2019

Citation: SUWAL, S.P., B. Shrestha, B. Pandey, B. Shrestha, P.L. Nepali, K.C. Rokaya & B.R. Shrestha (2019). Additional distribution records of the rare Nepal Comma *Polygonia c-album agnicula* (Moore, 1872) (Insecta: Lepidoptera: Nymphalidae) from Rara National Park, Nepal. *Journal of Threatened Taxa* 11(14): 14902–14905. https://doi.org/10.11609/jott.4899.11.14.14902-14905

Funding: The Rufford Foundation; The Mohamed bin Zayed Species Conservation Fund.

Competing interests: The authors declare no competing interests.

Acknowledgements: We would like to thank the Department of National Parks and Wildlife Conservation, Babarmahal, Kathmandu, Nepal and Rara National Park, Hutu, Mugu, Nepal for granting research permission. We thank prof. Dr. Bhaiya Khanal, Mr. Mahendra Singh Limbu and Mr. Peter Smetachek for the species identification and providing valuable information. Our sincere gratitude goes to the Rufford Foundation, UK and Mohamad bin Zayed Species Conservation Fund for providing financial support. Special thanks go to Mr. Naresh Kusi providing valuable information from Humla & RNP and Mr. Suman Prajapati for assisting us during map preparation and printing. Last but not least, we are truly grateful to Mr. Nanda Singh Rokaya, Mr. Prem Karki, and Mr. Deepak Rawat for their support during the field study.

Figure 1. Observation locations of Nepal Comma *Polygonium c-album* agnicula during 2017-2018.

Figure 2. Observation locations of Nepal comma, *Polygonia c-album agnicula* in Rara National Park, Nepal.

of 106km^2. The park is extended in Mugu and Jumla districts and ranges from 2,800m to 4,039m in elevation. RNP has pleasant warm summers and very cold winters. The park includes 170 species of floral diversity mainly dominated by *Rhododendron arboretum, Pinus excelsa*, fir, spruce and pine. Faunal diversity of RNP includes 241 species of birds, two species of reptiles and amphibia, and three species of fish (Bhuju et al. 2007).

We conducted the research in RNP during monsoon (June–Sept, 2017) and post-monsoon season (Oct–Nov, 2018). The Comma *Polygonia c-album* species was recorded while through trail transects of 100m length and photographed using DSLR camera (Nikon D500). We followed the guidebook by Smith (1989) and Evans (1927) and consulted experts in Nepal and India to confirm our identification. The species is characterized by F dorsum straight, H termen not produced to the same extent, tooth at v2 projects as far as the tornus; apex not or only

Table 1. Observation location of Nepal Comma *Polygonium c-album agnicula* at Rara National Park 2017/2018.

	Date	Time (h)	North	East	Elevation (m)	Frequency (no.)	Remarks
1	19.x.2017	11.00	29.538	082.076	2983	1	Trail, forest, and shrub land near lake outlet.
2	22.x.2017	15.00	29.529	082.062	2977	1	Trail and forest near lake outlet.
3	14.ix.2018	09.24	29.532	82.069	2977	3	Forest trail near lake.
4	14.ix.2018	13.05	29.516	82.081	2984	1	Grassland near lake.
5	15. ix.2018	13.30	29.481	82.085	3837	2	Ridgeline, grassland, and forest.
6	15. ix.2018	14.23	29.479	82.086	3875	1	Ridgeline, grassland, and forest.
7	15. ix.2018	14.41	29.477	82.088	3947	1	Ridgeline, grassland, and forest.

Image 1. Nepal Comma *Polygonium c-album agnicula* 20 October 2017.

slightly truncate (Evans 1927). We captured *P.c. agnicula* using insect net, handled carefully, photographed, and released. No samples were collected.

We present seven observations of the comma butterfly from 2017 to 2018 (Table 1). The first two observations of *P.c. agnicula* were recorded by authors (Sanej Prasad Suwal, Biraj Shrestha and Binita Pandey) in RNP during their first visit in October 2017 (Table 1). The *agnicula* species were basking on forest trail near the western outlet of Rara Lake and the remaining five observations were in June–Oct 2018 (Table 1). During the first two observations it was seen feeding on nectars of *Aster* sp., and *Anaphali* sp. while during the remaining observations, it was seen basking on the Chuchemara ridgeline trail, south-east of RNP where the habitat comprised of grass lands dominated by *Anaphali* sp. and Rhododendron forest (Image 3).

Studies on butterflies are scant in the western part of Nepal. A list of butterflies from western region of the country by Smith (1980) and Khanal (1999) does not mention *P.c. agnicula* from RNP and adjoining areas. Our sightings in RNP thus represents new distribution locality of the subspecies for Nepal obtained about 54.17km south-east from Humla, 371.18km north-west from Rasuwa, 213.24km north-east from Manang, 35.34km north-west from Karnali, and 7.52km north-west from Ghurchi lek, Mugu.

The butterfly photographed (Images 1 & 2) has more uniform fulvous above with narrower markings in comparison with the other three subspecies. The wing margins above are not as ashy as in the other subspecies, and on the upperside of the hindwing there

Image 2. Nepal Comma *Polygonium c-album agnicula* 19 October 2017.

Image 3. Habitat of Nepal Comma *Polygonium c-album agnicula* 14 September 2018.

are no yellow spots in the submarginal area. Instead, the submarginal area is represented by a red band, bordered along its inner margin by a broken dark brown postdiscal band (Evans 1932). Along with this there are clear white coloured comma markings on the outer side of hindwing (Evans 1932). All the features mentioned above identify the butterfly as *P.c. agnicula*.

There has been study on butterflies of RNP with a list of 64 species (Bhandari & Gea 2007). Butterflies like Nepal Meadow Blue *Polyommatus nepalensis*, Dusky Hedge Blue *Oreolyce vardhana*, Eastern Blue Sapphire *Heliophorus oda*, and Yellow Wood Brown *Zophoessa nicetas* can be observed in the park area. The subspecies *P.c. agnicula*, however, was not recorded. It appears that the subspecies is fairly distributed from central to western Nepal. Studies from the missing districts along the distribution range Rasuwa to Humla will be crucial in ascertaining the actual distribution status of this subspecies in Nepal.

References

Bhandari, B.B. & J.J. Gea (2007). *Himalayan Wetlands: Risk, Challenges and Opportunities*. Ramsar Wetlands Center Korea, Changwon, 125pp.

Bhuju, U.R., P.R. Shakya, T.B. Basnet & S. Shrestha (2007). Nepal Biodiversity Resource Book. Protected Areas, Ramsar Sites, and World Heritage Sites. International Centre for Integrated Mountain Development, Ministry of Environment, Science and Technology, in cooperation with United Nations Environment Programme, Regional Office for Asia and the Pacific, Kathmandu.

Evans, W.H. (1927). *The Identification of Indian Butterflies*. Bombay Natural History Society, Bombay, 116pp.

Evans, W.H. (1932). *The Identification of Indian Butterflies – 2nd Edition*. Bombay Natural History Society, Bombay, x+454pp+32pl.

Gogoi, M.J., B.B. Bhatt & A. Sarmah (2015). Notes on the Eastern Comma *Polygonia c-album agnicula* Moore, 1872 (Lepidoptera: Nymphalidae: Nymphalinae) from Tawang District, Arunachal Pradesh, India. *Journal of Threatened Taxa* 7(11): 7836–7838. https://doi.org/10.11609/JoTT.o3775.7836-8

Khanal, B. (1999). Checklist of butterflies from Kanchanpur and Kailali districts far-west Nepal. *Journal of Natural History Museum* 18: 61–69.

Kehimkar, I. (2008). *The Book of Indian Butterflies.* Bombay Natural History Society and Oxford University Press, New Delhi, xvi+497pp.

Poel, P.V.d. (2017). http://www.ifoundbutterflies.org/sp/1119/Polygonia-c-album. (accessed in Jan 2019).

Poel, P.V.d. (2012). http://www.ifoundbutterflies.org/sp/1119/Polygonia-c-album. (accessed in Jan 2019).

Poel, P.V.d. & T. Wangchuk (2007). *Butterflies of Bhutan. Mountains, Hills and Valleys Between 800 and 3000m*. Royal Society for Protection of Nature (RSPN), Thimpu, 71pp.

Smith, C. (1977). Some butterflies of western Nepal. *Journal of Natural History Museum* 1: 143–150.

Smith, C. (1980). Some butterflies of western Nepal Part II Pre and Post-Monsoon Butterflies. *Journal of Natural History Museum* 4(2): 41–53.

Smith, C. (1989). *Butterflies of Nepal (Central Himalayas)*. Craftman Press, Bangkok, 352pp.

Smith, C. (1990). *Beautiful Butterflies. A Colourful Introduction to Nepal's most Beautiful Insects*. Craftsman Press, Bangkok, 7pp.

Smith, C. (2011). *A Photographic Pocket Guide to Butterflies of Nepal*. Himalayan Map House, Basantapur, Kathmandu, Nepal.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14906–14907

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

PLATINUM
OPEN ACCESS

A new distribution record of the gall midge *Octodiplosis bispina* Sharma (Diptera: Cecidomyiidae) from the Western Ghats of Tamil Nadu, India

Duraikannu Vasanthakumar [1], Radheshyam Murlidhar Sharma [2] & Palanisamy Senthilkumar [3]

[1,2] Zoological Survey of India, Western Regional Centre, Akurdi, Pune, Maharashtra 411044, India.
[3] Department of Genetic Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamilnadu 603203, India.
[1] duraivasanthakumar@gmail.com (corresponding author), [2] rmsharma53@yahoo.in, [3] mpsenthilkumar@gmail.com

Gall midges are small, inconspicuous flies, but they may be very important in both forest and agro ecosystems. The body of the adult gall midges generally varies from 0.5–3 mm in length but occasionally may be as long as 8mm or less than 0.5mm. They usually have long antennae. The wing veins are reduced in number with only three or four veins normally present. Tibial spurs are absent. The larvae vary somewhat in their habits but most species are either phytophagous, producing galls on various plants, mycophagous, feeding on fungi, or zoophagous, feeding on invertebrates, especially insects (Skuhrava et al. 1984). While identifying the collections of gall midges of Tamil Nadu State, we came across a gall midge species identified as *Octodiplosis bispina* Sharma, 1987. Perusal of published works on the gall midges of Tamil Nadu and the Western Ghats (Sharma 2009) revealed that this species has not been reported from these areas earlier and hence the present collection forms a new distribution records (Figure 1). The adults were dissected and mounted on microscope slides in Canada balsam and the specimens were deposited in the National Zoological Collection of WRC, Zoological Survey of India, Entomology Section, Pune, India.

Material examined: Ent 10/179, 2 males, 17.i.2018, collected at light, near Maruthamalai, Coimbatore, Tamil Nadu, coll. D. Vasanthakumar. Ent 10/214, 2 males, 23.v.2018, collected at light, near Courtallam, Tirunelveli District, Tamil Nadu, coll. P. Senthilkumar.

Distribution: Aurangabad (Maharashtra), the Andaman Islands, and Tamil Nadu (this study).

Diagnostic Characters: Palpi quadriarticulate. Antenna with 2+12 segments, the flagellate antennal segments binodose in male (Image 1A), with long apical stems, enlargements with two whorls of long setae, one on each enlargement, with three whorls of regular circumfila, one on basal and two on apical enlargements; middle whorl shortest; wing, narrow, three times as long as broad (Image 1B); vein R_1 joining costa a little before the basal ¼ of the wing; vein Rs present, vein R5 reaching wing margin well beyond the apex and interrupting costa at its union, vein Cu forked. Claw, simple on all legs, curved, empodium rudimentary. Genitalia (Image 1C), Gonocoxite, with a median bilobed obtuse lobe, length 2.33 x its maximum thickness; gonostylus slender, curved, gradually tapering towards the tip, ending in tooth. Dorsal plate deeply bilobed, lobes triangular, rounded apically, narrowed medially, aedeagus slender, narrowed medially with a pair of strong, lateral upwardly or downwardly directed spines beyond middle, tip capitate (Sharma 1987).

DOI: https://doi.org/10.11609/jott.4317.11.14.14906-14907

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

Manuscript details: #4317 | Received 06 June 2018 | Final received 05 July 2019 | Finally accepted 19 October 2019

Citation: Vasanthakumar, D., R.M. Sharma & P. Senthilkumar (2019). A new distribution record of the gall midge *Octodiplosis bispina* Sharma (Diptera: Cecidomyiidae) from the Western Ghats of Tamil Nadu, India. *Journal of Threatened Taxa* 11(14): 14906–14907. https://doi.org/10.11609/jott.4317.11.14.14906-14907

Funding: None.

Competing interests: The author declares no competing interests.

Acknowledgements: Authors are grateful to the Director, Zoological Survey of India, Kolkata for providing the necessary facilities. Thanks are also due to the staff of the Western Regional Centre, ZSI, Pune, for their constant encouragement.

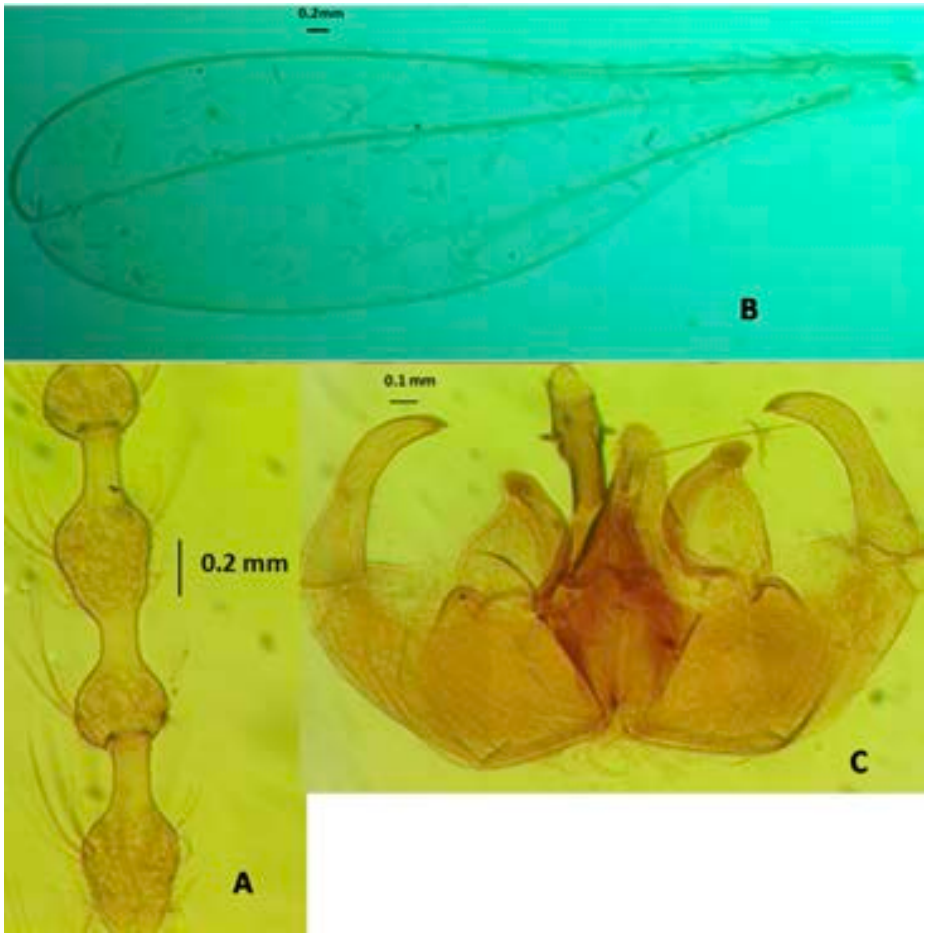

Image 1. *Octodiplosis bispina*: A—antennae | B—wing | C—genitalia.
© D. Vasanthakumar.

Figure 1. Locality records of *Octodiplosis bispina* Sharma.

References

Skuhrava, M., V. Skuhravy & J.W. Brewer (1984). Biology of Gall midges, pp. 169–222. In: Ananthakrishnan, T.N. (ed.). *Biology of Gall Insects*. Oxford & IBH Publishing Co. India, 362pp.

Sharma, R.M. (1987). On a new species of genus *Octodiplosis* Giard (Diptera: Cecidomyiidae) from India. *Geobios new reports* 6: 2–4.

Sharma, R.M. (2009). Insecta: Diptera: Cecidomyiidae. Zoological Survey of India, Fauna of Tamil Nadu, State Fauna Series 17: 111–113.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14908–14911

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

PLATINUM OPEN ACCESS

New recruitment of staghorn corals in the Gulf of Mannar – the emergence of a resilient coral reef

Koushik Sadhukhan [1], Ramesh Chatragadda [2], T. Shanmugaraj [3] & M.V. Ramana Murthy [4]

[1,2,3] National Centre for Coastal Research (NCCR), NCCR Field Office, Mandapam Camp, Ramanathapuram, Tamil Nadu 623519, India.
[4] National Centre for Coastal Research (NCCR), Ministry of Earth Sciences (MoES), Pallikaranai, Chennai, Tamil Nadu 600100, India.
[1] sadhukhan.1985@gmail.com (corresponding author), [2] chrameshpu@gmail.com, [3] raj@nccr.gov.in, [4] mvr@nccr.gov.in

Coral reefs in the Gulf of Mannar (GoM) have faced severe disturbances from the ever increasing human pressure which resulted in the rapid decline of marine biodiversity and biomass of the coastal ecosystems over the past few decades. Despite severe climatic and non-climatic stresses, scleractinian coral *Acropora* sp. in GoM exhibits new recruitment of coral colonies in recent times. The genus *Acropora* is commonly called staghorn corals for the antler like colony form (Johnson et al. 2011). Bleaching susceptibility among coral taxa depends on the resistance capacity of corals to subsequent bleaching episodes and broad geographic ranges, and staghorn corals are thought to be one of the most vulnerable species in scleractinian family (IUCN 2009). *Acropora* sp. and other corals reproduce both sexually and asexually and both are important to restore a degraded reef area (Zayasu et al. 2018). *Acropora* corals can grow fast by asexual reproduction method called fragmentation, which leads to the swift recovery of the degraded reef system. They contribute significantly to the reef growth (5.23cm^2/month) and form dense colonies which supports in island formation, coastal protection and fisheries (Bruckner 2002; Johnson et al. 2011). GoM Marine National Park has fringing type coral reefs which are distributed in 21 offshore islands ranging in between Rameswaram and Tuticorin (ENVIS 2015). During the 1998 coral bleaching event, shallow water coral reefs of GoM faced a severe mortality of 75% leading to a significant reduction in the live coral cover especially of *Acropora* spp. (Venkataraman 2000; Kumaraguru et al. 2003). Post bleaching assessment stated that recovery was too slow and live coral coverage increased to 36.98% during 2003–2005 (Edward et al. 2018). Thereafter, during 2009, live coral coverage was further increased to 42.85%. But coral bleaching in 2010 resulted in mass mortality of corals in GoM that reduce the coral cover upto 33.20% and in 2011, coral again started recovering and percentage of live coral cover increased to 38.86% (Edward et al. 2012). It was indicated that the recovery potential of a reef primarily depends on the successful sexual reproduction followed by coral recruitment and survival of the coral larvae (Vermeij et al. 2009). Therefore, an occurrence of new recruitment of corals brings back the reef to its previous state and maintains a healthy reef ecosystem. This study mainly describes the in situ observation on new recruitment of staghorn corals at selected sites of the GoM and also indicates possible resilient factors linked to this new recruitment.

The National Centre for Coastal Research (NCCR) team

DOI: https://doi.org/10.11609/jott.4767.11.14.14908-14911

Editor: M. Nithyanandan, Kuwait Institute for Scientific Research (KISR), Salmiya, Kuwait. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4767 | Received 16 December 2018 | Final received 31 July 2019 | Finally accepted 01 October 2019

Citation: Sadhukhan, K., R. Chatragadda, T. Shanmugaraj & M.V.R. Murthy (2019). New recruitment of staghorn corals in the Gulf of Mannar – the emergence of a resilient coral reef. *Journal of Threatened Taxa* 11(14): 14908–14911. https://doi.org/10.11609/jott.4767.11.14.14908-14911

Funding: Ministry of Earth Sciences (MoES), Government of India; National Centre for Coastal Research (NCCR).

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors thank the secretary, Ministry of Earth Sciences (MoES), Government of India and Director, NCCR, MoES, Government of India for the financial support and facilities. We are thankful to the field assistants for the field support.

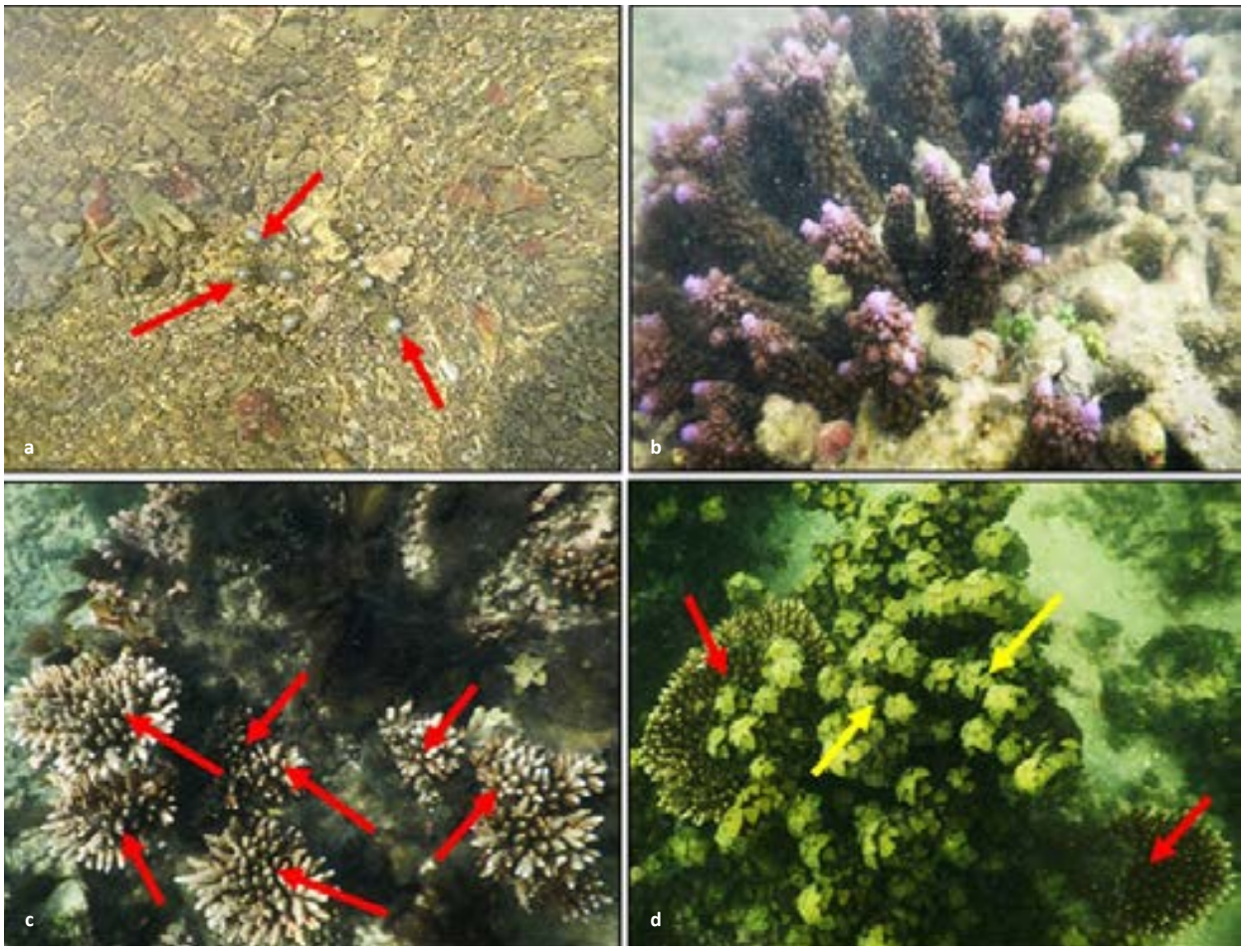

Image 1. a—*Acropora* colony (Size 0.5–2 cm) growing on undisturbed substratum at Hare Island | b—recruitment density (12–20 colonies/m^2) in Manoli & Manoliputti Island | c—newly recruited healthy coral colony (1.3–15.5 cm) on Hare Island | d—growth of native algal species *Turbinaria* sp. (Yellow arrow) with *Acropora digitifera* (red arrow) colony. © NCCR, Mandapam Field Office.

carried out several underwater surveys in Hare Island, and Manoli & Manoliputti islands of the Mandapam group, GoM from August 2018 to October 2018. Newly recruited corals distributed in different sites were marked with GPS location (Hare Island northern side: 09.206^{0}N, 79.084^{0}E; Hare Island southern side: 09.190^{0}N, 79.075^{0}E; Manoli & Manoliputti northern side: 09.219^{0}N, 79.134^{0}E; Manoli & Manoliputti southeastern side: 09.206^{0}N, 79.140^{0}E) and also photographed. Line intercept transect and quadrat sampling methods (English et al. 1997) were performed at the new recruitment sites. For detailed assessment, a 20-meter long flexible underwater tape was laid on selected reef areas, roughly parallel to shoreline with three replicates at each site and covering an area 20m × 2m (1m on each side of the transect line) for each transect. A total of four sites were selected and 12 transects and 36 quadrats (1m × 1m) were employed to estimate the live coral cover and recruitment density.

Recruitment of *Acropora* sp. was encountered at northern and southern sides of Hare Island, northern and southeastern sides of Manoli & Manoliputti Islands. The recruitment of different growth forms of *Acropora* such as *Acropora* branching (ACB), *Acropora* tabular (ACT), and *Acropora* digitate (ACD) were found on the dead *Acropora* branches and coral rubbles. The southern side of Hare Island, has several dead patches of coral comprising *Acropora* rubbles, and dead colonies of massive and submassive corals with algal growth. In Manoli & Manoliputti, many dead patches of massive corals were encountered and heavy sedimentation was also observed. Among the staghorn coral species, *Acropora formosa* and *Acropora hyacynthus* represented the maximum recruitment at both the study sites. The average coral cover of Hare Island and Manoli & Manoliputti Island was 58.4% and 51.5% of which *Acropora* sp. represented live coverage of 48.1% and 15.6%, respectively (Figure 1). The size of each individual coral colony ranges from 0.9 to 8.2 cm.

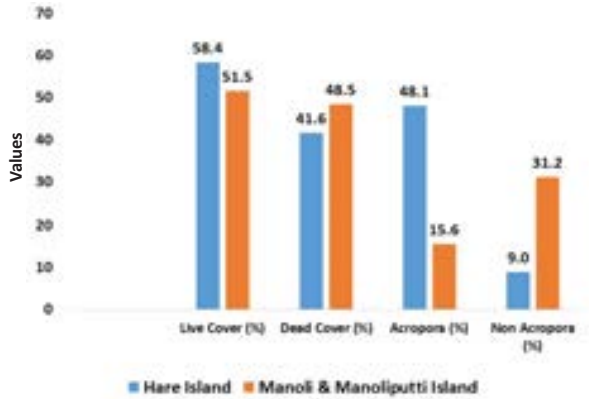

Figure 1. Average live coral coverage of Hare and Manoli & Manoliputti Islands.

Tropical reefs are increasingly impacted by multiple stressors that result in landscape loss of coral cover primarily due to adult coral mortality, aborted reproduction effort as well as unsuccessful recruitment at the disturbed habitat (Connell 1997; Graham et al. 2015). Reef resilience can protect these disturbances either by resisting change or by rapidly recovering to their pre-disturbed state (Holbrook et al. 2018). Reefs in GoM were challenged by intensive coral mining during the 1980s before the Indian Ocean tsunami event, which might have resulted in the destruction of *Acropora* sp. forming rubbles in the benthic substrate. After the Tsunami, the coral mining was completely stopped in GoM (Edward et al. 2008). We observed many new *Acropora* colonies (0.5–2 cm) on Hare Island coming up on largely undisturbed dead corals and rubbles (Image 1a). The percentage cover of live coral in Mandapam group of GoM has also significantly increased from the earlier report of 22.69% in 2016 (Edward et al. 2018) to 58.6% in the present study (Figure 1). We don't have a direct observation on coral spawning and larval settlement, but the emergence of new coral communities following disturbances indicates a function of multiple processes including coral recruitment, growth and survival of new recruits. As per the earlier report, the coral spawning of *Acropora* sp. mainly happened here during March every year (Raj & Edward 2010). Earlier studies also revealed that recruitment to reef habitats is dependent on the ability of juveniles to find a suitable substratum to settle and metamorphose (Graham et al. 2011). The reef structure of Manoli & Manoliputti is mainly made of rubbles and dead massive coral with algal growth. But on the southeastern side of Manoliputti Island we observed a significant density (12–20 colonies/m^2) of new recruits of *Acropora formosa* (Image 1b). The northern side of the Hare Island has a major settlement of *Acropora formosa*, *A.humilis* and *A.digitifera* whose colonies range 1.3–15.5 cm (Image 1c).

In degraded reefs, many negative driving forces also result in the mortality of post larval settlement of corals (Harrington et al. 2004). The major threat to successful coral recruitment is the excessive growth of algae on which coral planula may have settled, but later suffered severe mortality (Vermeij et al. 2009). In our observation, we have noticed that new recruits have high competition against the growth of native algal species *Turbinaria* sp. and *Caulerpa* sp. on the reef substrate (Image 1d). An earlier study also reported that GoM has faced heavy sedimentation ranging from 1.97 mg/cm2/day to 12.31 mg/cm2/day that was found to be the highest during the month of August and lowest during the month of April (Mathews & Edward 2006; Kumar et al. 2014). Despite high sediment deposition at the northern side and southeastern side of Manoli & Manoliputti Island, we have observed that the new recruitment of corals in this region is high. Staghorn corals play an important role in reef formation but are easily susceptible to environmental and anthropogenic stress (Johnson et al. 2011). The density of coral recruits is on the rise in Gulf of Mannar. The average density of coral recruits in GoM has increased from 4.1/m^2 in 2003–2005 to 7.7/m^2 in 2011 (Edward et al. 2012). In the present study, recruitment density was found to be the highest on the southeastern side of Manoli & Manoliputti Island with 12–20 colonies/m^2. Observation on the coral reproduction in GoM is rare, but studies using the experimental set up were carried out to assess the recruitment rate of coral spats in Krusadai Reef complex (Raj et al. 2014; Marimuthu et al. 2018). Coral recruitment is one of the indicators of coral reef health in marine protected areas, and also provide a positive sign of coral reef recovery of a degraded ecosystem (Acosta et al. 2011). The findings reported here suggest that increased percentage of coral cover brings a new hope for the researcher to find out the possible driving forces for the successful post larval settlement and survival of new recruits, which results in better conservation and management plan for the coral reefs of GoM Marine National Park. Therefore, NCCR initiated long term monitoring plan of the selected reef areas to assess the growth and survivability of newly recruited corals and investigate factors for reef resilience.

References

Acosta, A., L.F. Duenas & V. Pizarro (2011). Review on Hard Coral recruitment (Cnidaria: Scleractinia) in Colombia. *Universitas scientiarum* 16(3): 200–218.

Bruckner, A.W (2002). Proceedings of the Caribbean Acropora Workshop: Potential application of the U.S. Endangered Species Act as a conservation strategy. NOAA Technical Memorandum NMFS-OPR-24, Silver Spring, MD.s, 199pp.

Connell, J.H. (1997). Disturbance and recovery of coral assemblages. *Coral Reefs* 16: S101–S113. https://doi.org/10.1007/s003380050246

Edward, J.K.P., G. Mathews, J. Patterson, R. Ramkumar, D. Wilhelmsson, J. Tamelander & O. Linden (2008). Status of coral reefs of the Gulf of Mannar, southeastern India. Coral Reef Degradation in the Indian Ocean Status (CORDIO) - Status Report, 45–55pp.

Edward, J.K.P., G. Mathews, K.D. Raj, T. Thinesh, J. Patterson, J. Tamelander & D. Wilhelmsson (2012). Coral reefs of Gulf of Mannar, India – Signs of Resilience. Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia – 18F_3. http://www.icrs2012.com/proceedings/manuscripts/ICRS2012_18F_3.pdf

Edward, J.K.P., G. Mathwes, D. Raj, R.L. Laju, M.S. Bharath, A. Arasamuthu, P.D. Kumar, D.S. Bilgi & H. Malleshappa (2018). Coral mortalty in Gulf of Mannar, southeastern India, due to bleaching caused by elevated sea temperature in 2016. *Current Science* 114(9): 1967–1972.

English, S., C. Wilkinson & V. Baker (1997). *Survey Manual for Tropical Marine resource*. Australian Institute of Marine Sciences, Townsville, Australia, 390pp.

ENVIS (2015). *Database on Gulf of Mannar Biosphere Reserve*. Department of Environment and Forest, Government of Tamilnadu, 74pp.

Graham, N.A.J., K.L. Nash & J.T. Kool (2011). Coral reef recovery dynamics in a changing world. *Coral Reefs* 30: 283–294. https://doi.org/10.1007/s00338-010-0717-z

Graham, N.A.J., S. Jennings, M.A. MacNeil, D. Mouillot & S.K. Wilson (2015). Predicting climate-driven regime shifts versus rebound potential in coral reefs. *Nature* 518: 94–97. https://doi.org/10.1038/nature14140

Harrington, L., K. Fabricius, G.D. Ath & A. Negri (2004). Recognition and Selection of Settlement substrata determine post settlement survival in corals. *Ecology* 85(12): 3428–3437. https://doi.org/10.1890/04-0298

Holbrook, S.J., T.C. Adam, P.J. Edmunds, R.J. Schmitt, R.C. Carpenter, A.J. Brooks, H.S. Lenihan & C.J. Briggs (2018). Recruitment Drives Spatial Variation in reef Recovery Rates of resilient Coral Reefs. *Scientific reports* 8(1): 7338–7348. https://doi.org/10.1038/s41598-018-25414-8

IUCN (2009). Staghorn Corals and Climate Change. Better to burn out than to pHade away. Available online https://cmsdata.iucn.org/downloads/fact_sheet_red_list_staghorn_corals.pdf

Johnson, M.E., D.S. Gilliam, M.W. Millar, C. Lustic, L. Larson, K. Nedimyer, E. Bartels, I.B. Baums, D. Lirman & S. Schopmeyer (2011). *Carribean Acropora – Restoration Guide*: Best Practice for propagation and population enhancement, 64pp.

Kumaraguru, A.K., K. Jayakumar & C.M. Ramakritinan (2003). Coral bleaching 2002 in the Palk Bay, Southeast coast of India. *Current Science* 85: 1787–1793.

Kumar, J.S.Y., S. Geetha & R. Sornaraj (2014). Seasonal Changes of Sedimentation Rates and Sediment Characteristics Status in the Gulf of Mannar Coral Island, India. *International Letters of Natural Sciences* 6: 8–24. https://doi:10.18052/www.scipress.com/ILNS.6.8

Mathews G. & J.K.P. Edward (2006). Effect of sedimentation and pollution in the reefs of Thoothukudi coast of Gulf of Mannar, southeast coast of India, pp. 837–841. In: Proceedings of 10th International Coral Reef Symposium, Okinawa, Japan.

Marimuthu, N., P. Ramchandran, M. Sathish, N. Dinesh & R. Ramesh (2018). Recruitment pattern of Scleractinian coral spats on neighbouring artificial substrates at Kurusadai Reef Complex, Gulf of Mannar, India. *Aquatic Ecosystem Health & Management* 22(1): 77–85. https://doi.org/10.1080/14634988.2018.1435941

Raj, K.D. & J.K.P. Edward (2010). Observations on the reproduction of Acropora corals along the Tuticorin coast of the Gulf of Mannar, southeastern India. *Indian Journal of Geo-Marine Science* 39(2): 219–226.

Raj, K.D., K. Mathews & J.K.P. Edward (2014). Sexual reproduction of hard corals in Gulf of Mannar – A sign of reef recovery. In: Proceedings of the 3rd Indian Biodiversity congress, Chennai, Perspectives on Biodiversity of India 2(1): 100–107.

Venkataraman, K. (2000). Status of coral reefs of Gulf of Mannar, India. Proceedings of the 9th International Coral Reef Symposium, October 23-27, 2000, Bali, Indonesia.

Vermeij, M.K.J., J.E. Smith, C.M. Smith, R.V. Thurver & S.A. Sandin (2009). Survival and settlement success of coral planulae: independent and synergistic effects of macroalgae and microbes. *Oecologia* 159: 325–336. https://doi.org/10.1007/s00442-008-1223-7

Zayasu, Y., N. Satoh & C. Shinzato (2018). Genetic diversity of farmed and wild populations of the reef building coral, *Acropora tenuis*. *Restoration Ecology* 26(6): 1195–1202. https://doi.org/10.1111/rec.12687

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14912–14913

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

PLATINUM OPEN ACCESS

New records of coral diseases in the Persian Gulf

Parviz Tavakoli-Kolour [1] & Sanaz Hazraty-Kari [2]

[1,2] Graduate School of Engineering and Science, University of the Ryukyus, Okinawa, Japan.
[1] p.tavakoli@hotmail.com (corresponding author),
[2] s.hazrati@hotmail.com

Coral diseases as one of the most important stressor degrading global coral reefs including those in the Persian Gulf where there is little information on coral diseases (Riegl et al. 2012); however, in recent years more known and unidentified diseases have been recorded especially from the northern Persian Gulf including Larak, Qeshm, Hengam, and Hormuz Islands (Kavousi et al. 2011, 2013; Tavakoli-Kolour et al. 2015).

Here, we report first observations of three coral diseases including black band disease (BBD) on *Acropora* (Image 1), a syndrome resembling yellow band disease (YBD) and red band disease (RBD) on *Porites* colonies (Images 2–3) from depth 5–6 m at Abu-Musa Island (25.897°N, 55.043°E) after widespread coral bleaching in the northern part of the Persian Gulf (Kavousi et al. 2014) in October 2012. Although BBD (see Riegl et al. 2012; only from the southern part of the Gulf) and YBD were already recorded from the Persian Gulf, RBD (Image 3) is reported from the Persian Gulf for the first time.

The YBD-like syndrome was observed on *Porites* corals (Image 2), however, like YBD which is a disease of endosymbiotic algae rather than the host coral (Cervino et al. 2008), showing pale (not dead) tissues. Microbiological and histological investigation is needed to confirm the disease.

The RBD observed on *Porites* corals like the YBD-like syndrome was overgrown by algae at dead part of colonies (Images 2,3).

Unfortunately, due to banned diving and snorkeling activities around the island, ecological assessment of the diseases was not possible.

References

Cervino, J.M., F.L. Thompson, B. Gomez-Gil, E.A. Lorence, T.J. Goreau, R.L. Hayes, K.B. Winiarski-Cervino, G.W. Smith, K. Hughen & E. Bartels (2008). The *Vibrio* core group induces yellow band disease in Caribbean and Indo-Pacific reef-building corals. *Journal of Applied Microbiology* 105: 1658–1671.

Image 1. Black band disease on *Acropora* species.

DOI: https://doi.org/10.11609/jott.4266.11.14. 14912-14913

Editor: John E.N. Veron, Coral Reef Research, Townsville, Australia.

Date of publication: 26 November 2019 (online & print)

Manuscript details: #4266 | Received 02 May 2018 | Final received 21 November 2019 | Finally accepted 22 November 2019

Citation: Tavakoli-Kolour, P. & S. Hazraty-Kari (2019). New records of coral diseases in the Persian Gulf. *Journal of Threatened Taxa* 11(14): 14912–14913. https://doi.org/10.11609/jott.4226.11.14.14912-14913

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Acknowledgements: Acknowledgements Especial thanks to Drs. J. Kavousi, TJ Goreau, J. Cervino, E. Peters, and H. Rezai for their useful comments.

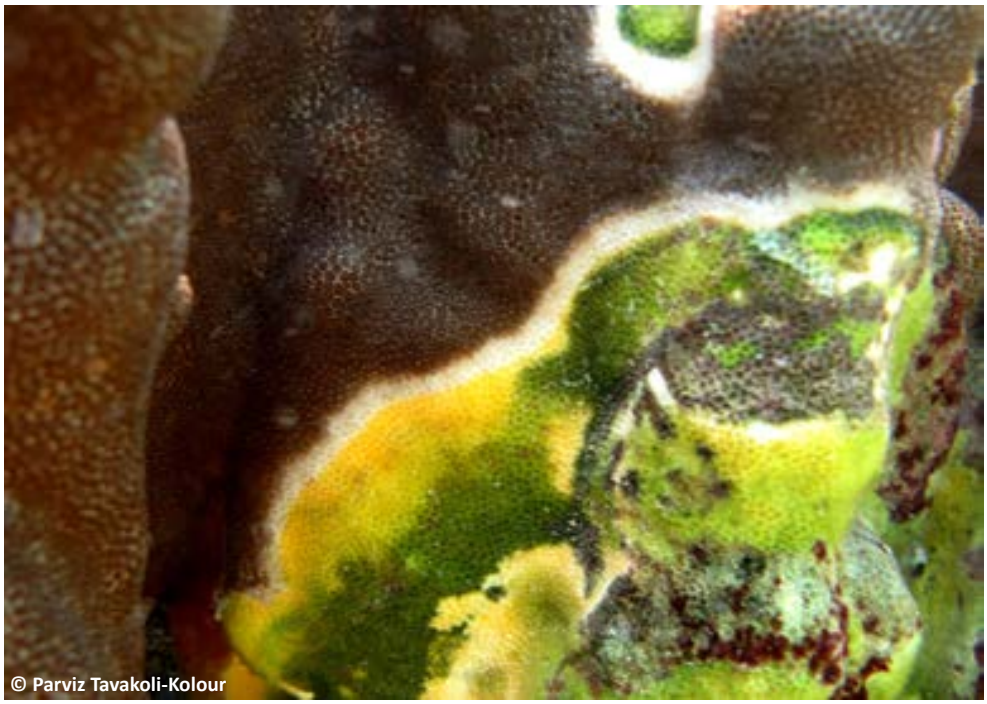

Image 2. Yellow band disease on *Porites* species.

Image 3. Red band disease on *Porites* species.

Kavousi, J. & H. Rezai (2011). Coral lesions around some Iranian Islands in the Persian Gulf. *Galaxea* 13: 5–6

Kavousi, J., P. Tavakoli-Kolour, M. Mohammadizadeh, A. Bahrami & A. Barkhordari (2014). Mass coral bleaching in the northern Persian Gulf, 2012. *Scientia Marina* 78(3): 397–404. https://doi.org/10.3989/scimar.03914.16A

Kavousi, J., P. Tavakoli-Kolour, A. Barkhordari & A. Bahrami (2013). Mass Mortality of *Porites* Corals on Northern Persian Gulf Reefs due to Sediment-Microbial Interactions. *International Journal of Marine Science* 3 (38): 306–310. https://doi.org/10.5376/ijms.2013.03.0038

Tavakoli-Kolour, P., H. Rezai & J. Kavousi (2015). Outbreak of growth anomalies in coral communities of Qeshm Island, Persian Gulf. *International Aquatic Research* 7(2): 151–156. https://doi.org/10.1007/s40071-015-0100-3

Riegl, B.M., A.W. Bruckner, K. Samimi-Namin & S.J. Purkis (2012). Diseases, harmful algae blooms (HABs) and their effects on gulf coral populations and communities, pp. 107–125. In: Riegl, B.M. & S.J. Purkis (eds.). *Coral Reefs of the Gulf*. Springer, 379pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 November 2019 | 11(14): 14914–14916

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

PLATINUM OPEN ACCESS

Crepidium aphyllum (Orchidaceae), a new record from Bhutan

Kinley Rabgay [1] & Pankaj Kumar [2]

[1] Senior Forest Ranger, Trashigang Forest Division, Department of Forest and Park Services, Ministry of Agriculture and Forests, Royal Government of Bhutan.
[2] Kadoorie Farm and Botanical Garden, Lam Kam Road, Lam Tsuen, Tai Po, New Territories, Hong Kong S.A.R., P.R. China.
[1] knlyrbg@gmail.com, [2] sahanipankaj@gmail.com (corresponding author)

The generic name *Crepidium* Bl. is derived from the Greek '*krepidion*', which means "little boot" referring to the saccate base of labellum (Blume 1825; Pridgeon et al. 2006). It is a large genus containing 280–292 species distributed from tropical and subtropical Asia to the Pacific region (Pridgeon et al. 2006; Govaerts et al. 2019). Of these, four *Crepidium* species are known to occur in Bhutan: *C. acuminatum* (D.Don) Szlach.—listed as *Malaxis acuminata* (Pearce & Cribb 2002); *C. khasianum* (Hook.f.) Szlach. and *C. purpureum* (Lindl.) Szlach.—listed as *Malaxis khasiana* and *M. purpurea* (Gurung 2006), and *C. josephianum* (Rchb.f.) Marg. (National Biodiversity Centre 2017).

During a recent field exploration in 2019, the first author discovered a few scattered plants of an unidentified leafless orchid growing along with another orchid, *Anthogonium gracile* Wall. ex Lindl. on moss and soil covered rock outcrops. The observation was made at moist oak forest (1,565m elevation) in Galing, Shongphu Gewog, Trashigang District, eastern Bhutan. After a careful investigation of the collected materials (i.e., plants and flowers), it was identified as *C. aphyllum* (King & Pantl.) A.N.Rao by the second author. *Crepidium aphyllum* is a new record for the Bhutanese orchid flora, and with this record the number of species under this genus goes up to five in Bhutan. A brief description of the plant and its biology is presented with photographs. A voucher specimen has been deposited at National Herbarium Center, Thimphu, Bhutan for future reference.

Enumeration of the species

***Crepidium aphyllum* (King & Pantl.) A.N. Rao**

J. Orchid Soc. India. 14: 65 (2000)

Malaxis aphylla (King & Pantl.) T.Tang & F.T.Wang in Acta Phytotax. Sin. 1: 71 (1951).

Microstylis aphylla King & Pantl. in Ann. Roy. Bot. Gard. (Calcutta) 8: 18, t.22 (1898).

Type: India, Sikkim, Teesta Valley, 305m, 11 July 1896, *Pantling No. 455* (*K000387669*) (K!).

Small leafless, probably partly-mycoheterotrophic, terrestrial or lithophytic herb, 7–15 cm tall, bearing flowers on the upper 1/3rd of the inflorescence. Roots very short and very few, vermiform. Pseudobulbs or corms, cylindric-ovate with irregular surface, erect or slightly inclined, white, rough surfaced, 1.0–2.5 cm long, 0.5–0.8 cm wide. Scape arising from apex of subterranean pseudobulbs or corms, sheathed towards the lower end with 3–5 scarious scales. Inflorescence racemose, open flowers laxly placed, buds (unopened) densely placed. Pedicel and ovary 1.6–2.0 mm long, 0.3mm wide, ribbed. Floral bracts lanceolate, deflexed, acuminate, 1.0–2.0 mm long, 0.5mm wide. Flowers

DOI: https://doi.org/10.11609/jott.5017.11.14.14914-14916

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

Manuscript details: #5017 | Received 14 October 2019 | Final received 25 October 2019 | Finally accepted 29 October 2019

Citation: Rabgay, K. & P. Kumar (2019). *Crepidium aphyllum* (Orchidaceae), a new record from Bhutan. *Journal of Threatened Taxa* 11(14): 14914–14916. https://doi.org/10.11609/jott.5017.11.14.14914-14916

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: Authors would like to express their gratitude to Mr. Karma Leki (Chief Forestry Officer) and colleagues of Trashigang Forest Division, Eastern Bhutan for their support and encouragement to the first author in studying orchids in the wild.

Image 1. *Crepidium aphyllum* (King & Pantl.) A.N. Rao from Bhutan. A—plant in its natural habitat, growing nearby another orchid, *Anthogonium gracile* Wall. ex Lindl. | B—plant in its natural habitat | C— close-up of the inflorescence | D—two voucher specimens deposited at National Herbarium Centre, Thimphu (THIM). © Kinley Rabgay.

shield-like, facing forward, non-resupinate, coloured uniformly in pale-yellow with dull purple towards edges, glabrous, 3.0–5.2 mm long, 1.5–2.5 mm wide; dorsal sepal ovate-oblong, erect, sub-obtuse, yellow tinted with reddish-brown, glabrous, margin curved backwards 1.5–1.8 mm long, 0.5–1.0 mm wide; lateral sepals obovate, sub-obtuse, margin entire, yellowish-green tinted with reddish-brown, reflexed backwards, 0.8–1.2 mm long, 0.2–0.3 mm wide; petals falcate or sickle shaped, placed close to the lateral sepals, acute, margin entire, yellowish-green, 0.8–0.2 mm long, 0.5mm wide; lip ovate, acute, margin entire, no constriction between midlobe and side lobes, concave, with a linear cavity lined with glands on the margin, yellowish-green, 2.3–2.6 mm long, 1.5–1.8mm wide; side lobes falcate, adpressed on the dorsal sepal, acute, margin entire, 0.7–1.0 mm long, 0.1–0.3 mm wide; column short, quadrangular, apically lobed with two stelidia, ca. 0.6mm long, 0.4mm wide. Mature fruits clavate, ribbed, 0.6–0.7 mm long, 1.2–1.4 mm wide.

Flowering: June–July.

Habitat: Plants were found growing in litter on moss covered rock outcrops in a moist deciduous Oak *Quercus griffithii* forest.

Specimens examined: India, Sikkim, Teesta Valley, 305m, 11.vii.1896, Pantling No. 455 (P00404840) (P!-isotype). Bhutan, Galing, Trashigang Forest Division, 11.viii.2019, K. Rabgay 20190711-01 (THIM).

Global conservation assessment: *Crepidium aphyllum* was previously considered to be endemic to India with distributions in Arunachal Pradesh, Sikkim and West Bengal (King & Pantling 1898; Chowdhery 1998; Lucksom 2007; Rao 2010; Sherpa et al. 2018; Govaerts et al. 2019) until its recent discovery in China (Fan et al. 2012). Hence it is an addition to the orchid flora of Bhutan. This is a very rare species, which is evident from the fact that the only specimens existing across the online herbaria of the world are the type and isotypes of Pantling collected almost 123 years ago., There is, however, a possibility of finding a specimen of this species at some non-online herbaria in India. There is not even a single digital image of this species available on google search except for the painting from King & Pantling (1898). The current sighting of *C. aphyllum* in Bhutan comprised only five mature plants. Based on GeoCAT (Moat 2007), the extent of occurrence is estimated as 29,310.577km^2 and area of occupancy as 20km^2. The total number of mature individuals seen in Bhutan was six, and the poor representation of the image on social media also points towards its rarity. Fan et al. (2012) already assessed this species as Critically Endangered globally, which seemed to be incorrect due to the occurrence of this species in at least two countries and four locations. With this rate of encounter the estimated number of mature individuals throughout its distribution range including the five known current locations cannot be more than 500. In this whole area, there is a major threat of habitat degradation due to forest loss. This is a partial mycoheterotrophic plant which are very specific to its mycorrhizal symbiosis and hence to their habitats (Jacquemyn et al. 2016). Based on current information, previous assessment and following IUCN Standards and Petitions Committee (2019) guidelines, this can be assessed as Vulnerable (VU-D2).

References

Chowdhery, H.J. (1998). *Orchid Flora of Arunachal Pradesh*. Bishen Singh Mahendra Pal Singh, Dehradun, 824pp.

Fan, J., X.-H. Jin & W.-T. Jin (2012). Two new records of Orchidaceae from China. *Journal of Tropical and Subtropical Botany* 20(3): 239–242.

Govaerts, R., M.A. Campacci, D.H. Baptista, P.J. Cribb, A. George, K. Kreutz & J.J. Wood (2019). *World checklist of Orchidaceae*. The Board of Trustees of the Royal Botanic Gardens, Kew. Published on the Internet: https://www.kew.org/wcsp/monocots/ (accessed 4 February 2019).

Gurung, D.B. (2006). *An Illustrated Guide to The Orchids of Bhutan.* DSB Publication, Thimphu, Bhutan, 178pp.

IUCN Standards and Petitions Committee (2019). *Guidelines for Using the IUCN Red List Categories and Criteria. Version 14.* Prepared by the Standards and Petitions Committee. Downloaded from http://www.iucnredlist.org/documents/RedListGuidelines.pdf (accessed 10 October 2 019).

Jacquemyn, H., M. Waud, V.S.F.T. Merckx, R. Brys, D. Tyteca, M. Hedrén & B. Lievens (2016). Habitat-driven variation in mycorrhizal communities in the terrestrial orchid genus Dactylorhiza. *Scientific Reports* 6: 37182. https://doi.org/10.1038/srep37182

King, G. & R. Pantling (1898). The orchids of Sikkim Himalaya. *Annals of Royal Botanic Garden (Calcutta)* 8: 18, t. 22.

Lucksom, S.Z. (2007). *The Orchids of Sikkim and North East Himalaya*. S.Z. Lucksom, Sikkim, 984pp.

Moat, J. (2007). Conservation assessment tools extension for Arc View 3.x, version 1.2. GIS Unit, Royal Botanic Gardens, Kew. Available from: http://www.rbgkew.org.uk/gis/cats (accessed 12 October 2019)

National Biodiversity Centre (2017). *A Century of New Orchid Records in Bhutan*. Kuensel Corporation Ltd., 209pp.

Pearce, N.R. & P.J. Cribb (2002). *The Orchids of Bhutan.* Royal Botanic Garden, 20A Inverleith Row, Edinburgh & Royal Government of Bhutan. 652pp.

Pridgeon, A.M., P.J. Cribb, M.W. Chase & F.N. Rasmussen (2006). *Epidendroideae (Part One). Genera Orchidacearum 4.* Oxford University Press, New York, Oxford, 672pp.

Rao, A.N. (2010). Orchid flora of Arunachal Pradesh - an update. *Bulletin of Arunachal Forest Research* 26(1&2): 82–110.

Sherpa, L., N. Sherpa & N. Thapa (2018). Occurrence of *Crepidium aphyllum* (King & Pantl.) A.N. Rao (Orchidaceae) in Darjiling Hills: a new record for West Bengal, India. *Pleione* 12(1): 114–117.

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

PLATINUM OPEN ACCESS

Rediscovery, after over a century, of the endemic climbing vine *Argyreia lawii* (Convolvulaceae) from the Western Ghats of India

Pramod R. Lawand [1], Rajaram V. Gurav [2] & Vinod B. Shimpale [3]

[1,3] Department of Botany, The New College, Kolhapur, Maharashtra 416012, India.
[2]Department of Botany, Shivaji University, Kolhapur, Maharashtra 416004, India.
[1] prl.botany@gmail.com, [2] botanyraj@rediffmail.com,
[3] shimpale@yahoo.com (corresponding author)

Argyreia Lour., a taxonomically complex genus of the family Convolvulaceae is represented by 135 taxa (Staples & Traiperm 2017) distributed in south eastern Asia, China, and the Indian subcontinent. In India, the genus is represented by about 40 species and is the second most species-rich genus of Indian Convolvulaceae. The genus has not been revised in its entirety which has resulted in the ambiguous identifications of many taxa. Some species are known only from their type localities and particularly, endemic species are poorly represented in the herbaria. So the authors have undertaken the revisionary studies in the genus *Argyreia* with a critical appraisal on an exploration and nomenclature; the present communication is the outcome of it.

The Western Ghats of India, one of the eight hottest hotspots of biodiversity (Myers et al. 2000), harbors endemic and threatened biodiversity of India. An exploration of the northern Western Ghats of India in the year 2016–2017 resulted in the collection of *Argyreia lawii* from two localities, viz., Bhudargad Fort and Patgaon, Kolhapur District of Maharashtra State. A relevant literature study (Clarke 1883; Cooke 1908; Biju 1997) revealed that the species was re-collected after a lapse of more than 100 years. The species was described by Clarke (1883) based on collections made by J.S. Law and named the species to honour his botanical contributions. Law collected the specimens from populations of the species in Malabar, Konkan Province and Bababudhan Hills of Karnataka State. After the type collections made by Law prior to 1883, no collections from the Konkan Province have been reported. Cooke (1908) mentioned that he had not seen any specimen from the Bombay Presidency in Flora of the Presidency of Bombay. It was further written that Talbot might not have collected it as he did not mention about locality. Singh et al. (2001) in flora of Maharashtra State cited the species on the authority of Talbot (1902). The digital flora of Karnataka(http://florakarnataka.ces.iisc.ac.in, accessed on 04 July 2018)by Sankara Rao et al. (2012) reports the occurrence of *A. lawii* from Chikkamagaluru District of Karnataka State based on the reference of Sharma et al. (1984). But it is clearly mentioned in the flora of Karnataka analysis that the species was not collected by them from Chikkamagaluru District. We searched at another type locality, Bababudhan Hills in Chikkamagaluru District and found populations of the species locally abundant. Therefore, the present collections are the recollection after the type collection.

DOI: https://doi.org/10.11609/jott.4419.11.14.14917-14920

Editor: Aparna Watve, Biome Conservation Foundation, Pune, India. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4419 | Received 20 July 2018 | Final received 12 October 2019 | Finally accepted 07 November 2019

Citation: Lawand, P.R., R.V. Gurav & V.B. Shimpale (2019). Rediscovery, after over a century, of the endemic climbing vine *Argyreia lawii* (Convolvulaceae) from the Western Ghats of India. *Journal of Threatened Taxa* 11(14): 14917–14920. https://doi.org/10.11609/jott.4419.11.14.14917-14920

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to the Principal, The New College, Kolhapur for providing laboratory facilities. PRL is grateful to the Council of Scientific and Industrial Research (CSIR), New Delhi (File No. 08/631(0001)2015-EMR-I) for providing financial assistance towards the research work.

***Argyreia lawii* C.B. Clarke**

in Hook.f., Fl. Brit. India 4:190. 1883 (Images 1–4).

Lectotype (designated by Lawand and Shimpale): Karnataka, Bababoodan (Bababudhan) Hills s.d., Law 28 *Argyreia*, (K000830722 digital image!).

Description: A semi-woody 1–1.5 meters high climber or sometimes prostrate shrub. Stem older semi-woody, young purple, strigose-villous, hairy, terete. Leaves simple, alternate, 7–11 × 3–6 cm, base cordate, apex acute, strigose on both the surfaces, secondary veins 6–7 pairs, conspicuous below; petiole 2–4 cm long, dorsally grooved, purple in colour, hairy like stem. Inflorescence a compact 4–9 flowered cyme; peduncle 6–12 cm long, longer than the petiole, purple coloured, terete, hairy like stem. Flowers sub-sessile, bracteate. Bracts 2, 1–2 cm long, linear-lanceolate, apex acute, bract of flower in fork larger, lance-ovate, midvein prominent, persistent, green, purple at margin, white hairy on both the sides. Calyx 5, polysepalous, sepals, sub equal, 0.7–1.0 cm long, ovate, apex acute, inner three wider than the outer two, strigose outer, glabrous inside, outer sepal purple margined, inner hyaline on margins. Corolla funnel form, pink-purple, 4–5 cm long × 4–5 cm wide, hairy outer on midpetaline bands, throat purple ca. 1 cm wide, corolla lobes twisted in bud and shortly apiculate in flower. Stamens 5, inserted in corolla tube, unequal in length, 2.5–3.5 cm long, filaments pink, dilated and glandular hairy at base, anthers basifixed, pale pink. Ovary 1–3 mm in diameter

Image 1. *Argyreia lawii*: A—habit | B—habit closeup | C—Corolla front view | D—Corolla side view. © V.B. Shimpale.

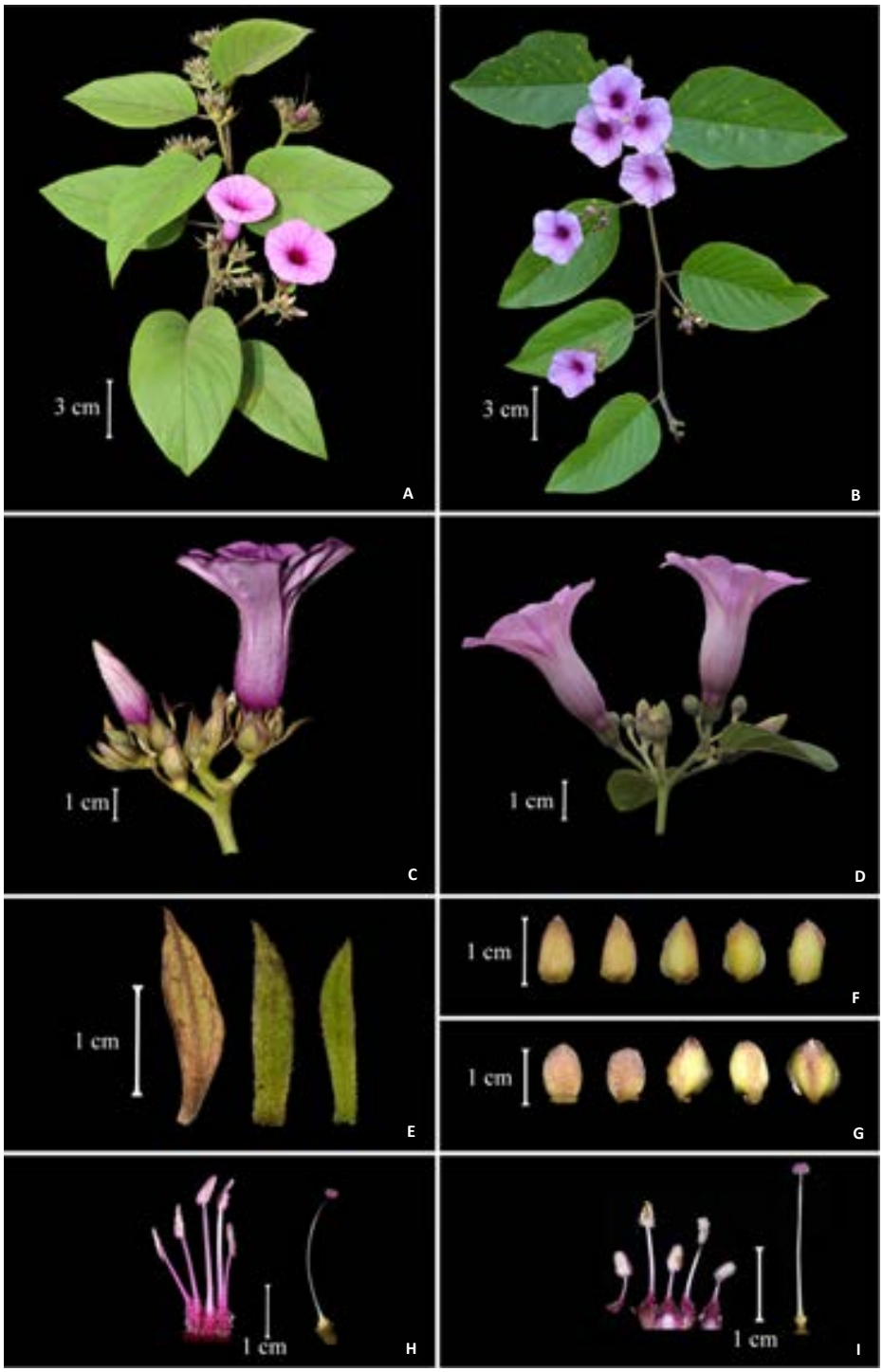

Image 2. ***Argyreia lawii*****: A—flowering twig | C—an inflorescence | E—bracts | F—sepals | H—reproductive parts.** ***Argyreia elliptica*****: B—flowering twig | D—an inflorescence | G—sepals | I—reproductive parts. © P.R. Lawand.**

encircled by an annular disc; style-1; stigma biglobose, pink. Fruit a berry, ca.1cm across, yellow.

Specimens examined: K000830722, K000830721 (K), 00135003 (GH), 00584825 (P) digital image!, s.d., Bababoodan Hills, Karnataka, India, coll. Law 28 *Argyreia*; PR Lawand1 (SUK), 15.ix.2017, 700 m Bhudargad Fort, Kolhapur District, Maharashtra coll. P.R. Lawand (Image 3); PRLawand50 (SUK), 10.x.2017, Patgaon, Kolhapur District, Maharashtra, coll. P.R. Lawand (Image 4).

Phenology: Flowering: August–October; Fruiting: November–January.

Habitat and Distribution: The populations of *Argyreia*

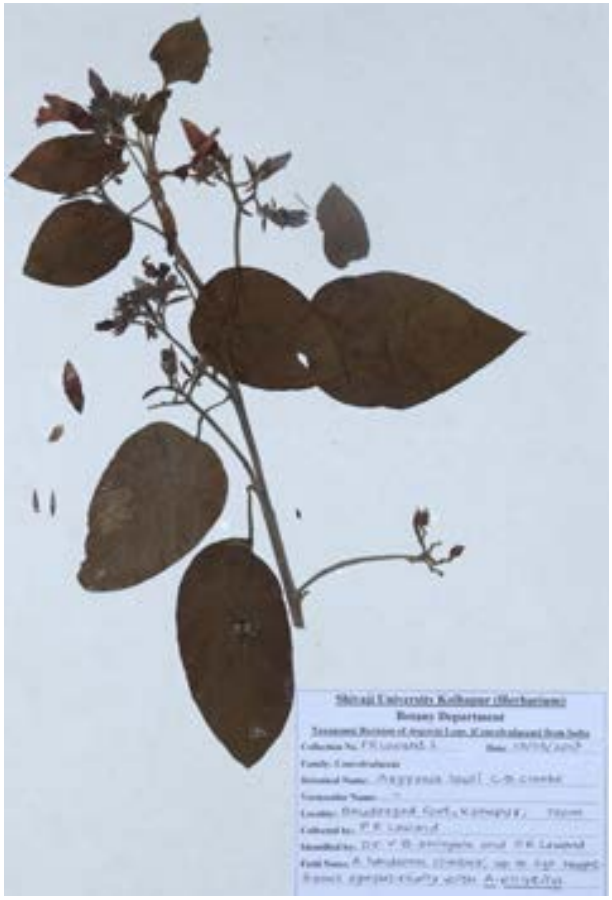

Image 3. Herbarium of *Argyreia lawii* [# PRLawand1 (SUK)].

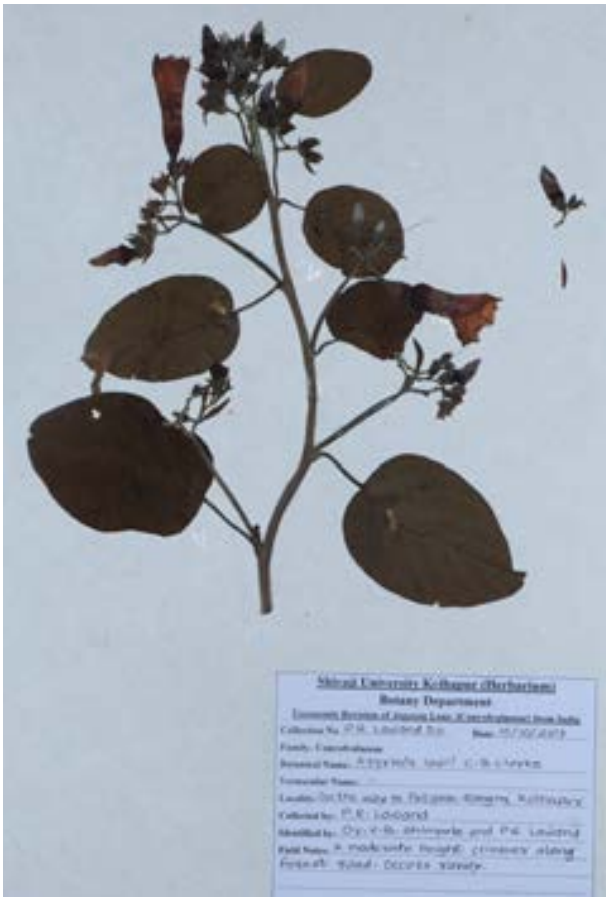

Image 4. Herbarium of *Argyreia lawii* [(# PRLawand50 (SUK)].

Table 1. Morphological comparison of *Argyreia lawii* and *A. elliptica*.

Character	*Argyreia lawii*	*Argyreia elliptica*
Habit	Climber up to height of 1–1.5 meters	Huge climber up to height of 10–12meter
Bracts	1–2 cm long, persistent in flower	3–4 mm long, early caducous
Inflorescence architecture	A lax (loosely arranged), dichotomously branched cyme	Compactly arranged cyme

lawii were encountered along forest roadsides at 700–800 m elevation. The species grows sympatrically with *A. elliptica* (Roth ex Roem. & Schult.) Choisy. *A. lawii* can be readily distinguished by the presence of linear-lanceolate, persistent bracts while in *A. elliptica* bracts are very early caducous (Table 1). Till date, the species is known from three localities from two different states, i.e., Bababudhan Hills from Karnataka, and Bhudargad Fort and Patgaon from Maharashtra, India.

In the two subpopulations at Bhudargad Fort and Patgaon in Kolhapur District of Maharashtra, we could observe 4–6 mature individuals. The populations are frequent at Bababudhan Hills, Karnataka but the total area may not exceed 10km^2.

References

Biju, S.D. (1997). *Taxonomic and Morphologic Studies on the Family Convolvulaceae of Southern Peninsular India*. PhD Thesis (unpublished), University of Calicut, India. 70pp.

Clarke, C.B. (1883). Convolvulaceae. In: Hooker, J.D. (ed.)*Flora of British India*: *Vol. 4*. L. Reeve and Co., London. 190pp.

Cooke, T. (1908). *Flora of the Presidency of Bombay Vol. 2*. Taylor and Francis, London, 257pp.

Lawand, P.R. & V.B. Shimpale (2017). Typifications in *Argyreia* (Convolvulaceae). *Taiwania* 62(3): 335–336. http://tai2.ntu.edu.tw/taiwania/pdf/tai.2017.62.335.pdf

Sankara Rao, K., A. N. Sringeswara, Deepak Kumar, Sandeep Pulla & R. Sukumar (2012). A digital herbarium for the flora of Karnataka. *Current Science* 102(9): 1268–1271. http://florakarnataka.ces.iisc.ac.in/hjcb2/index.php

Sharma, B.D., N.P. Singh, R.S. Raghavan & U.R. Deshpande (1984).*Flora of Karnataka analysis***.** Botanical Survey of India, Kolkata, 179pp.

Singh, N.P., P. Lakshminarsimhan, S. Karthikeyan & P.V. Prasanna (2001). *Flora of Maharashtra State: Dicotyledons Vol. 2*. Botanical Survey of India, Kolkata, 445pp.

Staples, G. & P. Traiperm (2017). A nomenclatural review of *Argyreia* (Convolvulaceae). *Taxon* 66(2): 445–477.

Talbot, W.A. (1902). *The Trees, Shrubs and Climbers of the Bombay Presidency*. The Government Central Press, Bombay, 249pp.

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

PLATINUM OPEN ACCESS

Linostoma decandrum (Roxb.) Wall. ex Endl. (Thymelaeaceae): an addition to the flora of Andaman Islands, India

L. Rasingam [1] & K. Karthigeyan [2]

[1]Botanical Survey of India, Deccan Regional Centre, Plot no. 366/1, Attapur, Hyderguda (P.O), Hyderabad, Telangana 500048, India.
[2]Botanical Survey of India, Central National Herbarium, P.O. Botanic Garden, Howrah, West Bengal 711103, India.
[1] rasingam@gmail.com (corresponding author),
[2] karthigeyan.murthy@gmail.com

Linostoma Wall. ex Endl. is a small genus in the family Thymelaeaceae distributed in Bangladesh, Myanmar, northeastern India to Indo-China, Thailand, Malay Peninsula, and Borneo (Nevling 1961). Nevling (1961) has recognized three species of *Linostoma,* of which *Linostoma decandrum* (Roxb.) Wall. ex Endl. is reported from the Assam and Manipur states of northeastern India.

While working on unidentified specimens collected from the Andaman & Nicobar Islands deposited at PBL and CAL, the authors came across a few specimens of *Linostoma*. After critical study with relevant literature, all the specimens were found belonging to *Linostoma decandrum*. Since the species had not been reported so far from the Andaman & Nicobar Islands (Rao 1986; Lakshminarasimhan & Rao 1996; Mathew 1998; Pandey & Diwakar 2008), it forms a new distribution record to the islands' biogeographic zone. A detailed description for the species along with a herbarium image is provided for easy identification.

Taxonomic treatment

Linostoma decandrum (Roxb.) Wall. ex Endl., Gen. 331. 1837; Kurz, Forest Fl. Burma 2: 334. 1877; Hook.f., Fl. Brit. India 5: 198. 1886; Brandis, Indian Trees 545. 1906; Nevling in J. Arnold Arbor. 42: 307. 1961. *Nectandra decandra* Roxb., [Hort. Beng. 90. 1814 nom. nud.] & Fl. Ind. 2: 425. 1832. (Image 1).

Specimens examined: s.n. (CAL!), 19.iii.1892, Anikhet Hill jungle, Andaman Islands, coll. Dr. King's collector; 47 (CAL!), 23.i.1901, Andamans, Coll. Dr. Prain's Collector; 12355 (PBL!), 23.xii.1986, Kalpong No. 10, North Andamans, Coll. G. Chakraborty & G.S. Kindo.

Climbing shrubs, up to 15m; branchlets terete, glabrous. Leaves simple, opposite, elliptic to oblong-elliptic or oblong-lanceolate, 3–9.5 × 1–4.5 cm, obtuse to acute or shortly acuminate at apex, entire along margin, cuneate to rounded at base, coriaceous, glabrous on both surfaces, lateral veins many, parallel. Petiole canaliculate, 2–9 mm long, glabrous. Inflorescence terminal, umbelliform, 2–3 flowered; peduncles 3–5 cm long, glabrous. Bracts foliar, opposite, oblong, 3–5.5 × 1–1.8 cm, obtuse at apex, entire along margin, rounded at base, chartaceous, white, glabrous. Flowers small, light greenish-pink. Calyx tube fusiform, 5–7 × 2–2.5 mm, reddish without, lobes 5, linear, 6–8 × *c.* 2 mm, greenish within, reflexed. Petals 10, white, clavate, 3–6 mm long. Stamens exserted, 15–16; filaments slender, white; anthers yellow. Ovary stipitate, ellipsoid, *c.* 3mm long, densely hairy; style filiform, 8–10 mm long; stigma capitate. Fruits ovoid-ellipsoid, 1–1.5 × 0.5–0.9 cm, appressed hairy; fruiting pedicels 5–6 mm long, swollen.

DOI: https://doi.org/10.11609/jott.5106.11.14.14921-14922

Editor: B. Ravi Prasad Rao, Sri Krishnadevaraya University, Ananthapuramu, India. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #5106 | Received 21 May 2019 | Final received 22 October 2019 | Finally accepted 01 November 2019

Citation: Rasingam. L. & K. Karthigeyan (2019). *Linostoma decandrum* (Roxb.) Wall. ex Endl. (Thymelaeaceae): an addition to the flora of Andaman Islands, India. *Journal of Threatened Taxa* 11(14): 14921–14922. https://doi.org/10.11609/jott.5106.11.14.14921-14922

Funding: Botanical Survey of India.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are grateful to the Director, Botanical Survey of India, Kolkata for facilities and Dr. P.V. Prasanna, Scientist 'G' & HoO, Botanical Survey of India, Deccan Regional Centre, Hyderabad, and Dr. V.P. Prasad, Scientist 'E' & HoO, Central National Herbarium, Botanical Survey of India, Howrah for encouragement.

Image 1. Herbarium of *Linostoma decandrum* (Roxb.) Wall. ex Meisn.

Seeds ovate- triangular, c. 9 × 4 mm.

Habitat: The plants grow in moist localities in evergreen forests.

Flowering & Fruiting: December–March.

Distribution: India: Assam, Manipur, the Andaman Islands; Bangladesh, Myanmar, Thailand, Indo-China, Malay Peninsula and Borneo.

References

Lakshminarasimhan, P. & P.S.N. Rao (1996). Supplementary list of angiosperms recorded (1983–1993) from Andaman & Nicobar Islands. *Journal of Economic and Taxonomic Botany* 20: 175–185.

Mathew, S.P. (1998). A supplementary report on the flora and vegetation of Bay Islands, India. *Journal of Economic and Taxonomic Botany* 22: 249–272.

Nevling Jr., L.I. (1961). A revision of the Asiatic genus *Linostoma* (Thymelaeaceae). *Journal of Arnold Arboretum* 42: 295–320.

Pandey, R.P. & P.G. Diwakar (2008). An integrated checklist of plants in Andaman & Nicobar Islands, India. *Journal of Economic and Taxonomic Botany* 32: 403–500.

Rao, M.K.V. (1986). A preliminary report on the angiosperms of Andaman & Nicobar Islands. *Journal of Economic and Taxonomic Botany* 8: 107–184.

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

PLATINUM
OPEN ACCESS

On the floral biology and pollination of a rare Twining Liana *Sarcolobus carinatus* Wall. (Asclepiadoideae: Apocynaceae) in Coringa Mangrove Forest, Andhra Pradesh, India

A.J. Solomon Raju

Department of Environmental Sciences, Andhra University, Waltair Junction, Visakhapatnam, Andhra Pradesh 530003, India.
solomonraju@gmail.com

Sarcolobus is a genus of sub-family Asclepiadoideae, family Apocynaceae according to APG IV System Classification (2016). Rintz (1980) documented that this genus formerly consisted of 17 described and eight undescribed species distributed in India, Malesia, Melanesia, and Australia. He revised the genus and listed only four species, *S. carinatus, S. retusus, S. globosus*, and *S. oblongus* as occurring in Australia. All four species are restricted to coasts and areas of brackish water, on mud in mangrove and swamp forests, and on sand and coral beaches scrambling over strand vegetation. Later, Forster (1991) documented that *Sarcolobus* is a genus of 13 species in India, Malesia including Papuasia, Melanesia, and Australia. Three species occur in Australia and eight species in Papuasia. ENVIS Centre on Floral Diversity hosted by Botanical Survey of India published a status document on Indian mangrove plant species in 2016. In this document, *S. globosus* and *S. carinatus* are the only species listed under the genus *Sarcolobus*; the former occurs in the Sunderbans, Mahanadi, and the Nicobar Islands while the latter occurs along the east coast in the mangrove areas of the Sunderbans, Mahanadi, Coringa tidal forests, and the Andaman Islands. Rintz (1980) reported that *S. carinatus* is distributed from India, Burma and the Andaman Islands with flowering during February to August and fruiting in June. He mentioned that the characters such as the shape of gynostegium, the presence or absence of double corona, the shape of twin-pollinia, the shape of fruit and the presence or absence of a coma on the seeds are important to distinguish *Sarcolobus* from other genera of the sub-family Asclepiadoideae. Forster (1991) also provided the characters important to distinguish *Sarcolobus* from other genera within the sub-family. These include the presence of slight to strongly papillate style-head, the narrowly oblong corpuscles that stand upright away from the anthers the length of the pollinia, and the geniculate caudicles of the pollinaria. The available information on *Sarcolobus* indicates that the taxonomic details of its species need revision to define total species accurately and provide distinguishing characters for each identified species. Further, none of the species of this genus have been studied thus far for their floral biology and pollination in any part of the world. Therefore, the present study is the first to document floral biology and pollination notes on *S. carinatus* based on field study conducted during January–December 2014 and January–December 2018 at Coringa Mangrove Forest (16^{0}43'47.413"N & 82^{0}12'54.864"E), Andhra Pradesh, India.

In the genus *Sarcolobus, S. carinatus* is the only species that occurs at Coringa Mangrove Forest. Here,

DOI: https://doi.org/10.11609/jott.4870.11.14.14923-14926

Editor: Analinda C. Manila-Fajardo, University of the Philippines, Laguna, Philippines. **Date of publication:** 26 November 2019 (online & print)

Manuscript details: #4870 | Received 07 February 2019 | Final received 11 October 2019 | Finally accepted 03 November 2019

Citation: Raju, A.J.S. (2019). On the floral biology and pollination of a rare Twining Liana *Sarcolobus carinatus* Wall. (Asclepiadoideae: Apocynaceae) in Coringa Mangrove Forest, Andhra Pradesh, India. *Journal of Threatened Taxa* 11(14): 14923–14926. https://doi.org/10.11609/jott.4870.11.14.14923-14926

Funding: University Grants Commission, Government of India, New Delhi.

Competing interests: The author declares no competing interests.

Acknowledgements: This work has been supported by the University Grants Commission, Government of India, New Delhi, in the form of BSR Mid-Career Award to Faculty Members.

it grows as a semi-evergreen twining liana along the brackish water creeks that end up after a short distance with the land (Image 1a-c). It uses *Clerodendrum inerme*, a common mangrove associate distributed towards landward side of mangrove forest, for vertical support. In areas where there is no supporting tree species, it grows erect for some time, then the stems twist and hang downwards almost touching the ground. It is rare in occurrence. The stem is light yellow initially and brown eventually. Leaf is petiolate, blade thick, coriaceous, elliptical and bright to dull green (Image 1d). Pheno-events, leaf fall, leaf flushing, flowering and fruiting occur sequentially. Leaf fall occurs during May and leaf flushing commences immediately from the old stems, but it is complete by July. Floral bud initiation occurs simultaneously (Image 1e–g) with leaf flushing and flowering commences in the last week of July, reaches to peak phase during second week of August and ceases by the end of August. Inflorescence is a pedunculate spirally elongating raceme with 6–7 hermaphroditic flowers borne at leaf axils (Image 2a). Calyx is represented by five inconspicuous green sepals with ciliate margins. Corolla is represented by five glabrous 6–10 cm long petals each with rows of brown to purple dots on the upper surface. Corolline corona composed of five distinct yellow pad-like segments, positioned on the petals in one whorl, aligned with the petals and located between the corolla and androecium; the coronal segments are separated from the staminal corona by a narrow cleft (Image 2d). Anthers are attached with the pistil forming papillate and capitate gynostegium (Image 2b, c); the style-head with five grooves support the anthers. The anther wings are narrow but extend back beneath the stigma to end up abruptly at the stamen tube without curving downward. Anthers are represented by twin sub-globose pollinia (Image 2e), each is attached to the caudicle by its basal end and hence held semi-erect and is away from the style-head. Both pollinia are attached by caudicles to the corpusculum which is a black horny structure and quite prominent against yellow corolline and staminal coronas. The ovary is bicarpellary syncarpous, whitish-green and many-ovuled on axile placentation (Image 2f); the style is one with stigma deeply 5-angled, the center with a papillose spherical knob, and five narrow ridges radiating from it to the apex of angles.

Rintz (1980) reported that *Sarcolobus* genus includes both coronal and non-coronal species. He noted that *S. retusus* and *S. oblongus* are non-coronal species lacking both corolline and staminal coronas while *S. carinatus* is a coronal species consisting of both corolline and staminal coronas. He noted that corolline and staminal coronas are either present or absent in *S. globosus*. Forster (1991) reported that *S. globosus* and *S. kaniensis* are coronal species consisting of both corolline and staminal coronas. In *S. vittatus*, corolline corna is present

Image 1. *Sarcolobus carinatus*: a–c—habit | d—close-up view of leaves | e–g—floral bud development stages. © A.J. Solomon Raju.

but staminal corona is absent. In *S. brachystephanus, S. hullsii, S. porcatus, S. ritae, S. secamonoides* and *S. spathulatus*, corolline corona is absent but staminal corona is present. The present study substantiates the report by Rintz (1980) that *S. carinatus* is a coronal species with well-developed corolline and staminal coronas. In *S. carinatus*, the stigmatic chamber in gynostegium has nectariferous tissues which secrete nectar in minute volume and the nectar can accumulate in the staminal corona or at the area where the corolline corona is connected to the gynostegium. Such a secretary pattern is related to the specialized pollination mechanism and it is characteristic of Asclepiadoideae (Kunze 1991, 1997; Demarco 2008). The pollinia in the flowers of *S. carinatus* represent coherent masses of pollen grains and are transferred as single units by flower-visiting insects when the latter collect nectar. Field observations indicated that only juvenile carpenter bees (*Xylocopa latipes* and *X. pubescens*) visit the flowers soon after anthesis and until evening for nectar collection during which their legs or tongue are trapped between the pollinia and in effect, their struggle to withdraw these parts from the flowers result in them capturing the pollinia. Then, they leave carrying the pollinia and in their subsequent visit to another flower get rid of the pollinia and deposit them on that flower effecting pollination. It is not clear if there is any chance of the carpenter bees losing the pollinia during flight. Field observations also indicated that carpenter bees make few visits and very often occasionally to the flowers of *S. carinatus*; such a situation could be attributed to the landward side location of the plants from tidal creeks, scattered occurrence of plants, production of a few flowers per day, which are mixed with the foliage and flowers of host plants, occurrence of high winds during flowering season, which influence the foraging activity of carpenter bees.

In *S. carinatus*, the fertilized flowers take 3–4 months to produce mature fruits (Image 2g-o). The fruits are of follicle type, 5–6 cm long, ellipsoid in shape with 3 flattened ribs, keeled along the dorsal side and terminated into a short beak. They are initially green and brown when mature. Each fruit produces many seeds attached to the vertical receptacle (Image 2p). Mature seeds are dark brown, lacking coma, papery, 10–12 mm long, broadly ovate and flattened. Fields observations indicated that individual plants produce 2–4 fruits in a flowering season suggesting that *S. carinatus* is an

Image 2. *Sarcolobus carinatus*: a—inflorescence with buds and flowers | b–c—gynostegium in the central portion of the flower | d—corollaine corona and staminal corona | e—pollinia | f—ovules | g–l—fruit development stages | m–o—inside view of fruit and seed development stages | p—developing seeds without coma | q—seedling. © A.J. Solomon Raju.

obligate out-crosser and essentially dependent on insect pollinators, particularly carpenter bees which act as efficient pollinators. Further, the fruit set rate is probably pollinator-limited but individual flowers upon receipt of a pair of pollinia each consisting of several pollen grains are able to produce several seeds per fruit as compensation against low fruit set. Therefore, the rare occurrence of *S. carinatus* is attributable mainly to specialized pollination system that prevents insect pollinators other than carpenter bees and pollinator limitation, resources available to the plant in areas where it occurs and edible nature of tender fruits which are often eaten by locals.

Forster (1991) reported that *Sarcolobus* seeds with a layer of seed coat and well-developed lateral margins appear to be adapted to water dispersal but suggested field observations to confirm the same. In this study, *S. carinatus* disperses seeds from mature and dry fruits upon dehiscence into the air during November–December. The flat, papery nature of seeds without coma appear to be a perfect adaptation for wind dispersal. The wind-driven seeds that fall into the tidal water subsequently disperse by floating and settle in muddy areas where they germinate and produce new plants from seedlings if the soil environment is favourable (Image 2q). Therefore, *S. carinatus* is both anemochorous and hydrochorous. Despite efficient seed dispersal modes this plant species is not able to recruit new plants due to its restricted habitat requirement; the sites along the tidal creeks which interface with landward zone.

In Coringa Mangrove Forest, ecotourism, fishing activity and fuel wood collection are regular activities and if these activities are not regulated, the mangrove plant species that grow along brackish water creeks interfacing with landward side are at risk. *S. carinatus* is one such species that is most likely to disappear in the near future because of its rare occurrence if proper conservation and management measures are not implemented by the forest department.

References

APG IV System Classification (2016). An update of the Angiosperm Phylogeny Group Classification for the Orders and Families of Flowering Plants: APG IV. *Botanical Journal of Linnean Society* 181: 1–20. https://doi.org/10.1111/boj.12385

Demarco, D. (2008). Glandulas de orgaos vegetativos aereos e florais de especies de Asclepiadoideae (R.Br.) Duby (Asclepiadoideae, Apocynaceae) de mata atlantica de estado de Sao Paulo. Ph.D Thesis, Universidade Estadual de Campinas, Campinas, Brazil, 392pp.

Forster, P.I. (1991). A taxonomic revision of *Sarcolobus* R.Br. (Asclepiadaceae: Marsdenieae) in Australia and Papuasia. *Austrobaileya* 3: 335–360.

Kunze, H. (1991). Structure and function in asclepiad pollination. *Plant Systematics and Evolution* 176: 227–253.

Kunze, H. (1997). Corona and nectar system in Asclepiadinae (Asclepiadaceae). *Flora* 192: 175–183. https://doi.org/10.1016/S0367-2530(17)30774-0

Rintz, R.E. (1980). A revision of the genus *Sarcolobus* (Asclepiadaceae). *Blumea* 26: 65–79.

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.10

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road,
Saravanampatti, Coimbatore, Tamil Nadu 641035, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa

www.threatenedtaxa.org

PLATINUM OPEN ACCESS

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

November 2019 | Vol. 11 | No. 14 | Pages: 14787–14926
Date of Publication: 26 November 2019 (Online & Print)
DOI: 10.11609/jott.2019.11.14.14787-14926

Publisher & Host

Partner

Member