

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

26 July 2018 (Online & Print)
Vol. 10 | No. 8 | 11999–12146

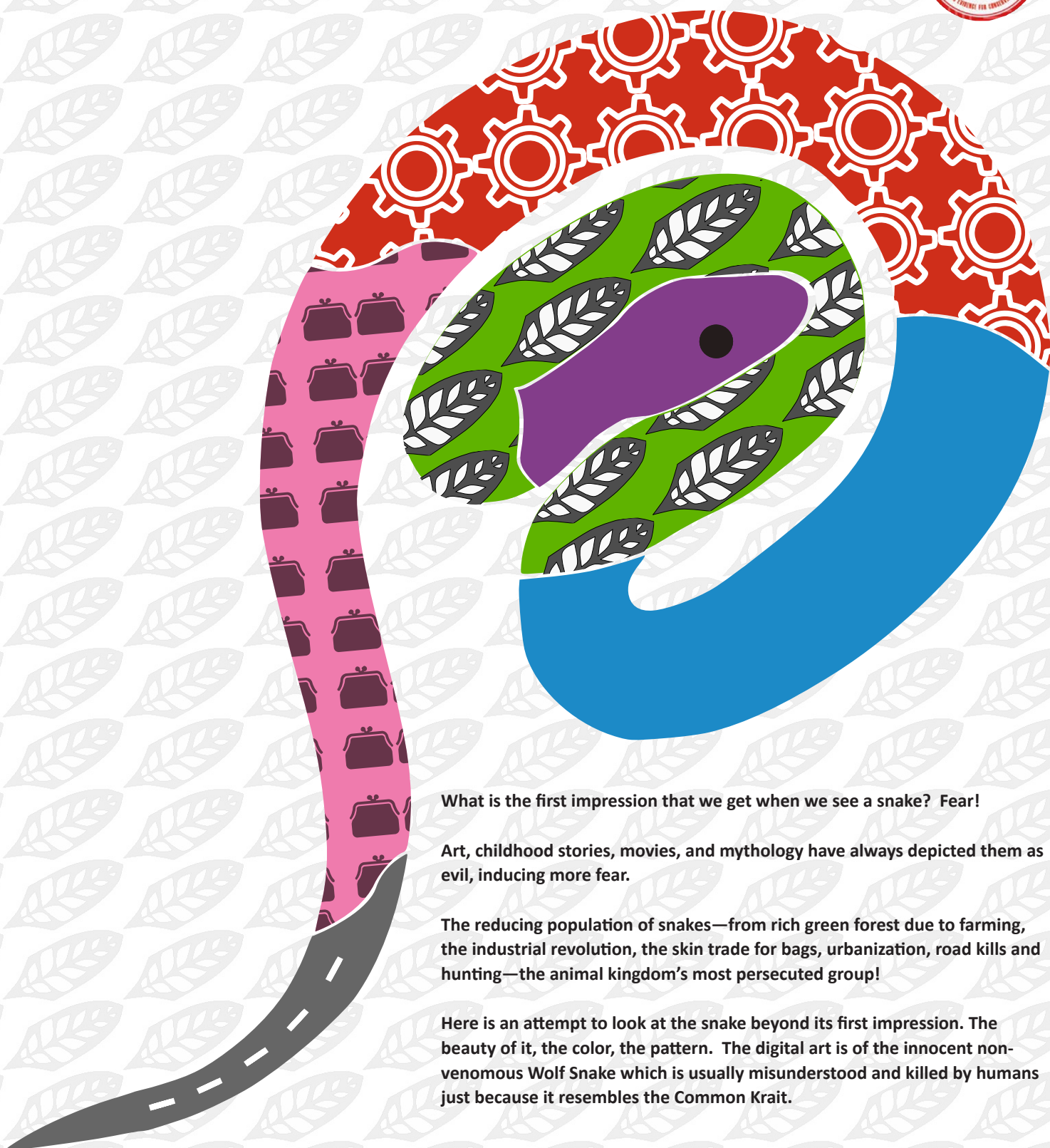
10.11609/jott.2018.10.8.11999-12146
www.threatenedtaxa.org

OPEN ACCESS



Building evidence for conservation globally

Journal of Threatened Taxa



What is the first impression that we get when we see a snake? Fear!

Art, childhood stories, movies, and mythology have always depicted them as evil, inducing more fear.

The reducing population of snakes—from rich green forest due to farming, the industrial revolution, the skin trade for bags, urbanization, road kills and hunting—the animal kingdom's most persecuted group!

Here is an attempt to look at the snake beyond its first impression. The beauty of it, the color, the pattern. The digital art is of the innocent non-venomous Wolf Snake which is usually misunderstood and killed by humans just because it resembles the Common Krait.



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

Published by
Wildlife Information Liaison Development Society

Typeset and printed at
Zoo Outreach Organization

No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti,
Coimbatore, Tamil Nadu 641035, India
Ph: 0 938 533 9863

Email: threatenedtaxa@gmail.com, sanjay@threatenedtaxa.org
www.threatenedtaxa.org

EDITORS

FOUNDER & CHIEF EDITOR

Dr. Sanjay Molur, Coimbatore, India

MANAGING EDITOR

Mr. B. Ravichandran, Coimbatore, India

ASSOCIATE EDITORS

Dr. B.A. Daniel, Coimbatore, India

Dr. Ulrike Streicher, Wildlife Veterinarian, Danang, Vietnam

Ms. Priyanka Iyer, Coimbatore, India

Dr. Manju Siliwal, Dehra Dun, India

Dr. Meena Venkataraman, Mumbai, India

EDITORIAL ADVISORS

Ms. Sally Walker, Coimbatore, India

Dr. Robert C. Lacy, Minnesota, USA

Dr. Russel Mittermeier, Virginia, USA

Dr. Thomas Husband, Rhode Island, USA

Dr. Jacob V. Cheeran, Thrissur, India

Prof. Dr. Mewa Singh, Mysuru, India

Mr. Stephen D. Nash, Stony Brook, USA

Dr. Fred Pluthero, Toronto, Canada

Dr. Martin Fisher, Cambridge, UK

Dr. Ulf Gärdenfors, Uppsala, Sweden

Dr. John Fellowes, Hong Kong

Dr. Philip S. Miller, Minnesota, USA

Prof. Dr. Mirco Solé, Brazil

EDITORIAL BOARD

SUBJECT EDITORS 2015–2017

Aaron Bauer, Villanova University, Villanova, USA

Amazonas Chagas Júnior, Universidade Federal de Mato Grosso, Cuiabá, Brasil

Anders G.J. Rhodin, Chelonian Research Foundation, Lunenburg, USA

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

A.J. Solomon Raju, Andhra University, Visakhapatnam, India

A.J.T. Johnsingh, Nature Conservation Foundation, Mysuru, India

Albert G. Orr, Griffith University, Nathan, Australia

Alessandre Pereira Colavite, Universidade Federal da Paraíba, Brazil

Alexi Popov, National Museum of Natural History, Sofia, Bulgaria

Alexander Ereskovsky, IMBE, Marseille, France

Andreas Köhler, Universidade de Santa Cruz do, Brazil

Angela R. Glatston, Rotterdam Zoo, The Netherlands

Anjana Silva, Rajarata University of Sri Lanka, Saliyapura, Sri Lanka

Ankita Gupta, ICAR-NBAIR, Bengaluru, India

Annemarie Ohler, Muséum national d'Histoire naturelle, Paris, France

Ansie Dippenaar-Schoeman, University of Pretoria, Queenswood, South Africa

Antonio D. Brescovit, Instituto Butantan, Brasil

Antonio A. Mignucci-Giannoni, Universidad Interamericana de Puerto Rico, Puerto Rico

Anwaruddin Chowdhury, The Rhino Foundation for nature in North East India, Guwahati, India

Aparna Watve, Tata Institute of Social Sciences, Osmanabad, India

Arthur Y.C. Chung, Sabah Forestry Department, Sandakan, Sabah, Malaysia

Asheesh Shivam, Nehru Gram Bharti University, Allahabad, India

Ashwin Naidu, University of Arizona, Tucson, USA

B.C. Choudhury (Retd.), Wildlife Institute of India, Dehradun, India.

B. Ravi Prasad Rao, Sri Krishnadevaraya University, Anantpur, India

B. Shivaraju, Bengaluru, Karnataka, India

B.S. Kholia, Botanical Survey of India, Gangtok, Sikkim, India

Bolívar R. Garcete-Barrett, FACEN, Universidad Nacional de Asunción, Paraguay

Brett C. Ratcliffe, University of Nebraska, Lincoln, USA

Brian Fisher, California Academy of Sciences, USA

C. Raghunathan, Zoological Survey of India, Andaman and Nicobar Islands

C. Srinivasulu, Osmania University, Hyderabad, India

Carl Ferraris, Smithsonian Institution, Portland, USA

Carol Inskipp, Bishop Auckland Co., Durham, UK.

Cecilia Kierulff, Victorville, California

Cecilia Volkmer Ribeiro, Porto Alegre, Brazil.

Chris Bowden, Royal Society for the Protection of Birds, Sandy, UK

Christoph Kueffer, Institute of Integrative Biology, Zürich, Switzerland

Christoph Schwitzer, University of the West of England, Clifton, Bristol, BS8 3HA

Christopher L. Jenkins, The Orianne Society, Athens, Georgia

Cleofas Cervancia, Univ. of Philippines Los Baños College Laguna, Philippines

Colin Groves, Australian National University, Canberra, Australia

Crawford Prentice, Nature Management Services, Jalan, Malaysia

C.T. Achuthankutty, Scientist-G (Retd.), CSIR-National Institute of Oceanography, Goa

Dan Challender, University of Kent, Canterbury, UK

D.B. Bastawade, Maharashtra, India

D.J. Bhat, Retd. Professor, Goa University, Goa, India

Dale R. Calder, Royal Ontario Museum, Toronto, Ontario, Canada

Daniel Brito, Federal University of Goiás, Goiânia, Brazil

David Mallon, Manchester Metropolitan University, Derbyshire, UK

David Olson, Zoological Society of London, UK

Davor Zanella, University of Zagreb, Zagreb, Croatia

Deepak Apte, Bombay Natural History Society, Mumbai, India

Diana Doan-Crider, Texas A&M University, Texas, USA

Dietmar Zinner, German Primate Center, Göttingen, Germany

Dunston P. Ambrose, St. Xavier's College, Palayamkottai, India

E. Vivekanandan, Central Marine Fisheries Research Institute, Kochi, India

Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain

Eric Smith, University of Texas, Arlington, USA

Erin Wessling, Max Planck Institute for Evolutionary Anthropology, Germany

Errol Vela, University of Montpellier, Montpellier, France

Farkhanda Manzoor Dugal, Lahore College for Women University, Pakistan

F.B. Vincent Florens, University of Mauritius, Mauritius

Ferdinando Boero, Università del Salento, Lecce, Italy

Francesco Dal Grande, Senckenberg Gesellschaft für Naturforschung, Frankfurt

Frederic H. Martini, University of Hawaii at Manoa, Honolulu, Hawaii.

George Mathew, Kerala Forest Research Institute, Peechi, India

Gernot Vogel, Heidelberg, Germany

Giovanni Amori, CNR - Institute of Ecosystem Studies, Rome, Italy

Gombobaatar Sunde, Professor of Ornithology, Ulaanbaatar, Mongolia

G.P. Mandal, Zoological Survey of India, Kolkata, India

G.P. Sinha, Botanical Survey of India, Allahabad, India

Hari Balasubramanian, EcoAdvisors, Nova Scotia, Canada

Hayrūnisa Baş Sermenli, Muğla University, Kötekli, Turkey

H.C. Nagaveni, Institute of Wood Science and Technology, Bengaluru, India

H.C. Paulo Corgosinho, Bairro Universitário, Frutal, Brazil

H.N. Kumara, Salim Ali Centre for Ornithology and Natural History, Anaikatty, India

H. Raghuram, The American College, Madurai, India

Hector Barrios-Garrido, James Cook University, Townsville, Australia

Heidi S. Riddle, Riddle's Elephant and Wildlife Sanctuary, Arkansas, USA

Hem Sagar Baral, Charles Sturt University, NSW Australia

Hemant V. Ghate, Modern College, Pune, India

Heok Hee Ng, National University of Singapore, Science Drive, Singapore

Himender Bharti, Punjabi University, Patiala, India

Hui Xiao, Chinese Academy of Sciences, Chaoyang, China

Ian J. Kitching, Natural History Museum, Cromwell Road, UK

Ian Redmond, UNEP Convention on Migratory Species, Lansdown, UK

Indraneil Das, Sarawak, Malaysia

Ivana Karanovic, Hanyang University, Seoul, Korea

J. Jerald Wilson, King Abdulaziz University, Jeddah, Saudi Arabia

J.W. Duckworth, IUCN SSC, Bath, UK

Jack Tordoff, Critical Ecosystem Partnership Fund, Arlington, USA

Jan Zima, Institute of Vertebrate Biology, Brno, Czech Republic

James M. Carpenter, American Museum of Natural History, New York, USA

James Young, Hong Kong Lepidopterists' Society, Hong Kong

Jean-Pierre Boudot, University of Lorraine, Nancy, France

Jeff McNeely, IUCN, Gland, Switzerland

Jesse Leland, Southern Cross University, New South Wales, Australia

Jill Pruetz, Iowa State University, Ames, USA

Jim Sanderson, Small Wild Cat Conservation Foundation, Hartford, USA

Jodi L. Sedlock, Lawrence University, Appleton, USA

John C. Morse, Clemson University, Long Hall, Clemson, USA

John Huber, Canadian National Collection of Insects, Ontario, Canada.

John Noyes, Natural History Museum, London, UK

John Veron, Coral Reef Foundation, Townsville, Australia

continued on the back inside cover

Caption: Digital art of Wolf Snake and text on cover by Arumugham, S., Mango Education, Coimbatore.



HABITAT SUITABILITY AND THREAT ANALYSIS OF GREATER ONE-HORNED RHINOCEROS *RHINOCEROS UNICORNIS* LINNAEUS, 1758 (MAMMALIA: PERISSODACTYLA: RHINOCEROTIDAE) IN RAUTAHAT DISTRICT, NEPAL

Saru Rimal¹, Hari Adhikari² & Shankar Tripathi³

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

OPEN ACCESS



^{1,3} Faculty of Forestry, Agriculture and Forestry University, Hetauda-10, 44100, Hetauda, Nepal

² Earth Change Observation Laboratory, Department of Geosciences and Geography, University of Helsinki, Finland

³ Institute for Atmospheric and Earth System Research, Faculty of Science, University of Helsinki, Finland

¹ rimalsaru7@gmail.com (corresponding author), ² hari.adhikari@helsinki.fi, ³ stripathi@afu.edu.np

Abstract: The Greater One-horned Rhinoceros *Rhinoceros unicornis* has been listed as a Vulnerable species on IUCN Red List, Appendix I of CITES, and a protected animal under the National Parks and Wildlife Conservation Act 2029 B.S., 1973. In Nepal, it was found only in Chitwan, Bardia, Shuklaphanta and Parsa national parks, but it has recently been also reported from the forests of Rautahat. The main objectives of the study were to assess habitat suitability and threats for rhinoceros in Rautahat at an elevation range of approximately 300–1,000 m. Remote sensing data and geospatial modeling techniques were used to assess habitat suitability of rhinoceros. Vegetation assessment was carried out for tree, shrubs, and herbs of plot size 10m × 10m, 5m × 5m, 1m × 1m respectively for habitat suitability. Threat analysis was carried out using purposive sampling among local people and their perceptions were collected on the movement of rhinoceros and threats. The integration of nine explanatory variables showed that about 0.06%, 29.18%, 20.45%, and 50.31% of the study area was found to be most suitable, suitable, moderately suitable and unsuitable habitat respectively for rhinoceros. Out of 30 respondents, 37%, 23%, 20%, and 20% identified the main threat to rhinoceros to be unmanaged habitat, poaching, human-wildlife conflict and environmental factors, respectively. This study recommends parts of the Rautahat District to be extended as the habitat of rhinoceros and starting of immediate conservation initiatives in the area.

Keywords: Habitat suitability, Rhinoceros, threat analysis, vegetation analysis.

Nepali Abstract

एक सिंगे गैंडा IUCN को रातो सुचिमा र CITES को Appendix I मा परेको जिव हो । नेपालमा एक सिंगे गैंडा चितवन, बर्दिया, शुक्लाफाँटा र पर्सा राष्ट्रिय निकुञ्जमा मात्र प तर हालसालै एक सिंगे गैंडा रौतहट जिल्लाको जंगलमा देखियो । यस्तो अवस्थामा रौतहटमा गैंडाको वासस्थानको अवस्था र सतराहरूको बारेमा अनुसन्धान गर्नुपर्ने आवश्यकता छ । अध्ययनको उद्देश्यहरू १. वासस्थान उपयुक्तता पता लगाउनु २. रौतहटमा गैंडालाई हुनसक्ने सतराको विश्लेषण गर्ने थियो । अध्ययन क्षेत्र रौतहट जिल्ला नेपालको दक्षिण भागमा । यसको उचाई लगभग ३०० देखि १००० मि. छ । यसका लागि Remote Sensing र Geospatial Modeling प्रविधिको प्रयोग गरेर वासस्थानको अनुकुलता पता लगा थियो । उपयुक्त वासस्थानको खोजिको क्रममा प.रा.नि. को गैंडाको निरन्तर आवागमन रौतहटमा भएको पाइन्छ । वनस्पतिको मुल्याङ्कनका लागि रुखका लागि १० मि. × १० म् ट्यानका लागि ५ मि. × ५ मि. र फाँटका लागि १ मि. × १ मि. को प्लटमा अध्ययन गरियो । गैंडालाई हुने सतराबारे जनसमुदायमा Purposive Sampling को माध्य बुझियो र गैंडाको हलचल र हलचल हुँदा आउने सतराबारे जनसमुदायको मानसिकता कस्तो छ बुझियो । ९ वटा variables को समिश्रणबाट गैंडाको लागि अध्ययन क्षेत्रको ०.०६% सवैभन्दा उपयुक्त, २९.१८% उपयुक्त, २०.४५% माध्य उपयुक्त, र ५०.३१% क्षेत्र अनुपयुक्त छ । गैंडाले हाल प्रयोग गरेको वासस्थान संरक्षित क्षेत्रबाट बाहिर पर्छ जहाँ, गैंडै धेरै सतरा छ जस्तै, शिकारको सतरा (३७%), ढुन्ड (२३%), अन्यवस्थित वासस्थान (२०%) र वातावरणीय तत्त्वहरू (२०%) । यस अध्ययनले यो बताउँछ कि रौतहट जिल्लाको केहि ठ गैंडाको वासस्थानको लागि बढाउन सकिन्छ र तुरुन्तै संरक्षणका लागि पहल गर्न आवश्यकता छ ।

DOI: <http://doi.org/10.11609/jott.3948.10.8.11999-12007>

Editor: Hem Sagar Baral, School of Environmental Sciences, Charles Sturt University, Albury-Wodonga, Australia.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3948 | Received 07 December 2017 | Final received 21 May 2018 | Finally accepted 01 July 2018

Citation: Rimal, S., H. Adhikari & S. Tripathi (2018). Habitat suitability and threat analysis of Greater One-horned Rhinoceros *Rhinoceros unicornis* Linnaeus, 1758 (Mammalia: Perissodactyla: Rhinocerotidae) in Rautahat District, Nepal. *Journal of Threatened Taxa* 10(8): 11999-12007; <http://doi.org/10.11609/jott.3948.10.8.11999-12007>

Copyright: © Rimal et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: None.

Competing interests: The authors declare no competing interests.

For Author Details & Author Contribution see end of this article.

Acknowledgements: We would like to thank Hari Bhadra Acharya and Ashok Kumar Ram from Parsa National Park, and Maheshwor Dhakal from Ministry of Forest and Environment. In addition, we would like to thank Ashok Kumar Ram for small financial support to carry out field work. This article is based on the bachelor thesis submitted to Agriculture and Forestry University, Faculty of Forestry, Hetauda, Nepal in partial fulfillment of the requirements for the degree of Bachelor of Forestry Science. We would also like to thank Bijay Neupane, Assistant Professor of Institute of Forestry for his encouraging comments. Anonymous reviewers and the journal editor are thanked for useful insights and comments that helped improve this work.

INTRODUCTION

Of the five remaining extant species of rhinoceros, three live in Asia: the Greater One-horned Rhinoceros *Rhinoceros unicornis*, Sumatran Rhinoceros *Dicerorhinus sumatrensis* and Javan Rhinoceros *Rhinoceros sondaicus*, and two are found in Africa: the White Rhinoceros *Ceratotherium simum* and Black Rhinoceros *Diceros bicornis* (Thapa 2016). In Nepal, the Greater One-horned Rhinoceros is found in Chitwan National Park (CNP), Bardia National Park (BNP), Shuklaphanta National Park (ShNP) and Parsa National Park (PNP), and it has recently been reported in the forests of Rautahat District. The Greater One-horned Rhinoceros (Indian Rhino), hereafter “rhinoceros”, has been listed as a Vulnerable species on IUCN Red List of Threatened Species (Talukdar et al. 2008) and is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Rhinoceros is listed as the protected animal under National Parks and Wildlife Conservation Act 2029 B.S., 1973 by the Government of Nepal.

Rhinoceroses are mostly solitary with the exception of mothers and calves and breeding pairs, although they sometimes gather at bathing areas. They are active mostly at night, early in the morning and in the late afternoon (Laurie 1978). In the middle of hot days they are commonly seen resting in the shade, or mud, wallowing and bathing in lakes, rivers, and pools. A recently published report by WWF Nepal showed that habitat loss and poaching are emerging as major threats to rhino conservation (Rookmaaker et al. 2016). Poachers kill rhinoceros for their horns, which are highly valued and used in Chinese traditional medicine to reduce fever and fear, and as an aphrodisiac (Crawford 1994).

Rautahat District is connected on the west to Bara District, which includes PNP. In the past few years Rhinoceros have frequently visited the area from PNP searching for suitable habitats, and the previous trends showed migration of rhinoceros from CNP towards the east via PNP to Rautahat. CNP is contiguous to PNP in the east and PNP, in turn, has some forest connectivity to Rautahat forests on the eastern side. Rautahat District is unique being outside the protected area and highly populated with diverse ethnic communities. Of the three rhinoceroses found in Rautahat, one was killed recently by poachers (Acharya & Ram 2017). Thus, it became necessary to find out the habitat suitability and threats to the rhinoceros in the study area for proper management.

Habitat suitability modeling for wildlife is currently gaining interest in wildlife conservation and management. To define habitat suitability, multivariate models are applied in combination with remote sensing (RS) and geographic information system (GIS). Remote sensing is an invaluable source of information and GIS is an excellent tool for creating land cover and habitat factor maps required for habitat modeling. Remote sensing has been used to produce land cover maps since the 1970s (Bradley & Fleishman 2008; Adhikari & Schneider 2012; Tripathi et al. 2012).

This study used remote sensing data and GIS technology with field study for analysis of habitat condition to predict suitable habitat for rhinoceros in Rautahat. Habitat suitability models have become well-accepted tools to understand the habitat attributes of different organisms, evaluating habitat qualities and developing wildlife management and conservation strategies (Verner et al. 1986; Kafley 2008). Habitat models are based on the relationship between animal and environment (Kushwaha et al. 2005). The habitat suitability index (HSI) modeling assumes that the amount of habitat is related to the potential of the land to support individuals or populations of wildlife and that habitat designated as high quality are more suitable than those assigned lower quality ranking. HSI models are analytical tools for determining relative potential of an area to provide habitat for wildlife (Clevenger et al. 2002).

The main objectives of this study were (1) to assess habitat suitability, and (2) to do a threat analysis for rhinoceros in the study area using geospatial datasets on topography, climate, land use and statistical modeling at the landscape scale in Rautahat District.

MATERIAL AND METHODS

Study area

The study area is situated in Chandrapur Municipality, Gujara Rural Municipality and Phatuwa Bijayapur Rural Municipality of Rautahat District in the central part of Nepal (Fig. 1). It is located between 85.23–85.50 °E and 26.73–27.23 °N. Lower tropical zone lies below 300m and covers 64.4% of the total area of Rautahat and upper tropical zone covers 5.6% of area and elevation ranges from 300–1,000 m (District Report 2011). It covers an area of 112,600ha. Forest covered by Rautahat District is 29,400ha or 26.11% of the forest area including the central ‘Charkoshe Jhadi’ of Nepal. Charkoshe Jhadi is the broad strip of forests south of the Siwaliks from east

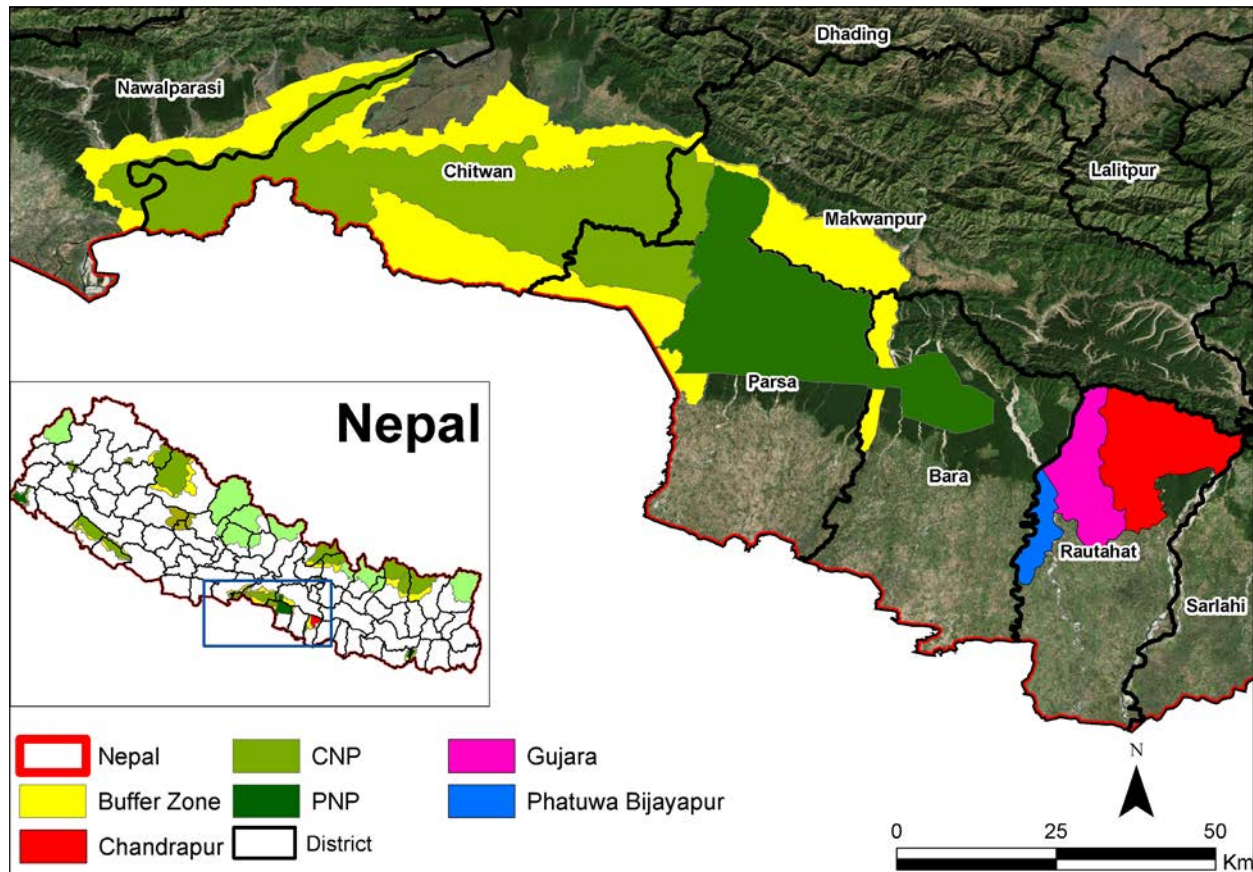


Figure 1. Location of study area

to west along almost the entire length of Nepal. Much of this wildlife-rich habitat has now been lost except those areas that lie in a protected area network. Sal forest *Shorea robusta* is the primary forest type along with mixed hardwood and riverine forests. The climate of Rautahat is tropical to sub-tropical, temperature ranging from 19.6–40 °C and average rainfall is 2,968mm per year (Annual Report, District Forest Office, DFO 2016, Rautahat). Rautahat District is the easternmost district identified under Terai Arc Landscape (TAL) programme (MoFSC 2015).

Bara District includes a part of PNP and lies west of Rautahat District. This district is dominated by 35% *Shorea robusta* forest. The major tree species are *Shorea robusta*, *Terminalia tomentosa*, *Acacia catechu*, *Adina cordifolia*, *Dalbergia sissoo*, with other riverine tree species. The major shrub and grass species in the study area are *Hemalthriya compressa*, *Imperata cylindrica*, *Saccharum spontaneum*, and invasive alien weeds *Mikania micrantha*, *Chromolaena odorata*. This district is an important habitat for a large number of animals including Tiger *Panthera tigris*, One-horned Rhinoceros,

Elephant *Elephas maximus*, Sloth Bear *Melursus ursinus*, Nilgai *Boselaphus tragocamelus*, Sambar Deer *Rusa unicolor*, Spotted Deer *Axis axis*, Wild Boar *Sus scrofa*, and a number of birds, including White-rumped Vulture *Gyps bengalensis*, Eurasian Black Vulture *Aegypius monachus*, Himalayan Griffon Vulture *Gyps himalayensis*, Indian Pitta *Pitta brachyura*, and Great Hornbill *Buceros bicornis*; though it is outside the protected area (Annual Report 2016, District Forest Office Rautahat).

Explanatory variables for modeling habitat suitability assessment

A range of explanatory variables was derived from geospatial datasets. Table 1 presents the complete list of variables. All topographic, climatic, and land use data available for the study area were resampled to 30m resolution and UTM 45N, WGS 84 projection system (Fig. 2). The habitat used by rhinoceros and the variables related to this habitat were established based on the existing information available for the species. In total, nine explanatory variables (aspect, slope, forest cover, precipitation, temperature, road, water, settlement, and

Table 1. Habitat suitability variables and analysis

Data Type	Weighted Influence	Format (Source)	Suitability criteria
Aspect (30m × 30m)	5	Raster (Jaxa DEM) 1*	Most suitable: Flat and South Suitable: East Less Suitable: North Unsuitable: West
Slope (30m × 30m)	10	Raster (Jaxa DEM) 1*	Most suitable: 5 Suitable: 10 Less Suitable: 15 Unsuitable: >15
Forest Cover (30m × 30m)	20	Raster (Globcover) 2*	Most suitable: 0–20 Suitable: 40–70 Less Suitable: 20–40 Unsuitable: > 70–90
Precipitation (1km × 1km)	5	Raster (Worldclim) 3*	Most suitable: 290–315 Suitable: 265–290 Less Suitable: 240–265 Unsuitable: 211–240
Temperature (1km × 1km)	5	Raster (Worldclim) 3*	Most suitable: 28.5–29.8 Suitable: 27–28.5 Less Suitable: 26–27 Unsuitable: 24.9–26
Road	5	Vector (Department of Survey) 4*	Most suitable: > 500m Suitable: 300–500 m Less Suitable: 200–300 m Unsuitable: < 200m
Water	20	Vector (Department of Survey) 4*	Most suitable: within 1km Suitable: 1–1.5 km Less Suitable: 1.5–2 km Unsuitable: > 2km
Settlement	10	Vector (Department of Survey) 4*	Most suitable: > 1km Suitable: 0.5–1 km Less Suitable: 0.3–0.5 km Unsuitable: < 0.3km
Land Cover	20	Vector (Department of Survey) 4*	Most suitable: river and grassland Suitable: Forest Unsuitable: Cultivation

1* http://global.jaxa.jp/press/2015/05/20150518_daichi.html

2* <https://landcover.usgs.gov/glc/TreeCoverDescriptionAndDownloads.php>

3* <http://www.worldclim.org/tiles.php?Zone=28>

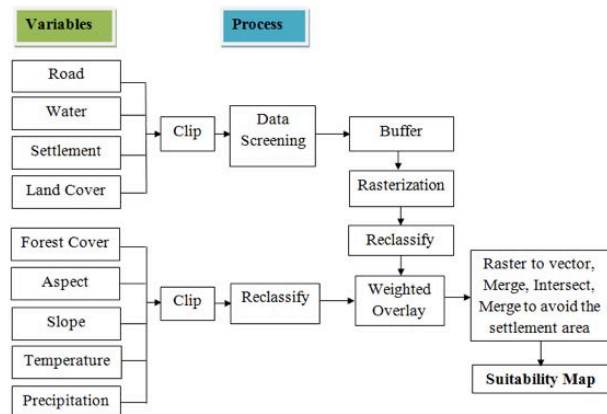
4* Department of Survey, Min Bhawan, Kathmandu, Nepal

land cover) related to habitat requirements of rhinoceros were used (Table 1).

Remote sensing satellite data were used as a source of information, and spatial analysis of the data was performed in Arc GIS Desktop 10.2.2 to process the data. Weightages that influence the habitat of rhinoceros by these different variables were decided after expert consultation from PNP (Table 1).

A four level suitability was depicted on the map with reference to habitat used by rhinoceros. Areas away from human settlements and close to water bodies were categorized as highly suitable while areas near roads and human settlements but away from water bodies were considered as unsuitable for rhinoceros (Thapa & Lichtenenegger 2005).

Suitable habitat categories included the areas currently being used by rhinoceros and the areas that could be potentially used. Overlay process was carried out to produce suitable area map (Fig. 4 (a)). Nine

**Figure 2. Process of preparing suitability map**

suitability maps were prepared based on the explanatory variables (Fig. 4 (b–j)) used in this study.

Field measurement

The field measurements from a total of 26 plots (10m × 10m) were conducted between May–June 2017 and used in this study for habitat assessment (Fig. 3). According to key informant survey, possibility of rhinoceros sightings can be high in this time-period. Sample plot centers were taken in the morning and positioned using Garmin Global Positioning System (GPS) with an accuracy of 2–5 m.

Various quadrats of 10m × 10m were randomly assigned to tree species. Within a quadrat, 5m × 5m quadrats were allocated randomly in the corner for shrub species. Likewise, herbs were recorded from nested sampling of 1m × 1m quadrat within the 5m × 5m quadrat. The distribution of nested sampling within main quadrat (Mandal & Joshi 2014) is shown in Fig. 3.

All plant species within each quadrat were identified and counted. For the entire tree stems, diameters at breast height (DBH) at 1.3m were measured using diameter tape, and height of each stem was measured by a clinometer. A local parataxonomist and field guide identified the tree species. Leaves of unidentified tree species were brought to the faculty of forestry at the Agriculture and Forestry University (AFU) for identification.

Threat analysis

Field visits were undertaken to major places where rhinoceros encounters had been reported, and relevant staff of PNP and district forest office were interviewed. A questionnaire survey was conducted among 30 respondents in the study area, including protected area managers, experts and community representatives; their

Density of species = (Total Number of individuals of a species) / (Total number of plots sampled × area of a plot) 1
Relative density of species (RD) = (Total individuals of species) / (Total individual of all species) 2
Frequency of species = Number of plots in which a particular species occurs / Total number of plot sampled × 100 3
Relative frequency of species (RF) = Frequency value of a species / Frequency value of a species × 100 4
Relative dominance of species = Total basal area of a species / Total basal area of all species × 100 5
Basal area = $\pi d^2 / 4$ 6
IVI = Relative density + Relative frequency + Relative dominance 7
PVX = MX (VFX) 8

where PVX = prominence value of species X; MX = mean percentage cover of species X; FX = Frequency of occurrence of species X

knowledge about rhinoceros and its habitat, threats to rhinoceros in the study area and possible conservation measures were documented.

The vegetation data collected in the field were used to calculate the importance value index (IVI), density, frequency, and relative frequency of the tree species by using the following procedure (Smith 1980).

To calculate the prominence value (PV), the percentage cover of each species is assumed in each quadrat recorded in classes as follows: for high coverage = >50%, medium = 26–50 %, low = 0–25 %. These data were used to calculate prominence value for each species (Jnawali 1995) and it is used to calculate the availability of plants in the study area.

RESULTS

Habitat Suitability Mapping

Suitability map based on RS and GIS application showed that only about 0.06% (28.8ha) of the area

was found to be most suitable, approximately 29.18% (13198.23ha) of the area was found to be suitable, 20.45% (9248.58ha) was moderately suitable and about 50.31% (22759.65ha) was unsuitable habitat for rhinoceros in the study area (Fig. 4 (a)).

Vegetation Analysis

Of the total species of trees recorded in the study area, *Shorea robusta* (IVI=56.35) was found to be the most dominant species followed by *Adina cordifolia* (IVI=19.17), *Mallotus philipensis* (IVI=15.43), and *Trewia nudiflora* (IVI=15.33). Among shrub species, *Leea macrophylla* was the most abundant species (PV=350.49) followed by *Chromolaena odorata* (PV=266.84) and *Clerodendron viscosum* (PV=258.75), and among herb/grass species *Imperata cylindrica* was the most abundant species (PV=285.33) followed by *Cynodon doctylon* (PV=158.85) and *Saccharum spontaneum* (PV=98.51).

Threat Analysis

Almost all the respondents were well informed

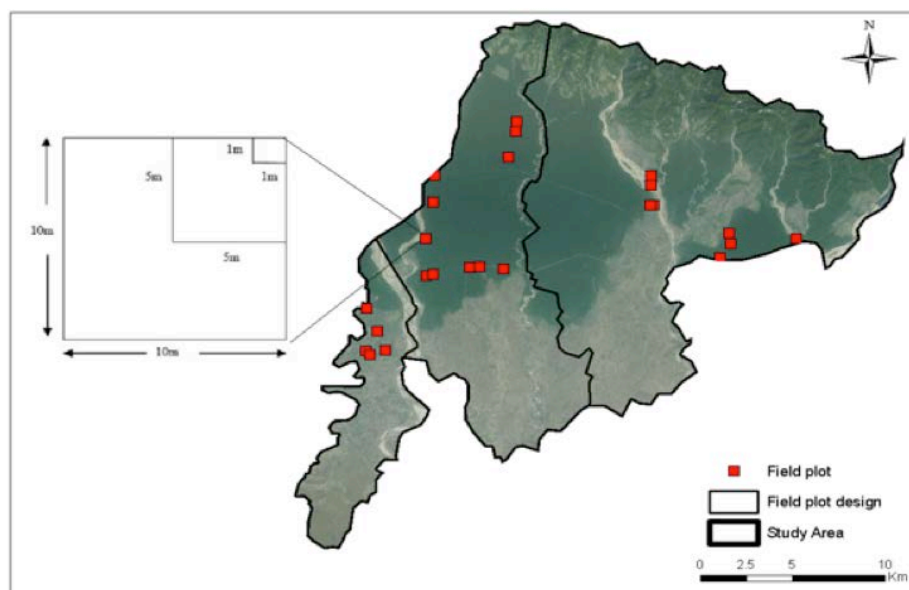


Figure 3. Map showing sample plot locations and layout of the quadrats

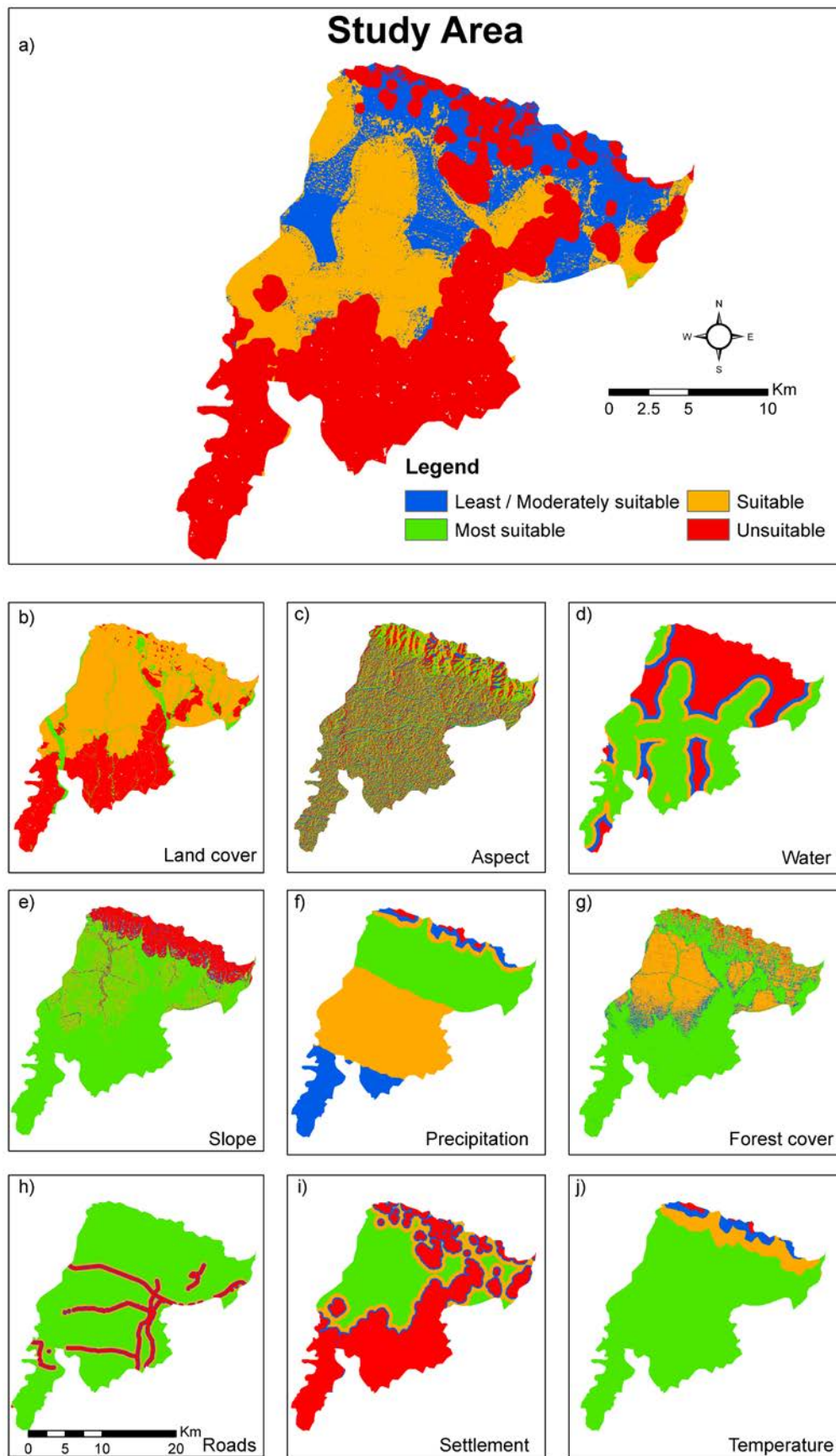


Figure 4. Habitat suitability map of the study area (a) and suitability map of different predictor variables (b–j).

about rhinoceros. About 10%, 87% and 3% of the respondents directly saw, heard and saw indirect signs of rhinoceros presence respectively. Particularly, activities of rhinoceros were found in March to June and October to November. Most of the respondents revealed that unsuitable habitat in PNP was the major cause of rhinoceros dispersal, followed by suitable habitat in Rautahat and encroachment in PNP. A small percentage (10%) of the respondents had no idea about rhinoceros in the study area (Fig. 5a); 43% of respondents answered that rhinos and their habitat were needed for biodiversity conservation; 30% for ecotourism; and 27% for future generations (Fig. 5b).

Among the 30 respondents of the questionnaire survey, about 37% answered that the main threat to rhinoceros and its habitat conservation was poaching, 23% of respondents said conflict, 20% answered that unmanaged habitat was also a threat to rhinoceros, so their conservation may become difficult. Twenty percent of the respondents considered environmental factors as one of the threats to rhinoceros (Fig. 5c). As many as 50% of the respondents answered that awareness program can be the main program for rhinoceros conservation, 32% of respondents gave their view that research programs can help to protect rhinoceros habitat, and 18% of the respondents said that regular patrolling can be helpful in rhinoceros conservation (Fig. 5d).

DISCUSSION

Habitat suitability mapping

Rhinoceroses inhabit the alluvial floodplains with sub-tropical vegetation where water and green growth is found all year round (Prater 1971; Kafley 2008). The results of this study reveal that the rhinoceroses in Rautahat are also found in floodplain grasslands and riverine forest located near perennial water bodies that provide food, cover and wallows throughout the year. A study carried out in Bardiya has shown that rhinoceroses prefer three types of habitat including khair sissoo forest, riverine forest, and tall grassland, and they avoid Sal forest (Jnawali 1995).

Vegetation Analysis

Our study has found out that *Saccharum spontaneum* is the most important grass species for rhinoceros, which is also reported in earlier studies by Laurie (1982), Jnawali (1995) and Pradhan et al. (2007). Kafley (2008) identified the suitable condition for rhinoceros as the areas with the availability of contiguous grasslands

interspersed with sufficient water bodies and sufficient distance from factors of disturbances. Similarly, this study has shown that rhinoceros prefers habitat with mixed forest type with grassland and nearness to water availability. Kafley (2008) documented that 443km² of the CNP is modeled as suitable. The result of this study revealed that 131.98km² of the study area is modeled as suitable habitat, which provides additional shelter to rhinoceros outside the protected areas.

No earlier studies of rhinoceros using GIS and other advanced applications were performed in the study area. Rhinoceros have been using the study area as major habitat for a long time, and this year also there was continuity in their regular visits (Acharya & Ram 2017). So, this study can be the basis for further studies and management of rhinoceros in Rautahat.

People's perceptions

Three to four rhinoceroses are found year-round in Rautahat District. During September 2016, one rhinoceros was shot by poachers. Rhinoceros have been using the Rautahat district as a major habitat for the past few years and continue to make regular visits (Acharya & Ram 2017). Respondents living in the study area reported frequent arrival of rhinoceros in their village and nearby forests. They have a positive attitude towards rhino conservation because of the importance of the species in ecotourism, and biodiversity conservation for future generations. Presently, cases of conflict between humans and rhinoceros are few, but they may increase in the future if concerned authorities are unable to apply proper conservation measures.

Conclusions and Recommendations

Factors affecting the population and habitat status of rhinoceros include poaching, conflict and environmental factors that include roads, rivers, settlements, forest cover, land cover, precipitation, temperature and terrain. The slope is the most important predictor of habitat suitability of terrestrial species, and rhinoceros locations were observed on gentle slopes with suitable vegetation cover and water availability. According to local people, the main causes of movement of rhinoceros were unsuitable habitat in PNP, suitable habitat in Rautahat, and encroachment in PNP. Unsuitable habitat in PNP is the result of weeds and dense forest cover due to forest protection. They want to conserve rhinoceros for ecotourism, biodiversity conservation and for future generations. The habitat used by rhinoceros in the study area is outside the protected area and poses threats like poaching, conflict with local people and unmanaged

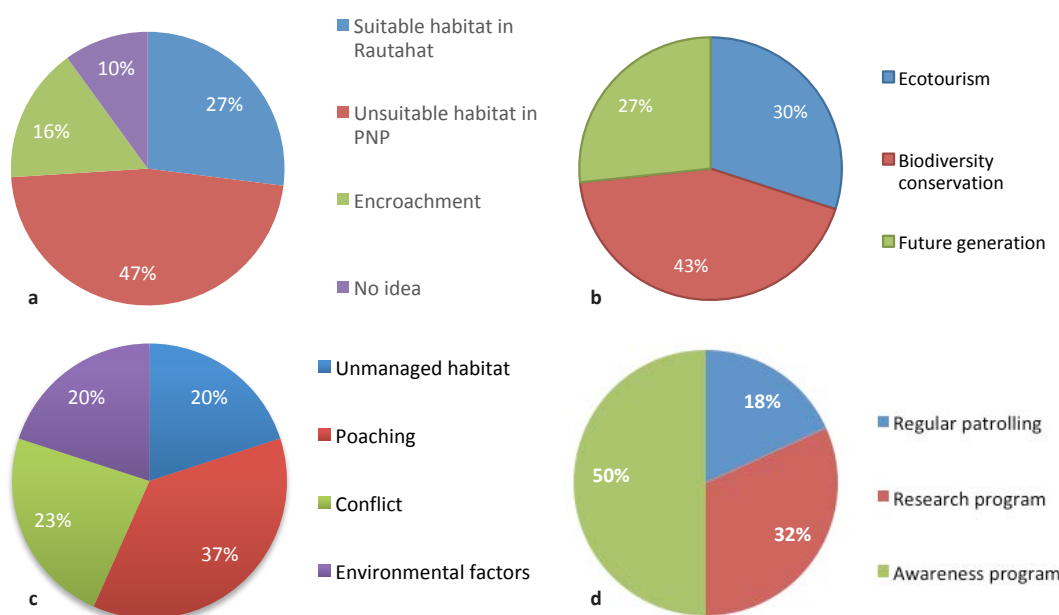


Figure 5. a - Causes of Rhinoceros dispersal; b - Importance of Rhinoceroses; c - Threats to Rhinoceroses; d - Programs for Rhinoceros conservation

habitats. Threats to rhinoceros in the Rautahat District need to be identified and suitably attended. If the government and conservation partners do not pay attention to this migration of rhinoceros from PNP to a new area like Rautahat and other suitable places, rhinoceros may decline in PNP. So, it is vital to conserve rhinoceros and its habitat. Hence, conservation efforts to create better permanent habitat should be provided to maintain remaining rhinoceros population.

Based on the present study, national level policy and conservation programs should be prepared for the conservation and management of rhinoceros in the study area. Since the study area is located outside the protected area, regular monitoring is required and strict laws need to be enforced for the conservation of rhinoceros. PNP and its buffer zone up to Bagmati River need to be extended for better protection of rhinoceros. This research is limited, as only two rhinoceros were present in the study area. The available time for the study was also short. We recommend further study to identify reasons for rhinoceros movement from PNP to the study area.

REFERENCES

- Acharya, H.B. & A.K. Ram (2017). Extended *Rhinoceros unicornis* population, habitat monitoring and rescue from Rautahat district of central Nepal. A report submitted to Department of National Park and Wildlife Conservation, Babarmahal, Nepal.
- Adhikari, H. & T. Schneider (2012). Change detection on the cultural landscape in the Philippines with regards to REDD + pilot area over a period of 21 years. Master Thesis submitted to Technische Universität München, Germany; <http://doi.org/10.13140/RG.2.1.2997.5285>
- Bradley, B. & E. Fleschman (2008). Can remote sensing of land cover improve species distribution modeling? *Journal of Biogeography* 35: 1158–1159; <http://doi.org/10.1111/j.1365-2699.2008.01928.x>
- Clevenger, A.P., J. Wierzchowski, B. Chruszcz & K. Gunson (2002). GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. *Conservation Biology* 16(2): 503–514; <http://doi.org/10.1046/j.1523-1739.2002.00328.x>
- Crawford, C. (1994). In conflicts between the Convention on International Trade in Endangered Species and the EATT in light of actions to halt the Rhinoceros and Tiger trade. *Georgetown International Environmental Law Review* 7: 555.
- DFO (2016). Annual Report. District Forest Office, Rautahat, Nepal.
- District Report (2011). Geographic Information. <http://ddcrautahat.gov.np/ne-brief-introduction/>? (Assessed 21.05.2018)
- Government of Nepal (1973). National Parks and Wildlife Conservation Act.
- IUCN (2008). IUCN Red List Categories. Prepared by the IUCN Species Survival Commission IUCN, Gland, Switzerland.
- Jnawali, S.R. (1995). Population ecology of greater one-horned Rhinoceros (*Rhinoceros unicornis*) with particular emphasis on habitat preference, food ecology and ranging behavior of a reintroduced population in Royal Bardia National Park in Low land Nepal. A doctor scientiarum thesis submitted to Agricultural University of Norway, i–vii, 128pp.
- Kafley, H. (2008). Habitat evaluation and suitability modeling of *Rhinoceros unicornis* in Chitwan National Park, Nepal: A geospatial approach. A report submitted to Aloca Foundation, Institute of International Education, World Wildlife Fund, USA.
- Kushwaha, S.P.S., A. Khan & B. Habib (2005). Evaluation of Samber and Munjtak habitats using geostatistical modelling. *Current Science Association* 86: 1390–1400.
- Laurie, W.A. (1978). The ecology and behavior of the Greater One-horned Rhinoceros. PhD Dissertation. University of Cambridge, Cambridge, UK.
- Laurie, W.A. (1982). Behavioral ecology of the Greater One-horned Rhinoceros (*Rhinoceros unicornis*). *Journal of Zoological Society of*

- London 196: 307–341; <http://doi.org/10.1111/j.1469-7998.1982.tb03506.x>
- Mandal, G. & S.P. Joshi (2014).** Analysis of vegetation dynamics and phytodiversity from three dry deciduous forests of Doon Valley, Western Himalaya, India. *Journal of Asia-Pacific Biodiversity* 7: 292–304; <http://doi.org/10.1016/j.japb.2014.07.006>
- MoFSC (2015).** Strategy and Action Plan 2015–2025, Terai Arc Landscape, Nepal. Ministry of Forests and Soil Conservation, Singha Durbar, Kathmandu, Nepal.
- Pradhan, N.M.B., P. Wegge, S.R. Moe & A.K. Shrestha (2007).** Feeding ecology of two endangered systematic mega-herbivores; Asian Elephant (*Elephas maximus*) and Greater One-horned Rhinoceros (*Rhinoceros unicornis*) in lowland Nepal. *Wildlife Biology* 14(1): 147–154; [http://doi.org/10.2981/0909-6396\(2008\)14\[147:FEOTES\]2.0.CO;2](http://doi.org/10.2981/0909-6396(2008)14[147:FEOTES]2.0.CO;2)
- Prater, S.H. (1971).** *The Book of Indian Animals*. Bombay Natural History Society, Twelfth Reprint 2005, 324pp.
- Rookmaaker, K., A. Sharma, J. Bose, K. Thapa, D. Dutta, B. Jeffries, A.C. Williams, D. Ghose, M. Gupta & S. Tornikoski (2016).** The Greater One-horned Rhino-Past, Present and Future, WWF, Gland, Switzerland.
- Smith, R.L. (1980).** *Ecology and Field Biology - 3rd Edition*. Harper and Row Publishers, New York, xii+835pp.
- Talukdar, B.K., R. Emslie, S.S. Bist, A. Chaudhary, S. Ellis, B.S. Bonal, M.C. Malakar, B.N. Talukdar & M. Burva (2008).** *Rhinoceros unicornis*. The IUCN Red List of Threatened Species 2008: e. T 19496A8928657. Downloaded on 03 July 2018; <http://doi.org/10.2305/IUCN.UK.2008.RLTS.T19496A8928657.en>
- Thapa, R. (2016).** Challenges of rhino conservation in Chitwan National Park. *Journal of Nepal Science Olympiad* 1:1-13.
- Thapa, T.B. & J. Lichtenegger (2005).** Rhinoceros (*Rhinoceros unicornis*) habitat evaluation in Bardia National Park using Remote Sensing and GIS. Decadal Proceedings of UN-EAS-SIDA Training Course Application, 1–9pp.
- Tripathi, S., S. Rayamajhi & L. Puri (2012).** A GIS-based approach to habitat suitability of Wild Water Buffalo (*Bubalus arnee*) on the Rapti floodplain of Chitwan National Park. Thesis submitted to Tribhuvan University.
- Verner, J., M.L. Morrison & C.J. Ralph (1986).** *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates: based on an international symposium held at Stanford Sierra Camp, Fallen Leaf Lake, California, 7–11 October 1984* University of Wisconsin Press.

Author Details: SARU RIMAL has completed her Bachelor of Science degree in Forestry from Agriculture and Forestry University. She is interested in wildlife, conservation biology, RS and GIS. HARI ADHIKARI is working as researcher and PhD candidate in University of Helsinki, Finland. He has international working experience on wildlife and forestry in Nepal, India, Philippines, Kenya, Germany and Finland. SHANKAR TRIPATHI is a young forestry professional with the interest in forest measurement and application of RS and GIS in the field of nature conservation. He has completed BSc and MSc degree in Forestry from Tribhuvan University and has been serving as a faculty on the Faculty of Forestry at Agriculture and Forestry University since 2016.

Author Contribution: SR planned and conducted this research, HA and ST supervised this research. Hari, Saru and Shankar together worked on manuscript. HA and SR collected RS and GIS data. SR and ST collected field data.





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

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2018 | 10(8): 12008–12017

CAMERA-TRAPPING SURVEY TO ASSESS DIVERSITY, DISTRIBUTION AND PHOTOGRAPHIC CAPTURE RATE OF TERRESTRIAL MAMMALS IN THE AFTERMATH OF THE ETHNOPOLITICAL CONFLICT IN MANAS NATIONAL PARK, ASSAM, INDIA

OPEN ACCESS



Dipankar Lahkar ¹, M. Firoz Ahmed ², Ramie H. Begum ³, Sunit Kumar Das ⁴,
Bibhuti Prasad Lahkar ⁵, Hiranya K. Sarma ⁶ & Abishek Harihar ⁷

^{1,3} Department of Life Science and Bioinformatics, Assam University (Diphu campus), Diphu, Karbi Anglong, Assam 782462, India

^{1,2,5} Aaranyak, 13, Tayab Ali Byelane, Bishnu Rabha Path, Guwahati, Assam, 781028, India

⁴ WWF-India, Parvati Nagar, Tezpur, Assam, 784001, India

⁶ Office of the Field Director, Manas Tiger Reserve, Assam Forest Department, Barpeta Road, Barpeta, Assam 781315, India

⁷ Panthera, 8 West 40th Street, 18th Floor, New York, 10018, USA

¹ Nature Conservation Foundation (NCF), 3076/5, IV Cross, Gokulam Park, Mysore 570002, India

¹ dipankar.lahkar@gmail.com, ² mfa.aaranyak@gmail.com (corresponding author), ³ ani.ara73@gmail.com, ⁴ sunit.das219@gmail.com, ⁵ bplahkar@gmail.com, ⁶ hiranya1961@gmail.com, ⁷ harihar.abishek@gmail.com

Abstract: Information on the presence and distribution of species is crucial for conservation planning and management within a region. Documentation of species assemblages in Manas National Park (MNP) in the aftermath of conflict is critical for informed conservation interventions. For nearly two decades (1990–2010), conservation efforts in MNP were compromised by ethno-political conflict. We conducted camera trapping surveys of terrestrial mammals across three administrative forest ranges (Panbari, Bansbari and Bhuyanpara) of MNP in 2017. A systematic survey with 118 trap locations accumulated data over 6,173 trap-days. We obtained 21,926 photographs of mammals belonging to 13 families and 25 species, of which 13 are threatened. We calculated photographic capture rate index (PCRI) using independent events. Trap specific PCRI's were used to map the spatial variation in capture rates. We observed variation in capture rate between Bansbari-Bhuyanpara where conflict ended in 2003 and has remained peaceful, and Panbari, a forest range where conflict ended later in 2016. Our results further indicate lower capture rates of mammalian prey species and small felids, but higher capture rates of four large carnivores in Panbari as opposed to Bansbari-Bhuyanpara. These results highlighted the fact that despite a history of ethno-political conflict in the region, although almost all mammalian species expected to occur in the park were detected and confirmed, present evidence indicated ethno-political conflict influences the distribution of several key species. In depth studies assessing mammalian prey densities, distribution and density are required to further understand the effects of conflict.

Keywords: Camera trap survey, capture rate, ethno-political conflicts, Manas National Park.

DOI: <http://doi.org/10.11609/jott.4039.10.8.12008-12017> | **ZooBank:** urn:lsid:zoobank.org:pub:08554F31-1BC3-40F6-95E4-53E433552DBA

Editor: Dr. James McNamara, The Breakthrough Institute, Oakland, California.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 4039 | Received 30 January 2018 | Final received 04 June 2018 | Finally accepted 27 June 2018

Citation: Lahkar, D., M.F. Ahmed, R.H. Begum, S.K. Das, B.P. Lahkar, H.K. Sarma & A. Harihar (2018). Camera-trapping survey to assess diversity, distribution and photographic capture rate of terrestrial mammals in the aftermath of the ethno-political conflict in Manas National Park, Assam, India. *Journal of Threatened Taxa* 10(8): 12008–12017; <http://doi.org/10.11609/jott.4039.10.8.12008-12017>

Copyright: © Lahkar et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: Government of India, Government of Assam, IUCN-KfW and Panthera.

Competing interests: The authors declare no competing interests.

For Author Details, Author Contribution and Acknowledgements see end of this article.

Aaranyak



INTRODUCTION

Information on the presence and distribution of species within a region is crucial for planning and evaluating conservation strategies (Tobler et al. 2008). This is especially true in sites where armed conflict has complicated conservation efforts (Hanson et al. 2009; Daskin & Pringle 2018) and impacted species populations and habitats. There is no general consensus as to whether conflicts have positive impacts on wildlife (through relaxing pressure on wildlife when people avoid combat zones or the decline of extractive industries; Hallagan 1981; Butsic et al. 2015) or negative impacts (through direct killing from the use of ordnance and chemicals or bushmeat hunting by soldiers; Orians & Pfeiffer 1970; de Merode et al. 2007; Beyers et al. 2011). Thus it is critical to assess the effects of conflict on biodiversity.

Manas National Park (MNP), spanning 500km² is located in the eastern Himalayan biodiversity hotspot. Falling within two administrative districts (Chirang and Baksa) of the state of Assam that are under the administration of the Bodoland Territorial Council (BTC), this region experienced intense ethno-political conflict in the late 1980s until 2003. During this period the population of Indian Rhinoceros *Rhinoceros unicornis* was poached out, necessitating a reintroduction program to repopulate the park (Barman et al. 2014). Preliminary studies and anecdotal evidence suggest that the conflict has severely impacted other wildlife species as well (Goswami & Ganesh 2014).

It is noteworthy that 80% of worldwide armed conflicts between 1950 and 2000 overlapped with biodiversity hotspots (Hanson et al. 2009). A more recent analysis from Africa highlights the fact that population trajectories of large mammals fell significantly below replacement levels (i.e., instantaneous rate of increase of population; λ less than 1) with an increase in conflict frequency (Daskin & Pringle 2018). Therefore, documenting species assemblages in the aftermath of conflict is critical to inform subsequent conservation interventions.

In this study we conducted camera trapping surveys across three administrative forest ranges (Panbari, Bansbari and Bhuyanpara) of MNP in 2017 with the aim to (a) document the mammalian species assemblage of the park, and (b) understand the influence of civil conflict on the mammalian assemblage. Given that there is no comparable data on mammal distribution prior to the conflict from the site, it was not possible for us to make direct comparisons of pre and post conflict effects on

the mammalian assemblage. Therefore, we evaluated differences in photo capture rates of mammalian prey and large carnivore species between Panbari (a forest range with conflict until 2016) and Bansbari-Bhuyanpara (forest ranges that have been conflict-free since 2003). These two forest sections of MNP differ in their history of conflict but are similar in terrain, climate, vegetation communities, and faunal assemblages. Therefore, we assume our comparisons to serve as a proxy for the effects of conflict.

MATERIAL AND METHODS

Study site

MNP, situated in the eastern Himalayan biodiversity hotspot, is also an UNESCO Natural World Heritage Site, a tiger reserve, an elephant reserve and a biosphere reserve. Contiguous with Royal Manas National Park (RMNP) in Bhutan, it is home to several endangered species. Located in the foothills of the Himalaya, MNP is predominantly flat, with the mountainous regions primarily falling within RMNP, Bhutan. The vegetation of MNP can be broadly classified into eastern wet alluvial grasslands, moist deciduous, and semi-evergreen forests (Champion & Seth 1968).

Spread over Kokrajhar, Chirang, Baksa and Udalguri districts of the Bodoland Territorial Areas Districts (BTAD) of Assam, much of the forests of the Manas Tiger Reserve (including core area of MNP) experienced large scale deforestation (i.e., conversion of forests to farmland and settlements) during the conflict period leading to the loss of over 40% of primary habitats (Sarma et al. 2008; Lahkar et al. 2012). While political stability was initiated in 2003 with the formation of the BTAD, since 2004, there have been several incidents of ethnic conflict in the region emphasizing the fragile socio-political environment around this site (Web data source: South Asia Terrorism Portal, Satp.org).

The forest ranges of Bansbari and Bhuyanpara have largely remained conflict free since 2003. Occasional conflict in Panbari until 2016 has resulted in our inability to conduct surveys within the forest range. Although we, in collaboration with the park management, have been carrying out long-term biological monitoring using camera traps since 2010 across Bansbari and Bhuyanpara, it was only in 2017 that surveys could be undertaken simultaneously across all three ranges of MNP (Panbari, Bansbari and Bhuyanpara).

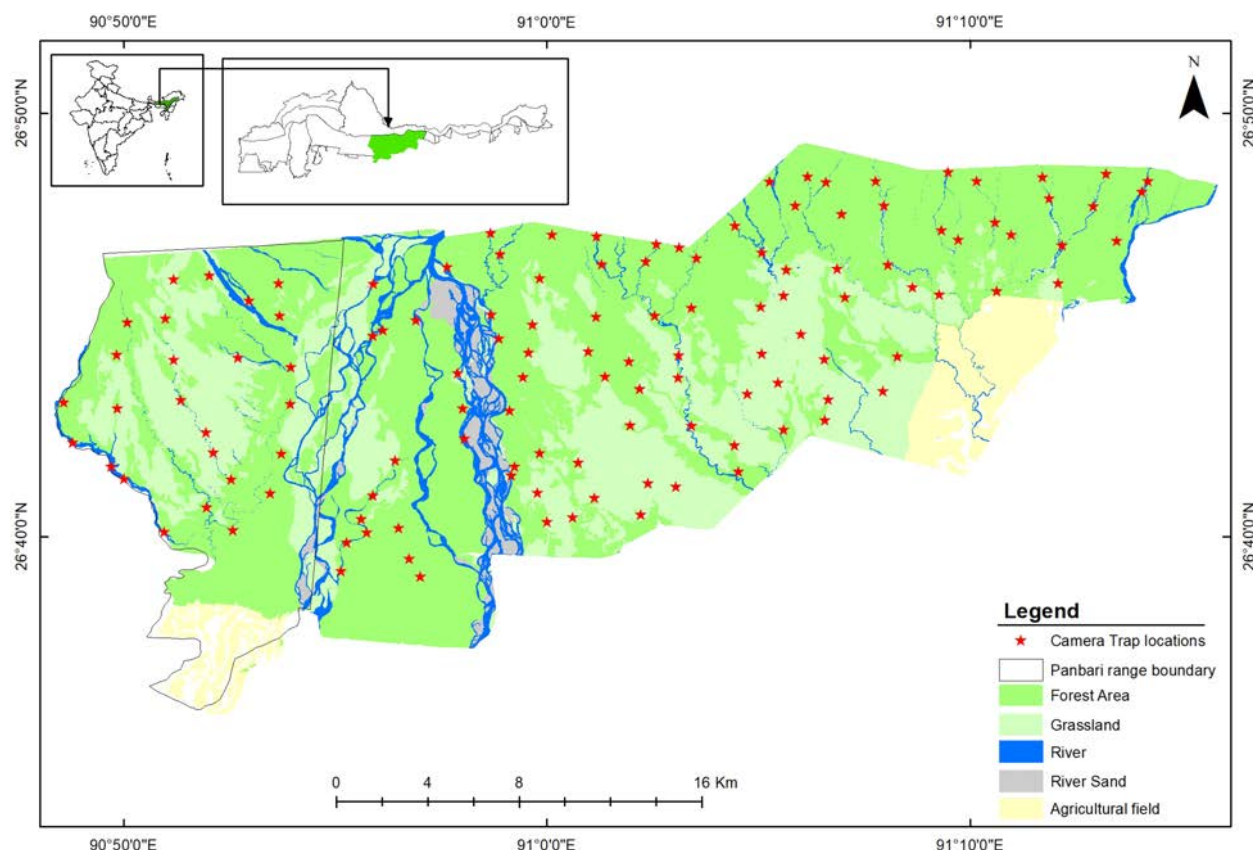


Figure 1. Manas National Park (MNP) highlighting the Panbari range with back boundary.

Field and analytical methods

We conducted a camera trapping survey in the winter of 2016–17 from 28 December 2016 to 24 February 2017 covering the three ranges of Panbari, Bansbari and Bhuyanpara. We used 4km² grids to guide camera placement. Cameras were operational for 24 hours a day. We used Panthera (New York, USA) V4 & V5 digital white flash passive camera traps mounted on trees, on poles in steel cages customised specifically for the cameras to minimise the damage from wild animals. In total, camera traps were placed at 118 locations (26 in Panbari and 92 in Bansbari-Bhuyanpara; Fig. 1).

We first downloaded photographs from all the trap stations across the park at regular intervals (usually twice a week) and catalogued all captures using Camera Trap File Manager software (Olliff et al. 2014). During the cataloguing process species identity was confirmed based on expert knowledge. We also referred to Menon (2014) to confirm species identity.

The camera traps were operational for 24 hours a day and each day was counted as a trap-day. The trapping effort at different trap locations differed due to time and days a camera trap was active. On average camera traps

were operational for 52.3 trap-days. To calculate the photo-capture rate index (PCRI) of all species captured we first identified independent captures (i.e., captures that were 30-minutes apart for each station). We then divided the number of independent captures obtained at each trap by trap-specific effort (i.e., number of trap-days that a particular trap was active) and expressed the estimate per 100 trap-days (Carbone et al. 2001). Trap specific PCRI were then used to map the spatial variation in capture rates. All maps were created in the open source software QGIS (QGIS Development Team 2012). To assess the difference in PCRI of mammalian prey and large carnivores between Panbari and Bansbari-Bhuyanpara, we summarized species-specific PCRI and tested for differences using a two sample T-test assuming unequal variances. Given that we were conducting a series of significance tests on the same set of data, we set the false discovery rate to 10% and used Benjamini-Hochberg procedure (Benjamini & Hochberg 1995).

RESULTS

Camera trapping effort totaled 6,173 trap-days in 2016–17 spread across MNP. We obtained 21,926 photographs of mammals from which we identified 25 mammal species belonging to 13 families (Appendix 2). Of these, six species are Endangered and seven are Vulnerable as per the IUCN Red List of Threatened Species (Table 1; IUCN 2017).

In addition to 2016–17, using the data from long term monitoring study in MNP since 2010, we observed presence of number of other species which included Spotted Deer *Axis axis* (confirmed its eastern range limit in Panbari; Least Concern), Chinese Pangolin *Manis pentadactyla* (Critically Endangered), Marbled Cat *Pardofelis marmorata* (Near Threatened), Golden Jackal *Canis aureus* (Least Concern), and Painted Bat *Kerivoula picta* (Least Concern).

For mammalian prey and large carnivore species

we mapped the spatial variation in photo capture rates across the Park (Figs. 2 & 3). In addition, we assessed the variation in capture rates between Panbari and Bansbari-Bhuyanpara (Figs. 4 & 5). In general our results indicated lower capture rates of mammalian prey species in Panbari as opposed to Bansbari-Bhuyanpara, while for four large carnivore species photo capture rates were higher in Panbari compared to Bansbari-Bhuyanpara. Significant differences in capture rates using a two sample T-test assuming unequal variances were, however, noticed only among four mammalian prey (Barking Deer, Sambar, Gaur and Buffalo) and one large carnivore (Wild Dog) (Figs. 4 & 5) (Appendix 1).

DISCUSSION

Our surveys confirm the presence of 25 mammalian species photo-captured in MNP, 13 of which are

Table 1. Summary of animals recorded in the Manas National Park, Assam, India from 28 December 2016 to 24 February 2017.

	Family	Common name	Scientific name	IUCN category	PCRI (CI 95%)
1	Felidae	Royal Bengal Tiger	<i>Panthera tigris</i>	Endangered	4.84 (3.21–6.47)
2	Felidae	Common Leopard	<i>Panthera pardus</i>	Vulnerable	5.42 (4.05–6.79)
3	Felidae	Clouded Leopard	<i>Neofelis nebulosa</i>	Vulnerable	0.54 (0.08–0.99)
4	Felidae	Leopard Cat	<i>Prionailurus bengalensis</i>	Least Concern	3.19 (2.32–4.06)
5	Felidae	Jungle Cat	<i>Felis chaus</i>	Least Concern	0.25 (0.11–0.40)
6	Canidae	Wild Dog	<i>Cuon alpinus</i>	Endangered	0.62 (0.32–0.92)
7	Cervidae	Barking Deer	<i>Muntiacus muntjak</i>	Least Concern	4.24 (2.99–5.50)
8	Cervidae	Hog Deer	<i>Axis porcinus</i>	Endangered	2.76 (1.24–4.27)
9	Cervidae	Sambar	<i>Rusa unicolor</i>	Vulnerable	22.80 (17.86–27.73)
10	Cervidae	Swamp Deer	<i>Rucervus duvaucelii</i>	Vulnerable	0.41 (0.0–0.92)
11	Suidae	Wild Pig	<i>Sus scrofa</i>	Least Concern	5.45 (4.10–6.79)
12	Bovidae	Gaur	<i>Bos gaurus</i>	Vulnerable	7.20 (5.23–9.15)
13	Bovidae	Wild Water Buffalo	<i>Bubalus arnee</i>	Endangered	3.50 (2.36–4.64)
14	Elephantidae	Asian Elephant	<i>Elephas maximus</i>	Endangered	17.21 (13.36–21.06)
15	Leporidae	Indian Hare	<i>Lepus nigricollis</i>	Least Concern	1.12 (0.59–1.65)
16	Leporidae	Hispid Hare	<i>Caprolagus hispidus</i>	Endangered	0.23 (0.03–0.42)
17	Viverridae	Large Indian Civet	<i>Viverra zibetha</i>	Least Concern	1.30 (0.77–1.82)
18	Viverridae	Small Indian Civet	<i>Viverricula indica</i>	Least Concern	2.69 (1.75–3.62)
19	Viverridae	Common Palm Civet	<i>Paradoxurus hermaphroditus</i>	Least Concern	0.70 (0.29–1.11)
20	Herpestidae	Crab-eating Mongoose	<i>Herpestes urva</i>	Least Concern	0.39 (0.18–0.59)
21	Herpestidae	Common Mongoose	<i>Herpestes edwardsii</i>	Least Concern	0.04 (0.0–0.10)
22	Hystricidae	Malayan Porcupine	<i>Hystrix brachyura</i>	Least Concern	1.51 (0.92–2.09)
23	Ursidae	Asiatic Black Bear	<i>Ursus thibetanus laniger</i>	Vulnerable	0.046 (0.0–0.10)
24	Rhinocerotidae	Indian Rhinoceros	<i>Rhinoceros unicornis</i>	Vulnerable	0.91 (0.10–1.72)
25	Mustelidae	Yellow-throated Marten	<i>Martes flavigula</i>	Least Concern	0.13 (0.03–0.233)

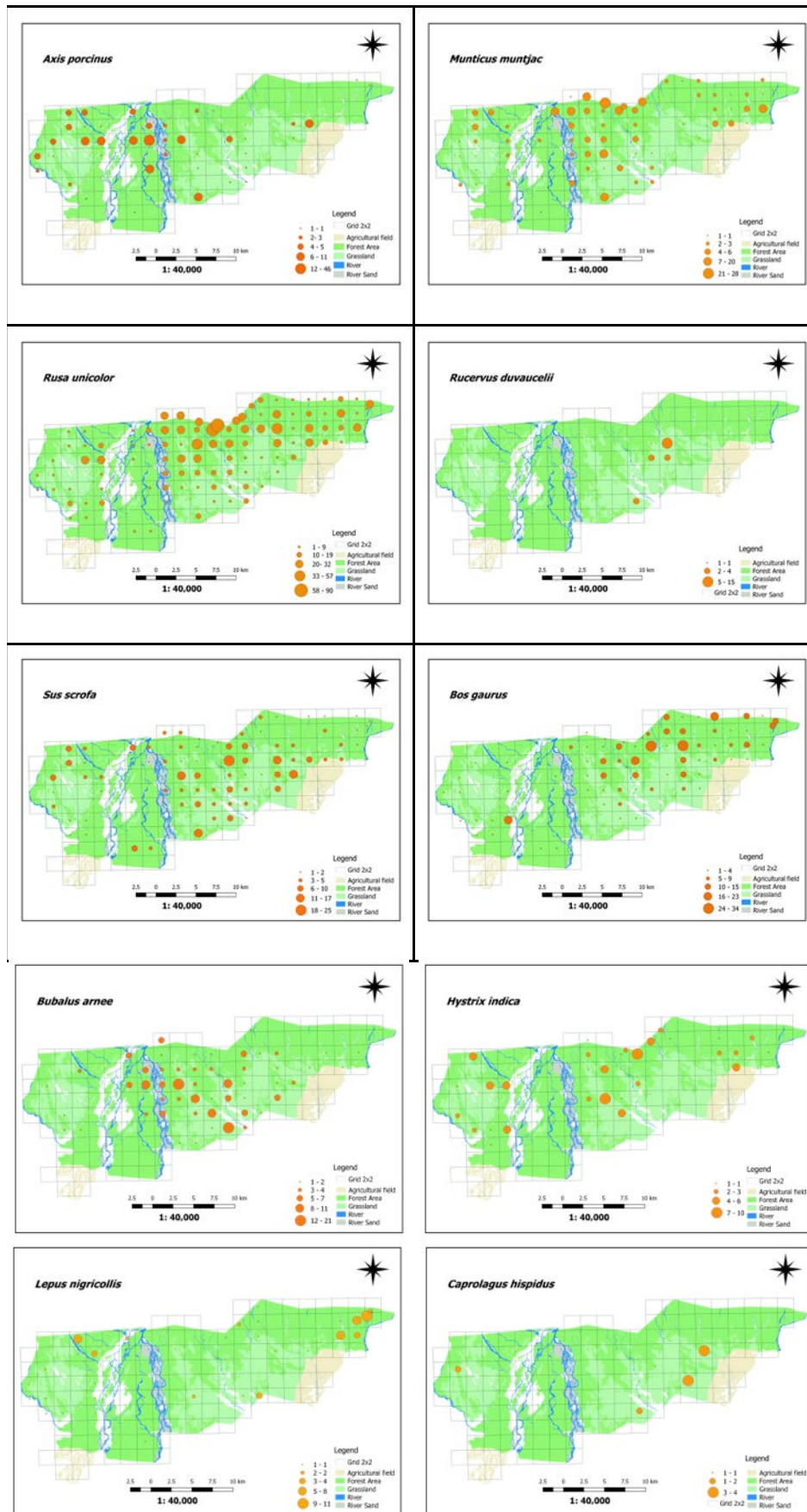


Figure 2. Photographic capture rate index of the mammalian prey species of MNP.

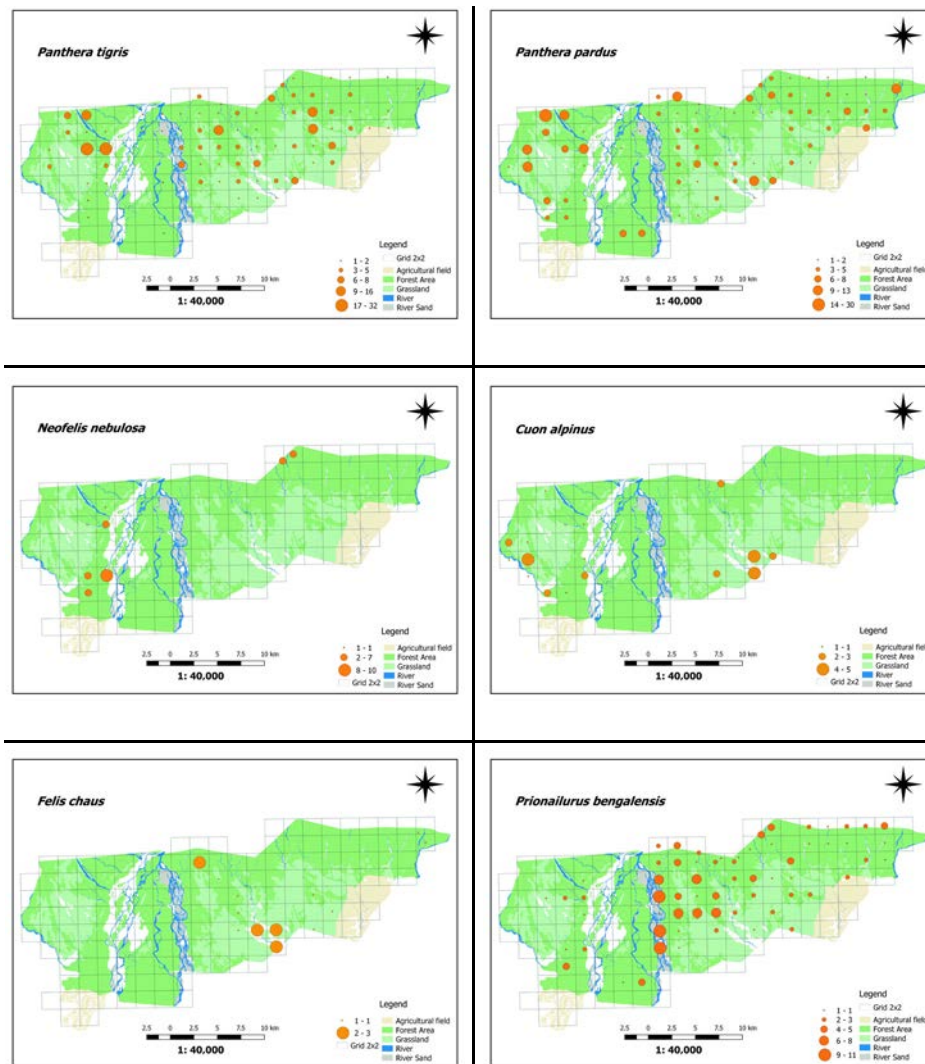


Figure 3. Photographic capture rate index of the major mammalian predator species of MNP.

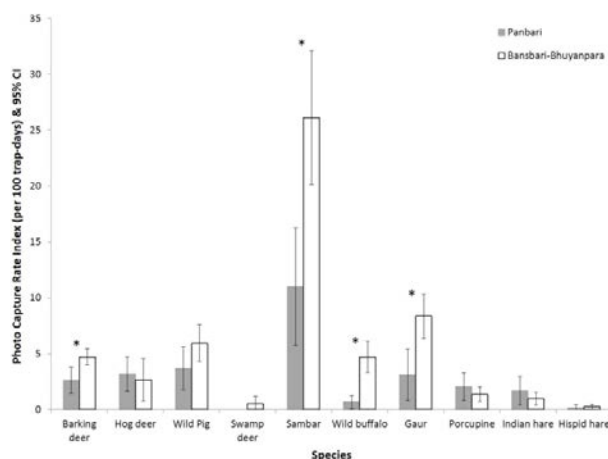


Figure 4. Variation in photographic capture rates of mammalian prey species between Panbari and Bansbari-Bhuyanpara ranges of MNP, from 28 December 2016 to 24 February 2017. Note: * indicates that mean PCRI differed significantly between Panbari and Bansbari-Bhuyanpara ranges

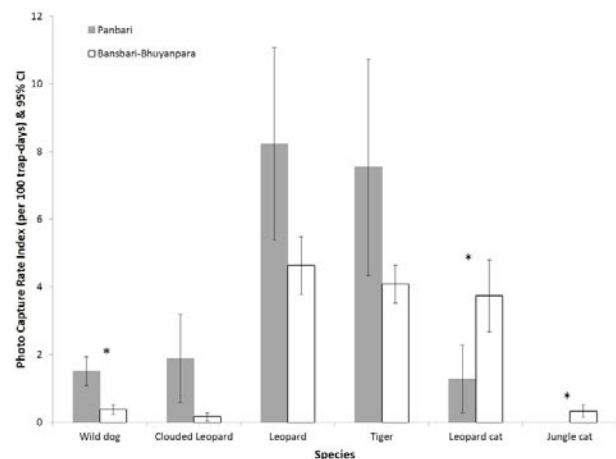


Figure 5. Variation in photographic capture rates of mammalian carnivore species between Panbari and Bansbari-Bhuyanpara ranges of MNP, from 28 December 2016 to 24 February 2017. Note: * indicates that mean PCRI differed significantly between Panbari and Bansbari-Bhuyanpara ranges.

threatened species (IUCN 2017). Although the camera trapping surveys underrepresented species groups such as rodents, arboreal and aerial mammals, direct observational records confirm the presence of three species of primates, Capped Langur *Trachypithecus pileatus* (Vulnerable), Golden Langur *Trachypithecus geei* (Endangered), and Rhesus Macaque *Macaca mulatta* (Least Concern). In addition, Black Giant Squirrel *Ratufa bicolor* (Near Threatened), Himalayan Striped Squirrel *Tamias maclellandi* (Least Concern) and one species of Suidae, Pigmy Hog *Porcula salvania* (Critically Endangered) were also recorded during the period of our long-term biological monitoring. These photo-capture results highlight the fact that despite a long history of ethno-political conflict in the region, almost all mammalian species expected to occur in the region were present and detected during this study, with the exception of Sloth Bear *Melursus ursinus* (Vulnerable) and Fishing Cat *Prionailurus viverrinus* (Vulnerable).

It is observed that ethno-political conflict likely has some impacts on abundance and distribution of species and habitats. While the mammalian species assemblage in MNP appears to be intact, we detect differences among photo capture rates of several species between Panbari (a forest range with conflict until 2016) and Bansbari-Bhuyanpara (forest ranges that have been conflict-free since 2003). In general, prey capture rates were higher in Bansbari-Bhuyanpara compared to Panbari, and significant differences were noticed for four mammalian prey species (i.e., Wild Buffalo, Gaur, Sambar and Barking Deer; Fig. 4). Three of these (Wild Buffalo, Gaur and Sambar; over 175kg) are large prey species that are all threatened and particularly vulnerable to poaching (Wolf & Ripple 2016; IUCN 2017). In the case of large mammalian carnivores, however, species capture rates were higher in Panbari compared to Bansbari-Bhuyanpara, although significant differences were noticed only for Wild Dogs (Fig. 5). While it is possible that Panbari acted as a refuge for large carnivores as villagers may have avoided the combat zone, it is also possible that disturbances emanating from the conflict could have depressed large prey populations. Disturbances, however, were more of armed militants camping deep inside the Panbari range two to three years preceding this survey, rather than ethnic conflict as such or severe anthropogenic disturbances due to natural resource collection. Thus, the disturbances within the park during that period were mostly related to hunting (potentially ungulate species) for food by those camping inside as well as subsequent sanitization operations by government forces.

From our study it appears that RMNP in Bhutan situated immediately north of MNP, next to Panbari, likely acted as a refuge, particularly for long ranging carnivore species. This is evidenced by the fact that in 2017 our camera trapping data confirmed presence of eight individual tigers (five males and three females) in Panbari range of which three individuals were captured the previous year (2016) in RMNP (Singye Wangmo pers. comm. 22 January 2018). This also indicates that the large carnivores have taken the advantage of the progressively re-established security in the area and rapidly moved there. The animals probably began using that area as well but did not relocate there - perhaps their ranges are wide enough to use portions of both areas. This may, however, also negatively impact the herbivore population that are still recovering and thus, may take longer to re-establish themselves.

Ideally, long-term data on population trajectories are required to uncover the effects of conflict-related disturbance on populations. MNP offers us the opportunity to compare capture rates of wildlife species across two study blocks that primarily differ in their history of ethno-political conflict. The contiguity within TraMCA (Trans-boundary Manas Conservation Area) certainly has a positive effect contributing to the repopulation of large carnivores in the aftermath of the conflict as RMNP has acted as a refuge for the animals displaced by disturbances in MNP. Ahmed et al. (2015) have highlighted the trans-boundary importance of the TraMCA based on data obtained through synchronized camera trapping exercises across the boundary. The present study further highlights the importance of large and contiguous conservation areas for the conservation of biodiversity.

Our study found camera trapping to be an effective method to document particularly rare and elusive mammalian species and their relative abundance across the park. Photographic capture-recapture methods could help assess the population trajectories of individually identifiable species such as tigers, leopards, clouded leopards and leopard cats. Additionally, the baselines we set through this study could be used to monitor future changes in the capture rates of several species, especially those which are not individually identifiable (e.g., Wild Dogs and Jungle Cats).

In conclusion, we present evidence that ethno-political conflict has likely influenced the spatial variation of several species in Manas National Park. It is critical, however, to note that more detailed studies assessing mammalian prey densities, distribution and density of large carnivores and correlation with specific

factors emanating from conflict are required to further understand the effects of conflict and peacetime conservation efforts on the species assemblage and abundances.

REFERENCES

- Ahmed, M.F., S. Wangmo, D. Lahkar, P. Chakraborty, A. Sarmah, J. Borah, D. Wangchuk, T. Nidup, T. Wangchuk, H.K. Sarma, A. Harihar & R. Pickles (2015). Tigers of Transboundary Manas Conservation Area, 2016. Aaranyak, Department of Environment and Forest, Government of Assam (BTC), Department of forests and Park Services, Ministry of Agriculture and Forests, Royal Government of Bhutan and WWF-India, Technical Report, Assam, India. 50pp.
- Barman, R., B. Choudhury, N.V.K. Ashraf & V. Menon (2014). Rehabilitation of Greater One-horned Rhinoceros calves in Manas National Park, a World Heritage Site in India. *Pachyderm* 55: 78–88.
- Benjamini, Y. & Y. Hochberg (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society Bulletin* 57: 289–300.
- Beyers, R.L., J.A. Hart, A.R.E. Sinclair, F. Grossmann, B. Klinkenberg & S. Dino (2011). Resource wars and conflict ivory: the impact of civil conflict on elephants in the Democratic Republic of Congo - the case of the Okapi Reserve. *PLoS ONE* 6(11): e27129; <http://doi.org/10.1371/journal.pone.0027129>
- Butsic, V., M. Baumann, A. Shortland, S. Walker & T. Kuemmerle (2015). Conservation and conflict in the Democratic Republic of Congo: The impacts of warfare, mining, and protected areas on deforestation. *Biological Conservation* 191: 266–273; <http://doi.org/10.1016/j.biocon.2015.06.037>
- Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J.R. Ginsberg, M. Griffiths, J. Holden, K. Kawanishi, M. Kinnaird, R. Laidlaw, A. Lynam, D.W. Macdonald, D. Martyr, C. McDougal, L. Nath, T. O'Brien, J. Seidensticker, D.J.L. Smith, M. Sunquist, R. Tilson & W.N. Wan Shahruddin (2001). The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation* 4: 75–79; <https://doi.org/10.1017/S1367943001001081>
- Champion, H.G. & S.K. Seth (1968). *A Revised Forest Types of India*. Manager of Publications, Government of India, Delhi, 404pp.
- Daskin, J. & R.M. Pringle (2018). Warfare and wildlife declines in Africa's protected areas. *Nature* 533: 1–5; <http://doi.org/10.1038/nature25194>
- de Merode, E., K.H. Smith, K. Homewood, R. Pettifor, M. Rowcliffe & G. Cowlshaw (2007). The impact of armed conflict on protected-area efficacy in Central Africa. *Biology Letters* 3: 299–301; <http://doi.org/10.1098/rsbl.2007.0010>
- Goswami, R. & T. Ganesh (2014). Carnivore and herbivore densities in the immediate aftermath of ethno-political conflict: the case of Manas National Park, India. *Tropical Conservation Science* 7(3): 475–487; <http://doi.org/10.1177/194008291400700308>
- Hallagan, J.B. (1981). Elephants and the war in Zimbabwe. *Oryx* 16: 161–164.
- Hanson, T., T.M. Brooks, G.A.B. Da Fonseca, M. Hoffmann, J.F. Lamoreux, G. Machlis, C.G. Mittermeier, R.A. Mittermeier & J.D. Pilgrim (2009). Warfare in biodiversity hotspots. *Conservation Biology* 23: 578–587; <http://doi.org/10.1111/j.1523-1739.2009.01166.x>
- IUCN (2017). The IUCN Red List of Threatened Species. Version 2017-3. <www.iucnredlist.org>. Downloaded on 20 January 2018.
- Lahkar, B.P., S. Nijhawan & M.F. Ahmed (2012). Assessment of local and landscape-level threats to the tiger population of the Manas landscape, Assam, India - Technical Report (Unpublished). Aaranyak, Assam, India, 15pp.
- Menon, V. (2014). *Indian Mammals - A Field Guide*. Hachette Book Publishing India Pvt. Ltd., India, 528pp.
- Olliff, E.R.R., C.W. Cline, D.C. Bruen, E.J. Yarmchuk, R.S.A. Pickles & L. Hunter (2014). The Pantheracam - a camera-trap optimized for monitoring wild felids. *Wild Felid Monitoring* 7: 21–23.
- Orians, G.H. & E.W. Pfeiffer (1970). Ecological effects of the war in Vietnam. *Science* 168: 544–554.
- QGIS Development Team (2012). *QGIS Geographic Information System*. Open Source Geospatial Foundation Project.
- Tobler, M.W., S.E. Carrillo-Percastegui, R.L. Pitman, R. Mares & G. Powell (2008). An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Animal Conservation* 11: 169–178; <http://doi.org/10.1111/j.1469-1795.2008.00169.x>
- Wolf, C. & W.J. Ripple (2016). Prey depletion as a threat to the world's large carnivores. *Royal Society Open Science* 3(8): 160252; <http://doi.org/10.1098/rsos.160252>

Appendix 1. Table for Two sample T-test.

Species	Photographic capture rate index		Two sample T-test	
	Panbari	Bansbari-Bhuyanpara	P	df
Mammalian prey				
Barking Deer	2.62	4.71	0.0390	104
Hog Deer	3.17	2.64	0.6717	98
Wild Pig	3.70	5.94	0.0865	64
Swamp Deer	0	0.54	0.1085	91
Sambar	11.01	26.13	0.0003	90
Wild Buffalo	0.67	4.71	0.0000	113
Gaur	3.09	8.36	0.0144	50
Porcupine	2.04	1.36	0.3506	41
Indian Hare	1.66	0.97	0.3404	36
Hispid Hare	0.15	0.25	0.5973	59
Carnivores				
Wild Dog	1.51	0.38	0.0173	31
Clouded Leopard	1.89	0.16	0.0761	26
Leopard	8.22	4.63	0.1715	27
Tiger	7.54	4.08	0.2976	27
Leopard Cat	1.00	1.07	0.0008	88
Jungle Cat	0.01	0.19	0.0010	91

Appendix 2. Photographs of species recorded in camera traps in this study during 28 December 2016 to 24 February 2017 in the Manas National Park, Assam, India.

*Panthera tigris**Panthera pardus**Rusa unicolor**Neofelis nebulosa**Prionailurus bengalensis**Sus scrofa**Felis chaus**Cuon alpinus**Bubalus arnee**Muntiacus muntjak**Axis porcinus**Lepus nigricollis**Rucervus duvaucelii**Bos gaurus**Elephas maximus*

*Viverra zibetha**Viverricula indica**Paradoxurus hermaphroditus**Herpestes urva**Herpestes edwardsii**Hystrix brachyura**Ursus tibetanus laniger**Rhinoceros unicornis**Caprolagus hispidus*

Acknowledgements: We are thankful to Forest Department, Government of Assam and Bodoland Territorial Council for giving opportunity to carry out the survey, and Assam University, Diphu Campus for academic support to the first author. We are grateful to Mr. Anindya Swargowari, IFS, Council Head of the Department of Forest, BTC for his continued support to our research work. We are thankful to Range officers of MNP, Babul Barhma, Kunja Basumatary, Pranab Das and their frontline staff for helping us by providing logistic support during the field surveys. Thanks are also extended to D.D. Boro, Kiran Ch. Basumatary, for sharing field knowledge and administrative supports. This study was made possible through field support by Arif Hussain, Tridip Kumar Sharma, Karpagam Chelliah, Binita Baruwati, Debasish Buragohain, Prosenjit Sheel, Pranit Basumatary, Mukesh Kherkatary, Bhaskor Barukial, Nanka Lakra, Ranjit Urang, Nandeswar Wary, Utpal Das, Dilli Boro, and Nibir Kr. Medhi who took part in this survey. Aaranyak is thankful to Integrated Tiger and Habitat Conservation Programme of IUCN-KfW and Panthera for financial support to carry out this study. Field Director, MNP is thankful to NTCA and Government of Assam for financial support.

Author Details: DIPANKAR LAHKAR has worked on tiger research and conservation across different landscapes in India in general and Manas National Park in particular since 2009. His prime research interest is on population ecology. Currently he is pursuing PhD on ecology of tigers and also working as a biologist at Aaranyak. M FIROZ AHMED has been involved in conservation research on herpetofauna and tigers India since 1998. He has worked on herpetofauna and reported new species to science. He has lead tiger research work in Kaziranga, Orang, Manas and Nandapha National Parks and currently focuses in the Transboundary Manas Conservation Area (TraMCA) tiger landscape. He currently heads the Tiger Research and Conservation Division of Aaranyak. RAMIE H BEGUM is a Biomedical scientist working in the field of animal disease monitoring and surveillance for more than 14 years. A DBT overseas associate and a visiting professor at University of California, USA, she currently Heads the Department of Life Science and Bioinformatics at Assam University Diphu Campus. SUNIT KUMAR DAS has worked in the field of wildlife conservation since 2006 in India. With the key interest of understanding human-wildlife interaction and wildlife population ecology, he is currently working as a project officer under species division of WWF-India. BIBHUTI PRASAD LAHKAR has worked on grassland ecology and management in Manas National Park since 2000 and currently works as a conservation biologist with research interest on obligate grassland fauna, Asian elephant, mitigation of human wildlife conflict, invasive plant species and conservation livelihood. He is currently a scientist at Aaranyak. HIRANYA KUMAR SARMA is an Indian Forest Service Officer serving in the department of Forest and Environment, Assam since 1982. He is a forest manager with experience and interests in forestry, wildlife and ecology. He is also a keen wildlife photographer. Currently he is serving as the Field Director, Manas Tiger Reserve. ABISHEK HARIHAR has worked on tiger conservation in northern India since 2003 and currently works as a tiger population ecologist, with research interests spanning population ecology, law enforcement monitoring, measuring conservation effectiveness, and conservation decision making. He is currently a population ecologist at Panthera and Adjunct Scientist at Nature Conservation Foundation-India.

Author Contribution: DL - field data collection, analysis and manuscript writing; MFA - developed the idea, manuscript writing and supervised the project; RHB - manuscript writing and guided DL; SKD - conducted field survey; BPL - contributed to the manuscript; HKS - contributed to the manuscript and lead the joint team; AH - data analysis and manuscript.



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

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2018 | 10(8): 12018–12026

IN PLAIN SIGHT: BACULAR AND NOSELEAF MORPHOLOGY SUPPORTS DISTINCT SPECIFIC STATUS OF ROUNDEAF BATS *HIPPOSIDEROS* *POMONA* ANDERSEN, 1918 AND *HIPPOSIDEROS GENTILIS* ANDERSEN, 1918 (CHIROPTERA: HIPPOSIDERIDAE)

OPEN ACCESS

Bhargavi Srinivasulu¹ & Chelmala Srinivasulu²



^{1,2} Natural History Museum and Wildlife Biology & Taxonomy Lab, Department of Zoology, University College of Science, Osmania University, Hyderabad, Telangana 500007, India

^{1,2} Systematics, Ecology & Conservation Laboratory, Zoo Outreach Organization (Zooreach), No 12, Thiruvannamalai Nagar, Saravanampatti-Kalapatti Road, Saravanampatti, Coimbatore, Tamil Nadu 641035, India

¹bharisrini@gmail.com, ²chelmalasrinivasulu@gmail.com (corresponding author)

Abstract: The taxonomic status of Andersen's Roundleaf Bat *Hipposideros pomona* (Chiroptera: Hipposideridae) and its relationship with the taxa assigned to it has been confusing. Knud Andersen described *H. pomona* (based on specimens from southern India) and *H. gentilis* (based on specimens from Myanmar) in 1918. Subsequently, the latter taxon was included under the former as a subspecies. Owing to disjunct distribution, it was speculated that these two taxa are distinct. Discovery of the type material and additional vouchers of both taxa in the National Collection of Zoological Survey of India, Kolkata allowed detailed comparison. Based on the morphological, craniodental and bacular characters, we establish the distinctness of these taxa. A redescription of *H. pomona* Andersen, 1918 is provided.

Keywords: Disjunct distribution, redescription, taxonomic status.

DOI: <http://doi.org/10.11609/jott.41111.10.8.12018-12026> | **ZooBank:** urn:lsid:zoobank.org:pub:CBA9604F-3847-4F04-9F63-F8490D62CA98

Editor: Pipat Soisook, Princess Maha Chakri Sirindhorn Natural History Museum, Hatyai, Thailand.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 4111 | Received 08 March 2018 | Final received 14 June 2018 | Finally accepted 10 July 2018

Citation: Srinivasulu, B. & C. Srinivasulu (2018). In plain sight: Bacular and noseleaf morphology supports distinct specific status of Roundleaf Bats *Hipposideros pomona* Andersen, 1918 and *Hipposideros gentilis* Andersen, 1918 (Chiroptera: Hipposideridae). *Journal of Threatened Taxa* 10(8): 12018–12026; <http://doi.org/10.11609/jott.41111.10.8.12018-12026>

Copyright: © Srinivasulu & Srinivasulu 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: University Grants Commission, New Delhi; UGC-UKIERI Thematic Partnership Programme, New Delhi; Science and Engineering Board, Department of Science and Technology, Government of India.

Competing interests: The authors declare no competing interests.

Author Details: BHARGAVI SRINIVASULU is interested in molecular phylogenetics, taxonomy and biogeography of endemic bats of peninsular India, and is currently focusing on roundleaf bats of South Asia. CHELMALA SRINIVASULU, who heads the Wildlife Biology and Taxonomy Lab at Department of Zoology, Osmania University, is working on molecular phylogenetics, taxonomy, ecology and biogeography of tetrapods of South Asia.

Author Contribution: Both the authors contributed equally in field work, designed and wrote the paper. BS conducted the museum studies.

Acknowledgements: We thank Dr. Kailash Chandra, Director; Dr. C. Venkatraman Officer-in-Charge, and Dr. M. Kamalakannan, Senior Zoological Assistant, Mammal and Osteology Section, for permission and help in conducting studies on the collection at Zoological Survey of India, Kolkata; and the Head, Department of Zoology, Osmania University for necessary facilities. We also thank Aditya Srinivasulu for help in conducting statistical analysis. The first author thanks UGC for research funding, and the authors also thank DST-SERB, UGC-UKIERI, and UGC DSA-I (SAP-II), Department of Zoology, for research grant and necessary facilities.



INTRODUCTION

The taxonomic status of *Hipposideros pomona* Andersen, 1918 sensu stricto has been confusing since its establishment. Knud Andersen's study on species allied to *Hipposideros bicolor* resulted in the description of two new species: *H. pomona* from southern India, and *H. gentilis* from northeastern India, Burma to west coast of Sumatra (Andersen 1918; Hill 1963; Hill et al. 1986; Douangboubpha et al. 2010) (Fig. 1). Andersen (1918) based his diagnosis of *H. pomona* in possessing broader than usual noseleaf, horseshoe and 'sella' (probably referring to posterior leaf) measuring 5.8mm and 5.2mm respectively, and forearm measuring 40.5 mm based on a single specimen from Coorg, southern India; while that of *H. gentilis* in possessing not broader than usual noseleaf, horseshoe and 'sella' measuring 4.5–5.5 mm and 3.7–4.8 mm, and forearm measuring 38.5–41.5 mm based on specimens from Masuri, Pegu (=Bago), Burma (=Myanmar). In addition to the nominate *gentilis*, Anderson (1918) described three other subspecies of *H. gentilis*—*sinensis*, *atrox*, and *major*.

Hill (1963) included *pomona*, *gentilis*, *sinensis*, *atrox* and *major* as subspecies of *H. bicolor*. Later, Hill et al. (1986) while revising *H. bicolor* considered *H. pomona* as distinct species including nominate form, *gentilis*, and *sinensis*, and assigned *atrox* and *major* to *H. bicolor*. A trend followed by subsequent authors (Yenbutra & Felten 1986; Zubaid & Davison 1987; Corbet & Hill 1992; Simmons 2005). The current known distribution of *H. pomona* sensu lato extends from India, Bangladesh, Nepal, Myanmar, Thailand, Laos, Cambodia, Viet Nam, south China and west Malaysia (Simmons 2005; Bates et al. 2008). Douangboubpha et al. (2010) opined that *H. pomona* (sensu Corbet & Hill 1992) might comprise two distinct species, pending further studies, with *H. pomona* being restricted in distribution to peninsular India and *H. gentilis* including the taxa *gentilis* and *sinensis* extending in distribution from northeastern India into Southeast Asia (Fig. 1).

Until now, there existed no information about the taxon *H. pomona* sensu stricto from southern India, as the type specimen (skin) was not traceable and the damaged skull (BMNH No. 18.8.3.4) in the British Museum of Natural History was the only material (Hill et al. 1986). During a museum study conducted by the authors, the type specimen in the type collection of the Zoological Survey of India, Kolkata was studied. Three more specimens from southern India (bearing ZSI No. 21535, and 7193 and 7196 collected from Travancore and Shevaroy Hills respectively) were found in the

collection of ZSI, Kolkata by the first author. These specimens were originally labelled *H. fulvus fulvus* and have been catalogued as *H. fulvus* (Ghosh 2008). This species has been collected from southern India in the recent past, and the specimens are in personal collections of bat researchers in Tamil Nadu which have not been taxonomically studied. This recent discovery of additional specimens in National Zoological Collection of Zoological Survey of India provided us with an opportunity to conduct detailed study and compare this taxon with *gentilis* from northeastern India, Andaman Islands, and Myanmar.

Through this communication, we present evidence based on morphometric, bacular, and acoustic characters that prompt distinct specific status of the populations assigned from southern India as *H. pomona*, and northeastern India and Southeast Asia as *H. gentilis*. We also provide a detailed description of *H. pomona* as the original description of the taxon lacks detail.

MATERIALS AND METHODS

The present study is based on museum specimens in the National Zoological Collection, Zoological Survey of India, Kolkata and the Natural History Museum, Department of Zoology, Osmania University, Hyderabad, Telangana State. We examined a total of 10 specimens of *H. pomona* sensu lato (four vouchers including the type specimen (skin only) of *H. pomona* sensu stricto, and six vouchers including one voucher specimen of *H. gentilis* sensu stricto from Sagaing, Myanmar about 560km north of the type locality of *gentilis*). External and craniodental measurements were taken (to the nearest 0.1mm) using a digital vernier caliper (Mitutoyo make) following Bates & Harrison (1997) and Srinivasulu et al. (2010). Measurements of the museum specimens were compared with published data (from Douangboubpha et al. 2010; Bates & Harrison 1997). External measurements included FA - forearm length, E - ear length, TI - tail length, Tib - tibia length, Hf - hindfoot length, 3mt - third metacarpal, 4mt - fourth metacarpal, 5mt - fifth metacarpal, 1ph3mt - first phalanx of third metacarpal, 2ph3mt - second phalanx of third metacarpal, 1ph4mt - first phalanx of fourth metacarpal, 2ph4mt - second phalanx of fourth metacarpal. Craniodental measurements included GTL - greatest length of the skull, CBL - condylobasal length, CCL - condylocanine length, CM³ - maxillary toothrow, C¹-C¹ - anterior palatal width, M³-M³ - posterior palatal width, ZB - zygomatic breadth, BB - braincase breadth,

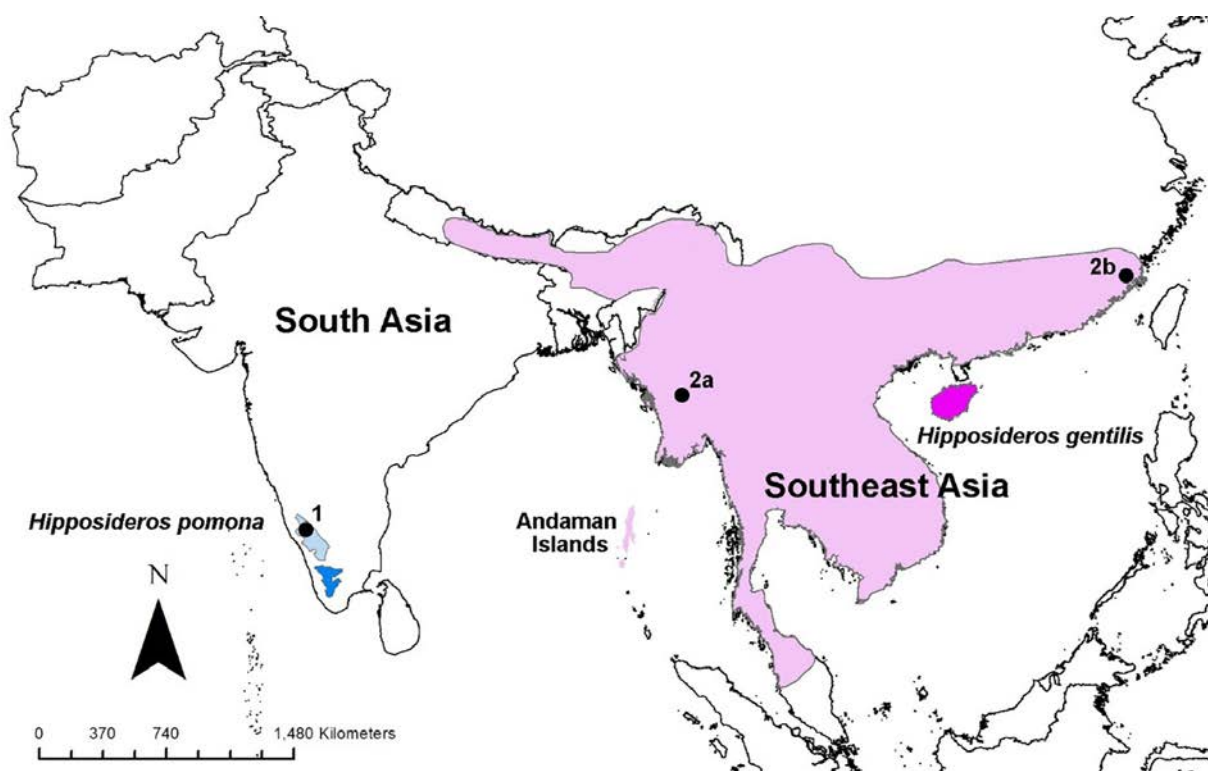


Figure 1. Distribution ranges of *Hipposideros pomona sensu stricto* and *Hipposideros gentilis sensu lato*.

Range of *H. pomona* depicted in blue [historic range - light blue shaded area & present range - dark blue shaded area] and *H. gentilis* in pink [dark pink range indicates the presence of a possible new subspecies vide Zhao et al. (2015)]; Black points indicate type localities: 1 - Haleri, Karnataka, India (*H. pomona*); 2a - Thayetmyo, Myanmar (*H. gentilis gentilis*); 2b - Foochow, Fujian, China (*H. gentilis sinensis*)

CM₃ - mandibular tooththrow, M - mandible length. Statistical analyses were conducted in R (R Development Core Team 2013). One-way ANOVAs were used to select significant ($p < 0.05$) variables for classification analysis. Of the 19 variables measured, 11 (GTL, CCL, CM₃, C¹-C¹, M³-M³, ZB, FA, E, CM₃, M, and HF) were selected for a principal component analysis (PCA).

The bacula of two male specimens (one each of *pomona* [ZSI No. 21535] from Kerala, India and *gentilis* [ZSI 131zz] from Myanmar) were extracted and prepared following the protocol outlined in Topal (1958), and later stored in glycerol. The information on the echolocation calls were sourced from published literature and our studies in Andaman Islands, India.

Materials examined

Hipposideros pomona ZSI No. 21529, Holotype, male, collected from Haleri, few miles north of Mercara, Coorg District, Karnataka, by G.C. Shortridge on 15.ii.1913, specimen only. Skull in BMNH collection (BMNH No. 18.8.3.4).

H. pomona pomona ZSI No. 21535, male, collected from Travancore, southern India, by Lt. Col. Beddome in

1878, specimen and skull.

H. pomona pomona ZSI No. 7193, female, collected from Shevaroy Hills, Tamil Nadu by W. Daly, collection year not known, specimen only, skull in situ.

H. pomona pomona ZSI No. 7196, sex unknown, collected from Shevaroy Hills, Tamil Nadu by W. Daly, collection year not known, specimen damaged and tied up.

H. pomona gentilis ZSI No. 21511, male, collected from Sibsagar, Assam, by S.E. Pearl in 1872, specimen and skull.

H. pomona gentilis ZSI No. 22325, female, collected from Peshoke (=Pashok), Darjeeling District, West Bengal by C.A. Crump between June and August 1915, specimen and skull.

H. pomona gentilis ZSI No. 131zz, male, collected from Cave No. 5, Tsagain (=Sagaing), right bank of Irrawaddy, Upper Burma (=Myanmar), by J. Anderson in 1875, specimen and skull.

H. pomona gentilis (misidentified and labelled as *Hipposideros larvatus leptophyllus*) ZSI No. 24773-75, males, collected from Andaman Islands by Indraneil Das.

H. pomona gentilis NHMOU.CHI.80.2014, male,

collected from Baratang Island, Andaman Islands, by A. Gopi and T.A.H. Dar in 2014, specimen and skull.

H. pomona gentilis NHMOU.CHI.115.2014, female, collected from Burmadera near Mayabunder, Middle Andaman, Andaman Islands, by A. Gopi and T.A.H. Dar in 2014, specimen and skull.

Abbreviations used: BMNH - British Museum (Natural History); ZSI - Zoological Survey of India; NHMOU - Natural History Museum of Osmania University.

RESULTS

External measurements show that *pomona* is smaller than *gentilis* (FA 39.46–39.70 mm vs. 39.70–44.1 mm) with shorter ears (16.76–17.03 mm vs. 17.5–24.0 mm). In both the taxa the third metacarpal was the shortest, being shorter than both the fourth and the fifth metacarpals, with fourth being the longest of the three. Similarly, the first phalanx of the third metacarpal

was longer than the second and was almost equal to the combined lengths of the first and the second phalanges of the fourth metacarpal (Table 1).

The cranial measurements show that the condylo-canine length of *pomona* being smaller than that of *gentilis* (14.66mm vs. 14.6–16.3 mm). The zygoma are more widely placed in *gentilis* than in *pomona*. The anterior palatal width and the posterior palatal width are also greater in *gentilis* than in *pomona* (5.7–6.6 mm vs. 5.43–5.8 mm) signifying that the rostrum of *gentilis* is broad and long. The mandible measures shorter in *pomona* in comparison with *gentilis* (10.05–10.1 mm vs. 10.4–11.8 mm) (Table 2). The sagittal crest in *gentilis* is well developed, and extends up to the parietal region of the skull, whereas in *pomona* it is weakly developed. The lambdoid crests are also well developed in *gentilis*. The first lower premolar (pm_1) is half to two third the height of the second lower premolar (pm_2). The pm_4 is one third the height of the tall canine. The lower molars are equal to or shorter than the pm_4 . The coronoid process

Table 1. External measurements (in mm) of *Hipposideros pomona sensu stricto* (from southern India) and *H. gentilis sensu lato* (from northeastern India, Andaman Islands, and Southeast Asia)

Species	FA	E	TIB	Hf	3mt	4mt	5mt	1ph3mt	2ph3mt	1ph4mt	2ph4mt
<i>H. pomona</i> Holotype (ZSI 21529)	39.70	16.76 (approx.)	16.99	6.28	31.0	32.88	31.78	16.49	14.76	10.13	7.50 (approx.)
<i>H. gentilis</i> holotype (BM.93.11.15.2) Thayetmyo	39.70	-	18.0	-	29.2	31.3	30.4	17.6	15.5	11.0	8.0
<i>H. pomona</i> (ZSI 7193)	39.49	17.02	17.24	6.92	31.18	32.80	31.73	16.73	14.84	10.46	9.72
<i>H. pomona</i> ZSI 21535	39.46	17.03	17.29	6.97	30.15	32.04	30.69	17.67	15.46	10.74	8.51
<i>H. gentilis</i> No. 131zz	40.11	17.66	17.54	7.90	30.08	32.10	30.84	17.49	15.14	10.29	9.98
<i>H. gentilis</i> ZSI 21511	40.19	18.71	17.56	8.22	29.47	30.03	29.89	16.77	15.49	10.27	7.61
<i>H. gentilis</i> ZSI 24773	41.88	19.15	19.34	6.89	32.13	32.92	32.25	17.29	16.90	10.87	8.26
<i>H. gentilis</i> ZSI 22325	40.73	20.18	18.88	8.09	30.30	32.35	31.60	17.78	13.70	10.90	7.78
<i>H. gentilis</i> NHMOU. CHI.80.2014	41.81	19.68	17.66	6.59	30.83	31.53	31.07	17.15	16.64	10.21	8.32
<i>H. gentilis</i> NHMOU. CHI.115.2014	43.5	20.12	19.58	6.29	33.47	35.03	34.18	18.11	17.46	10.83	8.20
<i>H. gentilis</i> (vide Bates & Harrison 1997)	41.0±1.1 (39.5–43.2) (n=17)	23.3±1.0 (22.0–25.0) (n=16)	18.6±0.4 (18.2–19.1) (n=12)	7.0±0.6 (6.3–8.5) (n=9)	30.5±1.3 (28.9–33.5) (n=17)	32.0±0.9 (30.4–33.7) (n=17)	31.5±1.0 (29.6–33.2) (n=17)	17.6±0.7 (16.6–18.6) (n=17)	16.0±0.7 (14.7–17.4) (n=17)	10.7±0.5 (9.8–11.6) (n=16)	8.4±0.4 (7.5–9.2) (n=16)
<i>H. gentilis</i> (males, n=20) (Douangboubpha et al. 2010)	41.7±1.2 (39.5–44.6)	21.0±1.3 (19.0–23.6)	19.0±0.7 (17.9–20.1)	6.8±0.5 (5.5–7.8)	30.9±0.9 (29.9–33.0)	33.2±0.9 (31.8–35.3)	31.6±0.9 (29.7–33.2)	17.9±0.8 (16.5–19.5)	16.7±0.8 (15.3–18.0)	10.9±0.5 (9.8–11.5)	8.6±0.4 (7.5–9.3)
<i>H. gentilis</i> (females, n=16) (Douangboubpha et al. 2010)	42.2±1.2 (40.4–44.1)	21.1±1.4 (18.7–24.0)	18.6±0.8 (17.5–20.0)	6.5±0.5 (5.8–7.5)	31.6±1.0 (30.0–33.1)	33.7±1.2 (31.4–35.6)	32.9±2.9 (30.2–43.2)	18.0±1.0 (16.3–20.3)	16.7±1.3 (14.5–18.6)	11.1±0.4 (10.6–11.9)	8.7±0.5 (7.9–9.4)



Image 1. Skull – lateral and dorsal view and mandible – lateral view of *Hipposideros pomona* sensu stricto (A. ZSI No. 21535, from Travancore (=Kerala), India) and *Hipposideros gentilis* sensu lato (B. ZSI No. 21511, from Sibsagar, Assam, India; C. ZSI No. 131zz, from cave No. 4, Tsagain, right bank of Irrawadi, Upper Burma; D.A. NHMOU.CHI.80.2014, from Baratang Island, Andaman Islands, India) (Scale – 10mm)

and the condyle of the mandible are well developed (Image 1A–D).

The structure of the noseleaf and the internarial septum in *pomona* varies from that of *gentilis*. The noseleaf of *gentilis* (Image 2C&D) is wider than long with the internarial septum being slightly narrow at the base, becoming parallel sided, and gradually narrows to a blunt tip (looking like a tapered triangle) almost touching the intermediate leaf. The internarial septum is separated from the walls of the anterior leaf by means of deep grooves due to which the narial lappets seem to be located away from the internarial septum. The nares are tear drop shaped and the well developed narial lappets are attached to the sides of the internal walls of the anterior leaf. The posterior and the anterior

leaves are of the same size while the intermediate leaf is smaller (Image 2C&D).

Principal component analysis on 10 individuals of *H. pomona* and *H. gentilis* from India, Southeast Asia, and the Andaman Islands generated three separate groups: *H. pomona* from India, *H. gentilis* from Southeast Asia, and *H. gentilis* sensu lato from the Andaman Islands (Fig. 2). These groups are clearly separated from each other (PC1 explained 73.41% of the variance), which shows that *H. pomona* and *H. gentilis* sensu lato are distinct. The present analysis also indicates the distinctness of *H. gentilis* from the Andaman Islands from the Southeast Asian forms. The factor loadings of 10 variables in the first PC were positive with the following factor loadings—E (1.242), FA (1.205), GTL (0.830), M (0.575),

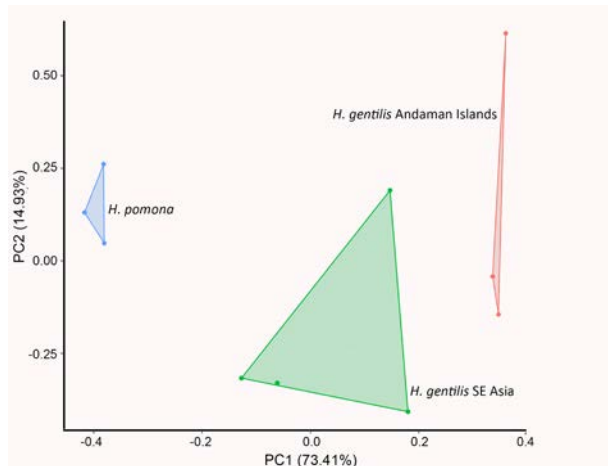


Figure 2. Principal component analysis of *Hipposideros pomona sensu stricto* and *Hipposideros gentilis*

CCL (0.567), ZB (0.395), M^3 - M^3 (0.267), CM^3 (0.249), CM_3 (0.232), and C^1 - C^1 (0.105). Only HF had negative factor loading (-0.043). This analysis supports that all the three taxa can be separated morphologically based on ear length and forearm length, and cranially based on greatest length of the skull, mandible length and condyle-canine length.

The penis is thin and long with a pointed tip in both the taxa. The baculum structure of *pomona* is distinct from that of *gentilis*. In *pomona*, the baculum is larger (1.367mm), bearing a long shaft ending with a bifid tip (present study) (Image 3A), while in *gentilis* it is simple, very small (0.4–0.8 mm) (present study; Douangboubpha et al. 2010), bearing a straight shaft narrowing to a bluntly rounded tip and a slightly expanded base (Douangboubpha et al. 2010) (Image 3B&C). Amongst the *gentilis* in some specimens both ends are same (present study based on specimens from northeastern India, Andaman Islands, and northern Myanmar) (Image 3C).

The echolocation calls of the taxon *pomona* from south India were recorded by Wordley et al. (2014) from Valparai Plateau, Tamil Nadu where in the average frequency at maximum energy (FMAXE) has 126.337 ± 1.25 (range: 123.7–128.2 kHz). Echolocation calls of *H. pomona* (= *H. gentilis*) recorded from Thailand (Douangboubpha et al. 2010) reported to be the average frequency at maximum energy (FMAXE) of 133.3 ± 3.9 (range: 127.3–139.3 kHz) in males and 133.9 ± 3.7 (range: 127.7–140.2 kHz) in female individuals. In Andaman Islands, the average frequency at maximum energy (FMAXE) of the echolocation calls produced by two populations *H. gentilis* (reported as *H. pomona*) were

126.5 ± 4.17 (range: 121.9–131.7 kHz) and 137.5 ± 2.1 (range: 133.3–140.3 kHz), respectively (Srinivasulu et al. 2017).

Basing on the distinctness of the structure of the baculum of the southern Indian specimen from that of Assam and Southeast Asia (present study; Douangboubpha et al. 2010), and on differences in morphometrics of the southern Indian specimens from that of *gentilis*, the peninsular Indian population is considered distinct here. The rest of the specimens from Nepal, northeastern India, Andaman Islands to Myanmar, southern China, Lao PDR, Thailand, Viet Nam, Cambodia, and Western Malaysia (Corbet & Hill 1992; Bates & Harrison 1997; Simmons 2005; Francis 2008; Douangboubpha et al. 2010) are here considered as *H. gentilis* Andersen, 1918. Owing to the disjunct distribution of the two taxa (Fig. 1), and considerable variations in bacular, morphological, and acoustic characteristics the resurrection of *H. gentilis* as a distinct species is well-supported.

Molecular phylogenetic studies to support the distinctness of *Hipposideros pomona sensu stricto* and *H. gentilis sensu lato* are in progress.

Systematic description

Hipposideros pomona Andersen, 1918

Andersen's Roundleaf Bat

Hipposideros bicolor pomona Andersen, 1918;

Haleri, Coorg, India

Holotype: *Hipposideros pomona* ZSI Reg. No. 21529, male, collected from Haleri, few miles north of Mercara, Coorg District, Karnataka, India by G.C. Shortridge on 15.ii.1913, specimen only. Skull extracted and in BMNH collection bearing No. 18.8.3.4.

Diagnostic characters

A small to medium sized bat, with an average forearm length of 39.6mm (38.1–40.84 mm). The noseleaf is longer than broad, and covers the muzzle. There are no supplementary leaflets. The internarial septum is thick, parallel sided, becomes broader as it is nearing the proximal end and slightly narrows to a broadly rounded tip. The skull is slender and has an average condylocanine length of 14.4mm (14.2–14.66 mm). The first lower premolar (pm_2) is small, triangular in outline, and is one half of the height of the second lower premolar (pm_4). The pm_4 is about one half to two third the height of the tall canine. The baculum is long with a straight shaft, the proximal end of which is broad

Table 2. Craniodental measurements (in mm) of *Hipposideros pomona* sensu stricto (from southern India) and *H. gentilis* sensu lato (from northeastern India, Andaman Islands, and Southeast Asia)

Species	GTL	CBL	CCL	CM ³	C ¹ -C ¹	M ³ -M ³	ZB	BB	CM ₃	M
<i>H. pomona</i> Holotype (BM.18.8.3.4)	-	-	-	5.80	-	-	8.5	8.2	6.0	10.1
<i>H. gentilis</i> holotype (BM.93.11.15.2) Thayetmyo	17.0	-	14.60	5.70	-	-	8.3	8.0	6.2	10.4
<i>H. pomona</i> ZSI 21535	-	-	14.66	5.43	3.15	5.61	8.31	8.84	5.58	10.05
<i>H. gentilis</i> No. 131zz	17.99	15.45	15.06	5.80	3.31	5.83	8.58	8.69	6.32	10.76
<i>H. gentilis</i> ZSI 21511	17.41	15.57	15.23	5.82	3.38	5.81	8.53	8.73	6.57	10.65
<i>H. gentilis</i> ZSI 24773	19.05	16.85	16.06	6.04	3.87	6.15	8.94	8.30	6.58	11.47
<i>H. gentilis</i> ZSI 22325	17.76	15.78	15.04	6.14	3.49	5.88	broken	8.42	6.58	10.51
<i>H. gentilis</i> NHMOU. CHI.80.2014	17.76	15.96	15.31	6.06	3.69	5.9	8.82	7.56	6.48	10.45
<i>H. gentilis</i> NHMOU. CHI.115.2014	19.15	16.80	16.40	6.35	3.9	6.35	9.29	9.44	6.97	11.66
<i>H. gentilis</i> (Bates & Harrison 1997)	17.9±0.3 (17.0-18.6) (n=15)	-	15.5±0.3 (15.0-16.0) (n=16)	6.0±0.1 (5.7-6.2) (n=17)	3.6±0.1 (3.5-3.8) (n=18)	5.8±0.1 (5.6-6.0) (n=18)	8.6±0.2 (8.3-9.0) (n=17)	8.1±0.1 (7.9-8.3) (n=16)	6.4±0.2 (6.0-6.8) (n=17)	10.8±0.2 (10.5-11.3) (n=19)
<i>H. gentilis</i> (males, n=20) (Douangboubpha et al. 2010)	18.0±0.5 (17.2-18.8)	15.8±0.4 (15.2-16.5)	15.6±0.5 (15.0-16.3)	6.2±0.2 (5.7-6.6)	3.5±0.1 (3.1-3.7)	6.1±0.2 (5.8-6.3)	9.0±0.2 (8.6-9.3)	8.2±0.1 (8.0-8.5)	6.5±0.2 (6.1-6.9)	11.2±0.4 (10.6-11.8)
<i>H. gentilis</i> (females, n=16) (Douangboubpha et al. 2010)	17.6±0.7 (15.6-18.5) (n=15)	15.7±0.4 (15.2-16.3) (n=15)	15.5±0.4 (14.8-16.3)	6.1±0.2 (5.7-6.4)	3.4±0.2 (2.8-3.6)	6.2±0.2 (5.6-6.3)	8.8±0.4 (7.6-9.4)	8.1±0.3 (7.0-8.5)	6.4±0.3 (5.9-6.8)	11.1±0.4 (10.5-11.6)

and bifid.

Descriptive characters

A small to medium sized bat with the forearm length ranging between 38.1–40.84 mm. Ears are large (16.76–19.0 mm) with ridges and rounded off tips. Feet are large (6.28–6.97 mm). The wing membrane and the interfemoral membrane are attached on either side of the ankles. In preserved specimens, the ventral fur is pale in colour; the fur along the flanks and toward the distal part of the body is pale at the base and light brown on the mid-portion, with pale tips; face has pale brown to darkish brown fur; while the dorsal surface is fawn to dark brown with pale hair bases. On the wing the third metacarpal is shorter than the fourth and the fifth metacarpal, with the fourth being the longest. The first phalanx of the third metacarpal is almost equal to the combined lengths of the first and second phalanges of the fourth metacarpal. The second phalanx of the third metacarpal is shorter than the first. The noseleaf is longer than broad and covers the muzzle (Image 2A&B). There are no supplementary leaflets. The internarial septum is thick, parallel sided and becomes broader as it is nearing the proximal end, and slightly narrows to a broadly rounded tip (Image 2A&B). The oval shaped nares are situated on either side of the tip

of the internarial septum. The narial lappets are fleshy and are located on the sides of the nares attached to the internal walls of the anterior leaf. There is not much of a gap between the internarial septum, the narial lappets and the internal walls of the noseleaf. The intermediate leaf is short and small, shorter than the posterior and the anterior leaves (Image 2A&B). Due to its small size the gap between the internarial septum and the intermediate leaf is more. The posterior leaf is slightly wider than the anterior leaf and is divided into four cells by means of three septa (Image 2A&B). Penis is thin, long with a pointed tip. The baculum is long (1.367mm) with a long straight shaft, the proximal end of which is broad and bifid (Image 3A). The distal end is four pronged, and shows an inner curvature on the ventral surface (Image 3A).

The skull is slender (Image 1A) and has an average condylo-canine length of 14.4 mm (14.2–14.66 mm). The rostrum is short with the CM³ measuring 5.4–5.7mm. The palate is narrow as is seen by the posterior palatal width being 5.3–5.6 mm and the anterior palatal width being 3.15–3.4 mm. The zygoma are slender toward the anterior portion, with a low jugal process on the posterior portion (Image 1A). The sagittal crest is weakly developed, and is visible on the anterior part of the braincase and not present on the posterior part.

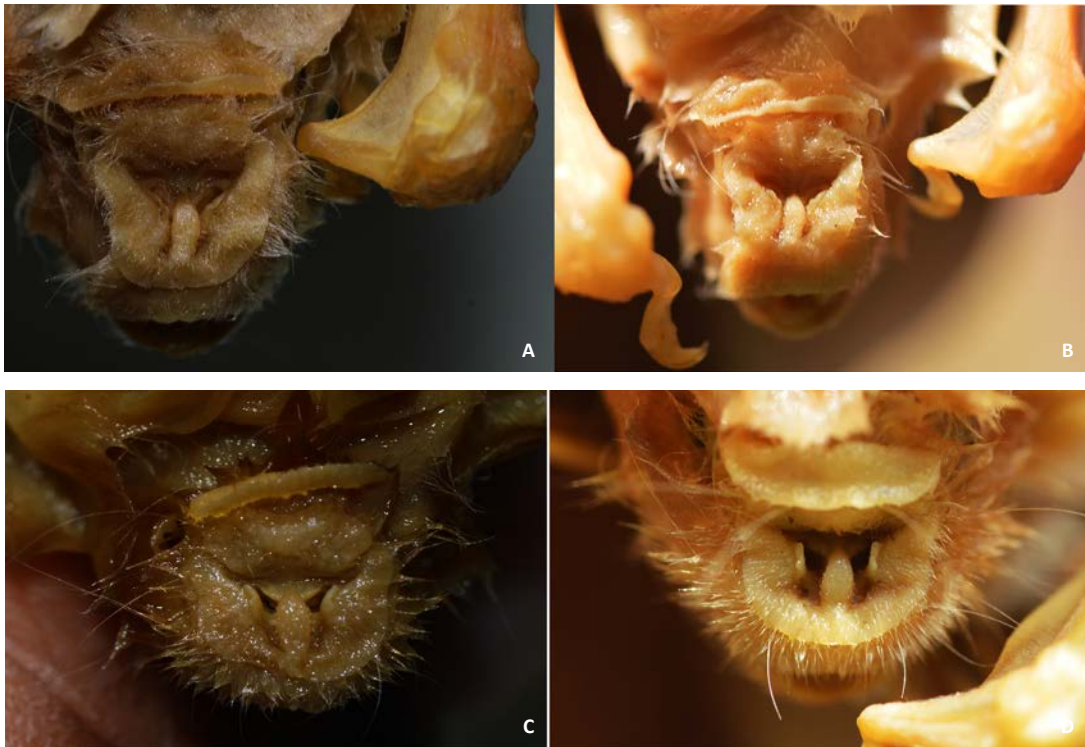


Image 2. Noseleaf structure depicting the size of the noseleaf and the shape of the internarial septum of *Hipposideros pomona sensu stricto* (A. ZSI No. 21535; B. ZSI No. 7193) and *Hipposideros gentilis sensu lato* (C. ZSI No. 21511; D. ZSI No. 131zz). © Bhargavi Srinivasulu



Image 3. Bacular morphology and size of *Hipposideros pomona sensu stricto* (A. ZSI No. 21535 from Travancore (=Kerala), India) and *Hipposideros gentilis sensu lato* (B. ZSI No. 131zz from cave No. 4, Tsagain, right bank of Irrawadi, Upper Burma; and C. NHMOU. CHI.80.2014, from Baratang Island, Andaman Islands, India) (Scale – 1mm). © Bhargavi Srinivasulu

The braincase is bulbous (8.84mm) and shows a slight depression over the parietal region in the lateral profile. The lambdoid crests are not well developed. The rostrum is bulbous with three nasal inflations, an elongated one located at the bottom, a kidney shaped inflation located on either side, and a round inflation on the top of the rostrum. The upper tooththrow averages 5.5mm (5.4–5.7

mm). The first upper premolar (pm^2) is minute located between the cingulum of the robust canine and the anterior border of the second upper premolar (pm^4) whereby the canine and the pm^4 are not in contact. The first lower premolar (pm_2) is small, triangular in outline and measures one half of the height of the second lower premolar (pm_4). The pm_4 is about one-half to two-third the height of the tall canine. The first lower molar is subequal to slightly taller than the pm_4 while the second lower molar is equal to the height of pm_4 . The average length of the mandible is 9.9 mm (9.8–10.1 mm) while the lower tooththrow (cm_3) measures 5.58–6.0 mm. The coronoid process and the condyle of the mandible are well developed.

Echolocation calls

The echolocation calls of *H. pomona* from southern India were recorded by Wordley et al. (2014) from Valparai Plateau, Tamil Nadu where in the average frequency at maximum energy (FMAXE) of the echolocation calls produced by this species was 126.337 ± 1.25 (range: 123.7–128.2 kHz).

Ecology

All that is known about the ecology of *H. pomona* is

that it was found in an old well in Venginiserry, Thrissur District, Kerala (A. Madhavan pers. comm. October 2016), and it is found in a mixed landscape of plantations interspersed with tropical rainforest fragments, streams and riverine vegetation (Wordley et al. 2014; Juliet Vanitharani pers. comm. September 2017).

Distribution

H. pomona is known from Haleri, Coorg District, Karnataka; Venginiserry, Thrissur District, Kerala and Madhovaram in Tamil Nadu. It was recorded recently (Wordley et al. 2014) from Valparai Plateau in Tamil Nadu. It also occurs in Kalakkad-Mundhunthurai Tiger Reserve in Tamil Nadu (Juliet Vanitharani pers. comm. September 2017). Our recent surveys conducted in the 2017 in Haleri, Coorg District, Karnataka and many locations in Kerala was not successful in detecting the presence of this species. The habitat has changed over the years in the areas where this species was historically found.

Conservation status

H. pomona sensu lato, according to Bates et al. (2008) included both the taxa *pomona* and *gentilis*, was assessed as Least Concern. In the light of new information and upgradation of these taxa as distinct species, with *H. pomona* being known south of Coorg in Western Ghats and *H. gentilis* being present from Nepal, northeastern India through Myanmar to Southeast Asia, there is a need to reassess these two species.

Remarks on misidentified specimens

A specimen (ZSI No. 19450) from Macherla, Andhra Pradesh labelled as *H. pomona pomona*, collected by B. Nath in 1962 (Bates & Harrison 1997; Ghosh 2008) is hereby identified as *H. fulvus* basing on the structure of internarial septum and morphometrics. Three specimens collected by Indraneil Das from Andaman & Nicobar Islands and labelled as *H. larvatus leptophyllus* (ZSI Reg. No. 24773-75) are hereby identified as *H. gentilis* based on noseleaf structure and morphometrics.

REFERENCES

- Andersen, K. (1918). Diagnoses of new bats of the families Rhinolophidae and Megadermatidae. *Annals & Magazine of Natural History* 2: 374–384.
- Bates, P.J.J., & D.L. Harrison (1997). *Bats of Indian Subcontinent*. Harrison Zoological Museum Publication, Sevenoaks, UK, xvi+258pp.
- Bates, P.J.J., S. Bumrungsri, G. Csorba, S. Molur & C. Srinivasulu (2008). *Hipposideros pomona*. In IUCN 2010. IUCN Red List of Threatened Species. Version 2010.2. www.iucnredlist.org.
- Corbet, G.B. & J.E. Hill (1992). *The Mammals of Indo-malayan Region: A Systematic Review*. Natural History Museum Publication, Oxford, 488pp.
- Douangboubpha, B., S. Bumrungsri, P. Soisook, C. Satasook, N.M. Thomas & P.J.J. Bates (2010). A taxonomic review of the *Hipposideros bicolor* species complex and *H. pomona* (Chiroptera: Hipposideridae) in Thailand. *Acta Chiropterologica* 12(2): 415–438; <http://doi.org/10.3161/150811010X537990>
- Francis, C.M. (2008). *A Field Guide to the Mammals of Thailand and South-East Asia*. New Holland Publishers (UK) Ltd. and Asia Books Co., Ltd, Bangkok, 392pp.
- Ghosh, M.K. (2008). Catalogue of Chiroptera in the collection of Zoological Survey of India (Part-II : Microchiroptera). *Records of the Zoological Survey of India, Occasional Paper* 281: 1–339.
- Hill, J.E. (1963). A revision of the genus *Hipposideros*. *Bulletin of the British Museum of Natural History (Zool.)*. 11: 1–129.
- Hill, J.E., A. Zubaid & G.W.H. Davison (1986). The taxonomy of the Roundleaf bats of the *Hipposideros bicolor* group (Chiroptera: Hipposideridae) from southeastern Asia. *Mammalia* 50(4): 535–540; <http://doi.org/10.1515/mamm.1986.50.4.535>
- R Development Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>
- 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, 3rd Edition*. The Johns Hopkins University Press, Baltimore, xxv +2142pp.
- Srinivasulu, C., A. Srinivasulu, B. Srinivasulu, A. Gopi, T.H. Dar, P.J.J. Bates, S.J. Rossiter & G. Jones (2017). Recent Surveys of Bats from the Andaman Islands, India: Diversity, distribution, and echolocation characteristics. *Acta Chiropterologica* 19(2): 419–437; <http://doi.org/10.3161/15081109ACC2017.19.2.018>
- Srinivasulu, C., P.A. Racey & S. Mistry (2010). A key to the bats (Mammalia: Chiroptera) of South Asia. *Journal of Threatened Taxa* 2(7): 1001–1076; <http://doi.org/10.11609/JoTT.o2352.1001-76>
- Topal, G. (1958). Morphological studies on the os penis of bats in the Capathian Basin. *Annales Historico-Naturales Musei Nationalis Hungarici* 50(New Series 9): 331–342.
- Wordley, C.F.R., E.K. Foui, D. Mudappa, M. Sankaran & J.D. Altringham (2014). Acoustic identification of bats in the southern Western Ghats, India. *Acta Chiropterologica* 16(1): 213–222; <http://doi.org/10.3161/150811014X683408>
- Yenbutra, S. & H. Felten (1986). Bat species and their distribution in Thailand according to the collections in TISTR and SMF, pp. 9–45. In: Felten, H. (ed.). *Contributions to the Knowledge of the Bats of Thailand*. Courier Forschungsinstitut Senckenberg, 112pp.
- Zhao, L.-Z., Y.-Z. Bu, H.-X. Zhou, H.-W. Zhou, Z.-X. Zhang & H.-X. Niu (2015). Differences in *Hipposideros pomona* from three geographical regions in China based on morphology and molecular sequences data. *Journal of Mammalogy* 96(6): 1305–1316; <http://doi.org/10.1093/jmammal/gyv139>
- Zubaid, A. & G.W. Davison (1987). A comparative study of the baculum in Peninsular Malaysian hipposiderines. *Mammalia* 51: 139–144.





THE AMPHIBIAN DIVERSITY OF SELECTED AGROECOSYSTEMS IN THE SOUTHERN WESTERN GHATS, INDIA

M.S. Syamili¹ & P.O. Nameer²

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

^{1,2} Centre for Wildlife Studies, College of Forestry, Kerala Agricultural University, Thrissur, Kerala, 680656, India

¹syamilimanojcof@gmail.com, ²nameer.po@kau.in (corresponding author)

OPEN ACCESS



Abstract: A study was conducted to evaluate amphibian diversity in selected agroecosystems of central Kerala within the southern Western Ghats of India, from January to May 2017. A total of 10 anurans were recorded from cashew plantation, coconut plantation, homegarden and rubber plantation using a combination of quadrat sampling and visual encounter survey. We recorded three species endemic to the Western Ghats: *Minervarya keralensis*, *Pseudophilautus wynaadensis* and *Indosylvirana urbis* from these agroecosystems. *Pseudophilautus wynaadensis* is a threatened species with Endangered status as per the IUCN Red List. The present study shows a strong relationship between the types of agroecosystems and abundance of different amphibian species. This study highlights the potential of agroecosystems within and adjacent to the Western Ghats mountains to act as important abodes to conserve generalist species of amphibians and to provide a suitable habitat for threatened and endemic species.

Keywords: Endangered, *Minervarya keralensis*, frog, *Indosylvirana urbis*, *Pseudophilautus wynaadensis*, threatened species, Thrissur.

Malayalam Abstract:

മദ്ധ്യകേരളത്തിലെ വിവിധ കാർഷിക ആവാസവ്യവസ്ഥകളിലുള്ള ഉഭയജീവികളുടെ ജൈവവൈവിധ്യം കണ്ടെത്തുന്നതിനായി ജനുവരി 2017 മുതൽ മെയ് 2017 വരെ നീണ്ടുനിന്ന ഒരു പഠനം നടത്തുകയുണ്ടായി. കശുമാവ് തോട്ടം, തെങ്ങിൻതോട്ടം, പൂർണ്ണകൃഷി, റബ്ബർ തോട്ടം തുടങ്ങിയ കാർഷിക ആവാസവ്യവസ്ഥകളിൽ പലതരത്തിലുള്ള പഠന രീതികൾ പ്രയോഗിച്ച്, 10 വിവിധ ഇനം തവളകളെ കണ്ടെത്തുവാൻ കഴിഞ്ഞു. പശ്ചിമഘട്ടത്തിലെ തദ്ദേശീയ ഇനങ്ങളായ കേരള ചിലച്ചൻ (*Minervarya keralensis*), വയനാടൻ കരിയിലത്തവള (*Pseudophilautus wynaadensis*), നാട്ടു മണവാട്ടിത്തവള (*Indosylvirana urbis*) എന്നീ ഇനങ്ങളെയും പ്രസ്തുത പഠനത്തിന്റെ ഭാഗമായി കാർഷിക ആവാസവ്യവസ്ഥകളിൽ നിന്നും രേഖപ്പെടുത്തുവാനായി സാധിച്ചു. ഇതിൽ തന്നെ വയനാടൻ കരിയിലത്തവള (*Pseudophilautus wynaadensis*) IUCNന്റെ ചുവപ്പ് പട്ടിക പ്രകാരം അത്യധികം വംശനാശഭീഷണി നേരിടുന്ന (Endangered) ഗണത്തിൽപ്പെടുന്നതാണ്. തിരഞ്ഞെടുക്കപ്പെട്ട കാർഷിക ആവാസവ്യവസ്ഥകളും ഉഭയജീവികളുടെ സമൃദ്ധിയും തമ്മിൽ അഭേദ്യ ബന്ധം ഉണ്ടെന്നു ഈ പഠനം ചൂണ്ടിക്കാണിക്കുന്നു. വംശനാശഭീഷണി നേരിടുന്നതും തദ്ദേശീയവുമായ ഉഭയജീവികളുടെ സംരക്ഷണത്തിൽ പശ്ചിമഘട്ടത്തോട് ചേർന്നു കിടക്കുന്ന കാർഷിക ആവാസവ്യവസ്ഥകൾക്കുള്ള പങ്ക് ഈ പഠനത്തിലൂടെ വ്യക്തമാവുന്നു.

DOI: <http://doi.org/10.11609/jott.3653.10.8.12027-12034> | **ZooBank:** urn:lsid:zoobank.org:pub:2C0BC2C3-66A3-4BE0-86FF-D8306F4A9398

Editor: Mirco Solé, Universidade Estadual de Santa Cruz, Bahia, Brasil.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3653 | Received 26 October 2017 | Final received 30 June 2018 | Finally accepted 18 July 2018

Citation: Syamili, M.S. & P.O. Nameer (2018). The amphibian diversity of selected agroecosystems in the southern Western Ghats, India. *Journal of Threatened Taxa* 10(8): 12027–12034; <http://doi.org/10.11609/jott.3653.10.8.12027-12034>

Copyright: © Syamili & Nameer 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: Kerala Agricultural University.

Competing interests: The authors declare no competing interests.

Author Details: M.S. SYAMILI is an Assistant Professor and works primarily on herpetofauna and birds. P.O. Nameer is a Professor and his research interest include the taxonomy, biogeography and ecology of the vertebrates except fishes.

Author Contribution: Both the authors contributed equally to the field work, morphometric data collection, analysis and manuscript preparation.

Acknowledgements: We express our deep sense of gratitude and thanks to Dr. Neelesh Dahanukar, IISER, Pune who helped us for analysing the data. Sreekumar, E.R. and Hari Krishnan, S. helped us in various ways during the course of the study. We thank the Dean, College of Forestry, Kerala Agricultural University for the financial and technical support. Azhar Ali, A, Jobin Joseph, U.S. Amal, Afthab Faisal, Habeel Sahal, Abhin M. Sunil, Abhirami M. Jayakumar, Dilgith Surendran, M.R. Bharath and Francis Scaria helped us in the field work. We also thank the anonymous reviewers and the Subject Editor for their critical comments.



INTRODUCTION

Amphibians are important predator and prey species in both aquatic and terrestrial habitats, especially in the tropics where the diversity and abundance of taxa are high. According to Whiles et al. (2006) loss of one species is akin to loss of two species in the case of amphibians. Baillie et al. (2004) stated that among the vertebrates of the world, amphibians are the most threatened taxa and have the highest proportion of species on the verge of extinction. The most pervasive threats to amphibians are habitat loss and habitat degradation.

For the amphibians of the Western Ghats the species accumulation curve has not yet reached a plateau (Aravind et al. 2004). According to Nameer et al. (2015) & Das (2015) 90% of amphibians in Kerala are endemic to the Western Ghats and 33% belong to various threatened categories. Generally, protected area networks are considered as the corner stone of biodiversity conservation efforts. Perfecto & Vandermeer (2008) commented that conservation strategies which focus on tropical forests while ignoring the multiple land uses in which they are embedded are failed strategies. According to Nair (2008), agroforests can be considered as potential oases for disappearing species, even though they cannot substitute for natural forests. Wanger et al. (2009) assessed the herpetological diversity in cacao agroforests of Southeast Asia, where they observed that

certain habitat features like increase in leaf litter favour the richness and abundance of disturbance-tolerant species. Bionda et al. (2011) worked on the amphibians of various agroecosystems in Argentina and found that there are species which take advantage of the hydrology and hydroperiod of agroecosystems for their survival. Not all agroecosystems contribute equally towards conservation.

Hence, for a realistic conservation strategy one should evaluate the conservation value of these multiple land use systems such as agroecosystems. The present study is expected to shed light on the amphibian diversity and richness in agroecosystems of Kerala.

STUDY AREA

The study was conducted in the selected agroecosystems in Thrissur District, southern Western Ghats, Kerala (10.53–10.55 °N & 76.27–76.28°E, 20–70 m). The chosen agroecosystems include, cashew plantation, coconut plantation, homegarden and rubber plantation (Fig. 1). The study area chosen mostly comes within the main campus of the Kerala Agricultural University, in Kerala, southern India. The campus has a total area of 391.44ha and is located very close to the Peechi-Vazhani Wildlife Sanctuary. The major habitats include gardens, botanical garden, plantations of rubber,

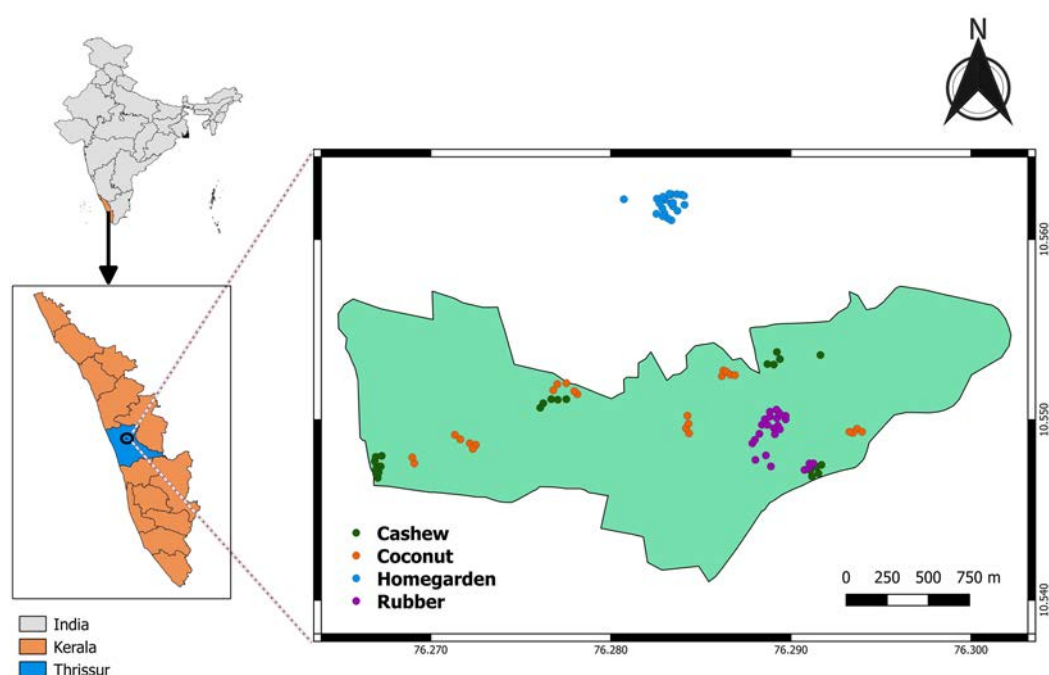


Figure 1. Location map of selected agroecosystems, Thrissur, Kerala

coconut, plantain, cacao, and orchards of mango, jackfruit, sapota and guava. The whole area must have been under the forests about one and a half century or so and was subsequently converted mostly into rubber plantations. Later the land was handed over to the Kerala Agricultural University (KAU) in 1971, and the KAU had developed these areas into the different land uses as is explained above. The 14-year mean minimum temperature is 23.3°C and 10-year mean maximum is 31.9°C. The area receives south-west and north-east monsoons, the greater portion of the rainfall, however is received from the south-west monsoon between June and September. The mean annual rainfall is 2,803.4mm. The mean number of rainy days per year is 112 days (KAU Weather Station 2014).

The study was conducted in four selected agroecosystems such as cashew plantation which is 16 years old and spreads over an area of 90 acres, a coconut plantation, which is about 35 years old and has an extent of 50 acres, a homegarden covering eight acres about 40 years old, and a rubber plantation with an extent of 60 acres and is about 67 years old.

METHODS

The study was conducted from January 2017 to May 2017. Quadrat sampling was the primary method adopted for the study and was supplemented with visual encounter survey.

Quadrat Sampling

One hundred quadrats each having a size of 10m × 10m were deployed in the study area randomly with a

minimum distance of 10m between two quadrats. The observations were taken between 19:00hr and 20:30hr. Two observers surveyed the quadrat from opposite corners approaching the center in a clockwise manner for thorough search of the ground-dwelling amphibians (Harikrishnan et al. 2012).

Visual Encounter Survey

Visual encounter survey was conducted in the study locations (Harikrishnan et al. 2012). This was done between 20:30–21:30 hr. LED torches and head lamps were used to spot the amphibians. During the survey, a range of possible microhabitats where the amphibians could be seen, such as rocks, marshes, fallen logs, tree holes, snags and water bodies were thoroughly examined.

RESULTS AND DISCUSSION

Amphibian diversity of selected agroecosystems

A total of 10 anurans belonging to five families were recorded from the selected agroecosystems of central Kerala (Table 1). This includes two species each from the families Microhylidae, Ranidae and Rhacophoridae, three species from Dicroglossidae and one species from Bufonidae. Dicroglossidae represented 30% of the amphibians encountered during the present study, however, these are commensal and generalist species. These include *Euphlyctis cyanophlyctis*, *Hoplobatrachus crassus* and *Minervarya keralensis*. According to Gururaja et al. (2007), anthropogenic changes in land use type, canopy cover and hydrological regimes support the presence of more generalist amphibian species.

Table 1. Species diversity of amphibians of selected agroecosystems of Thrissur District, Kerala

Common name	Scientific name	Family	Quadrat sampling	Visual encounter survey	IUCN status
Common Indian Toad	<i>Duttaphrynus melanostictus</i>	Bufonidae	1	1	LC
Skittering Frog	<i>Euphlyctis cyanophlyctis</i>	Dicroglossidae	1	0	LC
Jerdon's Bullfrog	<i>Hoplobatrachus crassus</i>	Dicroglossidae	1	0	LC
Kerala Warty Frog	<i>Minervarya keralensis</i>	Dicroglossidae	1	1	LC
Reddish Narrow-mouthed Frog	<i>Microhyla rubra</i>	Microhylidae	0	1	LC
Painted Frog	<i>Uperodon taprobanicus</i>	Microhylidae	0	1	LC
Fungoid Frog	<i>Hydrophylax malabaricus</i>	Ranidae	1	1	LC
Urban Golden-backed Frog	<i>Indosylvirana urbis</i>	Ranidae	1	0	NE
Common Indian Tree Frog	<i>Polypedates maculatus</i>	Rhacophoridae	0	1	LC
Jerdon's Bush Frog	<i>Pseudophilautus wynadensis</i>	Rhacophoridae	1	1	EN

EN - Endangered; LC - Least Concern; NE - Not Evaluated. 0 - Not encountered; 1 - Encountered

Table 2. Amphibian diversity and abundance from selected agroecosystems

Species	Cashew Plantation	Coconut Plantation	Home garden	Rubber Plantation	Total
<i>Duttaphrynus melanostictus</i>	1	0	0	6	7
<i>Euphylyctis cyanophlyctis</i>	0	0	0	5	
<i>Hoplobatrachus crassus</i>	0	0	0	14	
<i>Minervarya keralensis</i>	0	0	3	12	
<i>Microhyla rubra</i>	0	0	0	1	1
<i>Uperodon taprobanicus</i>	0	1	0	0	1
<i>Hydrophylax malabaricus</i>	0	0	0	1	1
<i>Indosylvirana urbis</i>	0	0	0	20	
<i>Polypedates maculatus</i>	0	3	0	0	3
<i>Pseudophilautus wynaadensis</i>	5	7	143	347	502
Total	6	11	146	406	569

Three species that are endemic to Western Ghats namely *Minervarya keralensis*, *Pseudophilautus wynaadensis* and *Indosylvirana urbis* were reported from the agroecosystems that were studied (Biju et al. 2004, 2014; Biju & Bossuyt 2009; Gururaja 2012; Das 2015;

Sanchez et al. 2018). *Pseudophilautus wynaadensis*, an Endangered species (Biju et al. 2004) was found to be present in all the agroecosystems surveyed during the present study (Table 2).

Rathod & Rathod (2013) reported highest diversity of amphibians from organic coffee plantations of Kodagu District where diversity of native rainforest trees was also high. Chemical contamination by the use of fertilizers and pesticides in the agricultural fields lead to incidence of abnormalities among common frog species as their breeding period coincides with the time of agrochemical application in the fields (Gurushankara et al. 2007; Kittusamy et al. 2014; Krishnamurthy et al. 2008). No abnormalities, however, were observed among the 569 individuals of amphibians recorded during the current study.

Quadrat sampling recorded only seven species from the study location. Though visual encounter survey also recorded seven species, it recorded three species that were not recorded through quadrat sampling (Table 1). It is potentially possible to obtain the complete species inventory of the sampled area when visual encounter survey is combined with another sampling technique (Eekhout 2010).

Duttaphrynus melanostictus (Schneider, 1799)

During the present study, Common Indian Toad

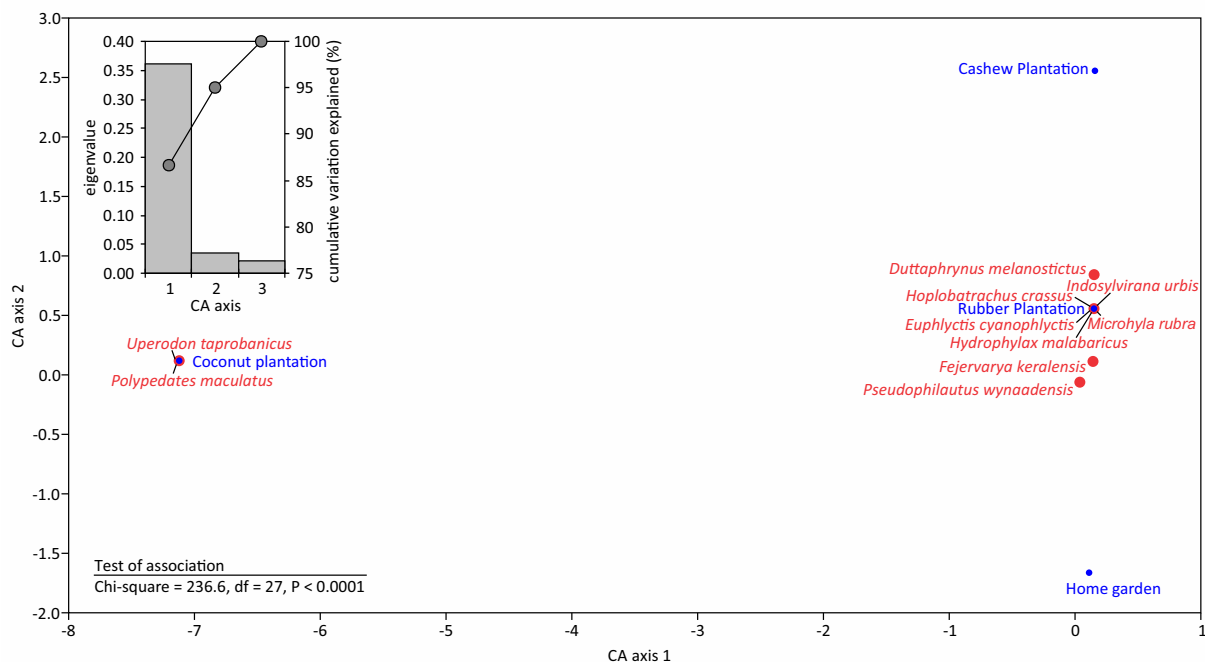


Figure 2. Correspondence analysis (CA) depicting the association between the agroecosystems and the abundance of different amphibian species. Note that *Hoplobatrachus crassus*, *Hydrophylax malabaricus*, *Euphylyctis cyanophlyctis*, *Indosylvirana urbis* and *Microhyla rubra* overlap with the rubber plantation. Test of association and scree plot of percentage variation explained by each CA axis are shown in the inset.

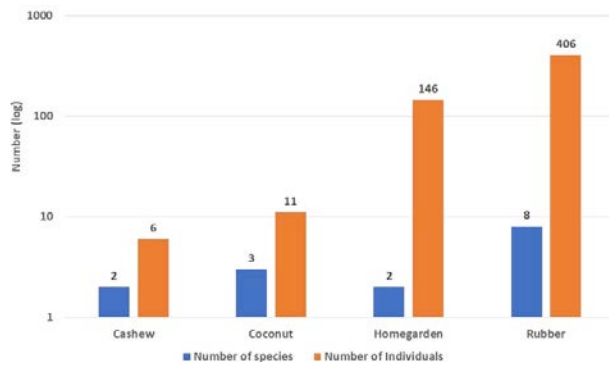


Figure 3. Species richness and abundance of amphibians of selected agroecosystems in southern Western Ghats, India

S = species richness ; N = number of individuals

(Image 1) was encountered from cashew and rubber plantations. It was also sighted in different colour morphs (Images 1A–D) and all individuals were adults.

***Euphlyctis cyanophlyctis* (Schneider, 1799)**

Skittering Frog (Image 2) was sighted only at the pond in the rubber plantation. In this case also only adult individuals were sighted.

***Hoplobatrachus crassus* (Jerdon, 1853)**

Jerdon's Bullfrog (Image 3) is another species which was detected only at the pond within the rubber plantation. The individuals sighted included both adults and juveniles. *Hoplobatrachus crassus* as well as *Euphlyctis cyanophlyctis* are species that prefer water bodies, thus justifying their presence at the pond.

***Minervarya keralensis* (Sanchez et al. 2018)**

Kerala Warty Frog (Images 4A–B) was detected from the homegarden and from the pond within the rubber plantations. Only adult individuals were sighted for this species. This species was formerly under the genus *Fejervarya*, but now is under the new genus *Minervarya* (Sanchez et al. 2018).

***Microhyla rubra* (Jerdon, 1854)**

Reddish Narrow-mouthed Frog (Image 5) was sighted from the premises of the pond in the rubber plantation during visual encounter survey. Interestingly, all the individuals recorded were juveniles of very small size.



Image 1. Common Indian Toad *Duttaphrynus melanostictus*. (A, B, C & D are different colour morphs)

Image 2. Skittering Frog *Euphlyctis cyanophlyctis*.Image 3. Jerdon's Bull Frog *Hoplobatrachus crassus*.Image 4. Kerala Warty Frog *Minervarya keralensis*.
(A & B are different morphs)Image 5. Reddish Narrow-mouthed Frog *Microhyla rubra*.Image 6. Fungoid Frog *Hydrophylax malabaricus*.Image 7. Urban Golden-backed Frog *Indosylvirana urbis*.***Uperodon taprobanicus* (Parker, 1934)**

Painted Frog was spotted from a tree hole within the coconut plantation. This species was sighted only once during the study period.

***Hydrophylax malabaricus* (Tschudi, 1838)**

Fungoid frog (Image 6) was detected only from the rubber plantation. It was found in the moist areas of the

plantation.

***Indosylvirana urbis* (Biju et al., 2014)**

Urban Golden-backed Frog (Image 7) was found on the rocky patches near the pond within the rubber plantation.



Image 8. Common Indian Tree Frog *Polypedates maculatus*.

Polypedates maculatus (Gray, 1834)

Common Indian Tree Frog (Image 8) is one of the most common tree frogs in Kerala. During the visual encounter survey, a male and female of the species were recorded from the coconut plantation. After the first summer shower in May, one additional individual was also observed from the coconut plantation.

Pseudophilautus wynaadensis (Jerdon, 1853)

Jerdon's Bush Frog (Image 9) was the most common frog during the present study and was recorded from all the agroecosystems selected for the present study. We observed four colour morphs of the species during the study period (Image 9A–D). All the 25 quadrats in the homegarden detected the presence of this species. The highest count of the species was from rubber plantation where there were 30–40 individuals on a single herb of *Rauwolfia tetraphylla* near a moist area, due to a leakage in the irrigation pipeline that passed through the rubber plantation.

It may be noted that all the amphibians sighted within the rubber plantations were either located in a pond in the rubber plantation or from artificially wet areas.

Association between the agroecosystems and abundance of amphibians

The null hypothesis is that there is no association between the type of agroecosystem and abundance of different amphibian species. The Chi-square test (Chi-square = 236.6, df = 27, $P < 0.0001$) suggested that there is a strong association between the type of agroecosystem and abundance of different amphibian species (Fig. 2). Correspondence analysis was performed to understand the association between selected agroecosystems and amphibian abundance.



Image 9. Jerdon's Bush Frog *Pseudophilautus wynaadensis* (A, B, C & D are different colour morphs).

Polypedatus maculatus and *Uperodon taprobanicus* were only present in coconut plantation and this agroecosystem was not preferred by other species of amphibians encountered in the study (Fig. 2). All other species of amphibians preferred rubber plantation. *Hoplobatrachus crassus*, *Hydrophylax malabaricus*, *Euphlyctis cyanophlyctis*, *Indosylvirana urbis* and *Microhyla rubra* were exclusively present in the rubber plantation, while *Minervarya keralensis* and *Pseudophilautus wynaadensis* also preferred homegardens at some level, while *Duttaphrynus melanostictus* showed a preference to the cashew plantation (Fig. 2).

Amphibian abundance and richness was found to be higher in rubber plantation followed by homegarden (Fig. 3). This higher amphibian diversity and abundance in the rubber plantation could be an artifact because of the presence of a pond as well as the presence of a couple of wet areas due to anthropogenic interventions, in the rubber plantations. This could also explain the presence of species such as *Euphlyctis cyanophlyctis*, *Hoplobatrachus crassus*, *Indosylvirana urbis*, and *Microhyla rubra* only from the rubber plantation, even during the summer months. According to Neckel-Oliveira & Gascon (2006), presence of an aquatic habitat is crucial for the existence of certain species of amphibians.

Rathod & Rathod (2013) explained that an open canopy can increase the temperature and evaporation and decrease the persistence of moist areas. This can be one reason for fewer encounters with amphibians from coconut plantation and cashew plantation.

CONCLUSION

Protected areas cover 18% of the Earth's land area and 8% of Kerala's geographical area, and they are considered to be corner stones of biodiversity conservation. It is a fact that most of these protected areas are virtual islands embedded within a matrix of multiple land uses. A large proportion of biodiversity coexists with humans in their managed ecosystems, which can hold minimum viable populations of rare and endangered native fauna and flora. The potential of such landscapes in conserving native biodiversity is still untapped. The present study showed that agroecosystems have not only the potential to conserve generalist species, but also help to provide suitable habitat for some threatened and endemic species of amphibians.

REFERENCES

- Aravind, N.A., R.U. Shaanker & K.N. Ganeshaiah (2004). Croak, croak, croak: are there more frogs to be discovered in the Western Ghats? *Current Science* 86(11): 1471–1472.
- Baillie, J., C. Hilton-Taylor & S.N. Stuart [eds.]. (2004). *2004 IUCN Red List of Threatened Species: A Global Species Assessment*. Thanet Press Ltd., Margate, UK, 195p.
- Biju, S.D. & F. Bossuyt (2009). Systematics and phylogeny of *Philautus* Gistel, 1848 (Anura, Rhacophoridae) in the Western Ghats of India, with descriptions of 12 new species. *Zoological Journal of the Linnean Society* 155(2): 374–444; <http://doi.org/10.1111/j.1096-3642.2008.00466.x>
- Biju, S.D., G.D. Buddhe, S. Dutta, K. Vasudevan, C. Srinivasulu & S.P. Vijayakumar (2004). *Pseudophilautus wynaadensis* (errata version published in 2016). The IUCN Red List of Threatened Species 2004. Downloaded on 16 March 2018; <http://doi.org/10.2305/IUCN.UK.2004.RLTS.T58937A11859437.en>
- Biju, S.D., S. Garg, S. Mahony, N. Wijayathilaka, G. Senevirathne & M. Meegaskumbura (2014). DNA barcoding, phylogeny and systematics of Golden-backed Frogs (Hylarana, Ranidae) of the Western Ghats-Sri Lanka biodiversity hotspot, with the description of seven new species. *Contributions to Zoology* 83(4): 269–335.
- Bionda, C.D.L., I.E. di Tada & R.C. Lajmanovich (2011). Composition of amphibian assemblages in agroecosystems from the central region of Argentina. *Russian Journal of Herpetology* 18(2): 93–98.
- Das, S. (2015). A checklist of amphibians of the Kerala State. *Journal of Threatened Taxa* 7(13): 8023–8035; <http://doi.org/10.11609/JoTT.2003.7.13.8023-8035>
- Eekhout, X. (2010). Sampling amphibians and reptiles, pp. 530–557. In: *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories*. National Focal Point to The Global Taxonomy Initiative, Belgium.
- Gururaja, K.V. (2012). *Pictorial Guide to Frogs and Toads of the Western Ghats*. Gubbi Labs LLP.
- Gururaja, K.V., K.P. Dinesh, M.J. Palot, C. Radhakrishnan & T.V. Ramachandra (2007). A new species of *Philautus* Gistel (Amphibia: Anura: Rhacophoridae) from southern Western Ghats, India. *Zootaxa* 1621: 1–16.
- Gurushankara, H.P., S.V. Krishnamurthy & V. Vasudev (2007). Morphological abnormalities in natural populations of common frogs inhabiting agroecosystems of central Western Ghats. *Applied Herpetology* 4(1): <http://doi.org/39-4510.1163/157075407779766651>
- Harikrishnan, S., S. Chandramouli & K. Vasudevan (2012). A survey of herpetofauna on Long Island, Andaman and Nicobar Islands, India. *Herpetological Bulletin* 119: 19.
- Kittusamy, G., C. Kandaswamy, N. Kandan & M. Subramanian (2014). Pesticide residues in two frog species in a paddy agroecosystem in Palakkad district, Kerala, India. *Bulletin of Environmental Contamination and Toxicology* 93(6): 728–734; <http://doi.org/10.1007/s00128-014-1351-1>
- Krishnamurthy, S.V., D. Meenakumari, H.P. Gurushankara & V. Vasudev (2008). Nitrate-induced morphological anomalies in the tadpoles of *Nyctibatrachus major* and *Fejervarya limnocharis* (Anura: Ranidae). *Turkish Journal of Zoology* 32(3): 239–244.
- Nair, P.R. (2008). Agroecosystem management in the 21st century: it is time for a paradigm shift. *Journal of Tropical Agriculture* 46: 1–12.
- Nameer, P.O., J. Praveen, A. Bijukumar, M.J. Palot, S. Das & R. Raghavan (2015). A checklist of vertebrates of the Kerala State. *Journal of Threatened Taxa* 7(13): 7961–7970; <http://doi.org/10.11609/jott.1999.7.13.7961-7970>
- Neckel-Oliveira, S. & C. Gascon (2006). Abundance, body size and movement patterns of a tropical treefrog in continuous and fragmented forests in the Brazilian Amazon. *Biological Conservation* 128(3): 308–315; <http://doi.org/10.1016/j.biocon.2005.09.037>
- Perfecto, I. & J. Vandermeer (2008). Biodiversity conservation in tropical agroecosystems. *Annals of New York Academy of Science* 1134(1): 173–200; <http://dx.doi.org/10.1196/annals.1439.011>
- Rathod, S. & P. Rathod (2013). CEPF Western Ghats Special Series: Amphibian communities in three different coffee plantation regimes in the Western Ghats, India. *Journal of Threatened Taxa* 5(9): 4404–4413; <http://doi.org/10.11609/JoTT.o3054.4404-13>
- Sanchez, E., S.D. Biju, M.M. Islam, M. Hasan, A. Ohler, M. Vences & A. Kurabayashi (2018). Phylogeny and classification of fejevryan frogs (Anura: Dicroglossidae). *SALAMANDRA* 54(2): 109–116.
- Wanger, T.C., A. Saro, D.T. Iskandar, B.W. Brook, N.S. Sodhi, Y. Clough & T. Tschardt (2009). Conservation value of cacao agroforestry for amphibians and reptiles in Southeast Asia: combining correlative models with follow-up field experiments. *Journal of Applied Ecology* 46(4): 823–832; <http://doi.org/10.1111/j.1365-2664.2009.01663.x>
- Whiles, M.R., K.R. Lips, C.M. Pringle, S.S. Kilham, R.J. Bixby, R. Brenes, S. Connelly, J.C. Colon-Gaud, M. Hunte-Brown, A.D. Huryn & C. Montgomery (2006). The effects of amphibian population decline on the structure and function of Neotropical stream ecosystems. *Frontiers in Ecology and Environment* 4(1): 27–34; [http://doi.org/10.1890/1540-9295\(2006\)004\[0027:TEOAPD\]2.0.CO;2](http://doi.org/10.1890/1540-9295(2006)004[0027:TEOAPD]2.0.CO;2)





TAXONOMIC STATUS AND ADDITIONAL DESCRIPTION OF WHITE'S STALKED-EYED FLY *CYRTODIOPSIS WHITEI* (CURRAN, 1936) (DIPTERA: DIOPSIDAE) FROM INDIA WITH A KEY TO THE ALLIED SPECIES AND NOTE ON ITS HABITAT

Basant Kumar Agarwala

Department of Zoology, Tripura University, Suryamaninagar, Bikramnagar, Tripura 799022, India
bagarwala00@gmail.com

OPEN ACCESS



Abstract: Systematics and ecology of *Cyrtodiopsis whitei* (Curran, 1936), initially described in brief from a tropical dry deciduous forest in eastern India as *Diopsis whitei*, remained obscure for want of the type specimens. Recent collections of male and female specimens of this species from a new locality in the northeastern part of India, the country of the type locality, has allowed a fresh appraisal of its morphology, taxonomic position and habitat ecology in the background of several studies done on Diopsidae. Herein are included some new characters, hitherto unknown in the species of *Cyrtodiopsis*, a taxonomic key to the separation of four species, considered monophyletic under the genus, and a note on the habitat of the species.

Keywords: *Cyrtodiopsis*, *Diopsis*, habitat, monophyletic, new characters, systematics, taxonomic key.

DOI: <http://doi.org/10.11609/jott.3272.10.8.12035-12043> | **ZooBank:** urn:lsid:zoobank.org:pub:5D25C79A-A3F6-46FA-A302-5BC3B013C713

Editor: Mihaly Foldvari, University of Debrecen, Hungary.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3272 | Received 06 January 2017 | Final received 12 May 2018 | Finally accepted 20 June 2018

Citation: Agarwala, B.K. (2018). Taxonomic status and additional description of White's Stalked-eyed Fly *Cyrtodiopsis whitei* (Curran, 1936) (Diptera: Diopsidae) from India with a key to the allied species and note on its habitat. *Journal of Threatened Taxa* 10(8): 12035–12043; <http://doi.org/10.11609/jott.3272.10.8.12035-12043>

Copyright: © Agarwala 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: This study was supported by Indian Council of Agriculture Research, New Delhi through a project no. F. No.16-16/2007-IA IV to the author.

Competing interests: The author declares no competing interests.

Author Details: BASANT KUMAR AGARWALA is a full Professor in the Department of Zoology at Tripura University, Tripura, India. His research interests comprise of systematic, ecology and diversity of insects of northeastern India.

Acknowledgements: The author is thankful to Dipankar Kishore Sinha for his tireless help in the field and in the drawing of some of the figures. Gratitude is extended to the subject editor for several improvements in the original manuscript.



INTRODUCTION

Worldwide, Stalked-eyed Flies of the family Diopsidae Bilberg, 1820 are known by 189 species from 12 genera (Roskov et al. 2015). These include reports of eight species in five genera from India (Mitra et al. 2014). Baker et al. (2001), Meier & Baker (2002), and Földvári et al. (2007) considered species of *Teleopsis* Rondani, 1875 and *Cyrtodiopsis* Frey, 1928 to be congeneric based on molecular affinity provided by partial nucleotide alignments of three mitochondrial and three nuclear genes. Feijen (2011), however, disputed the single clade phylogenetic hypothesis by Baker et al. (2001) and preferred *Teleopsis* and *Cyrtodiopsis* to be paraphyletic and that is being widely followed in diopsid taxonomy and biology till date (Roskov et al. 2015).

The original description of *Cyrtodiopsis whitei* under the genus *Diopsis* by Curran from India in 1936 had inadequate morphometrical details and illustrations of diagnostic characters. The whereabouts of the type specimens (male holotype and a female allotype) collected on 2 May 1935 and originally deposited in the American Museum of Natural History (New York) is uncertain, and Shillito (1940) based his study of the species on a single specimen by the identical name collected on 21 October 1920 from a location in 'Jungle of Assam', northeastern India. Földvári et al. (2007), based on laboratory culture specimens from Malaysia, provided another brief description of the species without sufficient illustration of diagnostic characters, and without reference to the original description provided by Curran (1936). It is, therefore, doubtful if the Malaysian specimens are really *C. whitei*. Extensive uses of laboratory-reared *C. whitei* in behavioral (Lorch et al. 1993; Wilkinson et al. 1998; Al-Khairulla et al. 2003), physiological (Burkhardt & de la Motte 1983; Buschbeck & Hoy 2005) and genetic studies (Wilkinson et al. 1997; Wilkinson & Sanchez 2001) has made this species name well known as an experimental object for molecular and behavioral studies of stalked-eyed flies in general.

Therefore, in view of the recent collection of both the sexes of *C. whitei* from a new location in northeastern India, the country of the type locality, it became necessary to provide accurate description of the species based on biometric data and supported by photographs and line drawings which include descriptions of new morphological characters previously unnoticed in this species. Another objective of this study is to provide a better understanding of *C. whitei* in its area of distribution and its relation to other species so as to ensure its accurate identification and a better taxonomic appraisal

of the genus. To that end, an identification key to the known species of *Cyrtodiopsis*, sensu Feijen (2011), and a note on the habitat have also been provided.

METHODS AND MATERIALS

Live specimens of *C. whitei* were collected from the wild habitat using insect nets and these were transferred to killing jars. Biotic and abiotic features of the habitat of occurrence were recorded on each occasion of specimen collection. Dead and dry specimens were brought to the laboratory and kept in relaxation boxes for 36 hours to allow softening of external parts. Individual insects were spread to their natural posture and mounted on paper tips, pinned, labeled, and studied under Leica M205C zoom stereoscopic microscope fitted with Leica DFC295 digital camera. Biometry to the accuracy of 0.01mm and microphotographs were taken using Leica Application 3.8.0 version software. Images, so acquired, were transferred in Microsoft power point slides to write the names of characters. Abdomens of six males and a female were dissected for genitalia study. These were individually subjected to heating in glass vials at 60°C, first in 10% KOH solutions for 10 minutes for maceration, then for five minutes each at increasing concentrations of ethyl alcohol (70%, 80%, 90% and 99.99%) for dehydration. Dehydrated specimens were boiled for five minutes in the saturated solution of choral phenol for softening of cuticle and sclerotised structures (Feijen & Feijen 2011). Finally, the abdomens with the ventral side up were mounted individually on clean glass slides with the help of fine tip needles under the Carl Zeiss Stemi 2000-C microscope and studied under Carl Zeiss AXIO Lab.1 microscope under 10X and 40X objectives and for Camera Lucida drawings. Specimens of this study are deposited with identical accession numbers, as used in Tables 1 and 2, in the Insect Biodiversity Laboratory, Department of Zoology of Tripura University.

RESULTS

Order Diptera

Infra order Muscomorpha

Super family Diopsoidea

Family Diopsidae Bilberg, 1820

Genus *Cyrtodiopsis* Frey, 1928

Diagnosis: Thorax with a pair of infra-alar spines, supra-alar spines absent, scutellar spines slightly to

Table 1. Morphometry* of *C. whitei***

Characters	Male 1 (4004)	Male 2 (4005)	Male 3 (4006)	Male 4 (4007)	Male 5 (4008)	Male 6 (4009)	Range (min.– max.)	Female 1 (4010)
Body length	5.58	5.69	5.12	5.59	5.34	4.56	4.56–5.69	6.49
Eye span	6.95	7.52	4.95	6.57	5.72	3.98	3.98–7.52	5.83
Eye stalk length	3.47	3.71	2.47	3.29	2.81	1.99	2.47–3.71	3.03
Eye stalk middle width	0.13	0.14	0.10	0.13	0.12	0.12	0.10–0.14	0.13
Inner vertical bristle	0.58	0.66	0.59	0.62	0.51	0.54	0.51–0.66	0.64
Outer vertical bristle	0.37	0.37	0.35	0.37	0.25	0.32	0.25–0.39	0.39
Antenna 1 st segment	0.10	0.07	0.08	0.08	0.08	0.07	0.07–0.10	0.09
Antenna 2 nd Segment	0.15	0.15	0.19	0.16	broken	0.16	0.15–0.20	0.20
Antenna 3 rd Segment	0.09	0.10	0.09	0.10	broken	0.12	0.09–0.14	0.14
Antenna length	0.34	0.32	0.36	0.34	broken	0.35	0.32–0.43	0.43
Arista length	0.82	0.70	0.90	0.81	broken	0.74	0.70–0.90	0.82
Longest hair: head dorsum with bifid apices	0.18	0.125	0.15	0.18	0.10	0.13	0.10–0.23	0.23
Longest hair: base of eye stalk	0.14	0.14	0.12	0.14	0.12	0.12	0.12–0.16	0.16
Longest hair: near IVB	0.07	0.10	0.08	0.10	0.10	0.08	0.07–0.10	0.10
Longest hair: near antennal base	0.07	0.07	0.08	0.06	0.08	0.08	0.06–0.08	0.06
Longest hair: thorax dorsum	0.32	0.38	0.27	0.33	0.28	0.25	0.27–0.39	0.39
Scutellum length	0.23	0.23	0.18	0.25	0.23	0.18	0.18–0.32	0.32
Scutellum width	0.57	0.61	0.48	0.55	0.48	0.44	0.44–0.61	0.61
Infra-alar spine length	0.29	0.31	0.25	0.32	0.29	0.24	0.24–0.35	0.35
Scutellar spine length	1.02	1.08	0.80	1.0	0.99	0.69	0.69–1.12	1.12
Longest hair: scutellar spine	0.30	0.35	0.28	0.32	0.26	0.27	0.26–0.35	0.32
Basal diameter of scutellar spine	0.13	0.13	0.11	0.13	0.11	0.19	0.11–0.19	0.16
Fore coxa length	0.84	0.85	0.68	0.83	0.78	broken	0.78–0.86	0.86
Fore femora length	1.70	1.81	1.43	1.66	1.58	broken	1.43–1.81	1.79
Fore femora maximum width	0.37	0.41	0.30	0.35	0.33	broken	0.33–0.37	0.36
Longest hair: Fore femora	0.31	0.32	0.27	0.29	0.25	broken	0.25–0.29	0.29
First tarsal segment length	0.66	0.68	0.66	0.72	0.74	0.68	0.66–0.74	0.68
Last tarsal segment length	0.10	0.10	0.10	0.10	0.12	0.10	0.10–0.12	0.10
Wing length	4.09	4.30	3.84	4.14	3.84	3.16	3.16–4.56	4.56

*All measurements in mm. **Specimens are provided with respective accession/ reference numbers in parenthesis.

strongly curved outward, hairy, and each spine with a terminal bristle; fore femora conspicuously constricted on inner side at apex with incrassate surface; a tubercle is present at the base of inner margins of fore tibia that seems to fit into the constricted apex of fore femora when the fly is in rest.

Taxonomic status of the genus: Frey (1928) proposed *Cyrtodiopsis* from a collection of the Stalk-eyed Flies of Philippines on the basis of a distinct “peg and hollow structure of forelegs in certain males” with *dalmanni* (Weidmann) as the type species. Shillito (1940) provided the first illustrated account of the family with a key to the

identification of eight genera with particular reference to five species of the genus *Cyrtodiopsis*. Shillito (1940) distinguished *Cyrtodiopsis* from its nearest taxonomic relative *Teleopsis* in the wings without an alula, the thorax with infra-alar spines but without supra-alar spines, scutellar spines strongly curved, hairy and with a terminal long bristle and, most important, fore femora with constricted apex ventrally and fore tibia with rounded tubercles present at the base of the ventral side. Földvári et al. (2007) added a new species *Teleopsis thaii*, which is considered to be a *Cyrtodiopsis* species in the present work.

***Cyrtodiopsis whitei* (Curran, 1936) (Images 1–5; Figs. 1–5)**

= *Diopsis whitei* Curran, 1936, *Am. Mus. Nov.* 833: 1–2

= *Teleopsis whitei* (Curran, 1936) in Földvári, M., A. Pomiankowski, S. Cotton & M. Carr (2007) *Zootaxa* 1620: 37–51.

Materials examined: TU/Dipt/Diop-4004, TU/Dipt/Diop-4005, TU/Dipt/Diop-4006, 3 males, 12.viii.2013, Sakaibari, Dhalai District, Tripura, 24.10995°N & 91.90888°E, decomposing organic mass floating in shallow waters of Gomti; TU/Dipt/Diop-4007, TU/Dipt/Diop-4008, TU/Dipt/Diop-4009, 3 males and 1 female, 30.vii.2015, coll. D.K. Sinha.

Habitat: The habitat of *C. whitei* in the Dhalai District of Tripura province is an evergreen primary virgin forest of low hills of 'Longtharai' (local name meaning 'deep valley') and is the catchment area of two rivers, each of which traverses through valleys forming wide and narrow to very narrow streams lined by rocky banks and verticals. Stalk-eyed flies were found to be active in the sunshine hours in decomposing mixed vegetation dominated with banana leaves that was either floating in streams or in organic mass formed near the bank of stream. Atmospheric temperature and humidity of the habitat at the collection sites were recorded to be 24.2–25.6 °C and 74–77 %, respectively, and that of the microhabitat within 10cm of aerial distance of the collection points were found to be 21.4–22.8 °C and 81–84 %, respectively.

Description of additional characters

Male: Length 4.56–5.69 mm; coloration generally brownish, head with antennae yellowish-brown to brown, thorax shining brown, scutellum darker than pre-scutellum or scutum; coxae and femora reddish-brown, tibiae and bases of tarsi reddish-brown to deep brown; wings pale brown with outer margins dark; abdomen with basal three segments pale brown and distal segments dark brown (Image 1). Head (Images 2,3; Fig. 1): sub-triangular, dorsum of central part yellowish brown (Image 2), conspicuously raised and bears three ocelli, one bigger in the front and two smaller on sides, with a pair of deep brown bristles having pointed apices (Fig. 1), about 0.14–0.18 mm long; frons brownish, humped, projected forward, with a dorsal curved deep brown band and a distinct mid-suture, face concolorous with dorsum of head, slightly protruding, bear several long blackish bristles with pointed apices, 1–2 of these with bifid apices, about 0.20–0.24 mm long; vertex yellowish brown to brown, narrower in front, broader at base and



Image 1. *Cyrtodiopsis whitei*: Paper point-mounted male specimen.

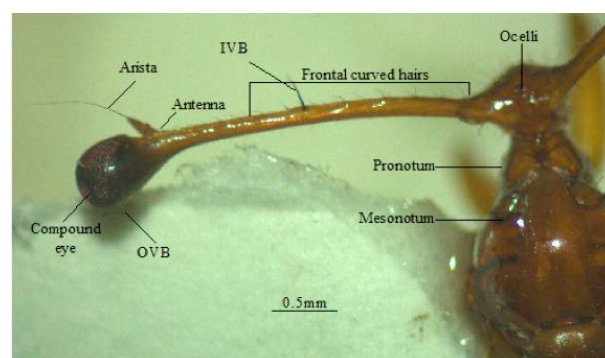


Image 2. *Cyrtodiopsis whitei*: Head with one side of the eye stalk showing details; IVB = inner vertical bristle, OVB = outer vertical bristle. © Basant Kumar Agarwala

with rounded edges, bearing long hairs of bifid apices on the posterior edges (Image 3a); eye stalks yellowish-brown, smooth, bears a row of sparse, thin hairs, facing outward, with pointed apices, curved gently to strongly, these gradually decrease in lengths from the origin of stalks in the central part of the head to the bases of antennae (Image 2), the longest ones at the base of eye stalk 0.12–0.14 mm long, 0.07–0.10 mm long in the middle of eye stalks, and 0.06–0.08 mm long at the bases of antennae, thus the longest ones at the base of eye stalk, on average, are 1.50–2.33 times longer than the shortest ones near the base of antenna; inner vertical bristles (IVB) and outer vertical bristles (OVB) at low tubercles, 0.51–0.66 mm and 0.25–0.37 mm long, respectively (Table 1), and these 4.31–5.90 times

and 2.10–3.38 times the middle width of eye stalks, respectively (Table 2); eye span 3.98–7.52 mm long and 0.87–1.32 times the body length; antennae light brown, 3-segmented (Image 2), 0.32–0.36 mm long, the shortest basal segment with a dark bristle on inner side, called scape, 0.07–0.10 mm long, the middle segment, called pedicel, 0.15–0.19 mm long (Table 1) and about 2–3 times longer than the basal segment (Table 2), bear 2–3 dark bristles, and the third and last segment, called first flagellomere, nearly bulbous, densely covered with small hairs, 0.09–0.12 mm long, about twice the length of the middle segment, and bears a thick, long bristle-like structure with pointed apex on a raised base, called arista (Fig. 2), 0.70–0.90 mm long (Table 1), and 1.30–1.52 times and 1.89–2.57 times the lengths of IVB and OVB, respectively (Table 2). Thorax (Image 3): collar glossy brown, V-shaped, scutum glossy brown, bi-lobed, smooth; scutellum shorter than wide, 0.18–0.25 mm long and 0.44–0.61 mm wide, with dorsum broad, glossy brown, densely pollinose in the centre of pronotum and mesonotum (Image 3b), bears many short thin hairs with pointed apices only and a few long and prominent hairs with pointed or bifid apices, the longest ones about 0.25–0.39 mm long; infra-alar spines yellowish, short, dorso-ventrally flattened, and with blunt apices (Image 3c), these about 0.24–0.32 mm long (Table 1); scutellar spines dark, slightly curved inward, 0.69–1.12 mm long, 3.75–4.73 times the length of scutellum, each spine bears on its inner side 2–3 small hairs with pointed apices and 3–4 longer hairs with bifid apices (Image 3d), the longest ones about 0.26–0.35 mm long, and a long apical bristle, about 0.44–0.49 mm long (Table 1). Wings (Image 4): 3.16–4.30 mm long, bases of fore wings leathery, rest membranous, dorsal surface densely covered with minute hairs; four distinct pale brown to brown bands present from base to the apex, the basal-most band paler than the other three bands, covers anal cell, discal cell, radial cell and subcostal-radial cell from lower to upper parts of the wing; the second band from the wing base broadest and darkest between R_{2+3} and R_{4+5} , and pale between costa and R_1 ; the sub-apical third band brownish, irregular, widest in the middle or radial-medial cell, and the fourth apical-most band narrowest, pale brown to brown in different specimens, extending from R_{2+3} to M_{1+2} from the apex and projects slightly to prominently towards the subapical band in the median cell; subapical and apical bands separated by three pale spots from apex to base of wings, with the median semi-circular hazy spot in comparison to pale but distinct anterior and posterior circular spots; hind wings leathery, stump-like with a short stalk and attached to the raised

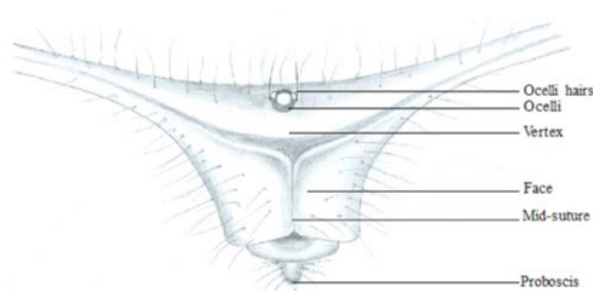


Figure 1. *Cyrtodiopsis whitei*: Frons of head showing ocelli, paired hairs on both sides of ocelli, face and proboscis.

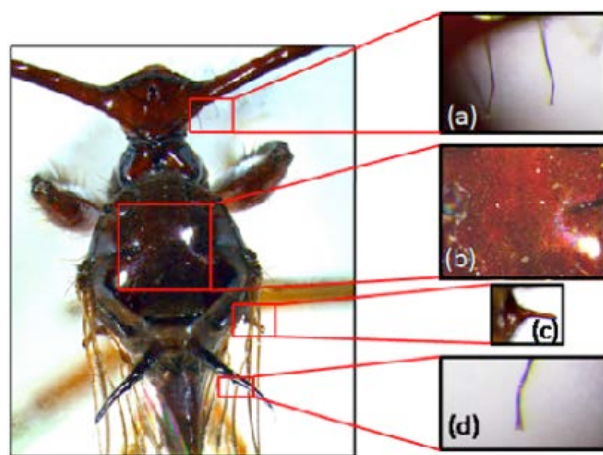


Image 3. *Cyrtodiopsis whitei*: Head and thorax showing (a) characteristic hairs with bifid apices on the rear part of vertex, (b) pollinose mesonotum, (c) infra-alar spine, (d) a long hair with bifid apex on scutellar spine. © Basant Kumar Agarwala

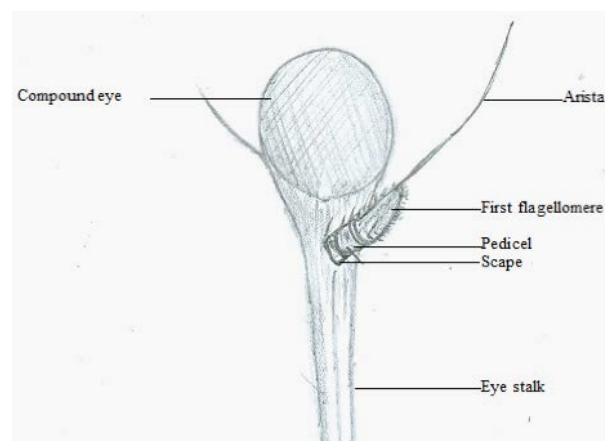


Figure 2. *Cyrtodiopsis whitei*: Eye stalk showing three segments of antenna and a long bristle, arista, arising from the third segment.

bases. Legs: conspicuously hairy, longer hairs with bifid apices; fore coxae 0.78–0.85 mm long, swollen in the middle; fore femora much wider (0.33–0.37 mm) than

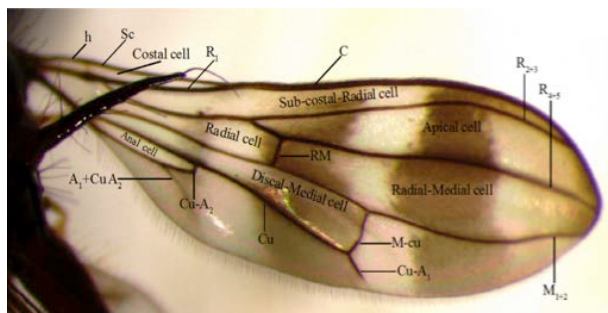


Image 4. *Cyrtodiopsis whitei*: Forewings - h = humerus vein, Sc = subcosta, C = costa, R_1 , R_{2+3} , R_{4+5} = radial veins, M_{1+2} = medial veins, M-Cu = medial-cubitus vein, Cu = cubitus vein, Cu- A_1 = Cubitus-anal vein, Cu- A_2 = cubitus and anal 2 veins, A_1 +Cu A_2 = anal1 and cubitus 2 veins. © Basant Kumar Agarwala

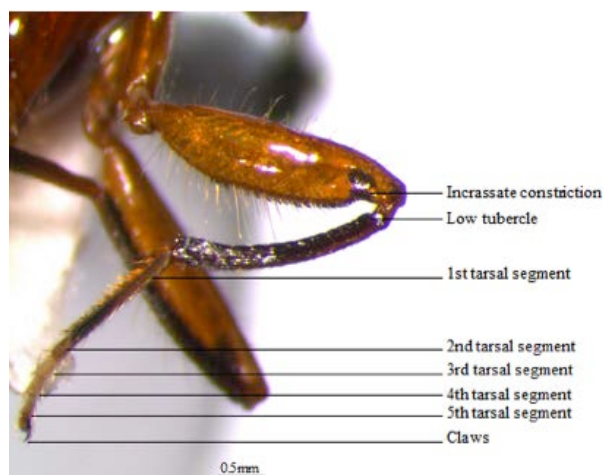


Image 5. *Cyrtodiopsis whitei*: Foreleg showing apical incrassate constriction in femur, low tubercle on inner base of tibia, 5 segments of tarsi, and a pair of claws. © Basant Kumar Agarwala

mid- (0.13–0.16 mm) and hind femora (0.10–0.12 mm), basal $\frac{1}{4}$ part of inner margins smooth, rest $\frac{3}{4}$ margins incrassate, with a shallow constriction near the joint with tibia (Image 5); fore tibia with a low, rounded and dark tubercle in the apex that seems to fit in the constricted part of the fore femur on each side when the fly is in rest; tibiae dark, sparsely hairy on margins; tarsi 5-segmented, first segment the darkest and the longest, 0.66–0.74 mm long, densely hairy on posterior margins, next four segments paler, decreasingly smaller in sizes, the apical-most segment the smallest, 0.10–0.12 mm long, about 6.16–7.20 times the first tarsal segment, bear two dark, curved divergent claws. Abdomen black, clavate shaped (Image 1), first three segments fused, fuscus, with sparse long and thin hairs having pointed apices, tergites mildly pollinose, fourth, fifth and sixth segments with distinct inter-segmental sutures, wider than first three segments, gently deflexed ventrally, tergites and pleurites with hairs all over, segments 7 to 10 narrow to very narrow, condensed, covered with microtrichia and a few sparsely distributed long hairs; sub-anal plate triangular, heart-shaped; cerci club-shaped, apically rounded, about twice the length at base. Genitalia (Figs. 3–5): In ventral view, epandrium rounded with sclerotised and smooth margins, with 18 pairs of long setae counted when mounted in slide; surstyli pale, broad basally with thin margins but brown, bulbous apically, bulbous ends sclerotised and proximate in the middle, covered with microtrichia, with four pairs of long setae, two pairs originate from the inner margins of the base and other two pairs originate from the outer margins of bulbous apex (Fig. 3); cerci

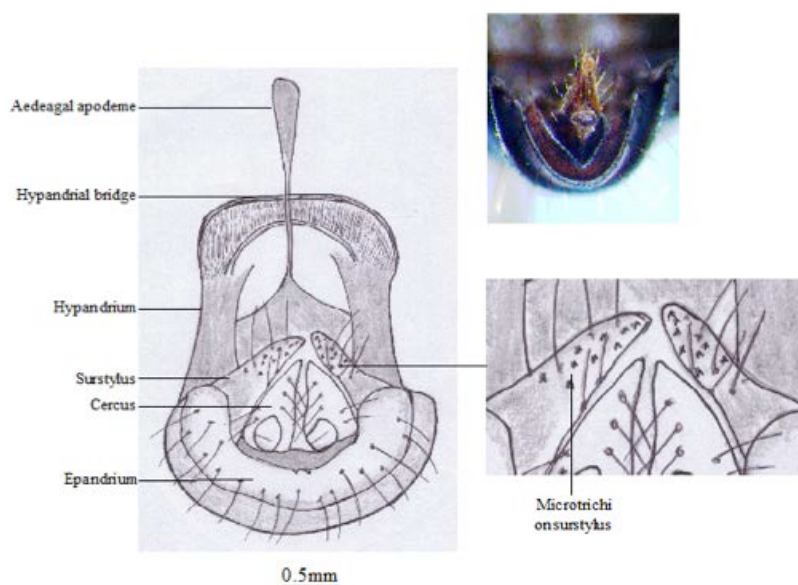


Figure 3. *Cyrtodiopsis whitei*: Structure of male genitalia - dorsal view showing magnified surstyli covered with long hairs and microtrichi; inset is the actual photograph.

Table 2. Ratio of bivariate characters of *C. whitei**

Ratio of Characters	Male1 (4004)	Male 2 (4005)	Male 3 (4006)	Male 4 (4007)	Male 5 (4008)	Male 6 (4009)	Range (min.-max.)	Female (4010)
Eye span/ body length	1.24	1.32	0.97	1.18	1.07	0.87	0.87–1.32	0.90
Inner vertical bristle/Eye stalk middle width	4.46	4.71	5.90	4.31	4.58	5.75	4.31–5.90	5.09
Outer vertical bristle/Eye stalk middle width	2.79	2.54	3.38	2.80	2.10	2.69	2.54–3.28	3.08
Arista length/Inner vertical bristle	1.41	1.06	1.52	1.30	broken	1.36	1.30–1.52	1.30
Arista length/Outer vertical bristle	2.20	1.89	2.57	2.21	broken	2.28	1.89–2.57	2.14
Scutellum: length/ width	0.41	0.37	0.37	0.47	0.49	0.41	0.37–0.52	0.52
Scutellar spine length/ Scutellum length	4.45	4.73	4.54	3.93	4.25	3.89	3.75–4.73	3.75
Longest hair at base of eye stalk/ longest hair at base of antennae	2.0	2.0	1.50	2.33	2.0	1.50	1.50–2.67	2.67
First tarsal segment/last tarsal segment	6.60	6.80	6.60	7.20	6.16	6.80	6.16–7.20	6.80

*Specimens are provided with respective accession numbers in parentheses.

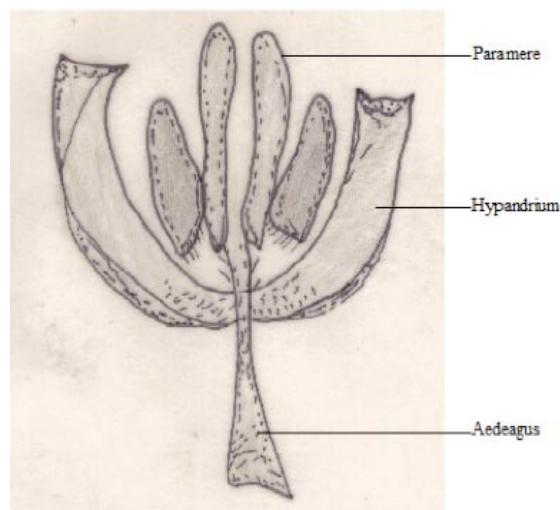


Figure 4. *Cyrtodiopsis whitei*: Male genitalia - ventral view of hypandrium and associated structures.

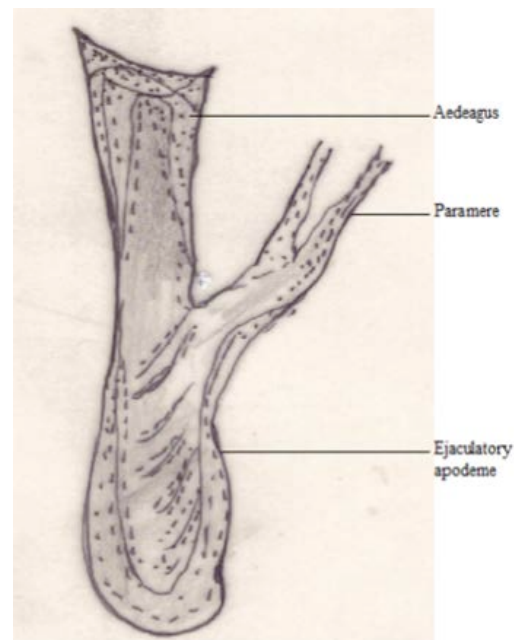


Figure 5. *Cyrtodiopsis whitei*: Male genitalia - lateral view of aedeagus and aedeagal apodeme.

large, with broad base and nearly conical apices, about twice as long as broad at the base, with thin margins and five pairs of hairs, two pairs of smaller hairs projected outwards and three pairs of longer ones projected inwards; hypandrium flat brown, with smooth margins, hypandrial bridge glabrous, in ventral view smooth, pale brown, bridge brown, with rough surface (Fig. 4); aedeagal apodeme elongated, brown, connected basally to hypandrium, in lateral view aedeagus with somewhat rounded end, sclerotic, and with a well developed ejaculatory apodeme (Fig. 5).

Female: The single female in the collection is similar to males except in longer body (6.49mm), longer OVB (0.39mm), longer antennae (0.43mm), longer hairs on head and eye stalks (Table 1), longer scutellum (0.32mm)

and scutellar spines (1.12mm), fore coxae, fore femora and wings (Table 1). Genitalia parts were damaged in course of slide mounting.

Taxonomic status: Curran (1936) described *Diopsis whitei* from a tropical dry deciduous forest in Jharkhand in eastern India. That description lacked illustrations or drawings of distinguishing characters of the species. Shillito (1940) transferred the species to *Cyrtodiopsis* because of the presence of characteristic apical incrassate constriction in fore femora and low rounded tubercles in the fore tibia. Since then six males and one female specimen of this species from a tropical evergreen forest

in northeastern parts of India have become available from the country of its type locality. These show strong similarities with *C. whitei* in the structure of wings, the pollinose pattern of the scutellum, and general description of body parts sensu Curran (1936) and Shillito (1940). Hans Feijen (pers. comm. 10.07.2015) found our specimens to show similarity with the single *C. whitei* specimen in his possession from Meghalaya in northeastern India. Detail examination of specimens used in this study, however, warranted description of new characters not described earlier; these include some of the hairs present on dorsal surfaces of head, thorax, scutellar spines and on femora and tibiae with bifid apices, presence of a row of progressively gently to strongly curved frontal hairs of decreasing lengths from the base of the eyestalk to the base of antenna, and in the structure of male genitalia which were not adequately described. None of existing literature on Diopsidae mention the occurrence of hairs with bifid apices and curved frontal hairs of eye stalks that were noted in specimens of *C. whitei* of this study. It is possible that earlier workers might have missed these characters in *whitei* or other taxa of Diopsidae, therefore, it may be premature to conclude that these characters are unique to *C. whitei* or that the sample of this study might represent a new population of a distinct species. The author was not able to access the type specimens of *whitei* or specimens of other species of Diopsidae from valid sources. Therefore, at this point, the specimens of

this study from moist evergreen forests of northeastern India are considered to represent possibly a part of widely distributed populations of *whitei* complex in its geographic range extending from the dry deciduous forest of eastern India (Jharkhand, the type locality) to moist evergreen forest in northeastern India, and, possibly, further east in Southeast Asia (Malaysia included), and it is assumed that populations of *whitei* might show habitat/area-specific variations and this position may be maintained until such time future study reveals more information.

DISCUSSION AND CONCLUSIONS

Feijen (2011) considered *Cyrtodiopsis* to be a weakly defined genus from the oriental region due to inclusion of several unrelated species at different times but preferred its distinct identity sensu Shillito (1940) in view of distinctive morphological attributes (chiefly in having prominent incrassate constrictions on apex of fore femora and low tubercles on the inner bases of fore tibiae) absent in the species of other genera under the family. Earlier, cladistic study using mitochondrial genes made by Baker et al. (2001), Meier & Baker (2002) and Földvári et al. (2007) revealed phylogenetic relationship between *Teleopsis* and *Cyrtodiopsis* but molecular distinctions between the two genera based on four marker genes, particularly between *T. thaii* and

Key to the identification of species of *Cyrtodiopsis*

1. IVB on high tubercles, the tubercles about 0.75 times the middle width of eye stalks; infra-alar spines roundish; forewings with sub-apical band darker and wider than the apical bands, with a nearly circular pale spot in the radial-medial cell (R_{4+5}), completely isolated from other cells *currani*
 IVB on low tubercles, the tubercles at most 0.40 times the middle width of eye stalks; infra-alar spines dorso-ventrally flattened with rounded tips; forewings with sub-apical bands pale to pale brown, with or without a spot in the radial-medial cell (R_{4+5}), not completely separated from other spots or cells 2
2. Thorax shining yellow, not pollinose; forewings with sub-apical bands narrow to wide, completely separated from the middle band *dalmanni*
 Thorax shining glossy yellow or brown, distinctly pollinose in mid-dorsum; forewings with or without a median pale spot between sub-apical and middle bands 3
3. Eye span, on average, 11.18mm long, 1.39 times the body length; scutellar spines up to 5.0 times the scutellar length *thaii*
 Eye span, on average, less than 8.0mm long, up to 1.25 times the body length; scutellar spines 3.50–4.0 times but never more than 4.30 times the scutellar length; pronotum and mesonotum pollinose, shining brown pleurally *whitei* complex
- (i) OVB up to 1.35 times and IVB up to 4.50 times as long as the width of eye stalks in the middle; eye span about 7.93mm long and 1.25 times the body length; cerci of male genitalia with several long, dispersed setae along their surface; habitat: laboratory culture specimens sourced from primary tropical rainforest in Malaysia (based on description from Földvári et al. 2007) *whitei* from Malaysia
- (ii) OVB 2.10–3.78 times and IVB 4.31–5.91 times as long as the width of eye stalks in the middle; eye span 3.99–5.93 mm long (Table 1) and up to 1.08 times the body length (Table 2); cerci of male genitalia on each side bears 5 hairs, 2 smaller ones protected outwards and 3 longer ones projected inwards (based on actual specimens); habitat: tropical moist deciduous forest *whitei* from northeastern India

T. breviscopium, were not conclusive (Földvári et al. 2007). To date, the presence of sharp incrassate apical constriction in fore femora and corresponding rounded tubercles on the basal parts of the fore tibia are the most robust and unique characters to the species of *Cyrtodiopsis*. Also, supra-alar spines, characteristic of all *Teleopsis* species, are absent in *Cyrtodiopsis* species. The presence of several hairs with bifid or split tips on the body of *C. whitei* could possibly be another unique character of this genus till further study reveals its presence in other species of *Cyrtodiopsis* and possibly in other genera of Diopsidae.

Despite prominent differences in morphometry between the two populations of *whitei* from geographically isolated locations of India and Malaysia, as evident from the taxonomic key above, we do not describe these specimens as a new species, because both populations share fundamental similarities in characters of fore wings, pollinosity distribution in thorax, body coloration, and general structure of genitalia. The observed differences in morphometry and presence of some of the body hairs with bifid tips in *whitei* from northeast India, among others, might represent the influence of differences in environments of the two habitats separated by several hundred miles. This study has founded the basis of future study to ascertain the prevalence of these characters when more specimens become available from these or nearby areas and also from the original type locality.

REFERENCES

- Al-khairulla, H., D. Warburton & R.J. Knell (2003). Do the eyestalks of female diopsid flies have a function in intra-sexual aggressive encounters? *Journal of Insect Behavior* 16: 679–686.
- Baker, R.H., G. Wilkinson & R. DeSalle (2001). Phylogenetic utility of different types of molecular data used to infer evolutionary relationships among stalk-eyed flies (Diopsidae). *Systematic Biology* 50: 87–105; <http://doi.org/10.1080/10635150118679>
- Burkhardt, D. & I. de la Motte (1983). How stalk-eyed flies eye stalk-eyed flies: Observations and measurements of the eyes of *Cyrtodiopsis whitei* (Diopsidae, Diptera). *Journal of Comparative Physiology* 151: 407–421.
- Buschbeck, E.K. & R.R. Hoy (2005). The development of a long, coiled, optic nerve in the Stalk-eyed Fly *Cyrtodiopsis whitei*. *Cell Tissue Research* 321: 491–504; <http://doi.org/10.1007/s00441-005-1142-4>
- Curran, C.H. (1936). A new *Diopsis* from India, with notes on others (Diptera). *American Museum Novitates* 833: 1–2.
- Feijen, H.R. (2011). The genus *Teleopsis* Rondani (Diptera, Diopsidae): discussion of its taxonomic position and revision of the species occurring in the Philippines. *Zoologische Mededelingen* 85: 79–140.
- Feijen, H.R. & C. Feijen (2011). On the biogeographic range of the genus *Teleopsis* Rondani (Diptera: Diopsidae), with re-description of *Teleopsis sykesii* from India and description of a new species from Borneo. *Zoologische Mededelingen* 85: 141–159.
- Földvári, M., A. Pomiankowski, S. Cotton & M. Carr (2007). A morphological and molecular description of a new *Teleopsis* species (Diptera: Diopsidae) from Thailand. *Zootaxa* 1620: 37–51.
- Frey, R. (1928). Philippinische Dipteren.V. Fam. Diopsidae. *Notulae Entomologicae Helsingfors* 8: 69–77.
- Lorch, P.D., G.S. Wilkinson & P.R. Reillo (1993). Copulation duration and sperm precedence in the Stalk-eyed Fly *Cyrtodiopsis whitei* (Diptera: Diopsidae). *Behavioral Ecology and Sociobiology* 32(5): 303–311; <http://doi.org/10.1007/BF00183785>
- Meier, R. & R.H. Baker (2002). A cladistic analysis of Diopsidae (Diptera) based on morphological and DNA sequence data. *Insect Systematics and Evolution* 33: 325–336.
- Mitra, B., S. Roy & P. Parui (2014). A revised checklist of stalk-eyed flies (Diptera: Diopsidae) with first record of *Eurydiopsis brevispinus* Feijen from India. *Biosystematica* 8(1&2): 59–60.
- Roskov, Y., L. Abucay, T. Orrell, D. Nicolson, T. Kunze, C. Flann, N. Baill, P. Kirk, T. Bourgoin, R.E. De Walt, W. Decock & A. De Wever (eds) (2015). Species 2000 & ITIS Catalogue of Life, Accessed on 20.xi.2015; <http://www.catalogueoflife.org/col>
- Shillito, J.F. (1940). Studies on Diopsidae (Diptera). *Novitates Zoologicae London* 42: 147–163.
- Wilkinson, G.S., H. Kahler & R.H. Baker (1997). Evolution of female mating preferences in Stalk-eyed Flies. *Behavioral Ecology* 9: 525–533.
- Wilkinson, G.S., D.C. Presgraves & L. Crymes (1998). Male eye span in stalk-eyed flies indicates genetic quality by meiotic drive suppression. *Nature* 391: 276–279; <http://doi.org/10.1038/34640>
- Wilkinson, G.S. & M.I. Sanchez (2001). Sperm development, age and sex chromosome meiotic drive in the Stalk-eyed Fly *Cyrtodiopsis whitei*. *Heredity* 87: 17–24.





COMMUNITY STRUCTURE OF BENTHIC MACROINVERTEBRATE FAUNA OF RIVER ICHAMATI, INDIA

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

Arnab Basu¹, Indrani Sarkar², Siddhartha Datta³ & Sheela Roy⁴

OPEN ACCESS



^{1,2,4}Department of Zoology, Vidyasagar College, 39, Sankar Ghosh Lane, Kolkata, West Bengal 700006, India

³Jadavpur University, Department of Chemical Engineering, Kolkata, West Bengal 700032, India

¹arnab.basu3@rediffmail.com, ²sarkarindrani.biswas@gmail.com, ³sdatta_che@rediffmail.com,

⁴roysheela77@yahoo.co.in (corresponding author)

Abstract: Benthic macroinvertebrate communities are frequently applied as indicators of aquatic ecosystem health as many species are responsive to pollution and abrupt changes in their surroundings. The qualities of benthic invertebrate communities greatly depend on habitat conditions. Thus the diversity in benthic community varies with different habitat conditions. This investigation on the structure of the benthic invertebrate communities was conducted on river Ichamati, a trans-boundary river between India and Bangladesh to assess the cumulative effects of water quality on the aquatic biota. The study period extended from February 2011 to January 2014 at three sites from Majdiah to Hasanabad (in West Bengal, India) a stretch of 124km. A total of 23 macrobenthic species belonging to three phyla, five classes and nine orders were identified. Fifteen species of benthic invertebrates belonging to Mollusca, three species under Annelida and five species under Arthropoda were found. The highest abundance density ($3633.33 \text{ indiv.m}^{-2}$) and species richness (18 species) were recorded up-stream (Majdiah) where marginal habitats covered by macrophytes were significantly higher than at other sites. Both the organic carbon (4.41 ± 1.11) and organic matter (7.48 ± 1.56) of soil at this site were the maximum thus influencing the richness of benthic macroinvertebrate communities. Hydrological variables, viz, dissolved oxygen, pH, alkalinity; hardness, salinity, nutrients, calcium, and magnesium were studied to determine their influences on the benthic community in the upper, middle- and down-streams of the river, respectively. Shannon's diversity index (0.95–2.07; 0.00–0.72; 0.00–0.64), dominance index (0.57–0.86; 0.00–0.44; 0.00–0.44), evenness index (0.72–0.95; 0.61–1.00; 0.00–1.00), Margalef index (0.72–2.23; 0.00–1.32; 0.00–0.28) of the upper, middle- and down-streams were calculated. Benthic macroinvertebrate density was correlated with hydrological variables which indicated that the abiotic factors had either direct or inverse influence on the richness and abundance; however, the abiotic factors did not correlate identically in all three sites.

Keywords: Diversity indices, hydrological variables, macrophytes, species richness.

doi: <http://doi.org/10.11609/jott.3439.10.8.12044-12055> | ZooBank: urn:lsid:zoobank.org:pub:FD3AD5B0-049B-4541-84AD-9D6CB288C406

Editor: Asheesh Shivam, Nehru Gram Bharti University, Allahabad, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3439 | Received 04 April 2017 | Final received 18 May 2018 | Finally accepted 30 June 2018

Citation: Basu, A., I. Sarkar, S. Datta & S. Roy (2018). Community structure of benthic macroinvertebrate fauna of river Ichamati, India. *Journal of Threatened Taxa* 10(8): 12044–12055; <http://doi.org/10.11609/jott.3439.10.8.12044-12055>

Copyright: © Basu et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: Department of Science and Technology, Government of West Bengal, India.

Competing interests: The authors declare no competing interests.

Author Details: DR. ARNAB BASU teaches fisheries science both in undergraduate and post graduate sections of the Zoology Department, Vidyasagar College. His field of research includes ecology, environmental biology and aquaculture. DR. INDRANI SARKAR is an assistant professor and at present the head of the department of Zoology, Vidyasagar college, Kolkata. She has been actively engaged in teaching (both in under graduate and post graduate levels) and aquaculture research for past ten years. PROF. SIDDARTHA DATTA, former pro-vice chancellor of Jadavpur University, Kolkata and the head of the department of Chemical Engineering, Jadavpur University is an eminent scientist and a teacher. His research interest stretches from engineering to many interdisciplinary fields of biological sciences. DR. SHEELA ROY, Associate Professor of Zoology (Retd.), Vidyasagar College, Kolkata has undergraduate/post graduate teaching experiences of more than twenty five years with simultaneous research experiences in different fields of fisheries science in India and abroad. She has worked on Government sponsored research projects to enhance the understanding of fisheries and ecology.

Author Contribution: AB & IS: fieldwork, data analysis and manuscript draft preparation. SR & SD: overall supervision of research work, editing and final manuscript preparation.

Acknowledgements: SR expresses gratefulness to the Department of Science and Technology, Government of West Bengal, India for financial assistance and to the Principal, Vidyasagar College, Kolkata, India for extending the laboratory facilities.



INTRODUCTION

Benthic macroinvertebrates are sedentary or sessile aquatic fauna that exist in the bottom substrates of their habitats (Lenat et al. 1981; Victor & Ogbeibu 1985; Rosenberg & Resh 1993; Idowu & Ugwumba 2005) at least for a part of their life cycle. The benthic fauna perform a key role in nutrient cycling and are also used as food for other aquatic animals (Lind 1979; Milbrink 1983; Jana & Manna 1995). Further they play a critical role as a link in the aquatic food chain affecting bio-geochemical processes in the sediment (Wetzel 2001; Heck et al. 2003; Pokorný & Kveřt 2004; Idowu & Ugwumba 2005). Benthic invertebrates are difficult to sample especially in deep subsurface sediments. Thus, the species richness and functional importance of freshwater benthic invertebrates usually goes unnoticed until unpredicted changes occur in the ecosystems. Besides these organisms are used as bio-indicators as they frequently respond to pollution stress (Stanford & Spacie 1994; Gamlath & Wijeyartne 1997; Ikomi et al. 2005). The community structure of benthic macroinvertebrates is influenced by the physico-chemical parameters of the water body (Timm et al. 2001; Johnson et al. 2004; Kagalou et al. 2006; Celik et al. 2010). Examination of parameters like richness, diversity, abundance, evenness and community composition are essential to determine the natural or anthropogenic changes with time (Mittermeier & Mittermeier 1997; Dudgeon et al. 2006; Srivastava 2007; Strayer & Dudgeon 2010; Jun et al. 2016). In riverine ecosystem macrobenthic invertebrates show an uneven distribution (Timms 2006).

River Ichamati ('Icha' - fish and 'moti' - pearl), is one of the important trans-boundary rivers between Bangladesh and India, has variable biological, physical and chemical characteristics due to its irregular discharge pattern, diverse habitat arising out of abiotic and anthropogenic activities and both brackish and freshwater characters. Presently, this river is facing various environmental constraints due to siltation, discharge of organic debris from human settlements, production of macrophytic biomass, lack of sanitation and over-fishing (Das et al. 2012). Thus, it is ever more important to preserve the biodiversity of aquatic flora and fauna in this river to lower the risk of sudden unwanted consequences. A number of studies on macrobenthic community structure and hydrochemistry of various water-bodies are well documented (Degani et al. 1992; Jana & Manna 1995; Mancini et al. 2004; Moretti & Callisto 2005; Dolbeth et al. 2007; Sharma &

Dhanze 2012; Basu et al. 2013; Mishra & Nautiyal 2013, 2017; Nautiyal & Mishra 2013; Nautiyal et al. 2017).

To the best of our knowledge, information on macrobenthic fauna of river Ichamati is unavailable so far. This encouraged us to undertake the present study on the river to ascertain: (i) the structure and composition of the benthic macroinvertebrate species, (ii) the environmental factors (natural as well as anthropogenic) responsible for the community patterns, (iii) the present ecological status of the river and (iv) determine the quality of water by using benthic fauna to establish the pollution level of the river to create a base line data.

MATERIALS AND METHODS

Description of the study area

The river Ichamati is among the important trans-boundary rivers sharing the boundaries between Bangladesh and India. River Mathabhanga originates from the right bank of Padma at Munshigunj in Kustia District, Bangladesh. It bifurcates near Majhdia (Nadia District, West Bengal, India) creating two rivers, Ichamati and Churni. River Ichamati traverses a course of about 216km and finally discharges into the river Kalindi at Hasnabad in the district of North 24 Parganas and ultimately finds its way into the Bay of Bengal near Moore Island as a part of Kalindi-Raimangal estuary in the deltaic southern part of West Bengal. After about a 19.5km long journey in India it re-enters Bangladesh. It crosses the border again near Duttafulia in Nadia District (West Bengal, India). After a further 21km, it falls into the Bay of Bengal in Bangladesh near Hasnabad and Taki.

The stream at its origin is narrow and shallow clogged by macrophytes such as *Eicchornia*, *Pistia*, *Lemna* and *Alternanthera*. The middle and down reaches of the river are now facing problems due to siltation, high fluvial allochthonous discharges from the river banks, discharge of organic debris from the human settlements along the river, all domestic works such as bathing, washing clothes, utensils, bathing of cattle, lack of sanitation practices, boat ferry, immersion of idols during festivals etc.

The study period extended from February, 2011 to January, 2014 at three sites from Majhdia to Hasnabad (in West Bengal, India) a stretch of 124km. The locations of the sites chosen were (1) near the origin (Majhdia; up-stream, site I), (2) middle part of the stretch (Tetulia; middle-stream, site II), finally Hasnabad (down-stream, site III) before it reaches river Kalindi in the south

(Mondal & Bandyopadhyay 2016).

Locations and characteristics of the sites

Locations of the sites (I, II and III) are marked in Images 1, 2. Physiological and geographical characteristics of the three sites are given in Table 1.

Sampling methods

Water samples were collected from two sampling points (140m apart) in each site in 1 L clean plastic containers between 06:00–08:00 hr during February 2011 to January 2014 twice a month and transported to the laboratory for chemical analyses.

Water temperature was recorded using mercury glass thermometer (0–60 °C). Electrical conductivity, total dissolved solids (TDS) and pH were measured by ELICO Ion analyzer (Model: PE 138, India). All other water quality variables such as dissolved oxygen (DO), free carbon dioxide, total alkalinity, total hardness, calcium, magnesium, phosphate, nitrate, salinity and transparency, organic matter and organic carbon were monitored following standard protocol, American Public Health Association (APHA) (2005).

Benthic invertebrates were collected twice a month with a specialized box sampler having a dimension of 15 x 15 cm which can penetrate a maximum depth of 15cm (Paul & Nandi 2003). The samples were sieved with No. 40 mesh (pore size: 0.420mm) (Jana & Manna, 1995; Tagliapietra & Sigovini 2010). Considering the depth of the down-stream, desired samples were collected with the help of local fishermen. Collected organisms were preserved in 4% formalin. Benthic macroinvertebrate were then identified following Michael (1977) for the phylum Annelida, Barnes et al. (1988) and Rao (1989) for the phylum Mollusca whereas Arthropoda by the Zoological Survey of India, Kolkata, India. Benthic macroinvertebrates were quantitatively analysed by individual counting of each taxon and expressed in individuals/m².

Taxonomic indices was subjected to univariate analyses for studying the benthic community structure using Margalef's richness index, Margalef (1968) for species richness (counts the number of different species in a community), Pielou's Evenness index (Pielou 1966) for species evenness (quantifies the relative abundance of species present in a community), Shannon-Weiner index (Shannon & Weiner 1964) for species diversity (reflects the types of species present in a particular area at a particular time) and Simpson's Dominance Index (Simpson 1949) for dominance (quantifies the dominance sharing species in a community). The



Image 1. Course of river Ichamati (Source: Nishat et al. 2014)

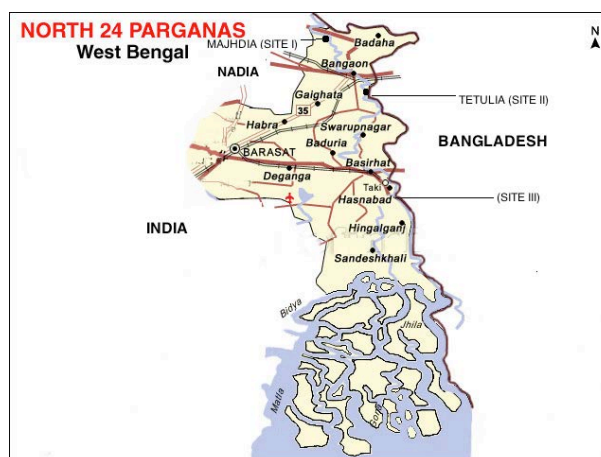


Image 2 . Location of sites (I), (II) and (III) of river Ichamati. (Source: North 24 Parganas Dist Police 2013)

data were computed using Paleontological Statistical software (PAST version 3.15). Pearson correlation (r) was applied to analyse the relationship between the benthic macroinvertebrates density and hydrological variables. The graphs were plotted with MS Excel Software.

RESULTS

The range and average of all water parameters were recorded in Table 2. In the Ichamati, 23 benthic

macroinvertebrate species were found from all the samples collected from upper-, middle- and down-streams (Table 3). Of these, up-stream was the richest with species (18) followed by middle-stream (5) and down-stream (2). The maximum density (individual m^{-2}) was found in the following sequence, i.e., up- > middle- > down- streams. Fig. 1 showed the monthly variations of total benthic macroinvertebrate community in three different sites of Ichamati. Benthic macroinvertebrate community was available throughout the year up-stream with peaks in the months of June and September (Fig. 1). Down- and middle-streams showed similar trends where the communities gradually increased from October and reached the maximum in May (Fig. 1). In down-stream, during monsoons (June–September) it was not possible to find and collect any benthic macroinvertebrate samples due to the dangerous rise in water levels and the highly turbulent character of the water. Perhaps, due to the same reason a low concentration of benthic macroinvertebrate was found mid-stream during the monsoons.

The results are presented separately for all three different study sites as follows:

(A) At upper reaches of Ichamati

In the upper-stream, 13 species of Mollusca belonging to class Gastropoda (three orders) and class Bivalvia (one order) dominated the community followed by Annelida (2 orders) and Arthropoda (one order). The population of benthic invertebrates was dominated mainly by three taxa of Mollusca: namely, *Bellamya bengalensis* Lamarck 1822, *Bellamya dissimilis* Muller, 1774 and *Gyraulus convexusculus* Hutton, 1849 (Table 3). The abundance of *B. bengalensis* increased to maximum density (322.22) in the pre-monsoon period then its population declined. In comparison, the *B. dissimilis* after attaining its population peak in pre-monsoons (255.54) drastically declined in the post-monsoon period (33.33). *B. crassa* was completely absent in pre-monsoon periods. On the other hand, species like *Segmentina* in monsoon and pre-monsoon periods and *Melanoides* in the monsoons were completely absent. *Brotia* and *Bythinia* were found in all seasons (Table 4).

During the investigation, one Bivalvia taxa (*Lamellidens marginalis* Lamarck 1819) was found exclusively in the pre-monsoons. Hutton 1849 found maximum *Gyraulus convexusculus* (411.10) in the monsoons was another dominant species among Mollusca (Table 4). Further, two species of phylum Annelida (*Glyphidrilus tuberosus* Stephenson, 1916 and *Pheretima posthuma* Kinberg, 1867) could be detected both in monsoon and post-

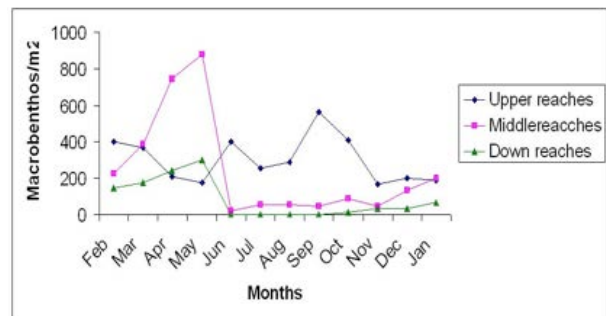


Figure 1. Variations of macrobenthic density in Ichamati

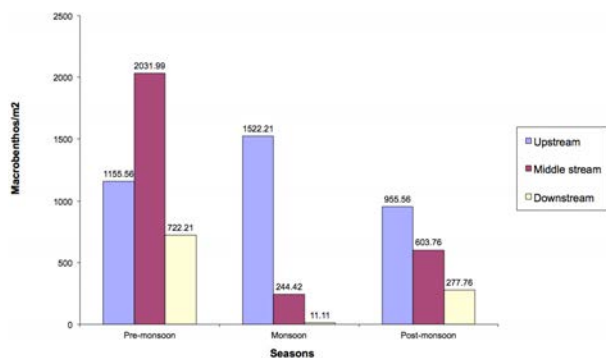


Figure 2. Seasonal variations of macrobenthic abundances in Ichamati at three different sites.

Table 1. Geographical and physical characteristics of three sites of river Ichamati

	Characteristics	Up-stream	Middle-stream	Down-stream
1	Geographical location	23.42049°N & 88.72759°E	22.78593°N & 88.85843°E	22.57190°N, 88.91355°E
2	Depth of river (m) Summer Monsoon	1.0–1.5 1.5–2.0	1.5–3.0 2.5–4.0	8.0–9.0 not measured
3	Width of river (m)	100.00	250.00	400.00
4	Substrate combination	clay, silt, and mud	sine sand, silt, small amount of mud with small pebbles	sand and silt, small amount of mud and gravels
5	Vegetation	aquatic plant present	absent	Absent
6	Land use type Right bank Left bank	none extensive agriculture	village, agriculture, bheri culture, brick kiln	urbanisation, town, bridge construction
7	Anthropogenic interferences	fishing	domestic activities, cattle farming, crematorium, fishing	domestic activities, ferry boat, idol immersion, fishing, sewerage
8	Flow of river	stagnant to gentle	strong	very strong

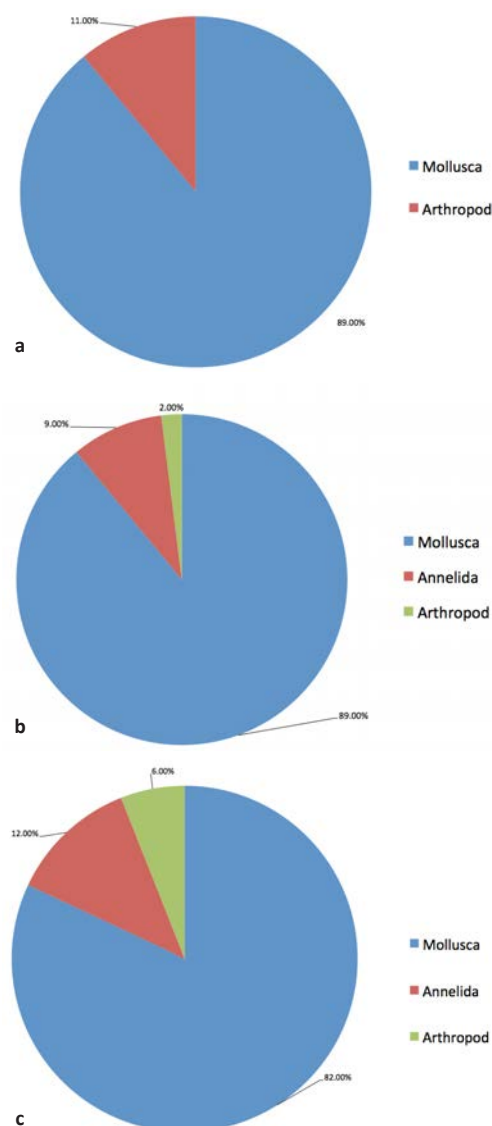


Figure 3. a, b, c - show the community structures of the benthic invertebrates of Ichamati at upper-, middle- and down-reaches, respectively.

monsoon periods. Interestingly, *Sartoriana spingera* Wood-Mason, 1871, was the only Arthropoda found up-stream during the monsoon period (Table 4).

The benthic macroinvertebrate community (Fig. 3a) was dominated by molluscans (82.35%) followed by annelids (11.76%), and arthropods (5.88%) (Fig. 3a). The data on analysis revealed that benthic macroinvertebrate abundance was the highest in post-monsoons followed by pre-monsoon and monsoon periods.

Maximum species diversity (1.79) and Simpson's dominance index (0.79) were recorded in the monsoon period and minimum species diversity (1.58) and dominance index (0.75) in the pre-monsoons. Species

Table 2. Limnological variables in Ichamati

Limnological Parameters	Upper reaches	Middle reaches	Down reaches
pH	7.10–8.50 (7.86 ± 0.15)	7.10–8.30 (7.51 ± 0.13)	7.10–8.75 (7.67 ± 0.15)
^a TDS (ppt)	141.00–353.90 (232.06 ± 19.61)	0.18–14.75 (4.43 ± 1.55)	1.70–17.11 (7.55 ± 1.63)
Water Temperature (°C)	16.50–31.00 (25.21 ± 1.52)	18.00–32.00 (26.67 ± 1.29)	18.6–32.20 (28.21 ± 4.08)
Water Transparency (cm)	17.70–70.00 (37.79 ± 4.93)	5.95–27.50 (13.75 ± 1.64)	4.20–12.75 (7.82 ± 0.79)
Dissolved Oxygen (ppm)	3.40–6.24 (4.50 ± 0.23)	4.02–14.20 (8.31 ± 0.88)	4.00–8.10 (5.61 ± 0.28)
Free ^b CO ₂ (ppm)	4.00–12.00 (7.5 ± 0.65)	0.00–8.65 (3.05 ± 2.61)	0.00–8.00 (3.33 ± 0.83)
Phosphate (ppm)	0.40–0.72 (0.55 ± 0.02)	0.40–1.46 (0.62 ± 0.09)	0.40–1.40 (0.81 ± 0.09)
Nitrate (ppm)	0.35–0.90 (0.68 ± 0.04)	0.40–2.50 (1.03 ± 0.19)	0.30–1.00 (0.75 ± 0.05)
Total Alkalinity (ppm)	52.80–108.00 (78.21 ± 3.98)	32.00–183.86 (75.24 ± 14.43)	46.60–73.20 (59.75 ± 2.48)
Total Hardness (ppm)	90.00–490.00 (270.27 ± 31.17)	165.30–2772.50 (750.64 ± 242.22)	380.00–3053.00 (1444.34 ± 289.32)
Calcium (ppm)	29.26–86.25 (52.54 ± 5.17)	31.20–532.26 (166.41 ± 54.93)	45.90–308.30 (125.82 ± 23.15)
Magnesium (ppm)	4.14–53.31 (28.66 ± 4.61)	12.80–352.50 (81.85 ± 28.18)	56.05–618.01 (285.81 ± 61.08)
Salinity (ppt)	0.03–0.04 (0.03 ± 0.0005)	0.03–0.47 (0.16 ± 0.05)	0.07–0.48 (0.24 ± 0.04)
Organic Carbon (mg/g)	0.73–11.56 (4.41 ± 1.11)	0.13–6.12 (2.90 ± 0.52)	1.15–6.9 (4.09 ± 0.59)
Organic Matter (mg/g)	1.19–19.56 (7.48 ± 1.56)	0.22–10.52 (4.94 ± 0.9)	1.95–11.73 (3.95 ± 0.78)

^aTDS = Total dissolved solids, ^bCO₂ = Carbon dioxide

richness, i.e., Margalef's index was found to be the maximum during monsoons and minimum in the pre-monsoon period. Pielou's evenness index was found to vary from 0.81 to 0.87 (Table 5).

Water temperature, transparency, free CO₂, salinity, organic carbon, TDS and nutrients were positively correlated with the benthic macroinvertebrate abundance (Table 6). Dissolved oxygen and total alkalinity, two important parameters were negatively correlated with benthic macroinvertebrate density. These water parameters were additionally correlated individually with density of Gastropoda, Bivalvia, Annelida and Arthropoda (Table 7) in up-stream only.

(B) At middle reaches of Ichamati

The benthic macroinvertebrate community was dominated by Mollusca (88.43%) followed by Arthropoda (9.26%) and Annelida (2.31%) (Fig. 3b). Arthropoda *Metapograpus latifrons* White, 1847 was found maximum (166.66) in post-monsoon whereas *Scylla serrata* Forsskal, 1775 was found only during the

Table 3. Distribution of benthic invertebrates in Ichamati

Benthic invertebrates		Up-stream	Middle-stream	Down-stream
Phylum: I Mollusca Class: I Gastropoda Order: I Mesogastropoda	1. <i>Brothia costula</i> Rafinesque, 1833	+	-	-
	2. <i>Bithynia cerameopoma</i> Benson, 1830	+	-	-
	3. <i>Bellamyia bengalensis</i> Lamarck, 1822	+	-	-
	4. <i>Bellamyia dissimilis</i> Muller, 1774	+	-	-
	5. <i>Bellamyia crassa</i> Benson, 1836	+	-	-
	6. <i>Segmentina calatha</i> Benson, 1850	+	-	-
	7. <i>Melanoides tuberculata</i> Muller, 1774	+	-	-
	8. <i>Gabbia orcula</i> Frauenfeld, 1862	+	-	-
Order: II Basommatophora	9. <i>Pseudosuccinea luteola</i> (Lamarck, 1799)	+	-	-
	10. <i>Pseudosuccinea acuminata</i> (Lamarck, 1799)	+	-	-
	11. <i>Gyraulus convexiusculus</i> Hutton, 1849	+	-	-
	12. <i>Indoplanorbis exustus</i> Deshayes, 1834	+	-	-
Order: III Megagastropoda	13. <i>Pila globosa</i> Swainson, 1822	+	+	-
Class: II Bivalvia Order: I Eulamellibranchiata Family: Unionidae	14. <i>Lamallidens marginalis</i> Lamarck, 1819	+	-	-
Order: II Mytiloida Family: I Mytilidae	15. <i>Modiolus striatulus</i> Hanley, 1843	+	+	-
Phylum: II Annelida Class: I Oligochaeta Order: I Ophisthophora	16. <i>Pheretima postuma</i> Kinberg, 1867	+	-	-
Order: II Haplotaxida Class: II Polychaeta Order: I Phyllodocida	17. <i>Glyphidrilus tuberosus</i> Stephenson, 1916	+	-	-
	18. <i>Neanthes</i> sp. Frey & Leuckart, 1847	-	+	-
Phylum: III Arthropoda Subphylum: I Crustacea Order: I Decapoda Family: I Portunidae	19. <i>Scylla tranquebarica</i> Fabricius, 1798	-	-	+
	20. <i>Scylla serrata</i> Forsskal, 1775	-	+	-
Family: II Gecarcinucidae	21. <i>Sartoriana spinigera</i> Wood-Mason, 1871	+	-	-
Family: II Grapsidae	22. <i>Metapograpsus latifrons</i> White, 1847	-	+	-
Family: III Ocypodidae	23. <i>Ocypode macrocera</i> H. Milne Edwards, 1837	-	-	+

monsoons (Table 4). Only one Annelida, i.e., *Neanthes* was found maximum during pre-monsoons and declined at the onset of the monsoon. *Pila globosa* Swainson 1822, the Gastropoda were identified during monsoon and post-monsoon periods. One bivalvian species, *Modiolus* was recorded in maximum density (1965.33) during pre-monsoons (Table 4). Diversity index and dominance index recorded were the maximum in the monsoons and minimum in the pre-monsoons (Table 5). Evenness index and richness index was found to be maximum in the post-monsoon period.

In the middle-stream, all the water and soil parameters except DO, free CO₂ and phosphate were positively correlated with benthic macroinvertebrate density (Table 6).

(C) At down reaches of Ichamati

The benthic macroinvertebrate community (Fig. 3c) was dominated by Mollusca (89.01%) followed by Arthropoda (10.99%; Fig. 3c). Two species of Arthropoda, *Ocypode* sp. were absent in the monsoons but were present in pre- and post-monsoon periods (Table 4). *Scylla tranquebarica* was minimum (11.11) in the monsoons, but found in the other two seasons. One bivalvian species *Modiolus* was maximum (711.10) during pre-monsoons (Table 4). All the taxonomic indices determined (Table 5) were found to have maximum values in post-monsoon and minimum in monsoon periods.

In down-stream, total alkalinity, phosphate, organic carbon and organic matter were negatively correlated with benthic macroinvertebrate density, the rest of the parameters were positively correlated (Table 6).

DISCUSSION

The glory of river Ichamati has faded a lot with time. Ichamati now faces problems like forcible land occupation, weed infestation, different environment hazards due to lack of sanitation facilities, encroachment, ground water contamination etc. Destruction of aquatic flora and fauna in the river is the most serious problem regarding the ecosystem.

The important factors that affect the abundance of benthic macroinvertebrate fauna in a given community include the hydro-biology of water, substrate of occupants and food availability (Olenin 1997; Nelson & Lieberman 2002; Carlisle et al. 2007; Coleman et al. 2007; Li et al. 2012; Basu et al. 2013).

The pH of water of all three sites indicated the alkaline nature of the water; the pH of the up-stream was the highest (7.86 ± 0.15) compared to the two other sites. The richness of diversity of benthic macroinvertebrates was found maximum in up-stream due probably to the alkaline nature and shallow depth of the river. Simpson et al. (1985), Feldman & Connor (1992) and Baldigo et al. (2009) also found that the site with the higher pH had a higher diversity of benthic macroinvertebrates.

Benthic macroinvertebrates density was negatively correlated with DO level as they could survive in poor DO conditions. In this study the low dissolved oxygen content observed in up-stream water might be due to the high organic matter decomposition from macrophyte vegetation and also bottom type which contained high percentage of mud (Sandin 2003; Williams & Gormally 2009; Jiang et al. 2010; Schultz & Dibble 2012; Zybek et al. 2012). The high DO contents in middle- and down-streams were attributed to non-vegetation and strong water current characteristics of these two sites (Soszka 1975; Cogerino et al. 1995).

The low density of benthic macroinvertebrate was observed during the present study in all three sites particularly in middle- and down- streams. The species richness of benthic macroinvertebrate were found to be the highest in up-stream probably due to suitable habitat conditions, organically enriched soft bottom (Ingole et al. 2002), slow water current, shallow depth (Roy & Gupta 2010), bottom substrate (muddy and clayey) and the presence of macrophytes in marginal water (Kumar et al. 2013; Tall et al. 2016).

Molluscs were mostly associated with very low oxygen and lentic ecosystems (Spyra 2010). The up-stream of Ichamati was enriched with molluscan density (13 species). The water in this region was motionless and had a shallow substratum with decomposed

Table 4. Average density of benthic macroinvertebrates in up-, middle- and down- streams of Ichamati

A. Up-stream	Pre-monsoon	Monsoon	Post-monsoon
I. Molluscs (Individuals/m ²)			
<i>Brotia costula</i>	66.66	88.88	88.88
<i>Bythinia cerameopoma</i>	44.44	144.44	199.99
<i>Pseudosuccinea acuminata</i>	55.55	11.11	11.11
<i>Pseudosuccinea luteola</i>	111.10	11.11	44.44
<i>Gyraulus convexusculus</i>	44.44	411.1	77.77
<i>Bellamya bengalensis</i>	322.22	233.32	233.31
<i>Bellamya dissimilis</i>	255.54	233.32	33.33
<i>Bellamya crassa</i>	0	77.77	33.33
<i>Segmentina calatha</i>	0	0	22.22
<i>Melanoides tuberculata</i>	0	0	55.55
<i>Lamellidens marginalis</i>	11.11	0	0
<i>Indoplanorbis exustus</i>	144.44	88.88	0
<i>Gabbia orcula</i>	88.88	44.44	66.67
<i>Pila globosa</i>	11.11	22.22	11.11
II. Annelids (Individuals/m ²)			
<i>Glyphidrilus tuberosus</i>	0	11.11	22.22
<i>Pheretima postuma</i>	0	88.88	55.55
III. Arthropods (Individuals/m ²)			
<i>Sartoria spinigera</i>	0	55.55	0
B. Middle-stream			
I. Molluscs (Individuals/m ²)			
<i>Pila globosa</i>	0	144.43	66.66
<i>Modiolus striatulus</i>	1965.33	0	370.44
II. Annelids (Individuals/m ²)			
<i>Neanthes sp.</i>	44.44	22.22	0
III. Arthropods (Individuals/m ²)			
<i>Scylla serrata</i>	0	44.44	0
<i>Metapograpus latifrons</i>	0	55.55	166.66
C. Down-stream			
I. Molluscs (Individuals/m ²)			
<i>Modiolus striatulus</i>	711.10	0	188.88
II. Arthropods (Individuals/m ²)			
<i>Ocypode sp.</i>	33.33	0	55.55
<i>Scylla transquebarica</i>	55.55	11.11	44.44

organic matter which facilitated the molluscs growth, especially Gastropoda (Principe & Corrigliano 2006; Zybek et al. 2012). The lowest concentrations of salinity, hardness and alkalinity of water may have enhanced the abundance of species in the up-stream, hence these parameters showed the negative correlations with benthic macroinvertebrate densities. This was

Table 5. Taxonomic indices of benthic macroinvertebrate community in river Ichamati

Seasons	Dominance index			Shannon's diversity index			Evenness index			Margalef's index		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Pre-monsoon	0.75	0.02	0.44	1.58	0.05	0.07	0.87	0.90	0.42	1.52	0.03	0.04
Monsoon	0.79	0.17	0.00	1.79	0.26	0.00	0.79	0.92	0.25	1.94	0.12	0.00
Post-monsoon	0.77	0.11	0.17	1.64	0.19	0.27	0.81	0.96	0.93	1.80	0.35	0.12

Table 6. Correlation among limnological parameters and benthic macroinvertebrate density.

Macro-benthos density/m ²	Limnological parameters	Up-stream	Middle-stream	Down-stream
	Water temperature (°C)	0.33 ^a	0.02	0.62
	Water transparency (cm)	0.07	-0.03	-0.55
	pH	-0.05	0.78 ^c	0.12
	Dissolved Oxygen (ppm)	-0.17 ^a	-0.24 ^a	0.00
	Free ^d CO ₂ (ppm)	0.10 ^a	-0.17 ^a	-0.24 ^b
	Total alkalinity (ppm)	-0.02	0.85 ^c	-0.37 ^a
	Total hardness (ppm)	-0.01	0.95 ^c	0.48 ^a
	Calcium (ppm)	-0.16 ^a	0.95 ^c	0.55 ^b
	Magnesium (ppm)	0.06	0.86	0.47
	Phosphate (ppm)	0.29 ^a	-0.08	-0.37 ^a
	Nitrate (ppm)	0.17 ^a	0.55 ^b	0.05
	Salinity (ppt)	0.06	0.93 ^c	0.50 ^b
	^e EC (ms)	-0.32	0.91	-0.67
	^f TDS (ppt)	0.23	0.90	0.53
	Organic carbon (mg/g)	0.47 ^a	0.48 ^a	-0.30 ^a
	Organic matter (mg/g)	0.47 ^a	0.48 ^a	-0.03

^a = 5% level of significance; ^b = 1% level of significance; ^c = 0.1% level of significance, ^d = carbon dioxide, ^e = electrical conductivity, ^f = total dissolved solids

Table 7. Correlation among limnological parameters and benthic macroinvertebrates density at up-stream.

Limnological parameters				
	Gastropoda	Bivalvia	Annelida	Arthropoda
Water temperature (°C)	0.95 ^c	0.34 ^a	-0.14 ^a	0.64 ^b
Water transparency (cm)	-0.58 ^b	-0.84 ^c	0.70 ^c	-0.05
pH	0.85 ^c	0.47 ^a	0.65 ^b	-0.99 ^c
Dissolved Oxygen (ppm)	-0.38 ^a	-0.90 ^c	-0.97 ^c	0.82 ^c
Total alkalinity (ppm)	0.96 ^c	0.33 ^a	-0.13 ^a	0.65 ^b
Total hardness (ppm)	-0.88 ^c	0.43 ^a	-0.61 ^b	-0.99 ^c
Calcium (ppm)	-0.98 ^c	-0.24 ^a	0.03	-0.72 ^c
Magnesium (ppm)	-0.51 ^a	-0.88 ^c	0.77 ^c	0.04
Phosphate (ppm)	0.99 ^c	0.08	0.13 ^a	0.82 ^c
Nitrate (ppm)	0.97 ^c	-0.17 ^a	0.37 ^a	0.94 ^c
Salinity (ppt)	0.05	1	-0.98 ^c	-0.5 ^a
^d EC (ms)	-0.98 ^c	-0.23 ^a	0.02	-0.72 ^c
^e TDS (ppt)	-0.99 ^c	-0.14 ^a	-0.07	-0.79 ^c
Organic carbon (mg/g)	0.87 ^c	-0.45 ^a	0.63 ^b	0.99 ^c
Organic matter (mg/g)	0.86 ^c	-0.45 ^a	0.63 ^b	0.99 ^c

^a = 5% level of significance; ^b = 1% level of significance; ^c = 0.1% level of significance, ^d = electrical conductivity, ^e = total dissolved solids

further substantiated by the observation of Brucet et al. (2012). Two oligochaetes, *Pheretima posthuma* and *Glyphidrilus tuberosus* were present up-stream due to their preference for organically enriched polluted water bodies with low oxygen content, also noted by Barquin & Beath (2011). This was further corroborated by the negative correlation with dissolved oxygen, total hardness, total alkalinity and positive correlation with nutrients, organic carbon and organic matter (Table 6). *Pheretima*, though a terrestrial species, was found during monsoon and post-monsoon periods when the riverbank was flooded. Possibly because of inundation, they were found within 1m inside the river from the edge during these periods; however, Braich & Kaur (2017) very recently described the abundance of *Pheretima* in 'Wetland of National Importance', the Nangal wetland which came into existence with the construction of a

barrage on the River Satluj, Punjab, India.

Gyraulus convexiusculus was found in all seasons in the upper reaches of Ichamati. A similar observation was reported on macroinvertebrates communities by Fisher & Williams (2006) and Spyra & Strzelec (2013) where *Gyraulus* sp. was found in all seasons.

During pre-monsoon and monsoon periods, the maximum species diversity was noted in the upper reaches. Jana & Manna (1995), Khalua et al. (2008) and Roy et al. (2008) also demonstrated the benthic abundance during these periods. Benthic macroinvertebrate density was high during both pre-monsoon and monsoon periods which may be attributed to the availability of appropriately nutrient-rich water and soft and organically rich bottom soil. Similar studies were reported by Beauchard et al. (2003) on African rivers and Li et al. (2012) on stream macroinvertebrates.

In this study the positive correlation between nutrients and organic matter with benthic macroinvertebrate density supports the observation. It was interesting to note that species like *Segmentina*, *Melanoides* and *Lamellidens*, were not found during the monsoons, probably due to increased water levels and a relatively strong water current to unsettle the bottom substrate on which these species were attached (Koperski 2011). In this study it was observed that the species richness of freshwater Gastropoda depended on the type of bottom substrate and the richness of aquatic macrophytes (Lodge 1985; Perez 2004; Spyra 2010). The density of Gastropoda was positively correlated with phosphate, nitrate, total alkalinity, TDS, pH, organic carbon and organic matter (Table 6) and supported by Pip (1987) and Williams & Gormally (2009).

In middle-stream, a very low species diversity comprising of two species of Mollusca (with one Gastropoda and one Bivalvia) and only one Polychaeta (*Neanthes sp.*) were observed. Polychaetes preferred fine to medium type of sandy bottom with moderate abundance of admixtures of silt and clay (Al-khayat 2005). The middle-stream had a very similar bottom type. Molluscan diversity was meager probably due to the high flow of river water and a particular bottom type (sand and clay). The Benthic macroinvertebrates experienced threats by the changes in its habitats associated with pollution and siltation. Moreover, the poor growth of bottom fauna could be associated with frequent water level fluctuations. The dependence of benthic macroinvertebrate fauna on a number of factors such as physical nature of the substratum, depth, nutritive contents, degree of stability and oxygen concentration of the water body (Barbour et al. 1999; Merz & Chan 2005; Braccia & Voshell 2006) was reflected by the findings of this investigation that in middle-stream - substratum, depth, nutrition and oxygen concentrations were not congenial for benthic macroinvertebrate diversity to flourish. This was supported further by the negative correlation between density and phosphate as well as oxygen concentrations studied. Presence of *Pila globosa* (Gastropoda) and *Neanthes sp.* (Polychaeta) indicated the freshness of the water (Perez 2004). Benthic macroinvertebrate in middle reaches were observed in the highest concentration level during pre-monsoons probably due to the maximum occurrence of *Modiolus sp.* (Bivalvia). It was likely that the species utilized the elevated concentration of calcium in the water during pre-monsoons contributing to the increase in the benthic macroinvertebrate density.

Meager existence of benthic macroinvertebrate

diversity in down-stream might be related to the depth of water, soaring water current, increased siltation, anthropogenic disturbances and unstable substratum (as noted by the studies of Kroncke & Reiss (2010), Xu et al. (2014). Absence of macrobenthos during monsoons was probably due to high turbulence and depth of water in the down-stream. Moreover, increased anthropogenic activities (organic debris from adjoining localities, ferry boats across the river, immersion of idols, domestic daily activities, river bank occupation by factories like brick kilns etc.) at this station caused substratum instability of macrobenthic community (Leprieur et al. 2008). The destructive effects of anthropogenic activities on different estuarine communities were recorded by Patricio & Marquis (2006); Dolbeth et al. (2007); Geetha et al. (2010). The presence or absence of benthic macroinvertebrates could be a good indicator of both chronic and episodic impact of human disturbances to river conditions (Hellawell 1986; Stanford & Spacie 1994; Pinel-Alloul et al. 1996; Gamalath & Wijeyaratne 1997). The plausible reasons for the complete absence of benthos at this site might be dominated by the silt in the sediment (Cloern 2001; Bode & Varela 2006).

Hydrological conditions such as extreme hard water and salinity alteration (due to freshwater inflow during monsoons) and food availability were major factors affecting the community dynamics of benthic invertebrates (Brucet et al. 2012).

Water temperature showed a positive correlation with benthos density. During the pre-monsoon period (summer: March–June) density of benthic macroinvertebrates were higher than the post-monsoon period (winter: November–December) in all three sites presumably indicating that the temperature had a positive influence on the benthic macroinvertebrate community as noted by Hauer & Hill (1996) and Sharma & Rawat (2009).

Water transparency was positively correlated with the benthic invertebrates as also noted by Basu et al. (2013). A significant positive correlation was found between organic carbon content of soil, organic matter and benthic invertebrate density. The presence of aquatic vegetation in the study area supported the availability of more organic matter (Bath et al. 1999; Rosenberg 2001; Mikulyuk et al. 2011; Basu et al. 2013).

Community structure index is a measurement for two distinct aspects of biological community: (i) number of taxa (richness) and (ii) distribution of individuals among taxa (evenness). Diversity indices depend on the quality and availability of habitat (Barbour et al. 1999). Mason (1996) set diversity index <1 for highly polluted,

1–3 for moderately polluted and >4 for unpolluted water bodies. In up-stream the diversity index (Table 5) indicated moderately polluted water and the presence of a rich habitat. In middle- and down- streams the diversity index indicated more polluted water than up-stream. In this study, the evenness indices of all three sites indicated that the taxa identified were consistently distributed (Table 5) in all sites.

The results pointed out that benthic macroinvertebrate diversity was very poor in middle- and down- streams but had a moderate population in up-stream. Structure of macrobenthic population was mainly driven by seasonal variations, depth of water, water current, habitat type, riverbed characteristics and influence of anthropogenic interferences. The macrophyte vegetated marginal habitats supported greater species richness and abundance (up-stream) than non-vegetated habitats (middle- and down-streams). The Mollusca could be regarded as a bio-indicator species thus indicated a good water condition of the river. It was evident from the investigations that the seasonal changes in the hydrological parameters influenced the community structure of the benthic invertebrates in river Ichamati.

REFERENCES

- Al-Khayat, J.A. (2005). Some macrobenthic invertebrates in the Qatari waters, *Arabian Gulf. Qatar University Science Bulletin* 25: 126–136.
- APHA (2005). *Standard Methods for the Examination of Water and Waste Water - 21st Edition*. American Public Health Association, Washington, D.C.
- Badigo, B.P., G.B. Lawrence, R.W. Bode, H.A. Simonin, K.M. Roy & A.J. Smith (2009). Impacts of acidification on macroinvertebrate communities in streams of the western Adirondack mountains, New York, USA. *Ecological Indicators* 9(2): 226–239; <http://doi.org/10.1016/j.ecolind.2008.04.004>
- Barbour, M.T., J. Gerritsen, B.D. Snyder & J.B. Stribling (1999). *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macro invertebrates and Fish - 2nd Edition*. EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C.
- Barnes, R.S.K., P. Callow & P.J.W. Olive (1988). *The invertebrates: A New Synthesis*. Blackwell Scientific Publications, Oxford, 582pp.
- Barquin, J. & R.G. Beath (2011). Down-stream changes in spring-fed stream invertebrate communities: the effect of increased temperature range. *Journal of limnology* 70(1): 134–146; <http://doi.org/10.3274/JL11-70-S1-10>
- Basu, A., S. Sengupta, S. Dutta, A. Saha, P. Ghosh & S. Roy (2013). Studies on macrobenthic organisms in relation to water parameters at east Calcutta wetlands. *Journal of Environmental Biology* 34: 733–737.
- Bath, K.S., H. Kaur & S.S. Dhillon (1999). Correlation of Molluscs with physico-chemical factors at Harike Reservoir (Punjab). *Indian Journal of Environmental Science* 3: 159–163.
- Beauchard, O., J. Gagneur & S. Brosse (2003). Macroinvertebrate richness patterns in North African streams. *Journal of Biogeography* 30: 1821–1833.
- Bode, A.-O.M.T. & M. Varela (2006). Phytoplankton and macrophytes contributions littoral food webs in the Galician upwelling estimated from stable isotopes. *Marine Ecology Progress Series* 318: 89–102.
- Braccia, A. & J.R. Voshell (2006). Environmental factors accounting for benthic macroinvertebrate assemblage structure at the sample scale in streams subjected to a gradient of cattle grazing. *Hydrobiologia* 573: 55–73.
- Braich, O.S. & R. Kaur (2017). Temporal composition and distribution of benthic macroinvertebrates in wetlands. *Current Science* 112(1): 116–125; <http://doi.org/10.18520/cs/v112/i01/116-125>
- Brucet, S., D. Boix, L.W. Nathansen, X.D. Quintana, E. Jensen, D. Balayla, M. Meerhoff & E. Jeppesen (2012). Effects of temperature, salinity and fish in structuring the macroinvertebrate community in shallow lakes: implications for effects of climate change. *PLoS ONE* 7(2): e30877; <http://doi.org/10.1371/journal.pone.0030877>
- Carlisle, D., M.R. Meador, S.R. Moulton & P.M. Ruhi (2007). Estimation and application of indicator value for common macro-invertebrates. *Ecological Indicator* 7: 22–33; <http://doi.org/10.1016/j.ecolind.2005.09.005>
- Celik, K., N. Akbulut, A. Akbulut & D. Ozatli (2010). Macro zoobenthos of lake Uluabat, Turkey, related to some physical and chemical parameters. *Pan-American Journal of Aquatic Sciences* 5(4): 520–529.
- Cloern, J.E. (2001). Our evolving conceptual model of the coastal eutrophication problem. *Marine Ecology Progress Series* 210: 223–253.
- Cogerino, I., B. Cellot & M. Bournaud (1995). Microhabitat diversity and associated macroinvertebrates in aquatic banks of a large European river. *Hydrobiologia* 304: 103–115.
- Coleman, N., W. Cuff, J. Moverley, A.S.H. Gason & S. Heislars (2007). Depth, sediment type, biogeography and high species richness in shallow-water benthos. *Marine and Freshwater Research* 58(3): 293–305; <http://doi.org/10.1071/MF06098>
- Das, M.K., M. Naskar, M.L. Mondal, P.K. Srivastava, S. Dey & A. Rej (2012). Influence of ecological factors on the patterns of fish species richness in tropical Indian rivers. *Acta Ichthyologica Et Piscatoria* 42(1): 47–58; <http://doi.org/10.3750/AIP2011.42.1.06>
- Degani, G., G.N. Herbest, R. Ortal, H.J. Bromley, P. Levanon, H. Glazman & Y. Regev (1992). Faunal relationships to abiotic factors along the river Dan in northern Israel. *Hydrobiologia* 246: 69–82.
- Dolbeth, M.C., P.G. Ferreira, S.M. Verdelhos, T.D. Raffaelli & M.A. Pardel (2007). Anthropogenic and natural effects on a macrobenthic estuarine community over a 10 year period. *Marine Pollution Bulletin* 54: 576–585.
- Dudgeon, D., A.H. Arthington, M.O. Gessner, Z. Kawabata, D.J. Knowler, C. Lévêque, R.J. Naiman, A.H. Prieur-Richard, D. Soto, M.L. Stiassny & C.A. Sullivan (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological reviews of the Cambridge Philosophical Society* 81(2): 163–182; <http://doi.org/10.1017/S1464793105006950>
- Feldman, R.S. & E.F. Connor (1992). The relationship between pH and community structure of invertebrates in streams of the Shenandoah National Park, Virginia, U.S.A. *Freshwater Biology* 27(2): 261–276; <http://doi.org/10.1111/j.1365-2427.1992.tb00538.x>
- Fisher, M.R. & W.P. Williams (2006). A feasibility study to monitor the macroinvertebrate diversity of the River Nile using three sampling methods. *Hydrobiologia* 56:137–147; <http://doi.org/10.1007/s10750-005-1262-6>
- Gamlath, G.A.R. K. & M.J.S. Wijeyaratne (1997). Indicator organisms of environmental condition in a lotic water body in Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* 2: 121–129.
- Geetha, P.N., T.A. Thasneem & S.B. Nandan (2010). Macrobenthos and its relation to ecosystem dynamics in the Cochin estuary. Lake 2010: Wetlands, Biodiversity and Climate Change. Indian Institute of Science, Bangalore, India. 22nd–24th December, 1–12 pp.
- Hauer, F.R. & W.R. Hill (1996). Temperature, light and oxygen, pp. 103–117. In: Hauer, F.R. & G.A. Lamberti (eds.). *Methods in Stream Ecology - 2nd Edition*. San Diego, Academic Press, 877pp.
- Heck, K.I., G. Hays & R.J. Orth (2003). Critical evaluation of the nursery

- role hypothesis for seagrass meadows. *Marine Ecology Progress Series* 253: 123–136.
- Hellawell, J.M. (1986). *Biological Indicators of Freshwater Pollution and Environmental Management*. Elsevier Applied Sciences Publishers, London, New York, 546pp.
- Idowu, E.O. & A.A.A. Ugwumba (2005). Physical, chemical and benthic faunal characteristics of a southern Nigeria reservoir. *The Zoologist* 3: 15–25.
- Ikomi, R.B., F.O. Arimoro & O.K. Odihirin (2005). Composition, distribution and abundance of macroinvertebrates of the upper reaches of River Ethiopie, Delta State, Nigeria. *The Zoologist* 3: 68–81.
- Ingole B., N. Rodriguez & Z.A. Ansari (2002). Macro benthic communities of the coastal waters of Dabhol, West coast of India. *Indian Journal of Marine Sciences* 31(2): 93–99.
- Nishat, B., S.K. Chakraborty, M.E. Hasan & A.J.M.Z. Rahman (2014). *Rivers Beyond Borders: India Bangladesh Trans-boundary River Atlas. Ecosystems for Life: A Bangladesh-India Initiative*, IUCN, International Union for Conservation of Nature, Drik publication, Dhaka, Bangladesh, xx+152pp.
- Jana, B.B. & A.K. Manna (1995). Seasonal changes of benthic invertebrates in two tropical fish ponds. *Journal of Freshwater Biology* 7(2): 129–136.
- Jiang, X.M., J. Xiong, J.J.W. Qiu, J.M. Wu, J.W. Wang & Z.C. Xie (2010). Structure of macroinvertebrate communities in relation to environmental variables in a subtropical Asian river system. *International Review of Hydrobiology* 95: 42–57.
- Johnson, R.K., W. Goedkoop & L. Sandin (2004). Spatial scale and ecological relationships between the macroinvertebrate communities of stony habitats of streams and lakes. *Freshwater Biology* 49: 1179–1194.
- Jun, Y.C., N.Y. Kim, S.H. Kim, Y.S. Park, D.S. Kong & S.J. Hwang (2016). Spatial distribution of benthic macroinvertebrate assemblages in relation to environmental variables in Korean Nationwide Streams. *Water* 8: 27; <http://doi.org/10.3390/w8010027>
- Kagalou, I., G. Economidis, I. Leonardos & C. Papaloukas (2006). Assessment of a Mediterranean shallow lentic ecosystem (Lake Pamvotis, Greece) using benthic community diversity: Response to environmental parameters. *Limnologia* 36: 269–278.
- Khalua, R.K., G. Chakravarty & S.K. Chakraborty (2008). *Community Structure of Macrobenthic Mollusks of Three Contrasting Intertidal Belts of Midnapur Coast, West Bengal, India*. Zoological Research in Human Welfare, Published-Director, Zoological Survey of India, Kolkata, 484pp.
- Kroncke, I & H. Reiss (2010). Influence of macrofauna long-term natural variability on benthic indices used in ecological quality assessment. *Marine Pollution Bulletin* 60(1): 58–68.
- Koperski, P. (2011). Diversity of freshwater macrobenthos and its use in biological assessment: a critical review of current applications. *Environmental Review* 19: 16–31; <http://doi.org/10.1139/A10-023>
- Kumar, R., H. Nesevann, G. Sharma, T. Li-Chun, A.K. Prabhakar & S.P. Roy (2013). Community structure of macrobenthic invertebrates in the river Ganga in Bihar, India. *Aquatic Ecosystem, Health and Management* 16(4): 385–394.
- Lenat, D.R., D.L.S. Penrose & K.W. Eagles (1981). Variable effects of Sediment addition on stream benthos. *Hydrobiologia* 79: 187–194.
- Leprieur, F., O. Beauchard, S. Blanchet, T. Oberdorff & S. Brosse (2008). Fish invasions in the world's river systems: when natural processes are blurred by human activities. *PLoS biology* 6(12): e28; <http://doi.org/10.1371/journal.pbio.0060028>
- Li, F., N. Chung, M.J. Bae, Y.S. Kwon & Y.S. Park (2012). Relationships between stream macroinvertebrates and environmental variables at multiple spatial scales. *Freshwater Biology* 57: 2107–2124.
- Lind, O.T. (1979). *Handbook of Common Method in limnology 2nd Edition*, The C.V. Mosby Company, St. Louis, USA, 136–145pp.
- Lodge, D.M. (1985). Macrophyte-gastropod associations: observations and experiments on macrophyte choice by gastropods. *Freshwater Biology* 15: 695–708.
- Mancini, L., P. Formichetti, J.G. Morgana, L.Tancioni, A.M. D'Angelo, P. P.Danieli, E. Pierdominici, M. Iaconelli & P. Andreani (2004). Analysis of macrobenthic communities in the river basins of Central Italy. *Limnetica* 23(3–4): 199–208.
- Margalef, R. (1968). *Perspectives in Ecological Theory*. University of Chicago Press, Chicago, USA.
- Mason, C.F. (1996). *Biology of Freshwater Pollution. 3rd Edition*. Longman, England, 356pp.
- Merz, J.R. & L.K.O. Chan (2005). Effects of gravel augmentation on macroinvertebrate assemblages in a regulated California river. *River Research and Applications* 21: 61–74; <http://doi.org/10.1002/rra.819>
- Michael, Q. (1977). *Invertebrates of Streams and Rivers: A Key to Identification*. Edward Arnold Publishers Ltd., London, 84pp.
- Milbrink, G. (1983). An improved environmental index based on the relative abundance of Oligochaeta species. *Hydrobiology* 102: 89–97; <http://doi.org/10.1007/BF00006072>
- Mikulyuk, A., S. Sharma, S.V. Egeren, E. Erdmann, M.E. Nault & J. Hauxwell (2011). The relative role of environmental, spatial, and land-use patterns in explaining aquatic macrophyte community composition. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 1778–1789.
- Mishra, A.S. & P. Nautiyal (2013). Functional composition of benthic macroinvertebrate fauna in the plateau rivers, Bundelkhand, central India. *Journal of Threatened Taxa* 5(13): 4752–4758; <http://doi.org/10.11609/JoTT.o3226.4752-8>
- Mishra, A.S. & P. Nautiyal (2017). Canonical correspondence analysis for determining distributional patterns of benthic macroinvertebrate fauna in the lotic ecosystem. *Indian Journal of Ecology* 44(4): 697–705.
- Mittermeier, R.A. & C.G. Mittermeier (1997). Megadiversity: earth's biologically wealthiest nation, pp 1–140. In: McAllister, D.E., A.L. Hamilton & B. Harvery (eds.). *Global Freshwater Biodiversity - Vol. 11*. Sea Wind, Cemex, Mexico City.
- Mondal, I. & J. Bandyopadhyay (2016). Physicochemical Analysis of Ichamati River and Estimation of Soil Parameters using Geospatial Technology. *Journal of The Institution of Engineers (India): Series E* 97(2): 151–158; <http://doi.org/10.1007/s40034-016-0086-4>
- Moretti, M.S. & M. Callisto (2005). Biomonitoring of benthic macro invertebrates in the middle Doce river watershed. *Acta Limnologica Brasiliensia* 17(3): 267–281.
- Nautiyal, P. & A.S. Mishra (2013). Variations in benthic macroinvertebrate fauna as indicator of land use in the Ken River, central India. *Journal of Threatened Taxa* 5(7): 4096–4105; <http://doi.org/10.11609/JoTT.o3211.4096-105>
- Nautiyal, P., A. S. Mishra, J. Verma & A. Agrawal (2017). River ecosystems of the Central Highland ecoregion: Spatial distribution of benthic flora and fauna in the Plateau rivers (tributaries of the Yamuna and Ganga) in Central India. *Aquatic Ecosystem Health & Management* 20(1–2): 43–58; <http://doi.org/10.1080/14634988.2017.1296324>
- Nelson, S.M. & D.M. Lieberman (2002). The influence of flow and other environmental factor on benthic invertebrates in the Sacramento River, USA. *Hydrobiologia* 489: 117–129.
- North 24 Parganas Dist Police (2013). Know Your Police Station. Retrieved May 13, 2018, from <http://n24pgspolice.in/home/police-station.php>
- Olenin, S. (1997). Benthic zonation of the Eastern Gotland Basin. *Netherlands Journal of Aquatic Ecology* 30: 265–282; <http://doi.org/10.1007/BF02085871>
- Patricio, J. & A.R. Marquis (2006). Mass balanced models of the food web in three areas along gradient eutrophication in three areas along gradient eutrophication symptoms in the South arm of the Mondego estuary (Portugal). *Ecological Modeling* 197: 21–34; <http://doi.org/10.1016/j.ecolmodel.2006.03.008>
- Paul, S. & N.C. Nandi (2003). Studies on intertidal macrobenthos of Hugli River in and around Calcutta in relation to water and soil conditions. *Records of the Zoological Survey of India, Kolkata*. Occasional Paper No. 213: 1–135.
- Perez, K.E. (2004). *Planorbidae*, pp. 40–43. In: Perez K.E., S.A.

- Clark & C. Lydeard (eds.). *Freshwater Gastropod, Identification Workshop "Showing your Shells" A Primer to Freshwater Gastropod Identification*. Freshwater Mollusk Conservation Society, University of Alabama, Tuscaloosa, Alabama.
- Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13: 131–144; [http://doi.org/10.1016/0022-5193\(66\)90013-0](http://doi.org/10.1016/0022-5193(66)90013-0)
- Pinel-Alloul, B., G.Methot, L. Lapierre & A. Willsie (1996). Macrobenthic community as a biological indicator of ecological and toxicological factors in Lake Saint-Francois (Quebec). *Environmental Pollution* 91: 65–87.
- Pip, E. (1987). Species richness of freshwater gastropod communities in Central North America. *Journal of Molluscan Studies* 53(2): 163–170.
- Pokorný, J. & J. Kveřt (2004). Aquatic plants and lake ecosystems, pp. 309–340. In: O'Sullivan, P.E. & C.S. Reynolds (eds.). *The Lakes Handbook, Vol. 1. Limnology and Limnetic Ecology*. Blackwell, Malden, Massachusetts.
- Principe, R.E. & M.C. Corrigliano (2006). Benthic, drifting and marginal macroinvertebrate assemblages in a low land river: temporal and spatial variations and Size structure. *Hydrobiologia* 553(1): 303–317.
- Rao, N.V.S. (1989). *HandBook. Freshwater Molluscs of India*. Zoological Survey of India, Kolkata, India.
- Rosenberg, D.M. & V.H. Resh (1993). *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman and Hall, New York. 488pp.
- Rosenberg, R. (2001). Marine benthic faunal successional stages and related sedimentary activity. *Scientia Marina* 65: 107–119; <http://doi.org/10.3989/scimar.2001.65s2107>
- Roy, M., A. Dey, S. Banerjee & N.C. Nandi (2008). Molluscan macrobenthic diversity of brackishwater wetlands in West Bengal. *Zoological Research in Human Welfare*. Zoological Survey of India, Kolkata, 25–34pp.
- Roy, S. & A. Gupta (2010). Molluscan diversity in river Barak and its tributaries, Assam, India. *Assam University Journal of Science and Technology: Biological and Environmental Science* 5(1): 109–113.
- Sandin, L. (2003). Benthic macroinvertebrates in Swedish streams: Community structure, taxon richness, and environmental relations. *Ecography* 26: 269–282.
- Schultz, R. & E. Dibble (2012). Effects of invasive macrophytes on freshwater fish and macroinvertebrate communities: the role of invasive plant traits. *Hydrobiologia* 84(1): 1–14; <http://doi.org/10.1007/s10750-011-0978-8>
- Shannon, C.F. & W. Weiner (1964). *The Mathematical Theory of Communications*. The University of Illinois Press, Urbana, USA.
- Sharma, I. & R. Dhanze (2012). Evaluation of macrobenthic fauna in hill stream environment of western Himalaya, India. *Journal of Threatened Taxa* 4(9): 2875–2882; <http://doi.org/10.11609/JoTT.o2725.2875-82>
- Sharma, R.C. & J.S. Rawat (2009). Monitoring of aquatic macroinvertebrates as bioindicator for assessing the health of wetlands: A case study in the central Himalayas, India. *Ecological Indicators* 9: 118–128.
- Simpson, E.H. (1949). Measurement of diversity. *Nature* 16: 688
- Simpson K.W., R.W. Bode & J.R. Colquhoun (1985). The macroinvertebrate fauna of an acid-stressed headwater stream system in the Adirondack Mountains, New York. *Freshwater Biology* 15: 673–681.
- Sosza, G.J. (1975). Ecological relationships between invertebrates and submerged macrophytes in the lake littoral. *Ekologia Polska* 23: 393–415.
- Spyra, A. (2010). Environmental factors influencing the occurrence of freshwater snails in woodland water bodies. *Biologia* 65(4): 697–703; <http://doi.org/10.2478/s11756-010-0063-1>
- Spyra, A. & M.I. Strzelec (2013). Occurrence and morphological variability of *Gyraulus crista* (Gastropoda: Pulmonata: Planorbidae) on different types of substratum in woodland ponds. *Biologia* 68(4): 679–686; <http://doi.org/10.2478/s11756-013-0197-z>
- Srivastava, V.K. (2007). River ecology in India: present status and future research strategy for management and conservation. *Proceedings of the Indian National Science Academy* 73(4): 255–269.
- Stanford, L.L. & A. Spacie (1994). *Biological Monitoring of Aquatic System*. CRC Press, London, 400pp.
- Strayer, D.L. & D. Dudgeon (2010). Freshwater biodiversity conservation: recent progress and future challenges. *Journal of the North American Benthological Society* 29(1): 344–358; <http://doi.org/10.1899/08-171.1>
- Tagliapietra, D. & M. Sigovini (2010). Benthic fauna: collection and identification of macrobenthic invertebrates. *NEAR Curriculum in Natural Environmental Science, Terre et Environnement* 88: 253–261.
- Tall, L., A. Armellin, B. Pinel-Alloul, G. Méthot & C. Hudon (2016). Effects of hydrological regime, landscape features, and environment on macroinvertebrates in St. Lawrence River wetlands. *Hydrobiologia* 778(1): 221–241.
- Timm, H., M. Ivsk & T. Mols (2001). Response of macroinvertebrates and water quality to long-term decrease in organic pollution in some Estonian streams during 1990–1998. *Hydrobiologia* 464: 153–164.
- Timms, B.V. (2006). A study of the benthic communities of twenty lakes in the South Island, New Zealand. *Freshwater Biology* 12: 123–138.
- Victor, R. & A.E. Ogbeibu (1985). Macrobenthic invertebrates of a stream flowing through farmland in Southern Nigeria. *Environmental Pollution (Series A)* 39: 339–349.
- Wetzel, R.G. (2001). *Limnology: Lake and River Ecosystems, 3rd Edition*. Academic Press, San Diego, California.
- Williams, C.D. & M.J. Gormally (2009). Spatio-temporal and environmental gradient effects on Mollusc communities in a unique wetland habitat (Turloughs). *Wetlands* 29(3): 854–865; <http://doi.org/10.1672/08-185.1>
- Xu, M., Z. Wang, X. Duan & B. Pan (2014). Effects of pollution on macroinvertebrates and water quality bioassessment. *Hydrobiologia* 729(1): 247–259.
- Zeybek, M., H. Kalyoncu & Ö.O. Ertan (2012). Species composition and distribution of Mollusca in relation to water quality. *Turkish Journal of Fisheries and Aquatic Sciences* 12: 719–727; http://doi.org/10.4194/1303-2712-v12_3_21





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

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2018 | 10(8): 12056–12063

CONSERVATION STATUS OF MASCARENE AMARANTH *AERVA CONGESTA* BALF.F. EX BAKER (EUDICOTS: CARYOPHYLLALES: AMARANTHACEAE): A CRITICALLY ENDANGERED ENDEMIC HERB OF THE MASCARENES, INDIAN OCEAN

OPEN ACCESS

Kersley Bruno Pynee¹, David Harold Lorence² & Poojanraj Khurun³



¹ The Mauritius Herbarium, Agricultural Services, Ministry of Agro-Industry and Food Security, Reginald Vaughan Building, Mauritius Cane Industry Authority Compound, Réduit, Mauritius

² National Tropical Botanical Garden, 3530 Papalina Road, Kalaheo, HI 96741, USA

³ The Forestry Service, Mauritius, Ministry of Agro Industry and Food Security, Head Office, Botanical Garden Street, Les Casernes, Curepipe, Mauritius

¹ kpynee@govmu.org (corresponding author), ² lorence@ntbg.org, ³ pkhurun@govmu.org

Abstract: *Aerva congesta* Balf.f. ex Baker (Amaranthaceae), an endemic of Mascarene Islands (Mauritius and Rodrigues) is assessed for its conservation status. Considering its local extinction in Rodrigues and very small population in Mauritius, in Round Island and at Gris Gris, south of Mauritius its area of occupancy (AOO) is estimated at 8km². Due to its small AOO and threats by increasing native vegetation and alien species, *A. congesta* is evaluated as Critically Endangered following the latest IUCN Red List criteria. The species needs an urgent well-defined restoration program and ecological studies to prevent its extinction.

Keywords: Amaranthaceae, conservation status, extinction, Mauritius, Rodrigues.

DOI: <http://doi.org/10.11609/jott.2402.10.8.12056-12063>

Editor: F.B. Vincent Florens, University of Mauritius, Moka, Mauritius.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 2402 | Received 04 January 2017 | Final received 12 June 2018 | Finally accepted 20 July 2018

Citation: Pynee, K.B, D.H. Lorence & P. Khurun. (2018). Conservation status of Mascarene Amaranth *Aerva congesta* Balf.F. Ex Baker (Eudicots: Caryophyllales: Amaranthaceae): a Critically Endangered endemic herb of the Mascarenes, Indian Ocean. *Journal of Threatened Taxa* 10(8): 12056–12063; <http://doi.org/10.11609/jott.2402.10.8.12056-12063>

Copyright: © Pynee. et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: None.

Competing interests: The authors declare no competing interests.

Author Details: MR. KERSLEY BRUNO PYNEE, is a Senior Technical Assistant at The Mauritius Herbarium, Agronomy Division, Agricultural Services of the Ministry of Agro-Industry & Food Security. His main research interests are botanical survey, population survey of Critically Endangered plants, plant identification and conservation of plant species. He is holder of a BSc in Botany with specialisation in Environmental Management. He has 16 years of experience in botanizing and identifying the local flora. DAVID H. LORENCE, Ph.D., is Director of the Science and Conservation Department and Curator of the Herbarium at the National Tropical Botanical Garden. His research specialties are systematics and floristics of tropical plants, specifically the Rubiaceae and Monimiaceae families and ferns of the Pacific and Indian Ocean islands. MR. POOJANRAJ KHURUN is Deputy Conservator of Forest in the Forestry Service of the Ministry of Agro-Industry & Food Security of Mauritius. He is holder of a MSc in Forestry Management. He has 17 years of experience in forest management and biodiversity conservation.

Author Contribution: KBP: participated in botanical survey at Gris Gris where he collected and identified the plant; contributed also in taxonomic and editorial expertise. DHL: contributed taxonomic and editorial expertise. PK: organized and participated in field survey at Gris Gris and contributed in editorial expertise

Acknowledgements: We thank the Sir Seewoosagur Ramgoolam Botanic Garden Trust, Pamplemousses, Ministry of Agro-Industry & Food Security (MoAIFS) for organizing the field trips, the staff from the National Parks & Conservation Service (MoAIFS) and the Mauritian Wildlife Foundation for sharing information on the species. Comments from Cláudia Baider greatly improved the manuscript.



INTRODUCTION

The genus *Aerva* Forssk. (Amaranthaceae) consists of 21 species (The Plant List 2013) distributed mostly in the arid or semi-arid regions of the world. Bojer (1837) noted three species of *Aerva* on Mauritius, *A. lanata* (L.) Juss., *A. caudata* Bojer (*nomen nudum*), and *A. chenopodifolia* Bojer (now *Nothosaerva brachiata* (L.) Wight), which are considered as native. Later, Baker (1877) described three species of *Aerva* on Mauritius, two perennials, *A. lanata* and *A. congesta* Balf. f. ex Baker, and one annual, *A. brachiata* Mart. More recently, Townsend (1994) listed three species, the Mascarene endemic *A. congesta*, and two alien species formerly known only from cultivation, *A. lanata* and *A. sanguinolenta* (L.) Blume.

Referring to Townsend (1994) and Sukhorukov (2013), *Aerva congesta* is one of the two known endemic species of the Amaranthaceae in the Mascarene Islands (South West Indian Ocean) (Image 1). It is known from both Mauritius (Image 2) and Rodrigues (Image 3), but is not recorded on Réunion Island. The first specimen was collected by Balfour in 1879 where he indicated that the species grew as a small compact herb present on coralline limestone, in association with *Abrotanella rhynchocarpa* Balf.f. (= *Rhizophyllum rhynchocarpa* S. Moore) and *Oldenlandia sieberi* Baker var. *congesta*. According to Strahm (1989) *A. congesta* has not been

seen or collected on Rodrigues since Balfour, and it is probably extinct there; extensive surveys made on mainland Rodrigues (e.g., Anse Quito) and some islets (e.g., Ile Gombrani, Ile Chat, Ile Crabe) were unfruitful (Wiehe 1949; Cadet 1972, 1975; Guého 1980; Smith et al. 2004a,b). On Mauritius, Strahm (1989) quoted that there were recent collections from one locality on mainland Mauritius, but only samples from Round Island, an outer islet northern of Mauritius (Image 2), were accessed at The Mauritius Herbarium.

MATERIAL AND METHODS

In June 2013, while carrying out a preliminary population survey of the endemic fern, *Ctenitis maritima* (Pynee & Khurun 2013) at Gris Gris, in the village of Souillac, south coastal region of Mauritius (-20.52526°S and 57.53086°E, 6m elevation) (from Google Earth), the authors (KBP & PK) collected an interesting small prostrate herb, 0.8–3.2 cm tall, on border of the cliffs. Two small patches of *A. congesta* sized 1.8 x 2 cm and 6 x 12.5 cm with a distance of 2.2m between them and consisting of around 10 plants were found. Through closer study and comparison with herbarium specimens and using the 'Flore des Mascareignes' at The Mauritius Herbarium (MAU), the sample collected was identified

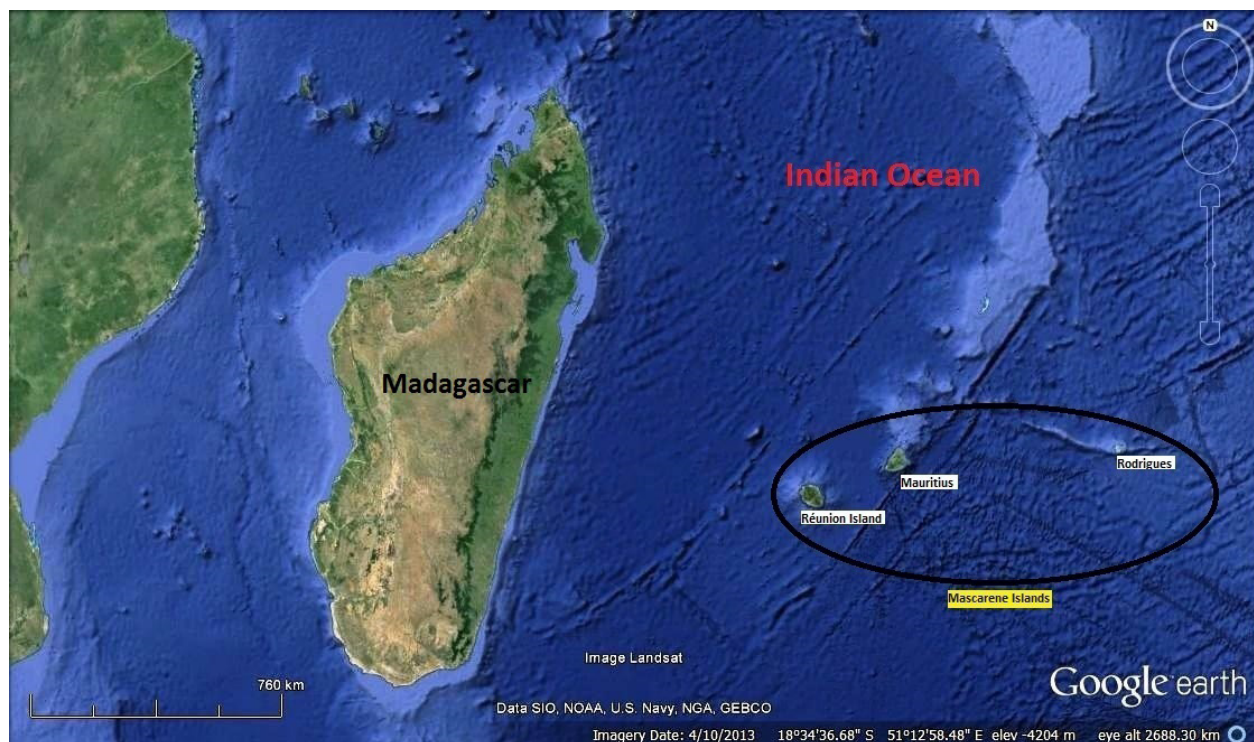


Image 1. Mascarene Islands (encircled) in the Indian Ocean

as *Aerva congesta* Balf.f. ex Baker. The herbarium specimen is deposited at The Mauritius Herbarium, Department of Agricultural Services for the Ministry of Agro Industry and Food Security (Image 4). Significant morphological characters, locality, absolute location, elevation, phenology, other associated species and distribution data were included in the herbarium label.

The actual collection at The Mauritius Herbarium (MAU 0014824) of this small herb is the first sample from mainland Mauritius accessed for this herbarium. The small dimensions of the species, coupled with the steepness of cliffs at Gris Gris (Image 5), are likely to have contributed towards it not being recently collected in this locality.

All MAU available collections before 2014 were from Round Island, with only one voucher (Strahm s.n., MAU 0016304) giving details of its habitat or ecology, showing that the species was restricted to an area near a big gully and below the helipad (-19.85668°S and 57.78629°E; 63m elevation) (from Google Earth), and found occasionally in cracks on bare rocks, similar to where the species was found at Gris Gris.

RESULTS

Aerva congesta in the Mascarenes is extant only on

Mauritius and is believed to be extinct in Rodrigues. This halophyte species grows in open areas and bare rocks, within the salt-sprayed region (Strahm 1986; Bullock et al. 2002; Lavergne 2007; Khadun et al. 2008). On Round Island it grows with native species of grasses, forming the only native dominated community in this islet (Johansson 2003) and includes a subpopulation of around 19 individuals (*A. Gungadurdoss*, pers. comm. 21 June 2016). At Gris Gris, the species shows a similar ecology; it is found rooted in rock crevices of exposed cliffs in association with the native grasses and sedges, including (*Zoysia matrella* (L.) Menill, *Stenotaphrum dimidiatum* (L.) Brongn. and *Fimbristylis cymosa* R.Br.), as well as other native species (*Dichondra repens* J.R. Forst. & G. Forst., *Ctenitis maritima* (Cordem.) Tardieu and *Selaginella obtusa* Spring). In Gris Gris, the fire prone alien invasive grass *Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult. is also present.

Evaluation of current conservation status (IUCN 2001)

The whole population of the species is considered under '2 locations' comprising two subpopulations. The extent of occurrence (EOO) of the species cannot be calculated from two localities and is deemed to be small. Taking the topographic limitations throughout its geographic range, the Area of Occupancy (AOO) was measured as 8.0km² (800ha) and the number of mature

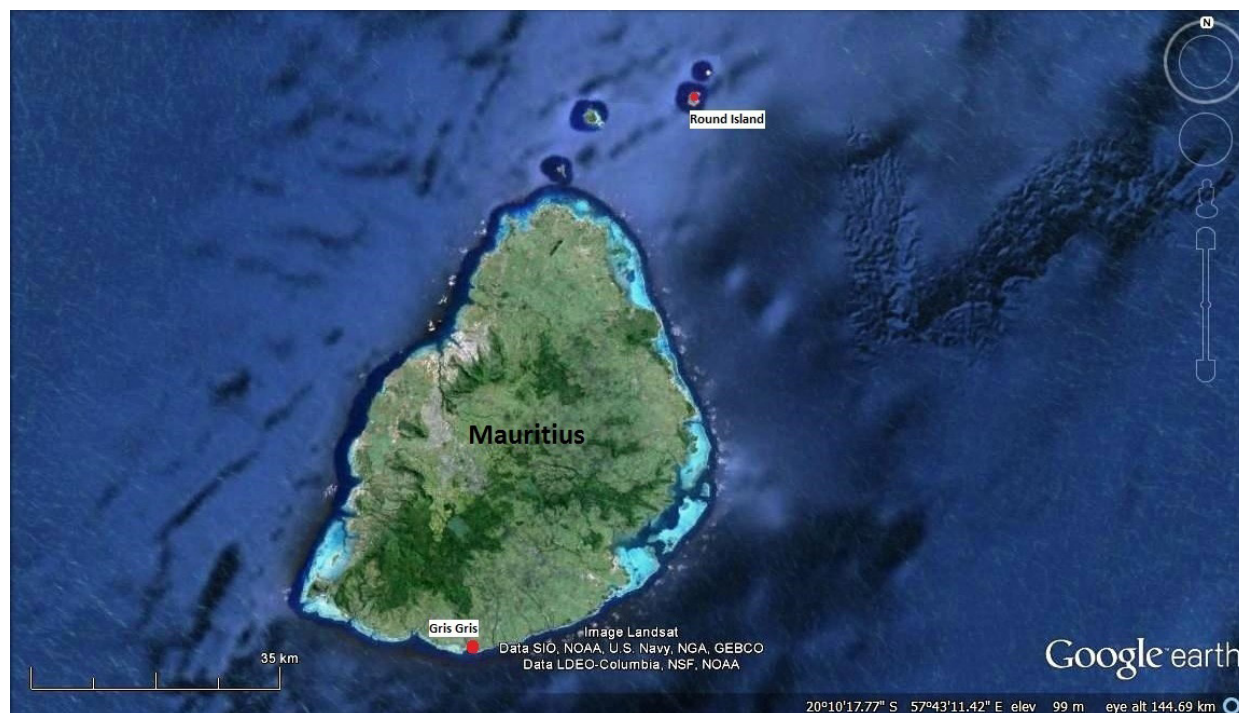


Image 2. Distribution (red dots) of *Aerva congesta* on Mauritius (including Round Island)

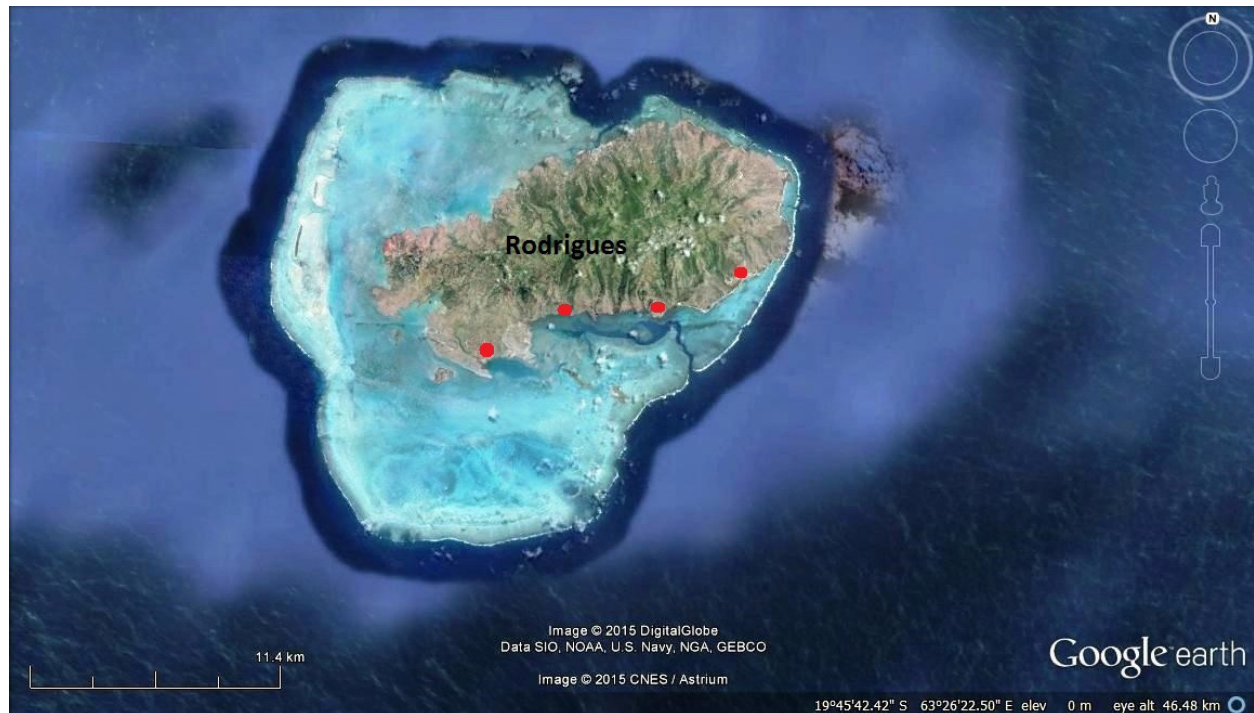


Image 3. Historic distribution (red dots) of *Aerva congesta* in Rodrigues

individuals was 29.

Criterion B: B1: The EOO of the species cannot be computed from two localities and is deemed to be very limited. Of the three conditions to be fulfilled under B1, the species is found to qualify for two: (a) severely fragmented and (b) continuing decline observed under the sub criteria: (iii) area, extent and or quality of habitat and (v) number of mature individuals. B2: The AOO is 8.0km² and since this estimate is less than 10km², and fulfils two of the three conditions: (a) severely fragmented, and (b) continuing decline observed under the sub criteria: (iii) area, extent and or quality of habitat, and (v) number of mature individuals; the species qualifies under 'Critically Endangered' category.

Criterion C: C2: Based on observed, estimated, projected and inferred continuing decline, the species is 'Critically Endangered' as it qualifies under C2, fulfilling one of the two conditions: (a) (i) number of mature individuals in each subpopulation comprises less than 50 mature individuals.

Criterion D: Since the estimated population comprises less than 50 mature individuals it qualifies under 'Critically Endangered' category.

Final assessment: CR B1ab(iii,v) & B2ab(iii,v); C2a(i); D (Appendix 1).

DISCUSSION

The species has been closely monitored on Round Island for nearly four decades and has always occurred in low density (Strahm 1986; Bullock et al. 2002; Khadun et al. 2008), with an estimated population of less than 100 individuals (Page 1995). From 1975 to 1996 the density and distribution remained unchanged (Bullock et al. 2002) even after eradication of invasive alien goats and rabbits, indicating that grazing by alien species seemed not to have been a threat. This could be related to the fact that the species might be adapted to grazing as both Mauritius and Rodrigues had two species of giant tortoises each. On the other hand, the species has declined by 50–60 % in more recent times and it was mentioned that increasing native vegetation cover could be the main threat on Round Island (Khadun et al. 2008). Indeed, it is known that grazing can promote species co-existence by reducing interspecific competition between plants and thereby reducing likelihood of competitive exclusion of one plant by another (Begon et al. 2006). In 2007, an analogue species of extinct tortoises of Mauritius, the Giant Aldabra *Aldabrachelys gigantea* and the Madagascan Radiated Tortoise *Astrochelys radiata*, were introduced to Round Island to help restore ecological function such as grazing and seed dissemination (Griffiths et



Image 4. (A) Steep cliffs where *Aerva congesta* grows at Gris Gris; (B) *Aerva congesta* with bare roots. (© Kersley Pynee).

al. 2013). The number of individuals of the species on Round Island after introduction of these tortoises has, however, decreased from an estimated population of less than 100 individuals (Page 1995; Bullock et al. 2002) to a subpopulation of 16 individuals (A. Gungadurdoss, pers. comm. 21 June 2016).

As a safeguard conservation action, the species is successfully propagated at the nursery of the Nature Reserve of Ile aux Aigrettes since over a decade. The propagated plants were used for both augmenting the population of Round Island (Khadun et al. 2008), and also trying to establish a new population on Ile aux Aigrettes. Of the 50 individuals planted on Ile aux Aigrettes in 2013, however, none survived the first year (M. Goder, pers. comm. 24 July 2014).

The discovery of a new population at Gris Gris reduces the species' chances of extinction. However, the newly discovered population in Gris Gris is very small. Furthermore, there are signs of natural erosion of the cliff around where the species is growing, decreasing the number of suitable sites. The presence of alien invasive weeds, as well as fast-growing native species, like *Stenotaphrum dimidiatum* has potentially negative impacts on *A. congesta* at Gris Gris through interspecific interactions detrimental to native plant populations as shown elsewhere on the island (Baider & Florens 2011). To conserve the recently located population, we suggest setting up ex situ propagation by the institutions concerned like the National Parks & Conservation Service and the Forestry Service; avoiding mixing the plants from the two populations to preserve their eventual genetic distinctiveness. A minor weeding would minimize the negative effect posed by alien species as well as the fast growing grasses like *Z. matrella* and *S.*

dimidiatum; however, this needs to be well planned to minimize soil erosion. A restoration program should also be implemented to increase native cover of the site that contains other threatened native species like the fern *Ctenitis maritima* and the endemic liana *Cissus anulata* Desc., which is known only from this region of the island; taking into account not to create too much shade over the plant which requires substantial exposure to thrive.

Considering the failed augmentation on Round Island since 2004 and the failed introduction on Ile aux Aigrettes in 2013, we suggest setting up systematic research to better understand the ecological requirements of the species. Finally, it is advisable to survey similar habitats in Mauritius, Rodrigues and Réunion to try to locate eventual new populations.

Specimens examined: Mauritius: Round Island, 22.vii.1968, Michel, s.n. (MAU 0015990); August 1975, Bullock et al., s.n. (MAU 0015991); August 1978 Gardner et al. s.n. (MAU 0016305); 2.viii.1986, Strahm s.n. (MAU 0016304); Gris Gris, 23.vii.2013, -20.525277S; 57.530555E, 9m elevation, Pynee et al. s.n. (MAU 0014824); Ile aux Aigrettes, 24.vii.2014, -20.420833S; 57.730833E, 8m elevation, Pynee s.n. (MAU 0016024; cultivated).

Rodrigues: no loc., August–December 1874, *Balfour* s.n. (holotype K 000243711; isotype M).

REFERENCES

- Baider, C. & F.B.V. Florens (2011). Control of invasive alien weeds averts imminent plant extinction. *Biological Invasions* 13(12): 2641–2646; <http://doi.org/10.1007/s10530-011-9980-3>
- Baker, J.G. (1877). *Flora of Mauritius and the Seychelles: A Description of the Flowering Plants and Ferns of Those Islands*. L. Reeve & Co. London, UK, 557pp; <http://doi.org/10.5962/bhl.title.139960>

Appendix 1. Assessment

RED LIST ASSESSMENT (IUCN 2001): *Aerva congesta*

Kingdom: Plantae
 Phylum: Tracheophyta
 Class: Magnoliopsida
 Order: Caryophyllales
 Family: Amaranthaceae
 Subfamily: Amaranthoideae
 Genus: *Aerva*
 Species: *congesta*
 Authority: Isaac Bayley Balfour, 1877.

Common name: Mascarene Amaranth

Taxonomic notes: The species was described first by Isaac Bayley Balfour (1877) with distribution in Rodrigues, where its presence was observed as frequent on the island. Type specimen is from Rodrigues: Balf.f. s.n., 1874 (holo. K, 1 sheet; isotyp. M, 1). The species is considered valid and *Aerva congesta* is an accepted name as per version 1.1 of The Plant List (2013).

ASSESSMENT INFORMATION

Red List Category and Criteria (Version 3.1): Critically Endangered CR B1ab(iii,v) & B2ab(iii,v); C2a(i); D.

Justification: The whole population of the species is restricted to two severely fragmented locations comprising two sub-populations. The area of occupancy is estimated as 8km² and the number of mature individuals is 29. Major threats such as erosion, fire, and alien species keep this species as Critically Endangered due to the continuing decline observed in the area/quality of habitat and number of mature individuals.

GEOGRAPHIC RANGE / DISTRIBUTION INFORMATION

Range description: The species is endemic to Mauritius and is found at an elevation range of 3–90 m.

Countries of occurrence: Endemic to Mauritius and presumed extinct in Rodrigues

Extent of Occurrence (EOO): Not estimated, but is very small.

Area of Occupancy (AOO): AOO is estimated to be 8km².

Number of locations: The species is currently found in two severely fragmented locations

Range map: See Image 2.

POPULATION INFORMATION

Population: The species is estimated to have about 29 mature individuals, of which 10 are estimated to be found at Gris Gris and the remaining 19 on Round Island.

Population trend: The population is declining. Over the last 10 years the population has declined by 50–60 %, mainly on Round Island due to various threats primarily due to competition with fast growing native and alien grasses and soil erosion.

HABITAT AND ECOLOGICAL INFORMATION

Habitat and ecology: This halophyte species is a small prostrate herb, 0.8–3.2 cm tall, grows in open areas, in cracks and bare rocks, within the salt-sprayed region on border of the cliffs and in rock crevices of exposed cliffs at an

elevation between 3-90 m. The species is mostly restricted to cliffs and predominantly brown soils. In association with the following native species of grasses and sedges (*Zoysia matrella* (L.) Menill, *Stenotaphrum dimidiatum* (L.) Brongn. and *Fimbristylis cymosa* R.Br.) as well as other native species (*Dichondra repens* J.R. Forst. & G. Forst., *Ctenitis maritima* (Cordem.) Tardieu and *Selaginella obtusa* Spring). In Gris Gris, the fire prone alien invasive grass *Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult. is also present. Key threats to the species observed in the study area are competition with fast growing native and alien grasses; sometimes competing for resources like light, water and nutrients and leading to poor plant growth.

System: Small prostrate perennial herb.

INFORMATION ON THREATS

Major Threats: The main threats to the two species population are:

- Direct competition for resources such as water, light, nutrients with exotic grasses and other herbaceous weeds.
- Increasing erosion, mainly during the dry season where there is less ground cover due to die off of exotic grasses like *Heteropogon contortus* and where the ground is more vulnerable to erosion.

Additional threats: Drought; fire; cyclones; diseases; pest attack; littering (at Gris Gris) burrowing by Shearwater birds (on Round Island) and thus leading to damage of plants are other possible threats.

USE AND TRADE INFORMATION

Use: Not known.

Livelihoods and sustenance: Not reported.

Trend in off take from the wild: Not reported.

Trend in off take from cultivation: Not reported.

INFORMATION ON CONSERVATION ACTIONS

Conservation actions:

- The Mauritian Wildlife Foundation is propagating the species through seeds and cuttings for augmentation on Round Island and introduction on Ile aux Aigrettes. Forms part of the Round Island Plant Restoration Plan
- Weeding and planting in localized patches

Research in place:

- Optimising choice of sites for the augmentation, re-introduction and introduction programmes to ensure that the correct conditions for the species, including microclimatic requirements are fulfilled.
- Investigating the translocation of *Aerva congesta* to other offshore islets and Rodrigues.
- Investigating the fate of native herbaceous community on Round Island and carrying out weed management in localized patches.

Research needed:

- Setting up systematic research to better understand the ecological requirements of the species.
- Determining the success of different planting techniques regimes on plant survivorship.

Monitoring in place:

- Protecting planted areas against Shearwater burrowing
- Sowing seeds into restoration areas
- Treating restoration planting and seed sowing as field trials in order to gain valuable information to aid future restoration work on Round Island and elsewhere.

Education in place: Not known

Education needed: Awareness and sensitization campaign

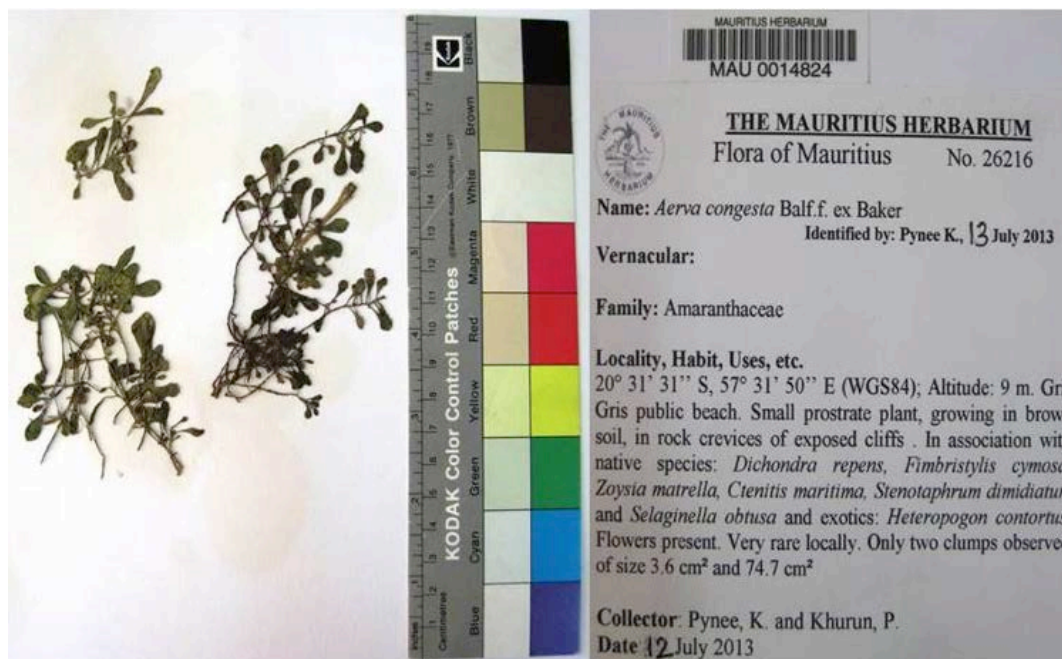


Image 5. Herbarium sample of *Aerva congesta*, MAU 0014824 (© Kersley Pynee).

Begon, M., C. Townsend & J.L. Harper (2006). *Ecology: From Individuals to Ecosystems*. Blackwell Publishing. ISBN : 978-1-405-11117-1

Bojer, W. (1837). *Hortus Mauritanus ou énumération des plantes, exotiques et indigènes, qui croissent à l'île Maurice, disposées d'après la méthode naturelle*. Aimé Mamarot et Compagnie, Mauritius, 456pp.

Bullock, D.J., S.G. North, M.E. Dulloo & M. Thorsen (2002). The impact of goat and rabbit eradication on Round Island, Mauritius. In: Veitch, C.R. & M.N. Clout (eds.) *Turning the Tide: The Eradication of Invasive Species*. Proceedings of the international conference on eradication of island invasives. Occasional Paper of the IUCN Species Survival Commission 27: 53–63.

Cadet, T. (1972). La végétation des régions calcaires de l'île Rodrigues. *Cahiers du Centre Universitaire Réunion*: 2: 1–6.

Cadet, T. (1975). Contribution à l'étude de la végétation de l'île Rodrigues. *Cahiers du Centre Universitaire Réunion*: 6: 5–29.

Griffiths, C.J., N. Zuel, C.G. Jones, Z. Ahamud & S. Harris (2013). Assessing the potential to restore historic grazing ecosystems with tortoise ecological replacements. *Conservation Biology* 27: 690–700.

Guého, J. (1980). A survey of the vegetation of the lagoon islets of Rodrigues. *Revue Agricole Sucrière de l'île Maurice* 59: 17–48.

IUCN (2001). IUCN Red List Categories and Criteria. Version 3.1. Gland, Switzerland.

Johansson, M.C. (2003). Vegetation Monitoring and Change on Round Island, Mauritius. MSc Thesis, University of Birmingham, Birmingham, UK.

Khadun, A., V. Bachraz, E. Dulloo, R. Atkinson, V. Tatayah, C. Griffiths & J. Mauremootoo (2008). A Management Plan for the Restoration of the Round Island, Mauritius (2008–2012), 36pp.

Lavergne, C. (2007). Les palmiers menacés de Maurice et de ses îlots. Technical Report. 45pp. http://palmeraie-union.com/pdf/rapport_Maurice.pdf

Page, W. (1995). Conservation management strategies for the endangered flora of Mauritius. Unpublished report submitted to the National Threatened Plant Technical Committee. Ministry of Agriculture, Food Technology and Natural Resources. January 1995.

Pynee, K. & P. Khurun (2013). A preliminary population inventory of *Ctenitis maritima* (Cordem.) Tardieu (Aspidiaceae) at Gris Gris, southcoast of Mauritius. *Cahiers Scientifiques de L'Océan Indien Occidental* 4: 39–44.

Smith, M.A.K., J. Hills, F.B.V. Florens, I. Sotharan & D. Daby (2004a). *Proposed management plan for Gombriani Island*. Ministry of Agriculture, Food Security and Natural Resources, Mauritius, 33pp.

Smith, M.A.K., J. Hills, F.B.V. Florens, I. Sotharan & D. Daby (2004b). *Proposed management plan for Crabe Island*. Ministry of Agriculture, Food Security and Natural Resources, Mauritius, 42pp.

Strahm, W.A. (1986). Botanical Report, Round Island 1986. Unpublished Report to WWF/IUCN.

Strahm, W.A. (1989). *Plant Red Data Book for Rodrigues*. IUCN-WWF Plants Conservation Programme. Konigstein, West Germany, 241pp.

Sukhorukov, A.P. (2013). A new *Atriplex* species from the island of Mauritius. (Amaranthaceae). *Skvortsovia* 1(1): 75–80

The Plant List (2013). Version 1.1. Published on the Internet; <http://www.theplantlist.org/> (accessed 1st January 2015).

Townsend, C.C. (1994). *Amaranthacées*. In: Bosser J., T. Cadet, J. Guého & W. Marais (eds.). *Flore des Mascareignes - La Réunion, Maurice, Rodrigues*. 81. Rosacées a 89. Callitrichacées. IRD/MSIRI/Kew., Paris, 32pp. ISBN 2709914115.

Wiehe, P.O. (1949). The vegetation of Rodrigues Island. *Bulletin of the Mauritius Institute* 2: 279–305.





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

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2018 | 10(8): 12064–12072



VEGETATIVE AND REPRODUCTIVE PHENOLOGY OF *AQUILARIA MALACCENSIS* LAM. (AGARWOOD) IN CACHAR DISTRICT, ASSAM, INDIA

Birkhungur Borogayary¹, Ashesh Kumar Das² & Arun Jyoti Nath³

OPEN ACCESS



^{1,2,3} Department of Ecology and Environmental Science, Assam University, Silchar, Assam 788011, India
¹birkhungari@gmail.com, ²asheshkd@gmail.com (corresponding author), ³arunjyotinath@gmail.com

Abstract: *Aquilaria malaccensis* Lam., a threatened tree commonly called agarwood, is emerging as one of the most promising commercially important aromatic species in the world. This paper presents the findings on the vegetative and reproductive phenology of *Aquilaria malaccensis* from the secondary tropical evergreen forest in Cachar district, Assam. The effect of tree phenology and the influence of seasonal drought and environmental variables, especially temperature and precipitation, on various phenophases such as leaf initiation, leaf-fall, flowering, and fruiting were investigated. For this, a quantitative assessment was made at 15-day intervals by tagging 35 trees over a period of two years. Seasonal influence on the phenology of different phenophases was correlated with environmental variables and Spearman's rank correlation coefficient was employed. Leaf initiation was positively correlated with temperature ($r_s=0.694$, $p<0.05$), while leaf-fall was negatively correlated with temperature ($r_s=-0.542$, $p<0.05$) and rainfall ($r_s=-0.521$, $p<0.05$). Flowering ($r_s=0.713$, $p<0.01$; $r_s=0.713$, $p<0.01$) and fruiting ($r_s=0.721$, $p<0.01$; $r_s=0.775$, $p<0.01$) were positively and significantly influenced by temperature and rainfall. The study suggests that temperature and rainfall were major determinants of the vegetative and reproductive phenology of *A. malaccensis*, and any changes in these variables under expected climate change phenomenon may have a profound effect on phenophases of this threatened tree species.

Keywords: Agarwood, evergreen, phenology, tropical secondary forest.

DOI: <http://doi.org/10.11609/jott.3825.10.8.12064-12072>

Editor: A.J. Solomon Raju, Andhra University, Visakhapatnam, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3825 | Received 26 October 2017 | Final received 14 May 2018 | Finally accepted 02 July 2018

Citation: Borogayary, B., A.K. Das & A.J. Nath (2018). Vegetative and reproductive phenology of *Aquilaria malaccensis* Lam. (Agarwood) in Cachar District, Assam, India. *Journal of Threatened Taxa* 10(8): 12064–12072; <http://doi.org/10.11609/jott.3825.10.8.12064-12072>

Copyright: © Borogayary et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: Mr. Birkhungur Borogayari received fellowship grant from the University Grants Commission (UGC) under Basic Science Research (BSR) programme (F.7-238/2009 (BSR)).

Competing interests: The authors declare no competing interests.

Author Details: MR. BIRKHUNGUR BOROGAYARI is a senior research fellow (UGC-BSR) and pursuing his PhD programme in the Department of Ecology and Environmental Science, Assam University. PROF. ASHESH KUMAR DAS and DR. ARUN JYOTI NATH are involved in teaching and research in the Department of Ecology and Environmental Science at Assam University, Silchar, Assam.

Author Contribution: Research design (AKD, AJN and BB); field study, data analysis and photography and manuscript writing (BB); manuscript correction and revision (BB, AKD and AJN). All authors approved the final version of the manuscript.

Acknowledgements: The authors gratefully acknowledge the infrastructural facilities provided by the UGC-SAP and DST-FIST assisted Department of Ecology and Environmental Science, Assam University, Silchar. We are thankful to Mr. Babulal Goala for assisting in the field during data collection. Authors are grateful to Tocklai Tea Research Association, Silcoorie, Assam for providing meteorological data. The fellowship provided by the University Grants Commission, Basic Scientific Research (UGC-BSR), New Delhi, Govt. of India to the senior author is gratefully acknowledged. The authors thank the anonymous reviewers for critically evaluating the manuscript and providing suggestions for improvement.

INTRODUCTION

Phenology of tropical trees has attracted much attention nowadays from the point of view of conservation of tree genetic resources as well as forestry management, and for a better understanding of the ecological adaptations of plant species and community-level interactions. The study of tree phenology provides knowledge about the pattern of tree growth and development as well as the effects of environment and selective pressures on flowering and fruiting behaviour (Zhang et al. 2006). Phenology of vegetative phases is important, as cycles of leaf flush and leaf-fall are intimately related to processes such as growth, plant water status, and gas exchanges (Reich 1995). Studies of phenology are of great importance in determining the temporal changes that constrain the physiological and morphological adaptations in plant communities for utilization of resources by fauna (van Schaik et al. 1993). The sunshine hours, temperature, and annual precipitation have been recognized as the main environmental indications for leafing and flowering in the tropics. In many evergreen species, leaf flush and flowering occur close in time on the same new shoot. Variation in flowering time relative to vegetative phenology, induced by a variety of factors (significant rain in winter/summer, decreasing or increasing photoperiod, or drought-induced leaf-fall), results in a number of flowering patterns in tropical trees (Borchert et al. 2004). Phenological processes are significant constituents of plant fitness, since the time and duration of vegetative and reproductive cycles affect the capability of a plant species to establish itself in a given site (Pau et al. 2011). Singh & Kushwaha (2005) suggested that climate change forced deviations in the length of the growing period, and competition among species may change the resource use patterns in different species. Global climate change may force variations in timing, duration, and synchronization of phenological events in tropical forests (Reich 1995).

Although a few research works have addressed the population dynamics of the species in homegardens, northeastern India (Saikia & Khan 2013), an attempt has been made to study the phenology of *A. malaccensis*, which could contribute towards the conservation and management of the species, considering its almost extinct status in the wild (Anonymous 2003). Therefore, the present study is aimed to assess the phenological behaviour of *Aquilaria malaccensis* in a secondary tropical evergreen forest to understand the response of climatic variables and the periodicity of seasons.

MATERIALS AND METHODS

Study area

The phenological study was conducted in a secondary tropical evergreen forest located at Sonachera in Cachar District of Assam, northeastern India (Fig. 1). Secondary forests are those forests that regrow largely through natural processes after significant anthropogenic disturbance of the primary forest vegetation at a single point in time or over an extended period of time, and place prominently a major change in tree diversity and/or species composition with respect to nearby original forests on similar sites (Chokkalingam & de Jong 2001). The studied secondary tropical evergreen forest covers an area of 5 hectares. The geographical location of the study site is 24.36°N latitude & 92.44°E longitude and altitude range from 73 to 102 m.

Topographically, the area is characterized by typical terrain and hillocks that harbour diverse biological diversity. The climatic condition of the study area is subtropical, warm, and humid. Maximum precipitation occurs during the months of May to September, which is

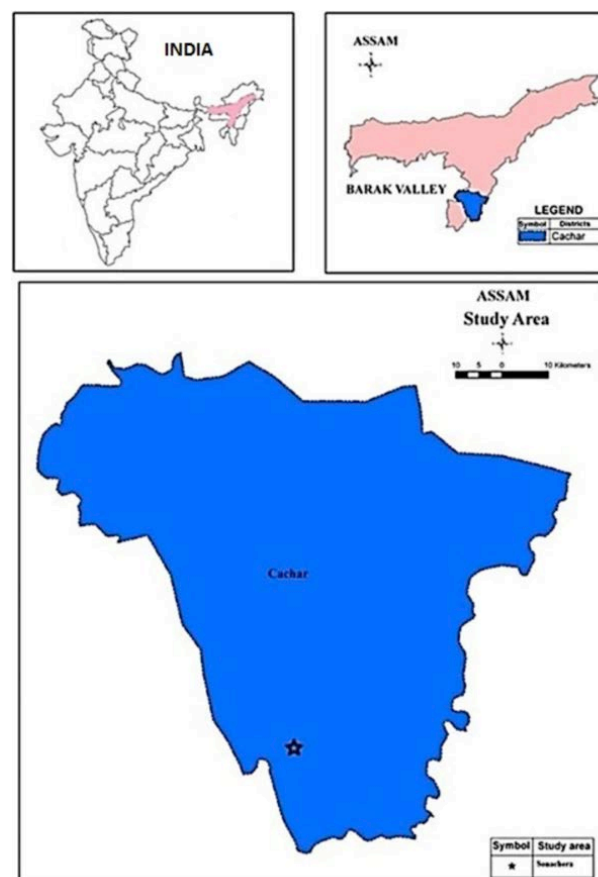


Figure 1. Map showing the location of the study area in Cachar District, Assam.

mainly controlled by the south-west monsoon season. The mean annual rainfall of the study area during the study period (2013–15) was about 2055.8mm, most of which (94%) occurred during April–September. The mean annual minimum and maximum temperatures were 19.9°C and 31.6°C, respectively (Fig. 2). The mean annual relative humidity was recorded at 75.9%.

The forest is categorized as “Cachar Tropical Evergreen Forest (Champion & Seth) (reprinted) (2005) (1B/C3)” type dominated by *Chrysophyllum roxburghii*, *Maniltoa polyandra*, *Memecylon celastrinum*, *Mesua floribunda*, *Palaquium polyanthum*, and *Pterospermum lanceifolium*. The selected secondary forest site is more than 35 years old. The secondary forest of this region is relatively unexplored and harbours a rich plant diversity.

Study species

Aquilaria malaccensis Lam. (Thymelaeaceae) is one of the most important species of commercial products in the world and is valued for its fragrant resinous dark-coloured wood known in trade as agar. Agarwood is formed by a complex plant-microbial interaction of a parasitic ascomycetous fungus known as *Phaeoacremonium parasiticum* (Ng et al. 1997). Phytogeographically, the distribution of *A. malaccensis* comprises the region of India, Myanmar, Sumatra, Peninsular Malaysia, Singapore, Borneo, and the Philippines (Chua 2008). In northeastern India, it occurs mostly in the foothills of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura (Saikia & Khan 2012a). In Upper Assam, the species is commonly cultivated in home gardens in association with other valuable plants for its high commercial demand (Saikia & Khan 2012c). The bark of the plant is also used as raw material for preparing a writing paper called ‘Sanchi pat’ for writing religious scripts (Nath & Saikia 2002). The agarwood is imported locally and exported internationally due to its wide use in the incense and perfume industry (Manohara 2013). Agarwood oil is a valuable component and is used as a digestive, sedative, analgesic, antiemetic and antimicrobial agents in tradition medicine (Cui et al. 2013). In the past few years, large-scale harvesting has caused rapid depletion of the stock in the natural forests. According to the IUCN Red List, the species is globally Vulnerable A1cd (Ver 2.3; IUCN 2017) and has been included in The World List of Threatened Trees (Oldfield et al. 1998). The species is also listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1994).

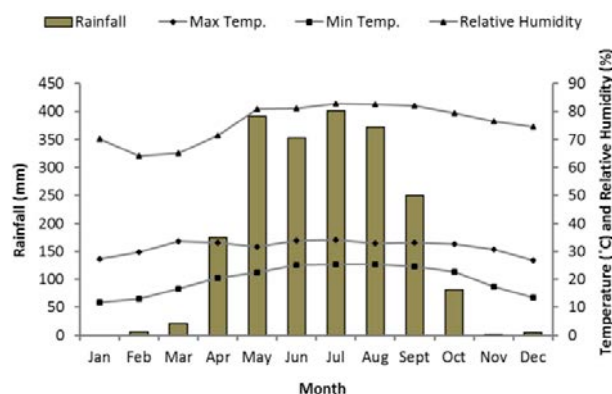


Figure 2. Ombrothermic diagram for the study period (2013–2015). Data collected from Tocklai Tea Research Association, Silcoorie, Silchar.

METHODS

A total of 35 individuals with girth size ranging from 12.7 to 81.7 cm were selected for phenological observations. The selected trees were marked with a metal tag for phenological observations. Using binoculars, phenological observations were made on leaf initiation, leaf-fall, flowering, and fruiting of the marked individuals. Phenological observations were based on phenological score: zero for no phenophase, one for less, two for moderate, and three for high (Broadhead et al. 2003). Detailed observations were carried out at 15-day intervals over a period of two years from February 2013 to January 2015.

Data analyses

Data analysis was performed using statistical software (MS Excel 2010) and (SPSS 21) version. Spearman rank correlations were performed to investigate correlations between monthly phenophase activity and environmental variables such as temperature and rainfall following (Zar 1984). The duration was classified as short (<2 months), intermediate (2–5 months), or extended (>5 months) based on the mean number of months in which the phenophase occurred (Luna-Nieves et al. 2017). Circular statistical analyses were performed to determine whether the vegetative and reproductive phenophases were homogeneously distributed throughout the year. For this purpose, months were converted into angles with intervals of 30°, and then the mean angle or mean date (α), the circular concentration (r), and the circular standard deviation (SD) were calculated. (α) indicates the time (month) of the year in which the largest number of individuals of a given species presented a phenophase, while (r)

indicates the degree of dispersion or concentration of the observations (Zar 1984). To determine the significance of the angle, a Rayleigh test (z) was used. There is a seasonality in the phenophases if the average angle is significant. The intensity of circular concentration (r) values varies from 0 (phenological activity uniformly distributed throughout the year) to 1 (phenological activity concentrated in a particular period of the year) (Morellato et al. 2010). We used the program ORIANA 3 (Kovach 2007) for these analyses. The meteorological data of the study area are presented in (Fig. 2).

RESULTS

Leafing activity

A. malaccensis initiated leafing during the pre-monsoon period (March–April) and continued up to a warm monsoon period throughout the favourable season (July–August) (Fig. 3A). The degree of circular dispersion or concentration ($r=0.99$) indicates that the phenophase leaf initiation was concentrated in a particular period of the year (Fig. 5). The phenophase leaf initiation was seasonal (Rayleigh Z , $p < 0.01$), and it occurred once a year. Peak leaf initiation was observed during March–April (Fig. 4). During the years 2013–14 and 2014–15, temperature registered its influence on leaf initiation significantly whereas rainfall displayed its impact in 2014–2015 (Table 1). The combined effect of temperature and precipitation, rather than their individual effects, more strongly influenced leaf initiation. Leaf-fall occurred during November–March with peak fall during January–February (Fig. 4). Rainfall and temperature presented a negative slope in correlation with leaf-fall due to decreasing day length and rainfall (Table 1).

Flowering

Flowering occurred during April–June (Fig. 3C & 4). The degree of circular dispersion or concentration ($r=0.97$) indicates that the phenophase flowering was concentrated in a particular period of the year (Fig. 5). The flowering phenophase was intermediate (Rayleigh Z , $p < 0.01$), and the open flower lasted one month. The duration of flowering phenophase ranged from 30 to 85 days with an average duration of 58.05 ± 6.35 days during 2013–14 and 32–90 days with an average duration of 61 ± 6.37 days during 2014–15, and it varied greatly among the individuals with a coefficient of variation (C.V. % = 20.62). Flowering was significantly influenced by temperature and rainfall while in one-month lag period



Image 1. a - Flowering initiation, b - Flowering inflorescences, c - Fruiting initiation, d - Young fruit, e - Mature fruit, f - Dehiscent fruit. © Birkhungur Borogayary

Table 1. Phenological patterns of *A. malaccensis* in relation to corresponding month and one month lag period of temperature and rainfall in Cachar District, Assam

Phenophases	Environmental factors			
	Spearman's rank correlation coefficients (r_s)			
	Temperature ($^{\circ}\text{C}$)		Rainfall (mm)	
	2013-14	2014-15	2013-14	2014-15
Leaf initiation	0.694*	0.861**	(0.251 NS)	0.528*
	(0.125 NS)	(0.340 NS)	(0.427 NS)	(0.199 NS)
Leaf-fall	-0.542*	-0.661*	-0.521*	(-0.444 NS)
	(-0.293 NS)	(-0.358 NS)	(-0.174 NS)	(-0.358 NS)
Flowering	0.713**	0.684*	0.713*	0.595*
	(0.509 NS)	(0.382 NS)	0.833**	0.683*
Fruiting	0.721**	0.824**	0.775 **	0.662*
	(0.518 NS)	0.679*	0.601*	0.833**

only rainfall was significantly correlated with flowering in 2013–2015 (Table 1). The flowers are yellowish-green and produced in umbels (Image 1a & b); the fruit is a woody capsule (Image 1e & f).

Fruiting

The fruiting phase extended over the monsoon period (April–September) with a peak during May (Fig. 3D &

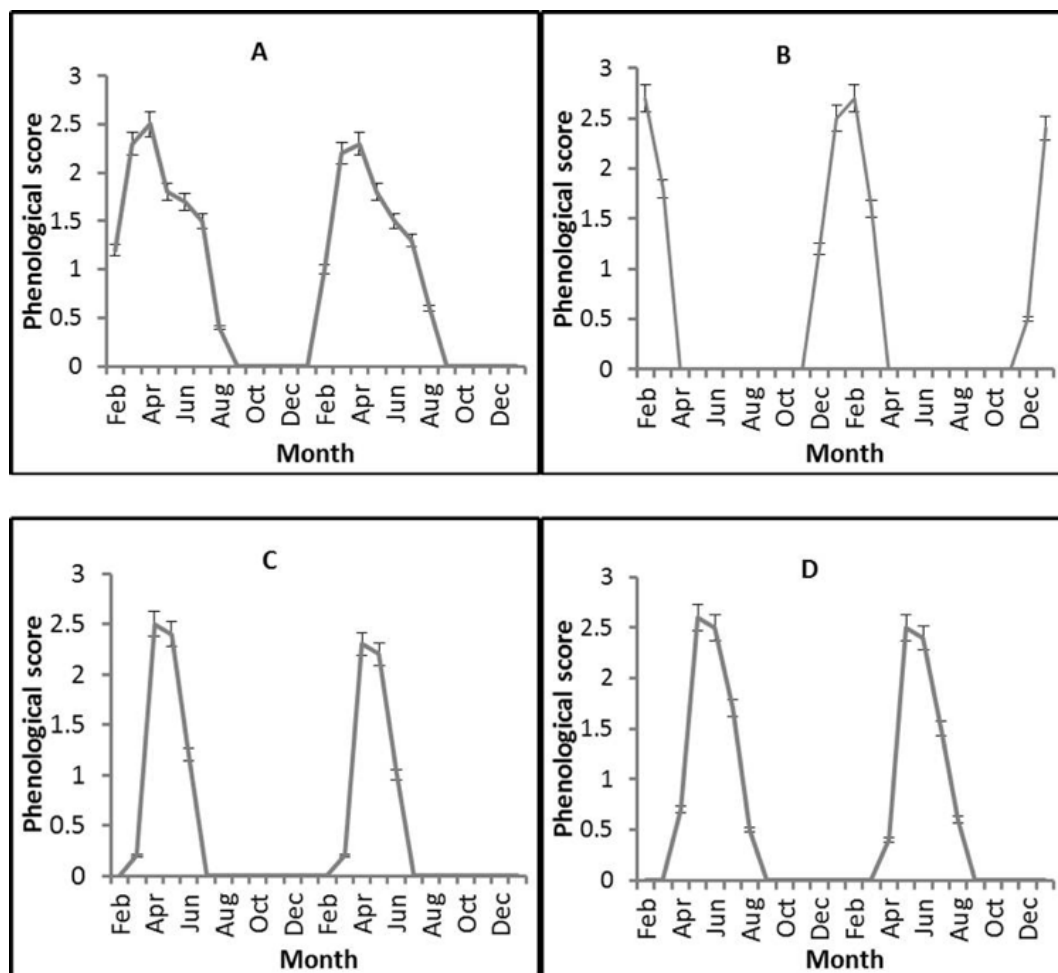


Figure 3. Periodicity of different phenophases in *A. malaccensis* during the study period (A) Leaf initiation, (B) Leaf-fall, (C) Flowering, and (D) Fruiting. Error bar represents standard error.

4). The degree of circular dispersion or concentration ($r=0.98$) indicates that the phenophase fruiting was concentrated in a particular period of the year (Fig. 5). The fruiting phenophase duration was intermediate (Rayleigh Z, $p < 0.01$), and the unripe fruits lasted for two months. The duration of fruiting phenophases ranged from 28 to 65 days with an average duration of 46.57 ± 5.24 days during 2013–14 and 30–72 days with an average duration of 51 ± 5.26 days during 2014–15, and fruiting duration varied greatly among the individuals with a coefficient of variation (C.V. % = 23.37). Fruiting presented the correlation distinctly with temperature and rainfall while in one-month lag only rainfall was significantly related with fruiting (Table 1). Availability of seasonal water had a strong impact on fruiting indicating that there was a significant relationship between one-month lag rainfall and fruiting. Fruits mature by the end of July. The fruit is a single seed which remains hanging through a small thread-like structure (Image 1f) for a few

days before dehiscence. Each seed bears a conspicuous crimson red, fleshy caruncle at the tip.

DISCUSSION

The phenological observations on the species and climatic characteristics of the study site suggest that the *A. malaccensis* is a seasonal flowering and fruiting tree species. Correlation of phenological characteristics with naturally occurring climatic events may be best documented by the pattern of leaf-fall. The greatest tendency of leaf-fall practice coincides with the relatively dry season during January–February. The timing of leaf-shedding is strongly correlated with a gradual increase in day-length, temperature, and solar insolation. This finding is in conformity with Mishra et al. (2006) who stated that maximum leaf-fall occurs during the dry period in tropical forest trees. Further, leaf-fall during this

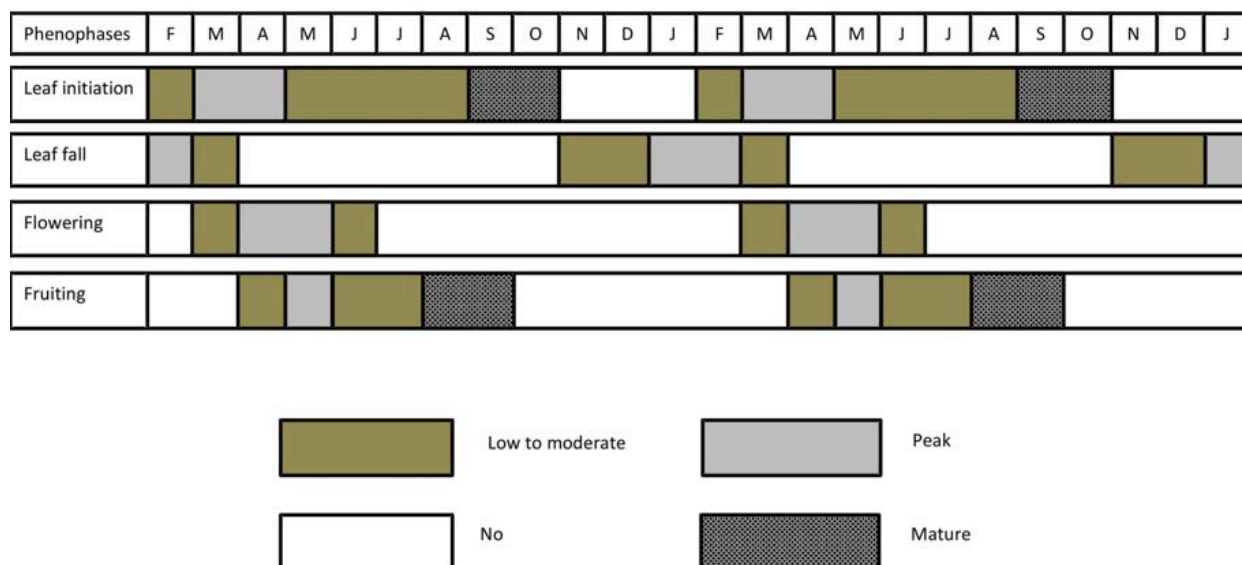


Figure 4. Vegetative and reproductive phenological events and duration recorded in *A. malaccensis* in a secondary tropical forest of Cachar District, Assam *.

* Month F=February, M=March, A=April, M=May, J=June, J=July, A=August, S=September, O=October, N=November, D=December, J=January

period appears to be an inherent strategy to minimize water loss and maximize photosynthetic activity during monsoon season (Rivera et al. 2002; Hamann 2004).

Leaf production and flushing of *A. malaccensis* start towards the end of the dry season. Short dry period, maximum temperature, and increased day length triggered the emergence of new leaves during the pre-monsoon period. The advantages of peak leaf initiation during pre-monsoon period could possibly be explained by the fact that it was to take advantage of the long rainfall period by the fully expanded foliage on trees (Singh & Kushwaha 2005). Maximum temperature and photoperiod as driving factors for leaf initiation have been reported for other tropical trees (Rivera et al. 2002; Singh & Kushwaha 2005). Saikia & Khan (2012b) observed that leaf flushing in *A. malaccensis* in home gardens starts in March and continues up to October. Species that produce leaf during the rainy season tend to have shorter periods of leaf production because this period of abundant water will normally last only for a few months. The species that greatly depend on rainfall for initiation of the leaf would also be expected to show rapid leaf growth in order to maximize photosynthetic activity during the rainy season (Reich 1995), and this type of behavior is quite common in plants growing in seasonally dry environments (Wright et al. 2002). Leaf initiation in the early rainy season is attributed to the end of the long dry season and also due to the joint action of increasing day length and temperature (Kushwaha et al. 2010). Rivera et al. (2002) have implicated that

increasing day length acts as the inducer of flushing which is relevant to the leaf phenology in *A. malaccensis*.

Flowering during the pre-monsoon season can be viewed as a strategy to make flowers more visible to pollinators and supply food sources during the poor periods of floral resources (Murali & Sukumar 1993). Species flowering during the pre-monsoon period can be capable of storing water in sufficient quantities to permit flowering even in the absence of rainfall (Borchert 1994). *A. malaccensis* as a dry season bloomer showed a significant positive correlation with photoperiod as observed for trees in tropical dry forests by Borchert et al. (2004). Soehartono & Newton (2001) reported flowering and fruiting in *A. malaccensis* growing in botanical gardens of Indonesia from April–September. Beniwal (1989) found flowering in March and fruiting in the middle of June in plantations of Arunachal Pradesh, northeastern India. Saikia & Khan (2012b) observed initiation of flowering from mid-February to May following fruiting from May and ending in August.

A. malaccensis concentrated peak fruiting during the wet season, producing dry fruits with small seeds. In tropical forests, fruiting during the rainy season may have evolved to ensure dispersal of seeds when soil water status is favourable for seed germination, seedling growth, and survival (Kushwaha et al. 2011). The requirement of moisture level for the proper development of fruits indicates that the decrease of soil water status reduced the rate of enlargement and final size of these fruits. During the wet season, availability

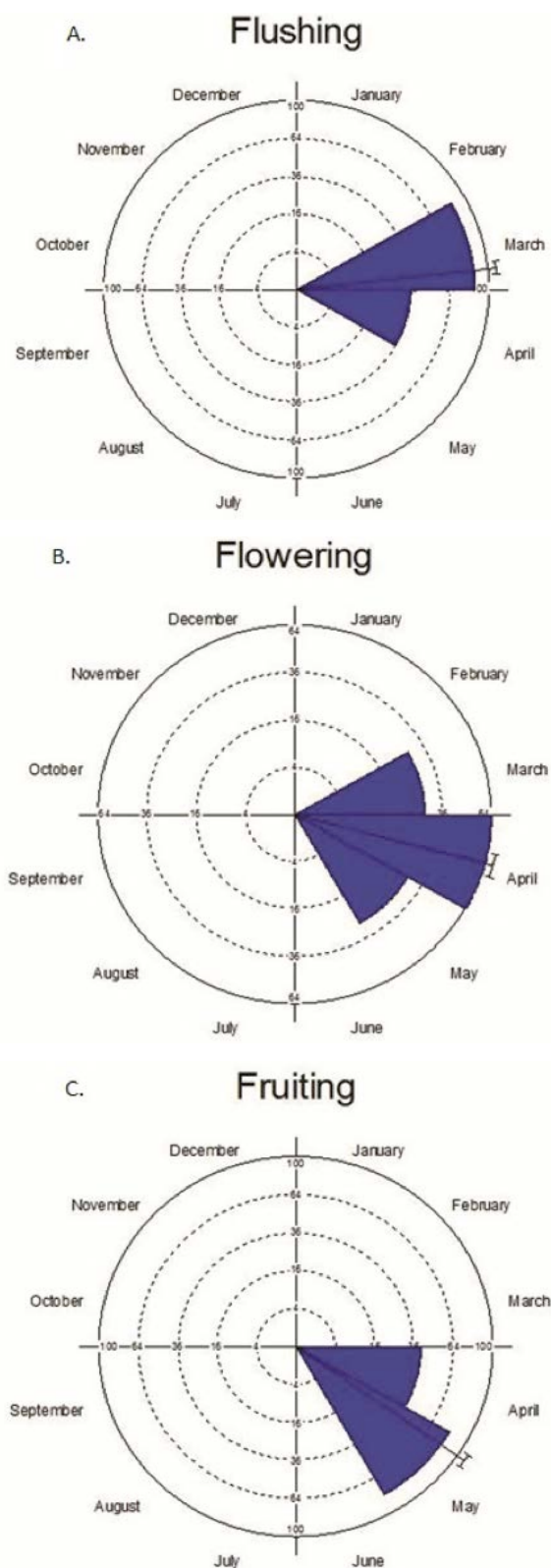


Figure 5. Circular histograms indicating the mean month of the phenophases of *A. malaccensis* in a secondary tropical forest of Cachar District, Assam. (A) Leaf flush (2013-2015: $r = 0.99$, $SD = 7.4^\circ$), (B) flowering (2013-2015: $r = 0.97$, $SD = 12.2^\circ$) and (C) fruiting (2013-2015: $r = 0.98$, $SD = 11.5^\circ$), where r = degree of dispersion or concentration and SD = circular standard deviation

of high moisture level also favours germination and establishment of seeds. The flowering phenology observed in *A. malaccensis* is reported in *Psidium guajava* and *Vatica lanceaefolia* growing in the home gardens of Barak Valley, northeastern India (Das & Das 2013). Synchronization of flowering during a particular season appears to be under the control of the prevailing climatic condition of that season (Singh & Kushwaha 2005). Maximum flowering activity during the pre-monsoon period may be related to the high insect population as pollen vectors in tropical forests. Further, seasonal flowering strategy observed in *A. malaccensis* may be a strategy to escape from seed predation on a timely basis.

In *A. malaccensis*, fruiting initiation during the rainy season is indicative of a close relationship between rainfall and fruiting, as the rainfall factor acts as a cue for reproductive phenology, especially in dry tropical forests as stated by Griz & Machado (2001). Further, autochorous seed dispersal in this species is also probably related to the humidity factor as it has an influence on fruit dehiscence. Fruit dehiscence during the monsoon season may enable the plant to escape from seed predators and produce seedlings for continued survival (Hamann 2004). Fruiting during the rainy season in tropical forests evolved to ensure dispersal of seeds and this could be attributed to utilization of available soil water for seed germination and seedling establishment (Singh & Kushwaha 2006). Tropical trees have adopted a systematic strategy so that there is adequate development time from flowering to seed dispersal so that seeds are released during the rainy period (Stevenson et al. 2008) when germination is most likely to be induced and seedlings start growing with a low probability of drought.

In the present study, the duration of flowering was longer (59.52 ± 6.36 days) and fruiting was shorter (48.78 ± 5.25 days) in *A. malaccensis* during the two years of study. This longer duration of flowering can be viewed as a difference in time taken for the formation to the maturation of buds. The short duration of fruiting is advantageous for the plant to mature fruits during the rainy season due to the availability of highest precipitation. This flowering and fruiting duration does not agree with the reports on the same in the tropical montane evergreen forest of southern India (Mohandass et al. 2016). Further, the duration of these two phenophases appears to be influenced by the changes in day length, temperature, sunshine hours, and precipitation associated with the season (Bawa et al. 2003).

The present study indicates that the vegetative and reproductive phenological events in *A. malaccensis* display a general annual flowering and fruiting pattern with a peak in these events during the pre-monsoon and monsoon seasons. Temperature and precipitation (by themselves) do not show any influence on leaf initiation but cumulatively show influence on leaf initiation. Availability of seasonal water had a strong impact on fruiting indicating that there is a significant relationship between one-month lag rainfall and fruiting. It seems that changes in temperature and rainfall pattern have a pronounced effect on the phenology of *A. malaccensis*. This information may be used as a baseline for further evaluation of phenological variations for this vulnerable tree with reference to climate change. The study suggests that there is a need to develop a long-term monitoring strategy on phenological aspects of *A. malaccensis* in order to understand the impact of climate change on phenology.

REFERENCES

- Anonymous (2003).** Review of Significant Trade *Aquilaria malaccensis*. Available at <http://www.cites.org/eng/com/PC/14/E-PC14-09-02-02-A2.pdf>. Accessed on 31 January 2012.
- Bawa, K.S., H. Kang & M.H. Grayum (2003).** Relationships among time, frequency, and duration of flowering in tropical rain forest trees. *American Journal of Botany* 90(6): 877–887.
- Beniwal, B.S. (1989).** Silvical characteristics of *Aquilaria agallocha* Roxb. *Indian Forester* 115(1): 17–21.
- Borchert, R. (1994).** Soil and stem water storage determine phenology and distribution of tropical dry forest trees. *Ecology* 75(5): 1437–1449; <http://doi.org/10.2307/1937467>
- Borchert, R., S.A. Meyer, R.S. Felger & L. Porter-Bolland (2004).** Environmental control of flowering periodicity in Costa Rican and Mexican tropical dry forests. *Global Ecology and Biogeography* 13(5): 409–425; <http://doi.org/10.1111/j.1466-822X.2004.00111.x>
- Broadhead, J.S., C.K. Ong & C.R. Black (2003).** Tree phenology and water availability in semi-arid agroforestry systems. *Forest Ecology and Management* 180(1–3): 61–73; [http://doi.org/10.1016/S0378-1127\(02\)00602-3](http://doi.org/10.1016/S0378-1127(02)00602-3)
- Champion, H.G. & S.K. Seth (2005).** *A Revised Survey of the Forest Types of India*. (Reprinted) Natraj Publishers, Dehradun, 404pp.
- Chokkalingam, U. & W. de Jong (2001).** Secondary forest: A working definition and typology. *International Forestry Review* 3(1): 19–26.
- Chua, L.S.L. (2008).** Agarwood (*Aquilaria malaccensis*) in Malaysia. NDF workshop case studies WG 1-Trees, Case study 3, Malaysia, 17pp. (in Mexico)
- CITES (1994).** *Resolution of the Conference of the Parties*. Ninth meeting of the Conference of the Parties, Fort Lauderdale, USA, 7–18 November 1994.
- Cui, J., C. Wang, S. Guo, L. Yang, P. Xiao & M. Wang (2013).** Evaluation of fungus-induced agailwood from *Aquilaria sinensis* in China. *Symbiosis* 60(1): 37–44; <http://doi.org/10.1007/s13199-013-0237-z>
- Das, T. & A.K. Das (2013).** Vegetative and reproductive phenology of some multipurpose tree species in the home gardens of Barak Valley, northeast India. *International Journal of Biometeorology* 57(1): 185–196; <http://doi.org/10.1007/s00484-012-0547-5>
- Griz, L.M.S. & I.C.S. Machado (2001).** Fruiting phenology and seed dispersal syndromes in Caatinga, a tropical dry forest in the northeast of Brazil. *Journal of Tropical Ecology* 17(2): 303–321.
- Hamann, A. (2004).** Flowering and fruiting phenology of a Philippine submontane rain forest: climatic factors as proximate and ultimate causes. *Journal of Ecology* 92(1): 24–31; <http://doi.org/10.1111/j.1365-2745.2004.00845.x>
- IUCN (2017).** The IUCN Red List of Threatened Species. Version 2017-3. International Union for Conservation of Nature. Accessed at <http://www.iucnredlist.org>. Downloaded on 27 December 2017.
- Kovach, W.L. (2007).** *Oriana for Windows 3*. Wales, Kovach Computing Services.
- Kushwaha, C.P., S.K. Tripathi & K.P. Singh (2011).** Tree specific traits affect flowering time in Indian dry tropical forest. *Plant Ecology* 212(6): 985–998; <http://doi.org/10.1007/s11258-010-9879-6>.
- Kushwaha, C.P., S.K. Tripathi, G.S. Singh & K.P. Singh (2010).** Diversity of deciduousness and phenological traits of key Indian dry tropical forest trees. *Annals of Forest Science* 67(3): 310; <http://dx.doi.org/10.1051/forest/2009116>.
- Luna-Nieves, A.L., J.A. Meave, L.P.C. Morellato & G. Ibarra-Manríquez (2017).** Reproductive phenology of useful seasonally dry tropical Forest trees: Guiding patterns for seed collection and plant propagation in nurseries. *Forest Ecology and Management* 393: 52–62; <http://doi.org/10.1016/j.foreco.2017.03.014>
- Manohara, T.N. (2013).** Wasp-mediated seed dispersal in agarwood plant (*Aquilaria malaccensis*), a critically endangered and overexploited species of North East India. *Current Science* 105(3): 298–299.
- Mishra, R.K., V.P. Upadhyay, S. Bal, P.K. Mohapatra & R.C. Mohanty (2006).** Phenology of species of moist deciduous forest sites of Similipal biosphere reserve. *Lyonia* 11(1): 5–17.
- Mohandass, D., A.C. Hughes & P. Davidar (2016).** Flowering and fruiting patterns of woody species in the tropical montane evergreen forest of southern India. *Current Science* 111(2): 404–416.
- Morellato, L.P.C., M.G.G. Camargo, F.F. D'EcaNeves, B.G. Luize, A. Mantovani & I.L. Hudson (2010).** The Influence of Sampling Method, Sample Size, and Frequency of Observations on Plant Phenological Patterns and Interpretation in Tropical Forest Trees, pp. 99–121. In: Hudson I. & M. Keatley (eds.). *Phenological Research*. Springer, Dordrecht; http://dx.doi.org/10.1007/978-90-481-3335-2_5.
- Murali, K.S. & R. Sukumar (1993).** Leaf flushing phenology and herbivory in a tropical dry deciduous forest, southern India. *Oecologia* 94(1): 114–119; <http://doi.org/10.1007/BF00317311>
- Nath, S.C. & N. Saikia (2002).** Indigenous knowledge on utility and utilitarian aspects of *Aquilaria malaccensis* Lamk. in Northeast India. *Indian Journal of Traditional Knowledge* 1(1): 47–58; <http://nopr.niscair.res.in/handle/123456789/19376>.
- Ng, L.T., Y.S. Chang & A.A. Kadir (1997).** A review on agar (gaharu) producing *Aquilaria* species. *Journal of Tropical Forest Products* 2(2): 272–285.
- Oldfield, S., C. Lusty & A. Mackinven (1998).** *The World List of Threatened Trees*. World Conservation Press, Cambridge, UK, 650pp.
- Pau, S., E.M. Wolkovich, B.I. Cook, T.J. Davies, N.J.B. Kraft, K. Bolmgren, J.L. Betancourt & E.E. Cleland (2011).** Predicting phenology by integrating ecology, evolution and climate science. *Global Change Biology* 17(12): 3633–3643; <http://doi.org/10.1111/j.1365-2486.2011.02515.x>
- Reich, P.B. (1995).** Phenology of tropical forests: patterns, causes, and consequences. *Canadian Journal of Botany* 73(2): 164–174; <http://doi.org/10.1139/b95-020>
- Rivera, G., S. Elliott, L.S. Caldas, G. Nicolossi, V.T. Coradin & R. Borchert (2002).** Increasing day-length induces spring flushing of tropical dry forest trees in the absence of rain. *Trees* 16(7): 445–456; <http://doi.org/10.1007/s00468-002-0185-3>.
- Saikia, P. & M.L. Khan (2012a).** Seedling survival and growth of *Aquilaria malaccensis* in different microclimatic conditions of northeast India. *Journal of Forestry Research* 23(4): 569–574; <http://doi.org/10.1007/s11676-012-0296-7>
- Saikia, P. & M.L. Khan (2012b).** Phenology, seed biology and seedling survival and growth of *Aquilaria malaccensis*: a highly exploited and red listed tree species of North East India. *Indian Forester* 138(3):

- 289–295.
- Saikia, P. & M.L. Khan (2012c). *Aquilaria malaccensis* Lam., a Red-listed and highly exploited tree species in the Assamese home garden. *Current Science* 102(4): 546–547.
- Saikia, P. & M.L. Khan (2013). Population structure and regeneration status of *Aquilaria malaccensis* Lam. in homegardens of Upper Assam, northeast India. *Tropical Ecology* 54(1): 1–13.
- Singh, K.P. & C.P. Kushwaha (2005). Emerging paradigms of tree phenology in dry tropics. *Current Science* 89(6): 964–975.
- Singh, K.P. & C.P. Kushwaha (2006). Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. *Annals of Botany* 97(2): 265–276; <http://dx.doi.org/10.1093/aob/mcj028>
- Soehartono, T. & A.C. Newton (2001). Reproductive ecology of *Aquilaria* spp. in Indonesia. *Forest Ecology and Management* 152(1–3): 59–71; [http://doi.org/10.1016/S0378-1127\(00\)00610-1](http://doi.org/10.1016/S0378-1127(00)00610-1)
- Stevenson, P.R., M.C. Castellanos, A.I. Cortes & A. Link (2008). Flowering patterns in a seasonal tropical lowland forest in western Amazonia. *Biotropica* 40(5): 559–567; <http://dx.doi.org/10.1111/j.1744-7429.2008.00417.x>
- van Schaik, C.P., J.W. Terborgh & S.J. Wright (1993). The phenology of tropical forests: adaptive significance and consequences for primary consumers. *Annual Review of Ecology and Systematics* 24: 353–377; <http://doi.org/10.1146/annurev.es.24.110193.002033>
- Wright, I.J., M. Westoby & P.B. Reich (2002). Convergence towards higher leaf mass per area in dry and nutrient-poor habitats has different consequences for leaf life span. *Journal of Ecology* 90(3): 534–543; <http://dx.doi.org/10.1046/j.1365-2745.2002.00689.x>.
- Zar, J.H. (1984). *Biostatistical Analysis*. Prentice-Hall International, Inc., Englewood Cliffs, New Jersey, 718pp.
- Zhang, G., Q. Song & D. Yang (2006). Phenology of *Ficus racemosa* in Xishuangbanna, Southwest China. *Biotropica* 38(3): 334–341; <http://dx.doi.org/10.1111/j.1744-7429.2006.00150.x>





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

TAKING THE FIRST STEPS: INITIAL MAPPING OF THE HUMAN-WILDLIFE INTERACTION OF THE MAURITIUS FRUIT BAT *PTEROPUS NIGER* (MAMMALIA: CHIROPTERA: PTEROPODIDAE) IN MAURITIUS BY CONSERVATION ORGANIZATIONS

Brandon P. Anthony¹, Vikash Tatayah² & Deborah de Chazal³

¹Department of Environmental Sciences and Policy, Central European University, Nádor utca 9, Budapest 1051, Hungary

^{2,3} Mauritian Wildlife Foundation, Grannum Rd., Vacoas, Mauritius

¹anthonyb@ceu.edu (corresponding author), ²vtatayah@mauritian-wildlife.org, ³deborah@chazal.co.uk

OPEN ACCESS



Abstract: Interactions between people and wildlife have both positive and negative aspects. Negative interactions, commonly termed human-wildlife conflict (HWC), have increased in recent decades due to a number of factors including difficulties in identifying and communicating the complexities of stakeholder values and positions over wildlife and its management. Here, we present the perceptions of two conservation organizations on the landscape of HWC involving the threatened Mauritius Fruit Bat *Pteropus niger*, Kerr 1792 in Mauritius, including damage to fruit crops and controversial government culls in 2015 and 2016. Participants identified 18 stakeholders in the conflict varying in importance and influence, examined where and how hostility is manifested, and delineated both perceived and real costs of the conflict. Additionally, 13 environmental and 17 social risk factors associated with the conflict were categorized, along with potential policy and management options for mitigation. We argue that initial in-house workshops are advantageous in understanding conservation conflicts before extending dialogue with other stakeholders.

Keywords: Conflict mitigation, fruit bat, human-wildlife conflict, Mauritius, *Pteropus niger*, stakeholder engagement.

DOI: <http://doi.org/10.11609/jott.4063.10.8.12073–12081>

Editor: Anonymity requested.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 4063 | Received 08 February 2018 | Final received 30 March 2018 | Finally accepted 15 June 2018

Citation: Anthony, B.P., V. Tatayah & D. de Chazal (2018). Taking the first steps: Initial mapping of the human-wildlife interaction of the Mauritius Fruit Bat *Pteropus niger* (Mammalia: Chiroptera: Pteropodidae) in Mauritius by conservation organizations. *Journal of Threatened Taxa* 10(8): 12073–12081; <http://doi.org/10.11609/jott.4063.10.8.12073-12081>

Copyright: © Anthony et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: This work was supported by Central European University Foundation of Budapest Academic Travel Grant BPF/11783.

Competing interests: The authors declare no competing interests.

Author Details: DR. BRANDON P. ANTHONY is an Associate Professor in the Environmental Sciences and Policy Department at the Central European University (CEU) in Budapest, Hungary. Prior to joining CEU, he served as advisor to the Hungarian Nature Conservation Institute, and as a park supervisor and agricultural habitat biologist in Canada. He has conducted research in North America, Africa, and Eurasia on a diverse range of fields including nature conservation, human-wildlife conflict, protected area management, community livelihoods, and amphibian ecology. DR. VIKASH TATAYAH is the Conservation Director of the Mauritian Wildlife Foundation. He has been active in conservation for over 20 years. He manages conservation programmes on Mauritius, Rodrigues and outer islands that have allowed the recovery of a long list of threatened plants and animals. He participates in fund-raising for projects and public relations initiatives, is a link with the Government of Mauritius and represents the Mauritian Wildlife Foundation on national conservation and environment consultations. He also represents the organization with several key international conservation organisations and universities. He has been a leading advocate for protection of bats. DEBORAH DE CHAZAL is the Executive Director of the Mauritian Wildlife Foundation. She has been active in the organisation for over 15 years. She has overall responsibility for all operations and directly manages the education, ecotourism, fundraising, financial and administrative activities with an oversight on the conservation programmes ensuring coordination between the functions. She has been actively involved in seeking and implementing solutions to protect bats.

Author Contribution: Designed study (BPA); data collection (BPA, VT); data analysis (BPA); write up (BPA, VT, DDC).

Acknowledgements: We thank MWF for logistical support, all workshop participants for their involvement, and Viktor Lagutov for Figure 1.



INTRODUCTION

Human-wildlife conflict (HWC) traditionally arises from a rivalry or antagonism between humans and wildlife (Woodroffe et al. 2005), or between people over wildlife and/or its management (Madden 2004; Redpath et al. 2013). The former typically emerge from territorial proximity between humans and wildlife, conflict over the same resource or even a direct threat to human wellbeing. People-people conflicts on the other hand, characteristically emerge when disparate values clash in the face of management decisions (Nyhus 2016).

While humans and wildlife have a long history of interaction, the frequency and complexity of conflicts has grown in recent decades, mainly because of the exponential increase in human populations and concomitant human footprint, expansion of some wildlife distributions (Chapron et al. 2014), as well as a frequent inability of institutions that are meant to mediate such conflicts to respond effectively (Anthony et al. 2010). HWC often pits disparate values against one another (Tajfel 1981; Kellert 1993; Young et al. 2010) and demands attention from economic, legal, social and environmental policy makers (Knight 2000; White et al. 2009; Nyhus 2016). Moreover, these values influence people's behaviour towards wildlife and institutions responsible for conservation (Manfredo & Dayer 2004; Manfredo 2008; Dickman et al. 2013). Therefore, HWCs are best managed through a shared understanding of the broader context of the situation, necessitating both natural and social science approaches (Dickman 2010; Redpath et al. 2013), and often utilizing workshops (Madden 2004; Reed et al. 2009; WWF 2015). This shared understanding is of key importance to finding long-lasting solutions to such conflicts, and to avoid potential escalation (Treves et al. 2009; Anthony et al. 2010).

The identification, differentiation and meaningful involvement of all affected stakeholders and the mapping of their goals and opinions on the resource(s) in question and potential mitigation strategies are crucial before crafting or implementing management decisions (Reed 2008; Reed et al. 2009; White et al. 2009; Redpath et al. 2013). Recent cases where stakeholder analysis and participatory strategies have been applied with the aim of conflict resolution range from conflicts concerning Hen Harriers *Circus cyaneus* in Scotland (White et al. 2009), Eastern Imperial Eagles *Aquila heliaca* in Hungary (Kovács et al. 2016), to livestock depredation by large carnivores in South Africa (Anthony & Swemmer 2015). Before engaging with wider actors, however, it has been suggested that organizations first develop a

coherent understanding of the issue within their own institution and/or with institutions that share common values, serving to enhance channels of communication and catering to a unified backing of wider stakeholder engagement (FAO 2002), particularly in contexts where complex multi-actor governance models exist (Funtowicz et al. 1999). Thus, there has been greater realization by management authorities that focusing on both wildlife and human dimensions together is critical, as opposed to treating them separately, even within organizations (Clark et al. 1996; Baruch-Mordo et al. 2009; Treves et al. 2009).

Mauritius Fruit Bats

Bats are the only mammals native to the Mascarene Islands, consisting of Mauritius, Réunion and Rodrigues (Fig. 1). Historically, three fruit bat species occupied these islands: one is now extinct (*Pteropus subniger*), leaving one species each on Mauritius (*P. niger*, Kerr 1792) and Rodrigues (*P. rodricensis*). Once widespread over Mauritius, the Mauritius Fruit Bat population decreased considerably from its original population due to habitat loss and degradation, cyclones, invasive alien species, climate change and illegal hunting (Hutson & Racey 2013; Vincenot et al. 2017). Due to lack of major cyclones for well over a decade, however, the population has increased, thus shifting its IUCN Red List status from Endangered (2008) to Vulnerable (in 2013), which was also based on an assurance that culling would not be considered (Hutson & Racey 2013). Assessing the status of this bat species has been complicated by discrepancies in population estimates yielded by different census techniques, ranging in 2015 from ~50,000 by the Mauritian Wildlife Foundation (MWF), to ~90,000 by the National Parks and Conservation Service (NPCS) (Hansard 2016). In October 2016 a population estimate was undertaken by the NPCS in collaboration with the Forestry Service and MWF, using both evening dispersal counts and direct counts, which are believed to be more accurate (Kunz 2003), yielding an estimate of ~62,000 individuals.

Mauritius Fruit Bats are considered keystone species as they provide critical pollinating and disseminating services (Vincenot et al. 2017). They are mainly nocturnal or crepuscular, and roost chiefly in primary forests or areas containing a mixture of native and introduced plant species. Bats may travel long distances to visit orchards and garden fruit trees for exotic fruits when their natural food supplies are limited (Aziz et al. 2016). The reported level of fruit damage by bats has ranged from 9.3%

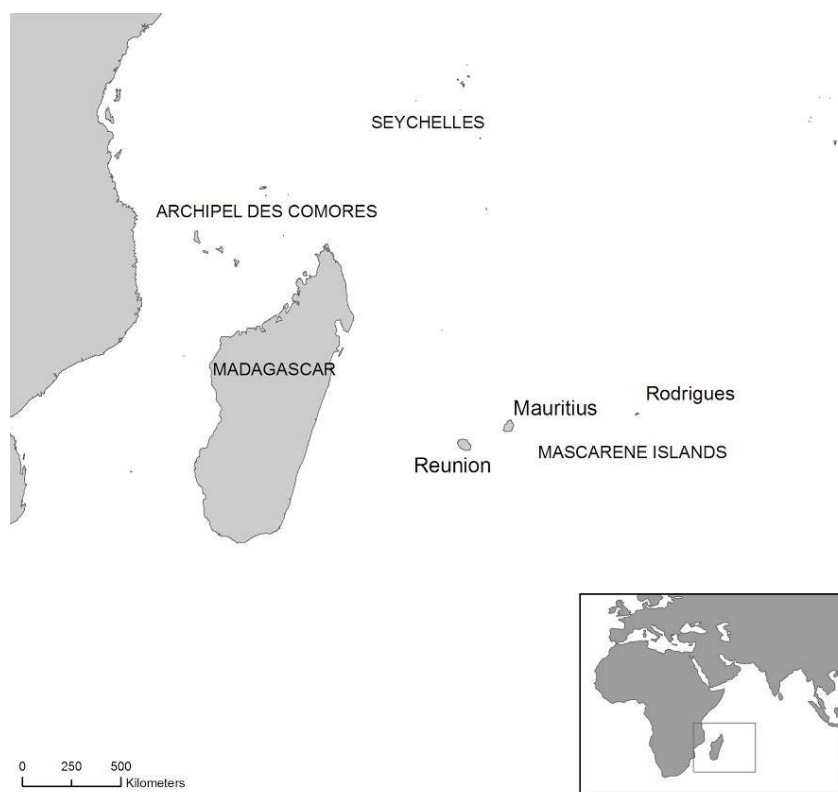


Figure 1. Location of Mascarene Islands

and 11.4% on Lychee *Litchi chinensis* and Large Mango *Mangifera indica* trees, respectively (Oleksy 2015), to over 50% of Lychee trees (Hansard 2016). Despite a subsidized tree netting scheme, and due in part to alleged significant increases in fruit damage by bats and the lobbying of fruit growers for its lethal control, the government passed the Native Terrestrial Biodiversity and National Parks Act in November 2015, legalizing the culling of any wildlife that has attained 'pest' status. Consequently, a highly controversial government sanctioned cull was conducted in November-December 2015, with a reported 30,938 bats culled (Hansard 2016). A second official cull was conducted in December 2016 in which 7,380 bats were killed (Hansard 2017). This culling largely contributed to a subsequent uplisting of the species from Vulnerable to Endangered by the IUCN in 2018 (Kingston et al. 2018).

The Mauritian Fruit Bat cull has pitted a number of stakeholders and their values against one another (MWF 2016). This sensitive situation, involving disputed bat population and fruit damage estimates, and the role of culling to alleviate fruit damage, requires joint actions from fruit growers, local organizations and governmental bodies, and also calls for a deeper understanding of the conflict by conservation organizations to provide a basis for developing effective management strategies. In order

to improve this understanding, we utilized a workshop targeted specifically to conservation organizations to map how they perceive the conflict landscape by identifying the scope and scale of human-bat interaction issues associated with relevant actors in Mauritius, and to propose strategies to navigate forward. It specifically aimed to explore intra-stakeholder complexities involved in preventing and resolving conflicts and fostering coexistence between people and bats, acknowledging data deficiencies along the way.

METHODS

As an overarching framework, but restricted to organizations with similar values, we utilized Lasswell's (1971) general strategy for problem solving that undertakes five 'intellectual tasks':

- (1) clarify the goals of people involved or affected by the problem and its solution.
- (2) describe the history and trends of the problem (including empirical data on the biophysical and cultural context of the problem and relevant processes such as decision making).
- (3) understand the relationships of all factors that have influenced, affected, or caused the problem.

(4) project the trajectory, severity, and consequences of future developments.

(5) invent, appraise, and select alternatives.

In addition, we incorporated a number of relevant sub-frameworks drawing from examples from the literature on the targeted theme.

To implement this framework, we convened a one-day workshop for MWF and NPCS staff in May 2017. All staff who were directly or indirectly engaged with the fruit bat conflict were invited, and included organization directors, project managers, and field-level officers. Participants were provided with a pre-workshop package consisting of a schedule, and group member allocation along with assigned readings and tasks. The workshop consisted of introductory sessions on the background of human-wildlife conflict and its mitigation, the Mauritius Fruit Bat, and an outline for group exercises (see Appendix 1). These were followed by three parallel group sessions, the composition of which was based on maintaining equally sized groups and personnel expertise and awareness. Each group had a number of iterative tasks to complete including an ongoing assessment of knowledge gaps and/or research needs (Table 1). A group-appointed rapporteur recorded notes on both a flip chart and notebook, then communicated findings back to all workshop participants at the end of the day. Notes for each group were subsequently compiled and categorized according to pre-defined conceptual codes according to the sub-frameworks used, and were largely descriptive in nature.

Secondly, in June 2017, we administered a follow-up questionnaire to all workshop participants consisting of two parts. First, we captured information on length of involvement in their organization, and perceived knowledge of the fruit bat conflict prior to the workshop. Second, we requested their opinion as to (i) whether the workshop met their expectations, (ii) assisted them to see and appreciate the wider conflict landscape, (iii) what was particularly useful with the workshop, and (iv) how it could be improved. Univariate statistics were computed using SPSS ver. 22 (IBM Corp 2013). Qualitative responses to questionnaire items were analysed using emergent content coding (Stemler 2001).

RESULTS

A total of 20 participants representing staff from MWF (18) and NPCS (2) attended the workshop, and contributed to its results. Below, we present findings from the group exercises, including coded indications of knowledge level of the respective concept/stakeholder by workshop participants (bold = well known; normal font = somewhat known; italics = unknown).

Group A

Group A participants identified 18 stakeholders involved in human-bat interaction, ranging from highly influential and important fruit-growers, to leisure parks holding relatively little influence and power in the

Table 1. Workshop outline and group tasks for participants

Objectives	Task(s)	Supporting reference(s)
Group A		
Stakeholder identification	<ul style="list-style-type: none"> identify relevant stakeholders in conflict rank stakeholders according to importance & influence using stakeholder matrix assess what is/isn't known about stakeholder(s) 	Messmer 2000; IFC 2007
Identify responses and consequences due to conflict	<ul style="list-style-type: none"> identify direct and indirect responses and consequences of conflict by stakeholders estimate level of hostility assess what is/isn't known about responses and consequences 	Dickman 2010
Group B		
Identify environmental and social risk factors associated with conflict	<ul style="list-style-type: none"> identify environmental risk factors associated with conflict: environmental characteristics; land use & management; human behavior (e.g. protection & management); species' behavior identify social risk factors associated with conflict: inequality & power; distrust & animosity; vulnerability & wealth; beliefs & values assess what is/isn't known about risk factors 	Clark et al. 1996; Treves et al. 2009; Dickman 2010
Identify perceived and real costs of conflict	<ul style="list-style-type: none"> identify type and variation in perceived costs of conflict identify type and variation in real costs of conflict assess what is/isn't known about perceived and real costs 	Inskip & Zimmermann 2009; Anthony & Szabo 2011; Barua et al. 2013
Group C		
Identify and assess policy and management options for conflict	<ul style="list-style-type: none"> explore and identify relevant and feasible policy and management options to minimize/mitigate conflict assess options according to efficiency, costs, and durability assess what is/isn't known about policy and management options 	Morrison et al. 2009; Chardonnet et al. 2010; Dickman 2010; Redpath et al. 2013

Table 2. Stakeholder matrix based on influence and importance of stakeholder (bold = well known; normal font = somewhat known; *italics* = unknown)

		Importance			
		Unknown	Little/No importance	Some importance	Significant importance
Influence	Significant influence			government (Cabinet)	fruit growers (commercial + backyard)
	Somewhat influential	<i>movies</i>	public press	fruit sellers/traders private companies NPCS	<i>FAREI</i> <i>funders</i>
	Little/No influence	hunters	<i>leisure parks</i>	tourists	conservationists (MWF)
	Unknown	<i>Religious organizations</i>	<i>nature-lovers (IUCN; NGOs; individuals)</i>		<i>net sellers</i>

FAREI = Food and Agricultural Research & Extension Institute; IUCN = International Union for Conservation of Nature; MWF = Mauritian Wildlife Foundation; NGO = Non-government organization; NPCS = National Parks and Conservation Service

conflict. In addition, there were a number of ‘unknown’ actors of varied influence and importance, including the role of religious organizations (Table 2). Group A also explicated a number of current interactions between stakeholder groups, outlining the perceived level of hostility, stakeholder activity, and current expressions of the conflict. These interactions represented public, government, and NGO sectors (Appendix 2), ranging from varied responses to media campaigns, frustration with current mitigation strategies (tree netting), and conflicting government mandates across ministries.

Group B

Group B participants identified 13 environmental and 17 social risk factors associated with the human-bat interaction, along with knowledge gaps (Appendix 4), which would necessitate targeted investigation before and during extended dialogue with other stakeholders. Environmental risk factors included the influence that climatic conditions (e.g., cyclones), forest health and composition, fruiting season, fruit tree pruning and protection, and bat behaviour have on the conflict. Social risk factors were also varied, ranging from market disparities, powerful lobbying interests, media influence, distrust, and folklore.

Further, Group B participants assessed both the perceived and real costs of conflict, with an indication of level of knowledge concerning these factors (Appendix 3). Most discrepancies between perceived and real costs of the conflict were economical in nature, including those relating to fruit tree maintenance, the price of fruit, and the potential impact on tourism if Mauritius’ world renowned reputation in conservation is seen as eroding.

Group C

Group C was assigned to outline what policy and management measures are, and potentially could be,

leveraged to mitigate conflict between fruit bats and the various stakeholders. Results are outlined in Appendix 5, conforming to the same scheme of level of knowledge about the effectiveness of policy and management options. Measures identified by workshop participants included extended tree netting and pruning service to fruit growers (both backyard and larger orchards), initiating decoy crops, increased bat awareness campaigns, stricter control on fruit prices, and expanded research on bat ecology.

Workshop Assessment

Fifteen (75%) workshop participants completed and returned the questionnaire, representing both the MWF (13), and the NPCS (combined response from 2 participants). Length of time employed in their respective organizations ranged from 0.5-20 years (\bar{x} = 7.9, sd = 5.63). On a 10 point scale (1=very low to 10=very high), prior knowledge regarding the fruit bat conflict ranged from 5 to 9 (\bar{x} = 7.4, sd =1.39), and was greater among those who held higher positions within their organization and/or those who worked directly with the bat issue.

On a scale of 1 to 10 (1=not at all to 10=completely), participants rated whether the workshop met their expectations, and opportunity was granted to explain their response. Scores ranged from 3 to 8 (\bar{x} = 6.0, sd =1.65). Those with higher scores noted that the workshop helped to (i) increase appreciation of the wider legal, social, and institutional aspects of the conflict, (ii) provide intra-agency exposure and awareness of the conflict complexity, and (iii) provide a much-needed platform to hear other agency views (and challenges) associated with the conflict.

Workshop participants were asked more specifically to rate how well the workshop helped them to see the wider social and management aspects of the issue both within their own organization and with another

conservation organization. Scores ranged widely (\bar{x} = 6.1, sd = 2.53), with those with higher scores noting how well the workshop helped them to understand the breadth of stakeholders directly or indirectly involved in the conflict, to see underlying issues, and recognize political dimensions of conservation conflicts (including public and political resistance). Others commented on how well the workshop disclosed how even two pro-conservation organizations can have disparate opinions on how to manage such conflicts. For those who perceived themselves to have moderate experience in conflict management and resolution, the workshop did not add much to their understanding of the breadth of social and management facets of this particular conflict. Participants believed the workshop was particularly useful in that, before extending dialogue with other stakeholders, it:

- involved group sessions within conservation-oriented stakeholders in which issues could be openly discussed and debated;
- encouraged wider understanding of models by which conservation conflicts can be framed; and
- provided pre-workshop readings and introductory sessions which facilitated improved framing of workshop tasks.

Finally, ideas on improving such workshops included eventually expanding stakeholder representation, extending its duration to 3–4 days, developing a common strategy to move forward, providing a broader array of theories, case studies, and bat research, and allowing for prolonged inter-group discussions on findings.

DISCUSSION

Our initial findings demonstrate that inter- and intra-organizational workshops designed to map conservation conflict landscapes, before extending dialogue with a wider spectrum of stakeholders, can be of immense value in a number of ways. First, a broader array of stakeholders can be acknowledged at the onset, each with varying degrees of influence and importance which, in turn, allows for more strategic and prioritized engagement (IFC 2007). Second, conflict nodes between stakeholders and their intensity can be identified, facilitating more nuanced strategies for addressing particular conflict dimensions, and allowing for a more appreciative inquiry of the conflict typology that currently exists, or may develop in the future. Third, delineating environmental and social risk factors including both perceived and real conflict costs can assist the designing of more complex

mitigation strategies including more focused awareness raising campaigns, as well as leveraging existing and potential policy and management options (Dickman 2010). Finally, by recognizing where knowledge gaps exist, conservation organizations can channel appropriate resources towards research needs and/or solicit support from other stakeholders for both research and appropriate monitoring.

We believe initial conflict mapping workshops of this nature can elevate pan-organizational understanding of conservation conflicts and build consensus by identifying, appreciating, and eventually communicating the positions and values of stakeholders, and their justification. Of course, this is only the first step in realizing true resolution, as other stakeholders may have vastly different or contrasting opinions, attitudes and values concerning the conflict (White et al. 2009). Moreover, we recognize that in-house workshops represent only one of many options for participatory and non-participatory processes which can be used to address conservation conflicts (Reed et al. 2009). Nevertheless, our assessment demonstrates that organizations would benefit from in-house workshops in order to develop an inclusive and coherent approach to engage other stakeholders before taking that next step.

Our findings also suggest that such workshops should extend to a minimum of three days, eventually involve more stakeholders, and generate more tangible outcomes in terms of mitigation strategies. We recommend, however, that such preliminary workshops be restricted to a limited number of stakeholders sharing similar values, involving relevant personnel who interact both directly or indirectly with other stakeholders (including the general public) in HWC issues. Doing so prompts a more collective and nuanced strategy for navigating forward as an organization, and for reducing the risk of conflict escalation. In our case, the fate of an entire species, and the services it provides, may depend on it.

REFERENCES

- Anthony, B.P., P. Scott & A. Antypas (2010). Sitting on the fence? Policies and practices in managing human-wildlife conflict in Limpopo Province, South Africa. *Conservation & Society* 8(3): 225–240.
- Anthony, B.P. & L. Swemmer (2015). Co-defining program success: Identifying objectives and indicators for a livestock damage compensation scheme at Kruger National Park, South Africa. *Journal for Nature Conservation* 26: 65–77.
- Anthony, B.P. & A. Szabo (2011). Protected areas: conservation cornerstones or paradoxes? Insights from Human-Wildlife Conflicts in Africa and Southeastern Europe, pp. 255–282. In: López-Pujol, J. (ed.). *The Importance of Biological Interactions in the Study of Biodiversity*. InTech Publishers, Rijeka, Croatia, 402pp.
- Aziz, S.A., K.J. Olival, S. Bumrungsri, G.C. Richards & P.A. Racey (2016). The conflict between Pteropodid bats and fruit growers: species,

- legislation and mitigation, pp. 377–426. In: Voigt, C.C. & T. Kingston (eds.). *Bats in the Anthropocene: Conservation of Bats in a Changing World*. Springer, Heidelberg, i–ix, 606pp.
- Barua, M., Bhagwat, S.A. & S. Jadhav (2013). The hidden dimensions of human-wildlife conflict: Health impacts, opportunity and transaction costs. *Biological Conservation* 157: 309–316.
- Baruch-Mordo, S., S.W. Breck, K.R. Wilson & J. Broderick (2009). A tool box half full: How social science can help solve human-wildlife conflict. *Human Dimensions of Wildlife* 14(3): 219–223.
- Chapron, G., P. Kaczensky, J.D.C. Linnell, M. von Arx, D. Huber, H. Andrén & J.V. López-Bao (2014). Recovery of large carnivores in Europe's modern human-dominated landscapes. *Science* 346(6216): 1517–1519.
- Chardonnet, P., B. Soto, H. Fritz, W. Crosmary, N. Drouet-Hoguet, P. Mesochina, M. Pellerin, D. Mallon, L. Bakker, H. Boulet & F. Lamarque (2010). *Managing the Conflicts between People and Lion: Review and Insights from the Literature and Field Experience*. Wildlife Management Working Paper 13. Food and Agriculture Organization of the United Nations, Rome, 66pp.
- Clark, T.W., A.P. Curlee & R.P. Reading (1996). Crafting effective solutions to the large carnivore conservation problem. *Conservation Biology* 10(4): 940–948.
- Dickman, A.J. (2010). Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation* 13(5): 458–466.
- Dickman, A., S. Marchini & M. Manfredo (2013). The human dimension in addressing conflict with large carnivores. *Key Topics in Conservation Biology* 2: 110–126.
- FAO (2002). *Methodological Guide for Designing and Implementing a Multimedia Communication Strategy*. Food and Agriculture Organization of the United Nations, Rome, 44pp.
- Funtowicz, S.O., J. Martinez-Alier, G. Munda & J.R. Ravetz (1999). *Information Tools for Environmental Policy under Conditions of Complexity*. Environmental Issues Series No. 9, European Environment Agency, Copenhagen, 34pp.
- Hansard (2016). Debate No. 08 of 2016, Tuesday 24 May 2016, Republic of Mauritius, Sixth National Assembly, First Session. <http://mauritiusassembly.govmu.org/English/hansard/Documents/2016/hansard0816.pdf>
- Hansard (2017). Debate No. 23 of 2017, Tuesday 31 October 2017, Republic of Mauritius, Sixth National Assembly, First Session.
- Hutson, A.M. & P.A. Racey (2013). *Pteropus niger*. The IUCN Red List of Threatened Species 2013: e.T18743A22084054. <http://doi.org/10.2305/IUCN.UK.2013-2.RLTS.T18743A22084054.en> Downloaded on 02 July 2018.
- IBM Corp. (2013). IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.
- Inskip, C. & A. Zimmermann (2009). Human-felid conflict: a review of patterns and priorities worldwide. *Oryx* 43(1): 18–34.
- International Finance Corporation (IFC) (2007). *Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets*. IFC, Washington, DC, 201pp.
- Kellert, S.R. (1993). The biological basis for human values of nature, pp. 42–72. In: Kellert, S.R. & E.O. Wilson (eds.). *The Biophilia Hypothesis*. Island Press, Washington, DC, 496pp.
- Kingston, T., V. Florens, R. Oleksy, K. Ruhomaun & V. Tatayah (2018). *Pteropus niger*. The IUCN Red List of Threatened Species 2018: e.T18743A86475525. Downloaded on 07 July 2018.
- Knight, J. (ed.) (2000). *Natural Enemies: People-wildlife Conflicts in Anthropological Perspective*. Routledge, New York, 254pp.
- Kovács, E., V. Fabók, A. Kalóczkai & H.P. Hansen (2016). Towards understanding and resolving the conflict related to the Eastern Imperial Eagle (*Aquila heliaca*) conservation with participatory management planning. *Land Use Policy* 54: 158–168.
- Kunz, T.H. (2003). Censusing bats: Challenges, solutions, and sampling biases, pp. 9–19. In: O'Shea, T.J. & M.A. Bogan (eds.). *Monitoring Trends in Bat Populations of the United States and Territories: Problems and Prospects*. U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report, USGS/BRD/ITR--2003--0003, Springfield VA, 274pp.
- Lasswell, H.D. (1971). *A Pre-view of the Policy Sciences*. Elsevier, New York, 173pp.
- Madden, F. (2004). Creating coexistence between humans and wildlife: global perspectives on local efforts to address human-wildlife conflict. *Human Dimensions of Wildlife* 9(4): 247–258.
- Manfredo, M.J. (2008). *Who Cares about Wildlife? Social Science Concepts for Exploring Human-Wildlife Relationships and Conservation Issues*. Springer, New York, 228pp.
- Manfredo, M.J. & A.A. Dayer (2004). Concepts for exploring the social aspects of human-wildlife conflict in a global context. *Human Dimensions of Wildlife* 9: 1–20.
- Messmer, T.A. (2000). The emergence of human-wildlife conflict management: turning challenges into opportunities. *International Biodeterioration and Biodegradation* 45: 97–102.
- Morrison, K., R. Victorine & C. Mishra (2009). Lessons Learned, Opportunities and Innovations in Human Wildlife Conflict Compensation and Insurance Schemes. WCS TransLinks Program, Bronx, NY, 24pp.
- MWWF (2016). Fruit damage claims do not justify a cull of the Mauritius Fruit Bat. Statement issued 9 December 2016, Mauritian Wildlife Foundation <http://www.mauritian-wildlife.org/application/index.php?tpid=30&tcid=81>
- Nyhus, P.J. (2016). Human-wildlife conflict and coexistence. *Annual Review of Environment and Resources* 41(1): 143–171.
- Oleksy, R. (2015). The impact of the Mauritius Fruit Bat (*Pteropus niger*) on commercial fruit farms and possible mitigation measures. Report to The Rufford Foundation; http://www.rufford.org/projects/ryszard_oleksy
- Redpath, S.M., J. Young, A. Evely, W.M. Adams, W.J. Sutherland, A.A. Whitehouse, R.A. Lambert, J.D.C. Linnell, A. Watt & R.J. Gutiérrez (2013). Understanding and managing conservation conflicts. *Trends in Ecology & Evolution* 28(2): 100–109; <http://doi.org/10.1016/j.tree.2012.08.021>
- Reed, M.S. (2008). Stakeholder participation for environmental management: a literature review. *Biological Conservation* 141: 2417–2431.
- Reed, M.R., A. Graves, N. Dandy, H. Posthumus, K. Hubacek, J. Morris, C. Prell, C.H. Quinn & L.C. Stringer (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management* 90(5): 1933–1949.
- Stemler, S. (2001). An overview of content analysis. *Practical Assessment, Research & Evaluation* 7(17): 1–6; <http://PAREonline.net/getvn.asp?v=7&n=17>
- Tajfel, H. (1981). *Human Groups and Social Categories: Studies in Social Psychology*. Cambridge University Press, Cambridge, UK, 384pp.
- Treves, A., R.B. Wallace & S. White (2009). Participatory planning of interventions to mitigate human-wildlife conflicts. *Conservation Biology* 23(6): 1577–1587.
- Vincenot, C.E., F.B.V. Florens & T. Kingston (2017). Can we protect island flying foxes? *Science* 355(6332): 1368–1370.
- White, R.M., A. Fischer, K. Marshall, J.M.J. Travis, T.J. Webb, S. di Falco, Salvatore, S.M. Redpath, & R. van der Wal (2009). Developing an integrated conceptual framework to understand biodiversity conflicts. *Land Use Policy* 26(2): 242–253.
- Woodroffe, R., S. Thirgood & A. Rabinowitz (eds.) (2005). *People and Wildlife: Conflict or Co-existence* (No. 9). Cambridge University Press, Cambridge, UK, 497pp.
- WWF (2015). Human Tiger Conflict Workshop Report. World Wide Fund for Nature, Kuala Lumpur, Malaysia, 21pp.
- Young, J.C., M. Marzano, R.M. White, D.L. McCracken, S.M. Redpath, D.N. Carss, C.P. Quine & A.D. Watt (2010). The emergence of biodiversity conflicts from biodiversity impacts: characteristics and management strategies. *Biodiversity and Conservation* 19(14): 3973–3990.

Appendix 1. Human-Wildlife Conflict Workshop- Schedule

Time	Activity
08:30-09:00	Welcome & Intro to HWC
09:00-09:30	Fruit bat case study - overview
09:30-10:00	Intro to workshop sessions
10:00-10:30	Tea/Coffee break
10:30-12:00	Group Work I: groups (A/B/C)
12:00-13:00	Lunch
13:00-15:00	Group Work II: groups (A/B/C) + finalizing presentation
15:00-16:00	Working groups report findings (knowledge gaps & research needs) [20' per group]
16:00-16:20	Closing remarks + tea/coffee

Appendix 2. Outline of selected stakeholder interactions leading to particular responses and consequences

Stakeholders	Level of Hostility	Activity	Current Response/Consequences
MWF x Public	High	MWF educates and raises public awareness on bat conservation to improve attitudes towards bats and their conservation	<ul style="list-style-type: none"> little/no change in attitude people still unaware of importance of bats some public participate in saving injured bats, but majority do not.
Fruit growers x MWF	High	MWF: Provide info to farmers (netting / pruning) but with mixed results	<ul style="list-style-type: none"> Fruit growers believe MWF 'do not understand their problems' because MWF has low influence, the opinion of growers is strongly influencing government decision damage level not based on scientific results
Government x Civil society	High	Government mandated to both protect wildlife and farmer interests, and wants to appease voters through approving bat culls	<ul style="list-style-type: none"> Ministry of Agro-Industry and Food Security has conflicting mandates (wildlife protection and food production) Conservation and animal welfare NGOs lobby for bat protection
Press x Public	Minimal	Press reporting on bat issue to public	<ul style="list-style-type: none"> Press provide media coverage (good info) Press communicate wrong or distorted info, leading to negative public opinion Press has been ambivalent: strongly encourage culling before cull, and after cull was more nuanced Public: blame MWF for high population of bats Encourages illegal culling

Appendix 3. Perceived and real cost factors identified by workshop participants

Note: **bold** = well known; normal font = somewhat known; *italics* = unknown

Perceived Costs of Conflict	Real Costs of Conflict
<ul style="list-style-type: none"> cleaning under fruit trees removal of fruit trees leads to less fruit ▲ price of fruit availability of fruits: <p>less fruit on backyard tree to eat or give to neighbours; market fruit usually available, just expensive</p> <ul style="list-style-type: none"> bat extinction will deprive future generations of wildlife less fruit leads to ▼ revenue sleep disturbance affects tourist industry negatively if bats culled Mauritius international reputation as biodiversity champion tarnished ▼ <i>bats leads to ▼ forest regeneration</i> <i>psychological impact of culling</i> <i>physical injury from installation/ removal of netting</i> <i>boycott in export of Mauritian fruits if bats culled</i> 	<ul style="list-style-type: none"> subsidy of netting cost of culling cost of surveys (bat population and questionnaire) cost of nets and installation and removal cost of pruning cleaning under trees other methods to keep bats away (guarding, lights, fire crackers, shooting)

Appendix 4. Environmental and social risk factors identified by workshop participantsNote: **bold** = well known; normal font = somewhat known; *italics* = unknown; arrows indicate effect between variables

Environmental Risk Factors	Social Risk Factors
<p>Environmental characteristics/land use and management</p> <ul style="list-style-type: none"> ▼ native forest extent leads to ▲ bats' reliance on exotic fruits ▼ forest quality leads to ▲ bats' reliance on exotic fruits ▲ urbanisation leads to ▼ tree abundance/density ▼ cyclones leads to ▲ bat population lychee season leads to less native food source for bats ▲ commercial fruit growers leads to ▲ fruit which, in turn, leads to ▲ bats 	<p><i>Inequality and power</i></p> <ul style="list-style-type: none"> lobbying by influential groups (fruit exporters, NGOs) political decision based on popularity (backyard growers as large voting base) press influence (affects public perception) lack of education leads to less informed judgement control of fruit price (for economic gain) and/or unfair trade practices (limiting supply) can lead to and maintain inflated fruit prices
<p>Human Behaviour</p> <ul style="list-style-type: none"> ▲ pruning and netting effectiveness leads to ▼ bat damage to fruits ▲ capacity/willingness to utilize netting leads to ▼ bat damage to fruits ▲ bat culling leads to ▲ illegal killing of bats by public orchard owners: ▲ <i>resources for tree protection</i> leads to ▲ <i>tree protection</i> backyard growers: ▼ <i>resources for tree protection</i> leads to ▲ <i>bats feeding in backyards</i> 	<p>Vulnerability and Wealth</p> <ul style="list-style-type: none"> Backyard growers and small scale planters cannot afford netting nor installation which leads to inability to reduce damage by bats and birds Returns from harvest significant percentage of annual revenue for orchard owners Physical incapacity to install nets may deter use
<p>Behaviour and management of conflict-causing species</p> <ul style="list-style-type: none"> bats non-territorial, thus damage by bats widespread ▲ protection by law leads to ▲ bat population 	<p>Distrust and animosity</p> <ul style="list-style-type: none"> people upset because of fruit predated by bats, noise and faeces/residue annoyance over legal protection of bats leads many Mauritians to consider bats as 'pests' <i>Distrust towards conservationists ('do not understand farmers losing fruits'; 'all they want to do is to protect bats')</i>
	<p>Beliefs and Values</p> <ul style="list-style-type: none"> as bats are believed to be nocturnal, their habits are unknown hunting is considered normal (acceptable) killing perceptions of bats due to folklore ('evil creatures') bats are considered by some to be edible, thus it is more acceptable to kill them (cultural for some sections of the population) religions do not promote killing superstitions (bats 'dark and evil', 'vampires', 'get entangled in people's hair')

Appendix 5. Existing and potential policy options identified by participants, and level of knowledge regarding these optionsNote: **bold** = well known; normal font = somewhat known; *italics* = unknown

Existing Policy/Management	Proposed Policy/Management	Relevant Considerations
Netting subsidy (75%) scheme	Full canopy netting	<ul style="list-style-type: none"> extend netting scheme to more than (current) half of all trees in orchards <2 acres, and 5 for backyard growers. service provider to train (i) teams in community allowing free net installation for backyard growers, and (ii) orchard staff which would increase uptake and effectiveness in orchards
Tree pruning	Tree pruning and compensation against losses	<i>identify team of wood cutters</i>
Sacrificial (decoy) crops	Provide incentive in private sector to plant sacrificial crop	free of charge to farmers
Culling (as and when required)	Controlled hunting	<ul style="list-style-type: none"> find appropriate hunting season and target number of bats seen as last option
	More study on bat ecology	Investigate local knowledge (e.g. use of smoke as deterrent)
	Pick your own	Pick your own scheme to lower price
	Price control of fruit	Government to implement measures to ensure free market without price fixing
	Awareness campaign	<ul style="list-style-type: none"> identify target group and effective communication method leisure parks: interaction with bats





THE TERM HUMAN-WILDLIFE CONFLICT CREATES MORE PROBLEMS THAN IT RESOLVES: BETTER LABELS SHOULD BE CONSIDERED

Priya Davidar

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

Sigur Nature Trust, Chadapatti, Mavinahalla P.O., Nilgiris, Tamil Nadu 643223, India
pdavidar@gmail.com

OPEN ACCESS



Abstract: A critique of the extensive use of the term human-wildlife conflict to describe a variety of situations involving wildlife.

Keywords: Anthropocene, forest fringes, human-wildlife conflict, species extinction, terminology.

DOI: <http://doi.org/10.11609/jott.4319.10.8.12082-12085>

Editor: Mewa Singh, University of Mysore, Mysuru, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 4319 | Received 07 June 2018 | Finally accepted 22 June 2018

Citation: Davidar, P. (2018). The term human-wildlife conflict creates more problems than it resolves: better labels should be considered. *Journal of Threatened Taxa* 10(8): 12082–12085; <http://doi.org/10.11609/jott.4319.10.8.12082-12085>

Copyright: © Davidar 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: None.

Competing interests: The author declares no competing interests.

Author Details: PRIYA DAVIDAR is a conservation biologist working on forest ecology, pollination biology and endangered species conservation. She retired as a Professor at the Department of Ecology and Environmental Sciences, Pondicherry University. Her current project is analysing tree distributions at the biogeographical scale, and the conservation genetics of endangered species such as the Asian Elephant and Nilgiri Tahr

Acknowledgements: I thank Dr. Jean-Philippe Puyravaud for insights into this debate.

Humans have had an uneasy relationship with wild animals since the dawn of human evolution as they preyed upon, were prey, and competed with wild animals (Knight 2013). As human populations dispersed across the globe during the Late Quaternary they were the main driver of the extinction of large mammalian fauna (Bartlett et al. 2016). For example, human dispersal into North America during the Pleistocene probably caused the extinction of 35 genera of mammals (Faith & Surovell 2009). Sites with mass killing of megafauna by Palaeolithic hunters have been documented across continents (Barnosky et al. 2004).

The remnants of this rivalry can be perceived in cultural practices of traditional societies, and cultural beliefs involving dangerous animals such as werewolves, vampires and others which are a metaphor of the pervasive human belief of the 'beast within', 'bestial', etc. Violent killing by humans is denounced in the idiom of natural predation where criminals and enemies are termed 'jackals', 'wolves', etc. (Knight 2013).

This rivalry is closely inter-twined with human expansion into wilderness habitats (Knight 2013). Even today, this continues, and tends to be the most intense in settlements at the forest edge, in many cases due to colonization of forests by frontier populations (Rudel & Roper 1997).

The modern depiction of this rivalry is termed human-wildlife conflict (HWC), defined by the IUCN World Parks Congress (Madden 2004) as "...when the needs and behavior of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact the needs of wildlife. These conflicts may result when wildlife damage crops, injure or kill domestic animals, threaten or kill people".

In terms of usage, a conflict is typically defined as 'an active disagreement between people with opposing opinions or principles; or fighting between two or more groups of people or countries' (<https://dictionary.cambridge.org/dictionary/english/conflict>, viewed 08–04–2018).

Therefore, HWC suggests 'conscious antagonism between wildlife and humans' and implies that wildlife act consciously and often places wildlife entities on an equal footing with people in the role of combatants, even though they cannot represent themselves in the political sphere against people (Raik et al. 2008; Peterson et al. 2010). The use of this term in which wildlife are blamed for every encounter or incident places culpability entirely on the wildlife side of the equation, suggesting that wildlife assert their interests to undermine human goals (Woodroffe et al. 2005). This promotes antagonism

towards wildlife that can exacerbate the problem, hinder resolution and can result in people directing their anger, frustration on wildlife with potentially adverse conservation outcomes for endangered species (Peterson et al. 2002; Brook et al. 2003; Redpath et al. 2015). Besides the HWC approach is often ineffective because it has led to purely technical solutions being proposed that may have worked in particular circumstances but have not addressed the underlying issues (Redpath et al. 2015). For example translocating wildlife to resolve 'conflicts' has often failed to achieve its objectives due to lack of understanding of the species' behaviour and/or the underlying issues (Athreya et al. 2011). Often the increasing human population densities and expansion into forest areas that result in such incidents (Newmark et al. 1994) are not addressed.

To the best of my knowledge, the earliest reference to 'conflict' between wild animals and humans was in the early 1990s (Sukumar 1991; Newmark et al. 1994). Before the term 'conflict' became popular, more precise terms such as crop raiding and livestock depredation were used to describe incidents involving wildlife (Jhala 1993; Oli et al. 1994). The use of this term has increased over time: Treves (2009) carried out a Google search based on the keywords "human AND wildlife AND conflict OR depredation OR damage", and Google Scholar returned 3140 hits between 1992–1999, and 8060 between 2000 and 2007.

Its popularity stems from its simplicity and ease of usage to describe a diversity of situations involving wildlife. Thereby it has become a buzz word used to amplify conservation initiatives, create funding opportunities, increase research productivity and create a sense of urgency that limits the array of potential solutions that may arise when the situation is more accurately described (Peterson et al. 2010). In many cases the damage or threat is exaggerated for gains, for example, in Japan the scale of concern over bears greatly exceeds the actual damage done by the animals (Knight 2013).

To understand in what context this term human-wildlife conflict is used in conservation literature, Peterson et al. (2010) carried out a meta-analysis of 422 case studies of HWC and found that over 95% of the 422 cases referred to animal damage in some form to (i) resources such as food, (ii) property, or (iii) attacks on people. Only one case represented a typical example of 'conflict' where there was human retaliation against Magpies (*Cracticus tibicen*) that repeatedly attacked specific humans that they considered threats (Warne & Jones 2003). Less than 4% related to human-

Human-wildlife conflict is described as “when the needs and behavior of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact the needs of wildlife. These conflicts may result when wildlife damage crops, injure or kill domestic animals, threaten or kill people” (Madden 2004). However, presenting wildlife in an antagonistic, anthropocentric and indiscriminate manner harms conservation of these species (Redpath et al. 2013). The usage of the term ‘conflict’ should be minimized and replaced with accurate terms instead. We propose an example of non-exhaustive list of terms, listed alphabetically that can be expanded and refined.

Adequate terms	Indicating
Conservation welfare	Emphasis on ethics and moral responsibility towards species and populations
Animal welfare	Emphasis on ethics and moral responsibility towards individuals
Forestry damage	Damages to tree plantations
Crop damage	Damages to agriculture or horticulture crops by invertebrates
Crop raiding	Damages to agriculture or horticulture crop by wild vertebrates
Property damage	Damages to houses, fences, walls, pipes and electrical lines
Livestock predation	Predation of livestock by carnivores
Snake bite	Bites by venomous snakes
Animal attack	Accidental or deliberate attack on people, excluding man-eating incidents
Human predation	Documented man-eating by carnivores
Human-wildlife coexistence	Promotion of wildlife conservation and human needs by terminology that is less antagonistic
Human-wildlife commensalism	Wildlife such as snakes that are of indirect benefit to humans by controlling pests
Human-wildlife competition	How humans and wildlife compete for resources
Human-wildlife tolerance	How humans and wildlife avoid competition
Human attack	Deliberate attack on animals by humans
Dispute over protection	Conflict over protected area management and people – instead of human-state conflict
Stakeholders dispute	Disputes between stakeholders on how to manage wildlife, social issues – instead of human-human conflict

human conflict such as those between conservationists and other parties on how wildlife should be managed (Peterson et al. 2010).

Thus human conflicts are often projected onto wildlife (Knight 2013), and may in fact be a symbolic vehicle for expression of social conflict between people at the local, national and international levels, such as between conservation movements and developers or between people and protected area management termed ‘human-state conflict’ (Knight 2013). In Japan, widespread concern about the bear is balanced by local support for the bear, based on the premise that given the extent of human colonisation into bear territory, it is humans that are problematic with regard to the bear and not vice versa (Knight 2013). These human-human conflicts need to be distinguished from human-wildlife impacts.

Therefore, more precise description of the issue at hand may lead to better solutions. For instance crop raiding is a widespread problem in forest fringe areas where the cultivation of edible crops attracts wild herbivores. When crop raiding is described as crop raiding instead of as ‘conflict’ then better solutions may emerge depending on the location, the crops cultivated and the herbivores in question. Whereas the conflict

terminology is provocative and emotional which could create more problem than it solves, particularly if sensationalised by the media (Bhatia et al. 2013; Redpath et al. 2013). In many cases rodents and monkeys cause more economic loss to people than large mammals such as bears, elephants and the great apes which take a disproportionate amount of the blame (Knight 2013).

Therefore in the Anthropocene, where the rate of species extinction is accelerating (Sanderson et al. 2002; Barnosky et al. 2011) there is a growing realization that humans need to move beyond their past history which has framed the narrative regarding wildlife. Finding ways to increase tolerance and coexistence with wildlife (Madden 2004) is needed to slow down the population declines of iconic megafauna. If not, future generations will no longer have the privilege of sharing their world with large charismatic animals. There are many examples of human tolerance to wildlife and acceptance of certain levels of loss of crops and livestock (Knight 2013). To protect human interests, however, innovative solutions need to be explored in forest fringe areas to ameliorate the situation.

This term which is problematic, semantically incorrect and which masks the underlying complexities of particular situations, needs to be avoided. It is well

known that language is a powerful tool that can intensify biases towards ethnic groups, genders or minorities (Keeley 2011). Therefore the terminology that we apply will make a difference to whether a species survives or disappears forever.

REFERENCES

- Athreya, V., M. Odden, J.D. Linnell & K.U. Karanth (2011). Translocation as a tool for mitigating conflict with leopards in human-dominated landscapes of India. *Conservation Biology* 25: 133–141.
- Barnosky, A.D., P.L. Koch, R.S. Feranec, S.L. Wing & A.B. Shabel (2004). Assessing the causes of Late Pleistocene extinctions on the continents. *Science* 306: 70–75; <http://doi.org/10.1126/science.1101476>
- Barnosky, A.D., N. Matzke, S. Tomiya, G.O. Wogan, B. Swartz, T.B. Quental, C. Marshall, J.L. McGuire, E.L. Lindsey, K.C. Maguire & B. Mersey (2011). Has the Earth's sixth mass extinction already arrived? *Nature* 47: 51; <http://doi.org/10.1038/nature09678>
- Bhatia, S., V. Athreya, R. Grenyer & D.W. Macdonald (2013). Understanding the role of representations of human-leopard conflict in Mumbai through media-content analysis. *Conservation Biology* 27: 588–594; <http://doi.org/10.1111/cobi.12037>
- Bartlett, L.J., D.R. Williams, G.W. Prescott, A. Balmford, R.E. Green, A. Eriksson, P.J. Valdes, J.S. Singarayer & A. Manica (2016). Robustness despite uncertainty: regional climate data reveal the dominant role of humans in explaining global extinctions of Late Quaternary megafauna. *Ecography* 39: 152–161; <http://doi.org/10.1111/ecog.01566>
- Brook, A., M. Zint & R. De Young (2003). Landowners' responses to an endangered species act listing and implications for encouraging conservation. *Conservation Biology* 17: 1638–1649; <http://doi.org/10.1111/j.1523-1739.2003.00258.x>
- Faith, J.T. & T.A. Surovell (2009). Synchronous extinction of North America's Pleistocene mammals. *Proceedings of the National Academy of Sciences* 106: 20641–20645; <http://doi.org/10.1073/pnas.0908153106>
- Jhala, Y.V. (1993). Damage to sorghum crop by blackbuck. *International Journal of Pest Management* 39: 23–27; <http://doi.org/10.1080/09670879309371754>
- Keely, K. (2011). Dangerous words: recognizing the power of language by researching derogatory terms. *The English Journal* 100: 55–60.
- Knight, J. (2013). *Natural Enemies: People-Wildlife Conflicts in Anthropological Perspective*. Routledge.
- Madden, F. (2004). Creating coexistence between humans and wildlife: global perspectives on local efforts to address human-wildlife conflict. *Human Dimensions of Wildlife* 9: 247–257; <http://doi.org/10.1080/10871200490505675>
- Newmark, W.D., D.N. Manyanza, D.M. Gamassa & H.I. Sariko (1994). The conflict between wildlife and local people living adjacent to protected areas in Tanzania: human density as predictor. *Conservation Biology* 8: 249–255.
- Oli, M., I.R. Taylor & M.E. Rogers (1994). Snow Leopard *Panthera uncia* predation of livestock: an assessment of local perceptions in the Annapurna Conservation Area, Nepal. *Biological Conservation* 68: 63–68.
- Peterson, M.N., J.L. Birkhead, K. Leong, M.J. Peterson & T.R. Peterson (2010). Rearticulating the myth of human-wildlife conflict. *Conservation Letters* 3: 74–82; <http://doi.org/10.1111/j.1755-263X.2010.00099.x>
- Peterson, M.N., T.R. Peterson, M.J. Peterson, R.R. Lopez & N.J. Silvy (2002). Cultural conflict and the endangered Florida Key Deer. *The Journal of Wildlife Management* 66: 947–968; <http://doi.org/10.2307/3802928>
- Raik, D.B., A.L. Wilson & D.J. Decker (2008). Power in natural resources management: an application of theory. *Society and Natural Resources* 21: 729–739.
- Redpath, S.M., J. Young, A. Evely, W.M. Adams, W.J. Sutherland, A. Whitehouse, A. Amar, R.A. Lambert, J.D. Linnell, A. Watt & R.J. Gutierrez (2013). Understanding and managing conservation conflicts. *Trends in Ecology & Evolution* 28: 100–109; <http://doi.org/10.1016/j.tree.2012.08.021>
- Redpath, S.M., S. Bhatia, & J. Young (2015). Tilting at wildlife: reconsidering human-wildlife conflict. *Oryx* 49: 222–225; <http://doi.org/10.1017/S0030605314000799>
- Rudel, T. & J. Roper (1997). The paths to rainforest destruction: cross-national patterns of tropical deforestation, 1975–90. *World Development* 25: 53–65; [http://doi.org/10.1016/S0305-750X\(96\)00086-1](http://doi.org/10.1016/S0305-750X(96)00086-1)
- Sanderson, E.W., M. Jaiteh, M.A. Levy, K.H. Redford, A.V. Wannebo & G. Woolmer (2002). The human footprint and the last of the wild: the human footprint is a global map of human influence on the land surface, which suggests that human beings are stewards of nature, whether we like it or not. *BioScience* 52: 891–904; [http://doi.org/10.1641/0006-3568\(2002\)052\[0891:THFATL\]2.0.CO;2](http://doi.org/10.1641/0006-3568(2002)052[0891:THFATL]2.0.CO;2)
- Sukumar, R. (1991). The management of large mammals in relation to male strategies and conflict with people. *Biological Conservation* 55: 93–102; [http://doi.org/10.1016/0006-3207\(91\)90007-V](http://doi.org/10.1016/0006-3207(91)90007-V)
- Treves, A. (2009). The human dimensions of conflicts with wildlife around protected areas, pp. 214–228. In: Manfredo, M. J. (ed.). *Wildlife and Society: The Science of Human Dimensions*. Island Press.
- Warne, R.M. & D.N. Jones (2003). Evidence of target specificity in attacks by Australian magpies on humans. *Wildlife Research* 30: 265–267; <http://doi.org/10.1071/WR01108>
- Woodroffe, R., S. Thirgood & A. Rabinowitz (2005). The impact of human-wildlife conflict on natural systems, pp. 1–12. In: Woodroffe, R., S. Thirgood & A. Rabinowitz (eds.). *People and Wildlife, Conflict or Co-existence?* Conservation Biology Series - Cambridge 9.





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

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2018 | 10(8): 12086–12090

FIRST PHOTOGRAPHIC EVIDENCE OF SNOW LEOPARD *PANTHERA UNCIA* (MAMMALIA: CARNIVORA: FELIDAE) OUTSIDE CURRENT PROTECTED AREAS NETWORK IN NEPAL HIMALAYA

Rinzin Phunjok Lama¹, Tashi R. Ghale², Madan K. Suwal³, Rishi Ranabhat⁴ & Ganga Ram Regmi⁵

OPEN ACCESS



^{1,2,3,5} Global Primate Network-Nepal, GPO Box 26288, Kathmandu, Nepal

³ Department of Geography, University of Bergen, Fosswinkelsgt 6, PB 7802, N - 5020 Bergen, Norway

⁴ Department of National Parks and Wildlife Conservation, Babarmahal, Kathmandu, Nepal

¹ Workgroup on Endangered Species, J.F. Blumenbach Institute of Zoology and Anthropology, Georg-August-Universität Göttingen, Göttingen, Germany

¹rinzinplama@gmail.com, ²tashirghale@gmail.com, ³madanksuwal@gmail.com, ⁴ranabhatrishi@gmail.com,

⁵regmigr1978@gmail.com (corresponding author)

Abstract: The Snow Leopard *Panthera uncia* is a rare top predator of high-altitude ecosystems and insufficiently surveyed outside of protected areas in Nepal. We conducted a rapid camera-trapping survey to assess the presence of Snow Leopard in the Limi valley of Humla District. Three individuals were recorded in two camera locations offering the first photographic evidence of this elusive cat outside the protected area network of Nepal. In addition to Snow Leopard, the Blue Sheep *Pseudois nayaur*, Beech Marten *Martes foina*, Pika *Ochotona* spp. and different species of birds were also detected by camera-traps. More extensive surveys and monitoring are needed for reliably estimating the population size of Snow Leopard in the area. The most urgent needs are community-based conservation activities aimed at mitigating immediate threats of poaching, retaliatory killing, and rapid prey depletion to ensure the survival of this top predator in the Himalaya.

Keywords: Camera-trapping, conservation, Humla, livestock depredation, monasteries, non-timber forest products, retaliatory killing, Tibetan Buddhism.

The Snow Leopard *Panthera uncia* is distributed throughout northern Nepal along the boundary with China over an area of 22,625.34 km² (Aryal et al. 2016). Snow Leopards research and conservation activities have been focused mostly on protected areas (PA) of Nepal (Jackson & Alhborn 1989; Oli 1991; Kyes & Chalise 2005; Khatiwada et al. 2007; Ale 2007; Ale et al. 2007; Devkota 2010; Karmacharya et al. 2011; Wegge et al. 2012; Aryal et al. 2014, 2016). To date, research institutions, conservationists and students have given very low priority to surveys and monitoring of Snow Leopard outside Nepal's PAs, in spite of the existence of suitable habitat. A few Snow Leopard studies based on sign surveys were conducted outside PAs in Humla District (R. Jackson

DOI: <http://doi.org/10.11609/jott.3031.10.8.12086-12090> | **ZooBank:** urn:lsid:zoobank.org:pub:BA0E0E04-6D20-4525-BB7F-83C6B946EFCF

Editor: Jim Sanderson, Small Wild Cat Conservation Foundation, Hartford, USA.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3031 | Received 28 May 2017 | Final received 07 June 2018 | Finally accepted 27 June 2018

Citation: Lama, R.P., T.R. Ghale, M.K. Suwal, R. Ranabhat & G.R. Regmi (2018). First photographic evidence of Snow Leopard *Panthera uncia* (Mammalia: Carnivora: Felidae) outside current protected areas network in Nepal Himalaya. *Journal of Threatened Taxa* 10(8): 12086–12090; <http://doi.org/10.11609/jott.3031.10.8.12086-12090>

Copyright: © Lama et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: Funding was obtained from Snow Leopard Conservation Grant (Snow Leopard Network, USA) and Nagao Natural Environmental Foundation, Japan. Field equipment were obtained from Snow Leopard Conservancy, USA and Global Primate Network-Nepal.

Competing interests: The authors declare no competing interests.

Acknowledgements: This work was financially supported by Snow Leopard Network, Seattle, USA and Nagao Natural Environment Foundation, Tokyo, Japan. Snow Leopard Conservancy and Global Primate Network Nepal provided camera traps and other field equipment. Department of Forest/Government of Nepal provided the research permission to carry out this work. We are thankful of K. Kandel, F. Huettmann, T. R. Ghimire and R. Jackson for their support and encouragement throughout the project. A. Ghoddousi provided initial comments and I. Khorozyan provided a detailed review which helped improve this manuscript. This work would not have been possible without the tireless support of local field assistants Chhapral Lama and Chhayang Lama. We also thank all local people of the Limi Valley who supported us with vital information during the study.



in litt. 2003; Khatiwada & Ghimirey 2009; FoN 2014) and Bhajang District (FoN 2014). Of the total potential habitats preferred by Snow Leopards in Nepal, 65% were located outside PAs (Jackson & Ahlborn 1990). More recent species distribution modeling, however, shows that only 34% of the total Snow Leopard habitat in Nepal lies outside the PA network, comprising a significant portion of potential unprotected habitats located in western Nepal, including Humla, Bajhang, and Bajura (Aryal et al. 2016).

The paucity of surveys and the resulting lack of reliable data for unprotected lands presumably increases leopard vulnerability to local extinction from poaching and retaliatory killing (R. Jackson pers. comm. 2017), and lack of effective government actions against poaching and wildlife trade aggravates the situation. Therefore, urgent collection of baseline data on Snow Leopard presence, distribution and status outside of PAs is warranted. To date, information on distribution and status of Snow Leopard is mostly based on anecdotal evidence and few sign surveys (Jackson & Hunter 1995). Due to challenging habitat structure, site accessibility and the cryptic nature of this felid species, direct sighting such as detection is virtually impossible (Jackson et al. 2006; Ale & Brown 2009). Camera trapping is a preferred method

for detecting such rare and elusive species. In addition, sign surveys and local residents' interviews generally lack scientific rigor for reliable status assessment (Jackson et al. 2006). Considering these facts, we conducted the first ever camera-trapping survey of Snow Leopards in the Limi valley of Humla District of Nepal. The findings of this study will make an important baseline for future monitoring and help government and conservation partners in conservation planning.

MATERIALS AND METHODS

Study Area

Limi Valley is located in the trans-Himalayan steppe environment in Humla District of Nepal (Fig. 1), covering an area of ca. 1200km² and including three villages (Halji, Jang, and Til) with 181 households and a total population of 904 humans. Historically, Limi residents depended on traditional barter economies and semi-nomadic animal husbandry. Now, trans-boundary grazing restrictions imposed by China compel community members to reduce livestock holdings and search for new economic options. Carving of Phuru, a wooden bowl made from maple knots, is an old and highly demanded economic activity for the people living in the upper part of Humla including the Limi Valley (R.P. Lama pers. obs. 2007–2015). Trade and

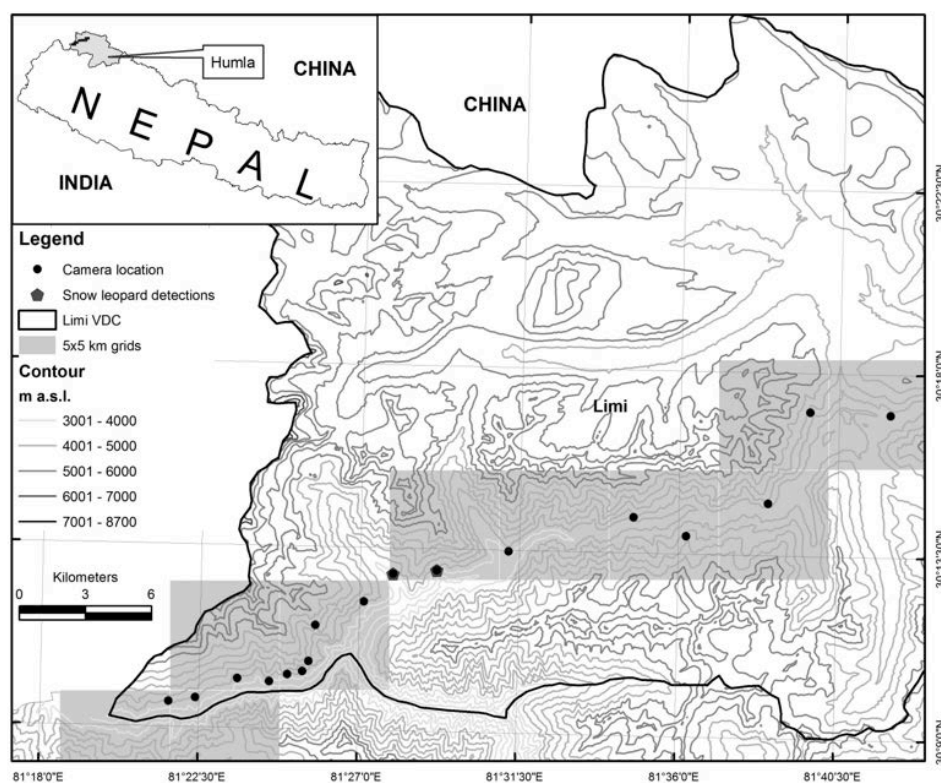


Figure 1. The study area showing the grid cells and camera-trap locations. Village Development Committee (VDC) is the smallest administrative unit of Nepal.

seasonal migrant labor work in the neighboring Chinese town also significantly contribute to the local economy.

The Mt. Gurla Mandata range divides Limi Valley into the southern and northern parts. The southern part has river valleys, settlements, agricultural lands, patches of open forest, rocky outcrops and broken terrain making favorable habitats for species like Blue Sheep *Pseudois nayaur*, Snow Leopard, Beech Marten *Martes foina*, and Tallus-dwelling Pikas *Ochotona roylei*, while the northern side of the range consists of plain steppe grasslands supporting the plateau species such as Tibetan Wild Ass *Equus kiang*, Plateau Pika *Ochotona curzoniae*, Tibetan Gazelle *Procapra picticaudata*, Tibetan Argali Sheep *Ovis ammon hodgsoni*, Wild Yak *Bos grunniens* and Himalayan Wolf *Canis Lupus himalayensis* (Werhahn et al. 2017).

Site selection and camera trapping

We conducted a camera-trapping survey in the Limi Valley during July and August, 2015 to conduct a rapid assessment of Snow Leopard status. We divided the total study area into 5x5 km² grid cells considering 24km² (11–37 km²) as the minimum home range of the Snow Leopard in western Nepal (Jackson 1996) and placed one or two cameras in each grid. Due to time limitations we could not cover an entire study area and placed camera-traps only in the least disturbed locations where we frequently observed Snow Leopard signs. We set up 17 Bushnell Trophy HD cameras in 17 locations (Fig. 1) within 10 grids following preferred habitat features like ridgelines, travel corridors and marking sites (Jackson et al. 2006). A minimum distance between camera-traps was kept at 2.5km, and they were placed at elevations from 3,092–4,608 m. Since the purpose of this preliminary survey was to assess the presence of Snow Leopard, we did not account for spatial autocorrelation of camera-trap sites. One camera-trap was lost thus only data from the remaining 16 camera-traps were used in the analysis.

Data management and analysis

We managed camera-trap images using the program described by Sanderson & Harris (2013). We defined capture events as independent images of a species at a location captured at least 60 minutes apart. We computed the relative abundance index (RAI) for all the mammals, birds and human recorded during the surveys. RAI was expressed as the number of independent images per 100 trap-nights (Sanderson & Harris 2013; Jenks et al. 2011).

RESULTS

Relative Abundance Index (RAI)

A total survey effort of 195 trap-nights recorded 39,839 images from 16 camera traps. We sorted out

and analyzed images of mammals, birds and human (n = 1,110) and discarded the ghosts, i.e., false images and also the unknown images (n = 38,729). The survey recorded 95 independent images of four species of mammals: Snow Leopard (n = 6 images), Blue Sheep (n = 6 images), Beech Marten (n = 14 images), and Pikas (n = 69 images). In addition to mammals, images of different species birds (n = 711 images) and human (n = 99 images) were also recorded. The birds had the highest RAI of 45.00 captures/100 trap-nights followed by Pika (30.45), human (13.64), Beech Marten (5.45), Snow Leopard (2.73), and Blue Sheep (2.73) (Table 1).

Photographic evidence of Snow Leopard

Snow Leopard was captured in two different locations (Til Gomba and Chhongerche) and the time to first detection was 16 days. We used pelage patterns (Jackson et al. 2006; Ale et al. 2014) to identify different individuals from camera-trap pictures. The dorsal side of the tail, forelegs, right hind legs and right flanks were particularly informative. We recorded total of three individuals, including two adults and one sub-adult (Image 1). In Til Gomba, individual 1 was recorded on 28 July 2015 from 00:06:05 h to 00:36:04 h (1a in Image 1) and individual 2 was captured on 30 July 2015 from 23:16:40–23:22:42 hr (2a in Image 1). The adjoining location Chhongerche also produced two events. Individual 3 was captured on 28 July 2015 from 17:14:36–17:14:37 hr (3b in Image 1) and individual 2 was captured on 31 July 2015 from 03:37:45–03:38:45 hr (2b in Image 1). In Til Gomba, individuals 1 and 2 were captured while scraping on the surface. In Chhongerche, individual 3 was captured while scent-marking a rock (3b in Image 1). Both these locations are dominated by broken terrain and cliffs providing good habitats for Snow Leopard and the middle elevations contain open areas with good grazing grounds for Blue Sheep.

DISCUSSION

This is the first camera-trapping survey in the Limi Valley that successfully recorded Snow Leopards during a short survey period in two locations. An opportunistic survey carried out in early 2000 suggested the presence of Snow Leopards in the Limi Valley (R. Jackson pers. comm. 2017). A study conducted in 2007 in the adjoining area which included some parts of the Limi Valley also showed a good abundance of Snow Leopard signs (Khatriwada & Ghimirey 2009). In May 2007, the first author observed two adult Snow Leopards in Til Gomba where we obtained camera-trap pictures during this study. Additionally, four independent sightings of Snow Leopards were reported

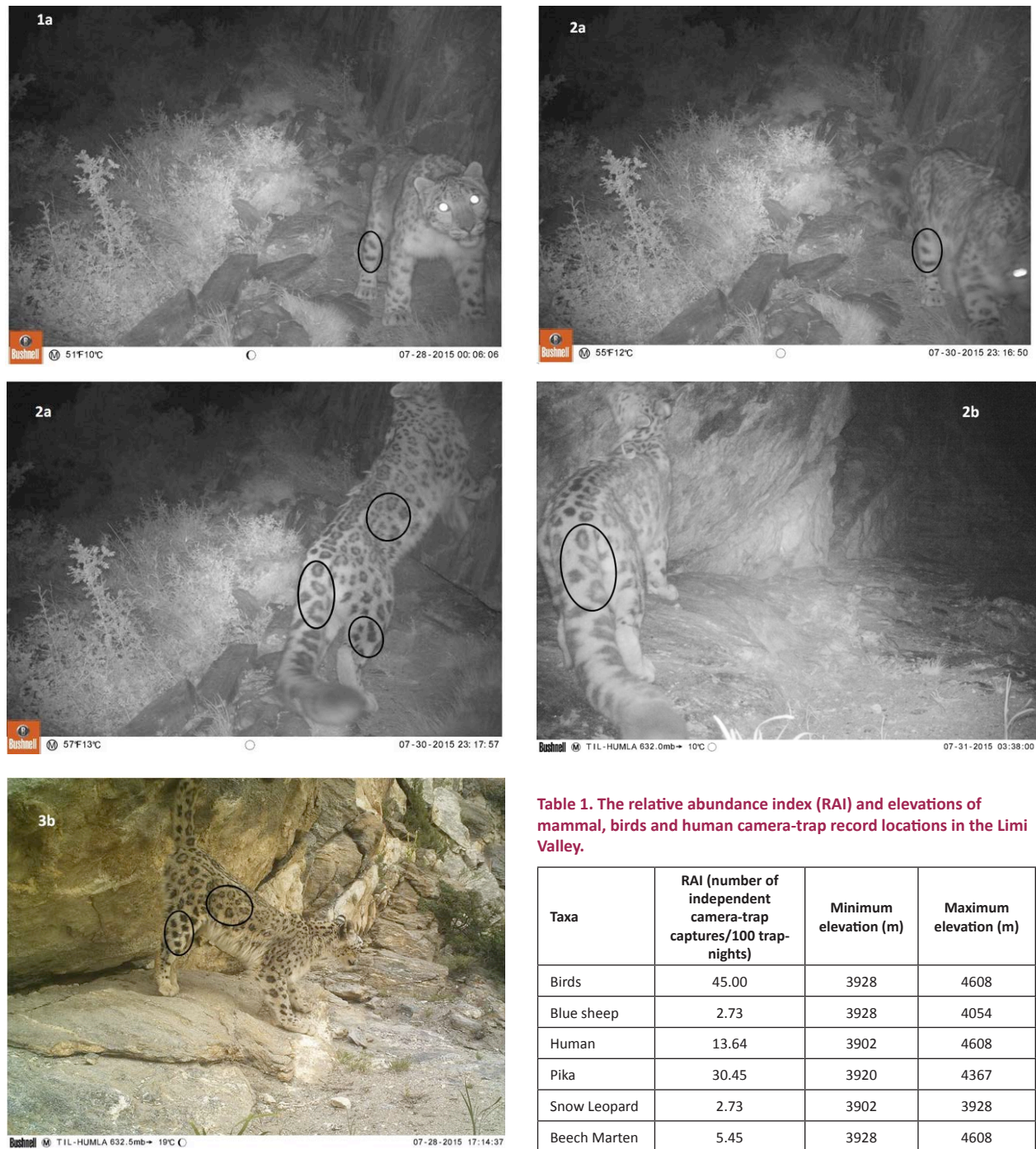


Table 1. The relative abundance index (RAI) and elevations of mammal, birds and human camera-trap record locations in the Limi Valley.

Taxa	RAI (number of independent camera-trap captures/100 trap-nights)	Minimum elevation (m)	Maximum elevation (m)
Birds	45.00	3928	4608
Blue sheep	2.73	3928	4054
Human	13.64	3902	4608
Pika	30.45	3920	4367
Snow Leopard	2.73	3902	3928
Beech Marten	5.45	3928	4608

Image 1. Photos 1a and 2a depict the individuals 1 and 2, respectively, in Til Gomba. Similarly, the photos 2b and 3b show the individuals 2 and 3 photographed in Chhongerche. Thus, the photos 2a and 2b belong to the same individual photographed in two different locations.

around Halij Village in the winter of 2011 (A. Hovden pers. comm. 2012). High encounter rates of Snow Leopards are reported in the inner part of Limi Valley, including Ningkhola, Rakaru and Hel, mostly during winter and spring (P. Tamang pers. comm. 2015). A female with three cubs was sighted in Rakaru in the winter of 2014 (P. Tamang pers. comm. 2015) and another female with two

cubs was sighted at a goat kill site in Takchi in July 2015 (N. Tamang pers. comm. 2015). Apart from photographic evidence of Snow Leopard presence, this study also provides the relative abundance of four mammal species, including the Snow Leopard and its main prey Blue Sheep.

Limi Valley is inhabited by people of Tibetan origin and the local culture is strongly influenced by Buddhist beliefs.

Tibetan Buddhist monasteries serve as cultural centers for non-violence and conservation actions (T. Lama pers. comm. 2017); for example in the Sanjiangyuan region of Tibet, monasteries have played an important role in conserving Snow Leopards and their habitats (Li et al. 2013). The Limi Valley is locally protected by the 1000-year-old Buddhist Monastery Rinchhen Ling, and no hunting and harvesting of medicinal herbs is allowed here. People violating these rules are strictly fined; however, at present this area is vulnerable to encroachment by poachers and harvesters from outside, as the valley is rich in wildlife and medicinal and aromatic plants (R.P. Lama pers. obs. 2015). Depredation of livestock by Snow Leopards and Wolves *Canis lupus* is frequent in the valley (R.P. Lama pers. obs. 2015), and leopards can also enter houses. Fear of attack and economic losses have negative impacts on local livelihoods, and motivate retaliatory killings. A female Snow Leopard was killed after a mass killing of goats (25 in a single night) in Halji Village in 2007 (FoN 2014). Similarly, a female Snow Leopard with two cubs was trapped in Til Village in 2011 (FoN 2014) after being perceived as a threat to livestock. A male Snow Leopard that entered Jang Village was killed in the winter of 2012 after attacking several goats inside a house (Local people pers. comm. 2015).

This survey confirms the presence of Snow Leopard in Limi Valley in Humla by successfully bringing the first photographic evidence to supplement previous local sightings and indirect signs. Implementation of predator-friendly human-leopard interaction measures such as predator-proofed corrals, improved husbandry practices, conservation education and livelihood improvement programs are recommended to ensure the survival of Snow Leopards in the Limi Valley.

REFERENCES

- Ale, S.B. (2007). Ecology of the Snow Leopard and the Himalayan Tahr in Sagarmatha (Mt. Everest) National Park, Nepal. PhD Thesis. University of Illinois, Chicago, 179pp.
- Ale, S.B. & J.S. Brown (2009). Prey behavior leads to predator: a case study of the Himalayan Tahr and the Snow Leopard in Sagarmatha (Mt. Everest) National Park, Nepal. *Israel Journal of Ecology and Evolution* 55: 315–327.
- Ale, S.B., B. Shrestha & R. Jackson (2014). On the status of Snow Leopard *Panthera uncia* (Schreber, 1775) in Annapurna, Nepal. *Journal of Threatened Taxa* 6(3): 5534–5543; <http://doi.org/10.11609/JoTT.03635.5534-43>
- Ale, S.B., P. Yonzon & K. Thapa (2007). Recovery of Snow Leopard *Uncia uncia* in Sagarmatha (Mt. Everest) National Park, Nepal. *Oryx* 41(1): 89–92; <http://doi.org/10.1017/S0030605307001585>
- Aryal, A., D. Brunton, W. Ji, D. Karmacharya, T. McCarthy, R. Bencini & D. Raubenheimer (2014). Multipronged strategy including genetic analysis for assessing conservation options for the Snow Leopard in the central Himalaya. *Journal of Mammalogy* 95(4): 871–881; <http://doi.org/10.1644/13-MAMM-A-243>
- Aryal, A., U.B. Shrestha, W. Ji, S.B. Ale, S. Shrestha, T. Ingty & D. Raubenheimer (2016). Predicting the distributions of predator (Snow Leopard) and prey (Blue Sheep) under climate change in the Himalaya. *Ecology and Evolution* 6(12): 1–11; <http://doi.org/10.1002/ece3.2196>
- Devkota, B.P. (2010). Prey Density and Diet relationship of Snow Leopard (*Uncia uncia*). Msc Thesis. Institute of Forestry, Tribhuvan University, Pokhara, 50pp.
- FoN (2014). Assessment of Snow Leopard Status and Distribution in Humla and Bajhang districts in Western Complex of Nepal. Report submitted to WWF Nepal Program, Baluwatar, Kathmandu, 60pp.
- Jackson, R.M. (1996). Home range, movements and habitat use of Snow Leopard (*Uncia uncia*) in Nepal. PhD Thesis, University of London, London, United Kingdom, 233pp.
- Jackson, R. & G. Ahlborn (1989). Snow Leopards (*Panthera uncia*) in Nepal - home range and movements. *National Geographic Research and Exploration* 5: 161–75.
- Jackson, R. & G. Ahlborn (1990). The role of protected areas in Nepal in maintaining viable population of Snow Leopards. *International Pedigree Book of Snow Leopard* 6: 51–69.
- Jackson, R. & D.O. Hunter (1995). Snow Leopard Survey and conservation handbook (First edition). Report, International Snow Leopard Trust, 120pp.
- Jackson, R., J.D. Roe, R. Wangchuk & D.O. Hunter (2006). Estimating Snow Leopard population abundance using photography and capture-recapture techniques. *Wildlife Society Bulletin* 34(3): 772–781; [http://doi.org/10.2193/0091-7648\(2006\)34\[772:ESLPAU\]2.0.CO;2](http://doi.org/10.2193/0091-7648(2006)34[772:ESLPAU]2.0.CO;2)
- Jenks, K.E., P. Chanteap, D. Kanda, C. Peter, P. Cutter, T. Redford, L. Antony & P. Leimgruber (2011). Using relative abundance indices from camera-trapping to test wildlife conservation hypotheses—an example from Khao Yai National Park, Thailand. *Tropical Conservation Science* 4(2): 113–131.
- Karmacharya, D.B., K. Thapa, R. Shrestha, M. Dhakal & J.E. Janecka (2011). Non-invasive genetic population survey of Snow Leopards (*Panthera uncia*) in Kangchenjunga conservation area. *BMC Research Notes* 4: 1–8; <http://doi.org/10.1186/1756-0500-4-516>
- Khatiwada J.R., M.K. Chalise & R.C. Kyes (2007). Survey of Snow Leopard (*Uncia uncia*) and Blue Sheep (*Pseudois nayaur*) populations in the Kanchenjunga Conservation Area (KCA), Nepal. Final Project Report Submitted to International Snow Leopard Trust, Seattle, USA, 13pp.
- Khatiwada, J.R. & Y.P. Ghimirey (2009). Status of Snow Leopard (*Uncia uncia*) in Humla District, Western Nepal. *Scientific World* 7: 49–52.
- Kyes, R.C. & M.K. Chalise (2005). Assessing the Status of the Snow Leopard Population in Langtang National Park, Nepal. Final Project Report submitted to International Snow Leopard Trust, Seattle, USA, 11pp.
- Li, J., D. Wang, H. Yin, D. Zhaxi, Z. Jiagone, G.B. Schaller, C. Mishra, T.M. McCarthy, H. Wang, L. Wu, L. Xiao, L. Basange, Y. Zhang, Y. Zhou & Z. Lu (2014). Role of Tibetan Buddhist Monasteries in Snow Leopard Conservation. *Conservation Biology* 28(1): 87–94; <http://doi.org/10.1111/cobi.12135>
- Oli, M.K. (1991). Ecology and conservation of the Snow Leopard (*Panthera uncia*) in the Annapurna Conservation Area, Nepal. MPhil Thesis. University of Edinburgh, Edinburgh, 197pp
- Sanderson, J. & G. Harris (2013). Automatic data organization, storage, and analysis of camera trap pictures. *Journal of Indonesian Natural History* 1: 6–14.
- Wegge, P., R. Shrestha & Ø. Flagstad (2012). Snow Leopard *Panthera uncia* predation on livestock and wild prey in a mountain valley in northern Nepal: implications for conservation management. *Wildlife Biology* 18(2): 131–141; <http://doi.org/10.2981/11-049>
- Werhahn, G., N. Kusi, C. Sillero-Zubiri & D. Macdonald (2017). Conservation implications for the Himalayan Wolf *Canis (lupus) himalayensis* based on observations of packs and home sites in Nepal. *Oryx* 1–7; <http://doi.org/10.1017/S0030605317001077>



SMALL CARNIVORES OF SILENT VALLEY NATIONAL PARK, KERALA, INDIA

Devika Sanghamithra¹ & P.O. Nameer²

^{1,2} Centre for Wildlife Studies, College of Forestry, Kerala Agricultural University, Thrissur, Kerala 680656, India

¹ devikasanghamithra@gmail.com, ² nameer.po@kau.in (corresponding author)



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

OPEN ACCESS



Abstract: A study on the small carnivores in Silent Valley National Park (SVNP), southern Western Ghats, Kerala, India was conducted from September 2015 to April 2016, using the camera trap technique. Seven species of small carnivores were recorded during the study. The most common species of small carnivore of SVNP was *Viverricula indica* (44%) followed by *Paradoxurus jerdoni* (20%) and *Herpestes vitticollis* (17%). The other small carnivores found at SVNP were *Herpestes fuscus* (7%), *Prionailurus bengalensis* (6%), *Aonyx cinereus* (5%) and *Martes gwatkinsii* (1%). *P. jerdoni* and *M. gwatkinsii* are endemic to the Western Ghats. We discuss the niche partitioning among small carnivores in SVNP.

Keywords: Camera traps, civets, martens, mongoose, otters, small cats, Western Ghats.

The need to undertake biodiversity studies is accelerated by the rapid destruction of forests, particularly in the tropics including the Western Ghats. The number of small carnivore species reported from different protected areas of Kerala vary, e.g., 11 species from Parambikulam Tiger Reserve (Sreehari & Nameer 2016), nine species from Eravikulam National Park (Nikhil & Nameer 2017), and Wayanad Wildlife

Sanctuary (Sreekumar & Nameer 2018). The first record of *Martes gwatkinsii* from Parambikulam Tiger Reserve was reported by Sreehari & Nameer (2013), and the social behavior, feeding habits and activity pattern of *Martes gwatkinsii* were reported from Pampadum Shola National Park (PSNP) (Anil et al. 2018). Sreehari et al. (2013) reported the presence of *Herpestes smithii* in Parambikulam Tiger Reserve and Chinnar Wildlife Sanctuary, and *Herpestes fuscus* in Parambikulam Tiger Reserve and Eravikulam National Park. The lack of details on small carnivores from the Silent Valley National Park (SVNP), except on the sighting records of *M. gwatkinsii* (Christopher & Jayson 1996) and habitat characterization of *M. gwatkinsii* (Balakrishnan 2005), prompted the present study. We report the status and distribution of small carnivores in SVNP.

MATERIALS AND METHODS

Study Area

Silent Valley National Park is part of the Nilgiri Biosphere Reserve and has an extent of 237.52km². The

DOI: <http://doi.org/10.11609/jott.2992.10.8.12091-12097> | **ZooBank:** urn:lsid:zoobank.org:pub:A49C8986-C249-47B5-9C2C-C4A23B414032

Editor: H.N. Kumara, SACON, Coimbatore, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 2992 | Received 16 March 2018 | Final received 16 May 2018 | Finally accepted 25 June 2018

Citation: Sanghamithra, D. & P.O. Nameer (2018). Small carnivores of Silent Valley National Park, Kerala, India. *Journal of Threatened Taxa* 10(8): 12091–12097; <http://doi.org/10.11609/jott.2992.10.8.12091-12097>

Copyright: © Sanghamithra & Nameer 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: Kerala Agricultural University.

Competing interests: The authors declare no competing interests.

Acknowledgements: We thank Principal Chief Conservator of Forests (WL) & Chief Wildlife Warden, Kerala Forest Department for granting the permission to study the small carnivores of Silent Valley National Park (WL10-49846/2014 dated 15-05-2015). We thank Wildlife Warden of Silent Valley National Park, the Asst. Wildlife Wardens and other staff of the Silent Valley Division for helping with the logistics and other support in the field. Dr. Neelesh Dahanukar helped us with the analysis of the data. Devipriya, K. S., Aswathy Chandran, U. B., Aby Crusha, Vishnu, M., Niyas, P., Akhil Das, Jobin Joseph, and Sachin K Aravind accompanied us in the field on various occasions. Our thanks are due to the Dean, College of Forestry, Kerala Agricultural University for encouragement. The Kerala Agricultural University provided the financial assistance for the study. We are grateful to the anonymous reviewers and the Subject Editor for their critical comments.



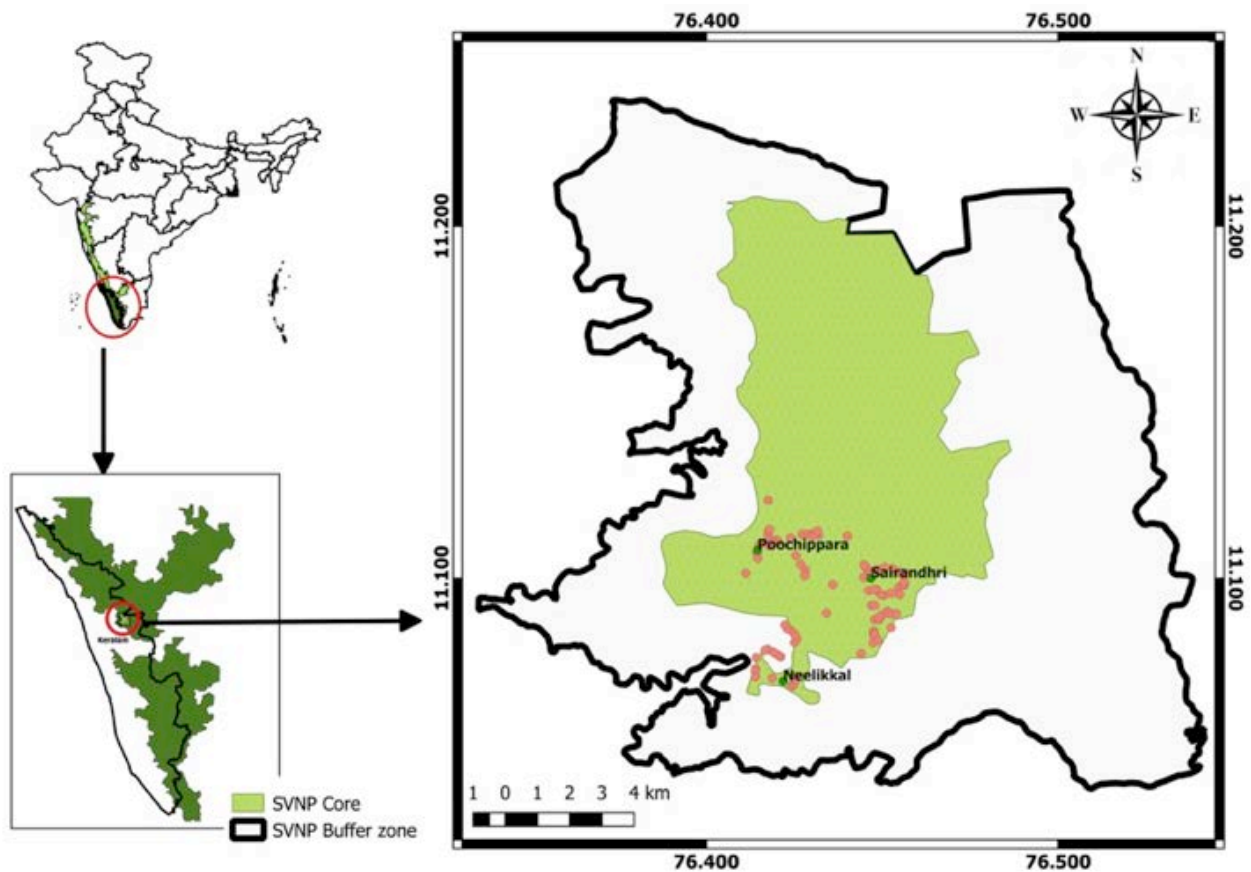


Figure 1. Camera trap locations at Silent Valley National Park

original extent of the Silent Valley National Park was 89.52sq.km. Subsequently in 2007 an area of 148sq.km. was added to the National Park as buffer zone. The SVNP is located within $76.25\text{--}76.58^\circ\text{E}$ & $11\text{--}11.25^\circ\text{N}$. The elevation ranges from 900–2,300 m with Anginda being the highest peak (2,383m) (Fig. 1) (Anonymous 2012). The study was conducted in the core area of SVNP from September 2015 to April 2016.

Camera Trap Survey

Digital scout cameras having passive infra red sensors for heat and motion detection (Cuddeback Attack model C1) were used for the current study. Camera trap stations were placed in the west coast tropical evergreen forest (1A/C4) and southern montane wet grasslands (11A/C1/DS2). Overall a 100 trapping stations (Fig. 1) were identified based on the presence of the indirect evidence of the small carnivores (Mudappa 1998). The camera traps were set at a height of 30cm above the ground and at least 250m apart from each other (Sreehari & Nameer 2016; Nikhil & Nameer 2017; Sreekumar & Nameer 2018). The cameras were set up

in default mode with the time-delay between pictures as fast as possible in daytime and the time-delay of five seconds between pictures during night time. The camera trap locations were marked using Garmin GPS eTrex 30. The cameras were kept open for 24 hours a day. The date and time of exposure were automatically recorded by the camera on the images, as and when the images were taken. At each trapping stations, each camera was opened for 15 days. Thus, a total of 1,500 camera-trap days, monitoring 36,000 hours were carried out in the Silent Valley National Park. The data analysis was done using the statistical packages such as the XL STAT (Version 2016.03.30846), and PAST (Hammer et al. 2001).

Microhabitat parameters were documented at each of the camera trapping sites. Microhabitat parameters that are crucial for the survival of the small carnivores, such as, canopy height (clinometer), canopy cover (visual estimation), height of shrubs (stems <10cm girth at breast height) and ground vegetation (herbaceous plants <50cm in height, measured with tape), litter depth (average of four measurements taken around the

trap using a calibrated probe), and basal area of trees >30cm girth, densities of shrubs (within 2m radius), trees, climbers, buttresses and canes, and distance to the nearest large tree (measured with a tape to a tree >60cm girth), frequency of natural hollow in the trees etc., were taken in the camera trapping sites. At each camera trap site, a circular plot having a dimension of 5m radius was taken and 100 such plots were enumerated for the microhabitat parameters listed above. Thus, a total of 7,850m² area was sampled. The relationship between these microhabitat variables on the distribution of small carnivores in the study area was analysed using discriminant analysis.

RESULTS AND DISCUSSION

We recorded seven species of small carnivores in SVNP representing four families such as Viverridae, Herpestidae, Mustelidae and Felidae. This comprises two herpestid, mustelid, and viverrid species each, and one felid species (Fig. 2; Table 1).

Of the total 607 photographs of all the mammals (20 species) obtained, 165 images (seven species) were of small carnivores. The most common species recorded was *Viverricula indica* (72, 44%) followed by *Paradoxurus jerdoni* (33, 20%) (Table 1). The camera trap success rate of small carnivore was 10.90%.

Family Viverridae

Out of the three species of viverrids (Nameer 2015) of Kerala, *V. indica* (Image 1) and *P. jerdoni* (Image 2) are found in SVNP. *V. indica* was the most common species of small carnivores, photo-captured 72 times (Fig. 3), between an altitudinal range of 900–1,200 m, and from the rainforests as well as from the grasslands. In the previous studies done in the Kerala part of the Western Ghats in Parambikulam Tiger Reserve (Sreehari & Nameer 2016) and in Wayanad WS (Sreekumar & Nameer 2018), *V. indica* was the most abundant species

Table 1. Small carnivores recorded from Silent Valley National Park

Family	Species	Number of captures	Relative abundance (%)
Viverridae	<i>Viverricula indica</i> Small Indian Civet	72	43.64
	<i>Paradoxurus jerdoni</i> Brown Palm Civet	33	20.00
Herpestidae	<i>Herpestes fuscus</i> Brown Mongoose	11	6.67
	<i>Herpestes vitticollis</i> Stripe-necked Mongoose	29	17.58
Mustelidae	<i>Aonyx cinereus</i> Asian Small-clawed Otter	8	4.88
	<i>Martes gwatkinsii</i> Nilgiri Marten	2	1.21
Felidae	<i>Prionailurus bengalensis</i> Leopard Cat	10	6.06

of small carnivore. Mudappa (2002), however, had reported that the *V. indica* is the most common small carnivore in the drier forests of the southern Western Ghats and rare in the tropical wet evergreen forests.

Paradoxurus jerdoni (Image 2) is an endemic small carnivore restricted to the rainforests of the Western Ghats (Rajamani et al. 2002). *P. jerdoni* was the most common small carnivore in Kalakkad-Mundanthurai Tiger reserve followed by *V. indica* (Kumar et al. 2002). A total of 33 captures of *P. jerdoni* were obtained during the study period from SVNP, and there was a single direct sighting in the night (06 October 2015) from Sairandri (Fig. 3). All the captures of the *P. jerdoni* were from the tropical evergreen forest and between the altitudes of 900–1,200 m.

Family Herpestidae

Four species of mongoose are known from the Western Ghats (Mudappa 2013) of which two species, *Herpestes vitticollis* and *H. fuscus* are seen at SVNP. The *H. vitticollis* (Image 3) is a wide-spread species of small carnivore that occurs in well-wooded habitats of

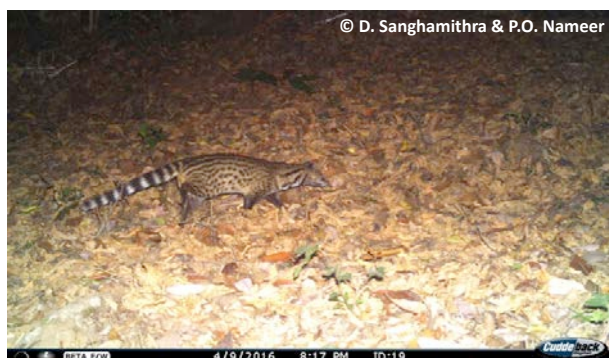


Image 1. Small Indian Civet *Viverricula indica*



Image 2. Brown Palm Civet *Paradoxurus jerdoni*

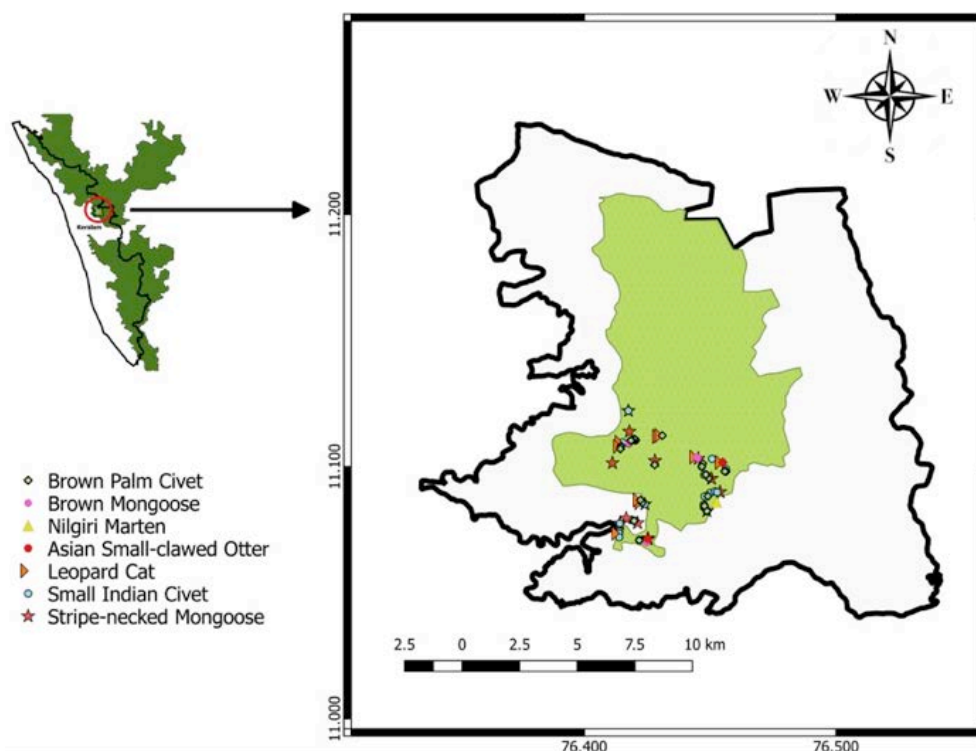


Figure 2. Camera trapped locations of the seven species of small carnivores in SVNP

the Western Ghats (Ramachandran 1985; Madhusudan 1995; Mudappa 2013; Rompaey & Jayakumar 2003; Pillay 2009; Kumara et al. 2014; Sreehari & Nameer 2016; Nikhil & Nameer 2017; Sreekumar & Nameer 2018), and the northernmost distribution range is Kolhapur and Sindhudurg districts of Maharashtra (Punjabi et al. 2014). During the present study, 27 captures were obtained, and there were also two independent sightings of the species from Sairandri (07 October 2015) and another from Panthanthode (24 February 2016) (Fig. 4).

H. fuscus (Image 4) is found in the forests of the southern Indian hill ranges at 900–1,850 m (Mudappa 1998) and is also seen in Sri Lanka (Phillips 1984). The previous records of this species from the Western Ghats are from Parambikulam Tiger Reserve (Sreehari et al. 2013; Sreehari & Nameer 2016), and Eravikulam National Park (Sreehari et al. 2013; Nikhil & Nameer 2017). During the present study, 10 captures were obtained between an altitude range of 900 and 1,200 m (Fig. 4). In southern India, *H. fuscus* is found from an altitude range of 492 and 2,032 m and is reported from different hill ranges of the Western Ghats such as Coorg, Nilgiri Hills, Palni Hills, Anamalai Hills, High Wavy Mountains and Agasthyamalai Hills (Sreehari et al. 2013; Mudappa & Jathanna 2015).

Family Mustelidae

Martes gwatkinsii (Image 5) is endemic to the Western Ghats and is currently listed in the IUCN Red List as *Vulnerable* (Choudhury et al. 2012). During the present study, two captures were obtained in the camera trap near a fig tree (*Ficus* sp.) in the evergreen forest (Fig. 5). *M. gwatkinsii* is also reported from various parts of the Western Ghats including Kalakkad-Mundanthurai Tiger reserve (Kumar et al. 2002), and Karnataka State (Kumara & Singh 2007; Krishna & Karnad 2010).

Of the two species of the otters seen in the Western Ghats, only the *Aonyx cinereus* could be found in SVNP that was captured five times during the current study (Fig. 5, Image 6), and all the captures were above 1,000m. The only previous records of the *Aonyx cinereus* from the Western Ghats were from Eravikulam National Park (Perinchery et al. 2011; Nikhil & Nameer 2017), Anamalai Tiger Reserve (Prakash et al. 2012) and Wayanad WS (Sreekumar & Nameer 2018). There is, however, a record of this species from the northern Western Ghats in Maharashtra (Punjabi et al. 2014).

Family Felidae

Prionailurus bengalensis (Image 7) is the only small cat recorded during the present study and 10 camera trap images were obtained from the SVNP between an altitude range of 900 and 1,200 m in evergreen forest

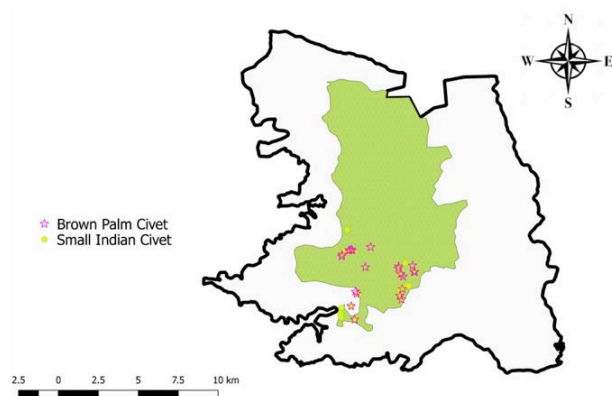


Figure 3. Camera trapped locations of Small Indian Civet and Brown Palm Civet in SVNP

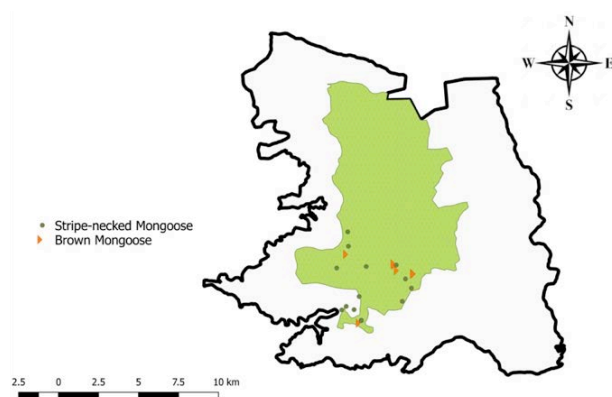


Figure 4. Camera trapped locations of Stripe-necked Mongoose and Brown Mongoose in SVNP

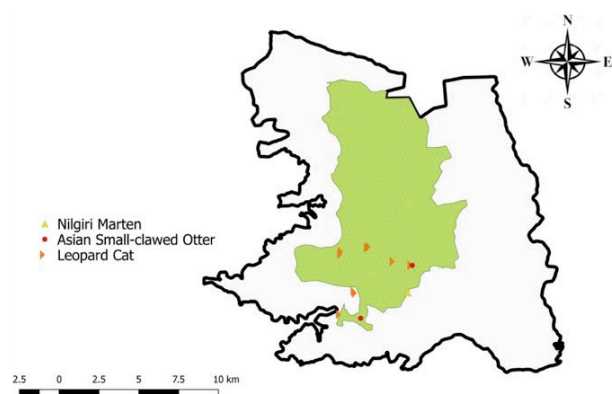


Figure 5. Camera trapped locations of Leopard Cat and Mustelids in SVNP

(Fig. 5). The other records of this species from the Western Ghats are from Peppara Wildlife Sanctuary (Jayson & Christopher 1996), Kalakkad-Mundanthurai Tiger Reserve (Mudappa 2002), Bilgiri Rangaswamy Tiger Reserve (Kumara et al. 2014), Parambikulam Tiger



Image 3. A pair of Stripe-necked Mongoose *Herpestes vitticollis*



Image 4. A pair of Brown Mongoose *Herpestes fuscus*



Image 5. Nilgiri Marten *Martes gwatkinsii*

Reserve (Sreehari & Nameer 2016), Eravikulam National Park (Nikhil & Nameer 2017), and Wayanad Wildlife Sanctuary (Sreekumar & Nameer 2018).

The microhabitat preference of the selected small carnivores in Silent Valley NP

The differential preferences for microhabitat variables in the study area by small carnivores were examined using discriminant analysis (Table 2). This helps to understand whether there is any niche partitioning between and among the species concerning the habitat

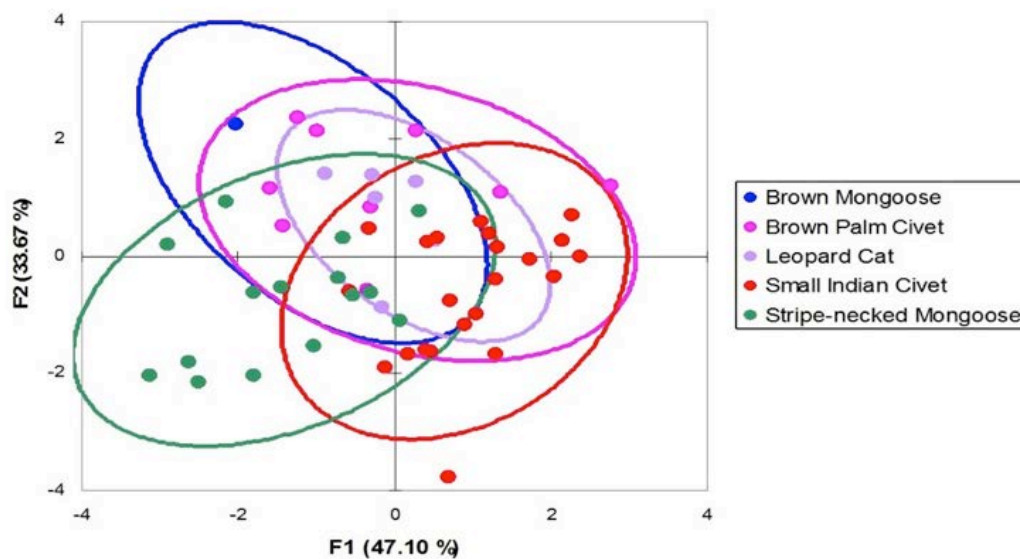
Image 6. Asian Small-clawed Otter *Anonyx cinereus*Image 7. Leopard Cat *Prionailurus bengalensis*

Figure 6. Niche partitioning of small carnivores in Silent Valley National Park

Table 2. Summary statistics on the microhabitat variables recorded at the camera trap stations at Silent Valley National Park

Parameters	Mean (n=100)	SD
Canopy Height (m)	21.2	8.50
Canopy cover (%)	61.52	27.45
Litter depth (cm)	1.75	1.26
Shrub density	35.28	35.88
Tree density	7.58	5.06
Climber density	2.46	3.31
Buttress density	0.63	0.98
Canes density	0.29	1.22
distance to largest tree (m)	5.26	6.37
Width of the waterbody	1.42	3.52
GBH (cm)	139.09	99.21
Slope (degrees)	21.4	15.02

variables studied. The pair-wise Fisher's distances (blue cells) and associated P values (red cells) clearly show that there is no significant difference in the clusters, thus indicating that the selected small carnivores show no significant niche partitioning (Table 3, Fig. 6).

CONCLUSION

The Silent Valley National Park which constitutes one of the few pristine rainforests of the Western Ghats is a home for many endemic and threatened species including small carnivore fauna. Even though some of the high-altitude areas of the SVNP could not be surveyed due to logistical reasons, it supports seven species of small carnivores. The disturbed habitats are vulnerable to incursions by more widespread species at the cost of restricted range species. The absence of widespread species of small carnivores in the national park indicates the intact habitats of SVNP.

Table 3. Fisher's distance matrix

	Brown Mongoose	Brown Palm Civet	Leopard Cat	Small Indian Civet	Stripe-necked Mongoose
Brown Mongoose		0.721	0.777	1.457	0.956
Brown Palm Civet	0.787		0.389	0.908	1.616
Leopard Cat	0.728	0.989		0.767	1.116
Small Indian Civet	0.136	0.579	0.739		1.757
Stripe-necked Mongoose	0.525	0.082	0.361	0.051	

REFERENCES

- Anil, G., N. Kishor, G. Naseef, N. Ommer & P.O. Nameer (2018). Observations on the Nilgiri Marten *Martes gwatkinsii* (Mammalia: Carnivora: Mustelidae) from Pampadum Shola National Park, southern Western Ghats, India. *Journal of Threatened Taxa* 10(1): 11226–11230; <http://doi.org/10.11609/jott.3446.10.1.11226-11230>
- Anonymous (2012). Silent Valley National Park Management Plan 2012–2022. Kerala Forest Department, Thiruvananthapuram, 244pp.
- Balakrishnan, P. (2005). Recent sightings and habitat characterization of the endemic Nilgiri Marten *Martes gwatkinsii* in Western Ghats, India. *Small Carnivore Conservation* 33: 14–16.
- Choudhury, A., W.C. Wozencraft, D. Muddapa & P. Yonzon (2012). *Martes gwatkinsii*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. www.iucnredlist.org
- Christopher, G. & E.A. Jayson (1996). Sightings of Nilgiri Marten (*Martes gwatkinsii* Horsfield) at Peppara Wildlife Sanctuary and Silent Valley National Park, Kerala, India. *Small Carnivore Conservation* 15: 3–4.
- Hammer, O., D.A.T. Harper & P.D. Ryan (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(1): 9.
- Jayson, E.A. & G. Christopher (1996). Sighting of two cat species (*Felis* sp.) from the Western Ghats, south India. *Journal of the Bombay Natural History Society* 93(3): 582.
- Krishna, Y.C. & D. Karnad (2010). New records of the Nilgiri Marten *Martes gwatkinsii* in Western Ghats, India. *Small Carnivore Conservation* 43: 23–27.
- Kumar, A., R. Chellam, B.C. Choudhury, D. Mudappa, K. Vasudevan, N.M. Ishwar & B. Noon (2002). Impact of rainforest fragmentation on small mammals and herpetofauna in the Western Ghats, south India: A summary of research findings. Final Report 2002. Wildlife Institute of India, Dehra Dun, India
- Kumara, H.N. & M. Singh (2007). Small carnivores of Karnataka: distribution and sight records. *Journal of the Bombay Natural History Society* 104(2): 155–162.
- Kumara, H.N., O. Thorat, K. Santhosh, R. Sasi & H.P. Ashwin (2014). Small carnivores of Biligiri Rangaswamy Temple Tiger Reserve, Karnataka, India. *Journal of Threatened Taxa* 6(12): 6534–6543; <http://doi.org/10.11609/JoTT.03766.6534-43>
- Madhusudan, M.D. (1995). Sighting of the Nilgiri Marten (*Martes gwatkinsii*) at Eravikulam National Park, Kerala, India. *Small Carnivore Conservation* 13: 6–7.
- Mudappa, D. (1998). Use of camera-traps to survey small carnivores in the tropical rainforest of Kalakad-Mundanthurai Tiger Reserve, India. *Small Carnivore Conservation* 18: 9–11.
- Mudappa, D. (2002). Observations of small carnivores in the Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India. *Small Carnivore Conservation* 27: 4–5.
- Mudappa, D. (2013). Herpestids, viverrids and mustelids, pp. 471–498. In: Johnsingh, A. & N. Manjrekar (eds.). *Mammals of South Asia*. University Press, Hyderabad.
- Mudappa, D. & D. Jathanna (2015). *Herpestes fuscus*. The IUCN Red List of Threatened Species 2015: e.T41612A45207051. Downloaded on 28 June 2016. <http://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T41612A45207051.en>
- Nameer, P.O. (2015). A checklist of mammals of Kerala, India. *Journal of Threatened Taxa* 7(13): 7971–7982; <http://doi.org/10.11609/JoTT.2000.7.13.7971-7982>
- Nikhil, S. & P.O. Nameer (2017). Small carnivores of the montane forests of Eravikulam National Park in the Western Ghats, India. *Journal of Threatened Taxa* 9(11): 10880–10885; <http://doi.org/10.11609/jott.2211.9.11.10880-10885>
- Perinchery, A., D. Jathanna & A. Kumar (2011). Factors determining occupancy and habitat use by Asian Small-clawed Otters in the Western Ghats, India. *Journal of Mammalogy* 92(4): 796–802.
- Phillips, W.W.A. (1984). *Manuals of the Mammals of Sri Lanka. Part III. Wildlife and Nature Protection Society of Sri Lanka. II Revised Edition*, 389pp.
- Pillay, R. (2009). Observations of small carnivores in the southern Western Ghats, India. *Small Carnivore Conservation* 40: 36–40.
- Prakash, N., D. Mudappa, R.T.R. Shankar & A. Kumar (2012). Conservation of the Asian Small-clawed Otter (*Aonyx cinereus*) in human-modified landscapes, Western Ghats, India. *Tropical Conservation Science* 5(1): 67–78.
- Punjabi, G.A., A.S. Borker, F. Mhetar, D. Joshi, R. Kulkarni, S.K. Alave & M.K. Rao (2014). Recent records of Stripe-necked Mongoose *Herpestes vitticollis* and Asian Small-clawed Otter *Aonyx cinereus* from the north Western Ghats, India. *Small Carnivore Conservation* 51: 51–55.
- Rajamani, N., D. Mudappa & H.V. Rompaey (2002). Distribution and status of the Brown Palm Civet in the Western Ghats, South India. *Small Carnivore Conservation* 27(2): 6–11.
- Ramachandran, K.K. (1985). A note on the scavenging behavior of Stripe-necked Mongoose on tiger's kill. *Journal of the Bombay Natural History and Society* 82(1): 182–183.
- Rompaey, V.H. & M.N. Jayakumar (2003). The Stripe-necked Mongoose *Herpestes vitticollis*. *Small Carnivore Conservation* 28: 14–17.
- Sreehari, R. & P.O. Nameer (2013). The first records of Nilgiri Marten *Martes gwatkinsii* from Parambikulam Tiger Reserve, Southern western Ghats, India. *Small Carnivore Conservation* 49: 40–42
- Sreehari, R. & P.O. Nameer (2016). Small carnivores of Parambikulam Tiger Reserve, southern Western Ghats, India. *Journal of Threatened Taxa* 8(11): 9306–9315; <http://doi.org/10.11609/jott.2311.8.11.9306-9315>
- Sreehari, R., C.T. Fredy, R. Anand, C.R. Aneesh & P.O. Nameer (2013). Recent Records of Ruddy Mongoose (*Herpestes smithii*) and Brown Mongoose (*Herpestes fuscus*) from Kerala, southern western Ghats, India. *Small Carnivore Conservation* 49: 34–36.
- Sreekumar, E.R. & P.O. Nameer (2018). Small carnivores of Wayanad Wildlife Sanctuary, the southern Western Ghats, India. *Journal of Threatened Taxa* 10(1): 11218–11225; <http://doi.org/10.11609/jott.3651.10.1.11218-11225>



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



Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2018 | 10(8): 12098–12102

STATUS SURVEY AND CONSERVATION OF THE HOUSE SPARROW *PASSER DOMESTICUS* (AVES: PASSERIFORMES: PASSERIDAE) THROUGH PUBLIC PARTICIPATION IN KANNUR, KERALA, INDIA

R. Roshnath¹, C.P. Arjun², J. Ashli³, D. Sethu⁴ & P. Gokul⁵

OPEN ACCESS



¹Department of Animal Science, Central University of Kerala, Tejaswini Hills, Periyar Post, Kasaragod, Kerala 671316, India

²National Institute of Advanced Studies, Indian Institute of Science Campus, Bengaluru, Karnataka 560012, India

³Indian Institute of Information Technology and Management-Kerala, P.O. Karyavattom, Kazhakoottam, Technopark Campus, Trivandrum, Kerala 695581, India

^{1,2,3,4,5}Malabar Awareness and Rescue Center for Wildlife, 3rd Floor, Lakshmi Complex, Opp. Koyili Hospital, Kannur, Kerala 670004, India

¹roshnath.r@gmail.com, ²arjuncp@gmail.com (corresponding author), ³ashli.jose@gmail.com,

⁴alwayshearty@gmail.com, ⁵7gpdas@gmail.com

Abstract: House Sparrows *Passer domesticus* are one of the most widespread passerines in the world. A survey was conducted to find out their status in Kannur District, Kerala. The survey recorded 553 sparrows in 35 sites in the district. The perspectives of the public were recorded through a questionnaire survey and conservational inputs from the public were noted. Most of the respondents (47%) suggested the provision of nest boxes for the enhanced breeding of sparrows. Thus, our NGO along with the support of students, the public and the Kerala Forest Department, placed 100 nest boxes in various identified sparrow dwelling places in the district and it was found effective in the conservation of sparrows.

Keywords: Conservation, environment, House Sparrow, nest box, threat.

House Sparrows *Passer domesticus* (here after sparrows) are one of the most widespread passerine species in the world facing a serious decline in their

population (Crick et al. 2002; Prowse 2002; Olsen et al. 2003; Robinson et al. 2005; Vincent 2005; Klok et al. 2006; Balmori & Hallberg 2007; Bohner & Witt 2007; De Laet & Summers-Smith 2007; Murgui & Macias 2010; Kekkonen et al. 2011). Similarly, there were reports of a population decline in India (Daniels 2008; Rajashekar & Venkatesha 2008; Bhattacharya et al. 2010; Dandapat et al. 2010; Ghosh et al. 2010; Khera et al. 2010; Dhanya 2011; Sethi & Vashisth 2013).

Urbanization and industrialization, leading to the loss of suitable foraging locations and nesting spaces in urban and rural areas has contributed much to the declining sparrow populations (Cramp et al. 1985; Rao 2000; Summer & Smith 2003; Robinson et al. 2005; Pineda et al. 2013). Besides, many reasons have been suggested for the decline of sparrow populations such

DOI: <http://doi.org/10.11609/jott.3528.10.8.12098-12102>

Editor: S. Subramanya, University of Agricultural Sciences, Bengaluru, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3528 | Received 29 May 2017 | Final received 04 July 2018 | Finally accepted 07 July 2018

Citation: Roshnath, R., C.P. Arjun, J. Ashli, D. Sethu & P. Gokul (2018). Status survey and conservation of the House Sparrow *Passer domesticus* (Aves: Passeriformes: Passeridae) through public participation in Kannur, Kerala, India. *Journal of Threatened Taxa* 10(8): 12098–12102; <http://doi.org/10.11609/jott.3528.10.8.12098-12102>

Copyright: © Roshnath et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: The project was funded under the CSR program of Krishna Mines, Tirunelveli, Tamil Nadu.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are grateful to Krishna Mines super white for providing financial support for the “Save Sparrow Project”. We extend our sincere gratitude to D. Jayaprasad IFS (CCF, Northern Circle), P. Biju (ACF, Social Forestry, Kannur Division), C.V. Rajan, (DFO, Kannur) and all other staff of Kerala Forest & Wildlife Department for their support. We are thankful to C. Sashikumar (Ornithologist), Dr. Jafer Palot (Zoological Survey of India), and Praveen J. for the advice given; and special acknowledgment to C. Sunil Kumar (Mathrubhumi) for the press releases. We also show our gratitude to Dr. Aravind (HOD, Zoology Department, S.N. College, Kannur), Satheesh C.P., Sooraj Kodieri, Ranjith Narayanan, Riyas Mangad and Sajith for helping out with the survey.



as lack of old fashioned buildings and weedy gardens (Monika 2005), changes in agricultural practices, predators (Summers & Smith 2003; Vincent 2005; Shaw et al. 2011), competitions (Vincent 2005; Khera et al. 2010, Mason 2006), disease (Vincent 2005), environmental pollution (Chamberlain et al. 2005; Vincent 2005; Balmori & Hallberg 2007; Dhanya 2011), electromagnetic radiation (Balmori & Hallberg 2007), lack of insect availability, nest sites, substratum, nesting materials, food items and roosting sites (Chamberlain et al. 2005; Vincent 2005; Mason 2006; Bohner & Witt 2007; Klok et al. 2008; Dhanya 2011). Use of unleaded fuel results in methyl nitrite during combustion, which is harmful for soft-bodied insects, as they form the major diet for sparrow chicks. This was also suggested to be a threat for sparrows (Summer-Smith 2007).

Hopping near grocery shops, picking up fallen grains and clearing out insect pests, they were once common sights in our markets and urban areas. The birdwatchers and nature enthusiasts in the district were concerned about the decline in one of the commonest urban birds. Also, no studies in the population of sparrows were conducted in Kannur District. Hence this study was taken up by an NGO, the Malabar Awareness and Rescue Centre for Wildlife-Kannur, aimed at documenting

sparrow populations in the district, the threats faced, the perception of the public towards sparrow conservation and possible conservation action.

MATERIALS AND METHODS

A press release was published in all leading newspapers in the district (with the details of the project and contact numbers of the volunteers) to identify the potential sparrow inhabiting areas in Kannur District (Fig. 1). The areas communicated by the respondents were visited during 08:00–11:00 hr and 15:00–18:00 hr and the numbers of sparrows sighted were recorded using point count method (Bibby et al. 1998) from March to July 2015.

An open-ended type questionnaire survey was done in markets, rural and urban towns in the district, targeting shop keepers, workers, and the local people. All the respondents were between 35–55 years old. The questionnaire survey was conducted in the local language (Malayalam).

RESULT AND DISCUSSION

Status of sparrows in Kannur District

A total of 35 sites were surveyed and 553 sparrows were recorded in Kannur District (Fig. 1). Compared to



Figure 1. Map showing the study area, Kannur, Kerala.

urban towns, more number of sparrows were found in smaller towns and in rural areas as reported earlier. Among the 140 individuals interviewed 89% stated to have seen the sparrows earlier (in the past), but only 56% of the people stated to have seen them in the present. This indicated that 33% of the respondents had seen the sparrows earlier but not at present. Hence, this data suggested that there has been a decline in the populations of sparrows in the district.

Perspective of public regarding sparrows

Sparrows are generally believed to be useful to the public (Fig. 2). As major pest control agents, they pick up insects and worms (39%) from food grains; they clean the surroundings by pecking on thrown out food materials (21%) and maintain an ecological balance (15%). Hence, they were believed to play a vital role in maintaining the health of the ecosystem. Twenty percent of the respondents felt that sparrows have an aesthetic value due to their cheerfulness and tweeting sounds to make the surroundings lively, and some respondents (5%) believed that sparrows were a good omen when they nest in their shops. Only faecal droppings and accidental hits on fans were noted as a menace caused by the sparrows. Thus, people had different perspectives on the sparrows, in terms of economic, aesthetic, ecological and belief values.

Different reasons were suggested by the public for the declining number of sparrows in the district (Fig. 3). Electromagnetic radiations from the mobile towers

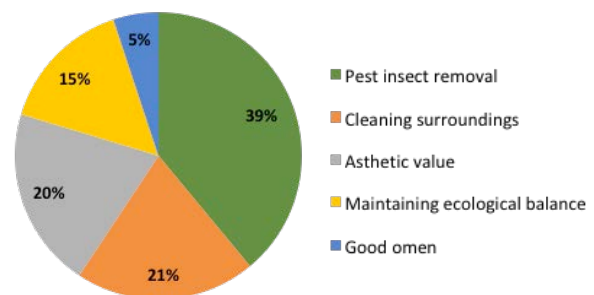


Figure 2. Percentage composition of suggested usefulness of sparrows

were the most suggested reason (35%), even though no proper scientific validation is available in this context (Balmori & Hallberg 2007). Other important reasons were climatic changes and its associated temperature rise (13%) (Global warming is known to affect physiology in House Sparrows (Yom-Tov, 2001)), modernization of buildings (9%) leading to a lack of nesting spaces. Cutting down of roosting trees and plants (6%) in towns had also caused decline in the population of sparrows, as they are known to roost in small and medium sized trees (Dhanya & Azeez 2010). Natural reasons like predation and reproductive problems might also have affected the population. Changes in grain storage practices like plastic bagging of grains to minimize spilling out and spoilage, use of pesticides and chemicals in grains, pollution, decreased ration/grocery shops (which might have reduced food availability causing a scarcity of food

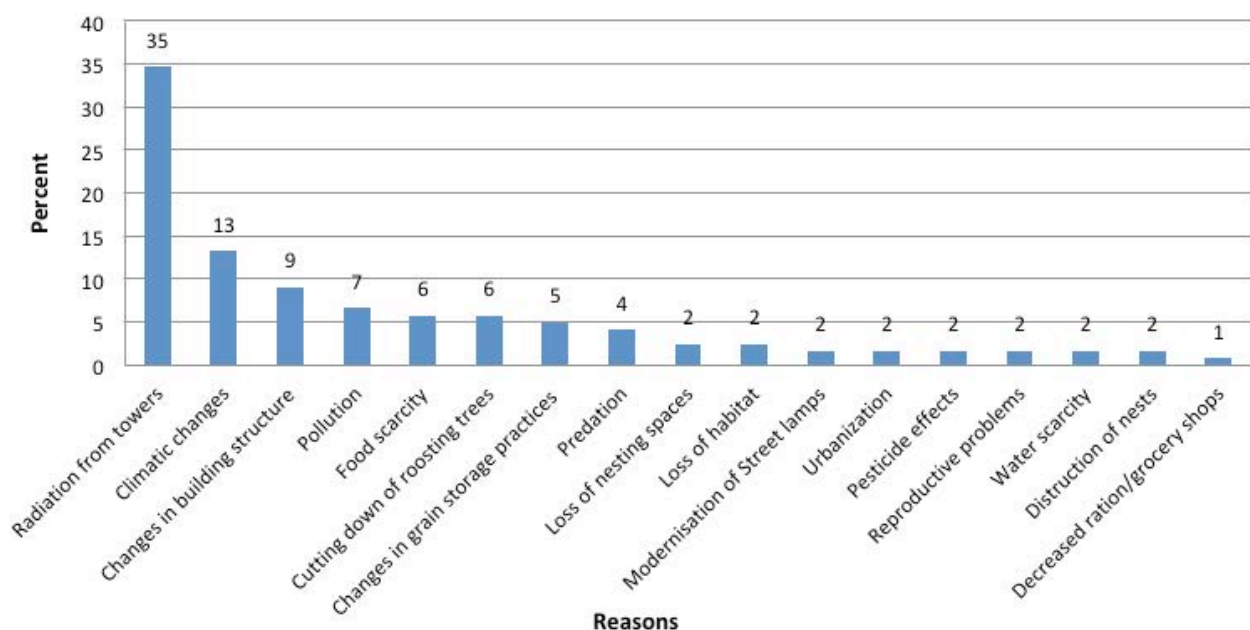


Figure 3. Reasons suggested by the public for the decline in sparrow numbers in Kannur

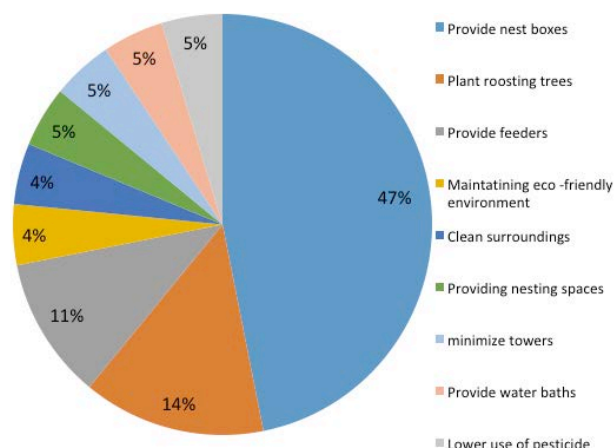


Figure 4. Percent composition of public suggestions for sparrow conservation in Kannur

for the birds), water scarcity, the destruction of nests and the loss of habitat and nesting spaces due to urbanization (Bokotey & Gorban 2005), had decreased the endurance of sparrows in towns. These were the other reasons suggested by the public in the questionnaire survey.

Various conservational plans were suggested by the respondents (Fig. 4) of which the provision of nest boxes (47%) were the most recommended suggestion to enhance sparrow population. Also, spaces for sparrow nesting have been thought of during modernisation of buildings; especially in towns (5%). Planting roosting trees (14%) of small heights of less than 5m are found to support and host good numbers of roosting sparrows (Dhanya & Azeez 2010). Provision for feeders with grains (11%) and water bath (5%) could also help to regain sparrow population. Other suggestions (13%) were to maintain eco-friendly and clean environments by minimizing pollution and by reduced use of pesticides. A section of respondents who believed mobile towers to be the major cause of the decline in the population, had suggested to minimize construction of mobile towers (5%) as well.

Efforts for conservation of sparrows

During the study, students and the public were involved in population assessment of sparrows in the district. Awareness programs were conducted in local colleges and schools to educate students about the importance of sparrows. Mass participation of public was assured by conducting sparrow photography competitions, during which the public had spent time to watch and observe sparrows in the city.

Sparrows are expected to build nests in any available places including nest-boxes (Shaw et al. 2008) and

studies showed that artificial nest boxes can enhance the population of sparrows in urban and sub-urban areas (Chethan 2012). Hence, with the preliminary knowledge of the status of sparrows in the district and with the suggestion from the public, we decided to create and fix nest boxes for sparrow conservation. A total of 100 wooden nest boxes were fixed in identified sparrow inhabiting sites in the district, which later was found to be effective. Hence with this preliminary study, we were able to map out some of the sparrow population in the district and understand its status and potential threats. Moreover, the project had created a network of students and members of the public who stood for conservation of sparrows in the district. Furthermore, with the continuous support from stake holders, we could create a bigger network of public, students, shopkeepers, vegetable sellers, etc. who can be utilized to monitor the sparrow population. Along with provision of more nest boxes and by planting short roosting trees and maintaining urban gardens, sparrow population in the district could be enhanced.

REFERENCES

- Balmori, A. & O. Hallberg (2007). The urban decline of the House Sparrow *Passer domesticus*; a possible link with electromagnetic radiations. *Electromagnetic Biology and Medicine* 26: 141–151; <http://doi.org/10.1080/15368370701410558>
- Bhattacharya, R., R. Roy, S. Ghosh & A. Dey (2010). "Observations on House Sparrow at Bandel, Hoogly", Proceedings of National Seminar on Biodiversity, Water resource and Climate change issues, 10 March 2010, Department of Environmental Science, Kalyani University, 147–152.
- Bibby, C., M. Jones & S. Marsden (1998). Expedition field techniques bird surveys. Publisher Expedition Advisory Centre, Royal Geographic Society.
- Bohner, J. & K. Witt. (2007). Distribution, abundance and dynamics of the House Sparrow *Passer domesticus* in Berlin. *International Studies on Sparrows* 32: 15–33.
- Bokotey, A.A & M.I. Gorban (2005). Numbers, distribution, and ecology of the House Sparrow in Lvov (Ukraine). *International Studies on Sparrow* 30: 7–22.
- Chamberlain, D.E., J.A. Vickery, D.E. Glue, R.A. Robinson, G.J. Conway, R.J.W. Woodburn & A.R. Cannon (2005). Annual and seasonal changes in the use of garden feeders by birds in winter. *Ibis* 147: 563–575; <http://doi.org/10.1111/j.1474-919x.2005.00430.x>
- Cramp, S., K.E.L. Simmons, D.C. Brooks, N.J. Collar, E. Dunn, R. Gillmor, P.A.D. Hollom, R. Hudson, E.M. Nicholson, M.A. Ogilvie, P.J.S. Olney, C.S. Roselaar, K.H. Voous, D.I.M. Wallace, J. Wattel & M.G. Wilson (1983). *Handbook of the Birds of Europe, the Middle East and North Africa. The Birds of the Western Palearctic*. Oxford University Press, Oxford, UK.
- Crick, H.Q.P., R.A. Robinson, G.F. Appleton, N.A. Clark & A.D. Rickard (2002). *Investigation into the Causes of the Decline of Starlings and House Sparrows in Great Britain*. British Trust for Ornithology, Thetford, vii+307pp.
- Dandapat, A., D. Banerjee & D. Chakraborty (2010). The case of the disappearing House Sparrow. *Veterinary World* 3(2): 97–100.
- Daniels, R.J.R. (2008). "Can we save the sparrow?" *Current Science* 95(11): 1527–1528.

- Dhanya, R. (2011). *Status and Ecology of House Sparrow Passer domesticus along an urban to rural gradient in Coimbatore, India*. PhD Dissertation. Bharathiar University 129pp.
- Dhanya, R. & P.A. Azeez (2010). The House Sparrow *Passer domesticus* population of Arakku township, Andhra Pradesh, India. *Indian Birds* 5(6): 180–181.
- De Laet, J., & J.D. Summers-Smith (2007). The status of the urban house sparrow *Passer domesticus* in north-western Europe: a review. *Journal of Ornithology* 148(2): 275–278; <http://doi.org/10.1007/s10336-007>
- Ghosh, S., K. Kim & R. Bhattacharya (2010). A survey on house sparrow population decline at Bandel, West Bengal, India. *Journal of Korean Earth Science Society* 31(5): 448–453.
- Kekkonen, J., P. Seppa, I. K., Hanski, H. Jensen, R.A. Väisänen & J.E. Brommer (2011). Low genetic differentiation in a sedentary bird: house sparrow population genetics in a contiguous landscape. *Heredity* 106: 183–190; <http://doi.org/10.1038/hdy.2010.32>
- Khera, N., A. Das, Srivastava & S. Jain (2010). Habitat-wise distribution of the House Sparrow *Passer domesticus* in Delhi, India. *Urban Ecosystem* 13(1): 147–154; <http://doi.org/10.1007/s11252-009-0109-8>
- Klok, C., R. Holtkamp, R.V. Apeldoorn, M.E. Visser & L. Hemerik (2006). Analysing population numbers of the House Sparrow in the Netherlands with a matrix model and suggestions for conservation measures. *Acta Biotheoretica* 54: 161–178; <http://doi.org/10.1007/s10441-006-7871-2>
- Mason, C.F. (2006). Avian species richness and numbers in the built environment: can new housing developments be good for birds? *Human Exploration and Biodiversity Conservation* 15:2365–2378; <http://doi.org/10.1007/978-1-4020-5283-5>
- Monika, G. (2005). Preliminary Survey of House Sparrow (*Passer domesticus*) in three Different Areas of Haridwar, Uttaranchal. MSc. Dissertation Gurukul Kangri University, Haridwar.
- Murgui, E. & A. Macias (2010). Changes in the house sparrow *Passer domesticus* population in Valencia (Spain) from 1998 to 2008. *Bird Study* 57: 281–288; <http://doi.org/full/10.1080/00063651003716762>
- Olsen, P., M. Weston, R. Cunningham & A. Silcocks (eds.) (2003). *The State of Australia's Birds 2003*. Supplement to Wingspan 13(4): 1–12.
- Pineda, J., A. Herrera, M.T. Antonio & J. Aguirre (2013). Urban models and their effects on immune system of house sparrow *Passer domesticus* populations in Central Spain. EOU2013UK - 9th Conference of the European Ornithologists' Union.
- Prowse, A. (2002). The urban decline of House Sparrow. *British Birds* 95: 143–146; <http://doi.org/10.1080/15368370701410558>
- Rajashekar, S. & M.G. Venkatesha (2008). "Occurrence of house sparrow, *Passer domesticus indicus* in and around Bangalore". *Current Science* 94(4): 446–449.
- Rao, R. (2000). A Field Study of The House Sparrow (*Passer domesticus*) <http://www.indianwildlifeclub.com/ResearchPapers/Field-Study-of-House-Sparrow.aspx>
- Robinson, R.A., G.M. Siriwardena & H.Q.P. Crick (2005). Size and trends of the House Sparrow *Passer domesticus* population in Great Britain. *Ibis* 147: 552–562; <http://doi.org/10.1111/j.1474-919x.2005.00427.x>
- Shaw, L.M., D. Chamberlain & M. Evans (2008). The House Sparrow *Passer domesticus* in urban areas: reviewing a possible link between post-decline distribution and human socioeconomic status. *Journal of Ornithology* 149: 293–299; <http://doi.org/10.1007/s10336-008-0285-y>
- Shaw, L.M., D. Chamberlain & M. Evans (2008). The House Sparrow *Passer domesticus* in urban areas: reviewing a possible link between post-decline distribution and human socioeconomic status. *Journal of Ornithology* 149(3): 293–299.
- Summers-Smith, J.D. (2007). Is unleaded petrol a factor in urban House Sparrow decline? *British Birds* 100(9): 558–559.
- Vincent, K. (2005). Investigating the causes of the decline of the urban House Sparrow *Passer domesticus* in Britain. PhD Thesis, De Montfort University, Leicester.
- Yom-Tov, Y. (2001). Global warming and body mass decline in Israeli passerine birds. *Proceedings of the Royal Society B: Biological Sciences* 268(1470): 947–952; <http://doi.org/10.1098/rspb.2001.1592>





THE ECOLOGY AND DISTRIBUTION OF PERCOID FISH *DARIO NEELA* FROM WAYANAD IN THE WESTERN GHATS OF KERALA, INDIA

Dencin Rons Thampy¹ & C.P. Shaji²

^{1,2} Centre For Wildlife Studies, Kerala Veterinary and Animal Sciences University, Pookode, Wayanad, Kerala 673576, India

¹ Permanent address: Kolanjiyil Tharavad, Seethamound Post, Pulpally, Wayanad, Kerala 673579, India

¹ densinrons@gmail.com, ² shajibarb@gmail.com (corresponding author)

OPEN ACCESS



Abstract: *Dario neela*, a newly described badid fish endemic to the Western Ghats is little known to science. Distribution and ecology of this species is not well documented. In this paper, we provide information on new records of this rare fish from Wayanad region of the Western Ghats and discuss its distribution, ecology and conservation.

Keywords: Badid fish, conservation, distribution, ecology, endemic, new records.

The genus *Dario* Kullander & Britz, 2002, of the family Badidae are known by three species from the Western Ghats, viz, *Dario urops* Britz, Ali & Philip, 2012, *D. huli* Britz & Ali, 2015, and *Dario neela* Britz, Anoop & Dahanukar, 2018. *Dario neela* is at present known only from the type locality, an unnamed stream joining Periya Stream a tributary of Kabini River in Wayanad, Kerala, 11.82416°N & 75.86250°E, 738m (Britz et. al 2018).

At present, the further distribution of *Dario neela* is not known, although the presence of *Dario* species in Wayanad is known from the collections by Francis Day about 140 years ago (Britz et al. 2012). The perusal of ichthyological literature until Britz et al. (2012) avows that none of them reported the presence of *Badis* or *Dario* from the Western

Ghats of Kerala and Wayanad in particular (Shaji & Easa 1995, 1997; Easa & Basha 1995). None of them could locate the specimens from Day's locality, which may either be due to the rarity of the species or unavailability of the exact location of Day's collection. *Dario neela* was described in 2018 based on the collections from Wayanad and the study also suggested that Day's collections were in fact *Dario neela* and not *Dario urops* (Britz et al. 2018).

A recent survey in the Kabini watershed of the Cauvery basin in Wayanad helped in documenting the further distribution of this species in the Kerala part of the Western Ghats (Fig. 1). We provide new information on the habitat and ecology of the species. Specimens were collected and a few were reared in captivity to study the social and reproductive behavior of the species.

MATERIALS AND METHODS

Fishes were collected mostly by sieving with clothes and mosquito nets. A few specimens were fixed in 10% formalin and transferred into 70% ethanol for permanent storage. Ten individuals with two males and eight females were selected, grouped and reared under captivity to study the

DOI: <http://doi.org/10.11609/jott.3393.10.8.12103-12107> | **ZooBank:** urn:lsid:zoobank.org:pub:AD8921DE-BB6B-4B26-872B-DB3071AA6FE1

Editor: Neelesh Dahanukar, IISER, Pune, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3393 | Received 03 March 2017 | Final received 01 July 2018 | Finally accepted 11 July 2018

Citation: Thampy, D.R. & C.P. Shaji (2018). The ecology and distribution of percoid fish *Dario neela* from Wayanad in the Western Ghats of Kerala, India. *Journal of Threatened Taxa* 10(8): 12103–12107; <http://doi.org/10.11609/jott.3393.10.8.12103-12107>

Copyright: © Thampy & Shaji 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The study was a part of the dissertation work, done for the fulfillment of M.S Wildlife Studies program at KVASU- CWS. The authors are grateful to the course director, Centre for Wildlife Studies, KVASU and all the teaching faculties of CWS for all the moral support. The authors sincerely thank the Department of Forest and Wildlife, Government of Kerala for providing the permissions and for their kind support throughout the study. Authors are extremely thankful towards Dr. M. Ashokkumar, Dr. Rajeev Raghavan and Mr. M. Bipin Paul for their cooperation and support during the study period.

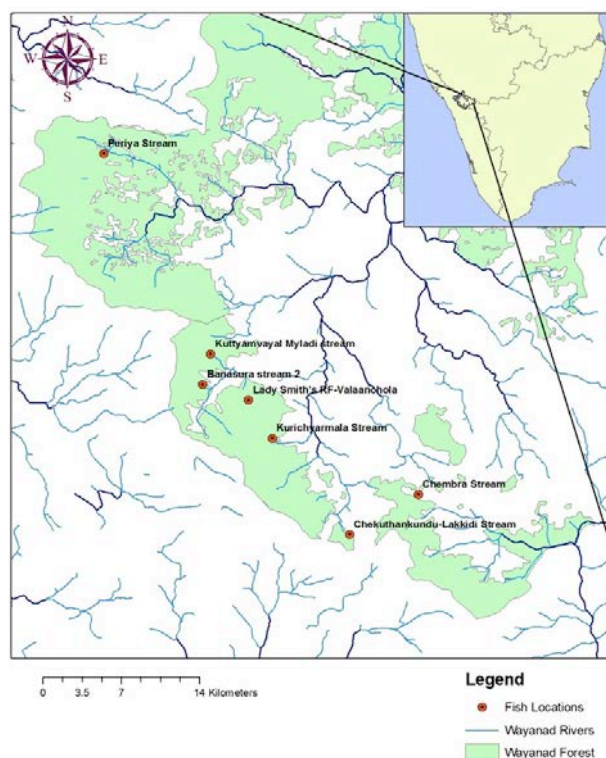


Figure 1. Distribution of *Dario neela* in Kabini watershed of Wayanad, Kerala

social and breeding behavior of the species.

Physical parameters of the stream habitat, viz, substrate, canopy cover, stream temperature, stream type, and stream width were recorded at each collection site. Substrate was classified as bedrock, boulder, cobble, pebble, gravel, sand, and mud. Canopy cover was measured using a spherical densiometer. Temperature was measured using a submersible digital thermometer (Mextex- Multi Thermometer). Elevation, altitude and latitude of sampling locations were recorded using global positioning system meter (Garmin- GPS 72H) ($\pm 10\text{m}$). Morphometric measurements were taken point-to-point to the nearest 0.1mm using digital calipers.

RESULTS

The morphological data of the species is given in Table 1.

There is an appreciable difference in the morphological attributes of male and female (Images 1 & 2). Males were larger than females with well-developed fin rays. The pectoral fin length and caudal fin length were found to be higher in males when compared with females. Caudal peduncle length and pre-anal length were higher in females.

Distribution in Wayanad

The specimens were collected from seven different

localities of South Wayanad Forest Division, viz., Kuttyamvayal-Myladi Stream and an unnamed stream of Banasura forests, Valaanchola Stream of Lady Smith's RF, Chekuthankundu Stream of Lakkidi RF (Image 4), two unnamed streams of Kurichyarmala and Chembra and from two locations in North Wayanad Forest Division, from the Periya Stream (Image 5) and the type locality, a small unnamed stream joining Periya Stream (Table 2). All these are lower order streams draining into Kabini, an east flowing river (Fig. 1). All these collection localities were sections of the streams flowing through evergreen forest patches and the species could be recorded from an elevation range between 700–1,050 m.

Habitat and Ecology

The flow rate was minimal and the collection localities were characterized mostly by pools and runs. The substrates were constituted by sand, mud, gravel, pebbles, boulders and bed rocks. Boulders and sand dominated in the study sites altogether (80%) and the average constitution of the pebbles and gravels were of 10% in the sites of collection. All the collection sites were characterized by heavy litter fall over various substrates. The water temperature varied from 17.9–22.6 °C. The canopy cover varied from 70.38–97.43 %. The physical parameters of various sites at the time of collection are given in Table 3. Shallow regions of the streams were heavily occupied by vegetation like *Lagenandra* sp., *Colocasia* sp. etc. which acted as fish cover. *D. neela* specimens were mostly collected from submerged leaf litter, tree roots, submerged vegetation and *Ochlandra* clumps. The co-occurring species recorded from various collection localities were *Devario* cf. *malabaricus*, *Barilius gatensis*, *Haludaria fasciata*, *Schistura* cf. *nilgiriensis*, *Schistura semiarmata* and *Neolissochilus wynaadensis*.

Although not a shoaling species, *D. neela* tend to live in small groups of 5–10 individuals in the wild, with a well-defined territory for each individual. The groups are typically formed by two males and several females defending territories near each other. In such groups, one male always dominated the other invariably. Larger dominant males defended larger territory when compared with the inferior male and females. The dominant males were darker colored (black with a bluish tinge) and the colour disappeared when the animal was stressed (Image 3). The distal margin of the fins were an iridescent blue-green. The inferior males were greyish brown in colour with faded brown vertical bands which fade away soon after preservation. The distal margin of fins were similar in colour and appearance to that of dominant males. Females were smaller than males and had a beige-brown colour on the body with irregular vertical bands and the fins were devoid of the iridescent colour. The

Table 1. Morphometric data of the *Dario neela* (n=11) collected from different locations in Wayanad.

Morphometric data (mm)	Range	Mean	SD
Total length:	28.4–38.6	33	5.1
Standard length:	23.1–31.1	27.2	4
Head length:	7.9–9.4	8.6	0.7
Eye Diameter:	2.4–2.6	2.5	0.1
Depth of body at D.O:	7.2–9.6	8.5	1.2
Depth of body at A.O:	6.4–8.9	7.8	1.3
Inter Orbital Width:	2.3–3.9	3.1	0.8
Snout Length:	0.6–1.9	1.2	0.6
Dorsal fin Height:	4.1–6.4	5.5	1.2
Pectoral fin Length:	4.2–6.8	5.2	1.3
Ventral fin length:	3.3–6.2	4.8	1.4
Anal fin Length:	3.4–6.9	5.4	1.8
Caudal peduncle length:	3.4–4.2	3.8	0.4
Caudal fin length :	5.3–7.5	5.8	1.5
Pre-dorsal length :	7.7–11.3	9.9	1.9
Pre-Anal length:	14.6–18.5	16.6	1.9
Pre—Pectoral length :	8.1–9.6	8.8	0.7
Pre- pelvic length:	8.6–10.5	9.6	0.9
Length of the base of dorsal fin:	12.5–16.1	14.4	1.8
Length of the base of Anal fin:	4.7–6.9	5.8	1.1
Inter nostril distance:	1.3–1.7	1.5	0.2
Height of Caudal peduncle:	2.3–4.2	3.5	1

Morphometric data (%SL)	Range	Mean	SD
Head length	30.2– 34.1	32.0	2.8
Eye diameter	8.3–10.3	9.4	1.4
Depth of body at dorsal origin	30.8– 32.4	31.5	1.1
Depth of body at anal origin	27.7–30.2	28.8	1.8
Inter orbital width	9.9– 12.5	11.2	1.8
Snout length	2.5 –6.1	4.2	2.4
Dorsal fin height	17.7–22.2	20.1	3.1
Pectoral fin Length	17.5–21.8	19.1	3.0
Ventral fin length	14.2–19.9	17.3	3.9
Anal fin Length	14.7–22.1	19.6	5.2
Caudal peduncle length	13.5–14.7	14.1	0.8
Caudal fin length	16.7–24.1	21.2	5.1
Pre-dorsal length	33.3–39.4	36.3	4.2
Pre-Anal length	59.4–63.2	61.3	2.6
Pre-Pectoral length	30.8–35.0	32.8	2.9
Pre-pelvic length	33.7–37.2	35.4	2.4
Length of the base of dorsal fin	51.7–54.1	53.2	1.6
Length of the base of anal fin	20.3–22.1	21.2	1.3
Inter nostril distance	5.4– 5.8	5.6	0.2
Height of caudal peduncle	9.9–15.3	12.9	3.7

**Image 1. General appearance and colour differences in the dominant male, inferior male and female of *Dario neela* under natural conditions**

A - Dominant male; B - Inferior male; C - Adult female

caudal spot was present in all specimens (Image 1).

Breeding behavior

The spawning behavior of *Dario neela* was studied in a well-planted glass tank, which mimicked the natural ecosystem from where the fish were collected. A large tank (190L) was used to study the social and breeding behavior of the species. Tank water properties like pH and temperature were almost similar to the stream condition. The tank was planted with locally available aquatic vegetation like *Lagenandra toxicaria* and *Cabomba* sp. Hiding spaces were provided in the form of large rocks and artificial caves. The substrate was set with sand and leaf litter collected from the streams.

Dominant males mostly occupied the heavily planted regions of the tank with enough hiding spaces and

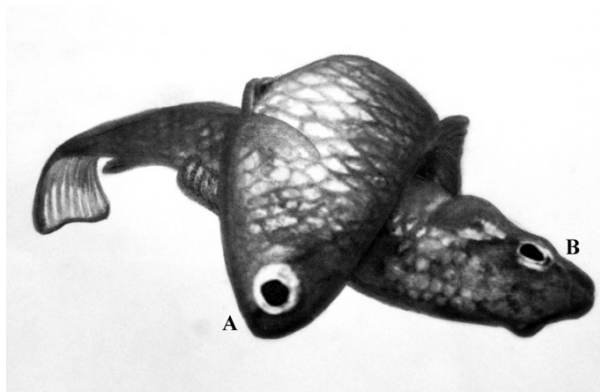


Figure 2. Simple U-loop spawning embrace in *Dario neela*: A - male, B - female

aggressively defended the territory (typically 40cm²) from the inferior male and females. Females were found to hide under leaf litter and rocks, while the inferior male defended smaller territory when compared to the dominant male.

Male *Dario neela* chased the females and displayed his bright colors to attract the females, shivering and shaking his body. Gravid females when ready to spawn followed the male to his territory. Mating is usually attained by a spawning embrace, where the mates wrap around each other (Fig. 2). The female released eggs after two to three fake matings and the males fertilized it. Eggs were usually scattered in dense vegetation, in caves or under leaf litter. After spawning, the male chased away the female preventing her from eating the eggs. Eggs were found to hatch within 48 hours in normal conditions, with the larvae hiding in vegetation immediately after hatching. Males were found to protect their territories aggressively after spawning.

DISCUSSION

Dario neela is the only species of badid fish known from the Western Ghats of Kerala. The present study described the distribution of this rare species in the Wayanad part of Nilgiri Biosphere Reserve. *Dario urops* was described based on the specimens collected from a stream draining into Barapole tributary of Valapattanam River in Karnataka and the specimens collected by Francis Day (1875–1878) from Wayanad were originally assigned to this species (Britz et al. 2012). A recent study (Britz et al. 2018), however, revealed that the specimens collected from Wayanad is in fact a separate species and named it as *Dario neela*, referring to its blue coloration.

Dario neela could not be recorded from any other locations outside Wayanad and in Wayanad the species could be recorded only from the east flowing streams draining into the Kabini River, suggesting that the species is



Image 2. Size differences in male and female specimens of *Dario neela*; A - male, and B - female



Image 3. Dominant male of *Dario neela* showing disappearance of dark body colours under stress

A - Dominant male under natural conditions; B - Dominant male after being handled - notice the disappearance of the natural dark colour.

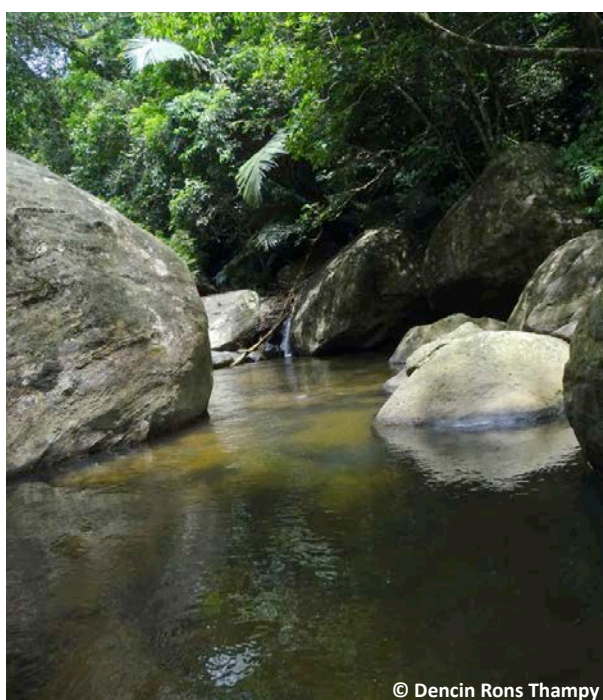
endemic to the Kabini River System in the Western Ghats of Kerala.

The population trends of this species is not well studied and the present study indicates that the species is a habitat specialist, recorded only from less disturbed clear water mountain streams which might have accounted for its rarity.

The antiparallel spawning embrace has been reported in Badidae, Anabantoides, Nandidae and Channidae by Barlow et al. (1968). A similar type of spawning embrace was observed in *Dario neela*. The present success in captive breeding helps in developing future ex situ conservation plans for this species.

Table 2. Physical settings of the habitat of *Dario neela*

Location	GPS location	Elevation (m)	Stream type	Stream width (m)	Substrate	Water temperature (C)	Canopy Cover (%)
Myladi-Banasura	11.66330°N & 75.93182°E	864.4	Pool	3	Sand (50%) Mud (50%)	19.00	89.45
Banasura-Unnamed Stream	11.63886°N & 75.92524°E	779	Run	3.3	Sand (40%) Mud (20%) Boulders (40%)	18.70	97.43
Valaanchola-Lady Smith's RF	11.62625°N & 75.96217°E	848.9	Run	4	Sand (30%) Gravel (10%) Pebbles (10%) Bed Rock (50%)	17.90	96.51
Chekuthankundu-Lakkidi RF	11.51808°N & 76.04332°E	857	Pool	7	Sand (70%) Boulders (20%) Gravel (10%)	18.60	95.98
Kurichyarmala-Unnamed Stream	11.59557°N & 75.98148°E	1019	Pool	2.5	Boulder (80%) mud (20%)	18.90	93.22
Chembra-Unnamed Stream	11.55043°N & 76.09874°E	1046	Run	2.2	Sand (80%) Mud (20%)	21.50	75.12
Periya Stream	11.82465°N & 75.84604°E	741	Run	8.5	Sand (50%) Mud (20%) Boulders (30%)	22.60	70.38
Type locality at a small unnamed stream flowing into Periya Stream	11.8241°N & 75.86250°E	738	Run	1.5	Sand (50%) Mud (10%) Boulders (40%)	21.43	76.52

**Image 4. *Dario neela* habitat - Lakkidi River****Image 5. *Dario neela* habitat - Periya stream showing dense growth of *Lagenandra toxicaria* in the shallow regions**

REFERENCES

- Barlow, G.W., K.F. Liem & W. Wickler (1968). Badidae, a new fish family behavioural, osteological, and developmental evidence. *Journal of Zoology* 156: 415–447; <http://doi.org/10.1111/j.1469-7998.1968.tb04363.x>
- Britz, R. & A. Ali (2015). *Dario huli*, A new species of Badid from Karnataka, southern India (Teleostei: Percomorpha: Badidae). *Zootaxa* 3911(1): 139–44; <http://doi.org/10.11646/zootaxa.3911.1.9>
- Britz, R., A. Ali & S. Philip (2012). *Dario urops*, a new species of badid fish from the Western Ghats, southern India (Teleostei: Percomorpha: Badidae). *Zootaxa* 3348: 63–68.
- Britz, R., V.K. Anoop & N. Dahanukar (2018). *Dario neela*, a new species of badid fish from the Western Ghats of India (Teleostei: Percomorpha: Badidae). *Zootaxa* 4429(1): 141–148; <http://doi.org/10.11646/zootaxa.4429.1.6>
- Day, F. (1875–78). *The Fishes of India: Being A Natural History of The Fishes Known to Inhabit The Seas and Fresh Waters Of India, Burma, And Ceylon*. William Dawson & Sons, London, 778pp+195pls.
- Easa, P.S. & C. Basha (1995). A Survey on the Habitat and Distribution of Stream Fishes in the Kerala Part of Nilgiri Biosphere Reserve. *Kerala Forest Research Institute Research Reports* 104: 1–87.
- Shaji, C.P. & P.S. Easa (1995). Freshwater Fish Diversity in Wayanad, Kerala, South India. *Journal of Zoological Society of Kerala* 5: 30–36.
- Shaji, C.P. & P.S. Easa (1997). Freshwater fish diversity in Kerala part of the Nilgiri Biosphere Reserve. *Current Science* 73: 180–182.



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

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2018 | 10(8): 12108–12116

A CHECKLIST OF THE ORNAMENTAL FISHES OF HIMACHAL PRADESH, THE WESTERN HIMALAYA, INDIA

Indu Sharma¹ & Rani Dhanze²

¹Zoological Survey of India, High Altitude Regional Center, Solan, Himachal Pradesh 173211, India

²Department of Fishery Resource Management, College of Fisheries, CAU, Lembucherra, Agartala, Tripura 799210, India

¹induzsi@gmail.com (corresponding author) ²rdhanze@yahoo.co.in

OPEN ACCESS



Abstract: Fifty-eight ornamental fish species belonging to five orders, 13 families and 36 genera occur in Himachal Pradesh. The dominant family is Cyprinidae (46.55%) followed by Nemacheilidae (15.51%); Sisoridae, Poeciliidae, Osphronemidae (9.89%); Cobitidae (5.17%); Amblycipitidae, Ambassidae, Badidae, Gobiidae, Helostomatidae, Cichlidae and Characidae (1.72%). Of the 58 species, 27.58% are exotic and have been mainly imported for aquarium keeping. The exotic species are being introduced in the region without any regulation, subsequently turning invasive and threatening the indigenous fauna. Thus, there is a need for developing scientific guidelines and regulatory mechanisms for importing exotic aquarium fishes. On the other hand, the breeding and culture of indigenous fishes can be a profitable venture, provided there is an availability of a standardized breeding technology. Such an enterprise will go a long way in conservation of native fishes, improving livelihoods as well as raising the socio-economic status of local communities.

Keywords: Aquarium trade, conservation, enterprise, socio-economic.

Aquarium fish keeping is one of the oldest hobbies in the world and next only to photography in popularity (Das et al. 2005; Singh & Ahmed 2005). The high demand for ornamental fishes has made them an important component of the world fish trade (Andrews 1990; Singh & Ahmed 2005; Tlustý et al. 2013); however, the aquarium industry is sighted as both positively (socio-economic and livelihood

benefits) and negatively (over-harvest, habitat destruction, alien species invasions) influential (Watson & Moreau 2006).

Himachal Pradesh is located in the western Himalaya between 30.36667–30.2 °N and 75.78333–79.06667 °E and altitudes ranging from 320–7,000 m. It has four physiographic zones (i) Shiwalik, (ii) Lower Himalayan, (iii) Higher Himalayan, and (iv) Trans Himalayan zone. The state has enormous potential for fishery in terms of aquatic resources with approximately 300km of perennial rivers, 775km of seasonal rivers (Satluj, Beas, Ravi, Chenab and Yamuna), 60,000ha reservoirs and 2,000ha, lakes and ponds including two Ramsar Sites, Pong Dam and Renuka Wetland.

A review of literature reveals that although much work has been undertaken on the general fish resources of Himachal Pradesh (Day 1875–1878; Hora 1937; Menon 1962, 1987, 1999; Bhatnagar 1973; Seghal 1974; Tilak & Hussain 1977; Sharma & Tandon 1990; Johal et al. 2002, 2003; Dhanze & Dhanze 2004; Mehta & Uniyal 2005; Mehta & Sharma 2008; Sharma 2014), no information is available on the potential aquarium fishes. For the first time, an attempt has been made to produce a comprehensive list of ornamental fishes recorded from the waters of Himachal Pradesh.

DOI: <http://doi.org/10.11609/jott.3716.10.8.12108-12116> | **ZooBank:** urn:lsid:zoobank.org:pub:F9D8D627-BBAB-4103-84EE-EAD1C9BCBE6F

Editor: Rajeev Raghavan, Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3716 | Received 05 August 2017 | Final received 10 July 2018 | Finally accepted 16 July 2018

Citation: Sharma, I. & R. Dhanze (2018). A checklist of the ornamental fishes of Himachal Pradesh, the western Himalaya, India. *Journal of Threatened Taxa* 10(8): 12108–12116; <http://doi.org/10.11609/jott.3716.10.8.12108-12116>

Copyright: © Sharma & Dhanze 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The first author is thankful to the Director, ZSI, Kolkata and Officer-in-Charge, HARC, ZSI, Solan for providing the facilities and encouragement. We are thankful to Dr. J.R. Dhanze, Dean, College of Fisheries, CAU, Lembucherra, Agartala, Tripura for support to carry out the work. The authors are grateful to the editors for critically going through the manuscript and giving the various suggestions for improvement.



MATERIAL AND METHODS

Fishes were collected from the Beas, Yamuna, Satluj, Ravi and Chandra Bhaga rivers in Himachal Pradesh and their tributaries using a combination of gears including cast net, scoop net and hand net. Fish specimens were preserved in 4% formalin solution and deposited in the High Altitude Regional Centre, Zoological Survey of India (ZSI), Solan, and identified using standard literature (Talwar & Jhingran 1991; Jayaram 2010). Conservation status of the fish species is based on the IUCN Red List of Threatened Species (2017) and nomenclature is as per Eschmeyer et al. (2016). Six fish species viz. *Barilius modestus* Day, 1872, *B. sacra* Hamilton, 1822, *Raiamas bola* (Hamilton, 1822), *Schistura himachalensis* Menon, 1987, *Paraschistura punjabensis* (Hora, 1923) and *Triplophysa microps* (Steindachner, 1866) which were not collected in the present study have been included based on records in published literature (Tilak & Hussain, 1977; Dhanze & Dhanze, 2004; Mehta & Uniyal 2005; Sharma 2014).

RESULTS AND DISCUSSION

A systematic list of 58 ornamental fish species belonging to five orders, 13 families and 36 genera from various ecosystem of the state is summarized in Tables 1 and 2, of which 42 are native and 16 imported for the aquarium trade (Figs. 1 & 2; Images 1–27). Besides, two exotic species, *Cyprinus carpio* var. *communis* and *Cyprinus carpio* var. *specularis* are also used for aquaculture practices in the state. Cyprinidae is the most dominant family of native ichthyofauna with 22 species, followed by Nemacheilidae with nine species, Sisoridae with four species, Cobitidae with three species and Amblycipitidae, Ambassidae, Badidae & Gobiidae represented by one species each. The exotic fauna comprises five species of Cyprinidae, four species of Poeciliidae and Osphronemidae and one species each under Helostomatidae, Cichlidae and Characidae. As per the criteria of Ghosh et al. (2003), all fish species come

under classified Aquarium fishes (CA) except three exotic varieties of *Cyprinus* species (*Cyprinus carpio* var. *communis*, *Cyprinus carpio* var. *specularis*, *Cyprinus carpio* var. *nudus*) and two *Carassius* species (*Carassius auratus* and *Carassius carassius*) which are non-classified aquarium (NCA) fishes. The exotic *Cyprinus* spp. has commercial value but due to its hardy nature, beautiful colour and disease resistance are used as aquarium fishes till they reach their fingerling stage. These exotic fishes have also entered the various natural water bodies (streams of Beas and Satluj River) of the region and are well established in the Pong dam, Govind Sagar Reservoir and Pandoh Dam.

Native fishes recorded as ornamental (Table 1) are hillstream species that are threatened by various anthropogenic stresses, viz., over exploitation, illegal fishing, invasive species, habitat loss and destruction due to channelization of water, and upcoming hydroelectric projects. Breeding and farming of these ornamental fish species can help in the restoration and conservation of indigenous fish fauna. Further, it will be a promising alternate livelihood for the farmers of the region. Thus the ornamental fish trade will go a long way to provide employment in the region.

The conservation status following the IUCN Red List of Threatened Species (2017) has revealed that among the 42 native fish species, 30 species (71.4%) come under the 'Least Concern' (LC) category; two species (4.8%) under 'Data Deficient' (DD) category and 10 species (23.8%) under 'Not Evaluated' (NE) category.

About 90% of the freshwater ornamental fish exported from India are wild caught indigenous species (Silas et al. 2011). Raghavan et al. (2013) stated that more than 1.5 million freshwater fish belonging to 30 threatened species were exported from India to Europe, US and other Asian countries from 2005 to 2012. Without any focus on conservation and sustainable use, freshwater fishes are collected from nature as an open access resource for the

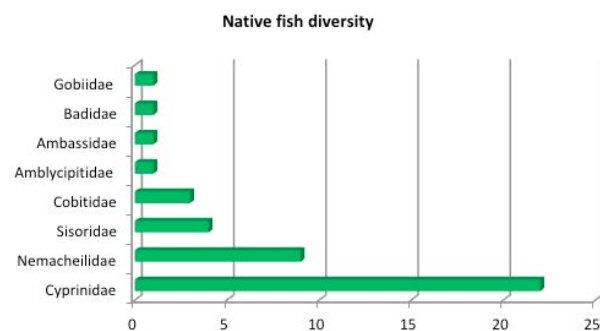


Figure 1. Family wise distribution of native ornamental fishes in Himachal Pradesh

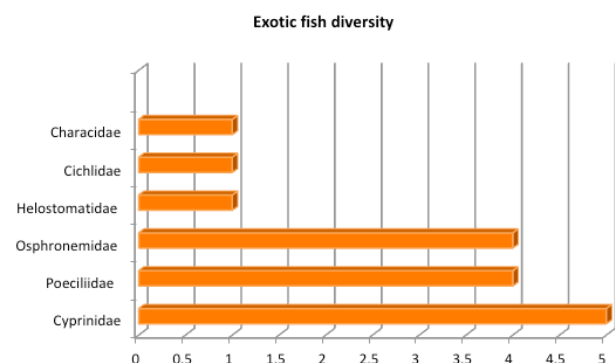


Figure 2. Family wise distribution of exotic ornamental fishes in Himachal Pradesh

Table 1. A systematic list of indigenous ornamental freshwater fishes of Himachal Pradesh along with their distribution and conservation status

	Species name	Common name	Distribution	IUCN status	Records	Voucher No.
Order: Cypriniformes Family: Cyprinidae Subfamily: Cyprininae						
1	<i>Pethia ticto</i> (Hamilton, 1822)	Ticto Barb	Beas: Kangra, Mandi, Kullu, Hamirpur Satluj: Bilaspur, Shimla, Una Yamuna: Solan, Sirmour Ravi: Chamba	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-870 (ZSI Solan)
2	<i>Pethia conchonius</i> (Hamilton, 1822)	Rosy Barb	Beas: Kangra, Mandi, Hamirpur Satluj: Bilaspur Yamuna: Solan, Sirmour Ravi: Chamba	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-245 (ZSI Solan)
3	<i>Puntius sophore</i> (Hamilton, 1822)	Stigma Barb	Beas: Kangra, Mandi, Kullu, Hamirpur Satluj: Bilaspur, Una Yamuna: Solan, Sirmour Ravi: Chamba,	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-730 (ZSI Solan)
4	<i>Puntius chola</i> (Hamilton, 1822)	Chola Barb	Beas: Kangra Satluj: Bilaspur, Una Yamuna: Solan, Sirmour	NE	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-178 (ZSI Solan)
5	<i>Systomus sarana</i> (Hamilton, 1822)	Olive Barb	Beas: Kangra Satluj: Bilaspur Yamuna: Solan, Sirmour	LC	Tilak & Hussain 1977; Mehta & Uniyal (2005); Sharma (2014)	Observed in aquarium at H.P. State Fisheries Department
6	<i>Osteobrama cotio</i> (Hamilton, 1822)	Cotio	Satluj: Bilaspur Yamuna: Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Observed in aquarium at H.P. State Fisheries Department
7	<i>Salmostoma bacaila</i> (Hamilton, 1822)	Large Minnow	Yamuna: Sirmour	LC	Tilak & Hussain, 1977; Mehta & Uniyal (2005)	F-345 (ZSI Solan)
8	<i>Barilius bendelisis</i> (Hamilton, 1807)	Hamilton's Barila	Beas: Kangra, Mandi, Kullu, Hamirpur Satluj: Bilaspur, Shimla, Una Yamuna: Solan, Sirmour Ravi: Chamba	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-867 (ZSI Solan)
9	<i>Barilius barila</i> (Hamilton, 1822)	Barred Barila	Beas: Kangra, Mandi, Hamirpur Satluj: Bilaspur, Yamuna: Solan, Shimla	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-868 (ZSI Solan)
10	<i>Barilius vagra</i> (Hamilton, 1822)	Vagra Barila	Beas: Kangra, Mandi Satluj: Bilaspur, Shimla Yamuna: Sirmour Ravi: Chamba	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-807 (ZSI Solan)
11	<i>Barilius barna</i> (Hamilton, 1822)	Barna Baril	Beas: Kangra Yamuna: Sirmour	LC	Tilak & Hussain 1977; Mehta & Uniyal (2005); Sharma (2014)	F-865 (ZSI Solan)
12	<i>Barilius modestus</i> Day, 1872	Indus Baril	Satluj: Bilaspur	NE	Tilak & Hussain 1977; Mehta & Uniyal (2005)	Recorded from literature
13	<i>Barilius shacra</i> (Hamilton, 1822)	Shacra Baril	Yamuna: Sirmour, Solan	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005)	Recorded from literature
14	<i>Raiamas bola</i> (Hamilton, 1822)	Indian Trout	Yamuna: Sirmour	LC	Tilak & Hussain 1977; Mehta & Uniyal (2005)	Recorded from literature
15	<i>Danio rerio</i> (Hamilton, 1822)	Zebra Fish	Beas: Kangra Satluj: Bilaspur Yamuna: Solan, Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-764 (ZSI Solan)
16	<i>Devario devario</i> (Hamilton, 1822)	Devario Danio	Beas: Kangra, Hamirpur, Una Yamuna: Solan, Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Observed in aquarium at H. P. State Fisheries Department
17	<i>Esomus danrica</i> (Hamilton, 1822)	Flying Barb	Beas: Kangra Satluj: Una Yamuna: Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-319 (ZSI Solan)
18	<i>Rasbora daniconius</i> (Hamilton, 1822)	Blackline Rasbora	Beas: Kangra, Hamirpur Satluj: Bilaspur Yamuna: Sirmour, Solan	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-627 (ZSI Solan)
19	<i>Tariqilabeo latius</i> (Hamilton, 1822)	Gangetic Latia	Beas: Kangra, Mandi, Hamirpur Satluj: Bilaspur, Una Yamuna: Solan, Sirmour Ravi: Chamba	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-871 (ZSI Solan)

	Species name	Common name	Distribution	IUCN status	Records	Voucher No.
20	<i>Tariqilabeo diplochilus</i> (Heckel, 1838)	Kashmir Latia	Beas: Mandi Satluj: Bilaspur Yamuna: Sirmour Ravi: Chamba	NE	Tilak & Hussain 1977; Mehta & Uniyal (2005)	F-233 (ZSI Solan)
21	<i>Garra gotyla</i> (Gray, 1830)	Gotyla	Beas: Kangra, Mandi, Kullu, Hamirpur Yamuna: Sirmour, Solan Ravi: Chamba	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-771 (ZSI Solan)
22	<i>Garra lamta</i> (Hamilton, 1822)	Lamta Garra	Beas: Mandi, Yamuna: Sirmour, Solan	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-234 (ZSI Solan)
Family: Nemacheilidae						
23	<i>Paracanthocobitis botia</i> (Hamilton, 1822)	Mottled Loach	Beas: Kangra, Mandi Yamuna: Solan, Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-866 (ZSI Solan)
24	<i>Paraschistura punjabensis</i> (Hora, 1923)	-	Satluj: Bilaspur	NE	Tilak & Hussain 1977; Mehta & Uniyal (2005)	Recorded from literature
25	<i>Schistura denisoni</i> (Day, 1867)	-	Yamuna: Sirmour	NE	Tilak & Hussain 1977	F-639 (ZSI Solan)
26	<i>Schistura rupecula</i> (McClelland, 1838)	Hill Loach	Beas: Kullu Satluj: Shimla Yamuna: Solan, Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-804 (ZSI Solan)
27	<i>Schistura montana</i> (McClelland, 1838)	Mountain Loach	Beas: Kangra Satluj: Shimla Yamuna: Solan, Sirmour	NE	Tilak & Hussain 1977; Mehta & Uniyal (2005); Sharma (2014)	F-813 (ZSI Solan)
28	<i>Schistura horai</i> (Menon, 1952)	Horai Loach	Beas: Kangra Yamuna: Solan, Sirmour	NE	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-795 (ZSI Solan)
29	<i>Schistura himachalensis</i> (Menon, 1987)	-	Beas: Kangra	NE	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Recorded from literature
30	<i>Triplophysa stoliczkae</i> (Steindachner, 1866)	Stoliczkae Triplophysa-Loach	Chanderbhaba: Lahaul & Spiti	NE	Tilak & Hussain 1977; Mehta & Uniyal (2005)	F-756 (ZSI Solan)
31	<i>Triplophysa microps</i> (Steindachner, 1866)	Leh Triplophysa-Loach	Chanderbhaba: Lahaul & Spiti	LC	Sharma (2014)	Recorded from Literature
Family: Cobitidae						
31	<i>Lepidocephalichthys guntea</i> (Hamilton, 1822)	Guntea Loach	Beas: Kangra, Ravi: Chamba Yamuna Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-780 (ZSI Solan)
32	<i>Botia dario</i> (Hamilton, 1822)	Necktie Loach	Yamuna: Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Observed in Aquarium at H. P. State Fisheries Department
33	<i>Botia birdi</i> Chaudhuri, 1909	Birdi Loach	Satluj: Bilaspur	NE	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Observed in Aquarium at H. P. State Fisheries Department
Order: Siluriformes						
Family: Amblycipitidae						
34	<i>Amblyiceps mangois</i> (Hamilton, 1822)	India Torrent Catfish	Beas: Kangra, Mandi	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-409 (ZSI Solan)
Family: Sisoridae						
35	<i>Glyptothorax brevipinnis</i> Hora, 1923	Mountain Catfish	Yamuna: Sirmour	DD	Tilak & Hussain 1977	F-594 (ZSI Solan)
36	<i>Glyptothorax conirostris</i> (Steindachner, 1867)	Mountain Catfish	Beas: Kangra, Mandi Satluj: Bilaspur, Shimla Yamuna: Solan, Sirmour	DD	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	F-862 (ZSI Solan)
37	<i>Glyptothorax pectinopterus</i> (McClelland, 1842)	Mountain Catfish	Beas: Kangra Satluj: Bilaspur Yamuna: Solan, Sirmour Ravi: Chamba	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Observed in Aquarium at Chaudhary Sarwan Kumar H.P. Agricultural University Farm, Palampur, district Kangra (H.P.)

	Species name	Common name	Distribution	IUCN status	Records	Voucher No.
38	<i>Glyptothorax stoliczkae</i> (Steindachner, 1867)	-	Ravi: Chamba Beas: Kangra Yamuna: Sirmour, Solan	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Recorded from Literature
Order: Perciformes Family: Ambassidae						
39	<i>Parambassis baculis</i> (Hamilton, 1822)	Himalayan Glassy Perchlet	Satluj: Bilaspur Yamuna: Sirmour, Solan	LC	Tilak & Hussain 1977; Mehta & Uniyal (2005)	Observed in Aquarium at H. P. State Fisheries Department
Family: Badidae						
40	<i>Badis badis</i> (Hamilton, 1822)	Dwarf Chameleon Fish	Yamuna: Solan, Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Observed in Aquarium at H. P. State Fisheries Department
Family: Gobiidae						
41	<i>Glossogobius giuris</i> (Hamilton, 1822)	Tank Goby	Beas: Kangra Yamuna: Sirmour	LC	Tilak & Hussain 1977; Dhanze & Dhanze (2004); Mehta & Uniyal (2005); Sharma (2014)	Observed in Aquarium at H. P. State Fisheries Department

aquarium trade (Raghavan et al. 2013), resulting in their population decline and general decline of the state of freshwater biodiversity (Allen et al. 2010; Molur et al. 2011). Marine Products Export Development Authority of India has developed a document on green certification, which is the first of its kind in the freshwater ornamental fish sector (Ramachandran 2012) with the intention to maintain socio-economic sustainability. This approach stresses on reducing the dependence on wild stocks and ensures that the fish collection is managed as per access and benefit sharing practices. Iyer et al. (2016) stated that there are 101 valid fish species under the green certification guide lines and suggested the development of captive breeding technology for the potential export species.

Currently, there is neither a domestic ornamental fish market nor documentation of export of ornamental fish in Himachal Pradesh. Ornamental fish trade can be a lucrative business for local communities to improve their livelihood but requires the development and standardization of captive breeding techniques. Besides, the economic upliftment related to freshwater ornamental fish trade, proper emphasis must also be given to the sustainable maintenance of critical ecosystems and conservation of endemic fish diversity. Further, the import of exotic ornamental fishes to the state is increasing day by day as a result of growing popularity of aquarium fish keeping, but without any regulations, which may lead to negative impacts on native fish fauna. Captive breeding of indigenous fishes should be attempted for export and no wild caught fish should be used for the aquarium trade.

REFERENCES

- Andrews, C. (1990). The ornamental fish trade and fish conservation. *Journal of Fish Biology* 37 (Supplement A): 53–59; <http://doi.org/10.1111/j.1095-8649.1990.tb05020.x>
- Das, M., S. Sarma & A.K. Das (2005). Status of ornamental fishes of Assam. *Fishing Chimes* 25(3): 13–15.
- Day, F. (1875–1878). *The fishes of India; Being a Natural History of The Fishes Known to Inhabit The Sea and Freshwater of India, Burma And Ceylon*. Reprinted in 1958, William Dawson & Co., London, 778pp.
- Dhanze, R. & J. R. Dhanze (2004). Fish diversity of Himachal Pradesh, pp. 39–60. In: Ayyappan, S., D.S. Malik, R. Dhanze & R.S. Chauhan (eds.). *Fish Diversity in Protected Habitats*. NATCON Publication, Muzaffarnagar, (U.P.), India.
- Eschmeyer, W.N., R. Fricke & R. van der Laan (eds.) (2016). *Catalog of Fishes*. California Academy of Sciences. <http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp> Electronic version accessed 12/05/2016
- Ghosh, A., B.K. Mahapatra & N.C. Datta (2003). Ornamental fish farming—successful small scale aqua business in India. *Aquaculture Asia* 8(3): 14–16.
- Hora, S.L. (1937). Distribution of Himalayan fishes and its bearing on certain paleogeographical problems. *Records of Indian Museum* 39: 251–259.
- Iyer, P., R. Raghavan, N. Dahanukar, N. Sood & S. Molur (2016). All that is green does not conserve: green certification of aquarium fishes in India. *Current Science* 110(11): 2054–2056.
- Johal, M.S., K.K. Tandon, A.K. Tyor & Y.K. Rawal (2002). Fish diversity in different habitats in the streams of lower Middle Western Himalayas. *Polish Journal of Ecology* 50(1): 45–56.
- Johal, M.S., O.S. Brar, R.K. Negi & Y.K. Rawal (2003). Economics evaluation of Pong dam reservoir situated on the river Beas, Himachal Pradesh (India). *Punjab Fisheries Bulletin* 24 (1): 5–15.
- Mehta, H.S. & D.P. Uniyal (2005). Pisces, pp. 255–268. *Fauna of Western Himalaya (Part-2)*. Zoological Survey of India, Kolkata, 359pp.
- Mehta, H.S. & I. Sharma (2008). Pisces, pp. 89–92. *Fauna of Pin Valley National Park, Conservation Area Series - 34*. Zoological Survey of India, Kolkata, 147pp.
- Menon, A.G.K. (1962). A distribution list of fishes of the Himalayas. *Journal of the Zoological Society of India* 14(1): 23–32.
- Menon, A.G.K. (1987). *Fauna of India and the Adjacent Countries*. Pisces, 4 (Part-I). Homalopteridae, Published by Director Zoological Survey of India, Calcutta, x+259pp.
- Menon, A.G.K. (1999). Checklist of freshwater fishes of India. *Records of the Zoological Survey of India Occasional Paper* 175: I-xxix: 1–366pp.
- Molur, S., K.G. Smith, B.A. Daniel & W.R.T. Darwall (compilers) (2011). *The Status of Freshwater Biodiversity in the Western Ghats*. International Union for Conservation of Nature (IUCN) Gland, Switzerland and Zoo Outreach Organization, Coimbatore, India, 116pp.
- Raghavan, R., D. Dahanukar, M. Tlustý, A.L. Rhyne, K.K. Kumar, S. Molur & A.M. Rosser (2013). Uncovering an obscure trade: threatened

Table 2. Introduced fishes used for aquarium purpose

	Order, Family & Species name	Common name	Distribution	IUCN status	Voucher No.
Order: Cypriniformes					
Family: Cyprinidae					
Subfamily: Cyprininae					
1.	<i>Carassius auratus</i> (Linnaeus, 1758)	Goldfish	Beas: Kangra, Mandi, Kullu, Hamirpur Satluj: Bilaspur, Shimla, Una Yamuna: Solan, Sirmour Ravi: Chamba		Observed in aquarium at Chaudhary Sarwan Kumar H. P. Agricultural University Farm, Palampur, district Kangra (H. P.)
2.	<i>Carassius carassius</i> (Linnaeus, 1758)	Crucian Carp	Beas: Kangra, Mandi, Kullu, Hamirpur Satluj: Shimla, Una, Yamuna: Solan, Sirmour Ravi: Chamba		Observed in aquarium at Chaudhary Sarwan Kumar H. P. Agricultural University Farm, Palampur, district Kangra (H. P.)
3.	<i>Cyprinus carpio</i> var. <i>communis</i> (Linnaeus, 1758)	Scale Carp	Beas: Kangra, Mandi, Kullu, Hamirpur Satluj: Bilaspur, Una, Shimla, Yamuna: Solan, Sirmour Ravi: Chamba		F-788
4.	<i>Cyprinus carpio</i> var. <i>specularis</i> Lacepède, 1803)	Mirror Carp	Beas: Kangra, Mandi, Kullu, Hamirpur Satluj: Bilaspur, Una, Shimla Yamuna: Solan, Sirmour Ravi: Chamba		F-789
5.	<i>Cyprinus carpio</i> var. <i>nudus</i> Bloch, 1784	Leather Carp	Beas: Kangra, Mandi, Kullu, Hamirpur Satluj: Bilaspur, Una, Shimla, Solan Yamuna: Sirmour Ravi: Chamba		Observed in aquarium at Chaudhary Sarwan Kumar H. P. Agricultural University Farm, Palampur, district Kangra (H. P.)
Order: Cyprinodontiformes					
Family: Poeciliidae					
6.	<i>Poecilia sphenops</i> Valenciennes, 1846	Black Molly	Only in aquarium	NE	Observed in aquarium at H. P. State Fisheries Department
7.	<i>Poecilia reticulata</i> Peters, 1859	Guppy	Only in aquarium	NE	Observed in aquarium at H. P. State Fisheries Department
8.	<i>Gambusia holbrooki</i> Girard, 1859	Eastern Fish	Only in aquarium	LC	Observed in aquarium at H. P. State Fisheries Department
9	<i>Xiphophorus hellerii</i> Heckel, 1848	Green Sword Tail	Only in aquarium	NE	Observed in aquarium at H. P. State Fisheries Department
Order: Perciformes					
Family: Osphronemidae					
10.	<i>Betta splendens</i> Regan, 1910	Siamese Fighting Fish	Only in aquarium	VU	Observed in aquarium at H. P. State Fisheries Department
11.	<i>Macropodus opercularis</i> (Linnaeus, 1758)	Paradise Fish	Only in aquarium	LC	Observed in aquarium at H. P. State Fisheries Department
12.	<i>Trichopodus trichopterus</i> (Pallas, 1770)	Three Spot Gourami	Only in aquarium	LC	Observed in aquarium at H. P. State Fisheries Department
13.	<i>Trichogaster fasciata</i> Bloch & Schneider, 1801	Banded Gourami	Yamuna: Sirmour	LC	Observed in aquarium at H. P. State Fisheries Department
Family: Helostomatidae					
14.	<i>Helostoma temminckii</i> Cuvier, 1829	Kissing Gourami	Only in aquarium	LC	Observed in Aquarium at H. P. State Fisheries Department
Order: Perciformes					
Family: Cichlidae					
15.	<i>Pterophyllum scalare</i> (Schultze, 1823)	Angel Fish	Only in aquarium	NE	Observed in aquarium at H. P. State Fisheries Department
Order: Characiformes					
Family: Characidae					
16.	<i>Gymnocorymbus ternetzi</i> (Boulenger, 1895)	Black Tetra	Only in aquarium	NE	Observed in aquarium at H. P. State Fisheries Department

freshwater fishes and the aquarium pet markets. *Biological Conservation* 164: 158–169; <http://doi.org/10.1016/j.biocon.2013.04.019>

Ramachandran, A. (2012). Greening the fresh water ornamental fish in India. In: Ornamental Kerala, 2012, Souvenir. International Seminar on Ornamental fish breeding, farming and trade held on 11–12 February 2012, Kochi, Kerala.

Silas, E.G., A. Gopalakrishnan, A. Ramachandran, T.V.A. Mercy, K. Sarkar, K. R. Pushpangadan, P.A. Kumar, M.K.R. Mohan & K.K. Anikuttan (2011). *Guidelines for Green Certification of Freshwater Ornamental*

Fish. The Marine Products Export Development Authority, Kochi, India, xii+106pp.

Singh, A.K. & S.H. Ahmed (2005). Ornamental fish culture in Bihar: prospects as a cottage industry. *Fishing Chimes* 25(6): 9–18.

Seghal, K.L. (1974). Fisheries survey of Himachal Pradesh and some adjacent areas with special reference to trout, Mahseer and allied species. *Journal of the Bombay Natural History Society* 70(3): 458–474.

Sharma, V.K. & K.K. Tandon (1990). The fish and fisheries of Himachal Pradesh state of India. *Punjab Fisheries Bulletin* 14(1): 41–46.

Image 1. *Pethia ticto* (Hamilton, 1822)Image 2. *Puntius sophore* (Hamilton, 1822)Image 3. *Pethia conchonius* (Hamilton, 1822)Image 4. *Puntius chola* (Hamilton, 1822)Image 5. *Salmostoma bacaila* (Hamilton, 1822)Image 6. *Barilius bendelisis* (Hamilton, 1807)Image 7. *Barilius barila* (Hamilton, 1822)Image 8. *Barilius vagra* (Hamilton, 1822)Image 9. *Barilius barna* (Hamilton, 1822)

Image 10. *Danio rerio* (Hamilton, 1822)Image 11. *Esomus danrica* (Hamilton, 1822)Image 12. *Rasbora daniconius* (Hamilton, 1822)Image 13. *Tariqilabeo latius* (Hamilton, 1822)Image 14. *Garra gotyla* (Gray, 1830)Image 15. *Paracanthocobitis botia* (Hamilton, 1822)Image 16. *Schistura montana* McClelland, 1838Image 17. *Lepidocephalichthys guntea* (Hamilton, 1822)Image 18. *Botia dario* (Hamilton, 1822)Image 19. *Botia birdi* Chaudhuri, 1909

Image 20. *Glyptothorax conirostris* (Steindachner, 1867)Image 21. *Glyptothorax brevipinnis* Hora, 1923Image 22. *Parambassis baculis* (Hamilton, 1822)Image 23. *Badis badis* (Hamilton, 1822)Image 24. *Carassius auratus* (Linnaeus, 1758)
& *Carassius carassius* (Linnaeus, 1758)Image 25. *Cyprinus carpio* var. *communis* (Linnaeus, 1758)Image 26. *Cyprinus carpio* var. *specularis* (Lacepède, 1803)Image 27. *Trichogaster fasciata* Bloch & Schneider, 1801

Sharma, I. (2014). *A Field Guide on Fishes of Himachal Pradesh*. Zoological Survey of India, Kolkata, 112pp.

Sandilyan, S. (2016). Occurrence of ornamental fishes: a looming danger for Inland fish diversity of India. *Current Science* 110(11): 2100–2104.

Thrusty, M.F., A.L. Rhyne, L. Kaufman, M. Hutchins, G.M. Reid, C. Andrews, P. Boyle, J. Hemdal, F. McGilvray & S. Dowd (2013). Opportunities for public aquariums to increase the sustainability of the aquatic animal

trade. *Zoo Biology* 32: 1–12; <http://doi.org/10.1002/zoo.21019>

Tilak, R. & H. Husain (1977). A checklist of fishes of Himachal Pradesh. *Zool. Jb. Syst. Bd.* 104: 265–301.

Watson, I. & M.A. Moreau (2006). The ornamental fish trade in support of livelihoods. *Ornamental Fish International* 50: 20–23.





ODONATE DIVERSITY OF NALSAROVAR BIRD SANCTUARY - A RAMSAR SITE IN GUJARAT, INDIA

Darshana M. Rathod¹ & B.M. Parasharya²

^{1,2} AINP on Agricultural Ornithology, Anand Agricultural University, Anand, Gujarat 388110, India

¹ darshanarathod500@gmail.com (corresponding author), ² parasharya@yahoo.com

OPEN ACCESS



Abstract: Odonate diversity of Nalsarovar Bird Sanctuary, a Ramsar site in Gujarat, was studied between January 2015 and July 2017. A total of 46 species belonging to two suborders, six families, and 27 genera were recorded, which included 14 species of Zygoptera (damselfly) and 32 species of Anisoptera (dragonfly). Out of the 46 species, 40 species are new records for the Nalsarovar Bird Sanctuary. The record of *Enallagma cyathigerum* Charpentier, 1840 in Gujarat needs verification. Need to monitor changes taking place in Odonata species composition after influx from Narmada canal at Nalsarovar is emphasized.

Keywords: Damselflies, diversity, dragonflies, odonates, protected area, wetland

Most of the Ramsar sites in India are recognized either because they are representative natural wetlands (Group A, Criterion 1) (Islam & Rahmani 2008) or based on information available on avian diversity and their abundance (Group B, Criterion 5 to 9) (Islam & Rahmani 2008). Besides birds (Ramakrishna et al. 2006; Kumar 2008, 2009), faunal studies of the Ramsar sites of India are largely restricted to fishes (Sharma & Mehta 2008; Dua & Chander 2009; Saikia & Saikia 2011). In India aquatic insect diversity is never used as criterion for recognition of Ramsar site. Among the 26 Ramsar sites

in India, odonate diversity of only three wetland sites are known (Palot & Soniya 2000; Kirti & Singh 2000; Singh et al. 2017). The present study on the Odonata was aimed to generate a basic database of the aquatic fauna of Nalsarovar Bird Sanctuary.

Nalsarovar Bird Sanctuary (NBS) in Gujarat was declared as a 'Ramsar Site' recently on 24 September 2012 largely because it is a natural wetland of very large size (Criterion 1), and it supports more than 20,000 water birds annually (Criterion 5), several bird species exceeding >1.0% geographic population (Criterion 6), and several globally threatened bird species (Criterion 2). Except for birds (Gauriar 1982; GEER Report 1998; Baskaran 1999; Urfi 2000; Muni 2004; Parasharya 2004; Kumar et al. 2007; Pandya 2007), meager attempts have been made to study aquatic fauna of Nalsarovar (Kumar 2009).

Biodiversity status and list of important species dependent on candidate wetland is a prerequisite for declaring any wetland as 'Ramsar site' (Ramsar Regional Center - East Asia 2017). Published literature on the fauna of NBS is either incomplete (GEER Report 1998) or erroneous (Kumar 2009); however, as no such

DOI: <http://doi.org/10.11609/jott.4017.10.8.12117-12122> | **ZooBank:** urn:lsid:zoobank.org:pub:FFF60E60-34EA-448E-BFDF-A1721B8FEB94

Editor: R.J. Andrew, Hislop College, Nagpur, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 4017 | Received 15 January 2018 | Final received 20 April 2018 | Finally accepted 18 July 2018

Citation: Rathod, D.M. & B.M. Parasharya (2018). Odonate diversity of Nalsarovar Bird Sanctuary - a Ramsar site in Gujarat, India. *Journal of Threatened Taxa* 10(8): 12117–12122; <http://doi.org/10.11609/jott.4017.10.8.12117-12122>

Copyright: © Rathod & Parasharya 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are thankful to Dr. S.S. Talmale, Zoological Survey of India for the assistance in identification of odonates. We also thank Gujarat Biodiversity Board and State Forest Department for the permission to carry out research on Odonata in the state and collect specimens (if needed) in the protected areas. One of us (DR) is grateful to University Grants Commission, New Delhi for awarding Rajiv Gandhi National Fellowship for pursuing Ph.D. programme (2014-2017).



published list of odonates is yet available (GEER Report 1998; Kumar 2009), this study was taken up to fill up the lacunae in our knowledge.

MATERIALS AND METHODS

Study area

NBS consists primarily of a 120.82km² area of the much larger natural low-lying area, and is situated about 64km to the west of Ahmedabad City, in the central part of Gujarat State, India (Fig. 1). It is considered a freshwater ecosystem, which gets inundated during south-west monsoon (June to September); its water becomes saline during summer (March– May) due to evaporation (GEER Report 1998). NBS is located at 22.81790°N and 72.04530°E, and it receives water from two rivers: Brahmini and Bhogavo (Singh 2001). It is a natural lake, originated by the elevation of the land between present-day Gulf of Khambhat and Gulf of Kachchh during the late quaternary period, thereby breaking the connection between the two gulfs. The area of Nalsarovar has remained a shallow depression with water depth ranging between 1.5–2.0 m as the land did not rise up to the height of mainland Gujarat or Saurashtra (Prasad et al. 1997).

The lake has around 300 small and big islands. The basin of the lake is elongated and nearly elliptical with gentle sloping margins. All around the basin, there is sandy to clayey shoreline. The water temperature rises up to 35°C during the month of May and falls below 15°C in January. The average rainfall is about 580mm (Kumar et al. 2006).

It is the largest wetland bird sanctuary in Gujarat, and one of the largest in India. About 48 species of phytoplanktons and 71 species of flowering plants, including 30 species of aquatic macrophytes, are recorded in this natural lake (Kumar et al. 2006). For establishing Narmada Canal network in Saurashtra, a site known as Bhaskarpura was created as storage reservoir of Narmada Canal water (GEER Report 1998). Narmada canal water started flowing in 2003, and since then the canal water is percolating to the Nalsarovar via Vadala depression (Fig. 1).

Sampling methods

This study was carried out between January 2015 and July 2017 in post monsoon period. Odonates were closely observed at the shallow edge of the wetland with naked eyes and occasionally using 7X35 binoculars. We also surveyed the marshy area of the adjoining villages and the small island areas within the lake (Images 10 & 11). Voucher specimens of some species were collected

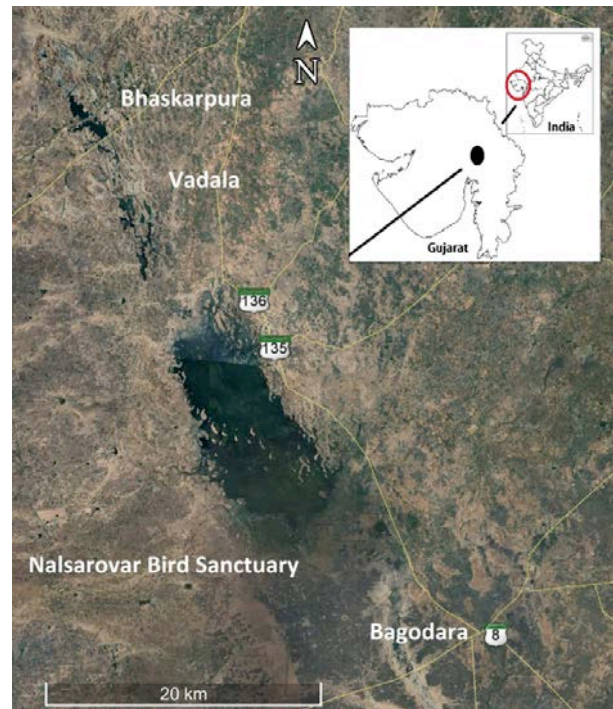


Figure 1. Nalsarovar Bird Sanctuary and surrounding areas

using insect collecting net. The specimens were either preserved in 70% alcohol or kept in envelopes, labeled with details of the collection. Odonates were counted using point count method (Smallshire & Beynon 2010; Rohmare et al. 2016) on the peripheral area of the sanctuary. Occurrence status was worked out on the basis of the frequency of occurrence as follows: >50%-common, 25-50%- Uncommon, 5-25%- Rare and <5%-very rare.

The species were identified with the help of photographic guides (Subramanian 2009; Nair 2011; Kiran & Raju 2013) and a suitable taxonomic book (Fraser 1933; 1934; 1936). The scientific names are adopted from the revised nomenclature by Subramanian & Babu (2017).

RESULTS

A total of 46 species belonging to two suborders and 27 genera under six families were recorded in and around NBS. Fourteen species of Zygoptera (damselfly) and 32 species of Anisoptera (dragonfly) were recorded. In this study, both Zygoptera and Anisoptera were represented by three families each (Table 1; Images 1–9).

At Nalsarovar, the most dominant families were Libellulidae with 26 species and Coenagrionidae with 10 species, respectively. Remaining families had two or three members each (Table 1). On 27 September

Table 1. List of Odonata of Nalsarovar Bird Sanctuary of Gujarat

Taxon	IUCN Red List status	Occurrence status
Suborder: Zygoptera		
Superfamily: Lestoidea		
Family: Lestidae		
<i>Lestes thoracicus</i> Laidlaw, 1920	LC	VR
<i>Lestes umbrinus</i> Selys, 1891	DD	R
Superfamily: Coenagrionoidea		
Family: Platycnemididae		
<i>Copera marginipes</i> (Rambur, 1842)	LC	UN
<i>Elattoneura nigerrima</i> (Laidlaw, 1917)	DD	R
Family: Coenagrionidae		
<i>Agriocnemis pygmaea</i> (Rambur, 1842)	LC	C
<i>Ceragrion coromandelianum</i> (Fabricius, 1798)	LC	C
<i>#Enallagma cyathigerum</i> (Charpentier, 1840)	LC	
<i>Ischnura aurora</i> (Brauer, 1865)	LC	UN
<i>Ischnura nursei</i> Morton, 1907	LC	UN
<i>Ischnura senegalensis</i> (Rambur, 1842)	LC	C
<i>Paracercion malayanum</i> (Selys, 1876)	NA	UN
<i>Pseudagrion decorum</i> (Rambur, 1842)	LC	UN
<i>Pseudagrion hypermelas</i> Selys, 1876	LC	R
<i>Pseudagrion microcephalum</i> (Rambur, 1842)	LC	UN
<i>Pseudagrion rubriceps</i> Selys, 1876	LC	R
Suborder: Anisoptera		
Super family: Aeshnoidea		
Family: Aeshnidae		
<i>Anax ephippiger</i> (Burmeister, 1839)	LC	C
<i>Anax guttatus</i> (Burmeister, 1839)	LC	VR
<i>Anax immaculifrons</i> Rambur, 1842	LC	VR
<i>Anax parthenope</i> (Selys, 1839)	LC	R
Superfamily: Gomphoidea		
Family: Gomphidae		
<i>Ictinogomphus rapax</i> (Rambur, 1842)	LC	R

Taxon	IUCN Red List status	Occurrence status
<i>Paragomphus lineatus</i> (Selys, 1850)	LC	VR
Superfamily: Libelluloidea		
Family: Libellulidae		
<i>Acisoma panorpoides</i> Rambur, 1842	LC	C
<i>Brachydiplax sobrina</i> (Rambur, 1842)	LC	UN
<i>Brachythemis contaminata</i> (Fabricius, 1793)	LC	C
<i>Bradinyopyga geminata</i> (Rambur, 1842)	LC	UN
<i>Crocothemis servilia</i> (Drury, 1770)	LC	C
<i>Diaplocodes lefebvrii</i> (Rambur, 1842)	LC	C
<i>Diplacodes nebulosa</i> (Fabricius, 1793)	LC	VR
<i>Diplacodes trivialis</i> (Rambur, 1842)	LC	C
<i>Indothemis carnatica</i> (Fabricius, 1798)	NT	R
<i>Neurothemis tullia</i> (Drury, 1773)	LC	UN
<i>Orthetrum luzonicum</i> (Brauer, 1868)	LC	R
<i>Orthetrum pruinosum</i> (Burmeister, 1839)	LC	UN
<i>Orthetrum sabina</i> (Drury, 1770)	LC	C
<i>Orthetrum taeniolatum</i> (Schneider, 1845)	LC	UN
<i>Pantala flavescens</i> (Fabricius, 1798)	LC	C
<i>Potamarcha congener</i> (Rambur, 1842)	LC	C
<i>Rhyothemis variegata</i> (Linnaeus, 1763)	LC	UN
<i>Tholymis tillarga</i> (Fabricius, 1798)	LC	VR
<i>Tramea basilaris</i> (Palisot de Beauvois, 1805)	LC	UN
<i>Tramea limbata</i> (Desjardins, 1832)	LC	UN
<i>Trithemis aurora</i> (Burmeister, 1839)	LC	C
<i>Trithemis festiva</i> (Rambur, 1842)	LC	UN
<i>Trithemis kirbyi</i> Selys, 1891	LC	UN
<i>Trithemis pallidinervis</i> (Kirby, 1889)	LC	C
<i>Urothemis signata</i> (Rambur, 1842)	LC	VR
<i>Zyxomma petiolatum</i> Rambur, 1842	LC	R

Note: IUCN Threat status, LC: Least Concern, DD: Data Deficient, NA: Not Available, NT: Near Threatened, #- Species not encountered during present study. Occurrence status: C-Common (>50%), UN-Uncommon (25-50%), R-Rare (5-25%), VR-Very Rare (<5%)

2016, most visible dragonflies were *Anax ephippiger*, *Potamarcha congener*, and *Tramea basilaris*, and they were abundant too.

On the basis of occurrence, odonates were categorized into four categories: Common, Uncommon, Rare and Very Rare. At NBS, 14 odonate species were most common. Uncommon odonate species were 16. Nine species, i.e., *Lestes umbrinus* Selys, 1891, *Elattoneura nigerrima* Laidlaw, 1917, *Pseudagrion hypermelas* Selys, 1876, *Pseudagrion rubriceps* Selys, 1876, *Anax parthenope* Selys, 1839, *Ictinogomphus*

rapax Rambur, 1842, *Indothemis carnatica* Fabricius, 1798, *Orthetrum luzonicum* Brauer, 1868, and *Zyxomma petiolatum* Rambur, 1842, were categorized under Rare category. Very rare species included *Lestes thoracicus* Laidlaw, 1920, *Anax guttatus* Burmeister, 1839, *Anax immaculifrons* Rambur, 1842, *Paragomphus lineatus* Selys, 1850, *Diplacodes nebulosa* Fabricius, 1793, *Tholymis tillarga* Fabricius, 1798, and *Urothemis signata* Rambur, 1842. These species were encountered only one or two times (Table 1).

Indothemis carnatica Fabricius, 1798 is listed as Near



Image 1. *Lestes thoracicus*



Image 2. *Ischnura senegalensis*



Image 3. *Elatoneura nigerrima*



Image 4. *Anax ephippiger*



Image 5. *Paragomphus lineatus*



Image 6. *Bradinopyga geminata*



Image 7. *Crocothemis servilia*



Image 8. *Potamarcha congener*



Image 9. *Tramea basilaris*



Image 10. Nalsarovar Lake view



Image 11. Shallow marsh of Nalsarovar Lake

Threatened species in the Red List (IUCN 2017). Though not abundant at any site, it occurs in marshy areas with reeds within the sanctuary as well as in the surrounding areas. *Lestes umbrinus* Selys, 1891 and *Elatoneura nigerrima* Laidlaw, 1917 are Data Deficient species and their encounter was very low. Forty-two species of odonates from the present study are listed under Least Concern species. Status of *Paracercion malayanum* Selys, 1876 is not available on the IUCN Red List. Hence, current records may help to undertake threat analysis.

DISCUSSION

Prasad (2004) reported seven species from the Nalsarovar during a general faunal survey of Gujarat State by the Zoological Survey of India. In the present study, 46 species of odonates were recorded. Hence, 40 species are additions to the list of Odonata of NBS. *Enallagma cyathigerum* Charpentier, 1840 recorded by Prasad (2004) was not encountered in the present study. In Gujarat, *Enallagma cyathigerum* Charpentier, 1840 was reported from Anandpura Village (Mandal Tahsil) and Nalsarovar of Ahmedabad District by Prasad (2004). This species is widely distributed in Europe and Northern Asia with only two records from India. In India, this species has been recorded from Kashmir and West Bengal (Fraser 1933; Srivastava & Sinha 1993). Rohmare et al. (2015, 2016) had reported the species from central Gujarat, however, it was considered a misidentification (Rathod 2017). Rathod (2017) had not encountered this species anywhere in Gujarat State.

The Odonata diversity of Thol Bird Sanctuary (Mokaria 2015) and Pariej wetland (Rathod et al. 2015) of Gujarat have been reported recently. Both the wetlands are located in central Gujarat within the direct distance of 55km (Thol Bird Sanctuary) and 65km (Pariej Wetland) from Nalsarovar and is fed by Narmada canal waters. Their reported species diversity was only 15 (Thol) and 29 (Pariej). The differences in reported numbers of species might be attributed to the structural differences and area of the wetland, and the relative efforts made by the researchers. In India, the faunal study of Odonata is done only on three Ramsar sites. The present study on Nalsarovar is fourth one. Comparison of the diversity of Odonata with other Ramsar sites across the country may not be meaningful as several factors such as biogeographic zones, the intensity of study, and period influence the reported diversity. However, a comparison with Keoladeo National Park would be worth as it is located in the adjoining state (Rajasthan) and in the same biogeographic zone (semi-arid zone).

Only 37 species of Odonata have been reported

from Keoladeo National Park till date. Interestingly, 32 species are shared between two Nalsarovar and Keoladeo; five species, namely, *Enallagma parvum* Selys, 1876, *Pseudagrion spencei* Fraser, 1922, *Anaciaeschna jaspidea* Burmeister, 1839, *Anax imperator* Leach, 1815, and *Palpopleura sexmaculata* Fabricius, 1787 were recorded from Keoladeo National Park but not from NBS. Except for *Anax imperator* Leach, 1815 and *Palpopleura sexmaculata* Fabricius, 1787, the remaining three species are reported from other parts of Gujarat (Rathod 2017).

Odonates are indicators of wetland health (Balaraman 2008; Subramanian et al. 2008; Dholu 2015). Long-term ecological studies of such Indicators of the ecosystem should be undertaken for wetland monitoring and conservation. This study was done after the implementation of Narmada Canal, and it is unfortunate that no information about the odonate fauna of Nalsarovar before implementation of Narmada canal project is available. Nalsarovar is rich in macrophytes with at least 30 species (GEER Report 1998), and when the water permanency of Nalsarovar increases with the percolation from Narmada canal, the aquatic vegetation is likely to flourish. In such a situation, the impact on Odonata species at NBS needs to be monitored.

REFERENCES

- Balaraman, U. (2008). The unique fauna of ephemeral wetlands of southern Kerala, India, pp. 401–409. In: Sengupta, M. & R. Dalwani (eds.). Proceedings of Taal 2007: The 12th World Lake Conference.
- Baskaran, S.T. (1999). Nalsarovar: a paradigm for wetland, pp. 154–157. In: Baskaran, S.T. (ed.). *The Dance of the Sarus: Essays of A Wandering Naturalist*. Oxford University Press, New Delhi, 260pp.
- Dholu, S. (2015). Odonate diversity reflected by wetland quality and DNA barcoding. MSc Thesis. Department of Agricultural Entomology, Anand Agricultural University, Anand, Gujarat, 108pp.
- Dua, A. & P. Chander (2009). Distribution and abundance of fish populations in Harike wetland - A Ramsar site in India. *Journal of Environmental Biology* 30(2): 247–251.
- Fraser, F.C. (1933). *The Fauna of British India Including Ceylon and Burma, Odonata* - Vol. I. Taylor and Francis Ltd., London, 423pp.
- Fraser, F.C. (1934). *The Fauna of British India Including Ceylon and Burma, Odonata* - Vol. II. Taylor and Francis Ltd., London, 398pp.
- Fraser, F.C. (1936). *The Fauna of British India Including Ceylon and Burma, Odonata* - Vol. III. Taylor and Francis Ltd., London, 461pp.
- Gauriar, S. (1982). A day at Nalsarovar Water Bird Sanctuary. *Newsletter for Birdwatchers* 22(3-4): 7–9.
- GEER Report (1998). *Environmental Impact Assessment of Sardar Sarovar Project on Nalsarovar Bird Sanctuary*. Gujarat Ecological Education and Research Foundation, Gandhinagar, 138+iii pp.
- Islam, M.Z. & A.R. Rahmani (2008). *Potential and existing Ramsar Sites in India*. Indian Bird Conservation Network: Bombay Natural History Society, BirdLife International and Royal Society for the Protection of Birds. Oxford University Press, 592pp.
- IUCN (2017). IUCN Red List of Threatened Species. Version 2017-3 downloaded on 10 January 2018.
- Kiran, C.G. & D.V. Raju (2013). *Dragonflies and Damselflies of Kerala: A Bilingual Photographic Field Guide*. Tropical Institute of Ecological

- Sciences (TIES), Kerala, India, 158pp.
- Kirti, J.S. & A. Singh (2000).** Species diversity in dragonflies of Kanjli wetland (Punjab). *Geobios* 133: 272–273.
- Kumar, N.J.I., H. Soni & R. Kumar (2007).** Patterns of site-specific variation of waterbirds community, abundance and diversity in relation to seasons in Nal Lake Bird Sanctuary, Gujarat, India. *International Journal of Bird Populations* 8: 1–20.
- Kumar, N.J.I., H. Soni & R.N. Kumar (2006).** Biomonitoring of selected freshwater macrophytes to assess lake trace element contamination: a case study of Nalsarovar Bird Sanctuary, Gujarat, India. *Journal of Limnology* 65(1): 9–16.
- Kumar, S. (2008).** Conservation of Sambhar lake - an important waterfowl habitat and a Ramsar site in India, pp. 1509–1517. In: Sengupta, M. & R. Dalwani (eds.). *Proceedings of Taal 2007: The 12th World Lake Conference*.
- Kumar, S. (2009).** *Fauna of Nalsarovar, Gujarat, Wetland Ecosystem Series 11*. Zoological Survey of India, Kolkata, 137pp.
- Mokaria, K. (2015).** Odonates of freshwater wetlands around Thol Bird Sanctuary and Blackbuck National Park, Gujarat. *Jalaplavit* 6(3): 22–37.
- Muni, N. (2004).** Waterfowl census at Nalsarovar. *Flamingo* 2(1&2): 2–3.
- Nair, M.V. (2011).** *Dragonflies & Damselflies of Orissa and Eastern India*. Wildlife Organization, Forest & Environment Department, Government of Orissa, 252pp.
- Palot, M.J. & V.P. Soniya (2000).** Odonata of Keoladeo National Park, Bharatpur, Rajasthan, India. *Zoos' Print Journal* 15(8): 317–320; <http://doi.org/10.11609/joTT.ZPJ.15.8.317-20>
- Pandya, P. (2007).** My experience at Nalsarovar Waterfowl Census, 2006. *Flamingo* 4(1&2): 14–15.
- Parasharya, B.M. (2004).** Waterfowl census at Nalsarovar Bird Sanctuary: Some important records. *Flamingo* 2(1&2): 4–5.
- Prasad, M. (2004).** Insecta: Odonata, pp. 19–40. In: Director-ZSI (ed.). *Fauna of Gujarat. State Fauna Series, 8 (Part 2)*. Zoological Survey of India, Kolkata.
- Prasad, S., K. Pandarinath & S.K. Gupta (1997).** Late quaternary evolution of the Nal region, Gujarat, India, pp. 176–179. In: Das, S.N. & R.S. Thakor (eds.). *Changes in Global Climate due to Natural and Human Causes*. Proceedings of the IGBP Symposium. Allied Publishers Limited, New Delhi, 296pp.
- Ramakrishna, S.Z. Siddiqui & P. Sahu (2006).** *Faunal Resources of Nalaban Wildlife Sanctuary, Chilka, Orissa, Conservation Area Series - 29*. Zoological Survey of India, Kolkata, 36pp.
- Ramsar Regional Center - East Asia (2017).** *The Designation and Management of Ramsar Sites - A Practitioner's Guide*, 26pp. Available at www.ramsar.org and www.rrcea.org accessed on 23rd December 2017.
- Rathod, D.M. (2017).** Odonates diversity of Gujarat and their DNA barcoding for taxonomic validation. PhD Thesis. Department of Agricultural Entomology, Anand Agricultural University, Anand, Gujarat, India, 250pp+73pp.
- Rathod, D.M., S.G. Dholu, B.M. Parasharya & V.S. Mistry (2015).** Odonate diversity of a Wetland of National Importance Pariej. *Jalaplavit* 6(3): 6–15.
- Rohmare, V.B., D.M. Rathod & B.M. Parasharya (2016).** Diversity and population dynamics of Odonata (Insecta: Odonata) in rice growing area of Central Gujarat. *Journal of Biological Control* 30(3): 129–137; <http://doi.org/10.18641/jbc/30/3/97792>
- Rohmare, V.B., D.M. Rathod, S.G. Dholu, B.M. Parasharya & S.S. Talmale (2015).** An inventory of odonates of central Gujarat, India. *Journal of Threatened Taxa* 7(11): 7805–7811; <http://doi.org/10.11609/joTT.o4292.7805-11>
- Saikia, P.K. & M.K. Saikia (2011).** *Biodiversity in Deepor Beel Ramsar Site of Assam, India*. LAP LAMBERT Academic Publishing, 132pp. <https://www.lap-publishing.com>. Accessed on 19 December 2017.
- Sharma, I. & H.S. Mehta (2008).** Fish diversity of Harike Wetland, Punjab - A Ramsar Site. *Bionotes* 10(1): 16–18.
- Singh, D., B. Singh & J.T. Hermans (2017).** Dragonflies and damselflies (Odonata: Insecta) of Keoladeo National Park, Rajasthan, India. *Journal of Threatened Taxa* 9(7): 10445–10452; <http://doi.org/10.11609/jott.3689.9.7.10445-10452>
- Singh, H.S. (2001).** *Natural Heritage of Gujarat*. Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar, India, 262pp.
- Smallshire, D. & T. Beynon (2010).** *Dragonfly Monitoring Scheme Manual*. British Dragonfly Society, UK, Version 2. 12 pp.
- Srivastava, V.D. & C. Sinha (1993).** Insecta: Odonata, pp. 51–168. In: Director-ZSI (ed.). *Fauna of West Bengal, State Fauna Series, 3 (Part 4)*. Zoological Survey of India, Kolkata, 552pp.
- Subramanian, K.A. & R. Babu (2017).** *Checklist of Odonata (Insecta) of India*. Version 3.0. www.zsi.gov.in
- Subramanian, K.A. (2009).** *Dragonflies of India - A Field Guide*. Vigyan Prasara, Department of Science and Technology, New Delhi, 168pp.
- Subramanian, K.A., S. Ali & T.V. Ramachandra (2008).** Odonata as indicators of riparian ecosystem health - a case study from South Western Karnataka, India. *Fraseria*. Proceeding of the 18th International Symposium of Odonatology, Nagpur, 7: 83–95.
- Urfi, A.J. (2000).** A bird count at Nalsarovar: experiences of a participant. *Newsletter for Birdwatchers* 40(3): 33–34.




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

ROOT HOLOPARASITE *BALANOPHORA POLYANDRA* GRIFF. (BALANOPHORACEAE) IN EASTERN HIMALAYA (SIKKIM, INDIA): DISTRIBUTION, RANGE, STATUS AND THREATS

Prem K. Chhetri¹, Alexander R. O'Neill² & Bijoy Chhetri³
^{1,2,3} G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Sikkim Unit, Pangthang, Gangtok, Sikkim 737103, India

¹ Forest Environment and Wildlife Management Department, Govt. of Sikkim, Pakyong, Sikkim, 737106, India

² United States-India Education Foundation (USIEF) and the United States Fulbright Commission, Washington, D.C., 20037, United States of America

¹ chhetriprem22@gmail.com, ² alexander.o.neill@duke.edu, ³ chhetribijoy@yahoo.co.in (corresponding author)

OPEN ACCESS



Abstract: *Balanophora* J.R. Forster & G. Forster (Balanophoraceae) is a poorly studied genus of root holoparasite native to temperate and tropical regions of Asia and the Pacific. The occurrences of *Balanophora polyandra* Griff. were first reported within two protected areas in eastern Himalaya (Sikkim, India), namely, Khangchendzonga National Park and Pangolakha Wildlife Sanctuary. The study assessed the distribution range of *B. polyandra* in Sikkim using data collected from both field surveys and herbarium records, and discussed the threats faced by *Balanophora* populations in the region.

Keywords: *Balanophora*, India, root holoparasite, Sikkim Himalaya.

Botanical surveys have exponentially increased throughout the eastern Himalaya over the past decade (Kandel et al. 2016). The diversity and status of parasitic plants, however, remain poorly understood (O'Neill & Rana 2016). *Balanophora* J.R. Forster & G. Forster (Balanophoraceae) is a genus of root holoparasite, native to the temperate and tropical regions of Africa, Asia, and the Pacific. There is a paucity of ecological records (Shumei & Murata 2003; Pelser et al. 2014; Rao

et al. 2015). Around the world, 19 species in this genus have been recognized so far, of which four are reported in the Himalaya: *Balanophora dioica* R.Br. ex Royle, *B. harlandii* Hook.f., *B. involucreta* Hook.f. & Thomson, and *B. polyandra* Griff. (Eberwein et al. 2009; Su et al. 2012; Rai et al. 2014). These species exhibit drastically reduced morphologies, including minute flowers and scaly leaves (Nickrent & Garcia 2009; Su et al. 2012). They forego photosynthesis, and obtain nutrients from diverse hosts using tuberous organs similar to haustoria (Eberwein et al. 2009). In this article, the occurrence of *B. polyandra* populations within two protected areas in Sikkim Himalaya (India), namely, Khangchendzonga National Park and Pangolakha Wildlife Sanctuary (Fig. 1), are discussed. Further, the distribution range of *B. polyandra*, *B. dioica*, *B. harlandii*, and *B. involucreta* in Sikkim is assessed using data collected from both field surveys and herbarium records of the Botanical Survey of India, Gangtok, Sikkim. Our report addresses the necessary aspects of conservation planning in eastern

DOI: <http://doi.org/10.11609/jott.3644.10.8.12123-12129>

Editor: V. Sampath Kumar, Botanical Survey of India, Howrah, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3644 | Received 08 July 2017 | Final received 04 May 2018 | Finally accepted 01 July 2018

Citation: Chhetri, P.K., A.R. O'Neill & B. Chhetri (2018). Root holoparasite *Balanophora polyandra* Griff. (Balanophoraceae) in eastern Himalaya (Sikkim, India): distribution, range, status and threats. *Journal of Threatened Taxa* 10(8): 12123–12129; <http://doi.org/10.11609/jott.3644.10.8.12123-12129>

Copyright: © Chhetri et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: G.B. Pant National Institute of Himalayan Environment & Sustainable Development, Kosi-Almora, India.

Competing interests: The authors declare no competing interests.

Acknowledgements: We appreciate the guidance of P.P. Dhyani, Director of GBPNIHESD; H.K. Badola, Scientist 'F' and Scientist-in-charge, GBPNIHESD-Sikkim Unit; D.K. Agrawala, Scientist-D, Botanical Survey of India-Gangtok; and the Department of Forests, Environment and Wildlife, Government of Sikkim.



Himalaya, which may guide future IUCN Red List of Threatened Species assessments.

METHODS

Study area

Sikkim is located in northeastern India between 27.53300°N and 88.51944°E surrounded by Bhutan in the east, Nepal in the west, West Bengal in the south, and the Tibetan Autonomous Region of the People's Republic of China in the north, and is contiguous with the Himalayan Biodiversity Hotspot (Telwala et al. 2013).

Data collection

Quarterly surveys were conducted in two protected areas, namely, Khangchendzonga National Park (IUCN Category II) and Pangolakha Wildlife Sanctuary (IUCN Category IV), between October 2015 and March 2017, following a systematic pollard walk transect methodology (see Pollard & Yates 1993; Kerr et al. 2000). While the transect in Khangchendzonga National Park extended from Kisong-Tholung to Panchpokhari, and in Pangolakha Wildlife Sanctuary extended from Lingtam to Zuluk (c. 1,600–4,500 m). During surveys, we recorded botanical characters and ecological notes, and confirmed our identifications at Regional Centre of Botanical Survey of India in Gangtok, Sikkim (see O'Neill

& Rana 2016). Digital media of these specimens are available upon request. The taxonomic designations of Shumei & Murata (2003) were crucial during the identification process, and served as the foundation of the systematic account. Eventually, a digital elevation model for *Balanophora* spp. populations using ArcGIS Version 9.3 was generated (Fig. 1).

RESULTS AND DISCUSSION

Systematic Account

Balanophora polyandra Griff., Proc. Linn. Soc. London 1: 220. 1844.

Holoparasitic herb, dioecious, tubers clustered in coarse agglomeration, cylindrical, surface covered in stellate protuberances and gray to white haustoria, 2–5 cm in diam., chiffon to bluish. Scapes emerge from apex of root segment, 2.0–10.0 × 0.5–1.5 cm, cream to crimson. Leaves decussate, 4–10, whorled, obovate to broadly oblong, concave, apex rounded, margin entire, base attenuate, 1.5–2 × 1.0–1.2 cm, cream to crimson. Inflorescences emerge endogenously from apex of root segments. Staminate inflorescence terminal, narrowly ellipsoid and spadix-like, racemose, 3–10 cm; pedicelled, bracts truncate, c. 1.0mm, cream to tan. Staminate flowers bisymmetrical to zygomorphic, numerous, spirally arranged in conspicuous vertical rows, c. 1cm

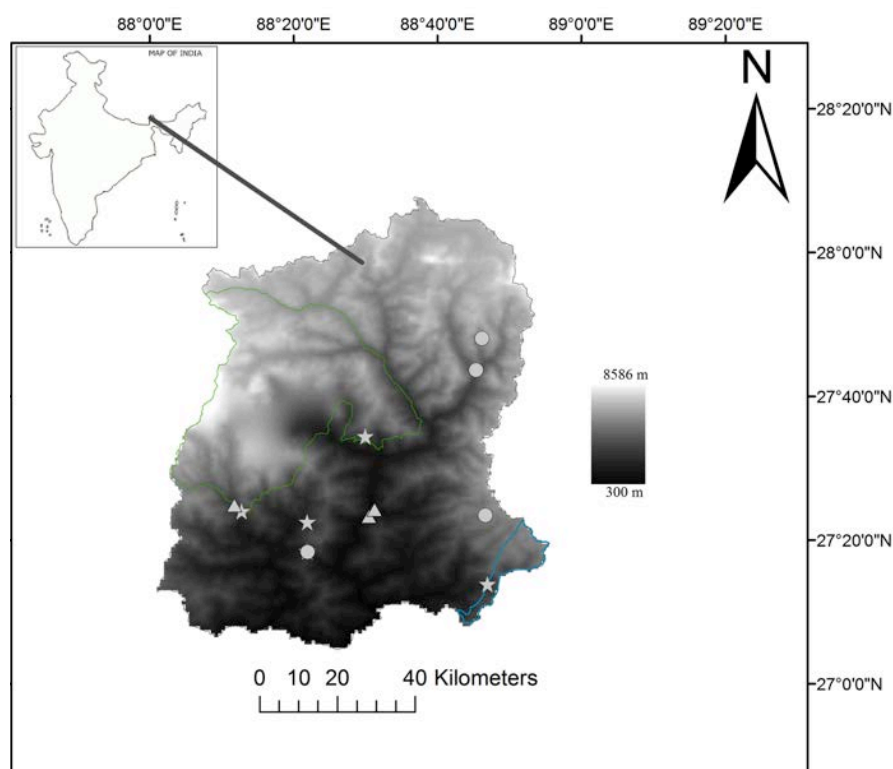


Figure 1. Distribution of *Balanophora* spp. in the Sikkim Himalaya (*Balanophora dioica* ▲; *B. polyandra* ★; *B. involucreta* ●) and new populations of *Balanophora polyandra* in Khangchendzonga National Park (area depicted by green line) and Pangolakha Wildlife Sanctuary (area depicted by blue line)

in diam., pedicels 2–4 mm, apex truncate; lateral tepals deltoid to ovate; syndaria subdiscoïd, 4–5 mm in diam., anthers 25–50 locelli, dehiscent, white. Pistillate inflorescence terminal, ellipsoid to oblong-ovoid, 2.0–3.0 x 1.0–2.5 cm, orange to crimson; spadicles clavate, 1.5–2.5 mm; “apical 1/2 to 2/3 ellipsoid to obovoid, cuticular ridges of apical cells short but distinct and congested” (Shumei & Murata 2003). Pistillate flowers zygomorphic, numerous and minute, c. 1.5mm, arranged on main axis of inflorescence and basal stipe of spadicles, white to cream. Flowering period from August to November.

Distribution and Habitat

B. polyandra exhibits a broad distribution throughout the Himalaya, with populations reported in Bhutan, India (Sikkim), Myanmar, Nepal (Kaski, Mustang, Sankhuwasava, Taplejung), and the People’s Republic of China (Guangxi, Hubei, Hunan, Xizang, and Yunnan) between 1,000m and 3,000m (Shumei & Murata 2003; O’Neill & Rana 2016). This species was first reported

in the eastern Himalaya by J.D. Hooker in the mid-19th century, and has 11 herbaria records at the Botanical Survey of India in Gangtok (Hooker 1855; Appendix 1). The current study is a first time report of seven new occurrences of the species within two protected areas in the Sikkim Himalaya: namely, the Khangchendzonga National Park (KNP) and Pangolakha Wildlife Sanctuary (PWS). In KNP, five populations comprised of 24 individuals (5 staminate and 19 pistillate inflorescences) were found; in the PWS, two populations comprising of four total individuals (1 staminate and 3 pistillate inflorescences; Image 1) were found. These populations found growing in warm-temperate forests (2,000m and 2,300m) dominated by the following woody taxa: *Acer campbellii* (Sapindaceae), *Alnus nepalensis* (Betulaceae), *Betula utilis* (Betulaceae), *Castanopsis tribuloides* (Fagaceae), *Engelhardia spicata* (Juglandaceae), *Eurya japonica* (Pentaphylacaceae), *Exbucklandia populnea* (Hamamelidaceae), *Juglans regia* (Juglandaceae), *Quercus lamellosa* (Fagaceae), *Q. pachyphylla* (Fagaceae),



Image 1. Pistillate (red colour) and staminate (cream colour) inflorescences of *Balanophora polyandra* Griff. (Balanophoraceae) in Khangchendzonga National Park, Sikkim, India.

and *Viburnum grandiflorum* (Adoxaceae). The preferred habitat of *B. polyandra* is shaded, northeastern slopes (35–55°), in soils with 5–8 cm of humus. This species parasitized seven species belonging to four families: *Castanopsis tribuloides* (Fagaceae), *Quercus lamellosa*, *Q. pachyphylla* (Fagaceae), *Eurya japonica* (Pentaphylacaceae), *Evodia fraxinifolia* (Rutaceae), *Symplocos theifolia*, and *S. spicata* (Symplocaceae). During autumn (October and November 2015), it was observed that *Apis cerana* (Apidae) was pollinating pistillate flowers of *B. polyandra* in KNP.

Threats

Deforestation threatens *B. polyandra* populations in Sikkim (Chettri et al. 2002; Pandit et al. 2007; Sharma et al. 2007, 2015). A rough estimate projects up to 40% decrease in forest cover by 2100, with transformations driven by road expansion for defense and ecotourism purposes (Sundriyal & Sharma 1996; Maharana et al. 2000; Chettri et al. 2002; Pandit et al. 2007). Herbaria records from the late 1990s suggest that populations of *B. polyandra* and the congeneric *B. dioica* were inundated during the construction of the Rangit Dam between Nauprik and Bey. The Government of Sikkim, however, has taken progressive strides to mitigate potential forest loss and habitat degradation through policies such as Sikkim Forests and Water Courses (Preservation and Protection) Act 2007. Moreover, the 2016 inscription of KNP as a UNESCO World Heritage Site extends additional protection to the *B. polyandra* populations. Agricultural expansion of large Cardamom (*Amomum subulatum*, Zingiberaceae) may also threaten *Balanophora* spp. habitat in Sikkim (Gaira et al. 2016; Sharma et al. 2016). The acute ramifications of forest conversion for agricultural purposes, however, may be overshadowed by chronic environmental changes, including range shifts of host-plant (*Quercus* spp.) populations (Kumar 2012; Telwala et al. 2013). These host plant populations, too, face high extraction pressures in rural Sikkim (Chettri et al. 2002; Tambe et al. 2011). Although *Balanophora* spp. are reported for their medicinal value, including the treatment of skin diseases, internal parasites, and sexually transmitted infections, they face minimal extraction pressure for these purposes in the eastern Himalaya (Venkatarreddi 1969; Podimuang et al. 1971; Ignacimuthu et al. 2006; Tao et al. 2009; Wang et al. 2013; Sharma 2015).

Based on IUCN Red List of Threatened Species criteria, *Balanophora polyandra* is a Least Concern (LC) species both in Sikkim and throughout the eastern Himalaya due to its wider distribution (extent of occurrence EOO

>20,000km²) and population stability within several protected areas (O'Neill & Rana 2016). Botanical records suggest that *B. dioica*, *B. harlandii*, and *B. involucrata*, too, are Least Concern (LC) species due to their wider distributions reportedly correlated with host-species ranges (Sharma 2002; Shumei & Murata 2003; Thriveni et al. 2016), and location within the protected areas (Jamir & Pandey 2003; Rai et al. 2014). Agricultural expansion threatens *Balanophora* habitats throughout the eastern Himalaya, as well as Assam and Manipur, where mining has increased in recent decades (Sharma 2002; Bora et al. 2010). Census data for *Balanophora* spp. remains limited. One additional species in the Balanophoraceae, *Rhopalocnemis phalloides*, also has a literature record in Sikkim; however, no herbaria accessions are available as of December 2016. MaxEnt habitat suitability modeling may further clarify the range and status of Balanophoraceae in Eastern Himalaya (Kumar 2012; Chhetri & Badola 2017).

REFERENCES

- Bora, H.R., A. Yadav, K. Das & R.K. Kumar (2010). *Balanophora dioica* R. Br. ex Royle (Balanophoraceae): a rare total root parasite reported from Karbi-Anglong District, Assam, India. *Journal of Economic and Taxonomic Botany* 34(2): 298–299.
- Chhetri, B. & H.K. Badola (2017). Predicting suitable habitats for the vulnerable species, *Rhododendron niveum* Hook.f. (Ericaceae) in eastern Himalaya. *NeBio* 8(3): 139–146.
- Chettri, N., E. Sharma, D.C. Deb & R.C. Sundriyal (2002). Impact of firewood extraction on tree structure, regeneration and woody biomass productivity in a trekking corridor of the Sikkim Himalaya. *Mountain Research and Development* 22(2): 150–158; [http://doi.org/10.1659/0276-4741\(2002\)022\[0150:IOFEOT\]2.0.CO;2](http://doi.org/10.1659/0276-4741(2002)022[0150:IOFEOT]2.0.CO;2)
- Eberwein, R., D.I. Nickrent & A. Weber (2009). Development and morphology of flowers and inflorescences in *Balanophora papuana* and *B. elongata* (Balanophoraceae). *American Journal of Botany* 96(6): 1055–1067; <http://doi.org/10.3732/ajb.0800289>
- Gaira, K.S., R.S. Rawal & K.K. Singh (2016). Variations in pollinator density and impacts on large cardamom (*Amomum subulatum* Roxb.) crop yield in Sikkim Himalaya, India. *Journal of Asia-Pacific Biodiversity* 9(1): 17–21; <http://doi.org/10.1016/j.japb.2015.12.010>
- Hooker, J.D. (1855). *Himalayan Journals: Notes of A Naturalist in Bengal, the Sikkim and Nepal Himalayas, the Khasia Mountains, etc.* John Murray, London.
- Ignacimuthu, S., M. Ayyanar & K.S. Sivaraman (2006). Ethno botanical investigations among tribes in Madurai District of Tamil Nadu (India). *Journal of Ethnobiology and Ethnomedicine* 2: 25; <http://doi.org/10.1186/1746-4269-2-25>
- Jamir, S.A. & H.N. Pandey (2003). Vascular plant diversity in the sacred groves of Jaintia Hills in northeast India. *Biodiversity and Conservation* 12: 1497–1510; <http://doi.org/10.1023/A:1023682228549>
- Kandel, P., J. Gurung, N. Chettri, W. Ning & E. Sharma (2016). Biodiversity research trends and gap analysis from a transboundary landscape, Eastern Himalayas. *Journal of Asia-Pacific Biodiversity* 9(1): 1–10; <http://doi.org/10.1016/j.japb.2015.11.002>
- Kerr, J.T., A. Sugar & L. Packer (2000). Indicator taxa, rapid biodiversity assessment, and nestedness in an endangered ecosystem. *Conservation Biology* 14(6): 1726–1734; <http://doi.org/10.1111/j.1523-1739.2000.99275.x>
- Kumar, P. (2012). Assessment of impact of climate change on *Rhododendrons* in Sikkim Himalayas using MaxEnt modelling:

- limitations and challenges. *Biodiversity Conservation* 21: 1251; <http://doi.org/10.1007/s10531-012-0279-1>
- Nickrent, D.L. & M.A. Garcia (2009). On the brink of holoparasitism: plastome evolution in dwarf mistletoes (*Arceuthobium*, Viscaceae). *Journal of Molecular Evolution* 68: 603–615; <http://doi.org/10.1007/s00239-009-9224-7>
- O'Neill, A.R. & S.K. Rana (2016). An ethnobotanical analysis of parasitic plants (*Parijibi*) in the Nepal Himalaya. *Journal of Ethnobiology and Ethnomedicine* 12: 14; <http://doi.org/10.1186/s13002-016-0086-y>
- Maharana, I., S.C. Rai & E. Sharma (2000). Environmental Economics of the Khangchendzonga National Park in the Sikkim Himalaya, India. *GeoJournal* 50: 329–337.
- Pandit, M.K., N.S. Sodhi, L.P. Koh, A. Bhaskar & B.W. Brook (2007). Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalayas. *Biodiversity and Conservation* 16: 153–163; <http://doi.org/10.1007/s10531-006-9038-5>
- Pelser, P.B., D.N. Tandang, & J.F. Barcelona (2014). *Balanophora coralliformis* (Balanophoraceae), a new species from Mt. Mingan, Luzon, Philippines. *Phytotaxa* 170(4): 291–295; <http://doi.org/10.11646/phytotaxa.170.4.7>
- Podimuang, V., S. Mongkolsuk, K. Yoshihira & S. Natori (1971). Constituents of three Thai medicinal plants: *Ardisia polycephala* (Myrsinaceae), *Rhabdia lycoides* (Boraginaceae), and *Balanophora poylandra* (Balanophoraceae). *Chemical and Pharmaceutical Bulletin* 19(1): 207–208.
- Pollard, E. & T.J. Yates (1993). *Monitoring Butterflies for Ecology and Conservation*. Chapman and Hall, London, 292pp.
- Rai, I.D., B.S. Adhikari & G.S. Rawat (2014). A rare and endangered root parasite *Balanophora involucreata* Hook.f. & Thompson. *Indian Forester* 140(4): 435–436.
- Rao, J.P., K.V. Satish, B.S. Sankar, C.S. Reddy & A. Kumar (2015). On the occurrence of parasitic plant *Balanophora fungosa* J.R. Forster & G. Forster (Balanophoraceae) in Andhra Pradesh, India. *Journal of Threatened Taxa* 7(2): 6943–6946; <http://doi.org/10.11609/JoTT.o3962.6943-6>
- Sharma, E., S. Bhuchar, M. Xing & B.P. Kothiyari (2007). Land use change and its impact on hydro-ecological linkages in Himalayan watersheds. *Tropical Ecology* 48(2): 151–161.
- Sharma, G., U. Partap, D.R. Dahal, D.P. Sharma & E. Sharma (2016). Declining large-cardamom production systems in the Sikkim Himalayas: climate change impacts, agro-economic potential, and revival strategies. *Mountain Research and Development* 36(3): 286–298; <http://doi.org/10.1659/MRD-JOURNAL-D-14-00122.1>
- Sharma, M.P. (2002). *Balanophora dioica* Royle (Balanophoraceae): an addition to the flora of Delhi. *Journal of Economic and Taxonomic Botany* 26(1): 103–104.
- Sharma, N. (2015). A restricted distribution of rare and endangered *Balanophora involucreata* Hook.f. & Thompson in Jammu and Kashmir, India. *Indian Forester* 141(5): 583–584.
- Sharma, N., A.P. Das & D.G. Shrestha (2015). Landuse and landcover mapping of East District of Sikkim using IRS P6 Satellite Imagery. *Pleione* 9(1): 193–200.
- Shumei, H. & J. Murata (2003). Balanophoraceae. *Flora of China* 5: 272–276.
- Su, H.J., J. Murata & J.M. Hu (2012). Morphology and phylogenetics of two holoparasitic plants, *Balanophora japonica* and *Balanophora yakushimensis* (Balanophoraceae), and their hosts in Taiwan and Japan. *Journal of Plant Research* 125: 317–236.
- Sundriyal, R.C. & E. Sharma (1996). Anthropogenic pressure on tree structure and biomass in the temperate forest of Mamlay watershed in Sikkim. *Forest Ecology and Management* 81: 113–134; [http://doi.org/10.1016/0378-1127\(95\)03657-1](http://doi.org/10.1016/0378-1127(95)03657-1)
- Tambe, S., M.L. Arrawatia & N. Sharma (2011). Assessing the priorities for sustainable forest management in the Sikkim Himalaya, India: a remote sensing based approach. *Journal of the Indian Society of Remote Sensing* 39(4): 555–564.
- Tao, R., F. Ye, Y. He, Y. Tian, G. Liu, T. Ji & Y. Su (2009). Improvement of high-fat-diet-induced metabolic syndrome by a compound from *Balanophora polyandra* Griff. in mice. *European Journal of Pharmacology* 616: 328–333; <http://doi.org/10.1016/j.ejphar.2009.06.011>
- Telwala, Y., B.W. Brook, K. Manish & M.K. Pandit (2013). Climate-Induced Elevation Range Shift and Increase in Plant Species Richness in a Himalayan Biodiversity Epicenter. *PLoS ONE* 8(2): e57103; <http://doi.org/10.1371/journal.pone.0057103>
- Thriveni, M.C., G.R. Shivamurthy & K.N. Amruthesh (2016). *Balanophora dioica* (Balanophoraceae): a new record for South India from Western Ghats. *The Bulletin of the Botanical Survey of India* 58: 1017–110; <http://doi.org/10.20324/nelumbo/v58/2016/105917>
- Venkatareddi, B. (1969). A new species of *Acroblastum* (Balanophoraceae) from Poona District, India. *Willdenowia* 5(3): 389–393.
- Wang, Y., J. Yang, A. Wang, J. Ma, J. Tian, T. Ji & Y. Su (2013). Hydrolyzable tannins from *Balanophora polyandra* Griff. *Acta Pharmaceutica Sinica B* 3(1): 46–50; <http://doi.org/10.1016/j.apsb.2012.12.003>

Appendix 1. Records of *Balanophora* spp. (Balanophoraceae) in Sikkim Himalaya based on herbarium data, (Sikkim Himalayan Regional Centre, BSI, Gangtok) and present field study (marked with *)

Species	District	Locality	Altitude	Coordinates (°N °E)		Date of Collection /date of study	Collector(s)/ observer(s)	Collection no./Acc. no.	Notes from Herbarium labels
<i>Balanophora dioica</i> Royle	West Sikkim	Sachen (Old Goath Below)	N/A	27.41353	88.19674	2009	S.K. Rai; K. Das	44711	Petals 4, anthers many, flowers white, clustered in dome head, young one pinkish, leafy stem
<i>Balanophora dioica</i> Royle	West Sikkim	Sachen (Old Goath Below)	N/A	27.41353	88.19674	2009	S.K. Rai; K. Das	44712	Petals 4, anthers many, flowers white, clustered in dome head, young one pinkish, leafy
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu (NHPC Dam Site)	750m	27.38785	88.50788	1997	S.K. Jana	33657	Grows on marshy land
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu (NHPC Dam Site); Note: Probably from Nauprik to Bey	720m	27.38785	88.50788	1997	S.K. Jana	33661	Grows on marshy land
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu (NHPC Dam Site)	720m	27.38785	88.50788	1997	S.K. Jana	33660	Grows on marshy land
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu (NHPC Dam Site)	721m	27.40359	88.52144	1997	S.K. Jana	33659	Grows on marshy land
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu, Right Flank	N/A	27.40359	88.52144	19-97	B.K. Shukla	33658	Root parasite, petal coffee colour, herbs up to 20cm tall
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu, Right Flank	N/A	27.40359	88.52144	1997	B.K. Shukle	22604	Root parasite, petal coffee colour, herbs up to 20cm tall
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu, Right Flank	N/A	27.40359	88.52144	1997	B.K. Shukla	22602	Root parasite, petal coffee colour, herbs up to 20cm tall
<i>Balanophora dioica</i> Royle	West Sikkim	Tshoka to Gumsa	N/A	27.38785	88.50788	2009	S.K. Rai; K. Das	44625	Flowering head pinkish, stem yellow, sheathed; root parasite
<i>Balanophora dioica</i> Royle	West Sikkim	Tshoka to Gumsa	N/A	27.38785	88.50788	2009	S.K. Rai; K. Das	44626	Flowering head pinkish, stem yellow, sheathed; root parasite
<i>Balanophora involucreta</i> Hook.f.	North Sikkim	Singba 'A'	N/A	27.80109	88.76956	2011	Dr. K Das; S.K. Rai	43891	Root parasite, found in the Rhododendron forest, head pinkish, red, root dotted below
<i>Balanophora involucreta</i> Hook.f.	North Sikkim	Singba 'A'	N/A	27.80109	88.76956	2011	Dr. K Das; S.K. Rai	43892	Root parasite, found in the Rhododendron forest, head pinkish, red, root dotted below
<i>Balanophora involucreta</i> Hook.f.	North Sikkim	Lachung to Dombeyang	N/A	27.73649	88.21318	1987	D.C.S. Raju; S. Singh	15918	Roots or stem parasites, whole plant yellow, leaves and flowers yellow
<i>Balanophora involucreta</i> Hook.f.	North Sikkim	Lachung to Dombeyang	N/A	27.73649	88.21318	1987	D.C.S. Raju; S. Singh	15917	Roots or stem parasites, whole plant yellow, leaves and flowers yellow
<i>Balanophora involucreta</i> Hook.f.	East Sikkim	Karponang	N/A	27.39104	88.77742	1984	B. Krishna; S. Singh	5636	Root parasite, petals 5, reddish
<i>Balanophora involucreta</i> Hook.f.	East Sikkim	Karponang	N/A	27.39104	88.77742	1984	B. Krishna; S. Singh	5637	Root parasite, petals 5, reddish
<i>Balanophora involucreta</i> Hook.f.	East Sikkim	Forest behind Elephant Mansion, Gangtok	N/A	27.30574	88.36578	1980	P. Chakraborty	4345	N/A
<i>Balanophora involucreta</i> Hook.f.	East Sikkim	Forest behind Elephant Mansion, Gangtok	N/A	27.30574	88.36578	1980	P. Chakraborty	4578	Fleshy leaves with tuberous roots

<i>Balanophora polyandra</i> Griff.	South Sikkim	Rabongla (East Side)	N/A	27.30654	88.3648	2008	S.K. Rai	42932	Herbs, flowers white, powdery, male cone reddish, bracteate, lanceolate
<i>Balanophora polyandra</i> Griff.	South Sikkim	Rabongla (East Side)	N/A	27.30654	88.3648	2008	S.K. Rai	42933	Herbs, flowers white, powdery, male cone reddish, bracteate, lanceolate
<i>Balanophora polyandra</i> Griff.	South Sikkim	Rabongla (East Side)	N/A	27.30654	88.3648	2008	S.K. Rai	42931	Herbs, flowers white, powdery, male cone reddish, bracteate, lanceolate
<i>Balanophora polyandra</i> Griff.	West Sikkim	Karchi R.F.	2,000m	27.37405	88.3648	1999	B.K. Shukla	22603	Root parasite grows in temperate forest up to 15 cm tall
<i>Balanophora polyandra</i> Griff.	West Sikkim	Karchi R.F.	2,000m	27.37405	88.3648	1999	B.K. Shukla	35022	Root parasite grows in temperate forest up to 15 cm tall
<i>Balanophora polyandra</i> Griff.	West Sikkim	Karchi R.F.	2,000m	27.37405	88.3648	1999	B.K. Shukla	35023	Root parasite grows in temperate forest up to 15 cm tall
<i>Balanophora polyandra</i> Griff.	West Sikkim	Karchi R.F.	2,000m	27.37405	88.3648	1999	B.K. Shukla	35024	Root parasite grows in temperate forest up to 15 cm tall
<i>Balanophora polyandra</i> Griff.	West Sikkim	Yuksom; After Karthok Pokhari	N/A	27.37233	88.22231	1992	R.C. Srivastava	35025	Parasitic herbs on hil base in bridge; basal thint yellowish seed stem brown flowers whorled
<i>Balanophora polyandra</i> Griff.	West Sikkim	Yuksom; After Karthok Pokhari	N/A	27.37233	88.22231	1992	R.C. Srivastava	35026	Parasitic herbs on hil base in bridge; basal thint yellowish seed stem brown flowers whorled
<i>Balanophora polyandra</i> Griff.	West Sikkim	Yuksom; After Karthok Pokhari	N/A	27.37233	88.22231	1992	R.C. Srivastava	35027	Parasitic herbs on hil base in bridge; basal thint yellowish seed stem brown flowers whorled
<i>Balanophora polyandra</i> Griff.	West Sikkim	Yuksom-Bakhim Trek (Sachen)	N/A	27.39917	88.21318	2004	S.K. Rai; Arun Kr. Chhetri	43293	Saprophytic, flowers globose white
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	2,227m	27.57263	88.49970	2016	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, female cone cream colour, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	1,991m	27.55239	88.49929	2016	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, female cone like racemose with cream colour, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	2,183m	27.57242	88.49916	2016	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, female cone like racemose with cream colour, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	2,376m	27.5765	88.51075	2017	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	1,826m	27.5765	88.51075	2017	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	East Sikkim	Pangolakha Wildlife Sanctuary	2,044m	27.2378	88.76441	2017	P.K. Chhetri*	N/A	Herbs, flowers, male cone reddish and female cone turned into blackish, grown on shady area of temperate forest
<i>Balanophora polyandra</i> Griff.	East Sikkim	Pangolakha Wildlife Sanctuary	2,152m	27.23868	88.76996	2017	P.K. Chhetri*	N/A	Herbs, flower male cone reddish grown on shady area of temperate forest





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

OPEN ACCESS



The family Zodariidae Thorell, 1881 is known with 1,123 species and 84 genera from the world but is very poorly represented in India: 29 species and 10 genera (WSC 2017); out of which, all the Indian species under *Storena* Walckenaer, 1805 (seven species) and *Lutica* Marx, 1891 (four species) are considered as misplaced in the genus (WCS

2017).

During spider surveys in Jambughoda Wildlife Sanctuary, Gujarat in January–March 2013, ground spiders were collected by pitfall trap method. A male specimen was collected from the sanctuary at: 22.36099°N & 73.665394°E, altitude 244m, Gujarat, India. All measurements are in mm. Morphological observations and illustrations were made by MS using CETII™ stereomicroscope and camera lucida attached to it. Scanning Electron Microscope images for palp were taken through SEM-Zeiss EVO-40EP at the Wadia Institute of Himalayan Geology, Dehradun. Specimen is deposited at the public museum of Wildlife Information Liaison Development Society, Coimbatore, Tamil Nadu, India.

Initially, the zodariid spider specimens collected were identified as *Storena gujaratensis* Tikader & Patel, 1975 based on the distinct palp structure (see details below). None of the other *Storena* spp. possess this character. *S. gujaratensis* was described from Napad, Kaira (=Kheda) District, Gujarat based on a male

TRANSFER OF *STORENA GUJARATENSIS* TIKADER & PATEL, 1975 TO THE GENUS *SUFFASIA* JOCQUÉ, 1991 (ARANEAE: ZODARIIDAE)

Reshma Solanki¹, Manju Siliwal² & Dolly Kumar³

^{1,3} Department of Zoology, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodra, Gujarat 390002, India

² Wildlife Information Liaison Development Society, 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti, Coimbatore, Tamil Nadu 641035, India

¹solankireshma46@gmail.com, ²manjusiliwal@gmail.com,

³dollymsu@gmail.com (corresponding author)

Abbreviations: ALE - anterior lateral eyes; AME - anterior median eyes; PLE - posterior lateral eyes; PME - posterior median eyes; WILD - Wildlife Information Liaison Development Society; WSC - World Spider Catalogue. Abbreviations used for spine count are: disp. - dispersed, not in obvious row; fe - femur; mt - metatarsus; p - prolateral; pa - patella; r - retrolateral; ti - tibia; v - ventral.

specimen. The authors did not provide information on the type specimen depository and catalog number. We assumed that the specimen was deposited at Zoological Survey of India (ZSI), Kolkata but one of the authors (MS) could not locate this specimen at ZSI, Kolkata. It is likely that Dr. B.H. Patel retained the specimen in his private collection (however, since his death in 2013 we have no knowledge of the status of his collection). Distance between the type locality and Jambughoda Wildlife Sanctuary is about 130km by road without any major geographical barrier, which reflects a wide distribution

DOI: <http://doi.org/10.11609/jott.3452.10.8.12130-12132>

Editor: Anonymity requested.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 3452 | Received 20 April 2017 | Final received 26 June 2017 | Finally accepted 18 July 2018

Citation: Solanki, R., M. Siliwal & D. Kumar (2018). Transfer of *Storena gujaratensis* Tikader & Patel, 1975 to the genus *Suffasia* Jocqué, 1991 (Araneae: Zodariidae). *Journal of Threatened Taxa* 10(8): 12130–12132; <http://doi.org/10.11609/jott.3452.10.8.12130-12132>

Copyright: © Solanki et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are grateful to the following personnel/Organizations: PCCF, Gujarat Forest Department for giving permission to carry out spider surveys in Jambughoda Wildlife Sanctuary; Department of Zoology, Faculty of Science, The Maharaja Sayajirao University of Baroda for granting UGC-RFMS fellowship; Dr. Rudy Jocque for confirmation of the genus; Dr. Yuri M. Marusik for reviewing the draft manuscript and providing valuable comments; Mr. Kartik Upadhyay and Mr. Harshad Bariya, for their assistance during field work; Shri N.K. Juyal, Jr. Technical Officer, Wadia Institute of Himalayan Geology, Dehradun for providing facility to procure SEM images.



range of this species.

As all Indian species under *Storena* are misplaced in the genus as per WCS (2017), we looked out for characters of *S. gujaratensis* matching with other genera. We noticed presence of hook shaped dorsal cymbial flange, large tegulum, moderately long and thick embolus and a few of these characters typically found in *Suffasia* Jacque, 1991. The members of *Suffasia* can be differentiated from other genera by presence of dorsal cymbial flange overlapping palpal tibia, presence of cymbial lateral pit and swollen venter of the abdomen in male, whereas females can be distinguished by the epigyne structure with frontal entrance openings and the course of the copulatory ducts (Jocqué 1991; Jocqué 1992). Although all characters of male did not match with the *Suffasia* especially absence of cymbial lateral pit and AME not being small but *Suffasia* also shows high variation in the palp structure within the genus. Further, we found the *S. gujaratensis* male palp structure closely resembled *Suffasia attidiya* Benjamin, 2007 from Sri Lanka by having large embolus and tegulum and RTA short. Therefore, here we transfer *Storena gujaratensis* to *Suffasia*. So far, only three species of the *Suffasia*, viz., *S. ala* Sen et al., 2015, *S. keralaensis* Sudhikumar et

al., 2009 and *S. tigrina* (Simon, 1893) are reported from India (WSC 2017). In this paper, we provide additional morphological characters for *Suffasia gujaratensis* comb. nov. along with illustrations, description of male and natural history notes. High variation is noticed amongst *Suffasia* spp. and therefore a revision of this genus is urgently needed.

Taxonomy

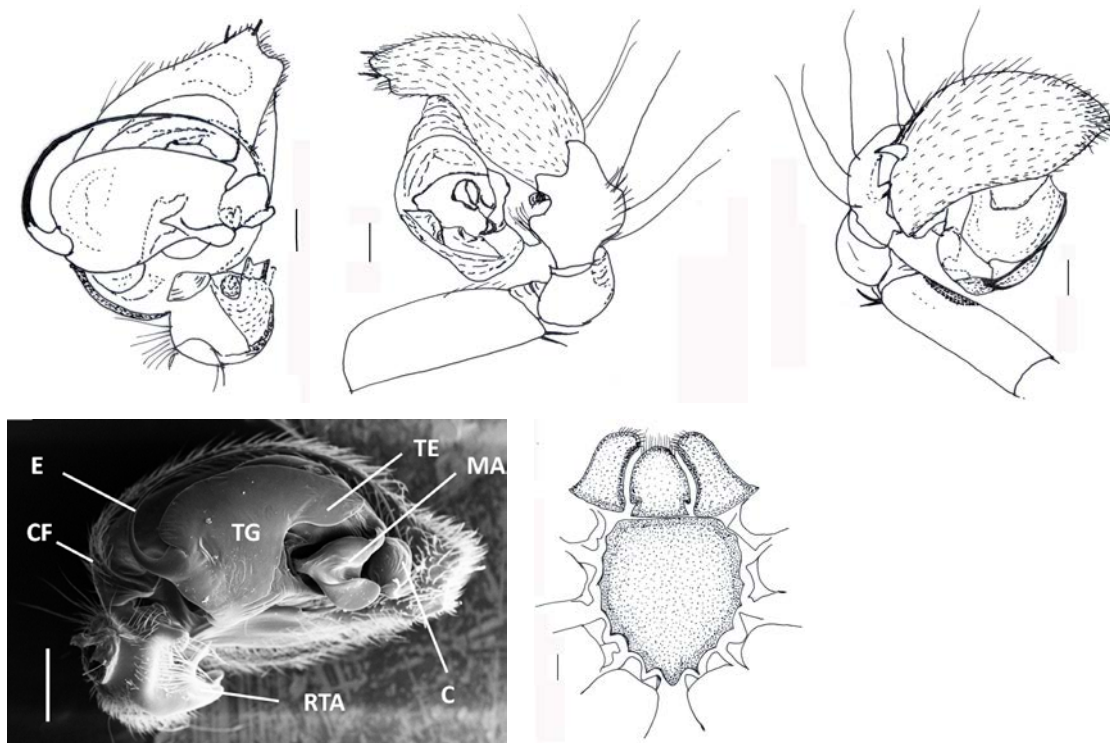
Suffasia gujaratensis (Tikader & Patel, 1975), comb. nov.

(Figs. 1–5, Table 1)

Storena gujaratensis Tikader & Patel, 1975: 138, description of male.

Material examined: WILD-13-ARA-1273, male, 23.i.2013, Bhat, Jambughoda Wildlife Sanctuary, Gujarat, coll. Reshma Solanki.

Description of male: Total length 6.31. Carapace 3.26 long, 2.47 wide. Abdomen 3.05 long, 2.05 wide. Eye diameters and inter-distances: AME 0.28, ALE 0.18, PME 0.15, PLE 0.18; AME-AME 0.078, AME-ALE 0.18, PME-PME 0.13, PME-PLE 0.39, PLE-ALE 0.052. Leg formula:



Figures 1–5. *Suffasia gujaratensis* comb. nov.

1–4 male palp (WILD-14-ARA-1273): 1 - ventral view; 2 - retrolateral view; 3 - prolateral view; 4 - SEM image in ventral view (C - conductor, CF - cymbial fold, E - embolus, MA - median apophysis, RTA - retrolateral tibial apophysis, TE - tegular extension, TG - tegulum); 5 - sternum, maxillae, labium. Scale = 0.1mm for figs. 1,2,3,5; scale = 0.3mm for fig. 4.

Table 1. Legs and palp length of male *Suffasia gujaratensis* comb. nov. from Jambughoda Wildlife Sanctuary, Gujarat.

	Fe	Pa	Ti	Me	Ta	Total
I	2.21	0.95	1.95	2.10	1.53	8.74
II	2.05	0.95	1.58	1.53	1.16	7.27
III	2.05	0.89	1.63	2.00	1.21	7.78
IV	2.58	1.00	2.26	3.00	1.68	10.52
PALP	1.18	0.55	0.58	–	1.79	4.10

4132. Leg spines: I fe d2 p1, ti p2 v6, mt p1 r1 v6; II fe d2 p1, ti p2 v5, mt p2 r1 v6; III fe d4disp. p1 r1, pa p2, ti d5disp. p2 r2 v6, mt d7disp. r2 v6; IV fe d3 p1 r1, pa p2, ti d3disp. p2 r2 v6, mt d17disp. p5 r5 v17disp.

Coloration: Carapace dark reddish-brown. Chelicerae dark reddish-brown with hairs. Sternum yellowish-red, with dark lateral margin, Abdomen dark grey dorsally with 6–7 pairs of white blotches, posterior ones are merged. Ventrally pale in color. Legs pale yellow with spines.

Carapace covered with grey hairs, dense in anterior half. Chelicerae with hairs, presence of sclerotized chillum with hairs. Sternum having triangular extensions which correspond with slight concavities in coxae, uniformly covered with bristles and hairs, bristles with warty appearance, integument rough having net like pattern. Maxillae wider at base gradually narrowing posteriorly, bordered ridge on prolateral surface. Labium longer than wide, arrow shaped. Abdomen dorsally covered with brown hairs, thin scutum ventrally covering book lungs and epigynal area. Ventral abdomen uniformly covered with brown and black color hairs and bristles intermixed. Tracheae small and broad covered with brown hairs, situated just in front of spinnerets, colulus with two hairs. Anterior spinnerets long with two segments, Posterior spinnerets two segmented with apical segment dome shaped.

Palp: Tibia digitiform with two short blunt apophyses and elevated retrolateral margin with distinct process. Cymbium with lateral fold, distally truncated with a notch in the middle; dorsal cymbial flange hook-shaped overlaying palpal tibia. Conductor large flap-like seen distally; tegulum large, sclerotized with very short and blunt tegular extension; embolus slender long and

originates at 6 o'clock position of tegulum on short embolic base.

Comments: *Suffasia gujaratensis* comb. nov. possess some unique characters which have not been previously reported in *Suffasia* like presence of distal cymbial notch, dorsal cymbial hook, large tegulum and absence of cymbial lateral pit. Though, *S. attidiya* possess large tegulum, moderately long embolus and short RTA, diagnosis for the genus is weak as variations within *Suffasia* spp. is high (like in the structure of cymbial flange, presence-absence of cymbial lateral pit; tibial apophysis structure, tegular shape and size; embolic length, etc.). Therefore, we consider *Suffasia* as a species complex and multiple specimens of both the sexes for all the species will help in assigning robust diagnosis for the genus.

Distribution: Jambughoda Wildlife Sanctuary, Gujarat, India.

References

- Benjamin, S. P. (2007). The male of *Suffasia attidiya* (Araneae, Zodariidae). *Journal of Arachnology* 34: 636–637.
- Dankittipakul, P., R. Jocqué & T. Singtripop (2012). Systematics and biogeography of the spider genus *Mallinella* Strand, 1906, with descriptions of new species and new genera from southeast Asia (Araneae, Zodariidae). *Zootaxa* 3369: 1–327.
- Jocqué, R. (1991). A generic revision of the spider family Zodariidae (Araneae). *Bulletin of American Museum of natural History* 201: 1–160.
- Jocqué, R. (1992). A new species and the first males of *Suffasia* with a redilimation [sic] of the subfamilies of the Zodariidae (Araneae). *Revue Suisse de Zoologie* 99: 3–9.
- Simon, E. (1905). Arachnides (1re partie). In Voyage de M. Maurice Maindron dans l'Inde méridionale. 7e Mémoire. *Annals of Society of entomology, France* 74: 160–180.
- Simon, E. (1906). Arachnides (2e partie). In Voyage de M. Maurice Maindron dans l'Inde méridionale. 8e Mémoire. *Annals of Society of entomology, France* 75: 279–314.
- Thorell, T. (1881). Studi sui Ragni Malesi e Papuani. III. Ragni dell'Austro Malesia e del Capo York, conservati nel Museo civico di storia naturale di Genova. *Annali del Museo Civico di Storia Naturale di Genova* 17: 1–727.
- Tikader, B.K. & B.H. Patel (1975). Studies on some rare spiders of the family Zodariidae from India. *Bulletin of the British Arachnological Society* 3: 137–139.
- Walckenaer, C.A. (1805). Tableau des aranéides ou caractères essentiels des tribus, genres, familles et races que renferme le genre Aranea de Linné, avec la désignation des espèces comprises dans chacune de ces divisions. Paris, 88pp.
- WSC (2017). World Spider Catalog. Natural History Museum Bern, online at <http://wsc.nmbe.ch>, version 18.0; accessed on 18th March 2017.



INTRAGUILD PREDATION OF GREEN LACEWING LARVAE (NEUROPTERA: CHRYSOPIDAE) ON SPIDER EGGS AND SPIDERLINGS

K.K. Srikumar¹, S. Smitha², B. Suresh Kumar³ & B. Radhakrishnan⁴

^{1–4} UPASI Tea Research Foundation, Nirar Dam (P.O.), Valparai, Coimbatore, Tamil Nadu 642127, India

¹ Present address: PT Riau Andalan Pulp and Paper, AAA R & D, RAPP Ltd., Pangalan Kerinci 28312, Indonesia

¹ sreeku08@gmail.com (corresponding author), ² smitazoology@gmail.com, ³ bsksuresh999@gmail.com, ⁴ dr.radhaupasi@gmail.com

Tea, *Camellia sinensis* L. (O. Kuntze) plantation provides habitats for thousands of insect species including pests and their natural enemies like parasitoids and predators. The immense value of predators in pest suppression has been well understood by entomologists and there is a renewed interest in biological pest suppression. Classical biological control or periodic inundative release of natural enemies has been most effective in cropping systems where large-scale use of insecticides or their ecologically disruptive practices are minimal (David & Easwaramoorthy 1988). Green lacewings are known to have tolerance to commonly used pesticides (Bigler 1984), and they are relatively easy to rear in captivity (Tulisalo et al. 1984). Laboratory culture and augmentation of *Mallada desjardinsi* (= *boninensis*) is feasible through *Corcyra cephalonica* larvae and artificial diet (Vasanthkumar et al. 2012).

Mallada desjardinsi is an important predator of pests such as mealy bugs and aphids. In tea they are important predator of Red Spider Mite *Oligonychus coffeae* (Vasanthkumar et al. 2012).

Distribution study in India showed Bengaluru, Karnataka, to have the highest density of *M. desjardinsi* population (26.6% and 5.05 ± 0.108 per plant) in the areas sampled (Boopathi et al. 2016).

The larvae of green lacewings are important predators largely used as biological agents. They feed on pest thrips, aphids, scales, caterpillars, and spider mites infesting a variety of plants (McEwen et al. 2001). Adults of green lacewing generally are not predatory and feed on nectar, pollen or honeydew while a few of them are predatory (Coppel & Mertins 1977).

Mallada desjardinsi (Navas) (= *boninensis*) (Neuroptera: Chrysopidae), is reported as an important predator of red spider mite (RSM) *Oligonychus coffeae* Nietner (Acari: Tetranychidae) (Babu et al. 2004; Vasanthkumar et al. 2012). *Mallada desjardinsi* are also considered as generalist predators and are reported as important natural enemies of a variety of pests such as mealy bugs (Mani & Krishnamoorthi 1987), white flies (Selvakumar et al. 1996), bollworms and aphids (Kabissa et al. 1996).

Generalist predators prefer to take prey of whatever size they can handle (Dong & Polis 1992; Finke 1994). If these prey include younger conspecifics or other predators, then control of the herbivore population is not guaranteed. Intraguild predation (IGP) is a combination of the killing and eating species that use similar, often limiting, resources and are thus potential competitors (Polis & Myers 1989); however, there has been little research on the IGP of chrysopids, especially on the *M.*



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

OPEN ACCESS



DOI: <http://doi.org/10.11609/jott.2555.10.8.12133–12136>

Editor: K. Rajmohana, Zoological Survey of India, Kolkata, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 2555 | Received 02 January 2017 | Final received 05 July 2018 | Finally accepted 10 July 2018

Citation: Srikumar, K.K., S. Smitha, B.S. Kumar & B. Radhakrishnan (2018). Intraguild predation of green lacewing larvae (Neuroptera: Chrysopidae) on spider eggs and spiderlings. *Journal of Threatened Taxa* 10(8): 12133–12136; <http://doi.org/10.11609/jott.2555.10.8.12133–12136>

Copyright: © Srikumar et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: UPASI Tea Research Foundation.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to UPASI Tea Research Foundation for providing financial assistance.



desjardinsi in tea ecosystem. Thus the seasonality, IGP on spider eggs and spiderlings and the relationship between the proportion of larvae population and spider population were studied to provide a theoretical foundation for future studies.

The current study was undertaken from December 2014 to November 2015 at UPASI Experimental Farm, Valparai (10.36666°N & 76.96666°E, 1,065m) in Anaimalais province, Tamil Nadu, southern India. Daily field surveys were conducted randomly for a year during morning hours (08:00–10:00 hr) in tea plantations. Wild guava trees, (*Psidium guajava* L.) dispersed in tea plantations support a huge population of the predator *Mallada desjardinsi*. The identification of lacewing was done following standard reference (Babu et al. 2004). The green lacewing larvae were collected and recorded on guava trees. Recorded lacewing larvae were tabulated on monthly interval. The spider population was also assessed in the trees. *Mallada desjardinsi* larvae were found in and around spider egg sacs and spiderlings. The spiders were collected in small glass vials (5ml) with 90% alcohol, brought to the laboratory and identified using standard reference (Tikader 1987; Sebastian & Peter 2009).

Mallada desjardinsi's prey preference was derived from extensive field observations of spiderlings and egg sacs feeding and identification of prey carcasses (trash) taken from the larvae. The larvae of *M. desjardinsi* were collected in glass tubes (25×200 mm length) and brought to the laboratory and trash was examined using a stereomicroscope. Spider egg sacs were also examined in the laboratory. Egg sacs were opened and examined using a

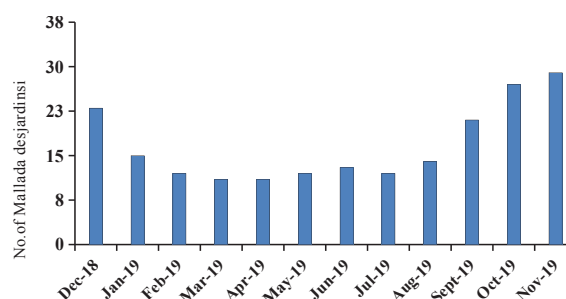


Figure 1. Population of *Mallada desjardinsi* recorded during the period of 2014–2015.

stereomicroscope to determine the number consumed by the predator. Any egg that appeared deflated was counted as consumed. The population abundance of *M. desjardinsi* and spiders (spiderlings and egg sacs) were correlated using Spearman's rank correlation (Siegel & Castellan 1988).

Mallada desjardinsi is a common chrysopid in tea plantations. The larvae are trash carriers and cover themselves with fluffy heaps of debris that conceal their body. The covering included remains of spider egg sacs. It is held in place by hooked spines or bristles on the larva's body. When in motion, the larva's legs and large mandibles can be seen on close inspection. The present study revealed that the fluctuation patterns of *M. desjardinsi* are more or less synchronized in different months. The population was higher during the months of September to December. A synchronized pattern of low population was observed during February to August (Fig. 1). According to regression analysis it seems that

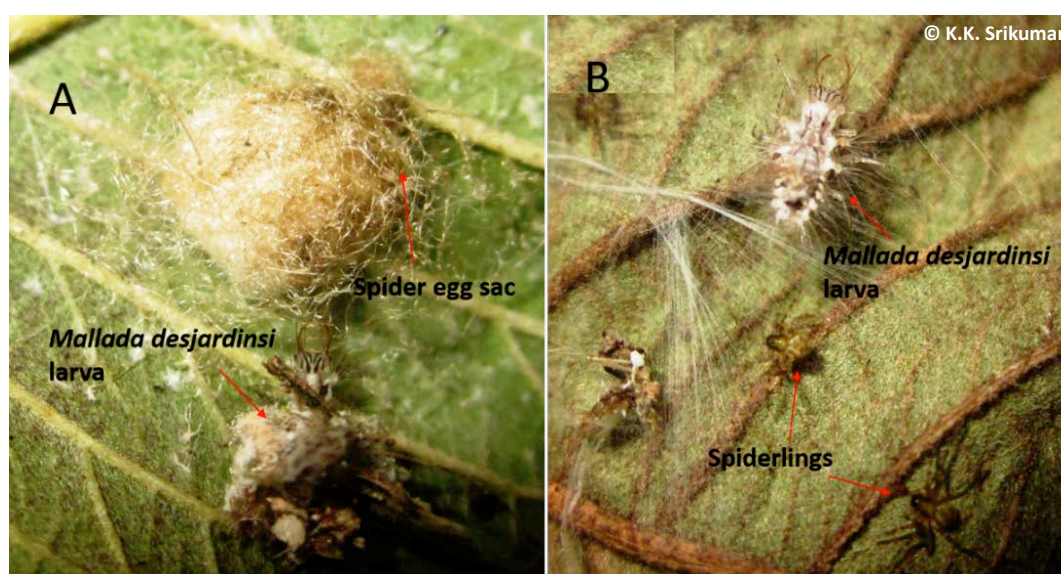


Image 1. *Mallada desjardinsi* larva predation on spider (A) egg sac and (B) spiderlings

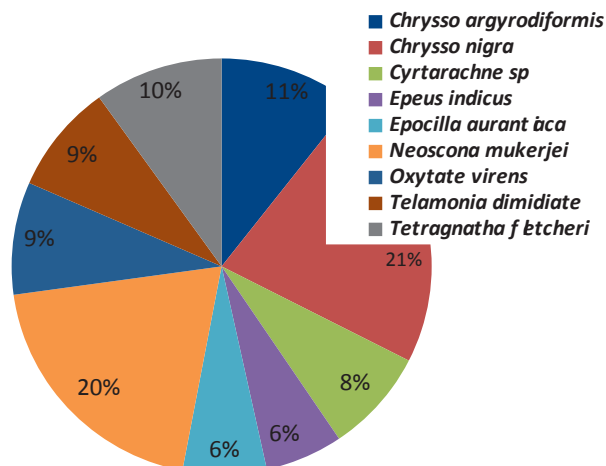


Figure 2. Spider egg sac preference by *Mallada desjardinsi*

the increase in number of species of lacewings correlates with increasing winter temperature, while they decrease with increasing summer precipitation (McEwen et al. 2001).

A total of nine species of spiders were recorded on the guava trees, viz., *Epeus indicus* Proszynski, *Epocilla aurantiaca* Simon, *Chrysso nigra* O.P. Cambridge, *Chrysso argyrodiformis* Yaginuma, *Cyrtarachne sp.*, *Neoscona mukerjei* Tikader, *Oxytate virens* Thorell, *Telamonia dimidiata* Simon and *Tetragnatha fletcheri* Gravely. *Neoscona mukerjei* and *Cyrtarachne sp.* belongs to Araneidae (Orb-web spiders). *Epeus indicus*, *Epocilla aurantiaca* and *Telamonia dimidiata* are jumping spiders (Salticidae). *Chrysso nigra*, *C. argyrodiformis* and *Cyrtarachne sp.* belongs to Theridiidae (Comb-footed spiders). *Oxytate virens* commonly called as green crab spider (Thomisidae). *Tetragnatha fletcheri* Gravely (Long-jawed spiders) belongs to Tetragnathidae. These spiders construct small, irregular webs, typically on the underside of leaves and within the branches. The larvae of *M. desjardinsi* are voracious feeders on these spider egg sacs. The larvae actively seek a previously constructed spider egg sac that they enter through direct penetration (Image 1).

Preference was mostly for abandoned egg sacs and spiderlings. In the field it was observed that the fully grown larvae of *M. desjardinsi*, roamed near and consumed 22% eggs of *C. nigra*, 20% of *N. mukerjei*, 11% of *C. argyrodiformis* and 10% of *Cyrtarachne sp.* and below 10% of the other spider species (Fig. 2).

In the laboratory studies Vanitha et al. (2009) showed that when egg sacs were offered to fully grown larvae of *Chrysoperla*, they consumed eggs of *Oxyopes javanus* and *Clubiona drassodes*, whereas no consumption was observed when the mother was present. The popula-

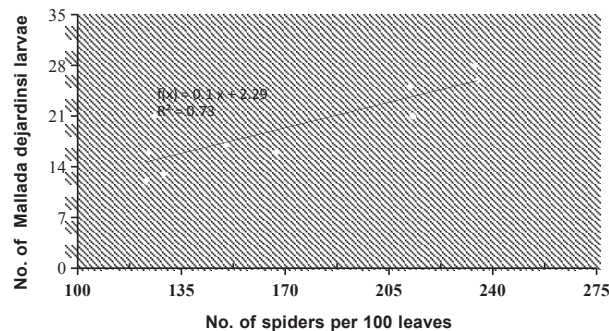


Figure 3. Relation between the population of *Mallada desjardinsi* larvae and spiders

tion of *M. desjardinsi* showed a positive correlation ($R = 0.7347$) with spider population. Thus, the larger the population of spiderlings and egg sacs, the greater the *M. desjardinsi* population (Fig. 3). Noppe et al. (2012) reported that green lacewing, *Chrysoperla carnea* was the superior intraguild predator, winning 88.9% when the experiment was repeated in petri dishes without plant material, regardless of whether green bugs or eggs of *Ephestia kuehniella* Zeller were offered as focal prey.

Intraguild predation by *M. desjardinsi* can be regarded as a mechanism for enabling survival when the red spider mite prey is scarce. Nevertheless, the intraguild predation of *M. desjardinsi* may reduce pest suppression in tea plantations.

References

- Babu, A., R. Selvasundaram, N. Muraleedharan & R. Sasidhar (2004). A new predator of red spider mites. *Newsletter. UPASI Tea Res. Foundation* 14: 1–2.
- Bigler, F. (1984). Biological Control by Chrysopids Integration with Pesticides, pp. 233–245. Canard, M., Y. Semeria & R.T. New (eds.). *Biology of Chrysopidae*. Dr. W. Junk Publishers, Boston.
- Boopathi, T., S. B. Singh, M. Ravi & T. Manju (2016). Distribution and biology of *Mallada desjardinsi* (Neuroptera: Chrysopidae) in India and its predatory potential against *Aleyrodicus dispersus* (Hemiptera: Aleyrodidae). *Journal of Economic Entomology* 109: 1988–1994.
- Coppel, H.C. & J.W. Mertins (1977). *Biological Insect Pest Suppression*. Springer, Berlin, 314pp.
- David, H. & S. Easwaramoorthy (1988). *Biocontrol Technology for Sugarcane Pest Management*. The Seshan Printers, Coimbatore, 372pp.
- Dong, Q. & G.A. Polis (1992). The dynamics of cannibalistic populations: A foraging perspective, pp. 13–37. Cannibalism. Elgar, M.A. & B.J. Crespi (eds.). *Ecology and Evolution Among Diverse Taxa*. Oxford: Oxford Science Publications.
- Finke, O.M. (1994). Population regulation of a tropical damselfly in the larval stage by food limitation, cannibalism, intraguild predation and habitat drying. *Oecologia* 100: 118–127.
- Kabissa, J.C.B., J.C. Yarro, H.Y. Kayumbo & S.A. Juliano (1996). Functional responses of two chrysopid predators feeding on *Helicoverpa armigera* (Lep.: Noctuidae) and *Aphis gossypii* (Hom.: Aphididae). *Entomophaga* 41: 141–151.
- Mani, M. & A. Krishnamoorthy (1987). Feeding potential and development of lacewings, *Mallada boninensis* (Okamoto) on the grape

- mealy bug, *Maconellicoccus hirsutus* (Green). *Entomon* 14: 19–21.
- McEwen, P., T.R. New & A.E. Whittington (2001).** *Lacewings. The Crop Environment*. Cambridge University Press, Cambridge, 546pp.
- Noppe, C., J.P. Michaud & P. De Clercq (2012).** Intraguild predation between lady beetles and lacewings: Outcomes and consequences vary with focal prey and arena of interaction. *Annals of the Entomological Society of America* 105(4): 562–571.
- Polis, G.A. & C.A. Myer (1989).** The ecology and evolution of intraguild predation: potential competitors that eat each other. *Annual review of Ecology and Systematics* 20: 297–330.
- Sebastian, P.A. & K.V. Peter (2009).** *Spiders of India. 1st Edition*. Universities Press, India, 615pp.
- Selvakumaran, S., M. Kallil, S. Devasahayam (1996).** Natural enemies of two major species of scale insects infesting Black Pepper (*Piper nigrum* L.) in India. *Pest Management Horticulture Ecosystem* 2: 79–83.
- Siegel, S. & N.J. Castellan (1988).** *Nonpara-metric Statistics for the Behavioral Sciences. 2nd Edition*. McGraw-Hill International Editions, Singapore.
- Tikader, B.K. (1987).** *Handbook of Indian Spiders*. Zoological Survey of India, Calcutta, 251pp.
- Tulisalo, U., M. Canard, Y. Séméria & T.R. New (1984).** *Biology of Chrysopidae - Biological Control in the Greenhouse*. Dr. W. Junk Publishers, Boston, 228–232pp.
- Vanitha, K.P., P. Sivasubramanian, Z. Kavitharaghavan, C. Vijayaraghavan & K. Samiayyan (2009).** Prey preference, cross predation and impact of some cultural practices on spiders and their abundance in cotton. *Karnataka Journal of Agricultural Science* 22: 548–551.
- Vasanthakumar, D., R.A. Kumar, J.V. Rahman, P. Kumar, C. Sundaravadivelan & A. Babu (2012).** Enhancement of reproductive potential of *Mallada boninensis* Okamoto (Neuroptera: Chrysopidae), a predator of red spider mite infesting tea: an evaluation of artificial diets. *Archives of Biological Science* 64: 281–285.



REDISCOVERY, EXTENDED DISTRIBUTION AND CONSERVATION ASSESSMENT OF *CINNAMOMUM GOAENSE* (LAURACEAE) IN THE WESTERN GHATS, INDIA

M.P. Geethakumary¹, S. Deepu² & A.G. Pandurangan³

^{1,2,3} Plant Systematics and Evolutionary Science Division, Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram, Kerala 695562, India
¹geethatbg@gmail.com, ²deepu_sdas@jntbgri.res.in, ³agpandurangan@gmail.com (corresponding author)

Abbreviation: ‘A’ - Arnold Herbarium; ‘L’ - Leiden Herbarium

The genus *Cinnamomum* Schaeffer includes an old-world group, predominantly distributed in subtropical to tropical Asia, plus a few species in Australia and the western Pacific area, as well as a New World group in Central and South America (Rohde et al. 2017). Rohwer (1993) estimated the total number of species to c. 350, of which 52 New World species have been recently transferred to *Aiouea* Aubl. (Rohde et al. 2017). In India, this genus is represented by 49 species of which 26 occur in the Western Ghats (Geethakumary et al. 2017). During our botanical explorations in the Western Ghats, we collected an interesting specimen of *Cinnamomum* from Idukki District of Kerala. A detailed study of the relevant literature confirmed its identity as *Cinnamomum goaense* Kosterm., described by Kostermans (1985) based on the collections of Fernandes and Stocks. From a thorough literature survey and herbarium consultation, it became apparent that this taxon had not been collected since

1950. Hence our discovery is a recollection of this species after a lapse of 57 years. In the collection by Fernandez (A00041271!, L0035798!) the locality is given as ‘towards old Gund village, E of Goa Border’, and the collection of Stocks is from Canara (L0309076!). Both these places refer not to point localities, but to geographically extensive political areas of the late colonial period, which belongs to “North Kanara” District, representing localities in Uttara Kannada, Karnataka State. Interestingly, the collection of Fernandez is around 100 years after the collection of Stocks as is evident from the fact that the collections of Stocks from this region were mainly during the 1840s (probably during 1847). The present collection forms a new record for Kerala and an extension in the distribution of this species to the southern Western Ghats after the Palghat gap, which is of phytogeographic significance.

A detailed description and other relevant information are provided based on recent collections. The conservation status of this species is also assessed in light of the present collection.

Cinnamomum goaense Kosterm., Bull. Bot. Surv. India 25: 94. 1985 (1983). (Fig. 1)

Type: India, southern India, Bombay Presidency, towards old Gund village, E of Goa border, 13 May 1950, J. Fernandes 1453 (Holotype: -A00041271!, Isotype: -L0035798!).

Trees, 6–9 m high; branchlets slender, angular, sub appressed pilose. Leaves opposite or sub-opposite,



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

OPEN ACCESS



DOI: <http://doi.org/10.11609/jott.4013.10.8.12137-12139>

Editor: P. Lakshminarasimhan, Botanical Survey of India, Pune, India.

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 4013 | Received 15 January 2018 | Final received 07 June 2018 | Finally accepted 30 June 2018

Citation: Geethakumary, M.P., S. Deepu & A.G. Pandurangan (2018). Rediscovery, extended distribution and conservation assessment of *Cinnamomum goaense* (Lauraceae) in the Western Ghats, India. *Journal of Threatened Taxa* 10(8): 12137–12139; <http://doi.org/10.11609/jott.4013.10.8.12137-12139>

Copyright: © Geethakumary et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: JNTBGRI Plan Grant and DST-SERB, Government of India (PDF/2016/000371).

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are grateful to the curators of Leiden (L) and Arnold (A) herbarium for providing access to images of the species, the Kerala Forest Department for giving permission and logistic support to conduct field studies and the Kerala State Council for Science and Technology for financial assistance through JNTBGRI Plan Grants. The second author acknowledges DST-SERB, Government of India for the financial assistance.



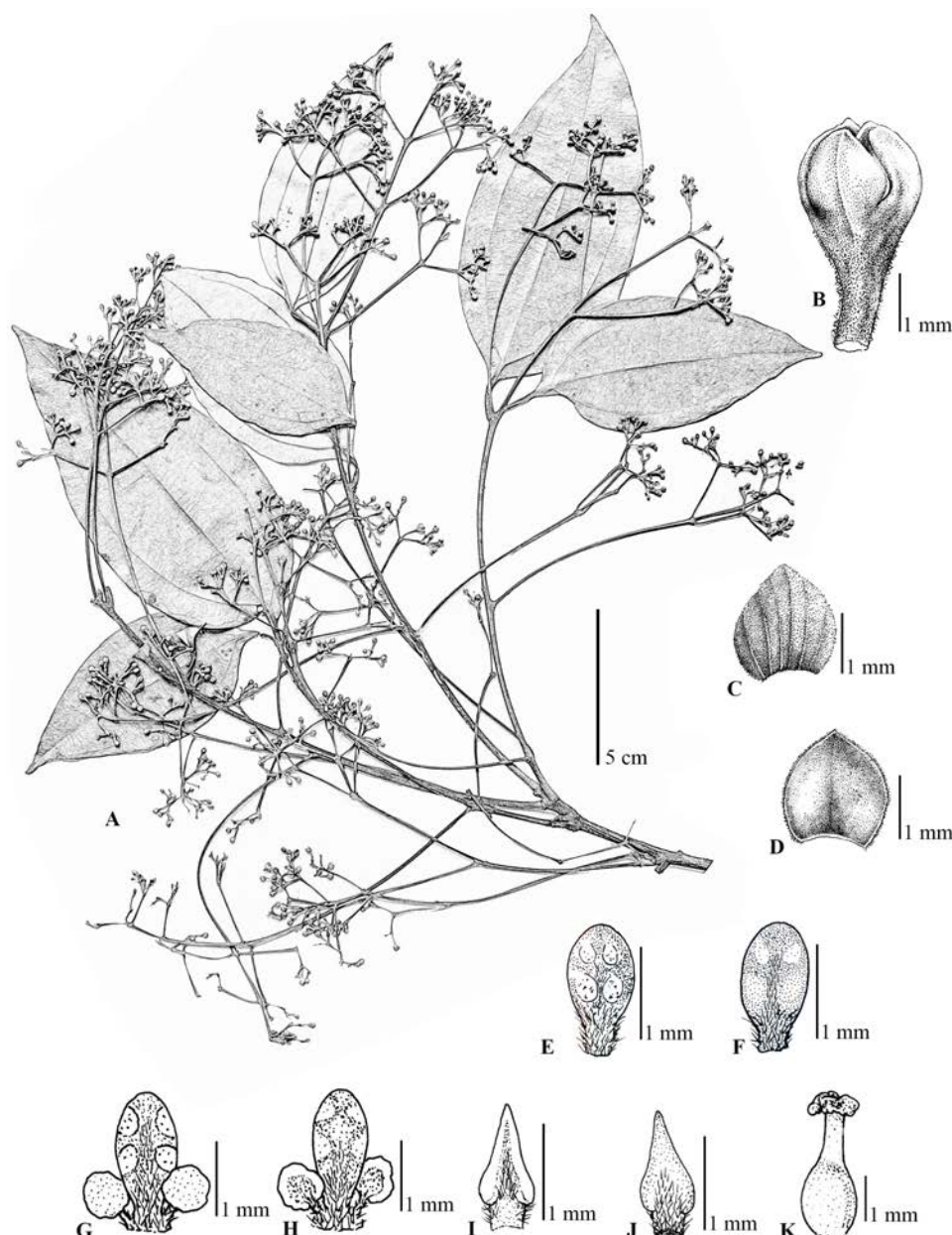


Figure 1. *Cinnamomum goaense* Kosterm.

A - Flowering twig; B - Flower; C-D - Tepal; E-F - Stamens of outer whorl; G-H - Stamens of inner whorl; I-J - Staminode; K - Pistil [from Geethakumary 53695].

sub-ovate or ovate-oblong or ovate-lanceolate, 7–26 × 5.2–7.3 cm, coriaceous, glabrous, paler beneath, acute at base, entire, gradually acuminate at apex, acumen 1–2 cm long; midrib slender, prominent, lateral nerves arising c. 5 mm above base, reaching near apex, tertiary nerves parallel, 3–4 mm apart; petioles slender, c. 1.6 cm long, slightly canaliculated. Panicles axillary or pseudo-terminal, many-flowered, minutely sericeous; main peduncle slender, 8–18 cm long; branchlets 2–6, slender, c. 6 cm long. Flowers pale yellow, 5–8 × c. 5 mm, aggregated near apex of inflorescence branches. Tepals 6

in 2 whorls of 3 each, ovate or ovate-oblong, 2–3 × 2–2.5 mm, sericeous within, apex obtuse to acute. Stamens 9 in 3 whorls of 3 each; all 4-locellate; whorls I and II 1.5–2 mm long, anthers ellipsoid, introrse; filaments c. 0.8 mm long, hirsute; whorl III c. 2 mm long, anthers oblong, extrorse; glands shortly stipitate, flat, c. 0.6 mm long, attached to basal portion of the filaments; staminodes shorter than anthers, c. 1.3 mm long, sagittate, stipes pilose. Ovary ellipsoid, c. 1 mm long, glabrous, style c. 1 mm long, cylindrical; stigma peltate. Fruits ellipsoid, c. 6 × 10 mm; cupule cup-shaped, base conical, with

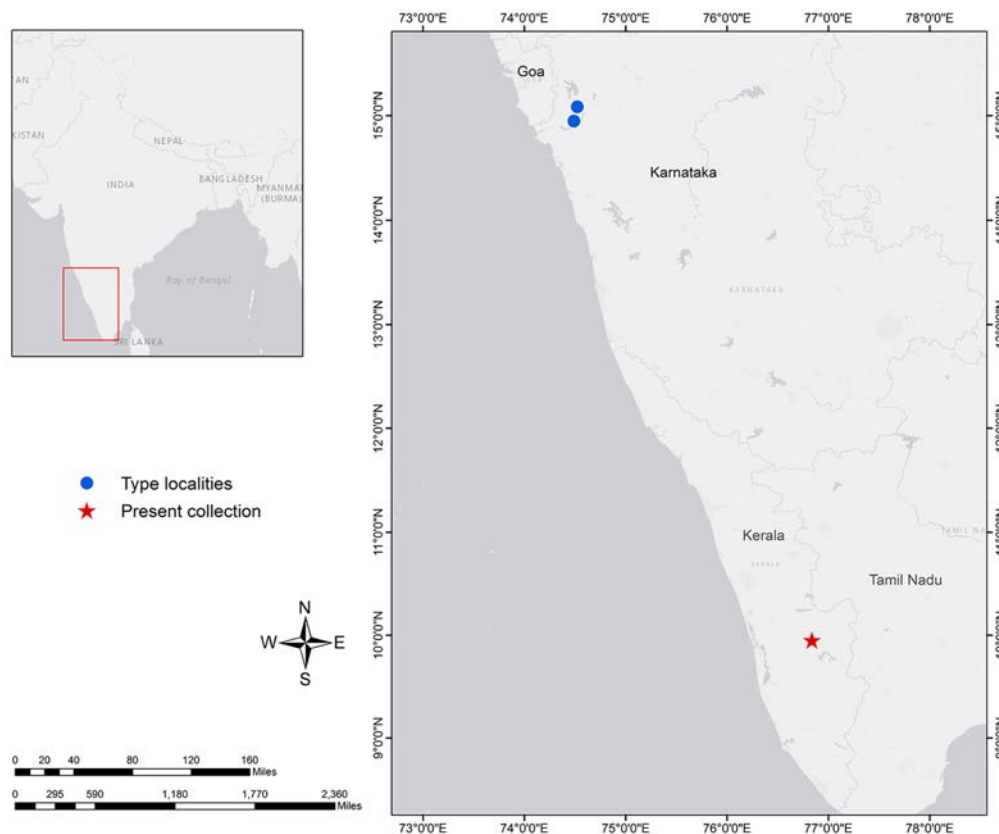


Figure 2. Distribution map of *Cinnamomum goense* Kosterm.

remnants of tepal bases.

Phenology

Flowering and fruiting are probably from March to September.

Specimens examined

53695 (TBGT!), 29.iii.2007, India, Kerala, Idukki District, Thodupuzha, ~600m, coll. Geethakumary; 73655 (TBGT!), 05.v.2012, India, Kerala, Idukki District, Thodupuzha, ~600m, coll. Deepu Sivadas. India, Karnataka, Uttara Kannada District, towards old Gund Village, east of Goa border, 13.v.1950, J. Fernandes 1453 (A00041271!, L0035798!), Canara, s.d., Stocks s.n. (L0309076!).

Conservation status

The species is presently known only from Uttara Kannada, Karnataka and Idukki, Kerala (Fig. 2). The population size of this species at Thodupuzha, Idukki is small with very few reproductively mature individuals. Apart from this, based on herbarium information a population is present at Uttara Kannada District, Karnataka. Even though there are no recent collections from this locality, we cannot rule out the probability of

finding it there. There are less than 25 mature individuals in the subpopulation at Thodupuzha, but we are not sure about the number of mature individuals or the quality of the habitat at Uttara Kannada. Due to its limited distribution knowledge from several botanical studies in the Western Ghats, we assume it is highly restricted and found in a few severely fragmented locations with a plausible threat that could impact the status of the species. We recommend immediate surveys in the type locality to determine its conservation status.

References

- Geethakumary, M.P., S. Deepu & A.G. Pandurangan (2017). A new species of *Cinnamomum* and notes on the status of *C. palghatensis* in Western Ghats, India. *Phytotaxa* 326(4): 252–258; <http://doi.org/10.11646/phytotaxa.326.4.3>
- Kostermans, A.J.G.H. (1985). The south Indian species of *Cinnamomum* Schaeffer (Lauraceae). *Bulletin of the Botanical Survey of India* 25: 90–133.
- Rohde, R., B. Rudolph, K. Ruthe, F.G. Lorea-Hernández, P.L.R. de Moraes, J. Li & J.G. Rohwer (2017). Neither *Phoebe* nor *Cinnamomum* - the tetrasporangiate species of *Aiouea* (Lauraceae). *Taxon* 66(5): 1085–1111; <http://doi.org/10.12705/665.6>
- Rohwer, J.G. (1993). Lauraceae, pp. 366–391. In: Kubitzki, K., J.G. Rohwer & V. Bittrich (eds.). *The Families and Genera of Vascular Plants - Vol. 2*. Springer, Berlin.





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

OPEN ACCESS



Northeastern India is home to a diverse group of wood-rotting fungi but studies related to them started only a decade ago. Very few studies have been conducted so far in this highly species-rich region. The last few studies have resulted in new records (Sailo 2010; Lyngdoh & Dkhar 2014a,b; Lyngdoh 2014). In the present study too, a new record *Coltriciella dependens* (Berk. & M.A. Curtis) Murrill is being reported from Meghalaya, India. This is the first record of genus *Coltriciella* as well. *Coltriciella* Murrill which was typified as *C. dependens* is a small genus of poroid Hymenochaetaceae with about 10 species accepted till 2012 (Corner 1991; Aime et al. 2003; Ryvarden 2004; Dai 2010; Dai & Li 2012; Valenzuela et al. 2012). Later three more species were added to the list in subsequent years: *C. baoshanensis* Y.C. Dai & B.K. Cui (Dai et al. 2014) and *C. globosa* L.S. Bian & Y.C. Dai, along with *C. pseudodependens* L.S. Bian & Y.C. Dai (Bian & Dai 2015). Very recently one more species *C. minuscula* Susan, Retnowati & Sukarno (Susan et al. 2018) has been added to the list making it to 14 species till now. *C. dependens* differs from other closely related genera *Coltricia* Gray mainly by the ornamented basidiospores (Ryvarden 1991, 2004; Dai 2010).

Fruit-bodies were collected from the campus of North Eastern Hill University, Shillong (Meghalaya) India on the partially burnt base of *Pinus kesiya* Royle ex Gordon. Specimens were deposited at the herbarium of Centre for Advanced Studies in Botany, North-Eastern Hill University, Shillong (Meghalaya) and Fungarium of

COLTRICIELLA DEPENDENS (BERK. & M.A. CURTIS) MURRILL, A NEW ADDITION TO WOOD-ROTTING FUNGI OF INDIA

Ayangla S. Pongen¹, Kuno Chuzho², N.S.K. Harsh³,
M.S. Dkhar⁴ & Manoj Kumar⁵

¹ Lower PWD Colony, Church Road, Kohima, Nagaland 797001, India
^{1,3,5} Forest Pathology Division, Forest Research Institute, Mason Road, Dehradun, Uttarakhand 248006, India

^{2,4} Microbial Ecology Laboratory, Centre for Advanced Studies in Botany, North-Eastern Hill University, Umshing Mawkyntoh, Shillong, Meghalaya 793022, India

¹yonglpnr@gmail.com, ²kunochuzho@gmail.com,

³nirmalharsh57@gmail.com, ⁴msdkhar@hotmail.com,

⁵mnoj23@gmail.com (corresponding author)

Forest Pathology Division, Forest Research Institute, Dehradun (Uttarakhand). The sections were observed in 2% and 5% KOH and lacto-phenol cotton blue and Phloxine using Leica Phase Contrast Microscope. Microphotographs were taken using a Motic DMWB Digital Microscope. Monographs consulted for identification were Ryvarden & Johansen (1980), Corner (1991) and Nunez & Ryvarden (2000).

Coltriciella dependens (Image 1 & Fig. 1)

(Berk. & M.A. Curtis) Murrill, Bull. Torrey bot. Club 31(6): 348 (1904).

=*Coltricia dependens* (Berk. & M.A. Curtis) Imazeki, Bull. Tokyo Sci. Mus. 6: 109 (1943)

Fruit-bodies very small pendant (geotropism)

DOI: <http://doi.org/10.11609/jott.4123.10.8.12140-12143>

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

Date of publication: 26 July 2018 (online & print)

Manuscript details: Ms # 4123 | Received 12 March 2018 | Final received 12 June 2018 | Finally accepted 04 July 2018

Citation: Pongen, A.S., K. Chuzho, N.S.K. Harsh, M.S. Dkhar & M. Kumar (2018). *Coltriciella dependens* (Berk. & M.A. Curtis) Murrill, a new addition to wood-rotting fungi of India. *Journal of Threatened Taxa* 10(8): 12140-12143; <http://doi.org/10.11609/jott.4123.10.8.12140-12143>

Copyright: © Pongen et al. 2018. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use of this article in any medium, reproduction and distribution by providing adequate credit to the authors and the source of publication.

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: Author (Kuno Chuzho) is thankful to University Grants Commission and Ministry of Tribal Affairs, Govt. of India for providing financial assistance in the form of NFHE-ST fellowship.



positive), solitary or fused, forms a distinct stipe, sometimes with a contracted base; new fruit body arises from older pore surface. Pilear surface fawn to rusty brown, usually circular, 0.5–1 cm wide, 1–1.5 cm long, tomentose, soft bristles can be easily seen with a hand lens, later become agglutinated, wither on maturity leaving striations on margin, fruit body fragile when dry, light in weight; Stipe concolorous with the pilear surface, 2–3 x 0.5–0.7 mm long, descending, simple, expanding gradually or abruptly into the central or excentric pileus, never lateral, base abrupt, thinly tomentose, weathering smooth. Pore surface rusty brown, applanate, pores angular, 1–2 per mm, tubes up to 5mm long, dissepiments thick; context rusty brown, soft, 0.5mm thick.

Hyphal system monomitic, generative hyphae simple-septate, 4–8 µm wide, tissue darkens in 4% KOH like other hymenochaetaceae members, contextual and tramal hyphae hyaline to pale yellow, thick-walled, hyaline and narrower in the sub-hymenium, moderately dichotomously branched; cystidia and cystidioles absent, basidia not seen; basidiospores ellipsoid to slightly oblong ellipsoid, yellowish, thick walled, finely verruculose, 7–9 x 4–6 µm.

Specimen examined: FPD 8734 (FRI, Dehradun), 07.iii.2016, on partially burnt *P. kesiya* from Shilong located at an elevation of 1,404m, 25.60°N & 91.89°E, coll. Ayangla S. Pongen & Kuno Chuzho (Image 2).

C. dependens is subject to neglect because of its small size. *C. dependens* is often associated with burnt

woody debris (Nunez & Ryvarden 2000), mostly on pine (Murrill 1919; Ryvarden & Johansen 1980) but have also been reported to occur on dead oak and poplar wood (Murrill 1919). Beside this, it has been reported on living roots (Corner 1991) or living tree trunks (Aime et al. 2003) but it might be just a physical support (Bian & Dai 2015). It forms anatomically conspicuous ectomycorrhiza with several host plants. Bian & Dai (2015) in their study found that all fruit bodies collected from the decayed log were associated with abundant ectomycorrhizae of pine. In molecular studies, *Coltricia* and *Coltriciella (dependens)* were found to possess similar ectomycorrhizal associations with host plants. Tedersoo et al. (2007a, 2007b) also demonstrated that four species of *Coltricia* and *Coltriciella (dependens)* form ectomycorrhizae associations with angiosperm trees of various families (Caesalpiniaceae, Dipterocarpaceae, and Myrtaceae) based on sequence data from the rDNA internal transcribed spacer (ITS) and large subunit (LSU) regions of both ectomycorrhizae root tips and fruit bodies. This tiny fungus is a pan-tropical species and reported from the subtropical regions of China (Dai & Li 2012), Japan, North Thailand, Singapore and New Zealand (Corner 1991), North and South America (Nunez & Ryvarden 2000), Seychelles (Tedersoo et al. 2007b) and Australia (Hubregtse 2017; Bougher 2017). *C. dependens* is very similar to *C. pseudodependens* and differs in larger pores and smaller basidiospores (Bian & Dai 2015).

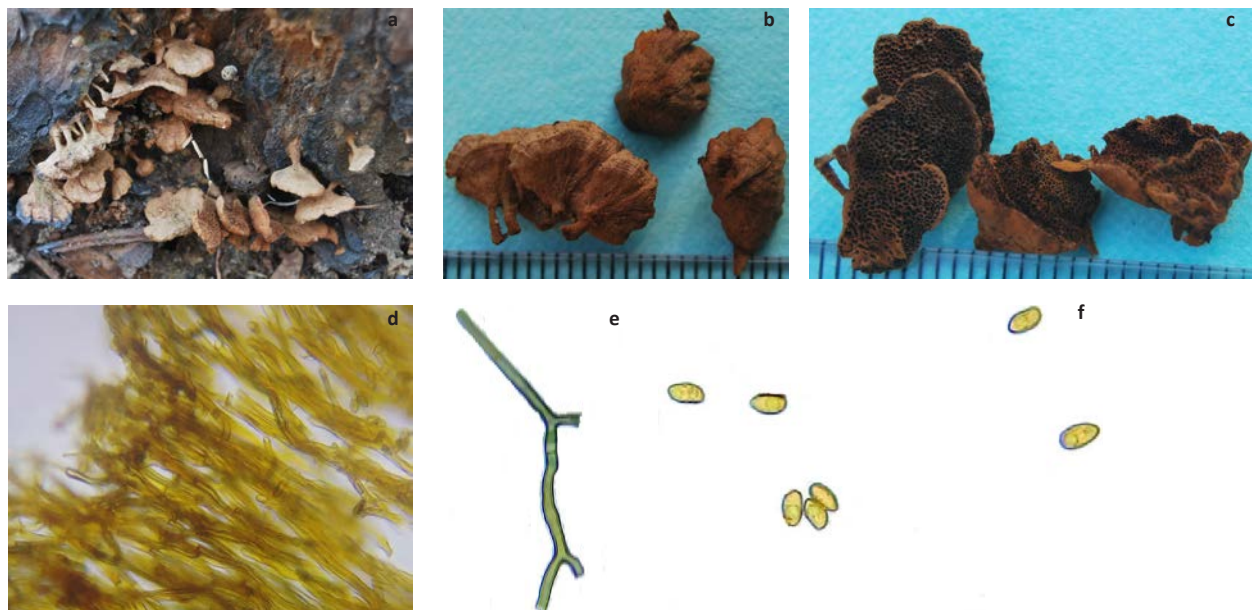


Image 1. *Coltriciella dependens*

a - on host; b - Pilear surface; c - pore surface; d - monomictichyphae; e - simple septate hypha; f - Basidiospores.

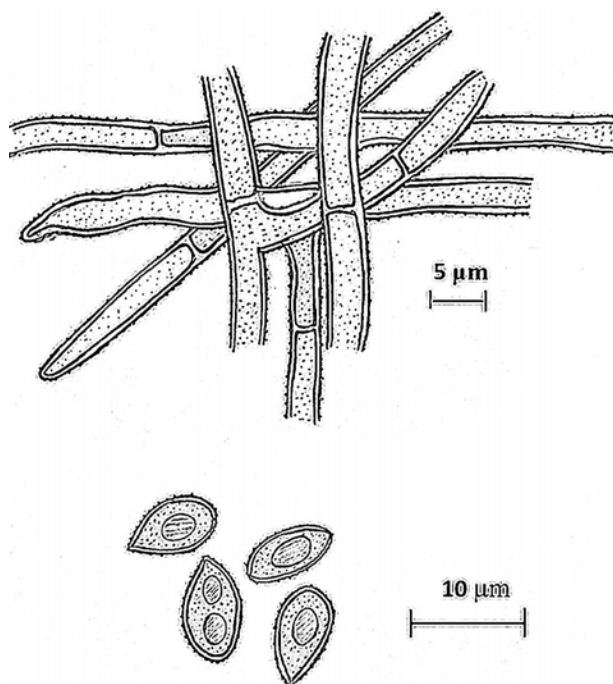


Figure 1. a - Hyphae from tramal region; b - Basidiospores

C. dependens is the sixth wood-rotting fungus from Meghalaya that is being reported as new. Before this, high wood-rotting fungal diversity has been reported from different forest stands and sacred groves of Meghalaya, northeastern India. New records of other wood-rotting fungi, viz., *Microporus quarrie* (Beeli) D.A. Reid was reported by Sailo (2010) and *Cyclomyces fuscus* Kunze ex Fr., *Heterobasidion perplexum* (Ryvarden) Stalpers, *Humphreya coffeata* (Berk.) Steyaert and *Bondarzewia berkeleyi* (Fr.) Bondartsev & Singer (from northeastern region) were reported by Lyngdoh and Dkhar (2014a, 2014b), Kumar & Harsh (2014). The fungus is easy to recognize because of the small, rusty brown, pendant fruiting body and microscopically by the finely verruculose (ornamented) basidiospores (Ryvarden & Johansen 1980).

Further studies of wood-rotting fungi in this region will enable us to unveil more interesting and rare wood-rotting fungal species as many forests of India, particularly in the north eastern parts still remain unexplored.

References

- Aime, M.C., T.W. Henkel & L. Ryvarden (2003). Studies in neotropical polypores 15: new and interesting species from Guyana. *Mycologia* 95: 614–619.
- Bian, L.S. & Y.C. Dai (2015). *Coltriciella globosa* and *C. pseudodependens* sp. nov. (Hymenochaetales) from southern China based on morphological and molecular characters. *Mycoscience* 56: 190–197;

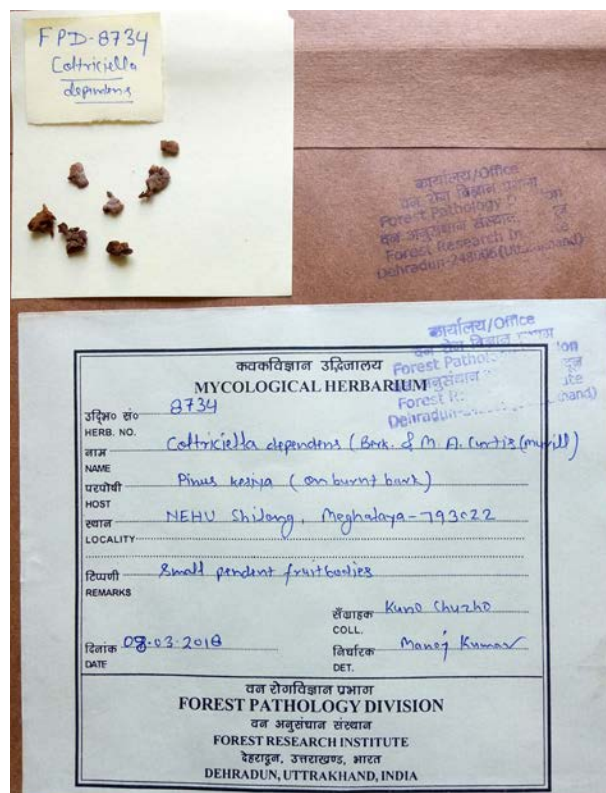


Image 2. Herbarium sheet of *Coltriciella dependens* (FPD 8734)

- <http://doi.org/10.1080/00275514.2017.1418578>
- Bougher, N.L. (2017). Fungi of Perth region and beyond. Western Australian Naturalists' Club (Inc.) Perth, 36pp.
- Corner, E.J.H. (1991). Ad Polyporaceas VII. Thexanthochroic polypores. *Nova Hedwigia Beiheft* 101: 1–175.
- Dai, Y.C. (2010). Hymenochaetaceae (Basidiomycota) in China. *Fungal Diversity* 45: 131–343; <http://doi.org/10.1007/s13225-010-0066-9>
- Dai, Y.C. & H.J. Li (2012). Type studies on *Coltricia* and *Coltriciella* described by E.J.H. Corner from Southeast Asia. *Mycoscience* 53: 337–346.
- Dai, Y.C., B.K. Cui, H. Shuang-Hui & S. Dmitry (2014). Wood decaying fungi in eastern Himalayas 4. Species from Gaoligong Mountains, Yunnan Province, China. *Mycosystema* 33(3): 611–620; <http://doi.org/10.1007/s10267-011-0174-8>
- Susan, D., A. Retnowati & N. Sukarno (2018). *Coltriciella minuscula* sp. nov., a new species of poroid fungus on *Pinus merkusii* from an Indonesian tropical forest. *Mycoscience* 59: 49–53; <http://doi.org/10.1016/j.myc.2017.08.005> 1340-3540
- Hubregtse, J. (2017). Fungi in Australia. Basidiomycota (Agaricomycotina II) revision 2.0. r Field Naturalist Club (Inc.) Victoria, 297pp.
- Kumar, M. & N.S.K. Harsh (2014). Taxonomy of *Merulius eurocephalus* (Berk. & Br.) Petch v/s *Bondarzewia berkeleyi* (Fr.) Bond. & Sing. (Basidiomycota: Agaricomycetes): synonym status reviewed. *Journal of Threatened Taxa* 6 (12): 6585–6589; <http://doi.org/10.11609/Jott.04054.6585-9>
- Lyngdoh, A. (2014). Diversity of wood-rotting macrofungi of East Khasi Hills and decay potential of some selected species. PhD Thesis. North Eastern Hill University, Shillong, India, viii+124pp.
- Lyngdoh, A. & M.S. Dkhar (2014a). First report of two wood-rotting fungi, *Cyclomyces fuscus* and *Humphreya coffeatum*, from India. *Journal of New Biological Reports* 3: 25–28.
- Lyngdoh, A. & M.S. Dkhar (2014b). Wood-rotting fungi in East Khasi Hills of Meghalaya, Northeast India, with special reference to

- Heterobasidion perplexa* (a rare species - new to India). *Current Research in Environmental & Applied Mycology* 4: 117–124; <http://doi.org/10.5943/cream/4/1/10>
- Murrill, W.A. (1904).** The Polyporaceae of North America-VII. The Genera Hexagona, Grifola, Romellia, *Coltricia* and *Coltriciella*. *Torrey Botanical Society* 31: 325–348.
- Murrill, W.A. (1919).** Notes and Brief Articles. *Mycologia* 11(4): 216–226.
- Nunez, M. & L. Ryvarden (2000).** East Asian Polypores - Volume 1 (Ganodermataceae and Hymenochaetaceae). Synopsis Fungorum 13. *Fungiflora*, Oslo, 168pp.
- Ryvarden, L. (1991).** Genera of Polypores. Nomenclature and Taxonomy. Synopsis Fungorum 5, Oslo, 363pp.
- Ryvarden, L. (2004).** *Neotropical Polypores 1*. Synopsis Fungorum 19, Oslo, 229pp.
- Ryvarden, L. & I. Johansen (1980).** *A Preliminary Polypore Flora of East Africa*. Synopsis Fungorum, Oslo, 636pp.
- Sailo, J.Z. (2010).** Studies on the wood rotting fungi of Meghalaya. PhD Thesis. North Eastern Hill University, Shillong, India, 233pp.
- Tedersoo, L., T. Suvi, K. Beaver & U. Koljalg (2007a).** Ectomycorrhizal fungi of the Seychelles: diversity patterns and host shifts from the native *Vaterio psisseychellarum* (Dipterocarpaceae) and *Intsia bijuga* (Caesalpiniaceae) to the introduced *Eucalyptus robusta* (Myrtaceae) but not to *Pinus caribea* (Pinaceae). *New Phytologist* 175: 321–333; <http://doi.org/10.1007/s11557-007-0530-4>
- Tedersoo, L., T. Suvi, K. Beaver & I. Saar (2007b).** Ectomycorrhizas of *Coltricia* and *Coltriciella* (Hymenochaetales, Basidiomycota) on Caesalpiniaceae, Dipterocarpaceae and Myrtaceae in Seychelles. *Mycological Progress* 6: 101–107; <http://doi.org/10.1111/j.1469-8137.2007.02104.x>
- Valenzuela, R., T. Raymundo, J. Cifuentes, M. Esqueda, M. Amalfi & C. Decock (2012).** *Coltriciella sonorensis* sp. nov. (Basidiomycota, Hymenochaetales) from Mexico: evidence from morphology and DNA sequence data. *Mycological Progress* 11: 181–189; <http://doi.org/10.1007/s11557-011-0740-7>



Corrigendum

Nandikar, M.D., P.T. Giranje & D.C. Jadhav (2018). Floristic enumeration of Torna Fort (Western Ghats, India): a storehouse of endemic plants. *Journal of Threatened Taxa* 10(7): 11895–11915; <http://doi.org/10.11609/jott.3705.10.7.11895-11915>

In the image 5, H - *Smithia hirsuta* should be read as *Smithia bigemina*.



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

OPEN ACCESS



Though most of us know that Jammu and Kashmir is politically, economically and culturally very different from the rest of India, few are really conversant with ground realities. Kashmir spells handicrafts for many and shahtoosh shawls are much coveted - lightweight but not light on the wallet! When I recently joined the Sher-e- Kashmir

University of Agricultural Sciences and Technology of Jammu for doctoral programme, I tried to understand the region and it was then that I happened upon Saloni Gupta's *Contesting conservation: Shahtoosh trade and forest management in Jammu and Kashmir*.

This book is published as part of the series 'Advances in Asian Human - Environment Research'. The series aims to elucidate and portray humans-ecosystem interactions, in highly populated regions of the world. While the series aims to be interdisciplinary, this particular book focuses on forest and wildlife sciences. It also highlights the state's rich biodiversity and conservation efforts. With 240 pages and 9 chapters, the book mainly deals with two subjects in the context of conservation: (i) banning the trade in Shahtoosh shawls (ii) introducing the Joint Forest Management (JFM) concept in the state.

Shahtoosh shawls are made from the fur of Chiru, an antelope protected under the wildlife law, 1972. It is illegal to trade in shahtoosh in parts of India as per the Wildlife Act. All laws enacted in the Indian parliament have an exact replica in Jammu and Kashmir, modified to suit local conditions. This holds good for conservation laws too. In the very first chapter, the author states that the international trade ban on shahtoosh shawls was implemented in the state only in 2002, after a tough legal battle in the Jammu and Kashmir High Court by the Wildlife Protection Society of India. This judgment brought the Chiru, the Tibetan Antelope (*Pantholops hodgsonii*), from Schedule II to Schedule I of the Jammu and Kashmir Wildlife (Protection) Act and thereby gave complete protection. I would also like to bring the attention of the reader to the fact that the Convention on International Trade on Endangered Species - CITES - declared trade in shahtoosh illegal in 1975. Though India was a signatory to the CITES in 1976, trade continued till 2002. This raises questions on a geopolitical aspect of the Indian constitution which are not within the purview of this review. In any case, there exists much literature on the shahtoosh shawl and its intricacies. So, what

THE NEED OF CONSERVATION LAWS COHERENT WITH COMMUNITIES FOR COMPLETE SUCCESS

S. Suresh Ramanan¹ & Lalit Upadhyay²

^{1,2} PhD Student, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir 180009, India

¹ sureshramanan01@gmail.com (corresponding author),

² silviculturetree@gmail.com

exactly does this book offer that is different?

Chapter Two briefs us as to the origin of the special provision and its political diorama of Jammu and Kashmir. This is attributed to the special status provided in the Indian Constitution – Article 370. The author also

Contesting conservation: *Shahtoosh* trade and forest management in Jammu and Kashmir, India

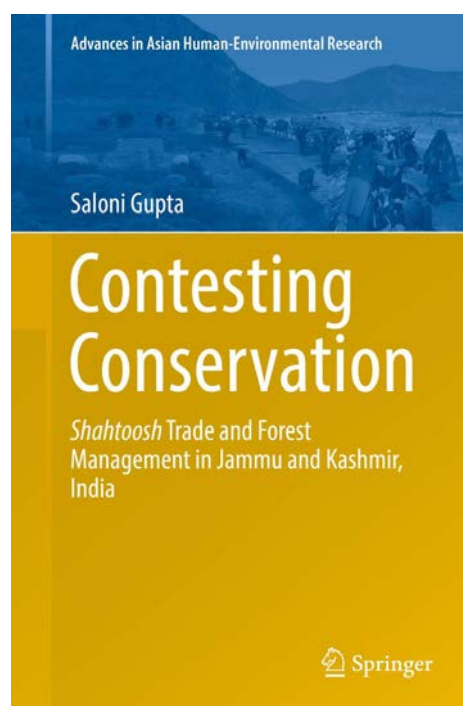
Saloni Gupta

Total Pages: xiv + 240 pages

ISBN 3319722565

ISBN 978-3319722566 (eBook)

Springer International Publishing AG 2018



DOI: <http://doi.org/10.11609/jott.4262.10.8.12144-12145>

Date of publication: 26 July 2018 (online & print)

explains the research methodology adopted and the constraints faced during the study. The ban on shahtoosh shawl production is good news for the conservationist but not for locals. Tourism and handicrafts are the main sources of income in the state. In this context, the author answers the question: 'Can the sustenance of people be sacrificed for nature conservation?' Though it depends purely on the situation, the author strongly argues that the decision should not be taken in a hasty manner. Given due considerations of the demographics of the state, the author concludes that some do reap the benefit of the ban: illegal traders. The trade in shahtoosh continues even after 2002.

Chapter Three presents a figure which might really indicate the size of the trade network (p.44). The chapter concludes that the failure of conservationists to understand regional politics and socio-economic relations is a hurdle to their success. The author fears that the very purpose of the ban might be defeated by illegal trade.

Chapter Five, aptly titled "The Micropolitics of the Ban on Shahtoosh: Costs and Reparations", sums it all up and it's my favourite chapter. Some of the bitter truths of the shahtoosh trade are pointed out here: (i) the public is not aware of the source of wool and they are mostly carried away by false propaganda (ii) the weavers are miserably exploited by a few influential traders (iii) the trade for chiru wool is done by barter system and the list goes on. I spoke to some Kashmiri students on campus and they were also not aware of the facts. This was really intriguing and this book will come as an eye-opener for them. The book provides other useful insights, as well.

The second half of the book focuses on joint forest management. After reading the previous chapters, one

can really understand ground realities and attitudes. As with the shahtoosh ban, the implementation of the Joint Forest Management was not very successful. The author, again, points a finger at caste politics and the disparity in economic standards. The style adopted is similar to the one she used for the shahtoosh issue. She begins with an introduction to forest management in the state (Chapter Six) and follows it up with details of the implementation of the JFM in Chapter Seven. Finally, Chapter Eight deals with the micropolitics of implementing joint forest management.

The second part of the book might not be that interesting to wildlife biologists. However, in the last chapter, the author points out the similarity in the two conservation actions taken in the state. Though the shahtoosh ban hampered the economy, the JFM attempted to aid and revamp livelihoods. Both attempts failed due to various reasons, including militancy. However, the take-home message for readers, especially conservationists, is that conservation policies should be based on local realities for long term stability. Otherwise, with the State as a dictator, one can only hope for partial success. There is a need to balance conservation hegemony and community needs.

This book is the outcome of the author's doctoral research work at the School of Oriental and African Studies, University of London. Regrettably, each chapter's abstract is written carelessly. However, the author is to be commended for the delicacy with which she highlights various aspects of the problems and conflicts in Jammu and Kashmir (p.32). Overall, the book enlightens readers and stresses the need to focus on socio-economic backgrounds in nature conservation efforts.



Access to Biological Resources

for Research and Commercial use



National Biodiversity Authority

Prior approval of NBA is required for obtaining any biological resource occurring in India or knowledge associated thereto, for undertaking research or for commercial utilization or for bio-survey and bio-utilization, as defined under the Biological Diversity Act 2002.



Apply in
Form - I

Timeline
180 days

You can apply online
@ <http://absefiling.nic.in>

Who has to take approval?

- Non-Indian Citizen - Research scholar / Scientist / Student
- Non- Resident Indian
- Entity - not incorporated or registered in India
- Entity registered or incorporated in India having non-Indian participation in its share capital or management

Approval will be in the form of an agreement (mutually agreed terms) entered with NBA.

What are regulated activities?

- study or systematic investigation
- technological application
- survey or collection of species / genes/ extracts
- characterisation / inventorisation / bioassay
- end uses of biological resources, such as drugs, industrial enzymes, food flavours, fragrance, cosmetics, emulsifiers, oleoresins, colours, extracts and genes used for improving crops and livestock.

Application
fee
INR 10,000/-

for more details: www.nbaindia.org

Benefit Sharing

- user shall pay benefit sharing in the form of monetary and/or non-monetary mode.
- user shall pay the benefit sharing ranging from 0.1 to 0.5% at graded percentage of the annual gross ex-factory sale.

As of now, NBA has granted 149 approvals to the users of biological resources under Form-I.

Jorg Freyhof, Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
 József Lanszki, University of West Hungary, Sopron, Hungary
 K. Haridasan, FRLHT, Bengaluru, India
 K. Karthigeyan, Botanical Survey of India, Howrah, India
 Klaus Ruetzler, NMNHHistory, Smithsonian Institution, Washington, USA.
 K. Ravikumar, FRLHT, Bengaluru, Karnataka, India
 K. Veenakumari, NBAIR, Bengaluru, India.
 K.A. Subramanian, Zoological Survey of India, New Alipore, Kolkata, India
 Kees Rookmaaker, Rhino Resource Center, United Kingdom
 Kelly B. Miller, University of New Mexico, USA
 K.S. Gopi Sundar, International Crane Foundation, Baraboo, USA
 K.S. Negi, NBPGR-ICAR, Nainital District, Uttarakhand, India
 K.R. Sasidharan, Institute of Forest Genetics and Tree Breeding, Coimbatore, India
 Kailash Chandra, Zoological Survey of India, Jabalpur, Madhya Pradesh, India
 Kareen Schnabel, NIWA, Wellington, New Zealand
 Karin Schwartz, George Mason University, Fairfax, Virginia
 Karol Bucsek, Witt Museum, München, Germany
 Kevin Smith, IUCN, Cambridge, UK
 Klaus Ruetzler, Smithsonian Institution, Washington, DC
 Kristin Leus, Copenhagen Zoo, Annuntiatenstraat, Merksem, Belgium
 Kurt R. Arnold, North Dakota State University, Saxony, Germany
 L.D. Singla, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India
 Lala A.K. Singh, Bhubaneswar, Orissa, India
 Larry R. Noblick, Montgomery Botanical Center, Miami, USA
 Lionel Monod, Natural History Museum of Geneva, Genève, Switzerland
 Llewellyn D. Densmore, Texas Tech University, Lubbock, USA
 Lukas Rüber, Department of Vertebrates, Natural History Museum, Switzerland
 M. Afzal Khan, Department of Zoology, Aligarh Muslim University, Aligarh, India
 Mandar N. Datar, Agharkar Research Institute, Pune, India
 Mandar S. Paingankar, University of Pune, Pune, Maharashtra, India
 Marc W. Holderied, University of Bristol, Bristol, UK
 Mario Cohn-Haft, Instituto Nacional de Pesquisas da Amazônia (INPA), Brasil
 Martin B.D. Stiewe, The Natural History Museum, UK
 Mary K. Wicksten, Texas A&M University, College Station, USA
 Matheus dos Santos Rocha, Universidade do Vale do Rio dos Sinos, Brasil
 Merlin Franco, Curtin University, Malaysia
 Michael J. Parr, American Bird Conservancy, Washington, USA
 Mewa Singh, Mysore University, Mysuru, India
 Mohammad Hayat, Aligarh Muslim University, Aligarh, India
 Mohilal Meitei, Manipur University, Camchipur, Manipur, India
 M. Nithyanandan, Environmental Department, La Ala Al Kuwait Real Estate. Co. K.S.C., Kuwait
 M. Mike Kerry, Seaford, East Sussex, UK
 M. Sabu, University of Calicut, Malappuram, India
 M.K. Vasudeva Rao, Shiv Ranjani Housing Society, Pune, India
 N.P. Balakrishnan, Ret. Joint Director, BSI, Coimbatore, India
 Nancy van der Poorten, Toronto, Canada
 Nathalie Yonow, Swansea University, Swansea, UK
 Nguyen Thi Phuong Lien, Vietnam Academy of Science and Technology, Hanoi, Vietnam
 Neelesh Dahanukar, IISER, Pune, Maharashtra, India
 Norbert Delahaye, Colombo, Sri Lanka
 Noor Azhar Mohamed Shazili, Universiti Malaysia Terengganu, Malaysia
 Oguz Turkozcan, Adnan Menderes University, Aydın, Turkey
 Okan Külköylüoğlu, Abant İzzet Baysal University, Bolu, Turkey
 Olivier S.G. Pauwels, Royal Belgian Institute of Natural Sciences, Belgium
 Pankaj Kumar, Kadoorie Farm and Botanic Garden Corporation, Hong Kong S.A.R., China
 Partha Pratim Bhattacharjee, Tripura University, Suryamaninagar, India
 Paul A. Racey, University of Exeter, Devon, UK
 Paul J.J. Bates, Harrison Institute, Kent, UK
 Penelope Greenslade, Federation University, Ballarat, Australia
 Peter Boveng, NOAA Alaska Fisheries Science Center, Seattle, USA
 Phyllis C. Lee, University of Stirling, Stirling, UK
 Pierre Moulet, Museum Requin, Avignon, France
 Pritpal S. Soorae, Environment Agency, Abu Dhabi, UAE
 Priya Davidar, Pondicherry University, Kalapet, Puducherry, India
 P. Lakshminarasimhan, Botanical Survey of India, Pune, India
 P.M. Sureshan, Zoological Survey of India, Kozhikode, Kerala, India
 P.O. Nameer, Kerala Agricultural University, Thrissur, Kerala, India
 P.S. Easa, Kerala Forest Research Institute, Peechi, India
 Purnendu Roy, London, UK
 Qiang Liu, Xishuangbanna Tropical Botanical Garden, Yunnan, China
 R. Sundararaj, Institute of Wood Science & Technology, Bengaluru, India
 R. Varatharajan, Manipur University, Imphal, Manipur, India
 R.K. Avasthi, Rohtak University, Haryana, India

R.K. Verma, Tropical Forest Research Institute, Jabalpur, India
 R.M. Sharma, (Retd.) Scientist, Zoological Survey of India, Pune, India
 Rainer Hutterer, Zoological Research Museum Alexander Koenig, Bonn, Germany
 Ragnar Kinzelbach, University of Rostock, Rostock, Germany
 Rajah Jayapal, SACON, Coimbatore, Tamil Nadu, India
 Rajashekhar K. Patil, Mangalore University, Mangalore, India
 Rajeev Raghavan, Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, India
 Rajiv S. Kalsi, M.L.N. College, Yamuna Nagar, Haryana, India
 Raju Vyas, Vadodara, India
 Raymond Henry, Auburn University, Auburn, USA
 Renkang Peng, Charles Darwin University, Darwin, Australia
 Reuven Yosef, Ben Gurion University of the Negev, Eilat Campus, Israel.
 Richard Corlett, Xishuangbanna Tropical Botanical Garden, Yunnan, China
 Richard Gallon, Llandudno, North Wales, LL30 1UP
 Richard Kiprono Mibey, Vice Chancellor, Moi University, Eldoret, Kenya
 Robert W. Sites, University of Missouri, Columbia, USA.
 Robert D. Sluka, Chiltern Gateway Project, A Rocha UK, Southall, Middlesex, UK
 Robin Wen Jiang Ngiam, National Parks Board, Singapore
 Robin Wilson, Museum Victoria, Melbourne, Australia
 Roland Wirth, Zoologische Gesellschaft für Arten-und Populationsschutz, Germany
 Rory Dow, National Museum of natural History Naturalis, The Netherlands
 Rosana Moreira da Rocha, Universidade Federal do Paraná, Curitiba, Brasil
 S. Ajmal Khan, Annamalai University, Parangipettai, India
 S. Arularasan, Annamalai University, Parangipettai, India
 S. Balachandran, Bombay Natural History Society, Mumbai, India
 S.C. Verma, Professor Emeritus, Panjab University, Chandigarh, India
 S. Gombobaatar, National University of Mongolia, Ulaanbaatar, Mongolia
 Saito Motoki, The Butterfly Society of Japan, Tokyo, Japan
 Sanjay Sondhi, Titli Trust, Dehradun, India
 Sanjeeva Nayaka, CSIR-National Botanical Research Institute, Lucknow, India
 Shomita Mukherjee, SACON, Coimbatore, Tamil Nadu, India
 Shonil A. Bhagwat, The Open University, UK
 Spartaco Gippoliti, Società Italiana per la Storia della Fauna 'G. Altobello', Roma, Italy
 Stephen D. Cairns, Smithsonian Institution, Washington, USA
 Stephen D. Nash, Scientific Illustrator, State University of New York, NY, USA
 Stephen C. Weeks, The University of Akron, Ohio, USA
 Sushil K. Dutta, Centre for Ecological Sciences, IISc, Bengaluru, Karnataka, India
 Tadashi Kawai, Wakkanai Fisheries Research Institute, Hokkaido, Japan
 Taej Mundkur, Wetlands International, Wageningen, The Netherlands
 Tim New, La Trobe University, Melbourne Victoria, Australia
 Tony Whitten, Fauna & Flora International, Cambridge, UK
 Topiltzin Contreras MacBeath, Universidad Autónoma del estado de Morelos, México
 Ullasa Kodandaramaiah, IISER-TVM, Thiruvananthapuram, India
 Uwe Braun, Martin-Luther-Universität, Neuwerk, Germany
 Vatsavaya S. Raju, Kakatiya University, Warangal, India
 V.B. Hosagoudar, Bilgi, Karnataka, India
 V. Irudayaraj, St. Xavier's College, Palayamkottai, Tamil Nadu, India
 V. Gokula, National College, Tiruchirappalli, India
 V. Sampath Kumar, Botanical Survey of India, Howrah, India
 V. Santharam, Institute of Bird Studies & Natural History, Chittoor, India
 Vijayasankar Raman, University of Mississippi, USA
 W. Vishwanath, Manipur University, Imphal, India
 Wiebke Herding, Amsterdam, The Netherlands
 Wioletta Tomaszewska, Museum and Institute of Zoology, Wilcza, Poland
 Xiaoli Tong, South China Agricultural University, Guangzhou, China

REVIEWERS 2015–2017

Due to pausity of space, the list of reviewers for 2015-2017 is available online.

English Editors

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

Web Design

Latha G. Ravikumar, Coimbatore India

Typesetting

Arul Jagadish, Coimbatore India
S. Radhika, Coimbatore India
K. Geetha, Coimbatore India
K. Ravindran, Coimbatore India

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, No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti, Coimbatore, Tamil Nadu 641035, India
 sanjay@threatenedtaxa.org



OPEN ACCESS



The Journal of Threatened Taxa is dedicated to building evidence for conservation globally by publishing peer-reviewed articles online every month at a reasonably rapid rate at www.threatenedtaxa.org. All articles published in JoTT are registered under [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/) unless otherwise mentioned. JoTT allows unrestricted use of articles in any medium, reproduction, and distribution by providing adequate credit to the authors and the source of publication.

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

July 2018 | Vol. 10 | No. 8 | Pages: 11999–12146

Date of Publication: 26 July 2018 (Online & Print)

DOI: 10.11609/jott.2018.10.8.11999-12146

www.threatenedtaxa.org

Communications

Habitat suitability and threat analysis of Greater One-horned Rhinoceros *Rhinoceros unicornis* Linnaeus, 1758 (Mammalia: Perissodactyla: Rhinocerotidae) in Rautahat District, Nepal

-- Saru Rimal, Hari Adhikari & Shankar Tripathi, Pp. 11999–12007

Camera-trapping survey to assess diversity, distribution and photographic capture rate of terrestrial mammals in the aftermath of the ethno-political conflict in Manas National Park, Assam, India

-- Dipankar Lahkar, M. Firoz Ahmed, Ramie H. Begum, Sunit Kumar Das, Bibhuti Prasad Lahkar, Hiranya K. Sarma & Abishek Harihar, Pp. 12008–12017

In plain sight: Bacular and noseleaf morphology supports distinct specific status of Roundleaf Bats *Hipposideros pomona* Andersen, 1918 and *Hipposideros gentilis* Andersen, 1918 (Chiroptera: Hipposideridae)

-- Bhargavi Srinivasulu & Chelmala Srinivasulu, Pp. 12018–12026

The amphibian diversity of selected agroecosystems in the southern Western Ghats, India

-- M.S. Syamili & P.O. Nameer, Pp. 12027–12034

Taxonomic status and additional description of White's Stalked-eyed Fly *Cyrtodopsis whitei* (Curran, 1936) (Diptera: Diopsidae) from India with a key to the allied species and note on its habitat

-- Basant Kumar Agarwala, Pp. 12035–12043

Community structure of benthic macroinvertebrate fauna of river Ichamati, India

-- Arnab Basu, Indrani Sarkar, Siddhartha Datta & Sheela Roy, Pp. 12044–12055

Conservation status of Mascarene Amaranth *Aerva congesta* Balf.F. Ex Baker (Eudicots: Caryophyllales: Amaranthaceae): a Critically Endangered endemic herb of the Mascarenes, Indian Ocean

-- Kersley Bruno Pynee, David Harold Lorence & Poojanraj Khurun, Pp. 12056–12063

Vegetative and reproductive phenology of *Aquilaria malaccensis* Lam. (Agarwood) in Cachar District, Assam, India

-- Birkhungur Borogayary, Ashesh Kumar Das & Arun Jyoti Nath, Pp. 12064–12072

Conservation Application

Taking the first steps: Initial mapping of the human-wildlife interaction of the Mauritius Fruit Bat *Pteropus niger* (Mammalia: Chiroptera: Pteropodidae) in Mauritius by conservation organizations

-- Brandon P. Anthony, Vikash Tatayah & Deborah de Chazal, Pp. 12073–12081

Peer Commentary

The term human-wildlife conflict creates more problems than it resolves: better labels should be considered

-- Priya Davidar, Pp. 12082–12085

Short Communications

First photographic evidence of Snow Leopard *Panthera uncia* (Mammalia: Carnivora: Felidae) outside current protected areas network in Nepal Himalaya

-- Rinzin Phunzok Lama, Tashi R. Ghale, Madan K. Suwal, Rishi Ranabhat & Ganga Ram Regmi, Pp. 12086–12090

Small carnivores of Silent Valley National Park, Kerala, India

-- Devika Sanghamithra & P.O. Nameer, Pp. 12091–12097

Status survey and conservation of the House Sparrow *Passer domesticus* (Aves: Passeriformes: Passeridae) through public participation in Kannur, Kerala, India

-- R. Roshnath, C.P. Arjun, J. Ashli, D. Sethu & P. Gokul, Pp. 12098–12102

The ecology and distribution of percoid fish *Dario neela* from Wayanad in the Western Ghats of Kerala, India

-- Dencin Rons Thampy & C.P. Shaji, Pp. 12103–12107

A checklist of the ornamental fishes of Himachal Pradesh, the western Himalaya, India

-- Indu Sharma & Rani Dhanze, Pp. 12108–12116

Odonate diversity of Nalsarovar Bird Sanctuary - a Ramsar site in Gujarat, India

-- Darshana M. Rathod & B.M. Parasharya, Pp. 12117–12122

Root holoparasite *Balanophora polyandra* Griff. (Balanophoraceae) in eastern Himalaya (Sikkim, India): distribution, range, status and threats

-- Prem K. Chhetri, Alexander R. O'Neill & Bijoy Chhetri, Pp. 12123–12129

Notes

Transfer of *Storena gujaratensis* Tikader & Patel, 1975 to the genus *Suffasia* Jocqué, 1991 (Araneae: Zodariidae)

-- Reshma Solanki, Manju Siliwal & Dolly Kumar, Pp. 12130–12132

Intraguild predation of green lacewing larvae (Neuroptera: Chrysopidae) on spider eggs and spiderlings

-- K.K. Srikumar, S. Smitha, B. Suresh Kumar & B. Radhakrishnan, Pp. 12133–12136

Rediscovery, extended distribution and conservation assessment of *Cinnamomum goaense* (Lauraceae) in the Western Ghats, India

-- M.P. Geethakumary, S. Deepu & A.G. Pandurangan, Pp. 12137–12139

***Coltriciella dependens* (Berk. & M.A. Curtis) Murrill, a new addition to wood-rotting fungi of India**

-- Ayangla S. Pongen, Kuno Chuzho, N.S.K. Harsh, M.S. Dkhar & Manoj Kumar, Pp. 12140–12143

Book Review

The need of conservation laws coherent with communities for complete success

-- S. Suresh Ramanan & Lalit Upadhyay, Pp. 12144–12145

Miscellaneous

National Biodiversity Authority

Member



Publisher & Host



Partners

