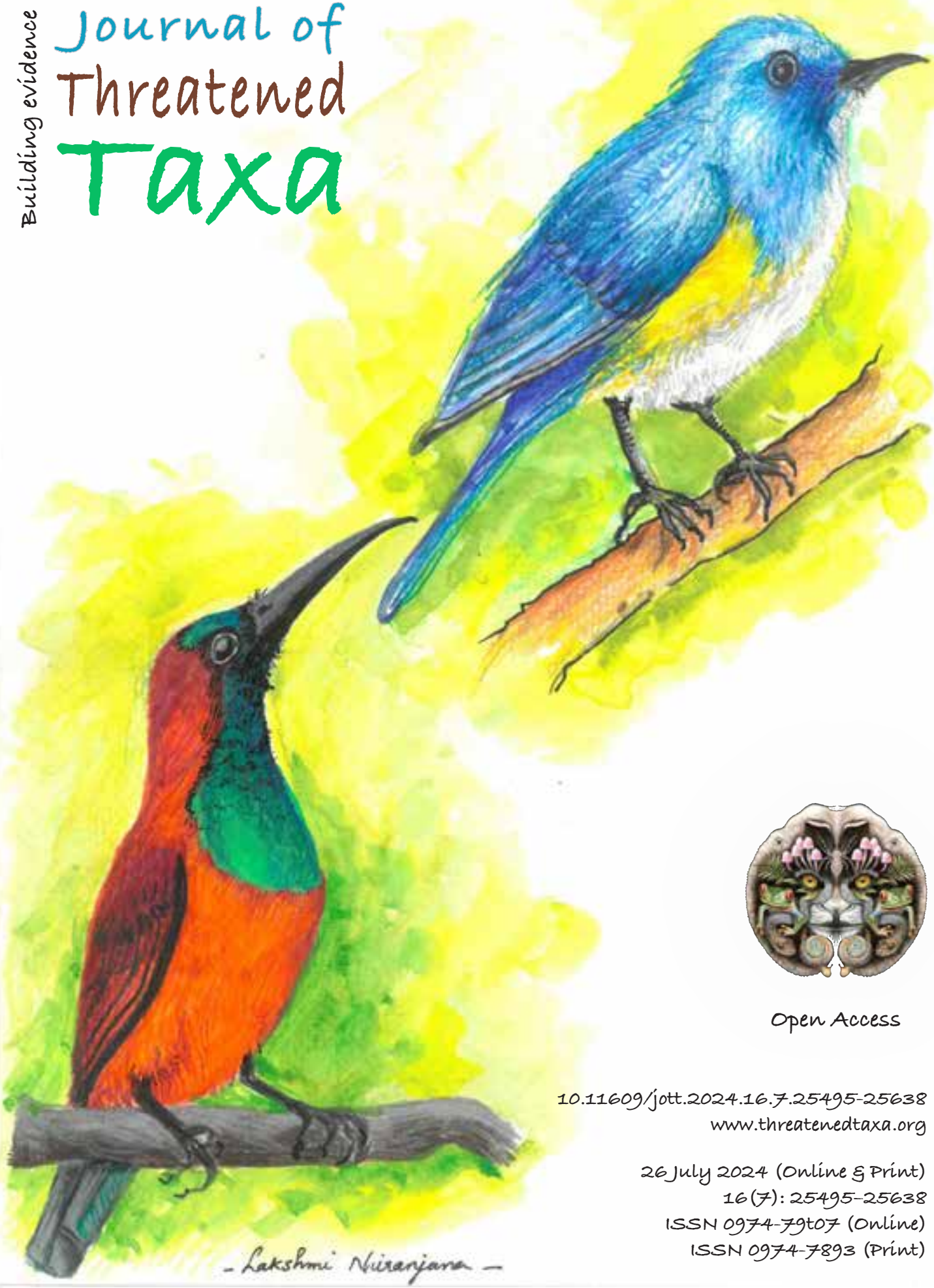
Building evidence for conservation globally

Journal of Threatened Taxa



Open Access

10.11609/jott.2024.16.7.25495-25638
www.threatenedtaxa.org

26 July 2024 (Online & Print)
16(7): 25495-25638
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

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

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

Host
Zoo Outreach Organization
www.zooreach.org

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope
For Article Submission Guidelines, visit https://threatenedtaxa.org/index.php/JoTT/about/submissions
For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: Mixed media illustration of a Blue bird and Sunbird. © Lakshmi Niranjana.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25495–25506

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

https://doi.org/10.11609/jott.9003.16.7.25495-25506

#9003 | Received 29 February 2024 | Final received 09 June 2024 | Finally accepted 18 July 2024

OPEN ACCESS

ARTICLE

Spatial assemblage of shorebirds (Aves: Charadriiformes) in an altered wetland of the southern coast of Sri Lanka

V.N. Mendis [1], E.J.A.P. Buddhi Priyankara [2], E.G.D.P. Jayasekara [3] & W.A.D. Mahaulpatha [4]

[1] Faculty of Graduate Studies, University of Sri Jayewardenepura, Gangodawila, Nugegoda 10250, Sri Lanka.
[2] Kalametiya Eco Birdwatching, 1/81, Bata Atha South, Hungama 82120, Sri Lanka.
[1,3,4] Department of Zoology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Gangodawila, Nugegoda 10250, Sri Lanka.
[1] vinurim@gmail.com, [2] buddhipriyankara1@gmail.com, [3] dulan@sjp.ac.lk, [4] mahaulpatha@sjp.ac.lk (corresponding author)

Abstract: The coastal wetlands along the southern coast of Sri Lanka are home to a diverse array of shorebirds thriving in their natural habitats, classified under the order Charadriiformes. This study examines the impact of land cover changes within the Kalametiya Sanctuary, situated on the southern coast, on the diversity, distribution, and habitat utilization of migrant and breeding resident shorebirds. Three distinct habitat types were selected within the study area: grassland, lagoon, and mixed mangroves. Employing Geographic Information System (GIS) data the land cover changes of these habitats from 2002 to 2023 were analyzed using satellite imagery. Results indicated a substantial decrease in lagoon habitat area by 70% and grassland habitat by 30%, while mixed mangrove habitat saw an increase of >90%. These changes were attributed to anthropogenic interventions and natural events such as the 2004 Tsunami. To determine the shorebird assemblages within the study area thriving in these changing habitats, surveys were conducted from May 2022 to April 2023 at 30 fixed point-count stations along transects in the selected habitat types. A total of 25 shorebird species belonging to six families were recorded. Notable among these were the globally 'Near Threatened' species such as the Black-tailed Godwit *Limosa limosa* and the Great Thick-knee *Esacus recurvirostris*, alongside nationally threatened species including Kentish Plover *Charadrius alexandrinus*, Gull-billed Tern *Gelochelidon nilotica*, and Common Tern *Sterna hirundo* species. The mixed-mangrove habitat exhibited the highest shorebird abundance, with 19 species recorded, surpassing the 13 and 11 species recorded in the grassland and lagoon habitats, respectively. Additionally, both grassland and mixed-mangrove habitats demonstrated similar diversity indices and shared more species in common (Shannon's diversity index [H] = 2.17; Jaccard Similarity Index = 0.45) compared to the lagoon habitat (H = 2.09). Despite the notable decline in lagoon habitat cover, during the present study, it was observed that the overall shorebird populations have been sustained within grassland and mixed-mangrove habitats utilized for their feeding and nesting. Additionally, over-summering migratory shorebirds were observed utilizing these habitats. Hence, the Kalametiya sanctuary serves as a unique setting to study the ecological resilience of migratory and breeding resident shorebirds amidst human interventions. This research provides valuable insights for biodiversity conservation and habitat management in the face of human-induced alterations within ecosystems located especially along migratory pathways of shorebird species. Both grassland and mixed-mangrove habitats exhibited similar diversity indices and shared more species (Shannon's diversity index [H] = 2.17; Jaccard Similarity Index = 0.45) compared to the lagoon habitat (H = 2.09). Despite the significant decline in lagoon habitat cover, this study observed that overall shorebird populations have been sustained within the grassland and mixed-mangrove habitats, which they use for feeding and nesting. Additionally, over-summering migratory shorebirds were observed utilizing these habitats. Thus, the Kalametiya sanctuary serves as a unique setting for studying the ecological resilience of migratory and breeding resident shorebirds amidst human interventions. This research offers valuable insights for biodiversity conservation and habitat management, particularly in ecosystems along migratory pathways of shorebird species, in the face of human-induced alterations.

Keywords: Bird migration, Central Asian Flyway, coastal wetland, habitat alteration, habitat utilization, land cover changes, protected areas, wetland conservation.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

Date of publication: 26 July 2024 (online & print)

Citation: Mendis, V.N., E.J.A.P.B. Priyankara, E.G.D.P. Jayasekara & W.A.D. Mahaulpatha (2024). Spatial assemblage of shorebirds (Aves: Charadriiformes) in an altered wetland of the southern coast of Sri Lanka. *Journal of Threatened Taxa* 16(7): 25495–25506. https://doi.org/10.11609/jott.9003.16.7.25495-25506

Funding: This research was funded by the University of Sri Jayewardenepura postgraduate grant (ASP/01/RE/SCI/2022/18).

Competing interests: The authors declare no competing interests.

Author details, Author contributions & Acknowledgements: See end of this article.

Wildlife Circle
University of Sri Jayewardenepura

INTRODUCTION

Sri Lanka serves as a major landmass for migratory birds traversing the Central Asian Flyway (CAF). The coastal wetlands on the island support a rich biodiversity and provide essential ecosystem services such as maintaining ecological balance and nutrient cycling (Basset et al. 2013; Gunatilleke et al. 2017; Newton et al. 2018). They also play a pivotal role in connecting global habitats by serving as a vital stopover, feeding and nesting grounds for migrating and breeding resident avifauna, especially shorebirds of the Order Charadriiformes (Kotagama et al. 2006). Notably, coastal wetlands particularly in southern Asia are known to offer critical habitat for threatened migratory shorebirds with decreasing populations due to the depletion of the coastal environment (Ferreira et al. 2005; Delany et al. 2009). They are indispensable for long-distance migrant shorebirds to replenish energy stores, feed, and rest, and for resident shorebirds to sustain their populations through nesting sites (Pérez-Ruzafa et al. 2011; Aycock & Sims 2015; Duan et al. 2022).

Despite their importance, human exploitation has led to threats and modifications to Sri Lanka's coastal wetlands over the years (Jayathilake & Chandrasekara 2015; Madarasinghe et al. 2020b; Kodikara et al. 2023). However, studies identify that understanding interactions with the ecology and biodiversity of coastal wetlands in developing countries including Sri Lanka show a lack of improvement in comparison to the well-developed regions of the world. Hence, it is important to determine the influence of such interventions on the biodiversity that depends on these habitats, especially for sensitive species like shorebirds, and what measures could be taken to manage and minimize any detrimental effects on the shorebird community.

The Kalametiya Sanctuary, located on the southern coast of Sri Lanka, is renowned for its biodiversity and ecological significance, serving as an avifaunal region (Ekanayake et al. 2005; Bernard et al. 2023). Encompassing over 700 hectares, the sanctuary comprises various habitats including mangrove swamps, lagoons, sandy shores, and grasslands, all of which support shorebird communities (Ekanayake et al. 2005; Bernard et al. 2023). Designated as a sanctuary since 1984, it is governed by the Fauna and Flora Protection Ordinance and the southern Province Hambantota Integrated Coastal Zone Management Project (Jayatissa et al. 2002; Ekanayake et al. 2005; Perera et al. 2013; Madarasinghe et al. 2020a). Scientific research within Kalametiya sanctuary can therefore provide valuable insights into not only avian ecology but also on coastal wetland dynamics and ecosystem resilience of sustaining faunal communities. Previous studies have documented the sanctuary's floral and fauna diversity and how various interventions, such as the Udawalawe Irrigation and Resettlement Project and the 2004 Tsunami tragedy, have altered the habitat composition within the sanctuary, over the course of the period from 2005 to 2020 (Bambaradeniya et al. 2005; Ekanayake et al. 2005; Madarasinghe et al. 2020a,b).

Based on the literature, one of the main factors for good shorebird habitat is the presence of adequate foraging sites. Effective conservation of shorebird habitats requires a thorough understanding of the patterns of shorebirds' spatial and temporal utilization of habitats. This knowledge can be difficult to attain and may be time-consuming, especially in coastal settings, since shorebirds can show complex local movements, being very specific in their habitat requirements and their capability of traversing long distances between preferred sites (Warnock & Bishop 1998; Pearce-Higgins et al. 2017). Hence, to better understand species-habitat relationships within coastal wetlands, it is imperative to adopt a multispectral and multi-temporal data analysis approach using modern remote sensing and GIS technologies (Albanese et al. 2012; Kaliraj et al. 2017; Vivekananda et al. 2021). Studies such as the present research that incorporates both on-ground field records and remote sensing analysis could serve the purpose of achieving the intended objectives of effective shorebird species conservation and habitat management.

Moreover, since shorebirds serve as biological indicators of ecosystem health (Colwell 2010), conservation efforts must focus on preserving their habitats, including wintering, feeding, and nesting grounds (Thomas et al. 2004; Jumilawaty et al. 2022). Yet none of the research conducted thus far has assessed shorebird diversity, distribution, and habitat utilization in the Kalametiya Sanctuary. This study aims to address this gap by determining shorebird diversity, distribution, and habitat utilization in Kalametiya Sanctuary, considering the effects of recent land cover changes, and proposing management options, including the possibility the Sanctuary be declared as a Ramsar-protected wetland based on identified human and natural threats.

MATERIALS AND METHODS

Study area

This study was conducted within Kalametiya Sanctuary (6.086 N, 80.936 E) situated in the southern province of Sri Lanka. This region falls within the island's dry zone, receiving an average annual rainfall ranging 1,000–1,250 mm. Spanning an area of 700 ha, the sanctuary is designated under the Fauna and Flora Protection Ordinance (FFPO) and governed by the Department of Wildlife Conservation (DWC) (Ekanayake et al. 2005; Perera et al. 2013). It comprises the larger Kalametiya lagoon and a smaller Lunama lagoon, connected by a man-made narrow channel. For the study, three primary habitat types were identified: grassland (G), lagoon (L), and mixed mangrove (MM), and selected (Image 1) based on accessibility and extensive land cover availability (Ekanayake et al. 2005).

Field survey and avifaunal sampling

Sampling was conducted from May 2022 to April 2023, employing 30-point count stations fixed along transects (Figure 1; GPS points of point count stations given in Table 4) (Bibby et al. 1998; Ntongani & Andrew 2013) in the three selected habitats. The point counts were fixed such that each station was separated by the other by 50 m or greater to minimize double counting (Bibby et al. 1998; Sutherland et al. 2012; Bernard et al. 2023) and the accessibility to each site was available throughout the study period. ArcGIS version 10.8 (Esri, Redlands, USA) was used to overlay the fixed-point count stations on a satellite map of the selected study area.

Two days of sampling were allocated for each of the three months during both the bird migratory season (October–April) and non-migratory season (May–September). Morning and evening point counts lasting 10 minutes each were conducted within a 2–3 h window of predicted low tide - conducted during daylight, although some shorebird foraging occurs at night (Bibby et al. 1998), on each sampling day at each station by pairs of observers with similar training levels. Surveys were conducted either on foot in the grassland and

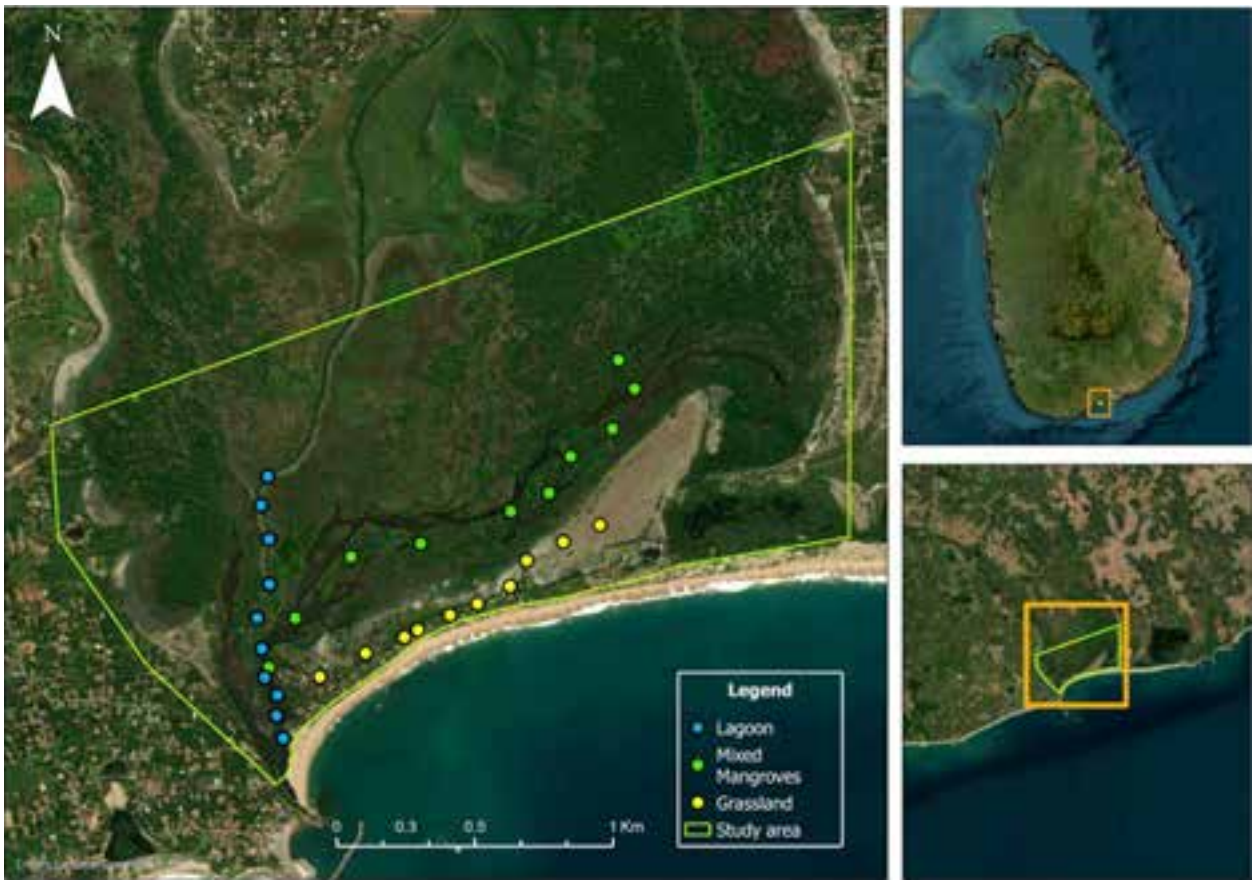


Figure 1. Point count stations along transects within the grassland, lagoon, and mixed-mangrove habitats in the Kalametiya Sanctuary, southern coast of Sri Lanka. Prepared by: E.G.D.P. Jayasekara.

mixed mangrove habitats or using slow paddle boats in the lagoon habitat, taking measures to minimize any disturbances to the species during the survey. Shorebirds that flew over a point were disregarded unless they landed or took off within the point count radius within the observation period. Standard birding equipment such as Nikon 8 × 40 Action Extreme and Nikon Monarch 10 × 42 binoculars, Vanguard Endeavor XF 60A 15–45 x 60 spotting scope, and standard field guides (Harrison & Worfolk 2011; Hayman et al. 2011) were utilized for species identification and recording. The observed shorebird species' common English names were documented, and their conservation status was later determined using the IUCN Red List of Threatened Species and the National Red List of Birds of Sri Lanka (Secretariat 2022).

Species richness, diversity, and similarity

Species richness was recorded as the number of shorebird species present in a particular habitat and season. PAST 4.15 open-source software was used to estimate Shannon's diversity index (H) based on the following equation:

$$H = \Sigma pi \log(ln)\ pi$$

where, *pi* is the proportion (n/N) of individuals of a particular species observed (n) divided by the total number of individuals recorded (N), while *ln* is the natural log, and Σ is the sum of the calculations. Significant differences between the seasonal diversity indices were calculated using the diversity t-test.

The Relative abundance was computed using [(number of individuals per species/total number of individuals) × 100%] and the Jaccard similarity index [SJ] was calculated between the habitats by using the equation,

$$SJ = S_a / (S_a + S_b + S_c)$$

where S_a is the number of species unique to the first habitat, S_b is the number of species unique to the second habitat, and S_c is the number of species common in both habitats.

Determination of habitat alteration

Multi-spectral satellite images from Landsat 7 (ETM+/path_141/row_56) and Landsat 8 (OLI_TIRS sensor/path_141/row_56) missions were obtained from the United States Geological Survey online database (https://earthexplorer.usgs.gov/). The search aimed to find Landsat datasets with minimal cloud cover during the months of June to August, consistent with previous studies (Jayatissa et al. 2002; Madarasinghe et al. 2020b; Bernard et al. 2023) to avoid months with extreme rainfall or drought conditions. The selected images for analysis were from 07 July 2002 (Landsat 7), July 18, 2012 (Landsat 7), and 09 July 2023 (Landsat 8). This approach minimized the seasonal impact on habitat spatial variation and allowed an unbiased evaluation of the lagoon's saltwater and freshwater balance, considering historical precipitation levels in July. To address differences in resolution and image quality among the Landsat datasets, Red and NIR (near-infrared) bands were utilized to generate normalized difference vegetation index (NDVI) rasters as the basis for image classification. NDVI values were calculated using the formula: NDVI = (NIR - Red)/(NIR + Red) (Grebner et al. 2013; Pantazi et al. 2020). Habitats were classified based on NDVI pixel values: lagoon <0.15, grassland 0.15–0.2, other vegetation 0.2–0.25, mixed mangrove >0.25 (Drisya & Roshni 2018). An accuracy assessment was performed on the classified images corresponding to the selected years and kappa coefficients were calculated using a confusion matrix (Vivekananda et al. 2021). Ground observations as well as Google Earth images were used for ground truthing the 2023 classified image. Google Earth images alone were used for the ground truthing accuracy assessment of 2002 and 2012 classified images. Therefore, the limited availability of corresponding Google Earth historical data was considered during the Landsat image selection.

RESULTS

Species Richness and Diversity

During the survey, 602 individuals of 25 shorebird species belonging to six families were recorded. A similar shorebird species diversity was recorded in the grassland and mixed-mangrove habitats (H = 2.17) and the least diversity was recorded in the lagoon habitat (H = 2.09) (Figures 2 & 3).

The Black-winged Stilt *Himantopus himantopus*, a breeding resident shorebird with a migrant population was the most abundant species recorded in all three habitats during the study period. The least abundant species recorded were the Gull-billed Tern *Gelochelidon nilotica* and the Whimbrel *Numenius phaeopus* species (Table 1). A notable observation was the record of over-summering populations of Common Redshank *Tringa totanus* and Ruddy Turnstone *Arenaria interpres* species utilizing the grassland and mixed mangrove habitats during the non-migratory season. The record of the globally 'Near Threatened' species Black-tailed Godwit *Limosa limosa* and Great Thick-knee *Esacus recurvirostris*,

Table 1. Shorebird species of Order Charadriiformes that were recorded during the study period in the selected three habitats.

Family	Scientific name	Common name	GCS (2021)	NCS (2021)	Phenological status	Relative abundance (%)	Habitat
Burhinidae	*Esacus recurvirostris* (Cuvier, 1829)	Great Thick-knee	NT	LC	R	3.99	G/ L/ MM
	Burhinus indicus (Salvadori, 1865)	Indian Thick-knee	LC	LC	R	1.66	G
Charadriidae	*Charadrius mongolus* (Pallas, 1776)	Lesser Sand Plover	LC	-	M	8.80	G/ MM
	Charadrius leschenaultia (Lesson, 1826)	Greater Sand Plover	LC	-	M	0.83	G/ MM
	Pluvialis fulva (Gmelin, 1789)	Pacific Golden Plover	LC	-	M	2.82	G/ MM
	Charadrius alexandrinus (Linnaeus, 1758)	Kentish Plover	LC	EN	R / M	1.16	G
	Pluvialis squatarola (Linnaeus, 1758)	Grey Plover	LC	-	M	0.83	G/ MM
	Vanellus indicus (Boddaert, 1783)	Red-wattled Lapwing	LC	LC	R	12.62	G/ L/ MM
	Vanellus malabaricus (Boddaert, 1783)	Yellow-wattled Lapwing	LC	LC	R	3.16	G
Jacanidae	*Hydrophasianus chirurgus* (Scopoli, 1786)	Pheasant-tailed Jacana	LC	LC	R	2.33	L
Laridae	*Chlidonias hybrida* (Pallas, 1811)	Whiskered-Tern	LC	-	M	3.49	L/ MM
	Gelochelidon nilotica (Gmelin, 1789)	Gull-billed Tern	LC	CR	R / M	0.49	L
	Sterna hirundo (Linnaeus, 1758)	Common Tern	LC	CR	R / M	1.16	L
	Sternula albifrons (Pallas, 1764)	Little Tern	LC	VU	R / M	1.83	L/ MM
Recurvirostridae	*Himantopus himantopus* (Linnaeus, 1758)	Black Winged Stilt	LC	LC	R / M	24.25	G/ L/ MM
Scolopacidae	*Tringa totanus* (Linnaeus, 1758)	Common Redshank	LC	-	M	16.45	G/ L/ MM
	Tringa nebularia (Gunnerus, 1767)	Common Greenshank	LC	-	M	0.33	MM
	Tringa stagnatilis (Bechstein, 1803)	Marsh Sandpiper	LC	-	M	0.49	L/ MM
	Tringa glareola (Linnaeus, 1758)	Wood Sandpiper	LC	-	M	0.83	MM
	Actitis hypoleucos (Linnaeus, 1758)	Common Sandpiper	LC	-	M	1.33	L/ MM
	Arenaria interpres (Linnaeus, 1758)	Ruddy Turnstone	LC	-	M	4.98	G/ MM
	Calidris minuta (Leisler, 1812)	Little Stint	LC	-	M	1.66	MM
	Numenius phaeopus (Linnaeus, 1758)	Whimbrel	LC	-	M	0.49	MM
	Limosa limosa (Linnaeus, 1758)	Black-tailed Godwit	NT	-	M	0.83	MM
	Gallinago stenura (Bonaparte, 1830)	Pintail Snipe	LC	-	M	1.16	G/ MM

M—Migrant | R—Resident | GCS—Global Conservation Status | NCS— National Conservation Status.

and nationally critically endangered species Gull-billed Tern *Gelochelidon nilotica* and Common Tern *Sterna hirundo* and the nationally endangered Kentish Plover *Charadrius alexandrinus* within the study area highlights the overall standpoint of Kalametiya Sanctuary to support thriving shorebird communities.

Changes in shorebird species diversity and richness during the migratory and non-migratory seasons depicted that most shorebirds were observed utilizing mixed mangrove habitats than the grassland and lagoon habitats during the migratory season, while in the non-migratory season, the highest occurrence was recorded in the grassland habitat (Table 2). A t-test comparison of the diversity indices of the migratory season indicates

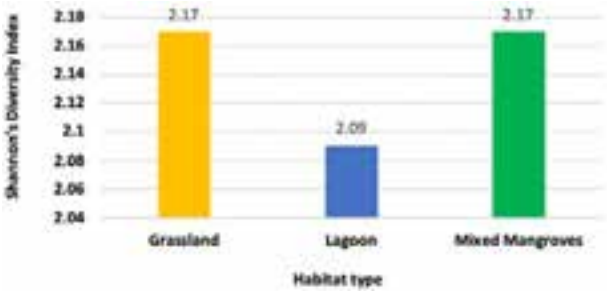


Figure 2. Shannon's diversity (H) indices which were recorded in the three habitats.

that there is a significant difference in the diversity recorded in the mixed mangrove habitat with that of the diversity recorded in the lagoon (t = 2.682, df = 85.52, p = 0.008) and grassland habitats (t = 2.034, df = 287.07, p = 0.0429). During the non-migratory season however, only the diversity of shorebird species recorded in the mixed mangrove and lagoon habitat (t = 3.132, df = 168.94, p = 0.002) significantly differed.

Changes in land cover within the study area

The spatio-temporal change in land cover within the study area for the past two decades is depicted in the maps (Figure 4) generated from satellite data. Overall, the lagoon area has decreased by 69.94% and the grassland area has decreased by 30.75%. However, the area of mixed mangroves within the study site has increased by 93% from 2002 to 2023 (Table 3). The accuracy assessment was performed for 2002, 2013, and 2023 land cover maps and an overall kappa statistic of 0.741, 0.754, and 0.736 were computed for each respectively.

DISCUSSION

The global decline in shorebird populations is of growing concern, highlighting the need for dedicated efforts towards their conservation and sustainable management (Clemens et al. 2010; Aarif et al. 2014). Coastal wetlands, particularly in Asia which support such migratory and breeding resident shorebird species, even though considered the most productive of the many types of wetlands categorized by the Ramsar Convention (https://rsis.ramsar.org/), are affected by exponential population growth and imbalances in demand-supply interactions arising mostly due to urban developments. Shorebirds are considered to play a significant role in maintaining the health of the environment they utilize (Colwell 2010) and therefore, the protection of their stopover resources within coastal wetlands could pave the way for the sustaining of both shorebird communities and the wetland habitats (Myers et al. 1987; Skagen & Knopf 1994). Considering the above concerns, it is evident that Sri Lanka's coastal wetlands present an understudied yet ecologically significant arena for investigating the dynamics of shorebird communities amidst continuing alterations in the southern Asian region. Hence, the present study conducted in the Kalametiya Sanctuary, located in southern Sri Lanka, which assesses the shorebird diversity, distribution, and habitat utilization considering habitat cover changes that have occurred over past decades, provides a reference framework for implementing timely species conservation and habitat management strategies.

During the present research, a total of 25 shorebird

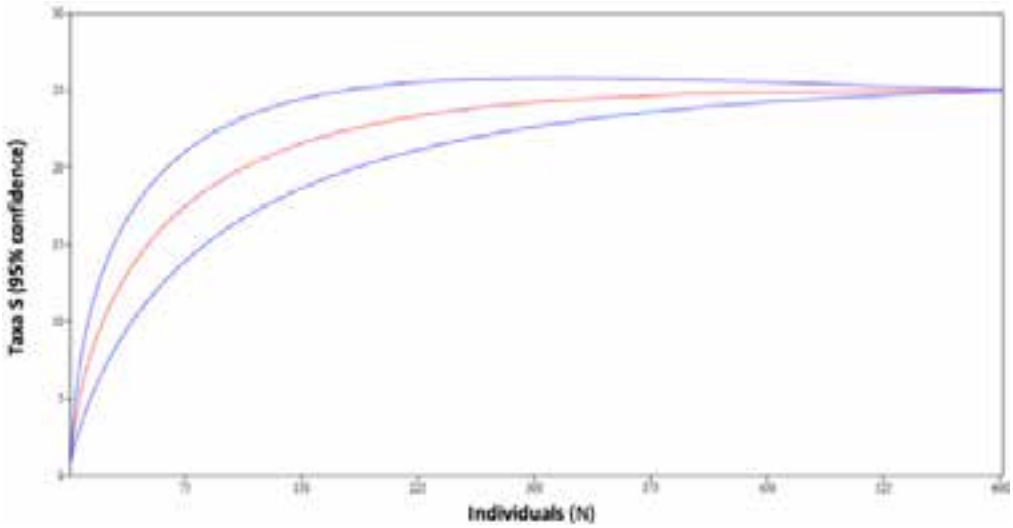


Figure 3. The rarefaction curve for species accumulation with the number of individuals recorded within the study area.

Image 1. A—grassland | B—lagoon | C—mixed mangrove habitats during the study period. © V.N. Mendis.

Table 2. Shorebird species diversity comparison of the migratory and non-migratory seasons in the three habitats.

	Non-migratory season			Migratory season		
	Grassland	Lagoon	Mixed mangrove	Grassland	Lagoon	Mixed mangrove
Shannon's diversity index (H)	2.055	1.919	1.472	2.207	2.079	2.429
Evenness	0.7811	0.757	0.436	0.699	0.799	0.630
Richness	10	9	10	13	10	18
Total number of individuals (N)	89	68	101	126	48	170

species belonging to the order Charadriiformes were documented, of which 60% can be classified as migratory species, 20% as breeding residents, and the remainder as breeding resident species with a migrant population. In contrast, a recent study by Bernard et al. (2023) reported only 10 shorebird species, while a previous biodiversity profile by Ekanayake et al. (2005) documented 38 species. However, it is important to note that the 2005 survey considered the entire Kalametiya-Lunama sanctuary area, whereas the present research focused specifically on habitats adjoining the Kalametiya lagoon. Further, the species that were recorded in the 2005 survey that were not recorded in the present research are some of the rare and uncommon migrant shorebird species such as the Ruff *Calidris pugnax* and Long-toed Stint *Calidris subminuta* and some of the uncommon migrant tern species such as the Saunders's Tern *Sternula saundersi*, Great Crested Tern *Thalasseus bergii*, and Lesser Crested Tern *Thalasseus bengalensis*, which have been found utilizing mostly the brackish lagoon water habitat within the entire Kalametiya-Lunama sanctuary area. Consequently, direct comparisons of species richness values between studies are not feasible due to differences in study area delineation. The demarcated study area of the present study was chosen to assess how changes in land cover within the Kalametiya lagoon and surrounding habitats have impacted the diversity and habitat utilization of shorebirds, considering the proportional area of the sanctuary. Further studies in the Lunama lagoon area to supplement the present study could be suggested to follow a comparative approach in identifying the shorebird habitat utilization within the larger sanctuary area post two decades since the last published biodiversity profile (Ekanayake et al. 2005).

Sanctuaries play a crucial role in supporting biodiversity, albeit often subjected to regulated human interventions (Green 1990). Over the past decades, Kalametiya Sanctuary has undergone alterations, necessitating an understanding of the degree of habitat cover change and its impact on long-distance migrant

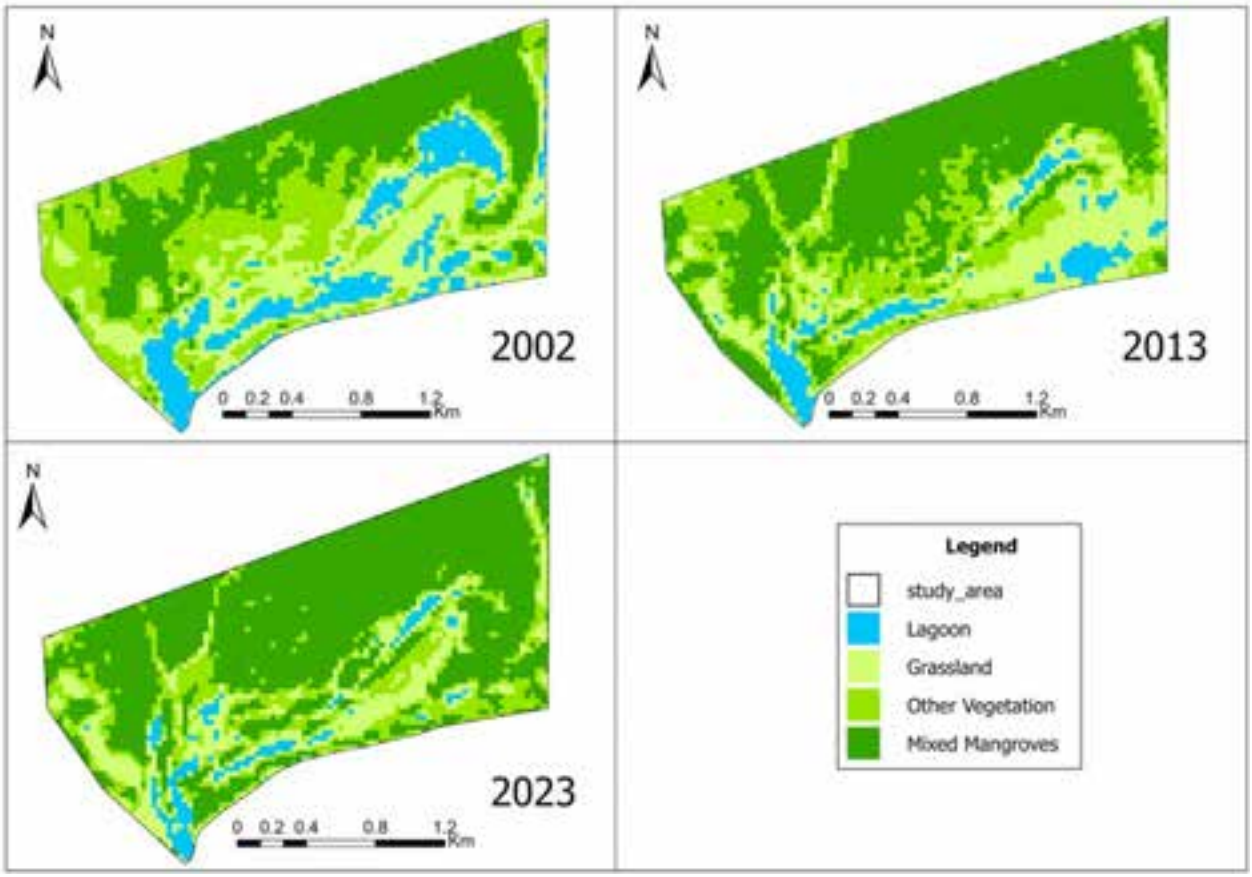


Figure 4. Spatio-temporal change of land cover within the study area depicted using satellite imagery. Prepared by E.G.D.P. Jayasekara.

and breeding resident shorebird species. Hence, the study analyzed satellite imagery data alongside spatial assemblage data of shorebirds utilizing the Kalametiya Lagoon and surrounding habitats with the intention of assessing the present conditions within the sanctuary. The findings revealed a significant decrease of over 69% in the lagoon area since 2002, a notable alteration that could potentially change the species composition within the sanctuary. Yet, this decrease in the lagoon area hasn't led to a drastic decline or a total displacement of shorebird communities. Based on the results of the present study, several reasons for this phenomenon can be proposed.

Studies identify that shorebirds feed and roost within the shallows of a wetland having water depths of less than 30cm, where prey availability and accessibility are mediated by their leg and bill lengths, or on the shores of wetland clusters during low tides, providing them chances with abundant prey (Zwarts & Wanink 1993; Bellio & Kingsford 2013). Hence, shorebirds continuing to sustain within the selected study area is reflected by the study results which show that their most utilized feeding grounds were the mixed mangrove and grassland habitats, recording shallower water depths (less than 30 cm) which match their bill length and leg heights, making these areas preferable over deeper lagoon waters.

Table 3. Land cover change (%) of the habitats in the study area over the period of 2002–2023.

	2002	2013	2023	Change (2002–2023)	% change
Lagoon	13.7	6.5	4.1	-9.6	-69.9373
Grasslands	24.6	22.7	17.0	-7.6	-30.7483
Other vegetation	30.0	24.0	17.7	-12.3	-40.9414
Mixed mangroves	31.6	46.8	61.1	29.5	93.19583

Additionally, breeding resident shorebirds such as the Black-winged Stilts (Ashoori 2011) and Red-wattled Lapwings (Hart et al. 2002; Arya et al. 2023) construct their nests in grassy areas or abandoned agricultural lands using dung, mud, and decayed plant materials, unlike waterbirds that prefer aquatic vegetation for nesting. Therefore, the decrease in the lagoon area doesn't significantly impact the nesting behaviors of these shorebirds. The nesting sites also contribute to

Table 4. Point count stations fixed along transects in the three selected habitats within the study area.

Grassland T1			Lagoon T2			Mixed mangrove T3		
Point count station	Longitude	Latitude	Point count station	Longitude	Latitude	Point count station	Longitude	Latitude
P1i	80.937	6.082	P1ii	80.936	6.080	P1iii	80.935	6.083
P2i	80.938	6.083	P2ii	80.935	6.081	P2iii	80.936	6.084
P3i	80.940	6.084	P3ii	80.935	6.081	P3iii	80.938	6.086
P4i	80.940	6.084	P4ii	80.935	6.082	P4iii	80.940	6.087
P5i	80.941	6.084	P5ii	80.935	6.083	P5iii	80.943	6.088
P6i	80.942	6.085	P6ii	80.935	6.084	P6iii	80.944	6.088
P7i	80.943	6.085	P7ii	80.935	6.085	P7iii	80.945	6.090
P8i	80.944	6.086	P8ii	80.935	6.087	P8iii	80.947	6.090
P9i	80.945	6.087	P9ii	80.935	6.088	P9iii	80.947	6.092
P10i	80.946	6.087	P10ii	80.935	6.089	P10iii	80.947	6.093

the notable species diversity observed in the grassland habitat during the non-migratory season. Furthermore, during the non-migratory season, coinciding with the dry spell in the study area, the drying up of mixed mangrove habitats reduces invertebrate food sources for shorebirds. In the grassland habitat where cattle grazing activities occur, the soil is disturbed, exposing land invertebrates such as snails and soft annelids, which serve as a vital food source for nesting parents and newly hatched shorebirds. However, such agricultural interventions contribute both positively and negatively to shorebird habitat utilization, and if not managed can lead to detrimental impacts.

Despite past recommendations for cattle grazing to be limited to demarcated buffer zones (Ekanayake et al. 2005), herds were observed in sensitive mixed mangrove and grassland habitats, risking nest trampling (Hart et al. 2002) and disturbing shorebird feeding grounds. A trampled nest of each of Red-wattled Lapwing and Black-winged Stilt were recorded during the present study. It is encouraged to conduct further research to actively monitor and quantify trampling rates of shorebird nests and highlight the need for the demarcation of grazing buffer zones within the Sanctuary.

The loss of wintering grounds in southern Asia for long distant migratory shorebirds due to coastal developments and habitat loss has posed a significant threat over the past years (Aarif et al. 2014; Byju et al 2023), especially to over-summering populations of shorebird species including the Common Redshank and Ruddy Turnstone (Aarif et al. 2020) which were recorded during the present study in the Kalametiya Sanctuary. Conservation of their over-summering habitats becomes crucial for successful population recruitment of these species into migratory counterparts in a consequent season or provides conditions supporting them to adapt and withstand changes beyond their home grounds. Moreover, habitat alterations following the 2004 Tsunami (Bambaradeniya et al. 2005; Perera et al. 2013; Madarasinghe et al. 2020a), the irrigation project bringing in more siltation into the lagoon (Madarasinghe et al. 2020b; Kodikara et al. 2023) and the recent breakwaters built in the Kalametiya fishing harbor, have impacted the ecosystem. Effective management actions are essential to regulate the environment for wildlife and humans. Despite past recommendations (Ekanayake et al. 2005) the present study notes continued habitat depletion due to inadequate intervention. This underscores the urgent need for enhanced conservation efforts to protect these vital habitats and their biodiversity.

Kalametiya Sanctuary sustains local livelihoods through fisheries and cattle farming (Ekanayake et al. 2005) and promotes eco-tourism with peaceful paddle boat rides dedicated to birdwatching. However, despite the numerous services the coastal wetland provides to maintain a healthy and productive ecosystem, it is evident that human interventions like habitat mismanagement, over-exploitation of resources, negligence, and uncontrolled waste disposal have disrupted the human-wildlife coexistence, especially in terms of the sustainability of thriving populations like shorebirds that bring not only ecological but also economical values using eco-tourism, habitat upliftment and food web balances within their utilized habitats. Therefore, advocating for heightened public awareness and community engagement in sustainable practices of living is recommended to safeguard the sanctuary for future generations. Awareness campaigns

among the local fisheries and farming communities on the effects of mismanaged waste disposal affecting both human health utilizing contaminants, and the health of the wetland mangroves that prevent coastal erosion, effective ways of reducing the risk of nest trampling and disturbances to the mixed mangroves by adhering to demarcated grazing buffer zones are some of the ground level initiatives that can be proposed to assist shorebird species conservation and sustainable coastal wetland habitat management implications. Further studies that identify the impacts of microplastic contamination similar to the study conducted by Luna et al. (2022) which found microplastics in nests of Black-winged Stilts in a Biosphere Reserve in Spain could comprehend to the present study in enhancing shorebird nesting habitat conservation. The year 2024 World Wetland Day theme, "Wetlands and Human Wellbeing," offers an opportune moment for initiating conservation efforts in the coastal wetland habitat of Kalametiya Sanctuary.

Since the shorebird ecology and causes and drivers for population decline in the CAF are less explored (Mundkur & Selvaraj 2023) research such as the present study supplements to identification of human interactions that affect the shorebird assemblage and their habitat utilization within coastal wetlands along the CAF and what are the timely conservation strategies that can be newly implemented and what existing strategies can be improved for better results in future. The present study, alongside previous research, suggests the potential declaration of the sanctuary as a Ramsar site due to its global conservation significance, providing crucial habitats for long- distant migrant shorebirds, threatened shorebirds, and over-summering shorebird species. Moreover, it sheds light on the impacts of land cover and land use changes on biodiversity in this altered coastal wetland, providing valuable insights for authorities and communities to recognize Kalametiya Sanctuary as a vital hub for biodiversity conservation and environmental sustainability in Sri Lanka.

CONCLUSION

The present study highlights the resilience of Kalametiya Sanctuary in supporting both migratory and breeding resident shorebird species despite ongoing habitat alterations over the past two decades. A survey conducted covering both migratory and non-migratory seasons recorded 25 shorebird species from six families, including globally and nationally threatened species. Land cover changes were assessed using satellite imagery, achieving acceptable accuracy rates exceeding 70% for each assessment year. Encouragingly, the study found that the present status of the habitats did not adversely affect migratory and breeding resident shorebirds, avoiding a wipe out of the species from the habitats. Over-summering species were also found utilizing the habitats. However, proactive management and conservation efforts are crucial to ensure the continued thriving of shorebird populations and to prevent further habitat depletion. Overall, this research underscores the significance of conserving altered coastal wetlands to maintain vital stopover and over-summering sites, especially in the southern Asian region along the CAF, while promoting sustainable livelihoods within and surrounding the sanctuary.

REFERENCES

Aarif, K.M., S.B. Muzaffar, S. Babu & P.K. Prasadan (2014). Shorebird assemblages respond to anthropogenic stress by altering habitat use in a wetland in India. *Biodiversity and Conservation* 23(3): 727–740. https://doi.org/10.1007/s10531-014-0630-9

Aarif, K.M., S.A. Kaiser, A. Nefla & S. Almaarofi (2020). Over-summering abundance, species composition, and habitat use patterns at a globally important site for migratory shorebirds. *The Wilson Journal of Ornithology* 132(1): 165–172. https://doi.org/10.1676/19-06

Albanese, G., C.A. Davis & B.W. Compton (2012). Spatiotemporal scaling of North American continental interior wetlands: Implications for shorebird conservation. *Landscape Ecology* 27(10): 1465–1479. https://doi.org/10.1007/s10980-012-9803-7

Arya, A.K., K.K. Joshi, D. Kumar & A. Bachheti (2023). A study on the breeding habits of Red-wattled Lapwing *Vanellus indicus* Boddaert, 1783 (Aves: Charadriformes: Charadridae) in the agricultural landscape of Muzaffarnagar District, Uttar Pradesh, India. *Journal of Threatened Taxa* 15(4): 23119–23122. https://doi.org/10.11609/jott.8066.15.4.23119-23122

Ashoori, A. (2011). Breeding Ecology of the Black-winged Stilt *Himantopus himantopus* in Boujagh National Park, Gilan Province, Northern Iran. *Podoces* 6(1): 87–91

Aycock, J.E. & C. Sims (2015). Shorebird Foraging Habitat in Southeast Arkansas. *Journal of the Arkansas Academy of Science* 69: 25–28. https://doi.org/10.54119/jaas.2015.6901

Bambaradeniya, C., S.P. Ekanayake, S.J. Perera & R.K. Rodrigo (2005). A report on the terrestrial assessment of Tsunami impacts on the coastal environment in Rekawa, Ussangoda and Kalametiya (RUK) area of southern Sri Lanka. IUCN – The World Conservation Union, Horton Place, Colombo, 33 pp.

Basset, A., M. Elliott, R.J. West & J.G. Wilson (2013). Estuarine and lagoon biodiversity and their natural goods and services. *Estuarine, Coastal and Shelf Science* 132: 1–4. https://doi.org/10.1016/j.ecss.2013.05.018

Bellio, M. & R.T. Kingsford (2013). Alteration of wetland hydrology in coastal lagoons: Implications for shorebird conservation and wetland restoration at a Ramsar site in Sri Lanka. *Biological Conservation* 167: 57–68. https://doi.org/10.1016/j.biocon.2013.07.013

Bernard, T., K.A.S. Kodikara, J. Sleutel, G.G.N.K. Wijeratne, J. Hugé, M.P. Kumara, M.A.Y.N. Weerasinghe, D.P.D. Ranakawa, W.A.K.G. Thakshila & F. Dahdouh-Guebas (2023). Assessing the Influence of Anthropogenic Land-Use Changes on Bird Diversity and Feeding Guilds—A Case Study of Kalametiya Lagoon (Southern Sri Lanka). *Diversity* 15(3): 383. https://doi.org/10.3390/d15030383

Bibby, C.J., M. Jones & S. Marsden (1998). *Bird surveys*. Expedition Advisory Centre, London, 137 pp.

Byju, H., N. Raveendran, S. Ravichandran & R. Kishore (2023). Importance of conserving a critical wintering ground for shorebirds in the Valinokkam Lagoon—a first study of the avifaunal distribution of the southeastern coast of India. *Journal of Threatened Taxa* 15(8): 23696–23709. https://doi.org/10.11609/jott.2023.15.8.23631-23836

Clemens, R.S., M.A. Weston, A. Haslem, A. Silcocks & J. Ferris (2010). Identification of significant shorebird areas: Thresholds and criteria. *Diversity and Distributions* 16(2): 229–242. https://doi.org/10.1111/j.1472-4642.2009.00635

Colwell, M.A. (2010). *Shorebird ecology, conservation, and management*. In: Delany, S., D. Scott, A.T.F. Helmink, T. Dodman, S. Flink, D. Stroud & L. Haanstra (2009). *An Atlas of Wader Populations in Africa and Western Eurasia*. Wetlands International, University of California Press.

Drisya, J. & T. Roshni (2018). Spatiotemporal Variability of Soil Moisture and Drought Estimation Using a Distributed Hydrological Model. *Integrating Disaster Science and Management* 2018: 451–460. https://doi.org/10.1016/B978-0-12-812056-9.00027-0

Duan, H., X. Yu, K. Shan, C. Zhang & H. Liu (2022). Effects of habitat loss on migratory shorebird community structure at stopover sites: A case study in the Yellow River Delta, China. *Frontiers in Marine Science* 9: 1049765. https://doi.org/10.3389/fmars.2022.1049765

Ekanayake, S.P., C.N.B. Bambaradeniya, W.P.N. Perera, M.S.J. Perera, R.K. Rodrigo, V.A.M.P.K. Samarawickrema & T.N. Peiris (2005). A Biodiversity Status Profile of Lunama - Kalametiya Wetland Sanctuary. *Occassional Paper*. 8. IUCN, Sri Lanka., iv–43.

Ferreira, W.L.S., L.C. da Rosa & C.E. Bemvenuti (2005). Effects of the shorebirds predation on the estuarine macrofauna of the Patos lagoon, south Brazil. *Thalassas. An International Journal of Marine Sciences* 21: 77–82.

Grebner, D.L., P. Bettinger & J.P. Siry (2013). Forest Measurements and Forestry-Related Data. *Introduction to Forestry and Natural Resources* 2013: 191–220. https://doi.org/10.1016/B978-0-12-386901-2.00008-7

Green, M.J.B. (1990). IUCN Directory of South Asian Protected Areas. IUCN – The World Conservation Union. http://www.archive.org/details/iucndirectoryofs90gree

Gunatilleke, N., R. Pethiyagoda & S. Gunatilleke (2017). Biodiversity of Sri Lanka. *Journal of the National Science Foundation of Sri Lanka* 36: 25. https://doi.org/10.4038/jnsfsr.v36i0.8047

Harrison, J. & T. Worfolk (2011). *A Field Guide to the Birds of Sri Lanka* (2). Oxford University Press, New York, 224 pp.

Hart, J.D., T.P. Milsom, A. Baxter, P.F. Kelly & W.K. Parkin (2002). The impact of livestock on Lapwing *Vanellus vanellus* breeding densities and performance on coastal grazing marsh. *Bird Study* 49(1): 67–78

Hayman, P.J., J.H. Marchant & A.J. Prater (2011). *Shorebirds: An identification guide to the waders of the world*. Christopher Helm Publishers, London, 17–202 pp.

Jayathilake, M.B. & W.U. Chandrasekara (2015). Variation of avifaunal diversity in relation to land-use modifications around a tropical estuary, the Negombo estuary in Sri Lanka. *Journal of Asia-Pacific Biodiversity* 8(1): 72–82. https://doi.org/10.1016/j.japb.2015.02.001

Jayatissa, L.P., M.C. Guero, S. Hettiarachchi & N. Koedam (2002). Changes in vegetation cover and socio-economic transitions in a coastal lagoon (Kalametiya, Sri Lanka), as observed by teledetection and ground truthing, can be attributed to an upstream irrigation scheme. *Environment, Development and Sustainability* 4(2): 167–183. https://doi.org/10.1023/A:1020831416827

Jumilawaty, E., A.L.A. Nasution & S. Siregar (2022). Shorebird community and diversity in Bagan Serdang Beach, North Sumatra. IOP Conference Series: *Earth and Environmental Science* 1115: 012001. https://doi.org/10.1088/1755-1315/1115/1/012001

Kaliraj, S., N. Chandrasekar, K.K. Ramachandran, Y. Srinivas & S. Saravanan (2017). Coastal landuse and land cover change and transformations of Kanyakumari coast, India using remote sensing and GIS. *Egyptian Journal of Remote Sensing and Space Science* 20(2): 169–185. https://doi.org/10.1016/j.ejrs.2017.04.003

Kodikara, K.A.S., T. Hoessein, P.M.C.S. De Silva, P. Ranasinghe, H.P.P.S. Somasiri, S.K. Madarasinghe, D.U.V. Gunathilaka, D. Ranawaka, M. Danaee, J. Andrieu & F. Dahdouh-Guebas (2023). Spatial distribution of heavy metals in surface sediments of the Kalametiya Lagoon in southern Sri Lanka: Insights into the pollution status and socio-economic interactions. *Journal of the National Science Foundation of Sri Lanka* 51(3): 387–397. https://doi.org/10.4038/jnsfsr.v51i3.11193

Kotagama, S., M. Bellio & K. Dayananda (2006). Pioneering shorebird research in Sri Lanka: launch of the National Bird Ringing Programme. *Bulletin Wader Study Group* 109: 106–110.

Luna, Á., J. Gil-Delgado & E. Bernat-Ponce (2022). Plastic Debris in Nests of Two Water Bird Species Breeding on Inland Saline Lakes in a Mediterranean Biosphere Reserve. *Animals* 12(22): 3222. https://doi.org/10.3390/ani12223222

Madarasinghe, S.K., K.K.A.S. Yapa, B. Satyanarayana, P.M.P. Udayakantha, S. Kodikara & L.P. Jayatissa (2020a). Inland Irrigation Project Causes Disappearance of Coastal Lagoon: The Trajectory of Kalametiya Lagoon, Sri Lanka from 1956 to 2016. *Coastal Management* 48(3): 188–209. https://doi.org/10.1080/08920753.2020.1747914

Madarasinghe, S.K., Y.W.P. Amarasinghe, C.H. Liyanage, H.M.S.A.T. Gunathilake, J.A.I.K. Jayasingha, M. Jayasingha, W.K.L. Priyankara, K.A.S. Kodikara, N. Koedam, F. Dahdouh-Guebas & L.P. Jayatissa (2020b). Retrospective study on changes in Dondra lagoon (2006–2017) resulting from tsunami impact and post-tsunami development. *Journal of Coastal Conservation* 24: 58. https://doi.org/10.1007/s11852-020-00777-1

Mundkur, T. & R. Selvaraj (2023). Central Asian Flyway – Situation Analysis: The status of migratory birds and their habitats and recommendations for their conservation, 67 pp. https://doi.org/10.13140/RG.2.2.32281.80480

Myers, J., R. Morrison, P. Antas, B. Harrington, T.E. Lovejoy, M. Sallaberry, S. Senner & A. Tarak (1987). Conservation strategy for migratory species. *American Scientist* 75: 19–26

Newton, A., A.C. Brito, J.D. Icely, V. Derolez, I. Clara, S. Angus, G. Schernewski, M. Inácio, A.I. Lillebø, A.I. Sousa, B. Béjaoui, C. Solidoro, M. Tosic, M. Cañedo-Argüelles, M. Yamamuro, S. Reizopoulou, H. Tseng, D. Canu, L. Roselli & V. Khokhlov (2018). Assessing, quantifying and valuing the ecosystem services of coastal lagoons. *Journal for Nature Conservation* 44: 50–65. https://doi.org/10.1016/j.jnc.2018.02.009

Ntongani, W.A. & S.M. Andrew (2013). Bird species composition and diversity in habitats with different disturbance histories at Kilombero Wetland, Tanzania. *Open Journal of Ecology* 03(07): 482–488. https://doi.org/10.4236/oje.2013.37056

Pantazi, X.E., D. Moshou & D. Bochtis (2020). Utilization of multisensors and data fusion in precision agriculture. *Intelligent Data Mining and Fusion Systems in Agriculture* 2020: 103–173. https://doi.org/10.1016/B978-0-12-814391-9.00003-0

Pearce-Higgins, J.W., D.J. Brown, D.J.T. Douglas, J.A. Alves, M. Bellio, P. Bocher, G.M. Buchanan, R.P. Clay, J. Conklin, N. Crockford, P. Dann, J. Elts, C. Friis, R.A. Fuller, J.A. Gill, K. Gosbell, J.A. Johnson, R. Marquez-Ferrando, J.A. Masero & Y.I. Verkuil (2017). A global threats overview for Numeniini populations: Synthesising expert knowledge for a group of declining migratory birds. *Bird Conservation International* 27(1): 6–34. https://doi.org/10.1017/S0959270916000678

Perera, W.P.N., M.S.J. Perera, R. Rodrigo, N. Peiris, V.A.M.P.K. Samarawickrema, S.P. Ekanayake & C.N.B. Bambaradeniya (2013). An assessment of biodiversity in the Rekawa, Ussangoda and Kalametiya inland coastal ecosystems in southern Sri Lanka. Proceedings of International Forestry and Environment Symposium, 41 pp. https://doi.org/10.31357/fesympo.v0i0.1519

Pérez-Ruzafa, A., C. Marcos, I.M. Pérez-Ruzafa & M. Pérez-Marcos (2011). Coastal lagoons: "transitional ecosystems" between transitional and coastal waters. *Journal of Coastal Conservation*

15(3): 369–392. https://doi.org/10.1007/s11852-010-0095-2

Secretariat, B., S. Dayananda, S. Fernando, T. Herath, N. Perera, S. Perera, S. Seneviratne, A. Sumanapala, S. Wickramasinghe & D. Weerakoon (2022). *The National Red List: Conservation Status of Birds of Sri Lanka*. Biodiversity Secretariat Ministry of Environment, Sri Lanka, viii + 476 pp.

Skagen, S.K. & F.L. Knopf (1994). Wilson Ornithological Society Migrating Shorebirds and Habitat Dynamics at a Prairie Wetland Complex. *The Wilson Bulletin* 106(1): 91–105.

Sutherland, W.J., J.A. Alves, T. Amano, C.H. Chang, N.C. Davidson, C.M. Finlayson, J.A. Gill, R.E. Gill, P.M González, T.G. Gunnarsson, D. Kleijn, C.J. Spray, T. Székely & D.B.A. Thompson (2012). A horizon scanning assessment of current and potential future threats to migratory shorebirds. *Ibis* 154(4): 663–679. https://doi.org/10.1111/j.1474-919X.2012.01261

Thomas, G.H., M.A. Wills & T. Székely (2004). A supertree approach to shorebird phylogeny. *BMC Evolutionary Biology* 4: 28. https://doi.org/10.1186/1471-2148-4-28

Vivekananda, G.N., R. Swathi & A.V.L.N. Sujith (2021). Multi-temporal image analysis for LULC classification and change detection. *European Journal of Remote Sensing* 54(2): 189–199. https://doi.org/10.1080/22797254.2020.1771215

Warnock, N. & M. Bishop (1998). Spring stopover ecology of migrant Western Sandpipers. *The Condor* 100: 456–467. https://doi.org/10.2307/1369711

Zwarts, L. & J. Wanink (1993). How the food supply harvestable by waders in the Wadden Sea depends on the variation in energy density, body weight, biomass, burying depth and behaviour of tidal-flat invertebrates. *Netherlands Journal of Sea Research* 31: 441–476. https://doi.org/10.1016/0077-7579(93)90059-2

Author details: Vinuri Nisansa Mendis—post graduate researcher engaged in research in the field of wildlife ecology conservation with a focus on ornithology. E.J.A.P. Buddhi Priyankara—naturalist based in southern Sri Lanka contributing to conservation actions locally and nationally and engaging in sustainable ecotourism activities. E.G. Dulan Pathum Jayasekara—lecturer in Zoology from the University of Sri Jayewardenepura having over 10 years of experience in research in the fields of wildlife ecology and conservation, mammalogy, herpetology, population ecology and GIS and remote sensing. W.A. Dharshani Mahaulpatha—professor in Zoology from the University of Sri Jayewardenepura having over 30 years of experience in research in the fields of wildlife ecology and conservation, population ecology, wildlife management, herpetology and ornithology.

Author contributions: All authors contributed equally to data collection, sampling and analysis, and preparing the manuscript. The maps were prepared by E G D P Jayasekara, and the photographs were taken by V N Mendis.

Acknowledgements: We acknowledge the immense support and guidance given by the Department of Wildlife Conservation Sri Lanka (Permit No: WL/3/2/42/22), Department of Zoology and Faculty of Graduate Studies of the University of Sri Jayewardenepura, and the members of the Wildlife Circle of the University of Sri Jayewardenepura to conduct this research successfully.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25507–25515

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

https://doi.org/10.11609/jott.8247.16.7.25507-25515

#8247 | Received 31 October 2022 | Final received 05 July 2024 | Finally accepted 09 July 2024

OPEN ACCESS

ARTICLE

Current conservation status of Bengal Florican *Houbaropsis bengalensis* in Manas National Park, Assam, India

Miranda Thakur [1], Jonmani Kalita [2], Namita Brahma [3], Koushik Rajbongshi [4], Kangkanjyoti Bhattacharyya [5], Amal Chandra Sarmah [6], Alolika Sinha [7], Deba Kumar Dutta [8], Dhritiman Das [9] & Bibhuti Prasad Lahkar [10]

[1,2,4,5,7,10] Aaranyak- 13 Tayab Ali Byelane, Bishnu Rabha Path, Beltola, Guwahati, Assam 781028, India.
[3] TISS Guwahati- Tetalia Road, Jalukbari, Guwahati, Assam 781013, India.
[6] Office of the Field Director- Manas Tiger Project, Barpeta Road, Assam 781315, India.
[8] WWF India- Barpeta Road, Milan Nagar, Assam 781315, India.
[9] Pygmy Hog Research and Breeding Centre- Bashistha, Indira Nagar Road, Guwahati, Assam 781029, India.
[1] 14mirandathakur@gmail.com, [2] jonmani@aaranyak.org (corresponding author), [3] namita.brahma@tiss.edu, [4] koushik@aaranyak.org, [5] kangkanjyotibhattacharyya1@gmail.com, [6] amal.sarmah14@gmail.com, [7] alolika@aaranyak.org, [8] debakumerdutta@gmail.com, [9] dhritiz@gmail.com, [10] bibhuti@aaranyak.org

Abstract: This study aimed to examine the current conservation status of the 'Critically Endangered' bird species *Houbaropsis bengalensis* (Gmelin, 1789), commonly known as the Bengal Florican or Bustard, in Manas National Park in Assam. The grasslands of this park, once home to the largest population of Bengal Floricans in India, are undergoing natural and anthropogenic changes. Field surveys conducted from February to April 2021 to assess florican populations recorded 50 males and 17 females, while a 2009 survey estimated 24 males in Manas NP (Brahma et al. 2009), indicating long-term population increase. Land use and land cover change maps of florican habitats were created using supervised classification. Grassland habitats face several threats, including uncontrolled natural succession coupled with livestock grazing, growth of invasive alien plants and collection of non-timber forest products (NTFPs) by local people. These disturbances reflect the condition of grasslands that are home to a wide variety of wildlife, including grassland specialists like Pygmy Hog *Porcula salvania*, Hispid Hare *Caprolagus hispidus*, Hog Deer *Axis porcinus,* and mega herbivores like Indian Rhino *Rhinoceros unicornis*, wild Water Buffalo *Bubalus arnee*, Eastern Swamp Deer *Rucervus duvaucelii ranjitsinhi*, Gaur *Bos gaurus,* and Asian Elephant *Elephas maximus*. These findings indicate an urgent need to protect and restore grasslands for conservation of the Bengal Florican and other grassland-dependent species.

Keywords: Aves, conservation threats, grassland specialists, habitat supervised classification, habitat disturbance, Otididae, sub-Himalayan grassland.

Editor: Hem S. Baral, Ullens School, Lalitpur Nepal.

Date of publication: 26 July 2024 (online & print)

Citation: Thakur, M., J. Kalita, N. Brahma, K. Rajbongshi, K. Bhattacharyya, A.C. Sarmah, A. Sinha, D.K. Dutta, D. Das & B.P. Lahkar (2024). Current conservation status of Bengal Florican *Houbaropsis bengalensis* in Manas National Park, Assam, India. *Journal of Threatened Taxa* 16(7): 25507–25515. https://doi.org/10.11609/jott.8247.16.7.25507-25515

Funding: The Habitats Trust, WCS Cambodia.

Competing interests: The authors declare no competing interests.

Author details: See end of this article.

Author contributions: MT and JK contributed to data collection, scientific analysis, and manuscript writing. KR, AS, and KB contributed to data collection. NB, DD, and BPL critically analyzed all findings. ACS led the team, supported by DKD, DD and BPL.

Acknowledgements: We thank Manas National Park range officers Babul Brahma, Kameswar Boro and the frontline staff for their support throughout the survey. We would also like to express our gratitude to Dr. Jyoti Das, Dr. Biswajit Chakdar, Dr. Joydev Mandal, Dr. Hilloljyoti Singha, Mr. Udayan Borthakur, and Mr. Rustom Basumatary for their assistance during the survey period. We are grateful to the Habitats Trust for their financial support through the Pygmy Hog Conservation Programme and to WCS Cambodia for enabling us to undertake the field survey and other activities.

INTRODUCTION

Bengal Florican, *Houbaropsis bengalensis* (Gmelin, 1789), is a 'Critically Endangered' grassland bird (IUCN 2022) belonging to the family Otididae. In India, it is protected under Schedule I of the Wildlife Protection Act, 1972. The population of Bengal Florican is 350–400 in India, <100 in Nepal (Collar et al. 2017; Baral et al. 2020) and <500 individuals in Cambodia (BirdLife International 2022). In India, the population of Bengal Florican is restricted to the sub-Himalayan region of the Indo-Gangetic floodplains and the Brahmaputra floodplains (Rahmani et al. 2017). They are extremely habitat specialists and are restricted to grasslands (Prasai et al. 2021). Bengal Floricans were once distributed from Uttar Pradesh, Bihar, and West Bengal to the foothills of Assam and Arunachal Pradesh in India. However, at present, it is confined to a few protected areas in India including Manas National Park (MNP), Kaziranga National Park, Orang National Park, Dibru-Saikhowa National Park, Burachapori Wildlife Sanctuary in Assam, D'Ering Wildlife Sanctuary in Arunachal Pradesh, and Dudhwa National Park in Uttar Pradesh. The species is confined to only these few protected areas and appears nowhere outside these areas (BirdLife International 2022).

In 1989–90, the Bombay Natural History Society (BNHS) conducted a survey in India and found that Manas National Park had the highest Bengal Florican population. Around 80 birds were estimated during the study, which is perhaps the largest known population of Bengal Florican in any single locality. However, the population of Bengal Floricans declined from 1990–2000 because of the socio-political unrest created during Bodo agitation in the areas adjoining Manas. However, according to reports, the population has shown an increasing trend from 2003–2012 (Brahma et al. 2009). The population of Bengal Florican was estimated to be around 50 individuals in Manas National Park (Brahma et al. 2009). Since 1989–1990, approximately 40% of the Bengal Florican population has been lost, and grass height was the main factor. It is assumed that these birds are site-selective in establishing their territory, and prefer wet alluvial grassland for breeding, which is reduced by 47% and succeeding towards savanna grassland (Brahma 2013). The global population of the species has been rapidly declining, and the IUCN Red List for Threatened Species has upgraded Bengal Florican from 'Endangered' to 'Critically Endangered' (BirdLife International 2010).

The highest number of Bengal Floricans was reported from Kokilabari Agriculture Farm (KAF) (Brahma et al. 2009). The KAF is 9 km^2, which is a large grassland site. The KAF is under extensive agricultural practice and leased to local communities for paddy cultivation. Paddy cultivation began in June and harvested in December. It has been reported that the Bengal Florican population was established during 2000–2001, the period when the farm was not under cultivation. One reason for the selection of these sites by Bengal Floricans is the lack of waterlogging (Brahma et al. 2009).

The aim of this study is to address the lack of information on the populations and habitats of the Bengal florican in Manas National Park through a systematic approach, thereby contributing to the development of long-term conservation strategies. This research serves as a stepping stone for further research and education aimed at preserving the Bengal florican and its habitat.

METHODS

Study site

Manas National Park

Manas National Park (MNP) is a World Heritage Site, a Tiger Reserve, a Biosphere Reserve, and an Elephant Reserve located in the state of Assam (Das et al. 2022). MNP ((26.583–26.833 ^{0}N, 90.750–91.250 ^{0}E) is the core area of Manas Tiger Reserve with an area of 500 km^2, located in Baksa and Chirang districts of the Bodoland Territorial Council, Assam (Figure 1). Apart from Bengal Floricans the grasslands are home to a wide variety of wildlife including grassland specialist like Pygmy Hog *Porcula salvania*, Hispid Hare *Caprolagus hispidus*, Hog Deer *Axis porcinus* and other mega herbivorous like Indian Rhino *Rhinoceros unicornis*, Brahma et al. 2009 Wild Water Buffalo *Bubalus arnee*, Eastern Swamp Deer *Rucervus duvaucelii ranjitsinhi*, Gaur *Bos gaurus,* and Asian Elephant *Elephas maximus*. It is a regional priority site for the conservation of charismatic species, including 55 mammals, 50 reptiles, and more than 450 bird species (Sarma et al. 2008; Das et al. 2022). A total of 462 plant species have been reported from within the national park, but the region is rich in plant life with about 622 plant species reported from the larger Manas Biosphere region. This includes 429 dicotyledons, 162 monocotyledons, 30 pteridophytes, and one gymnosperm (Hajra & Baishya 2002). It lies at an altitude of 57–280 m. The temperature ranges from 6–37 °C. The rainfall lies between 3,000 mm to 4,000 mm per year. The rainfall reaches its peak in July and

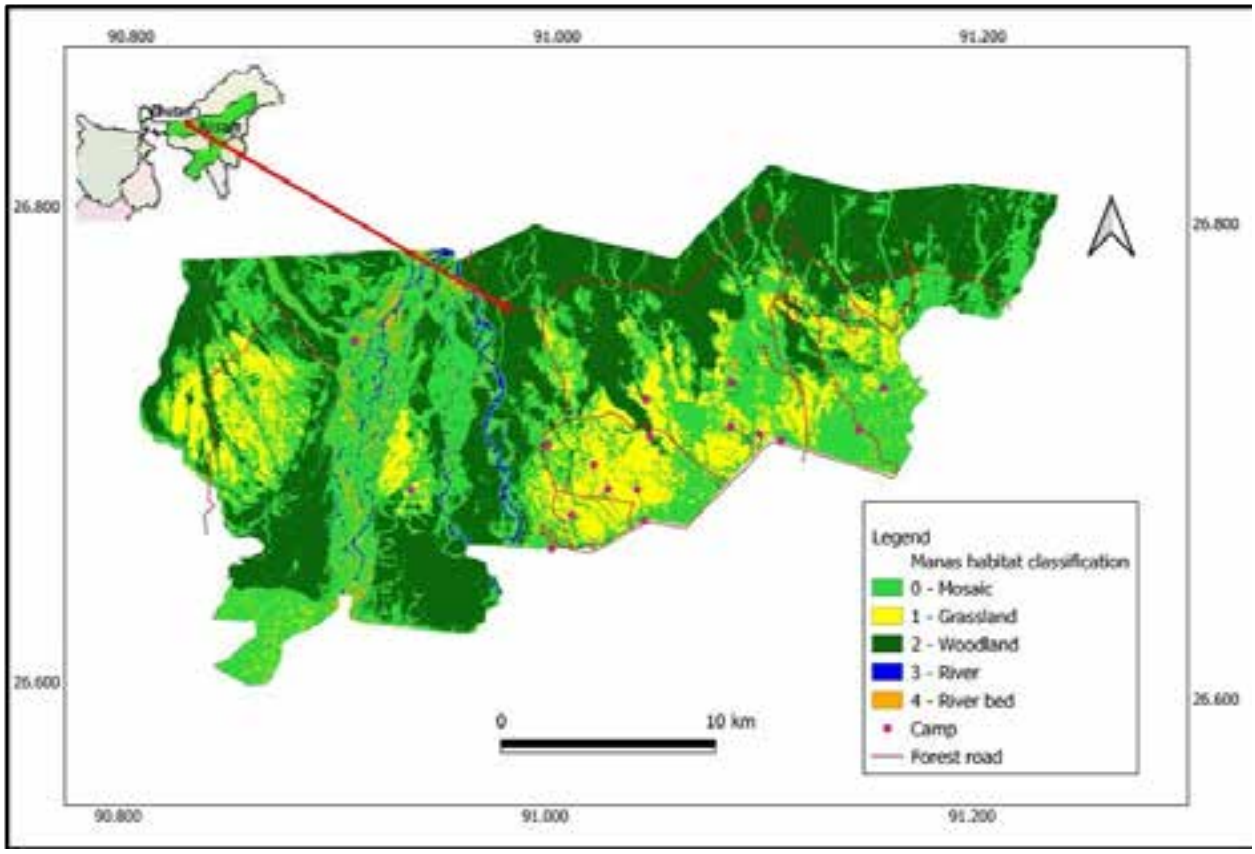


Figure 1. Map of Manas National Park in Assam.

August. The vegetation of the park is moist deciduous forest, early successional woodland grassland, and dry-wet alluvial grassland (Sarma et al. 2008; Banerjee et al. 2021). Due to resource extraction by local communities and livestock grazing, MNP experiences biotic pressure. Local people may start fires to encourage the growth of fresh grass, but processes are mostly initiated by park managers to control woody plant encroachment into grassland areas. However, the dynamics of fires after ignition are not controlled by forest managers, and the spatial patterns and extent of fires are determined by habitat factors (Banerjee et al. 2021).

Methods for population assessment

The survey was conducted based on habitat maps and past records of the complete population census of Bengal Florican. The surveys were carried out in the three ranges, namely, Bansbari, Bhuyanpara, and Panbari of Manas National Park during the peak breeding season of the Bengal Florican from 20 February–22 April 2021. Birds were observed using vehicles, walking on foot, or from elevated forest towers. Sightings and GPS locations were recorded. Field surveys were carried out during the early morning (0600–0930 h) and late evening (1500–1800 h). On certain days, the survey was conducted until noon. The number of Bengal Floricans spotted, the number of males and females sighted, the time of sightings, along with the location of the species were recorded. Since, the species is territorial in nature during the breeding season, the display site of a male, was considered as an individual male territory and each displaying male was recorded as an individual male and the females are difficult to locate (Images 1 & 2). The breeding territories were identified and marked using handheld GPS (Garmin etrex 30x) and GIS-based map of identified Bengal Florican territories was prepared using QGIS (QGIS Development Team 2020).

The methodologies employed in this survey were consistent with those used in the studies by Brahma (2013) and Narayan (1992). Similar techniques and area coverage were utilized to ensure comparability between the current and previous surveys. No higher conservation technologies were employed during this survey, maintaining the same level of effort and methodological approach as in the earlier studies.

Method for land cover change

Satellite images from 2000 and 2020 were analyzed to detect the change in land cover using remote sensing and geographic information system tools. The open-source satellite images were obtained from Landsat 7 and Landsat 8 through https://earthexplorer.usgs.gov. Landsat 7 and Landsat 8 images were used for classification at 30 x 30 m resolution and I, II III, IV, V, VII and II, III, IV, V, VI, VII bands were used respectively. Open-source QGIS software (QGIS Development Team 2020) was used to classify the image objects. Using supervised classification, Bengal Florican record sites were classified and land cover changes were analyzed and the classified habitat into three classes: grassland, woodland, and grassland woodland mosaic.

Method for vegetation survey

First, a grid map of Florican locations was prepared using GIS. The standardized grid size was 1 × 1 km. The total area of grassland was divided into 10; 1 x 1 km blocks. Within each 1 x 1 km grid area, 10 quadrats of × 1 m were placed centrally. To fulfill the objectives, quadrat sampling method (Stohlgren et al. 1995) was used for the quantitative study of the vegetation of Bengal Florican.

Method for disturbance study

To study the disturbance drivers of the Bengal florican and their habitats, the same 1 x 1 km grids were used for data collection. Cattle grazing, the presence of invasive alien plant species, problematic native species, and other human-induced disturbances were recorded.

RESULT

Distribution and population status

Houbaropsis bengalensis were recorded from Bansbari, Bhuyanpara, and Panbari grasslands. (Figure 3, Table 1). 50 males and 17 females were observed in Kuribeel, Rupahi, Sidajhar, Kokilabari, Bhumuk, Abiwidora, Agrang, and Murabari (Table 1). Eighteen males were sighted displaying: nine in Kokilabari, four in Rupahi, three in Agrang, and two in Kuribeel. The highest number of individuals were sighted in Kokilabari located in the Bhuyanpara range of the National Park, followed by Rupahi and Kuribeel. Seven males were observed during flight, looking at their flight direction. Females are difficult to spot, and direct observations estimate the total count of Bengal Floricans to be 74 (Table 2). No floricans could be sighted in areas such as Kasindaha, Mahout Camp Fields, Palsiguri, Uchila-Bongali Hathdhowa, Bura Buri Jhar, Dighlatari, and Pohu Field, where floricans had been previously reported (Narayan 1992; Brahma 2013).

Table 3 list the names of grassland blocks located in Manas National Park where Bengal Floricans have been reported in the past and in the current study. The map was generated using QGIS to study and compare Bengal Florican locations in grasslands over the last few decades. The results of past surveys carried out in 1989 (Narayan 1992), 2011 (Brahma 2013), and 2021 were used to compare the data with those of the current study (Figures 2 & 3).

Land cover change

The results indicated habitat changes in vegetation within the recorded site. In the year 2000; 11.7 km^2 area of grassland represent 79%, 3.03 km^2 area of grassland woodland mosaic represent 21%, and 0.036 km^2 area of woodland are represent 0.24 % (Table 4, Figures 4 & 6). In the year 2020; 7.3 km^2 area of grassland represent 49.6%, 0.75 km^2 area of woodland represent 5.1%, and 6.67 km^2 area of grassland woodland mosaic represent 45.3% (Table 5, Figures 5 & 6). From 2000–2020; 4.7 km^2 of grassland area was converted to mosaic representing 32%, 0.49 km^2 of grassland area was converted to woodland representing 3.4%, 0.0009 km^2 of the mosaic area was converted to a waterbody representing 0.01%,

Table 1. Bengal Florican sightings along with GPS locations.

	Locations	Area	Number of males sighted	Number of territories established (Female)
1	N26.74857, E91.17289	Kokilabari	20	7
2	N26.68549, E91.02865	Kuribeel	5	2
3	N26.68469, E91.04027	Bhumuk	2	0
4	N26.71303, E91.08633	Rupahi	7	4
5	N26.72930, E91.08080	Abiwidora	3	3
6	N26.71128, E91.15022	Agrang	7	0
7	N26.68044, E90.91007	Murabari	2	1
8	N26.69722, E90.92653	Sidhajhar	4	0

Table 2. Total count of Bengal Florican population.

	Bengal Florican	Population
1	Male	50
2	Female	17
3	Additional male sighted in flight	7
	Total	74

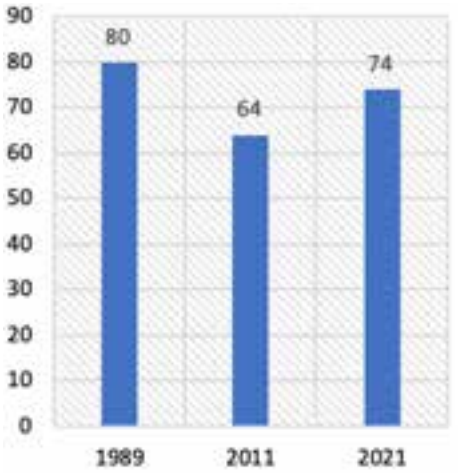


Figure 2. Bengal Florican recorded in 1989, 2011, and 2021.

Table 4. Classification of L7 Satellite imageries of 2000.

Class ID	Class name	Pixel sum	Area [km^2]	Percentage [%]
0	Mosaic	3368	3.031	20.57
1	Grassland	12960	11.664	79.17
2	Woodland	40	0.036	0.244

0.81 km^2 of the mosaic area was converted to grassland representing 5.5%, 0.24 km^2 mosaic area converted to woodland representing 1.63%, and 0.02 km^2 woodland area converted to mosaic representing 0.13% (Table 6).

Vegetation survey

The grasslands were burned in the month of February and a fresh flush of grasses emerged soon after establishing a suitable habitat for the Bengal Floricans to breed. The following plant species were observed during the survey (Table 7). And most of the Bengal Florican habitats where they are recorded in the grassland have short grass *Imperata cylindrica* and moderately tall and dense grasses like *Saccharum spontaneum* and *Saccharum narenga.*

Threats

The grasslands of the park are subjected to a number of natural and anthropogenic disturbances. The conversion of grasslands into woodlands is a serious threat to grassland species. *Bombax ceiba* (Simul), a tree species was found growing extensively in the grasslands. Cattle grazing is one such disturbance that has been observed in the National Park. The grazing of livestock by communities living in the fringes of the National Park is one of the major causes of habitat degradation. *Premna herbacea*, a medicinal herb that grows profusely in the grasslands of Manas is a major non-timber forest products (NTFPs). Local communities depend on these products for their livelihoods. The presence of humans in these grasslands inhabited by Bengal Floricans is another cause of disturbance to the species. The presence of invasive alien plants is another major disturbance to the habitat. *Chromaelaena odorata* a shrub was found growing extensively in the grasslands of the national park occupied by Bengal Floricans.

Table 3. Male Bengal Florican sightings over the last four decades (Narayan 1992; Brahma 2013).

	Grassland Block	1989	2011	*2021*
1	Kasindaha	7	NA	NA
2	Mahout Camp Fields	4	NA	NA
3	Palsiguri	3	NA	NA
4	Kuribeel	6	5	5
5	Uchila-Bongali Hathdhowa	1	NA	NA
6	Bura Buri Jhar	1	NA	NA
7	Lafasari	NA	4	NA
8	Kapur-pura/ Sidhajhar	8	5	4
9	Pohu Field	NA	2	NA
10	Dighlatari	NA	4	NA
11	Agrang	NA	4	7
12	Kokilabari	NA	8	20
13	Murabari	NA	NA	2
14	Abiwidora	NA	NA	3
15	Rupahi	NA	NA	7
16	Bhumuk	NA	NA	2
Total		**30**	**32**	**50**

Table 5. Classification of L8 Satellite imageries of 2020.

Class ID	Class name	Pixel sum	Area [km^2]	Percentage [%]
0	Mosaic	7421	6.6789	45.33
1	Water	1	0.0009	0.0061
2	Grassland	8110	7.299	49.54
3	Woodland	836	0.7524	5.10

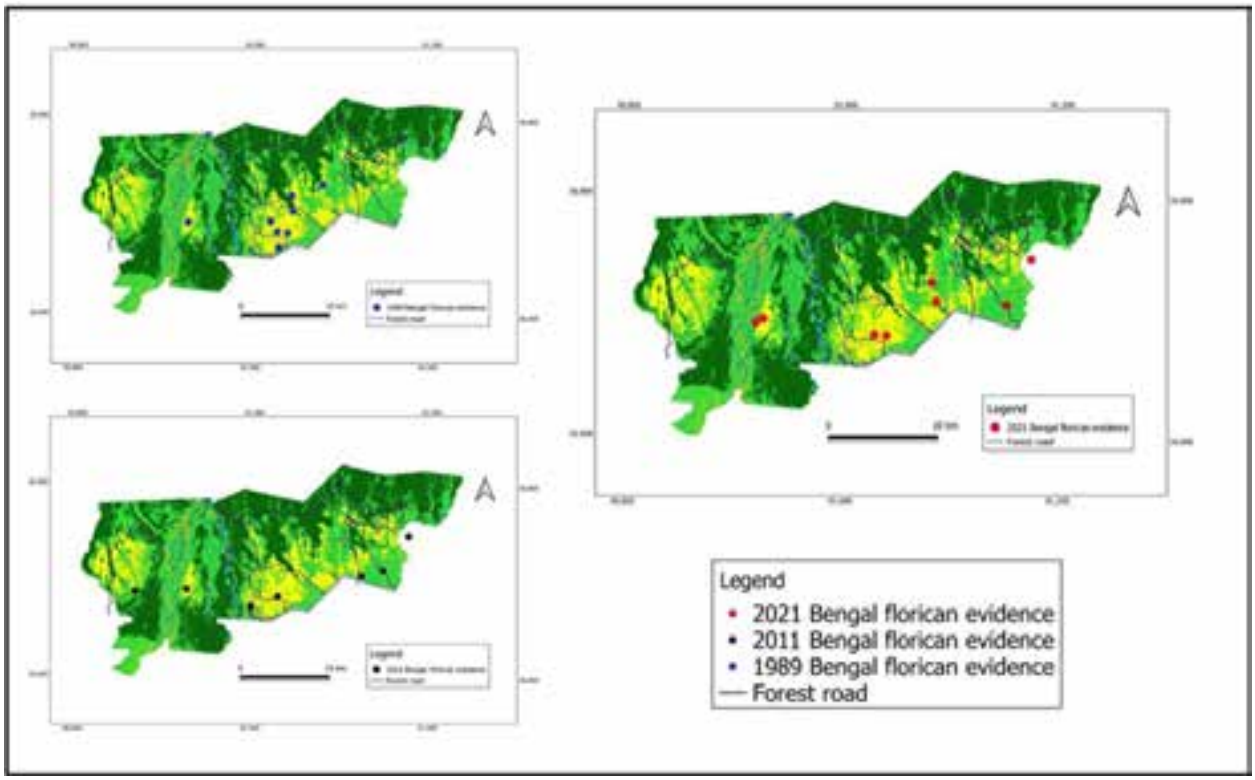


Figure 3. The distribution of Bengal Florican in the surveys carried out in 1989, 2011, and in the current study 2021.

Table 6. Land cover change between 2000 and 2020.

Cross class code	Reference class (L7)	New class (L8)	Pixel sum	Area [km²]	Percentage of change (%)
6	Mosaic	Mosaic	2202	1.98	13.45
10	Mosaic	Water	1	0.0009	0.01
14	Mosaic	Grassland	898	0.8082	5.49
18	Mosaic	Woodland	267	0.2403	1.63
7	Grassland	Mosaic	5197	4.6773	31.78
15	Grassland	Grassland	7212	6.4908	44.10
19	Grassland	Woodland	551	0.4959	3.37
8	Woodland	Mosaic	22	0.0198	0.13
20	Woodland	Woodland	18	0.0162	0.11

DISCUSSION

Our survey estimated 74 Bengal Floricans in Manas, which compared to 2011 represents an increase (Figure 3). The Florican number 74 is higher than the result of the last survey conducted in 2011 (Brahma 2013), but lower than the result of a previous survey conducted in 1989 (Narayan 1992). Interestingly, at least 20 male floricans and seven female floricans were recorded at the Kokilabari Agriculture Farm (KAF). The highest number of floricans was recorded in KAF. Thus, there is a long term need to conserve such sites such as the KAF for long term conservation of the species.

The survey for Bengal Floricans in Manas National Park provides important evidence for the presence of Bengal Floricans at the study site. It also indicates an increasing trend since the last survey carried out in 2011 which is encouraging (Brahma 2013). This survey also provided new information from previously surveyed areas such as Murabari, Abiwidora, and Bhumuk grassland areas,

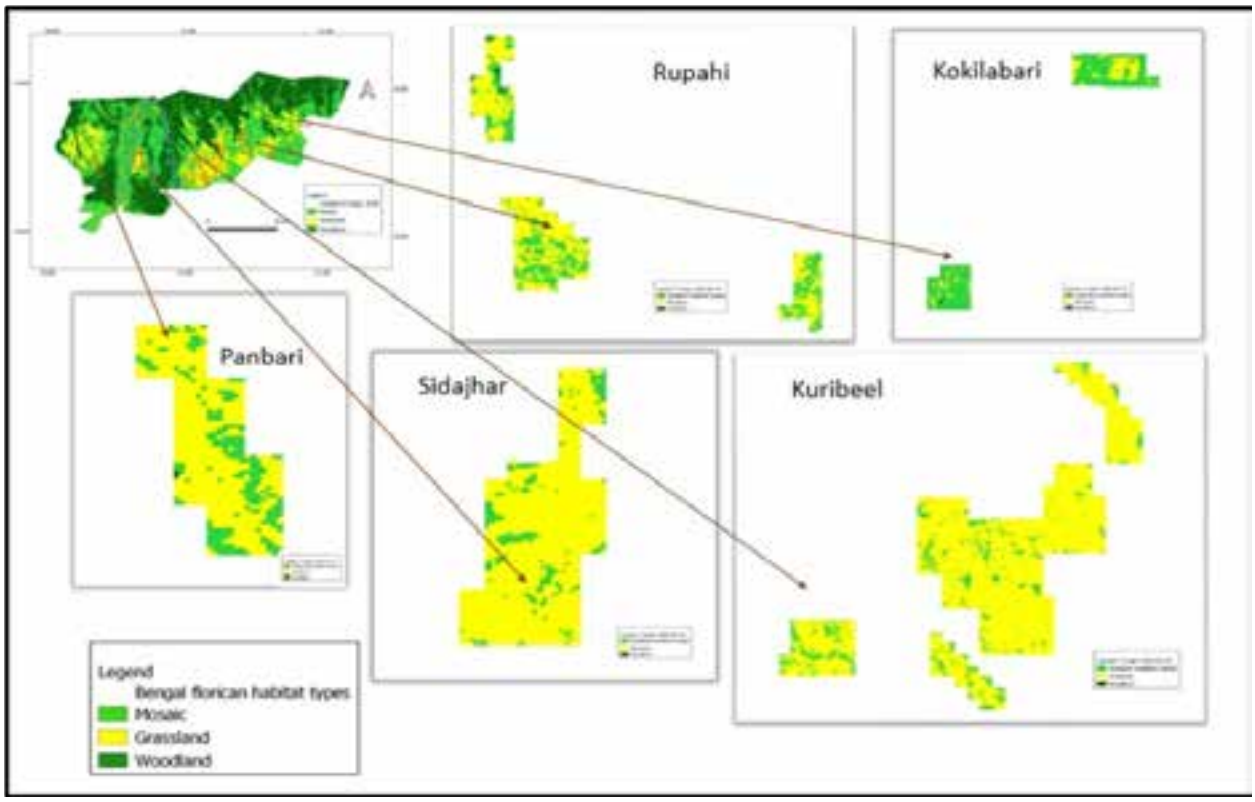


Figure 4. Land use map of Bengal Florican habitat as in 2000.

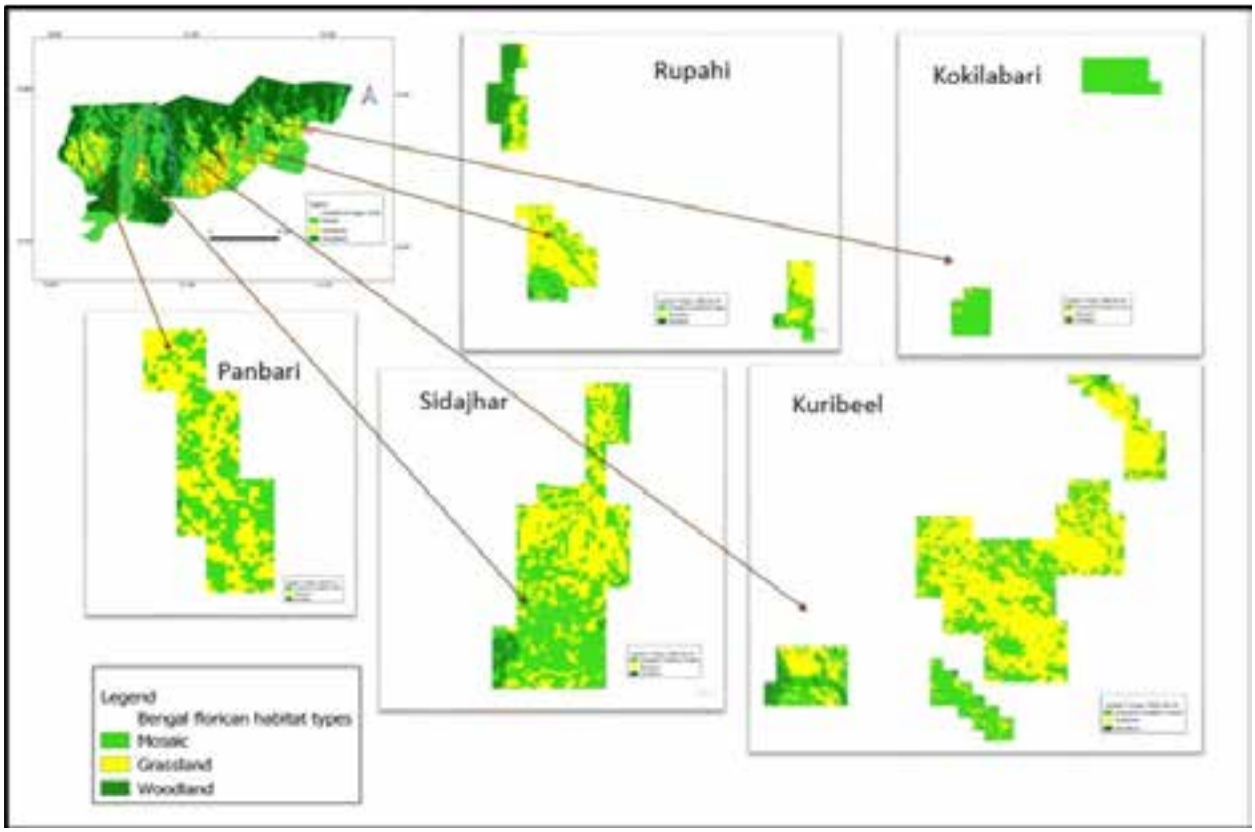


Figure 5. Land use map of Bengal Florican habitat as in 2020.

Table 7. List of plants observed in the habitats occupied by Bengal Florican.

	Scientific name	Local name	Family
1	*Saccharum narenga*	Barenga	Poaceae
2	*Saccharum spontanum*	Kohua	Poaceae
3	*Leea asiatica*	Athu bhanga	Vitaceae
4	*Cymbopogon flexuosus*	Gondho birina	Poaceae
5	*Imperata cylindrica*	Ulu kher	Poaceae
6	*Phragmites karka*	Khagori	Poaceae
7	*Premna herbacea*	Mati kaldhab	Lamiaceae
8	*Commelina* sp.	Konaximolu	Commelinaceae
9	*Bombax ceiba*	Simul	Bombacaceae
10	*Croton bonplandianus*	Bon tulsi	Euphorbiaceae
11	*Scleria terrestris*	Har kata	Cyperaceae
12	*Cyperus* sp.	NA	Cyperaceae
13	*Grewia sapida*	Mati phehura	Tiliaceae
14	*Senecio madagascariensis*	NA	Asteraceae
15	*Plectranthus ternifolius*	NA	Lamiaceae

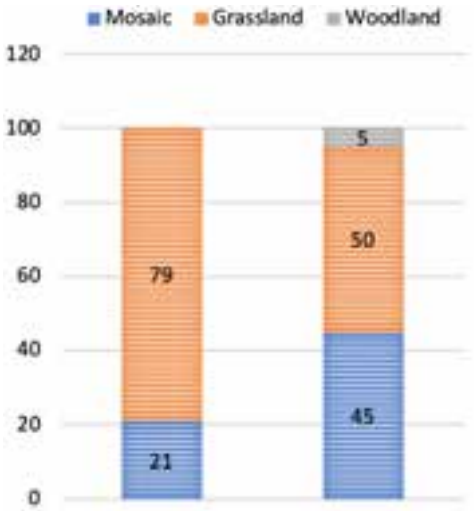


Figure 6. Percentage of land cover change in 2000 and 2020.

where Floricans have been recorded. The survey also clearly indicated the success of the method wherein the collaboration between forest frontline staff, invited experts and local guides was instrumental in obtaining a quick result.

The Bengal florican population in Manas has faced severe problems due to habitat loss and degradation, with grassland habitats decreasing alarmingly. Key factors contributing to this conservation challenge include the indiscriminate conversion of grasslands, domestic cattle grazing, unauthorized burning, opportunistic hunting, and egg collection. Invasive species such as *Chromolaena* and *Mikania* further exacerbate the problem by outcompeting native flora crucial for Bengal florican survival. Despite these challenges, our data shows a paradoxical increase in the Bengal florican population. This can be attributed to the concentrated conservation efforts by stakeholders, particularly within the KAF areas, which host sizable populations contributing to the overall increase in the park. However, the persistence of habitat issues necessitates robust management interventions to ensure sustainable population growth.

In Assam, most grasslands are confined to protected areas and a few in the Brahmaputra floodplains. Thus, conserving these grasslands is imperative to protect grassland-obligate avifauna (Brahma 2013). Scientific studies are essential to manage these remaining grasslands effectively. Our study involved mapping the habitat and assessing the current Bengal Florican population in Manas. While it is encouraging that the BF population is increasing in Manas, the concurrent decrease in grassland habitat is concerning. While an increase in vegetation cover is often beneficial for forests, in Manas, the increase in specific land cover types such as woodland and woody plant infested mosaic forest poses a serious threat to the unique grassland habitat (Das et al. 2022). Burning of grasslands conducted in January aimed to regenerate grasses and control invasive species. However, this practice is insufficient to reduce the encroachment of alien invasive plants and problematic native plants (Das et al. 2019). Therefore, appropriate habitat management actions must be undertaken to restore and conserve grassland habitats.

RECOMMENDATIONS

- Maintenance of mosaic grassland: Which include both tall and short grasslands.
- Implement comprehensive habitat restoration programs to remove invasive species and native woody species.
- Strategic implementation of prescribed burning.
- Enforce stricter regulations against unauthorized land conversion, grazing, and burning.
- Promote conservation friendly agricultural practices adjacent to grassland areas, especially in KAF.
- Engage local communities in conservation efforts through education and incentivizing sustainable practices.
- Conduct long-term scientific studies to monitor the impact of management practices in BF population.

Image 1. Male Bengal Florican in flight.

Image 2. Male Bengal Florican in the grassland.

REFERENCES

Baral, H.S., T.R. Bhatt, S.R. Giri, A.K. Ram, S.K. Shah, L.P. Poudyal, D. Chaudhary, G. Bhattacharya & R. Amin (2020). Status of the Critically Endangered Bengal Florican *Houbaropsis bengalensis* (Gmelin, 1789) in Koshi Tappu Wildlife Reserve, Nepal. *Journal of Threatened Taxa* 12(9): 16006–16012. https://doi.org/10.11609/jott.4832.12.9.16006-16012

Banerjee, S., D. Das & R. John (2021). Grassland vegetation and roads have dominant influence on decadal-scale spatial-temporal patterns of fires in a species-rich protected Terai habitat in northeastern India. *Agricultural and Forest Meteorology* 304–305: 108411. https://doi.org/10.1016/j.agrformet.2021.108411

BirdLife International (2010). *Houbaropsis bengalensis*. The IUCN Red List of Threatened Species 2010: e. T22692015A29263371. https://datazone.birdlife.org/species/factsheet/bengal-floricanhoubaropsisbengalensis on 12/06/2020.

BirdLife International (2022). *Houbaropsis bengalensis*. *The IUCN Red List of Threatened Species* 2022. https://datazone.birdlife.org/species/factsheet/bengal-floricanhoubaropsisbengalensis on 15/03/2023.

Brahma, N. (2013). Ecological evaluation of grassland using Bengal florican as indicator species in Manas national park Assam. Ph.D. Thesis, Gauhati University.

Brahma, N., K. Choudhury, R.K. Sharma & M. Basumatary (2009). Bengal Florican Conservation and Research Initiative in BTAD, India. Aaranyak report, 63 pp.

Collar, N., H.S. Baral, B. Nyambayar, B. Gobind, N. Brahma, B. Robert, A. Choudhury, O. Combreau, P. Dolman, P. Donald, S. Dutta, D. Gadhavi, K. Gore, O. Goroshko, C. Hong, G. Jathar, R. Jha, Y. Jhala, M. Koshkin & M. Kessler (2017). Averting the extinction of bustards in Asia. *Forktail* 33: 1–26.

Das, D., S. Banerjee & R. John (2019). Predicting the distribution and abundance of invasive plant species in a sub-tropical woodland-grassland ecosystem in northeastern India. *Plant Ecology* 220: 935–950. https://doi.org/10.1007/s11258-019-00964-7

Das, D., S. Banerjee, J. Lehmkuhl, J. Krishnaswamy & R. John (2022). The influence of abiotic and spatial variables on woody and herbaceous species abundances in a woodland–grassland system in the Eastern Terai of India. *Journal of Plant Ecology* 15(1): 155–167. https://doi.org/10.1093/jpe/rtab080

Hajra, P.K. & A.K. Baishya (2002). Manas Biosphere Reserve, pp. 2627–2646. In: Singh, N.P. & K.P. Singh (eds.). Floristic Diversity and Conservation Strategies in India. Botanical Survey of India, Calcutta.

Narayan, G. (1992). Ecology, distribution and conservation of the Bengal Florican Houbaropsis begalensis (Gmelin) in India. PhD thesis, University of Bombay.

Prasai, R., H. Kafley, S. Upadhaya, S. Thapa, P. Shrestha, A. Dudley & Y.P. Timilsina (2021). Population status and distribution of the Critically Endangered Bengal Florican *Houbaropsis bengalensis* in the grassland of Koshi Tappu Wildlife Reserve, Nepal. *Journal of Threatened Taxa* 13(9): 19293–19301. https://doi.org/10.11609/jott.6503.13.9.19293-19301

QGIS Development Team (2020). QGIS Geographic Information System. Open Source Geospatial Foundation Project.

Rahmani, A.R., R.R.S. Jha, N. Khongsai, N. Shinde, R. Talegaonkar & M. Kalra (2017). Studying movement pattern and dispersal of the Bengal Florican (*Houbaropsis bengalensis*): A Satellite Telemetry Pilot Project. Final Report 2013-2016. Bombay Natural History Society, Mumbai, 157 pp.

Sarma, P., B. Lahkar, S. Ghosh, A. Rabha, J. Das, N. Nath & N. Brahma (2008). Land-use and land cover change and future implication analysis in Manas National Park, India using multi-temporal satellite data. *Current Science* 95(2): 223–227.

Stohlgren T.J., M.B. Falkner & L.D. Schell (1995). A modified-whittaker nested vegetation sampling method. Kluwer Academic Publishers. Printed in Belgium. *Vegetation* 117: 113–121.

Author details: Miss Miranda Thakur—intern of TSRP, Aaranyak. She completed her master's in Forestry from Forest Research Institute, Dehradun. Mr. Jonmani Kalita—junior field biologist at the Threatened Species Recovery Programme (TSRP) of Aaranyak. His main role is to monitor Pygmy Hog through radio telemetry and camera trapping, sign surveys, and collect grassland-related data from the field. Dr. Namita Brahma—assistant professor at the Centre for Ecology, Environment and Sustainable Development at Tata Institute of Social Sciences, Guwahati Campus. She did her PhD on Bengal Florican in Manas National Park. Mr. Koushik Rajbongshi—assistant field biologist at TSRP of Aaranyak. His main role is to manage and execute field-based research on habitat monitoring and restoration. Mr. Kangkanjyoti Bhattacharyya—intern of TSRP, Aaranyak. He completed his master's in Zoology from Sikkim University. Mr. Amal Chandra Sarmah, IFS—senior forest official from the Govt of Assam and ex-field director of Manas National Park. Dr. Alolika Sinha—senior wildlife biologist working with the Elephant Research and Conservation Division of Aaranyak. She is a member of the IUCN SSC Deer Specialist Group. Dr. Deba Kumar Dutta—completed his PhD in Rhino ecology in Manas. He is the Landscape Coordinator of BHL Manas Conservation Area, WWF-India. Dr. Dhritiman Das—field scientist of the Pygmy Hog Conservation Programme with Durrell Wildlife Conservation Trust. His primary research focus is grassland conservation, Pygmy hog ecology, and an interdisciplinary approach to biodiversity conservation. Dr. Bibhuti Prasad Lahkar—senior conservation scientist and head of the Elephant Research and Conservation Division of Aaranyak. He is also a member of the IUCN SSC Bustard Specialist Group.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25516–25527

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

https://doi.org/10.11609/jott.8930.16.7.25516-25527

#8930 | Received 27 January 2024 | Final received 30 April 2024 | Finally accepted 21 May 2024

OPEN ACCESS

ARTICLE

Assemblages of frugivorous butterflies in two urban parks in Quezon City, Philippines

Micael Gabriel A. Itliong [1], Nikki Heherson A. Dagamac [2] & Jade Aster T. Badon [3]

[1] The Graduate School, University of Santo Tomas, España Blvd, Sampaloc, Manila, 1008 Philippines.
[1,2] Initiatives for Conservation, Landscape Ecology, Bioprospecting, and Biomodeling (iCOLABB), Research Center for the Natural and Applied Sciences, University of Santo Tomas, España Blvd, Sampaloc, Manila, 1008 Philippines.
[2] Department of Biological Sciences, College of Science, University of Santo Tomas, España Blvd, Sampaloc, Manila, 1008 Philippines.
[2] Research Center for the Natural and Applied Sciences, University of Santo Tomas, Manila 1008, Philippines.
[3] Animal Biology Division, Institute of Biol. Sciences, Univ. of the Philippines Los Baños, Laguna, 4031, Philippines.
[1] imicaelgabriel@gmail.com (corresponding author), [2] nadagamac@ust.edu.ph, [3] jtbadon@up.edu.ph

Abstract: Urban parks play a crucial role in supporting biodiversity, yet limited research on urban insect diversity poses challenges for conservation. Comprehensive biodiversity records are essential for monitoring insect population trends. Despite their significance as bioindicators, many urban parks lack baseline data on butterfly populations. This study utilized bait traps to assess butterfly diversity in two Quezon City parks: La Mesa Ecopark (LME) and Ninoy Aquino Parks and Wildlife Center (NAPWC). Bait trapping facilitates species identification and population trend monitoring without harming local butterfly populations. From April to August 2023, two bait traps equipped with fermented bananas and rum as lures were deployed in each park. A total of 145 individuals representing nine morphospecies of the Nymphalidae family were recorded. Differences in butterfly diversity were noted between LME and NAPWC, with LME showing greater diversity. However, sampling efforts at NAPWC may need expansion to ensure exhaustiveness, potentially affecting comparison accuracy. Notably, four species observed in both parks are endemic to the Philippines, while data on the IUCN Red IIst status of the remaining species are unavailable.

Keywords: Bait trap, biodiversity, bioindicators, La Mesa Ecopark, Lepidoptera, Ninoy Aquino Parks and Wildlife Center, Nymphalidae.

Filipino: Ang mga parke sa lungsod ay mayroong mahalagang papel sa pagsuporta sa iba't ibang uri ng buhay, ngunit ang limitadong pananaliksik sa dami ng mga insekto sa lungsod ay nagsisilbing hamon sa pangangalaga ng kapaligiran. Ang kumpletong tala ng iba't ibang uri ng buhay ay mahalaga para sa pagsubaybay sa mga pagbabago ng populasyon ng mga insekto. Sa kabila ng kanilang kahalagahan bilang mga *bioindicator*, maraming parke sa lungsod ang kulang sa pangunahing datos tungkol sa populasyon ng mga paru-paro. Gumamit ang pag-aaral na ito ng mga bitag na may pain upang masuri ang dami ng mga paru-paro sa dalawang parke sa Lungsod ng Quezon: *La Mesa Ecopark* (LME) at *Ninoy Aquino Parks and Wildlife Center* (NAPWC). Ang paggamit ng pain ay tumutulong sa pagkilala ng mga sarihay at pagsubaybay sa pagbabago ng populasyon nang hindi nakapipinsala sa mga lokal na populasyon ng paru-paro. Mula Abril hanggang Agosto 2023, dalawang bitag na may pain na naglalaman ng binurong saging at rum bilang pang-halina ang inilatag sa bawat parke. Nakapagtala ng 145 na indibidwal na kumakatawan sa siyam na sarihay na kabilang sa pamilyang Nymphalidae. Kapansin-pansin ang pagkakaiba sa uri ng mga paru-paro sa pagitan ng LME at NAPWC, kung saan mas mataas ang baryedad ng paru-paro sa LME. Gayunpaman, maaaring kailanganing palawakin pa ang pagsisiyasat sa NAPWC upang matiyak ang kasakupan nito, na maaaring makaapekto sa kawastuhan ng paghahambing. Kapansin-pansin, apat na sarihay ng paru-paro na nakita sa parehong parke ay endemiko sa Pilipinas, habang wala namang datos sa katayuan ng mga natitirang sarihay ang naitala sa IUCN Red List.

Editor: Aisha Sultana, University of Delhi, Delhi, India. **Date of publication:** 26 July 2024 (online & print)

Citation: Itliong, M.G.A., N.H.A. Dagamac & J.A.T. Badon (2024). Assemblages of frugivorous butterflies in two urban parks in Quezon City, Philippines. *Journal of Threatened Taxa* 16(7): 25516–25527. https://doi.org/10.11609/jott.8930.16.7.25516-25527

Funding: This study was funded by the DOST-SEI Accelerated Science and Technology Human Resource Development Program-National Science Consortium Component (ASTHRDP-NSC), through the Student Research Support Fund (SRSF). NHAD has received small support from RCNAS and as a Balik Scientist of DOST-PCAARRD.

Competing interests: The authors declare no competing interests.

Author details, Author contributions & **Acknowledgements:** See end of this article.

INTRODUCTION

Importance of studying butterfly species in urban parks

Urban parks play a crucial role in cities by providing a range of ecosystem services, such as biodiversity preservation and urban climate regulation (Sadeghian & Vardanyan 2013; Mexia et al. 2018; Taylor et al. 2020; Sarı & Bayraktar 2023). Traditional efforts to combat global biodiversity decline have focused mainly on conserving natural environments, yet various flora and fauna persist in urban refuges (Gentili et al. 2023). Promoting biodiversity in urban ecosystems enhances the well-being of urban residents (Carrus et al. 2015; Cameron et al. 2020; Marselle et al. 2021) and contributes to conserving biodiversity in natural ecosystems (Savard et al. 2000).

While the literature extensively covers the impact of urbanization on prominent animal like birds and mammals (Seress & Liker 2015; Isaksson 2018; Schmidt et al. 2020), research focusing on invertebrates remains notably scarce, creating a concerning knowledge deficit in biodiversity conservation. Despite evidence of insect sensitivity to environmental change (Kellermann & van Heerwaarden 2019; Harvey et al. 2023), comprehensive data is still lacking. Butterflies are an exception, with extensive research covering many species (Essens et al. 2017). The conservation status of butterfly species is primarily assessed by analyzing population trends and changes in range, relying on extensive and systematic monitoring efforts spanning several decades.

Role of urban parks as crucial habitats for butterflies

Concomitant with economic growth engendered by urban development are significant alterations to human-environmental interactions (Haase 2021). Urban expansion, a hallmark of this expansion, demonstrably deteriorates biodiversity, disrupts vital ecosystem functions, and alters microclimates (Frank et al. 2017). However, recent research suggests that even seemingly inconsequential urban greenspaces, such as parks, can possess significant ecological value (Loures et al. 2007). Despite their relatively small size and artificial composition, these urban parks play a crucial role within the intricate network of the urban ecosystem, providing essential ecosystem services (Davies et al. 2011).

Butterflies face a multitude of challenges, such as habitat degradation (Geyle et al. 2021; Warren et al. 2021), climate change (Davies 2019; Crossley et al. 2021) and pollution (Shephard et al. 2020; Liu et al. 2021; Parlin et al. 2022), resulting in a worldwide decrease in butterfly populations. Assessing changes in butterfly populations is challenging because natural fluctuations (e.g., short-term weather changes (Oliver et al. 2015)) make it difficult to confirm actual decline (Van Strien et al. 1997). This raises serious concerns about ecosystem function as well as human food security, since some species are pollinators or otherwise agriculturally important (van der Sluijs 2020). Studies of butterfly populations underscore the need to assess trends in insect populations, identify vulnerable species and potential pest species (Badon et al. 2023; Eastwood et al. 2006), and determine the underlying causes of their decline. The majority of data so far has come from Europe (Warren et al. 2021), United States (Wepprich et al. 2019; Crossley et al. 2021; Grant et al. 2021), and Australia (Geyle et al. 2021; Sanderson et al. 2021).

The Philippines features a remarkable diversity of butterflies, with a documented total of 927 species, of which >300 are endemic (Treadaway 2012). The archipelagic nature of the Philippines significantly contributes to shaping its biological diversity (Brown et al. 2013). While it poses challenges for conservation, it also provides opportunities for understanding unique ecosystems. While species isolation can lead to speciation, some species are at risk of extinction if their habitat becomes too fragmented. Moreover, anthropogenic environmental changes provide novel ecological niches, which modify selection in many ways to stimulate diversification-however, these changes also frequently eliminate niches and result in extirpations (Ålund et al. 2023).

Understanding how increasing urban sprawl affects biodiversity is imperative in conserving biodiversity in urban green areas (Kuussaari et al. 2021). Among the numerous threats to butterflies in the Philippines is habitat fragmentation brought about by anthropogenic activities (Posa & Sodhi 2006). However, despite the extensive effects of urbanization on natural ecosystems, butterflies remain resilient components within the urban landscape (Pignataro et al. 2023). Moreover, there is a noticeable scarcity of data that looks into the butterfly diversity in urban parks; thus, this research sought to compile a list of butterflies found in two major urban parks in Quezon City. This study primarily focuses on the efficacy of bait traps for capturing frugivorous butterflies, aiming to gather data representative of the broader butterfly population in urban areas.

METHODS

Study Sites

La Mesa Ecopark

The La Mesa Ecopark, established in 1929, is an essential ecological reserve that serves as the primary water source for Metro Manila. This 700-hectare reserve in Quezon City includes a dam and an ecological reserve spanning 2,000 ha of contiguous forest (Image 1). The La Mesa Ecopark is characterized by its dense tree canopies, which provide ample shade, and the paved main trails, which accommodate bicycles. Visitors can access the park via public transportation, and sufficient parking is available (Masangkay et al. 2016; Estoque et al. 2018).

The La Mesa Dam Reservoir, the only major watershed in the metropolitan area, is protected and located adjacent to the park. The park's biodiversity surveys have revealed a diverse range of species, including ants (Pag-Ong et al. 2022), slime molds (Macabago et al. 2010), trees (Malabrigo et al. 2016), and vertebrates (Estoque et al. 2018). The park used to have a butterfly sanctuary, but it was closed during the 2020 pandemic. The sanctuary, managed by a concessionaire, was intended to house butterflies bred in captivity. There has yet to be a study on butterfly diversity within the park, making it an appropriate study site to evaluate butterfly diversity in urban areas.

Ninoy Aquino Parks and Wildlife Center

The Ninoy Aquino Parks and Wildlife Center (NAPWC) was established in 1954 as part of the Quezon Memorial Park. It spans over an area of 197.28 ha and is located at 14.6522°, 121.0453° (Image 2). Despite being located beside a busy highway the park has a tranquil atmosphere. It features an artificial lagoon that is surrounded by lush, cultivated plants. Visitors can access the park through paved pathways and can find shaded areas to relax and have picnics.

The NAPWC is a protected area that is home to diverse tree species. It also has a rescue center that houses various animals, including tigers, monkeys, birds, and snakes. Research conducted within the park has primarily focused on animal diseases (Maluping et al. 2007; Lumabas et al. 2018; Sioson et al. 2018; Gamalo et al. 2019), bird surveys (Vallejo et al. 2009), and freshwater invertebrates (de Leon et al. 2023) in the Philippines. However, there has been no study on butterfly diversity in this park to date.

Sampling

Duration of the Study, Trap Placement, and Monitoring Scheme

The investigation, conducted over five months of April–August 2023, comprised systematic weekly observations throughout both dry (April–May) and wet seasons (June–August). La Mesa Ecopark (LME) facilitated 13 bait trapping sessions, while Ninoy Aquino Parks and Wildlife Center (NAPWC) hosted ten sessions. Bait trapping sessions were subject to postponement during inclement weather, and the frequency of sessions was overseen by the regulatory constraints imposed by the respective management authorities of the urban parks.

Traps were set up between 0800 h and 1000 h in sunny conditions, equipped with rainproof plastic coverings to keep captured butterflies dry in case of sudden rain. After a minimum of 24 h placement, traps were retrieved, and captured butterflies and bycatches were released before deploying fresh traps for subsequent sessions. Each urban park had two traps, at least 200 m away from each other and positioned on sunlit trees less frequented by park visitors' areas to prevent disturbance and theft, in strict adherence to the regulations stipulated in permits issued by the respected administrative bodies responsible for park management.

Bait trapping facilitated the evaluation of specimens caught and subsequent bait replacement. After identifying and recording, butterflies and other insect bycatches were released. The identification of butterflies at the species level and endemicity in the Philippines was accomplished by consulting a wide range of relevant taxonomic literature, including comprehensive publications by Page & Treadaway (2004), Schroeder & Treadaway (2005), Treadaway & Schroeder (2012), Hardy & Lawrence (2017), and Badon (2023). Additionally, the website authored by Badon et al. (2013) entitled "Philippine Lepidoptera" was employed as a resource for conducting image comparisons and species identification, ensuring the research's thoroughness and reliability.

Bait trap Specifications and Observation Method

This study employed modified Van Someren-Rydon traps (see Image 2), initially proposed by DeVries et al. (1997). These traps, constructed from white nylon netting, are cylindrical with dimensions measuring 38 cm in diameter and 100 cm in height. The choice of these traps was based on their proven effectiveness in capturing butterflies, as demonstrated in previous studies. To protect captured specimens from dew and

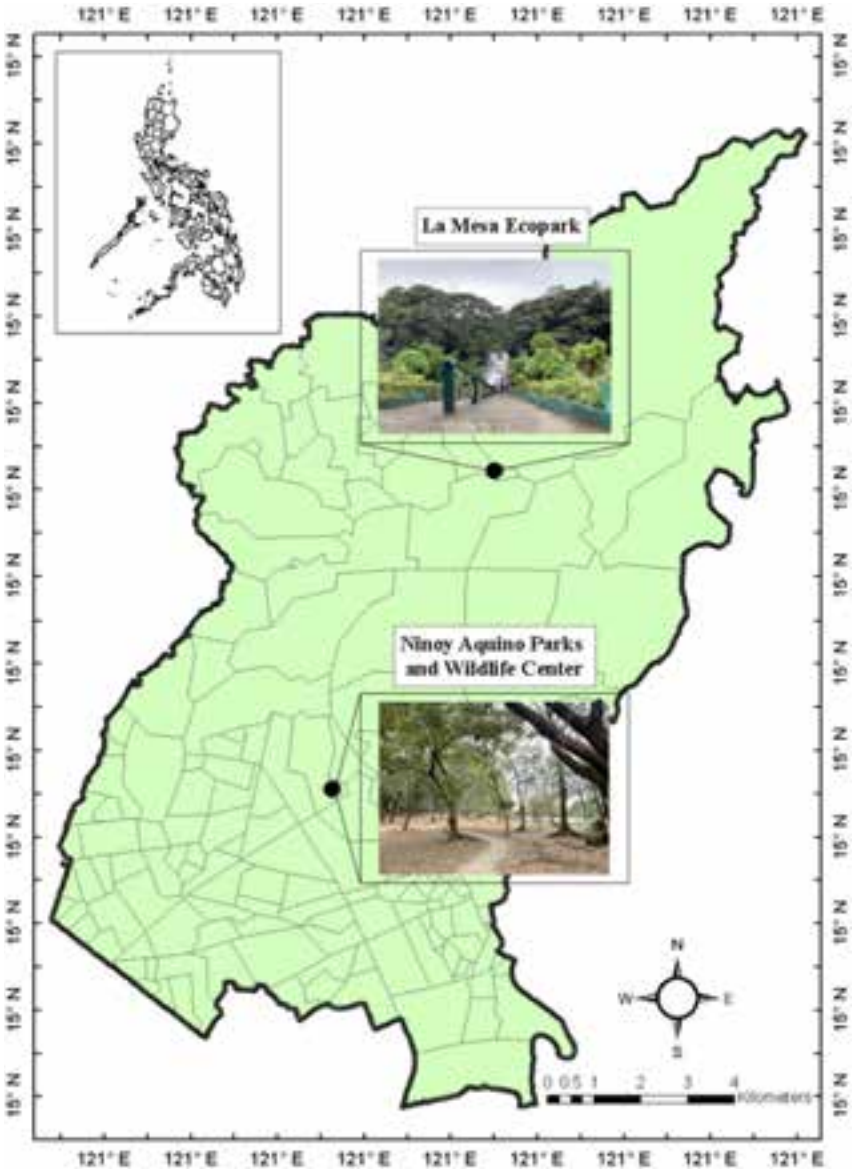


Image 1. This study was conducted in the confines of two urban parks: the Ninoy Aquino Parks and Wildlife Center (NAPWC), located in Diliman, Quezon City, and La Mesa Ecopark (LME), located in Greater Lagro, Quezon City.

rain, two wire hoops, enclosed within plastic casings, are affixed to the top end of each trap. A zippered aperture on the side was employed for ease of insect removal, replacing the use of Velcro. Additionally, a 25 cm diameter plywood sheet was affixed to the lower portion of the netting to serve as an entrance for insects. Beneath this entrance, another plywood sheet of identical dimensions was suspended using hooks, allowing for a five-inch clearance for butterflies. Positioned centrally on the suspended plywood sheet was a reusable plastic plate, 15 cm in diameter, intended for precise bait placement.

The bait selection process relied on prior research from the Philippines, selecting fermented banana as the bait—a mixture of Tanduay Rhum, with a 40% alcohol content by volume, and mature, fermented bananas. The preparation of this bait mixture occurred two days before its use to ensure thorough fermentation. The researchers deposit generous quantity of the bait mixture at each trap's base and left it undisturbed for a minimum of 24 hours to effectively monitor captures.

Permits issued for both parks stipulated minimal to no direct contact with wildlife, including butterflies. Accordingly, captured butterflies were visually observed, photographed using a smartphone camera, and documented. All butterflies and incidental catches were

released from the traps by gently tapping the exterior of the bait trap to encourage flight. This tapping was done with hand to minimize any potential harm to the butterflies. The zippered access was used to facilitate this process. Additionally, bait replenishment occurred at the commencement of each baiting session.

Diversity analyses

All ecological data analyses were conducted using R version 3.6.0 (Team 2013) through RStudio version 1.1.453 (Team 2016). Firstly, species accumulation curves (SAC) to assess the adequacy of the sampling effort in this study and estimate species diversity. SAC is a useful tool for evaluating the effectiveness of a fauna survey in accurately representing the fauna population within a geographic area (Thompson & Withers 2003; Ugland et al. 2003; Colwell et al. 2004). The curve shows the cumulative species count in relation to sampling effort and indicates the rate of new species discovery. A steep initial slope suggests rich species diversity or limited sampling, while a flattening curve indicates diminishing returns in species identification. This study calculated SAC using R packages ggplot2 (Wickham & Wickham 2016) and iNEXT (Hsieh et al. 2016). Next, species diversity was calculated using the Hill series of diversity indices (Hill 1973; Jost 2007). This approach considers species richness and evenness based on the occurrence of butterfly species gathered during the rapid assessment. The researchers used the R package iNEXT (Hsieh et al. 2016) for these calculations as well.

RESULTS

Species richness

One-hundred-and-forty-five individuals representing nine species of butterflies were recorded in La Mesa Ecopark and Ninoy Aquino Parks and Wildlife Center. All were fruit-feeding nymphalids of the subfamilies Charaxinae, Nymphalinae, and Satyrinae. The subfamily Satyrinae presented the highest abundance and number of species, followed by Nymphalinae in terms of abundance. The most dominant species were *Amathusia phidippus pollicaris* Butler, 1870 (N = 38, 26%), *Hypolimnas bolina philippensis* Butler, 1874 (N = 30, 22%) and *Melanitis leda leda* (Linnaeus, 1758) (N = 26, 17%).

Species diversity

The quantified alpha diversity, which measures species richness and diversity within local habitats, is essential for understanding the ecological dynamics of

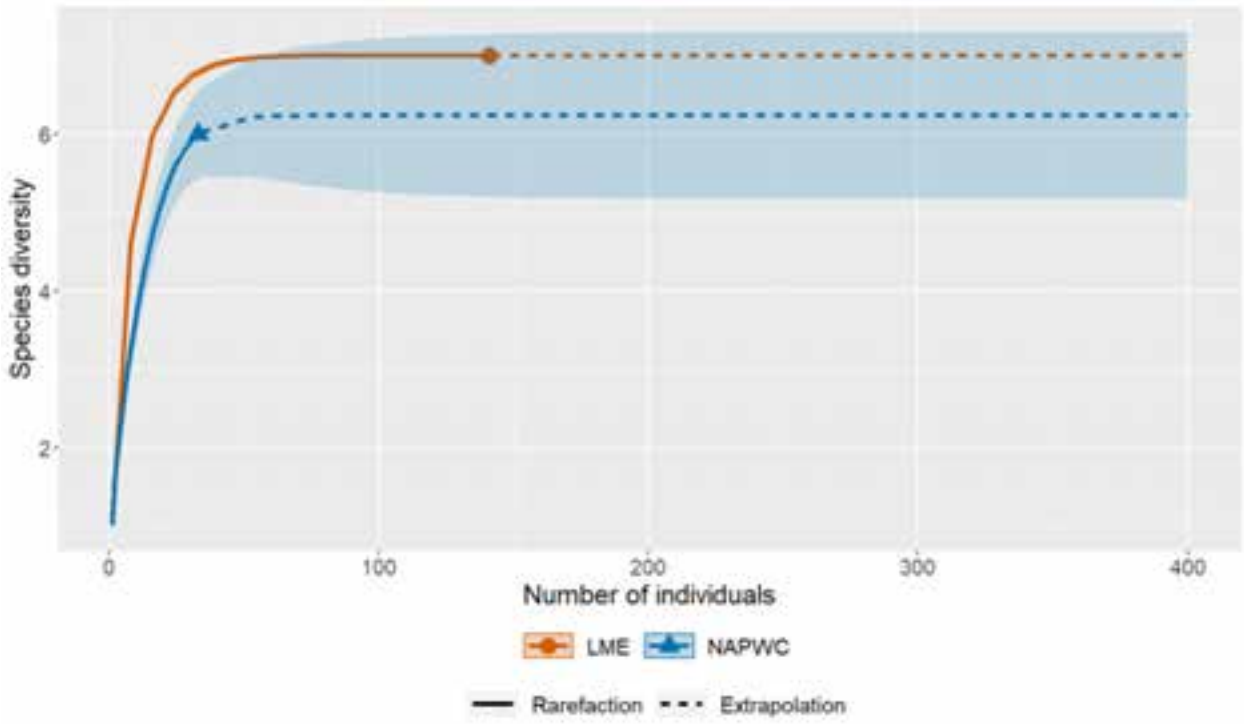


Figure 1. Species accumulation curves for La Mesa Ecopark (LME) and Ninoy Aquino Parks and Wildlife Center (NAPWC). (NOTE: data: solid lines; extrapolation: dashed line). Shaded areas indicate 95% confidence intervals.

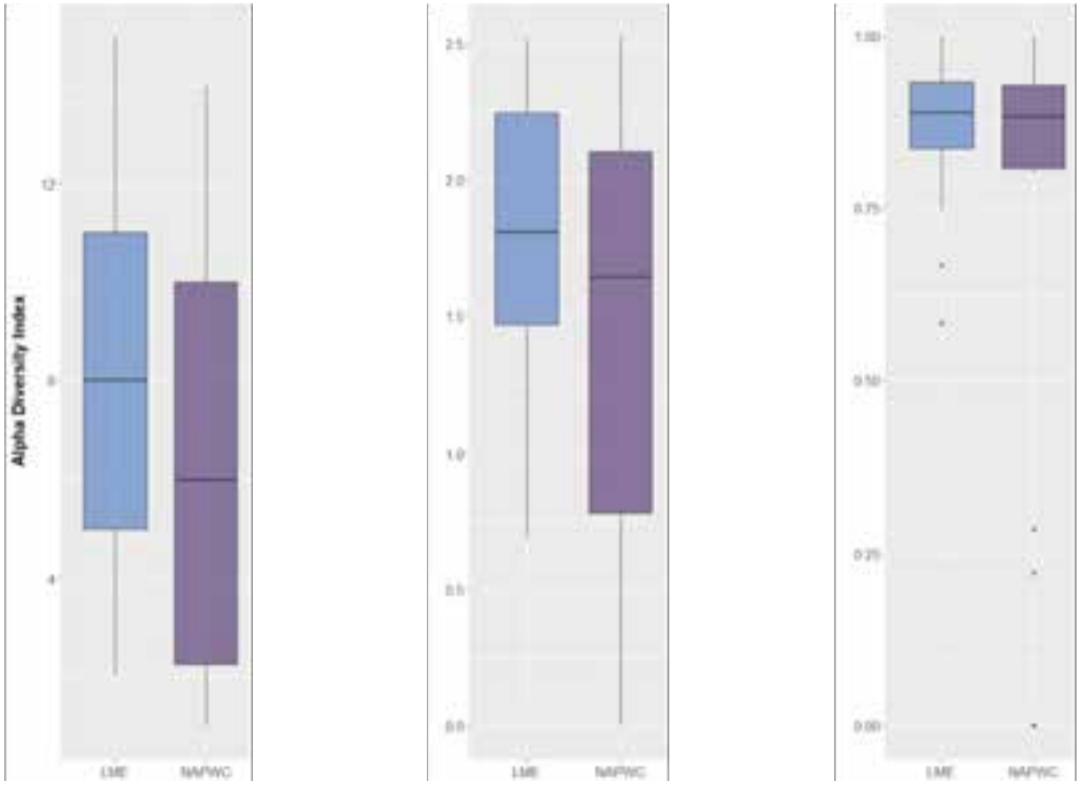


Figure 2. Boxplots illustrating alpha diversity in the two urban parks, highlighting variations in species richness, Shannon diversity, and Simpson diversity in La Mesa Ecopark (LME) and Ninoy Aquino Parks and Wildlife Center (NAPWC).

Table 1. Geographical coordinates for bait traps at La Mesa Ecopark (LME) and Ninoy Aquino Parks and Wildlife Center (NAPWC).

Study Site	Bait Trap One			Bait Trap Two		
	Latitude	Longitude	Elevation	Latitude	Longitude	Elevation
LME	14.711944	121.072778	60 m	14.711389	121.077222	70 m
NAPWC	14.649167	121.043889	40 m	14.6525	121.043333	50 m

Image 2. Details of the bait trap: A—Researcher descending down the bait trap, documenting the captured butterflies and bycatches | B—Details of the top portion of the trap with *Amathusia phidippus* and *Hulodes caranea* on resting positions | C—Detail of the narrowed portion of the trap base where the mixture of fermented banana is placed with *Discophora ogina* feeding. © © Micael Gabriel A. Itliong.

Table 2. List of nymphalids recorded in La Mesa Ecopark (LME) and Ninoy Aquino Parks and Wildlife Center (NAPWC). The species' endemicity is based on whether they have only been recorded in the Philippines, as indicated in the relevant taxonomic literature.

Subfamily	Scientific name	Common name	Endemicity in the Philippines	IUCN Status
Charaxinae	*Charaxes solon* (Fabricius, 1793)	Black Rajah	Native	Not Available
Nymphalinae	*Hypolimnas bolina philippensis* Butler, 1874	Great Egg-fly	Non-endemic	Not Available
Nymphalinae	*Junonia hedonia ida* (Cramer, [1775])	Brown Pansy	Non-endemic	Not Available
Nymphalinae	*Athyma gutama gutama* (Moore, 1858)	Sergeant	Endemic	Not Available
Satyrinae	*Amathusia phidippus pollicaris* Butler, 1870	Palm King	Non-endemic	Not Available
Satyrinae	*Discophora ogina ogina* (Godart, [1824])	Duffer	Endemic	Not Available
Satyrinae	*Melanitis atrax atrax* (C. & R. Felder, 1863)	Evening Brown	Endemic	Not Available
Satyrinae	*Melanitis leda leda* (Linnaeus, 1758)	Common Evening Brown	Non-endemic	Least Concern
Satyrinae	*Mycalesis igoleta* C. & R. Felder, 1863	Igoleta Bush Brown	Endemic	Not Available

Table 3. Occurrence and number of individual butterflies recorded in LME (La Mesa Ecopark) and NAPWC (Ninoy Aquino Parks and Wildlife Center), recorded from April to August 2023.

	Species	LME	NAPWC
1	*Charaxes solon* (Fabricius, 1793)	0	3
2	*Hypolimnas bolina philippensis* Butler, 1874	9	23
3	*Junonia hedonia ida* (Cramer, [1775])	0	3
4	*Athyma gutama gutama* (Moore, 1858)	0	1
5	*Amathusia phidippus pollicaris* Butler, 1870	38	0
6	*Discophora ogina ogina* (Godart, [1824])	9	0
7	*Melanitis atrax atrax* (C. & R. Felder, 1863)	13	2
8	*Melanitis leda leda* (Linnaeus, 1758)	24	2
9	*Mycalesis igoleta* C. & R. Felder, 1863	18	0

Table 4. Number of species recorded in each Nymphalidae subfamily in the two urban parks: LME (La Mesa Ecopark) and NAPWC (Ninoy Aquino Parks and Wildlife Center). Dry season—April–May | rainy season—June–August.

Nymphalidae Subfamily	LME		NAPWC	
	Dry	Wet	Dry	Wet
Charaxinae	0	0	0	1
Danainae	1	1	0	1
Morphinae	2	2	0	0
Nymphalinae	3	4	1	7
Satyrinae	3	4	1	3
Number of species	9	11	2	12

Table 5. Comparison of Shannon diversity index between LME (La Mesa Ecopark) and NAPWC (Ninoy Aquino Parks and Wildlife Center) using Hutcheson t-Test.

	LME	NAPWC
Abundance	111	34
Species Richness	6	6
Shannon Diversity	0.002647	0.036779
t value	2.627909081	
Degree of freedom	39	

butterfly populations in urban parks. Figure 2 presents box plots illustrating alpha diversity metrics between two urban parks: La Mesa Ecopark (LME) and Ninoy Aquino Parks and Wildlife Center (NAPWC). LME emerges to be more diverse in terms of species richness and Shannon diversity.

DISCUSSION

Before this study, there was no available data on what butterfly species occur in both parks; therefore, inferring diversity and population changes over time is impossible. All of the butterfly species recorded in both of the parks belong to the Nymphalidae family, which consists of around 7,200 species that are distributed throughout all continents except Antarctica (Zhang et al. 2008; Yan et al. 2023) and are mostly known to be frugivorous. Although alternative bait lures could have been employed, potentially leading to different results, the choice was guided by previous butterfly trapping research conducted in the Philippines (Toledo & Mohagan 2011; Gestiada et al. 2014; Mohagan et al. 2018; Reeves & Daniels 2020). Nevertheless, the species accumulation curve (see Figure 1) indicates adequate sampling was conducted in LME. Conversely, the curve has yet to reach its asymptote in NAPWC, implying that further sampling efforts could reveal additional

Image 3. Butterfly species caught in bait traps. A—*Charaxes solon* (Fabricius, 1793) ♂ | B—*Hypolimnas bolina philippensis* Butler, 1874 ♂ | C—*Junonia hedonia ida* (Cramer, [1775]) | D—*Athyma gutama gutama* (Moore, 1858) | E—*Amathusia phidippus pollicaris* Butler, 1870 ♂ | F—*Discophora ogina ogina* (Godart, [1824]) | G—*Melanitis atrax atrax* (C. & R. Felder, 1863) | H—*Melanitis leda leda* (Linnaeus, 1758) dry season form | I—*Mycalesis igoleta* C. & R. Felder, 1863. © © Micael Gabriel A. Itliong.

species. Various factors could contribute to the species accumulation curve failing to reach the asymptote. The most evident explanation is the possibility that the sampling effort has yet to achieve full exhaustiveness. Another plausible scenario is that the baits used might not be effective in attracting butterflies. However, it is more probable that the constraints of time imposed by park authorities impeded the optimal number of bait trapping, and increasing the sampling effort beyond the confines stipulated by the park might have facilitated the capture of additional butterfly species.

Among the butterfly species, only three occur in both parks (see Table 3), namely, *Hypolimnas bolina philippensis* Butler, 1874, *Melanitis atrax atrax* (C. & R. Felder, 1863), and *Melanitis leda leda* (Linnaeus, 1758). Both parks have recorded three unique butterfly species (see Table 2). NAPWC exclusively recorded *Charaxes solon* (Fabricius, 1793), *Junonia hedonia ida* (Cramer, 1775), and an individual *Athyma gutama gutama* (Moore, 1858). La Mesa Ecopark, on the other hand, recorded three satyrine species: *Amathusia phidippus pollicaris* Butler, 1870, *Discophora ogina ogina* (Godart, 1824), and *Mycalesis igoleta* C. & R. Felder, 1863.

As indicated by the abundance data presented in Table 4, it is anticipated that a greater number of species would be observed during the wet season. This trend is commonly associated with the wet season's propensity to foster lush vegetation and abundant flowering plants, consequently offering substantial food sources for both butterfly larvae and adults.

It is worth discussing the presence of *D. ogina* in LME. According to Schroeder & Treadaway (2005), species under this genus can be found in forests. They may be attracted to lights and ripened fruits such as pineapple, sometimes flying towards lowland areas. This occurrence and behavior were observed in the Balinsasayao Twin Lakes Natural Park (a Montane Forest). The species were attracted to the bait trap (bananas with Tanduay rhum). It was also observed near the Sierra Madre in Baler, Aurora, where it got attracted to household lights. The presence of *D. ogina* in LME may indicate isolation caused by urbanization, or there may be habitat corridors that connect LME to the mountains of Sierra Madre on the east.

The findings depicted in Figure 2 highlight a contrast between the LME and NAPWC in terms of species richness and diversity. Notably, the LME site demonstrates a considerably higher level of Shannon and Simpson diversity than NAPWC. However, it is crucial to reiterate the caution when interpreting this discrepancy, given the ongoing nature of sampling efforts at NAPWC, as indicated by the species accumulation curve depicted in Figure 1. This curve underscores that the sampling conducted at NAPWC may still need to be exhaustive, potentially impacting the accuracy of the comparison. Therefore, it's essential to approach these findings with caution. Nevertheless, the T-test results presented in Table 5 underscore a statistically significant difference in the number or diversity of observed butterflies between the two urban parks.

It is worth noting that LME is situated adjacent to a semi-natural landscape, suggesting that preserving natural habitats surrounding the city will be crucial for successfully preserving urban butterfly species (Koh et al. 2004). This result is consistent with previous studies conducted in Singapore (Koh & Sodhi 2004), southern China (Sing et al. 2016), and Brazil (Brown & Freitas 2002), which found that urban parks connected to forests had a greater diversity of butterfly species than standalone parks with limited space or lacking diverse flora. It is also expected that LME would have the most butterfly species, as Mohagan et al. (2011) have emphasized that butterflies prefer forested habitats over disturbed areas.

Challenges and opportunities in conservation

Utilizing bait traps for butterfly diversity assessment presents several advantages over the conventional insect net sampling technique. This approach allows researchers to target a more specific subset of local butterfly populations. The presence or absence of butterfly species in both study sites may offer insights into the type of habitat these species inhabit. Notably, the occurrence of endemic species in urban parks carries significant implications for public awareness and biodiversity conservation (Padrón et al. 2020; Koethe et al. 2023) The presence of endemic butterfly species in these urban parks, as evidenced in Table 2, serves as an indicator of the overall ecological health and habitat integrity (Pe'er & Settele 2008; Miller III et al. 2011) —a trend observed among invertebrates in general (Paoletti 1999; Gerlach et al. 2013). Thus, the presence of these species within urban parks underscores the critical importance of preserving natural habitats within urban environments. Habitat alterations, as noted by de Carvalho (Santos et al. 2020) and Uehara-Prado et al. (2007), can influence the diversity of frugivorous butterflies, potentially explaining the disparities in abundances and species presence or absence between LME and NAPWC. Consequently, long-term monitoring of butterflies in these parks is essential to establish baseline data regarding their occurrence and abundance.

CONCLUSION

The findings of this study emphasize the importance of urban parks in sustaining butterfly diversity, including the presence of endemic species. To ensure the survival of butterfly populations, it is important to focus on preserving and restoring interconnected natural forests and facilitating gene flow among butterfly populations. Monitoring schemes should be implemented to track butterfly populations in these parks as they are sensitive to environmental changes. Bait trapping is an effective method for monitoring butterfly populations in urban parks. However, due to urban management protocols, the use of fermented bananas as bait is limited. Therefore, future research should explore the efficacy of alternative lure bait traps in urban park settings. Butterflies are considered umbrella species and can serve as vital conservation indicators for these remaining refuges. Protecting these species is vital in the face of increasing urbanization risks. Urgent measures must be taken to safeguard these unique habitats and ensure the preservation of butterfly populations within urban parks. Integrating scientific data into urban planning and management processes is essential to understand the ecological significance of these habitats and devise effective conservation strategies.

REFERENCES

Ålund, M., M. Cenzer, N. Bierne, J. Boughman, J. Cerca, M. Comerford, A. Culicchi, B. Langerhans, S. McFarlane, M. Möst, H. North, A. Qvarnström, M. Ravinet, R. Svanbäck & S. Taylor (2023). Anthropogenic Change and the Process of Speciation. *Cold Spring Harbor Perspectives in Biology* 16(5): 1–22. https://doi.org/10.1101/cshperspect.a041455

Badon, J.A.T. (2023). *A Naturalist's Guide to the Butterflies of the Philippines*. John Beaufoy Publishing, 176 pp.

Badon, J.A.T., D.E.M. General & D.J. Lohman (2023). The larval host plant and ant associate of Nacaduba pavana georgi (Lepidoptera: Lycaenidae) in Negros, Philippines. *Tropical Lepidoptera Research* 33(22): 124–129.

Brown, K.S., & A.V.L. Freitas (2002). Butterfly communities of urban forest fragments in Campinas, São Paulo, Brazil: structure, instability, environmental correlates, and conservation. *Journal of Insect Conservation* 6(4): 217–231. https://doi.org/10.1023/A:1024462523826

Brown, R.M., C.D. Siler, C.H. Oliveros, J.A. Esselstyn, A.C. Diesmos, P.A. Hosner, C.W. Linkem, A.J. Barley, J.R. Oaks & M.B. Sanguila (2013). Evolutionary processes of diversification in a model island archipelago. *Annual Review of Ecology, Evolution, and Systematics* 44: 411–435. https://doi.org/10.1146/annurev-ecolsys-110411-160323

Cameron, R.W., P. Brindley, M. Mears, K. McEwan, F. Ferguson, D. Sheffield, A. Jorgensen, J. Riley, J. Goodrick & L. Ballard (2020). Where the wild things are! Do urban green spaces with greater avian biodiversity promote more positive emotions in humans? *Urban ecosystems* 23: 301–317. https://doi.org/10.1007/s11252-020-00929-z

Carrus, G., M. Scopelliti, R. Lafortezza, G. Colangelo, F. Ferrini, F. Salbitano, M. Agrimi, L. Portoghesi, P. Semenzato & G. Sanesi (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. *Landscape and Urban Planning* 134: 221–228. https://doi.org/10.1016/j.landurbplan.2014.10.022

Colwell, R.K., C.X. Mao & J. Chang (2004). Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology* 85(10): 2717–2727.

Crossley, M.S., O.M. Smith, L.L. Berry, R. Phillips-Cosio, J. Glassberg, K.M. Holman, J.G. Holmquest, A.R. Meier, S.A. Varriano & M.R. McClung (2021). Recent climate change is creating hotspots of butterfly increase and decline across North America. *Global Change Biology* 27(12): 2702–2714.

Davies, W.J. (2019). Multiple temperature effects on phenology and body size in wild butterflies predict a complex response to climate change. *Ecology* 100(4): e02612. https://doi.org/10.1002/ecy.2612

Davies, Z.G., J.L. Edmondson, A. Heinemeyer, J.R. Leake & K.J. Gaston (2011). Mapping an urban ecosystem service: quantifying above-ground carbon storage at a city-wide scale. *Journal of Applied Ecology* 48(5): 1125–1134.

de Leon, J. R., D.T. Tordesillas, S. Souissi, G.A. Cuadrasal, S.K.P. Guinto, E.Z.C. Rizo & R.D.S. Papa (2023). Temperature as main driver of the growth of an endemic Philippine freshwater copepod (Copepoda: Calanoida: Diaptomidae). *Journal of Crustacean Biology* 43(2): ruad031. https://doi.org/10.1093/jcbiol/ruad031

DeVries, P.J., D. Murray & R. Lande (1997). Species diversity in vertical, horizontal, and temporal dimensions of a fruit-feeding butterfly community in an Ecuadorian rainforest. *Biological journal of the Linnean Society* 62(3): 343–364. https://doi.org/10.1111/j.1095-8312.1997.tb01630.x

Eastwood, R., S.L. Boyce & B.D. Farrell (2006). The provenance of Old World Swallowtail butterflies, *Papilio demoleus* (Lepidoptera: Papilionidae), recently discovered in the New World. *Annals of the Entomological Society of America* 99(1): 164–168. https://doi.org/10.1603/0013-8746(2006)099[0164:TPOOWS]2.0.CO;2

Essens, T., F. Langevelde, R. Vos, C. Swaay & M. Wallisdevries (2017). Ecological determinants of butterfly vulnerability across the European continent. *Journal of Insect Conservation* 21: 1–12. https://doi.org/10.1007/s10841-017-9972-4

Estoque, R.C., Y. Murayama, R.D. Lasco, S. W. Myint, F.B. Pulhin, C. Wang, M. Ooba & Y. Hijioka (2018). Changes in the landscape pattern of the La Mesa Watershed–The last ecological frontier of Metro Manila, Philippines. *Forest Ecology and Management* 430: 280–290.

Gamalo, L.E., J. Dimalibot, K.A. Kadir, B. Singh & V.G. Paller (2019). Plasmodium knowlesi and other malaria parasites in long-tailed macaques from the Philippines. *Malaria Journal* 18(1): 1–7.

Gentili, R., L. Quaglini, G. Galasso, C. Montagnani, S. Caronni, E. Cardarelli & S. Citterio (2023). Urban refugia sheltering biodiversity across world cities. *Urban Ecosystems* 27: 219–230. https://doi.org/10.1007/s11252-023-01432-x

Gerlach, J., M. Samways & J. Pryke (2013). Terrestrial invertebrates as bioindicators: an overview of available taxonomic groups. *Journal of Insect Conservation* 17: 831–850.

Gestiada, E.C., M.L. Castillo, N.C. Bantayan & J.B. Balatibat (2014). Butterfly species diversity and habitat heterogeneity across altitudinal gradients of Mt. Banahaw de Majayjay, Philippines. *Ecosystems and Development Journal* 5(1): 3–10.

Geyle, H.M., M.F. Braby, M. Andren, E.P. Beaver, P. Bell, C. Byrne, M. Castles, F. Douglas, R.V. Glatz & B. Haywood (2021). Butterflies on the brink: identifying the Australian butterflies (Lepidoptera) most at risk of extinction. *Austral Entomology* 60(1): 98–110.

Grant, T.J., N. Krishnan & S.P. Bradbury (2021). Conservation risks and benefits of establishing monarch butterfly (Danaus plexippus) breeding habitats close to maize and soybean fields in the north central United States: A landscape-scale analysis of the impact of foliar insecticide on nonmigratory monarch butterfly populations. *Integrated Environmental Assessment and Management* 17(5): 989–1002.

Haase, D. (2021). Continuous integration in urban social-ecological systems science needs to allow for spacing co-existence. *Ambio* 50(9): 1644–1649. https://doi.org/10.1007/s13280-020-01449-y

Hardy, P.B. & J.M. Lawrence (2017). *Field Guide to Butterflies of the Philippines*. Siri Scientific Press, 448 pp.

Harvey, J.A., K. Tougeron, R. Gols, R. Heinen, M. Abarca, P.K. Abram, Y. Basset, M. Berg, C. Boggs & J. Brodeur (2023). Scientists' warning on climate change and insects. *Ecological Monographs* 93(1): e1553. https://doi.org/10.1002/ecm.1553

Hill, M.O. (1973). Diversity and evenness: a unifying notation and its consequences. *Ecology* 54(2): 427–432.

Hsieh, T., K. Ma & A. Chao (2016). iNEXT: an R package for rarefaction and extrapolation of species diversity (H ill numbers). *Methods in Ecology and Evolution* 7(12): 1451–1456.

Isaksson, C. (2018). Impact of Urbanization on Birds, pp. 235–257. In: Tietze, D.T. (ed.). *Bird Species: How They Arise, Modify and Vanish*. Springer International Publishing. https://doi.org/10.1007/978-3-319-91689-7_13

Jost, L. (2007). Partitioning diversity into independent alpha and beta components. *Ecology* 88(10): 2427–2439.

Kellermann, V. & B. van Heerwaarden (2019). Terrestrial insects and climate change: adaptive responses in key traits. *Physiological Entomology* 44(2): 99–115.

Koethe, S., N. Bakanov, C. Brühl, L. Eichler, T. Fickel, B. Gemeinholzer, T. Hörren, A. Lux, G. Meinel, R. Mühlethaler, L. Schäffler, C. Scherber, F. Schneider, M. Sorg, S. Swenson, W. Terlau, A. Turck & G. Lehmann (2023). Recommendations for effective insect conservation in nature protected areas based on a transdisciplinary project in Germany. *Environmental Sciences Europe* 35: 2–10. https://doi.org/10.1186/s12302-023-00813-5

Koh, L.P., R.R. Dunn, N.S. Sodhi, R.K. Colwell, H.C. Proctor & V.S. Smith (2004). Species coextinctions and the biodiversity crisis. *Science* 305: 1632–1634.

Koh, L.P. & N.S. Sodhi (2004). Importance of reserves, fragments, and parks for butterfly conservation in a tropical urban landscape. *Ecological Applications* 14(6): 1695–1708.

Kuussaari, M., M. Toivonen, J. Heliölä, J. Pöyry, J. Mellado, J. Ekroos,

V. Hyyryläinen, I. Vähä-Piikkiö & J. Tiainen (2021). Butterfly species' responses to urbanization: differing effects of human population density and built-up area. *Urban Ecosystems* 24: 515–527.

Liu, Y., M.J. Wooster, M.J. Grosvenor, K.S. Lim & R.A. Francis (2021). Strong impacts of smoke polluted air demonstrated on the flight behaviour of the painted lady butterfly (Vanessa cardui L.). *Ecological Entomology* 46(2): 195–208.

Loures, L., R. Santos & T. Panagopoulos (2007). Urban Parks and Sustainable City Planning-The Case of Portimão, Portugal. *WSEAS Transactions on Environment and Development* 3(10): 171–180.

Lumabas, J.L.C., F.G M. Tomwong, P.M.V. Cabero & R.J.S. Vitor II (2018). Determination of hematological and serum biochemical values and detection of Chlamydophila psittaci antibodies in captive hornbills at the Ninoy Aquino Parks and Wildlife Nature Center. *National Journal of Physiology, Pharmacy and Pharmacology* 8(4): 575–575.

Macabago, S.A., N.H. Dagamac & T.E. Dela Cruz (2010). Diversity and Distribution of Plasmodial Myxomycetes (Slime Molds) from La Mesa Ecopark, Quezon City, Philippines. *Biotropia* 17(2): 51–61. https://doi.org/10.11598/btb.2010.17.2.76

Malabrigo Jr, P.L., C.L. Tiburan Jr, M.A. Galang & I. Saizen (2016). Tree diversity at La Mesa Watershed in Luzon, a reforested urban watershed. *Asian Journal of Biodiversity* 6(2): 22–40.

Maluping, R.P., R.B. Oronan & S.U. Toledo (2007). Detection of Chlamydophila psittaci antibodies from captive birds at the Ninoy Aquino Parks and Wildlife Nature Center, Quezon city, Philippines. *Annals of Agricultural and Environmental Medicine* 14(1): 191–193.

Marselle, M.R., S.J. Lindley, P.A. Cook & A. Bonn (2021). Biodiversity and health in the urban environment. *Current environmental health reports* 8(2): 146–156.

Masangkay, F.R., G.D. Milanez, N.E.R. Chua, F.M.N. Angulo, P.D.M. Aquino, D.N.D. Calucin & G.R.O. Urtal (2016). Water-borne coccidians in Philippine water sheds: a national inceptive study. *Asian Journal of Biological and Life Sciences* 5(2): 112–119.

Mexia, T., J. A. Príncipe, A. Anjos, P. Silva, N. Lopes, C. Freitas, M. Santos-Reis, O. Correia, C. Branquinho & P. Pinho (2018). Ecosystem services: Urban parks under a magnifying glass. *Environmental Research* 160: 469–478.

Miller III, D.G., J. Lane & R. Senock (2011). Butterflies as potential bioindicators of primary rainforest and oil palm plantation habitats on New Britain, Papua New Guinea. *Pacific Conservation Biology* 17(2): 149–159.

Mohagan, A.B., D.P. Mohagan & A.E. Tambuli (2011). Diversity of butterflies in the selected key biodiversity areas of Mindanao, Philippines. *Asian Journal of Biodiversity* 2(1): 121–148. https://doi.org/10.7828/ajob.v2i1.95

Mohagan, A.B., S.G. Remulta B., D.J.B. Mohagan, D.P. Mohagan, V.B. Amoroso, H.C. Porquis & J.A. Escarlos Jr (2018). Species composition and status of butterflies across vegetation types in Mt. Pinamantawan Sto. Domingo, Quezon, Bukidnon, Philippines. *Asian Journal of Biodiversity* 9(1): 118–135. https://doi.org/10.7828/ajob.v9i1.1237

Oliver, T.H., M.S. Heard, N.J. Isaac, D.B. Roy, D. Procter, F. Eigenbrod, R. Freckleton, A. Hector, C.D.L. Orme & O.L. Petchey (2015). Biodiversity and resilience of ecosystem functions. *Trends in ecology & evolution* 30(11): 673–684.

Padrón, P., A. Vélez, N. Miorelli & K. Willmott (2020). Urban areas as refuges for endemic fauna: description of the immature stages of Catasticta flisa duna (Eitschberger & T. Racheli, 1998)(Lepidoptera: Pieridae) and its ecological interactions. *Neotropical Biodiversity* 6(1): 109–116.

Pag-Ong, A.I., D. Nisperos & R. Flores (2022). Diversity and relative abundance of ants (Hymenoptera: Formicidae) in the National Capital Region, Philippines. *Asia Life Sciences* 31(1): 1–21.

Page, M. & C. Treadaway (2004). *Papilionidae of the Philippine Islands: Butterflies of the World.* Verlag Goecke & Evers, Germany, 71 pp.

Paoletti, M.G. (1999). Using bioindicators based on biodiversity to assess landscape sustainability. *Elsevier* 1–18. https://doi.org/https://doi.org/10.1016/B978-0-444-50019-9.50004-2

Parlin, A.F., S.M. Stratton & P.A. Guerra (2022). Oriented migratory flight at night: Consequences of nighttime light pollution for monarch butterflies. *Iscience* 25(5): 104310. https://doi.org/10.1016/j.isci.2022.104310

Pe'er, G. & J. Settele (2008). The rare butterfly Tomares nesimachus (Lycaenidae) as a bioindicator for pollination services and ecosystem functioning in northern Israel. *Israel Journal of Ecology and Evolution* 54(1): 111–136.

Pignataro, T., G. Lourenço, M. Beirão & T. Cornelissen (2023). Wings are not perfect: increased wing asymmetry in a tropical butterfly as a response to forest fragmentation. *The Science of Nature* 110: 28. https://doi.org/10.1007/s00114-023-01856-7

Posa, M.R.C. & N.S. Sodhi (2006). Effects of anthropogenic land use on forest birds and butterflies in Subic Bay, Philippines. *Biological Conservation* 129(2): 256–270.

Reeves, L.E. & J.C. Daniels (2020). Conservation value of secondary forest habitats to endemic frugivorous butterflies at Mount Kanlaon, Negros Occidental, Philippines. *Journal of Insect Conservation* 24(6): 913–926.

Sanderson, C., M.F. Braby & S. Bond (2021). Butterflies Australia: a national citizen science database for monitoring changes in the distribution and abundance of Australian butterflies. *Austral Entomology* 60(1): 111–127.

Santos, A.D.C., P.C.L. Sales, D.B. Ribeiro & P.R.R. Silva (2020). Habitat conversion affects beta diversity in frugivorous butterfly assemblages. *Studies on Neotropical Fauna and Environment* 55(3): 180–192. https://doi.org/10.1080/01650521.2019.1710335

Sarı, E.N. & S. Bayraktar (2023). The role of park size on ecosystem services in urban environment: a review. *Environmental Monitoring and Assessment* 195(9): 1072. https://doi.org/10.1007/s10661-023-11644-5

Savard, J.P.L., P. Clergeau & G. Mennechez (2000). Biodiversity concepts and urban ecosystems. *Landscape and Urban Planning* 48(3): 131–142. https://doi.org/https://doi.org/10.1016/S0169-2046(00)00037-2

Schmidt, C., M. Domaratzki, R. Kinnunen, J. Bowman & C. Garroway (2020). Continent-wide effects of urbanization on bird and mammal genetic diversity. *Proceedings of the Royal Society B* 287(1920): 20192497. https://doi.org/10.1098/rspb.2019.2497

Schroeder, H.G. & C.G. Treadaway (2005). *Nymphalidae IX, Amathusiini der Philippinen, Amathusiini of the Philippine Islands (Nymphalidae: Morphinae).* Verlag Goecke & Evers, Germany, 32 pp.

Seress, G. & A. Liker (2015). Habitat urbanization and its effects on birds. *Acta Zoologica Academiae Scientiarum Hungaricae* 61(4): 373–408.

Shephard, A.M., T.S. Mitchell, S.B. Henry, K.S. Oberhauser, M.E. Kobiela & E.C. Snell-Rood (2020). Assessing zinc tolerance in two butterfly species: consequences for conservation in polluted environments. *Insect Conservation and Diversity* 13(2): 201–210.

Sing, K.W., W.F. Jusoh, N.R. Hashim & J.J. Wilson (2016). Urban parks: refuges for tropical butterflies in Southeast Asia? *Urban ecosystems* 19: 1131–1147.

Sioson, J.C.C., N.A.V. Tacuboy & R.J.S. Vitor II (2018). Determination of the hematological values and detection of Chlamydophila psittaci antibodies in captive Palawan Hill Mynah at the Ninoy Aquino Parks and Wildlife Nature Center. *National Journal of Physiology, Pharmacy and Pharmacology* 8(1): 107–107.

Taylor, L., E.H. Leckey, P.J. Lead & D.F. Hochuli (2020). What visitors want from urban parks: diversity, utility, serendipity. *Frontiers in Environmental Science* 8: 595620. https://doi.org/10.3389/fenvs.2020.595620

Thompson, G.G. & P.C. Withers (2003). Effect of species richness and relative abundance on the shape of the species accumulation curve. *Austral Ecology* 28(4): 355–360.

Toledo, J. & A.B. Mohagan (2011). Diversity and Status of Butterflies in Mt. Timpoong and Mt. Hibok-hibok, Camiguin Island, Philippines. *JPAIR Multidisciplinary Journal* 6: 103–110.

Treadaway, C. & H. Schroeder (2012). Revised checklist of the butterflies of the Philippine Islands (Lepidoptera: Rhopalocera).

Entomologischer Verein Apollo 20: 1–64.

Uehara-Prado, M., K.S. Brown Jr & A.V.L. Freitas (2007). Species richness, composition and abundance of fruit-feeding butterflies in the Brazilian Atlantic Forest: comparison between a fragmented and a continuous landscape. *Global Ecology and Biogeography* 16(1): 43–54.

Ugland, K.I., J.S. Gray & K.E. Ellingsen (2003). The species–accumulation curve and estimation of species richness. *Journal of animal ecology* 72(5): 888–897.

Vallejo, B.M., A.B. Aloy & P.S. Ong (2009). The distribution, abundance and diversity of birds in Manila's last greenspaces. *Landscape and Urban Planning* 89(3): 75–85. https://doi.org/10.1016/j.landurbplan.2008.10.013

van der Sluijs, J.P. (2020). Insect decline, an emerging global environmental risk. *Current Opinion in Environmental Sustainability* 46: 39–42. https://doi.org/10.1016/j.cosust.2020.08.012

van Strien, A., R. Van De Pavert, D. Moss, T. Yates, C. VanSwaay & P. Vos (1997). The statistical power of two butterfly monitoring schemes to detect trends. *Journal of Applied Ecology* 34(3): 817–828. https://doi.org/10.2307/2404926

Warren, M.S., D. Maes, C.A. van Swaay, P. Goffart, H. Van Dyck, N.A. Bourn, I. Wynhoff, D. Hoare & S. Ellis (2021a?). The decline of butterflies in Europe: Problems, significance, and possible solutions. *Proceedings of the National Academy of Sciences* 118(2): e2002551117. https://doi.org/10.1073/pnas.200255111

Warren, M.S., D. Maes, C.A.M. van Swaay, P. Goffart, H. Van Dyck, N.A.D. Bourn, I. Wynhoff, D. Hoare & S. Ellis (2021b?). The decline of butterflies in Europe: Problems, significance, and possible solutions. *Proceedings of the National Academy of Sciences* 118(2): e2002551117. https://doi.org/doi:10.1073/pnas.2002551117

Wepprich, T., J.R. Adrion, L. Ries, J. Wiedmann & N.M. Haddad (2019). Butterfly abundance declines over 20 years of systematic monitoring in Ohio, USA. *PLoS ONE* 14(7): e0216270. https://doi.org/10.1371/journal.pone.0216270

Wickham, H. & H. Wickham (2016). Package 'ggplot2'. Create elegant data visualisations using the grammar of graphics. *Version* 2(1): 1–189.

Yan, Z.T., Z.H. Fan, S. He, X.Q. Wang, B. Chen & S.T. Luo (2023). Mitogenomes of Eight Nymphalidae Butterfly Species and Reconstructed Phylogeny of Nymphalidae (Nymphalidae: Lepidoptera). Available online 14 December 2020. https://doi.org/10.3390/genes14051018

Zhang, M., Y. Zhong, T. Cao, Y. Geng, Y. Zhang, K. Jin, Z. Ren, R. Zhang, Y. Guo & E. Ma (2008). Phylogenetic relationship and morphological evolution in the subfamily Limenitidinae (Lepidoptera: Nymphalidae). *Progress in Natural Science* 18(11): 1357–1364. https://doi.org/10.1016/j.pnsc.2008.03.025

Author details: Micael Gabriel A. Itliong, M.Sc., a graduate of the University of Santo Tomas Graduate School, focused his master's thesis on butterflies in Metro Manila's urban parks. Currently an instructor at the Polytechnic University of the Philippines, he teaches Ecology and Invertebrate Zoology. His research interests lie in Philippine butterflies, and he advocates for Philippine biodiversity conservation as an active member of iCOLABB. Nikki Heherson A. Dagamac, Dr. rer. nat., assistant professor at the University of Santo Tomas' Department of Biological Sciences, studies the evolution and ecology of slime molds in the Philippines and the tropics. He now leads various conservation projects using ecological modeling and founder of iCOLABB (Initiatives for Conservation, Landscape Ecology, Bioprospecting, and Biomodeling). Jade Aster T. Badon, assistant professor at the University of the Philippines Los Baños' Animal Biology Division, holds M.S. and Ph.D. degrees in Entomology and Nematology from the University of Florida. As president of PhiLep (Philippine Lepidoptera), he focuses his research on Philippine butterfly biology.

Authors contributions: Concept, design, and supervision: MGAI, NHAD & JATB; Data collection & analysis: MGAI, NHAD & JATB; Manuscript writing MGAI, NHAD & JATB; Manuscript review & comments: MGAI, NHAD & JATB; Funding acquisition: MGAI.

Acknowledgements: We want to thank Cherry Lopez and Sarah Agacaoili of La Mesa Ecopark and Fides Sandoval and Melody Malano of Ninoy Aquino Parks and Wildlife Center in Quezon City, Metro Manila, for their authorization and assistance provided by these urban parks played a crucial role in the successful implementation of this study on butterfly diversity. The researchers would also like to thank Marietta Itliong, Nieves Itliong, and Mica Itliong for their assistance during the data gathering, Christian Elmarc Ocenar-Bautista for his assistance in data analysis, and James Eduard Dizon for generating the study site map. All identifications were validated by Dr. Jade Aster T. Badon, an entomologist and butterfly systematist from the University of the Philippines, with accompanying photographic vouchers. This collaboration hopes to contribute substantially to the progress of Philippine Lepidoptera's ecological study and conservation efforts.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25528–25535

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

https://doi.org/10.11609/jott.8983.16.7.25528-25535

#8983 | Received 19 February 2024 | Final received 28 June 2024 | Finally accepted 15 July 2024

OPEN ACCESS

ARTICLE

Assessment of the status of *Spodoptera* species (Lepidoptera: Noctuidae: Armyworm) in India through DNA barcoding technique

Dinesh Nalage [1], P.S. Kudnar [2], Tejswini Sontakke [3], Ishwar Chittapure [4], Yashdeep Gowda [5], Shantanu Kharbal [6] & Yashashri Alamwar [7]

[1,4,5,6,7] Department of Molecular Biology and Microbiology, IBT, MGM University, Aurangabad, Maharashtra 431103, India.
[2] Post-Graduate Research Centre, Department of Zoology, Modern College of Arts, Science and Commerce (Autonomous), Shivajinagar, Pune, Maharashtra 411005, India.
[3] Department of Zoology, MGV's, MPH Mahila Mahavidyalaya, Malegaon, District Nashik, Maharashtra 423105, India.
[1] dnalage@mgmu.ac.in (corresponding author), [2] kpravin95@gmail.com, [3] tejaswinisontakke27@gmail.com, [4] ichittapure@gmail.com, [5] yashdeepgowda@gmail.com, [6] kharbalshantanu@gmail.com, [7] yashashri.mobile@gmail.com

Abstract: Insects constitute the majority of animal fauna worldwide, but quantifying their species diversity is still incomplete. A few recent studies indicate a marked decrease in the population of insects which calls for urgent efforts to document and understand insect diversity to get a complete picture of Earth's ecosystems. Modern technology can accelerate species identification beyond traditional methods' limitations. Hence, a focused and expedited approach through DNA barcoding coupled with morphological identification is necessary. This present research highlights the gaps that exist and it examines the current status of *Spodoptera* species barcode in India. Six *Spodoptera* species were studied confirming their presence in India including two invasive species. That means less than 50% of taxa or described *Spodoptera* species are covered by genetic data from barcoded specimens after analysis. Therefore, comprehensive DNA barcoding should be achieved from all insect species occurring on the Indian subcontinent to speed up the discovery and documentation of new species by involving both traditional taxonomists and molecular biologists working towards a common goal.

Keywords: Biodiversity in India, conservation, current status, insect, identification, molecular biology, species, taxa.

Editor: Mandar Paingankar, Government Science College Gadchiroli, Maharashtra, India. **Date of publication:** 26 July 2024 (online & print)

Citation: Nalage, D., P.S. Kudnar, T. Sontakke, I. Chittapure, Y. Gowda, S. Kharbal & Y. Alamwar (2024). Assessment of the status of *Spodoptera* species (Lepidoptera: Noctuidae: Armyworm) in India through DNA barcoding technique. *Journal of Threatened Taxa* 16(7): 25528–25535. https://doi.org/10.11609/jott.8983.16.7.25528-25535

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Dinesh Nalage is assistant professor in MGM University. He is expert in molecular taxonomy. P.S. Kudnar is assistant professor in Modern College of Arts, Science and Commerce, Shivajinagar, Pune. His research interests include Hydrobiology and Entomology. Tejswini Sontakke is assistant professor in MGV's, MPH Mahila Mahavidyalaya, Malegaon, District Nashik. Her research interests include Entomology and Hydrobiology. Ishwar Chittapure is undergraduate student of Biotechnology. Yashdeep Gowda is undergraduate student of Biotechnology. Shantanu Kharbal is graduate student of Microbiology. Yashashri Alamwar is graduate student of Biotechnology.

Author contributions: DN, IC, TS and YG conducted the investigation, collected, and curated the data, and wrote the original draft of the manuscript. SK, YA and PK contributed to the development of the initial concept of the study and was responsible for the design and implementation of the methodology also he was responsible for reviewing and editing the manuscript, creating visualizations, and supervising the overall progress of the study. All authors have read and approved the final manuscript.

Acknowledgements: We would like to express our sincere gratitude to the vice chancellor and registrar of MGM University for their continuous support and encouragement. We extend our heartfelt thanks to the director of the Institute of Biosciences and Technology for providing the necessary resources and guidance throughout this study. Special thanks to Prof. Sanjay Harke for his invaluable insights and assistance, which significantly contributed to the success of this research.

INTRODUCTION

Identifying insect species is crucial for understanding ecological, evolutionary, and conservation-related queries. Properly diagnosing these species is vital for monitoring biodiversity and utilizing it effectively (Khedkar et al. 2016). Despite the contributions of the long-standing Linnaean classification system to taxonomy, its reliance on morphology has limitations. These limitations, like difficulties in resolving cryptic species and identifying immature stages, hinder progress. Furthermore, the scarcity of experts in morphotaxonomy restricts this approach (Shashank et al. 2022), leaving many species undiscovered or known only through descriptions and lost type specimens. The backlog of unidentified specimens in museum collections has existed for decades. After its introduction in 2003, DNA barcoding has evolved as a complementing technique to conventional taxonomy (Hebert et al. 2003). By characterizing species using standardized DNA regions, DNA barcoding aids in identifying cryptic species, and immature stages, and rapidly distinguishing species in various contexts, such as identification food stuff (Khilare et al. 2019; Tiknaik et al. 2019; Suryawanshi et al. 2020). However, creating high-quality reference libraries based on voucher specimens remains crucial for its applications. Despite challenges due to the vast diversity of life forms and limited taxonomic expertise, several countries, including India, have created massive DNA barcode reference collections for certain creature categories, such as insects. India, known for its rich insect diversity, houses a significant portion of the world's insect fauna.

Major biotic stress on crops is insect pests. Hundreds of insects can cause severe crop damage (Mahmood-ur-Rahman et al. 2014; Nalage et al. 2023). The *Spodoptera* (Lepidoptera: Noctuidae) genus comprises a few of the world's most important crop predators. They are commonly referred to as 'armyworms'. Thirty-one species have been described with members present on six continents (Kergoat et al. 2021). These species feed on a wide range of vegetable, grain, row, forage, and ornamental crops. While young larvae burn leaf tissue and skeletonize into leaves, advanced stages on all leaves are roughly and brutally fed and transported from leaf to leaf (Chandel et al. 2013). The group *Spodoptera* includes species closely related to a similar ecology, difficult to identify at the level of the species (Henaish & Elmetwaly 2020). It is also referred to as the caterpillar cluster, cotton leaf worm, tropical armyworm, and tobacco cutworm (Meagher et al. 2008).

So far, DNA barcoding in Lepidoptera has shown mixed success in determining species. There are several examples of fake DNA barcodes that determine the potential limitations of the methodology (Dasmahapatra et al. 2010; Goergen et al. 2016). This is because current diversity may be difficult to quantify due to missing barcode scopes, absence of uniform barcode spaces in some taxa, and perhaps confounding consequences of an incomplete pedigree (Rubinoff et al. 2006; Silva-Brandão et al. 2009). However, the approach was effectively employed in a variety of investigations, where 150 insect specimens were appropriately assigned and used a barcode information of 200 closely related species (Hebert et al. 2003). To adequately document India's diverse insect population across various ecological zones, efficient methods like DNA barcoding are essential. However, as of 2024, the Barcode of Life Data (BOLD) system contained only a small fraction of Indian insect species barcodes, highlighting the need for more comprehensive data. The paper aimed to analyze DNA barcode data of the *Spodoptera* (Lepidoptera: Noctuidae) genus from India on BOLD to assess the current status and discuss future steps.

MATERIAL AND METHODS

All sequences and data were collected from The Barcode of Life Data System (BOLD) (Ratnasingham & Hebert 2007) and the National Center for Biotechnology Information (NCBI) (Benson et al. 2012). Specifically, from public data sources we retrieved genetic data of the *Spodoptera* genus dated 19/12/2023, filtering by country ("India"), gene ("COI"), and length (">500bp"). With these settings, we created a dataset named "DS-SPODOPTERA" on BOLD (https://v3.boldsystems.org/index.php/MAS_Management_OpenDataSet?datasetcode=DS-SPOD). Additionally, data for *Spodotera mauritia*, *S. littoralis*, and *S. exempta* were obtained using similar filtering criteria for gene and sequence length, adding them to the same dataset. Two outgroup sequences, *Lymantria dispar dispar* (NCBI ID: XAG005-05) and *Hyphantria cunea* (NCBI ID: XAB076-04), were also included.

Following alignment, all DNA sequences were translated into amino acid sequences, guaranteeing the absence of stop codons. The aligned files were then utilized for phylogenetic analysis and distance matrix computation using Mega 10.2. The phylogenetic tree was constructed using the neighbor-joining method (Saitou & Nei 1987) with bootstrap analysis (1,000 replicates) to assess the reliability of the branches. Genetic distances

were computed using the Kimura 2-parameter model (Kimura 1980).

Single GYMC Analysis

The Generalized Mixed Yule Coalescent (GYMC) model was applied to delineate species boundaries using the COI gene sequences. This approach integrates both yule processes (modeling species diversification) and coalescent processes (modeling intraspecific variations). We implemented the GYMC method using the 'GMYC ' package in R, setting the MCMC chain to run for 100,000 generations with a burn-in of 10,000 generations to ensure robust and accurate delineations (Pons et al. 2006).

BPP Analysis

Bayesian phylogenetics and phylogeography (BPP) analysis was employed to confirm the species boundaries suggested by the GYMC model. We used the BPP v4.0 software, incorporating multi-locus sequence data. The analysis involved specifying a guide tree based on prior phylogenetic knowledge and running the MCMC for 200,000 generations, sampling every 20 generations, and discarding the first 10% as burn-in. Priors were set as theta ~ G(2, 2000) and tau0 ~ G(2, 1000), reflecting prior expectations of population size and divergence time, respectively (Yang & Rannala 2010).

mPTP Analysis

The multi-rate poisson tree processes (mPTP) model was utilized to further validate species delimitation results. This method accounts for rate variation among branches, providing a more flexible framework compared to traditional PTP models. The analysis was conducted using the mPTP web server, with default parameters and a bootstrap analysis (1,000 replicates) to assess confidence in species boundaries (Kapli et al. 2017).

By integrating these methods, our analysis aims to provide a comprehensive and robust species delimitation for the *Spodoptera* genus in India, contributing to the accurate identification and understanding of both native and invasive species.

RESULTS

We analyzed the COI region DNA sequences of six *Spodoptera* species, totaling 817 sequences. For the four species found in India, we obtained COI region sequences for only two species, *S. litura* and *S. exigua*, from the BOLD database of the 817 sequences, 365 were from outside India, including *S. littoralis* (51 sequences), *S. mauritia* (190 sequences), and *S. exempta* (124 sequences). The remaining 450 sequences were from India, comprising S. frugiperda (265 sequences), *S. exempta* (1 sequence), *S. exigua* (58 sequences), and *S. litura* (126 sequences) (Table 1). These were contrasted with barcode sequences from *S. frugiperda* and *S. exempta*, two possible invasive species, since its confirmed status based on the literature. No deletions, insertions, or no stop codons were found when the COI sequences were aligned, suggesting that the amplified DNA originated from functional COI genes. The sequences' total mean GC content is 29–30 %. The mean GC content on codon pos 1 is 39–41 % (except *S. litura*, which has a mean GC% content of 41.07%), the mean GC% content on codon pos 2 is 42–43 %, and the mean GC% content on codon pos 3 is 6–7 %. There was no discernible variation in the overall GC% for Codon Pos 1, Pos 2, and Pos 3.

With the exception of *S. frugiperda* species, which has the largest nucleotide divergence among species at 5.38%, the dataset has no considerable barcode gap. The maximum nucleotide difference within species is ≤2.2% (Table 2). The minimal nucleotide difference between species *S. littoralis* and *S. litura* was 2.9%, which was quite near to the cut off (≤3.0%). Apart from this, there was ≥4.2% minimal nucleotide difference between species. The two host strains of *S. frugiperda*, *S. mauritia* & *S. exigua*, and *S. litura* & *S. littoralis* showed the closest similarities, however even these pairings separated at >95% bootstrap values. Neighbor-joining phenetic analysis, which distinguished at > 75% bootstrap scores among the predicted species and showed that *S. exigua* was the most divergent, supported this. The phylogeny based on morphological and phenetic connections was typically in agreement (Pogue 2002). According to those cladistic analyses, *S. exigua* is the most plesiomorphic species in the *Spodoptera* group, whereas *S. littoralis* and *S. litura* are closely related sister species (Figure 1). Comparisons of adult genital morphology are the only way to distinguish between *S. littoralis* and *S. litura* (Mochida 1973; Ellis 2004). The morphological study of the male and female genitalia of *Spodoptera* species have been provided to identify the species from India (Supplementary Tables 1 & 2).

Comparative Morphological Analysis of *Spodoptera* Species

This section provides a comparative morphological analysis of key Spodoptera species found in India. By

Table 1. Current genetic and morphological reports, number of COI gene sequences from India and outside of India and mean GC% content, mean GC% content on codon pos. 1, mean GC% content on codon pos. 2 and mean GC% content on codon pos. 3 sequences on the BOLD status of *Spodoptera*.

	Native species name in India	Genetically reported till date in India	Morpholo-gically reported to date in India	Genetically reported till date outside of India	No. of sequences public on BOLD from India	No. of sequences public on BOLD from Outside of India	Total no. of sequences public on BOLD	Mean GC % content of sequences public on BOLD	Mean GC % content on codon pos 1 of sequences on BOLD	Mean GC % content on codon pos 2 of sequences on BOLD	Mean GC% content on codon pos 3 of sequences on BOLD
1	*S. littoralis*	No	Yes	Yes	0	51	51	29.32	39.22	41.78	6.97
2	*S. mauritia*	No	Yes	Yes	0	190	190	29.94	40.90	42.14	6.85
3	*S. exigua*	Yes	Yes	Yes	58	626	684	29.43	40.40	41.77	6.05
4	*S. litura*	Yes	Yes	Yes	126	250	376	29.72	41.07	41.71	6.39
	Invasive Species Name in India										
5	*S. exempta*	Yes	Yes	Yes	1	124	125	29.51	39.57	42.52	6.45
6	*S. frugiperda*	Yes	Yes	Yes	265	1088	1353	29.77	40	42.07	7.25

Table 2. Genetic distance between the Spodoptera species (indicated by green color) and within the species (indicated by yellow color).

	S. exempta	*S. exigua*	*S. frugiperda*	*S. littoralis*	*S. litura*	*S. mauritia*
S. exempta	1.59					
S. exigua	6.3	1.15				
S. frugiperda	4.8	8.6	5.38			
S. littoralis	4.2	6.0	5.3	2.14		
S. litura	4.5	7.1	5.3	2.9	2.18	
S. mauritia	6.0	9.1	8.3	8.3	9.3	1.91

highlighting differences and similarities in the male and female genitalia, this comparison facilitates accurate identification crucial for pest management.

Male Genitalia Comparison

Valve

S. exigua: Broad elongate oval

S. exempta: Narrow rectangular

S. mauritia: Narrow tapering

S. frugiperda: Very broad, quadrate

S. littoralis: Broad quadrate with dentate ventral margin

S. litura: Broad

S. eridania: Not specified

Juxta

S. exigua: Narrow elliptical band

S. exempta: Narrow elliptical band with triangular median process

S. mauritia: Narrow elliptical band with triangular median process

S. frugiperda: Narrow rectangular band

S. littoralis: Broad quadrate

S. litura: Triangular

S. eridania: Narrow rectangular band

Coremata

S. exigua: Moderately elongate, no distinct lobes

S. exempta: Single lobe

S. mauritia: Single lobe

S. frugiperda: Single lobe, elongate

S. littoralis: Two lobes

S. litura: Two lobes

S. eridania: One lobe

Ampulla

S. exigua: Elongate, slightly curved apex

S. exempta: Elongate, bent in the middle

S. mauritia: Elongate, slightly curved downwards

S. frugiperda: Elongate, curved with decurved apex

S. littoralis: Short, curved with decurved apex

S. litura: Short, curved

S. eridania: Straight clasper proper

Female Genitalia Comparison

Corpus Bursae

S. exigua: Elongate
S. exempta: Bulbous
S. mauritia: Bulbous, constricted caudally
S. frugiperda: Bulbous
S. littoralis: Bulbous
S. litura: Bulbous
S. eridania: Elongate

Ductus Bursae

S. exigua: Short, sclerotized
S. exempta: Medium length, sclerotized
S. mauritia: Short, sclerotized
S. frugiperda: Short, sclerotized
S. littoralis: Short, sclerotized
S. litura: Elongate, sclerotized
S. eridania: Short, sclerotized

Signum

S. exigua: Elongate, <30° angle
S. exempta: Elongate, almost vertical
S. mauritia: Medium elongate
S. frugiperda: Short, >30° angle
S. littoralis: Short
S. litura: Short
S. eridania: Elongate, >30° angle

Key Distinguishing Features

S. exigua vs. *S. frugiperda: S. exigua* has a broad elongate oval valve and elongate corpus bursae, while *S. frugiperda* has a very broad quadrate valve and bulbous corpus bursae.

S. exempta vs. *S. mauritia:* Both have a narrow rectangular valve, but *S. exempta's* coremata is a single lobe, while *S. mauritia's* is also a single lobe but with a constricted caudal end in the corpus bursae.

S. littoralis vs. *S. litura:* Both have broad quadrate valves, but *S. littoralis* has a dentate ventral margin and two lobes in the coremata, while *S. litura* has a triangular juxta and two lobes.

Species Delimitation using Single GYMC, BPP, and mPTP

Single GYMC Analysis:

The Generalized Mixed Yule Coalescent (GYMC) model identified six distinct species within the *Spodoptera* genus using COI gene sequences. The species boundaries had posterior probabilities exceeding 0.95, demonstrating strong support for the classifications. This analysis differentiated the closely related species *S. littoralis* and *S. litura*, which were previously difficult to distinguish based on morphology alone.

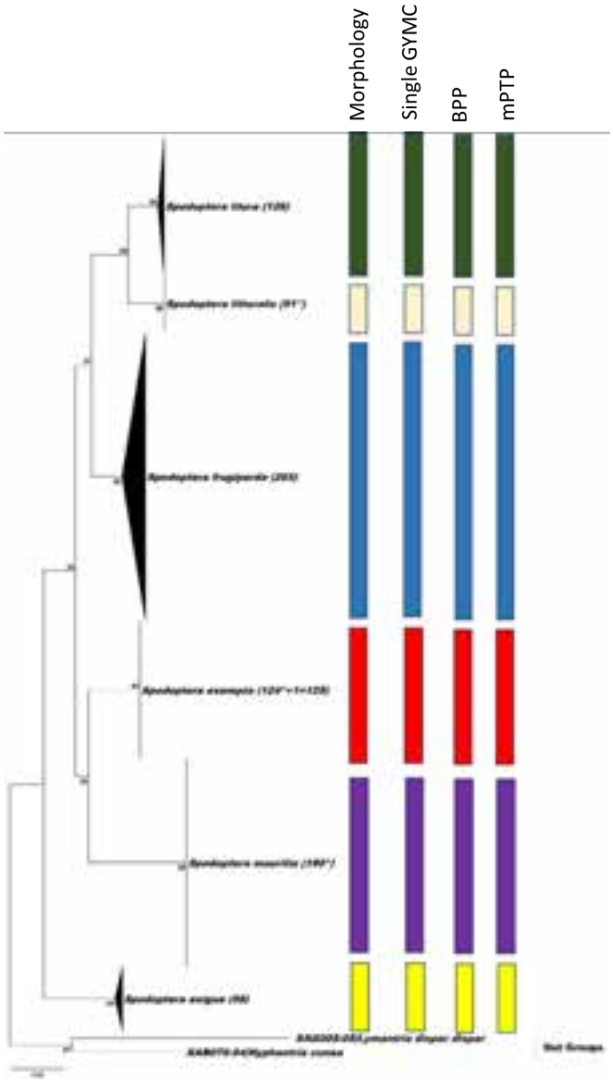


Figure 1. Phylogenetic analysis of *Spodoptera* species (*indicates genetic data taken from outside of India).

BPP Analysis

The Bayesian phylogenetics and phylogeography (BPP) analysis further validated the species boundaries suggested by the GYMC model. The results showed high posterior probabilities (>0.90) for all nodes representing species splits, reinforcing the delineation of six species within the dataset. The BPP analysis confirmed the presence of distinct evolutionary lineages corresponding to the species identified by morphological and genetic data.

mPTP Analysis:

The multi-rate poisson tree processes (mPTP) model analysis supported the species boundaries identified by both GYMC and BPP methods. The mPTP analysis revealed the same six species with high confidence,

and bootstrap support values were above 95% for all species delimitations. This method effectively accounted for rate variation among branches, providing additional robustness to our species delimitation results.

Comparative Analysis

Comparative analysis across the three methods showed a high level of congruence, with all methods consistently identifying the same six species: *S. littoralis*, *S. mauritia*, *S. exigua*, *S. litura*, *S. exempta*, and *S. frugiperda*. The use of multiple methods provided a comprehensive framework for species delimitation, ensuring that the results were robust and reliable.

Genetic Distances and Phylogenetic Relationships

Genetic distance analysis revealed minimal within-species variation (≤2.2%) and clear between-species differences (≥4.2%), except the difference between species *S. littoralis* and *S. litura* was 2.9%, The phylogenetic tree constructed using the neighbor-joining method showed distinct clades for each species with high bootstrap support (>75%), consistent with the species boundaries identified by GYMC, BPP, and mPTP analyses. *S. exigua* was identified as the most divergent species within the genus, while *S. littoralis* and *S. litura* were confirmed as closely related sister species.

DISCUSSION

In the Indian subcontinent, four *Spodoptera* species were previously identified as native: *S. litura* (Muthusamy et al. 2024), *S. exigua* (Ramaiah et al. 2022), *S. littoralis*, and *S. mauritia* (Madhu et al. 2023). Additionally, one invasive species, *S. frugiperda* (fall armyworm or FAW), was reported (Ganiger et al. 2018), originating from North and South America (Jing et al. 2020). Recent comprehensive genomic analyses suggest that *S. frugiperda* likely consists of two closely related sister species, known as the corn-preferred and rice-preferred strains. These findings are supported by multiple studies (Pashley 1986; Meagher et al. 2004; Kergoat et al. 2012; Dumas et al. 2015; Gouin et al. 2017; Le Ru et al. 2018). Both sister species are present in India, but the manner of their introduction, whether together or separately, remains uncertain. Additionally, it is unclear if they have spread as a unified population since their introduction.

We observed that all four native *Spodoptera* species were reported through morphological methods, but genetic data is available for only two species on BOLD to date (Table 1). On BOLD/NCBI, only one sequence of *S. exempta* was submitted from India. This is very surprising that commonly found species' genetic data was lacking. The same observation was noted by Shashank et al. (2022). They also highlighted the present state of insect species barcoding in India. They pointed out the existing gaps which must be addressed soon. Their examination indicates that barcoded specimens encompass a minimal percentage, specifically less than 3.73%, of the recognized taxa or described species. The most predominant orders include Lepidoptera and Hemiptera, followed by Diptera and Coleoptera. It is imperative to accelerate the discovery and documentation of insect species through collaborative efforts between traditional taxonomists and molecular biologists. This collaborative approach aims to achieve comprehensive DNA barcoding for all identified insect taxa in India.

The genus *Spodoptera* presents challenges for morphological identification across all species due to variability and shared characteristics. The complexity arises due to overlapping rib numbers between species, and the morphology of eggs in many *Spodoptera* species remains unknown. Therefore, molecular methods become essential for accurate species-level identification during this developmental stage (European and Mediterranean Plant Protection Organization (OEPP/EPPO) 2015). While fully grown larvae of quarantine *Spodoptera* species can be distinguished, molecular identification is recommended for early stages, especially when the larva's origin is unknown or expertise is lacking. Distinguishing between younger larvae of *S. littoralis*, *S. litura*, and *S. frugiperda* is possible, but molecular identification is advised for early stages, offering reliability in cases where experience is limited or larval origin is uncertain. For *S. eridania*, *S. frugiperda*, *S. littoralis*, and *S. litura*, a practical approach involves using four simplex real-time PCR tests based on TaqMan® chemistry (Van de Vossenberg & Van der Straten 2014). To address geographical distribution overlap, tests for *S. eridania* and *S. frugiperda*, as well as *S. littoralis* and *S. litura*, are combined into single tests, providing an effective means of identification (European and Mediterranean Plant Protection Organization (OEPP/EPPO) 2015).

Biodiversity-rich nations like India, grappling with burgeoning populations, confront significant challenges in harmonizing economic progress, ensuring food security, and preserving biodiversity (Shashank et al. 2022). The foundational field of systematics, crucial for biodiversity research, is under considerable strain. Traditional taxonomy has historically played a pivotal role in identifying over 1.4 million global insect species for the past two centuries. However, the pace of this progress falls short of documenting the entire biota before it faces

extinction. Consequently, novel technologies (Patil et al. 2023; Sontakke et al. 2023), notably DNA barcoding, have gained traction for rapid and cost-effective biodiversity documentation.

As one of the mega-diverse countries, India aspires to make substantial contributions toward achieving the United Nations Sustainable Development Goals (SDGs) (Nalage et al. 2023) and targets (Shashank et al. 2022). However, this review unveils a disconcerting scenario concerning the status of DNA barcoding in India, which described very less insect species. There is apprehension that in the genomics era, the delayed establishment of DNA barcode reference libraries for insects may hinder our ability to comprehensively document India's abundant biodiversity.

CONCLUSION

This study has left a remarkable footprint in understanding *Spodoptera* species in India. It confirms the presence of four native species—*S. litura*, *S. exigua*, *S. littoralis*, and *S. mauritia*—along with two invasive species—*S. frugiperda* and *S. exempta*—in the country. The confirmation of the presence of *S. eridania* in India awaits the reporting of its mature larva or molecular data.

The study underscores the importance of a combined approach, emphasizing that both morphological and genetic studies must complement each other to accurately identify invasive and native species in the country. It highlights the integration of DNA barcoding and molecular analysis as indispensable for improving the precision and comprehensiveness of *Spodoptera* species identification.

The combined use of Single GYMC, BPP, and mPTP methods provided a robust and comprehensive approach to species delimitation in the *Spodoptera* genus. The results confirmed the presence of six distinct species within India, highlighting the importance of integrating multiple analytical methods to accurately delineate species boundaries in taxonomically challenging groups. This study contributes valuable genetic data and methodological insights for the improved identification and management of *Spodoptera* species in India.

This approach not only tackles challenges associated with morphological identification positively but also contributes valuable data for the development of more targeted and efficient strategies in pest management and conservation efforts.

REFERENCES

Benson, D.A., M. Cavanaugh, K. Clark, I. Karsch-Mizrachi, D.J. Lipman, J. Ostell & E.W. Sayers (2012). GenBank. *Nucleic Acids Research* 41(D1): D36–D42. https://doi.org/10.1093/nar/gks1195

Chandel, R.S., V.K. Chandla, K.S. Verma & M. Pathania (2013). Insect pests of potato in India, pp. 227–268. In: *Insect Pests of Potato*. Elsevier. https://doi.org/10.1016/B978-0-12-386895-4.00008-9

Dasmahapatra, K.K., M. Elias, R.I. Hill, J.I. Hoffman & J. Mallet (2010). Mitochondrial DNA barcoding detects some species that are real, and some that are not. *Molecular Ecology Resources* 10(2): 264–273. https://doi.org/10.1111/j.1755-0998.2009.02763.x

Dumas, P., J. Barbut, B. Le Ru, J. F.Silvain, A.L. Clamens, E. d'Alençon & G.J. Kergoat (2015). Phylogenetic molecular species delimitations unravel potential new species in the pest genus *Spodoptera* Guenée, 1852 (Lepidoptera, Noctuidae). *Plos ONE* 10(4): e0122407. https://doi.org/10.1371/journal.pone.0122407

European and Mediterranean Plant Protection Organization (OEPP/EPPO) (2015). EPPO standards PM 7/124(1) diagnostic protocol for Spodoptera littoralis, Spodoptera litura, Spodoptera frugiperda, Spodoptera eridania. *EPPO Bulletin* 45(3): 410–444. https://doi.org/10.1111/epp.12258

Ganiger, P.C., H.M. Yeshwanth, K. Muralimohan, N. Vinay, A.R.V. Kumar & K. Chandrashekara (2018). Occurrence of the New Invasive Pest, Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), in the Maize Fields of Karnataka, India. *Current Science* 115(4): 621. https://doi.org/10.18520/cs/v115/i4/621-623

Goergen, G., P.L. Kumar, S.B. Sankung, A. Togola & M. Tamò (2016). First report of outbreaks of the Fall Armyworm Spodoptera frugiperda (J E Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. *Plos ONE* 11(10): e0165632. https://doi.org/10.1371/journal.pone.0165632

Gouin, A., A. Bretaudeau, K. Nam, S. Gimenez, J.M. Aury, B. Duvic, F. Hilliou, N. Durand, N. Montagné, I. Darboux, S. Kuwar, T. Chertemps, D. Siaussat, A. Bretschneider, Y. Moné, S.J. Ahn, S. Hänniger, A.S.G. Grenet, D. Neunemann & P. Fournier (2017). Two genomes of highly polyphagous lepidopteran pests (Spodoptera frugiperda, Noctuidae) with different host-plant ranges. *Scientific Reports* 7(1): 11816. https://doi.org/10.1038/s41598-017-10461-4

Hebert, P.D.N., A. Cywinska, S.L. Ball & J.R. DeWaard (2003). Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 270(1512): 313–321. https://doi.org/10.1098/rspb.2002.2218

Henaish, M. & N. Elmetwaly (2020). Identification and taxonomic notes of spodoptera species (Lepidoptera: Noctuidae) known to occur in Egypt. *Egyptian Academic Journal of Biological Sciences. A, Entomology* 13(2): 161–175. https://doi.org/10.21608/eajbsa.2020.88035

Jing, D., J. Guo, Y. Jiang, J. Zhao, A. Sethi, K. He & Z. Wang (2020). Initial detections and spread of invasive *Spodoptera frugiperda* in China and comparisons with other noctuid larvae in cornfields using molecular techniques. *Insect Science* 27(4): 780–790. https://doi.org/10.1111/1744-7917.12700

Kapli, P., S. Lutteropp, J. Zhang, K. Kobert, P. Pavlidis, A. Stamatakis & T. Flouri (2017). Multi-rate Poisson tree processes for single-locus species delimitation under maximum likelihood and Markov chain Monte Carlo. *Bioinformatics* 33(11): 1630–1638. https://doi.org/10.1093/bioinformatics/btx025

Kergoat, G.J., P.Z. Goldstein, B. Le Ru, R.L. Meagher, A. Zilli, A. Mitchell, A.L. Clamens, S. Gimenez, J. Barbut, N. Nègre, E. d'Alençon & K. Nam (2021). A novel reference dated phylogeny for the genus Spodoptera Guenée (Lepidoptera: Noctuidae: Noctuinae): new insights into the evolution of a pest-rich genus. *Molecular Phylogenetics and Evolution* 161: 107161. https://doi.org/10.1016/j.ympev.2021.107161

Kergoat, G.J., D.P. Prowell, B.P. Le Ru, A. Mitchell, P. Dumas, A. L. Clamens, F.L. Condamine & J.F. Silvain (2012). Disentangling dispersal, vicariance and adaptive radiation patterns: A case study using armyworms in the pest genus Spodoptera (Lepidoptera:

Noctuidae). *Molecular Phylogenetics and Evolution* 65(3): 855–870. https://doi.org/10.1016/j.ympev.2012.08.006

Khedkar, G.D., S.B. Abhayankar, D. Nalage, S.N. Ahmed & C.D. Khedkar (2016). DNA barcode based wildlife forensics for resolving the origin of claw samples using a novel primer cocktail. *Mitochondrial DNA Part A* 27(6): 3932–3935. https://doi.org/10.3109/19401736.2014.987270

Khilare, V., A. Tiknaik, B. Prakash, B. Ughade, G. Korhale, D. Nalage, N. Ahmed, C. Khedkar & G. Khedkar (2019). Multiple tests on saffron find new adulterant materials and reveal that Ist grade saffron is rare in the market. *Food Chemistry* 272: 635–642. https://doi.org/10.1016/j.foodchem.2018.08.089

Kimura, M. (1980). A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. *Journal of Molecular Evolution* 16(2): 111–120. https://doi.org/10.1007/BF01731581

Le Ru, B., J. Barbut, C. Capdevielle-Dulac, M. Goftishu & G.J. Kergoat (2018). Re-establishment of *Spodoptera teferii* Laporte *in* Rougeot (Lepidoptera: Noctuidae, Noctuinae), with an updated molecular phylogeny for the genus *Spodoptera* Guenée. *Annales de La Société Entomologique de France (N.S.)* 54(6): 497–510. https://doi.org/10.1080/00379271.2018.1528886

Madhu, T.N., R. T.P. Pandian, S.E. Apshara, A. Bhavishya, A. Josephrajkumar, B.J.N. Kumar & P.S. Kumar (2023). New Occurrence of the *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) Infestation on Cocoa in India. *The Journal of the Lepidopterists' Society* 77(2): 110–115. https://doi.org/10.18473/lepi.77i2.a4

Mahmood-ur-Rahman, M. Qasim, S.A. Bukhari & T. Shaheen (2014). Chapter 6 -Bt Crops: a sustainable approach towards biotic stess tolerance, pp. 125–142. In: *Emerging Technologies and Management of Crop Stress Tolerance. Volume-1.* Elsevier, 551 pp. https://doi.org/10.1016/B978-0-12-800876-8.00006-0

Meagher, R.L., R.N. Nagoshi, C. Stuhl & E.R. Mitchell (2004). Larval development of fall armyworm (lepidoptera: noctuidae) on different cover crop plants. *Florida Entomologist* 87(4): 454–460. https://doi.org/10.1653/0015-4040(2004)087[0454:LDOFAL]2.0.CO;2

Muthusamy, R., G. Ramkumar, S. Kumarasamy, M.F. Albeshr, A.F. Alrefaei, Y. Ma & M. Narayanan (2024). Resistance to synthetic pyrethroid and neonicotinoid is associated with reduced reproductive efficiency in the field population of *Spodoptera litura* (Insecta: Lepidoptera). *Biocatalysis and Agricultural Biotechnology* 56: 103031. https://doi.org/10.1016/j.bcab.2024.103031

Nalage, D., T. Sontakke, R. Patil & A. Biradar (eds.) (2023). *Environmental Impact Assessment*. Gaurang Publishing Globalize Private Limited. Mumbai, 108 pp.

Nalage, D., T. Sontakke, R. Kale, K. Patil & V. Dange (eds.) (2023). *Integrated Pest Management*. Gaurang Publishing Globalize Private Limited. Mumbai, 89 pp. https://doi.org/10.5281/ZENODO.10823681

Pashley, D. P. (1986). Host-associated genetic differentiation in fall armyworm (Lepidoptera: Noctuidae): a sibling species complex? *Annals of the Entomological Society of America* 79(6): 898–904. https://doi.org/10.1093/aesa/79.6.898

Patil, R., R. Satpute & D. Nalage (2023). The application of omics technologies to toxicology. *Toxicology Advances* 5(2): 6. https://doi.org/10.53388/TA202305006

Pons, J., T.G. Barraclough, J. Gomez-Zurita, A. Cardoso, D.P. Duran, S. Hazell, S. Kamoun, W.D. Sumlin & A.P. Vogler (2006). Sequence-Based species delimitation for the DNA taxonomy of undescribed insects. *Systematic Biology* 55(4): 595–609. https://doi.org/10.1080/10635150600852011

Ramaiah, M., T.U. Maheswari & N. Kamakshi (2022). Biology and morphometric studies of beet armyworm, Spodoptera exigua (Hub.). *Journal of Entomological Research* 46(4): 883–887. https://doi.org/10.5958/0974-4576.2022.00152.9

Ratnasingham, S. & P.D.N. Hebert (2007). BOLD: The Barcode of Life Data System (http://www.barcodinglife.org). *Molecular Ecology Notes* 7(3): 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x

Rubinoff, D., S. Cameron & K. Will (2006). A Genomic Perspective on the Shortcomings of Mitochondrial DNA for "Barcoding" Identification. *Journal of Heredity* 97(6): 581–594. https://doi.org/10.1093/jhered/esl036

Saitou, N. & M. Nei (1987). The neighbor-joining method: A new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution* 4(4): 406–425. https://doi.org/10.1093/oxfordjournals.molbev.a040454

Shashank, P.R., N.L. Naveena, N.N. Rajgopal, T.A. Elliott, K. Sreedevi, S. Sunil & N.M. Meshram (2022). DNA barcoding of insects from India: Current status and future perspectives. *Molecular Biology Report* 49(11): 10617–10626. https://doi.org/10.1007/s11033-022-07628-2

Silva-Brandão, K.L., M.L. Lyra & A.V.L. Freitas (2009). Barcoding lepidoptera: Current situation and perspectives on the usefulness of a contentious technique. *Neotropical Entomology* 38(4): 441–451. https://doi.org/10.1590/S1519-566X2009000400001

Sontakke, T., A. Biradar & D. Nalage (2023). The role of genetics in determining resistance to coccidiosis in goats a review of current research and future directions. *Molecular Biology Reports* 50(7): 6171–6175. https://doi.org/10.1007/s11033-023-08520-3

Suryawanshi, R., A. Tathe, M. Salunke, D. Nalage & A. Kalyankar (2020). DNA barcoding analysis of brackish water shrimps from chilika lagoon. *Journal of Emerging Technologies and Innovative Research* 7(10): 838–846. https://doi.org/10.5281/ZENODO.11470556

Tiknaik, A., A. Kalyankar, M. Shingare, R. Suryawanshi, B. Prakash, T. A. Sontakke, D. Nalage, R. Sanil & G. Khedkar (2019). Refutation of media reports on introduction of the red bellied piranha and potential impacts on aquatic biodiversity in India. *Mitochondrial DNA Part A* 30(4): 643–650. https://doi.org/10.1080/24701394.2019.1611798

Van de Vossenberg, B. T. L. H. & M. J. Van der Straten (2014). Development and validation of real-time PCR tests for the identification of four Spodoptera species: *Spodoptera eridania*, *Spodoptera frugiperda*, *Spodoptera littoralis*, and *Spodoptera litura* (Lepidoptera: Noctuidae). *Journal of Economic Entomology* 107(4): 1643–1654. https://doi.org/10.1603/ec14132

Yang, Z. & B. Rannala (2010). Bayesian species delimitation using multilocus sequence data. *Proceedings of the National Academy of Sciences* 107(20): 9264–9269. https://doi.org/10.1073/pnas.0913022107

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25536–25544

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

https://doi.org/10.11609/jott.8686.16.7.25536-25544

#8686 | Received 11 August 2023 | Final received 25 June 2024 | Finally accepted 03 July 2024

OPEN ACCESS

ARTICLE

Taxonomy and distribution of some orthopteran species (Orthoptera: Gryllidae, Trigonidiidae, Acrididae) from northwestern Morocco

Hanae El Harche [1], Samiha Kaioua [2] & Dalale Mansouri [3]

[1,2,3] University Ibn Tofail, Faculty of Sciences, Department of Biology, Laboratory of Plant, Animal and Agro-Industry Productions, Kenitra, Morocco.

[1] hanae.elharche@yahoo.com (corresponding author), [2] samiha.kaioua@uit.ac.ma, [3] dalale.mansouri@uit.ac.ma

Abstract: Orthopterans have emerged as a crucial group of invertebrates for environmental monitoring and assessment. According to available literature the study of Moroccan orthopteran species remains limited in comparison to other countries. In recent years, the field of orthopteran classification has witnessed significant progress thanks to groundbreaking research in taxonomy and phylogeny that have shed new light on relationships and evolutionary history. In Morocco, there are many types of Orthoptera, including grasshoppers, crickets, and locusts, and different regions of the country have not been equally well sampled and studied. Notably the northwestern, particularly the Sidi Kacem region, are little studied. Here we present a taxonomic update of the most abundant orthopterans in Morocco based on field visits between spring and summer 2019. Five species were identified: *Dociostaurus maroccanus, Aiolopus strepens, Gryllus bimaculatus, Gryllus campestris*, and *Nemobius sylvestris*. We aim to use this publication as a baseline for future work on Orthopterans from northwestern Morocco.

Keywords: Caelifera, Ensifera, grasshopper, invertebrates, taxonomic update.

Editor: Wael El Sayed, Hokkaido University, Sapporo, Japan.

Date of publication: 26 July 2024 (online & print)

Citation: El Harche, H. , S. Kaioua & D. Mansouri (2024). Taxonomy and distribution of some orthopteran species (Orthoptera: Gryllidae, Trigonidiidae, Acrididae) from northwestern Morocco. *Journal of Threatened Taxa* 16(7): 25536–25544. https://doi.org/10.11609/jott.8686.16.7.25536-25544

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Hanae El Harche, a PhD graduate from Ibn Tofail University in Morocco, specializes in animal ecology, entomology, systematics (taxonomy) and faunistics. Her research projects have focused on exploring spatial and seasonal variations, as well as the impact of human activities on arthropod communities. In particular, she has contributed to the establishment of a comprehensive checklist of terrestrial arthropods present in agroecosystems in northwest Morocco. Samiha Kaioua, a PhD graduate from Ibn Tofail University, has a keen interest in the bioecology and systematic structure of molluscs and crustaceans. Her research focuses on the complex relationships and classifications of these marine organisms. Dalale Mansouri, a PhD graduate from Ibn Tofail University, studies biology, environmental chemistry, biochemistry and environmental pollution.

Author contributions: El Harche Hanae—conducted surveys, collected specimens, identified the species, and writing - review and editing the manuscript. Mansouri Dalale & Kaioua Samiha—assisted with data collection.

INTRODUCTION

The order Orthoptera, comprising a vast array of species, holds a prominent position among insect orders (Bidau 2014). With approximately 28,000 species worldwide, it ranks as the sixth largest order, trailing only Hemiptera (Cigliano et al. 2022). These insects, commonly known as grasshoppers, locusts and crickets, are present in many terrestrial environments and exhibit remarkable diversity (Yadav & Kumar 2017). The composition of grasshopper communities serves as a valuable indicator, as their structure is highly responsive to environmental changes (O'Neill et al. 2003). Moreover, these insects play a crucial role in the functioning of ecosystems and can potentially serve as useful bioindicators for land disturbance (Saha et al. 2011). This order can be classified into two distinct suborders: the Ensifera, which includes crickets, katydids, and their relatives, characterized by their long antennae (longer than their bodies and consisting of more than 30 segments); and the Caelifera, which encompasses grasshoppers and their allies, distinguished by their short antennae (shorter than their bodies and comprising less than 28 segments) (Song et al. 2018).

Grasshoppers play a crucial role as ecological and biological indicators, providing valuable insights into ecosystem qualities and the effectiveness of ecological networks (Zhang et al. 2019). However, they have also garnered significant attention due to the extensive damage they inflict on crops and various forms of green vegetation (Dakhel et al. 2020). Despite the rich biodiversity of grasshoppers, Morocco has received little attention in terms of research, with only a few localities being studied. The first significant contribution to our understanding of Moroccan grasshoppers was made by Chopard (1936, 1943, 1949). Subsequently, several taxonomic studies were conducted such as: Badih & Pascual (1998), Latchininsky (1998), and Faucheux et al. (2013). More recently, some faunistic surveys have been carried out, including those by Defaut & Francois (2018, 2020, 2021), Mabrouki et al. (2021), Defaut (2022), and Aziz et al. (2023). Despite these efforts, our knowledge of the grasshopper fauna in many regions of Morocco remains insufficient, and further research is needed. There is a lack of published work or reports on the grasshopper fauna in the northwestern region of Morocco. This region remains poorly studied, presenting an opportunity for future research and exploration. The aim of this study was to improve our comprehension to the grasshopper fauna in Morocco, with a specific focus on the taxonomy, ecology, and distribution of the most prevalent orthopteran species found in a poorly studied northwestern region. By conducting this research, we aimed to contribute valuable insights to the existing knowledge in this field.

MATERIAL AND METHODS

Study area

The study was conducted in three stations in the region of Sidi Kacem (34.13.00 N, 5.42.00 E) located in the northwest of Morocco (Figure 1). The climate of the region is classified as semi-arid, the temperature in autumn goes down to 6 °C while in summer it can exceed 40 °C, with a probability of daily precipitation above 13%.

Station 1: 34.2295^{0}N; -5.7013^{0}E. It is a field of *Vicia faba* L. beans (Fabaceae).

Station 2: 34.2402^{0}N; -5.7094^{0}E. This is a field of cereal crops: soft wheat: *Triticum aestivum* L. (Poaceae).

Station 3: 34.2302^{0}N; -5.7055^{0}N. This is an uncultivated area. The plant species dominate the area are *Nicotiana glauca* Graham tree tobacco (Solanaceae), *Ferula communis* L. fennel (Apiaceae), *Cynara humilis* L thistle (Asteraceae), and *Ammi visnaga* L. toothpick weed (Apiaceae).

Sampling

The orthopteran specimens collected, studied, and documented during faunistic surveys between April and August 2019. The insects were captured by sweeping vegetation using an entomological net, to collect orthopterans from plants and by handpicking, seeking under stones and different substrates. After the collection, insects were transferred into specimen bottles containing 70% alcohol. Specimens were identified using a relevant, published key, and by referring to the Orthoptera collection at the Scientific Institute of Rabat (Morocco) and Data available in the Global Biodiversity Information Facility (GBIF) of Morocco. The nomenclature has been updated using the websites http://orthoptera.speciesfile.org, https://www.gbif.org and MNHN Paris website http://acrinwafrica.mnhn.fr.

Abbreviations used in the examined material are the following: CSIR—Collection at the Scientific Institute of Rabat (Morocco). GBIF—https://www.gbif.org /country/ MA.

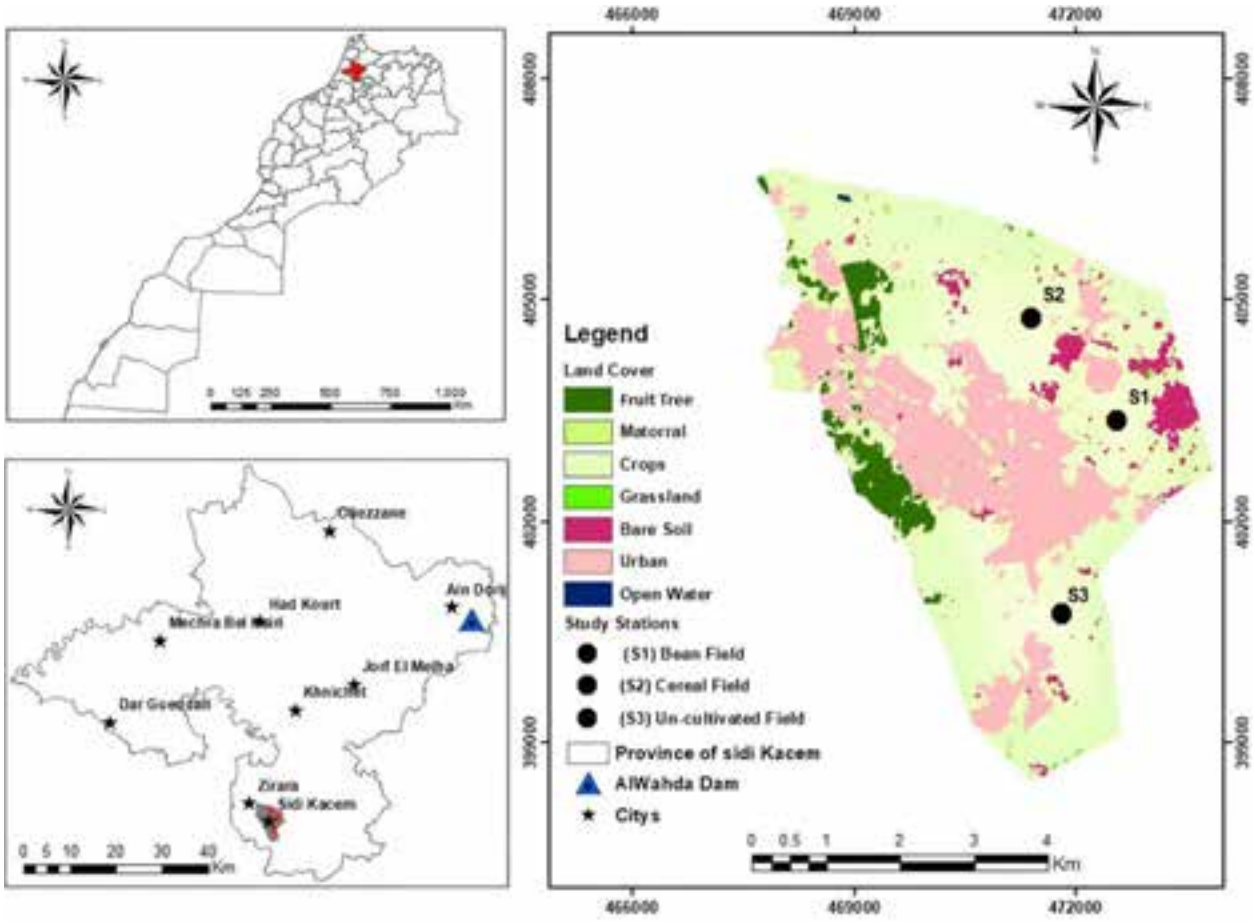


Figure 1. Map of Morocco showing the location of sampling stations.

RESULTS

Systematic Account

Suborder: Ensifera Chopard, 1922

Family: Gryllidae Laicharting, 1781

Subfamily: Gryllinae Laicharting, 1781

Tribe: Gryllini Laicharting, 1781

Genus: *Gryllus* Linnaeus, 1758

***Gryllus* (*Gryllus*) *bimaculatus* De Geer, 1773**

Material examined: MOROCCO: Sidi Kacem (Station 1), 34.2295^{0}N; -5.7013^{0}E, 191 m; 15.v.2019, H. El Harche leg, 1 adult (♂), GBIF. Sidi Kacem (Station 3), 34.2302^{0}N; -5.7055^{0}N, 192 m, 20.vi.2019, H. El Harche leg, 2 adults (♂), CSIR.

Diagnosis: 17–23 mm. Black almost all over the body, males have a yellowish area between the pronotum and the elytra and light legs. This species can be differentiated from other cricket species by the two yellow/white spots on the dorsum of its thorax. Females have a tubular organ at the rear, the ovipositor , which is used to lay eggs in the ground.

Nutrition: Foliage, seeds, roots, and small insects

Habitat: Inhabits pastures, shrubs, dunes, grasslands and ruderal terrain (Bent et al. 2018).

Life cycle: Adults appear from June, July to autumn (Gawałek et al. 2014). This species, like other crickets, has an incomplete metamorphosis (hemimetabolous) with an egg, nymph, and adult stage (Donoughe & Extavour 2016; Watanabe et al. 2017). Females lay their eggs in humid soil or sand and hatchlings emerge from the eggs in about two weeks (Donoughe & Extavour 2016).

General distribution: A Palearctic species; occurs predominantly in the Mediterranean area (Ferreira & Ferguson 2010; Panagiotopoulou et al. 2016) northern Africa, Madagascar, the Indo-Malayan area, Ethiopia, and Central Asia (Gorochov & Llorente 2001).

Distribution in Morocco: Recorded at Oued Cherrat, Korifla, Tafrata, Amizmiz (Chopard 1936), in the cork oak forest, Mamora (El Alami Idrissi 2013), and the Oriental region (Mabrouki et al. 2021).

***Gryllus* (*Gryllus*) *campestris* (Linnaeus, 1758)**

Material examined: MOROCCO: Sidi Kacem (Station 1), 34.12.35N, 5.42.31E , 191 m; 10.vi.2019, H. El Harche leg, 1 adult (♂), CSIR. Sidi Kacem (Station 3), 34.13.50N, 5.40.12E , 192 m, 18.vii.2019, H. El Harche leg, 1 adult (♂), CSIR.

Diagnosis: Male: range from 19–23 mm. Female: from 17–22 mm. Body: shiny black to rarely brown of compact cylindrical shape and with strong legs. Head: black, large, wider than the pronotum. Tegmina: brown with yellow spots at base, with rounded end not exceeding the abdomen. Wings not exceeding elytra: Inner side of hind femur red

Nutrition: Mostly plants (herbs, grasses), but also occasionally (dead) insects.

Habitat: inhabits nutrient-poor grasslands of all kinds, rather dry, extensive hay meadows, large embankments, heathland, and extensive, sunny pastures (Witzenberger & Hochkirch 2008).

Life cycle: The life cycle includes eggs, several instars of nymphs and adults. Nymphs can be found together with adults (Vrenozi & Uchman 2020). During growth, the nymph's males dig out the burrow and hibernate until late April and early May–July (Witzenberger & Hochkirch 2008; Gawałek et al. 2014). Mature females lay hundreds of eggs into the soil around May and June (Rodriguez-Munoz et al. 2010). Only eggs laid fairly early in the season (late May–early June) are robust enough to hibernate successfully .

General distribution: A Palearctic species, the distribution of *G. campestris* includes all of Europe, northern Africa (Morocco, Algeria & Tunisia), and western Asia (Gorochov & Llorente 2001; Hochkirch & Adorf 2007; Panagiotopoulou et al. 2016).

Distribution in Morocco: Recorded in the cork oak forest, Mamora (El Alami Idrissi 2013).

Family: Trigonidiidae Saussure, 1874
Subfamily: Nemobiinae Saussure, 1877
Tribe: Nemobiini Saussure, 1877
Genus: *Nemobius* Audinet-Serville, 1838

***Nemobius* (*Sylvestris*) *sylvestris* (Bosc, 1792)**

Material examined: MOROCCO: Sidi Kacem (Station 3), 34.2402^{0}N; -5.7094^{0}E, 192 m, 28.viii.2019, H. El Harche leg, 1 adult (♂). GBIF.

Diagnosis 7–10 mm. Both adults and nymphs of *N. sylvestris* may be recognized by their unique color pattern golden brown to almost black body. **Head:** black with pale Y-shaped marking attached to the body with very short wings. **Pronotum:** very pale with dark speckles. Male: Absence of glandular hind tibial spines. **Female:** ovipositor shape and tooth dentation, straight, about as long as the hind femur, and without teeth. Straight ovipositors**.**

Nutrition: Omnivorous, feeding on a wide range of organic matter, including carrion, leaf litter, decaying plant parts, fruits & also fresh plants, and dead or living insects (Martín-Vega et al. 2013).

Habitat: It can be found at ground level in meadows, in leaf litter, shrubs, and woodland borders in which it looks for food (Brouwers & Newton 2008; Brouwers et al. 2011). It inhabits also boulders in grasslands, where they are hidden in the pore systems of the stones.

Life cycle: *Nemobius sylvestris* passes through two to three winters in its life cycle. The first winter is spent as eggs, and the second as nymphs of a medium size. These mature by the middle of the summer, and some of these adults may endure a third winter (Vahed 2020). Adults appear from July–October (Brouwers et al. 2011).

General distribution: A Palearctic species, found-in the Iberian Peninsula, covers the southwestern Europe, the south of England, France, the south of Portugal, and Poland (Gorochov & Llorente 2001). Also recorded in North America (Woo 2022).

Distribution in Morocco: Recorded in Tangier (Defaut et al. 2016).

Suborder: Caelifera Ander, 1939
Family: Acrididae MacLeay, 1821
Subfamily: Gomphocerinae Fieber, 1853
Tribe: Dociostaurini Mishchenko, 1974
Genus: *Dociostaurus* Fieber, 1853

***Dociostaurus* (*Dociostaurus*) *maroccanus* (Thunberg, 1815)**

Material examined: MOROCCO: Sidi Kacem (Station 1), 34.2295^{0}N; -5.7013^{0}E, 191 m; 16.viii.2019, H. El Harche leg, 2 adults (♂), GBIF. Sidi Kacem (Station 2), 34.2402^{0}N; -5.7094^{0}E, 190 m, 12.vi.2019, H. El Harche leg, 1 adult (♂), GBIF. Sidi Kacem city (Station 3), 34.2402^{0}N; -5.7094^{0}E, 192 m, 20.v.2019, H. El Harche leg, 1 adult (♂), GBIF.

Diagnosis: Body: 16.5–28.5 mm for males and 20.5–38.0 mm for females. Tegmina: are 17.5–27.0 mm for males and 23.0–36.0 mm for females, nearly transparent that extend far behind the tip of the hind femur can have sporadic, tiny brownish or gray patches. The pronotum: bears a pale cross-shape. Wings: longer than wide. Hind Femurs: femora slender. Hind femur male 13.2–17.4 mm, female 15.5–21.6 mm. Grayish-yellowish in color overall, with dark markings on the body. Depending on

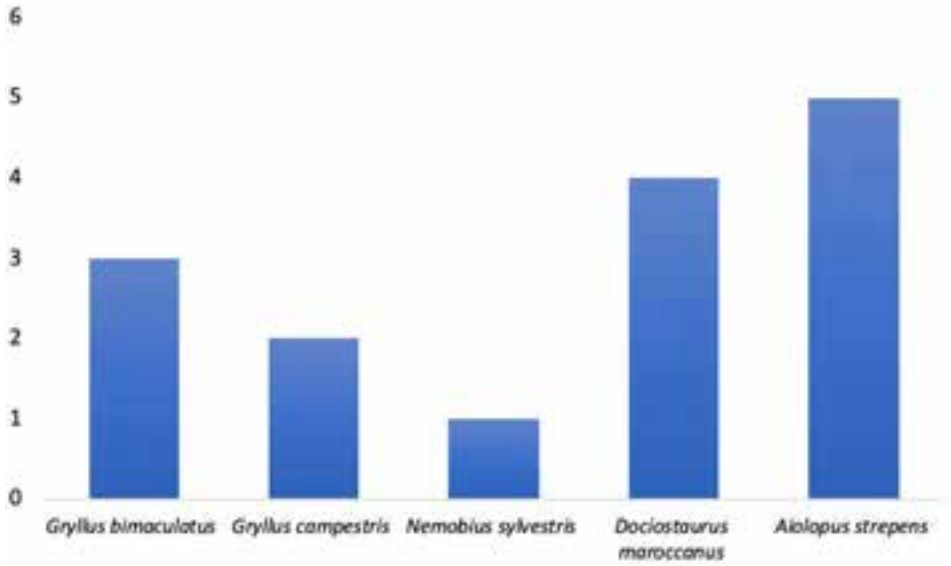


Figure 2. Number of orthoptera individuals caught in the study area.

the phase, the hind femora may or may not have black bands. Tibia: usually red, less often yellow, pinkish, or even whitish, with short striae that don't reach behind the transversal furrow. Pronotum: yellow or pale.

Nutrition: Polyphagous insect, mostly plants (herbs, grasses), but also occasionally insects.

Habitat: *Dociostaurus maroccanus* is a thermophilous and xerophilous species inhabiting open, well-lit areas (Victorovich & Zlatanov 2020). The species is mainly adapted to valleys and foothills with xerophytic vegetation at an altitude of between 400 m and 800 m (Song 2011).

Life cycle: This cricket species undergoes a single annual generation and exhibits an incomplete metamorphosis, known as heterometabolous development. Interestingly, during this process, the nymph closely resembles the adult form, eliminating the presence of a distinct nymphal stage. To ensure successful reproduction, female crickets require firm and exposed ground to lay their eggs. Once laid, these eggs hatch during the subsequent spring and the young crickets migrate towards vegetated areas to find nourishment. It is worth noting that the egg-laying activity primarily occurs in early summer. Each female lays between 18 and 42 eggs. Usually, a single female provides two egg-pods (Quesada-Moraga & Santiago-Álvarez 2001). Nymph development is quite rapid, lasting no more than 25–35 days. The adult stage actively migrates from the hatchling sites to humid depressions where the adults find a sufficient amount of food (Popova & Popov 2009). The breeding season starts in May (Victorovich & Zlatanov 2020).

General distribution: A Palearctic species; in Africa the species occurs in Morocco, Algeria, Tunisia, Libya, and Egypt (Latchininsky & Launois-Luong 1992). It is also present in west and central Europe, i.e., Portugal, Spain, France, Italy, countries of ex- Yugoslavia, Greece, Bulgaria, Moldova and southwestern Ukraine, as well as in the Caucasus, i.e., Armenia, Azerbaijan, and Georgia. The northern limits of its distribution area reached in Hungary and Rumania. The species is also found in countries of the Middle East and Minor Asia, i.e., Turkey, Syria, Lebanon, Jordan, Iraq, and Afghanistan (El Ghadraoui et al. 2003; Guerrero et al. 2017).

Distribution in Morocco: recorded in Al-Azaghar of the Middle Atlas (El Ghadraoui et al. 2008) and the Oriental region (Mabrouki et al. 2021).

Subfamily: Oedipodinae
Tribe: Parapleurini Brunner von Wattenwyl, 1893
Genre: *Aiolopus* Fieber, 1853

***Aiolopus* (*Strepens*) *strepens* (Latreille, 1804)**

Material examined: MOROCCO: Sidi Kacem (Station 2), 34.2402^{0}N; -5.7094^{0}E, 190 m, 26.vi.2019; H. El Harche leg, 2 adults (♂), GBIF. Sidi Kacem city (Station 3), 34.2302^{0}N; -5.7055^{0}N, 192 m, 19.viii.2019, H. El Harche leg, 3 adults (♂), GBIF.

Diagnosis: Body: 19–24 mm for males while females reach 24–31 mm. *Aiolopus strepens* has a wide range of coloration (green, yellow, and brown). Their strong bodies are typically light brown, though occasionally they might be green, have green patches, or have reddish stripes. Females, can also be totally green in

color. Wings: translucent, slightly bluish, marked by a clear dark spot in the apical region. Antennae: 22–24 segmented, shorter than head and pronotum together. Eyes: ellipsoid, almost twice as long as wide. Pronotum: male 3.9–5.0 mm, female 4.5–7.0mm, usually brown, the disc may occasionally have median longitudinal stripes that reach the vertex. Subtectiform, rather flat. Tegmina: male 16.7–23.6 mm, female 19.6–30.9 mm, relatively short and broad, exceeding end of hind femur. Hind femur: male 11.3–14.8 mm, female 13.4–19.2 mm, brown with testaceous spots, blackish at upper surface, reddish on inner surface. Wings: transparent with darkened brownish apex. Tibia: as long as hind femur, with 10 outer and 11 inner spines.

Nutrition: The insects feed mainly on grasses.

Habitat: It inhabits dry meadows, riverbanks, dry to mesophilic grasslands, woodland edges, shrubland with open soil spots, quarries. The species can be found over 1,500 m.

Life cycle: The presence of *Aiolopus strepens* adults for most of the year, with only one generation per year (univoltine) in imaginal hibernation. The imagines (= adults) can be found from August–May of the following year. Some of these animals hibernate and reproduce the following spring. There is therefore only one generation per year, but due to the extended lifespan of some individuals, they may still be alive when the nymphs from the eggs laid the previous year are already hatching (Baur et al. 2006). According to the work of Hamdi (1989) in the mid-northern region of Algeria, Benrima (1990) in the Koléa region, Gueciqueur (1990) in the Lakhdaria region, Fellaouine (1989) in the Sétif region, Zergoun (1991, 1994), and Douadi (1992) in the Ghardaïa region, *Aiolopus strepens* is present as an adult throughout most of the year. The larvae begin to appear in April. These authors note that Aiolopus strepens has only one annual generation and spends the winter in the imaginal state.

Remark: In southern Spain, *A. strepens* exhibits a fascinating life cycle, characterized by two distinct generations per year. The first generation commences in March, when larvae make their initial appearance, followed by the emergence of adults in April. The second generation, on the other hand, commences from July and extends until December, during which a dense population is observed. Between these two periods, the species enters a state of hibernation. Notably, the two generations overlap, resulting in the presence of adult individuals throughout the year (Hernández et al. 1985).

General distribution: A west Palearctic species: widespread throughout the Mediterranean region until Asia Minor, often reported throughout southern Europe and North Africa (Algeria, Morocco & Tunisia) (Defaut 1999).

Distribution in Morocco: Observed in Moroccan Middle Atlas (Sefrou at an altitude altitude of 800 m and Mazdou at an altitude of 1,200 m) (Essakhi et al. 2014).

DISCUSSION

During the course of this study, five distinct species were collected from three sections of the Sidi Kacem region, representing three families: Acrididae, Gryllidae, and Trigonidiidae. These insect families are widely distributed and typically abundant in nature. However, it is worth noting that the level of biodiversity within the Sidi Kacem region is relatively low for these three families. This can be attributed to the prevalence of anthropogenic pressures in the area. The expansion of agricultural areas and the intensification of management practices are significant factors that contribute to the loss of terrestrial biodiversity at both local and global scales (El Harche et al. 2022). Specifically, the application of pesticides, tillage, and the timing of harvest periods have all had a detrimental impact on the fauna's biodiversity (El Harche et al. 2023). The current state of low biodiversity within these families highlights the potential ecological consequences of human activities. As agricultural areas continue to expand and management practices become more intensive, the delicate balance of the ecosystem is disrupted, leading to a decline in biodiversity (El Harche et al. 2023). Ecosystem alterations have a profound impact on the behavior of organisms, particularly poikilotherms like grasshoppers, which heavily rely on plant matter for sustenance (Bronwyn 2013). Latchininsky et al. (2011) have demonstrated that certain grasshopper species face significant threats from anthropogenic pressures, such as overgrazing and ploughing. The limited number of orthopteran species discovered in our study sites suggests that these species have developed adaptive strategies to withstand human disturbances (Havyarimana et al. 2013).

Orthopterans are widely recognized for their herbivorous habit and are generally regarded as a dominant group of insects in terrestrial habitats. They have a voracious appetite for various types of plants, often leading to significant economic losses. The extent of crop damage is contingent upon the populations and movements of orthopterans within the fields. This poses a significant threat to food crops in Africa.

In our current investigation, the orthopterans were

found to be omnivorous or phytophagous, exclusively consuming plants and seeds. This finding underscores the importance of understanding their feeding habits and preferences. The impact of orthopteran pests on agricultural productivity cannot be overstated. Their relentless feeding habits and ability to decimate crops pose a serious challenge to farmers' livelihoods. Consequently, it is crucial to develop effective strategies for managing and mitigating the damage caused by these insects.

Gryllus sp. and *Dociostaurus maroccanus* pose a significant threat to agricultural crops. These voracious locusts indiscriminately target a wide range of crops, including cereals, vegetables, forage crops, oilseed crops, fruit trees, date palms, and even conifers (Latchininsky 1998). The destructive impact of *D. maroccanus* on crops has been documented in more than 25 countries, often necessitating military intervention for effective control (Latchininsky 1998). This species feeds on over 150 plant species from 33 different families, with 50 of them being important agricultural crops (Latchininsky & Launois Luong 1992). However, despite its potential for devastation, the detailed study of this species has been limited due to its relatively low occurrence rate.

This investigation, conducted in the Sidi Kacem region, has enabled us to compile an initial inventory of the local orthopteran biodiversity of most frequent species that exists in this area. It is important to note that this list can be expanded and updated as new species could be discovered in the future. The Orthoptera, being highly sensitive to changes in vegetation structure, seasonal temperature, and humidity, play a crucial role in ecological studies. They serve as effective indicators of environmental changes (El Harche et al. 2023)

This comprehensive list serves as a valuable reference for future studies aimed at examining the development of biodiversity and determining the real impact of landscape change & degradation on entomofauna. The article focuses mainly on the description of the specimens collected and their distribution, providing an in-depth analysis of the subject. The article presents detailed observations and measurements of each specimen, highlighting its morphology, nutrition, habitat, and life cycle. In addition, this study examines the distribution patterns of these specimens in various locations in Morocco and abroad. This meticulous examination provides valuable information on the range and abundance of different species in a given area, revealing complex relationships within ecosystems. Overall, this article is a crucial resource for scientists in this field, documenting important results on specimen collection and distribution patterns, while opening the door to further research opportunities.

REFERENCES

Aziz, Z., R. Nabil, E. Said, E. Nabil, N. Houria & L. Abderrahim (2023). Review of the Taxonomic Status of the Most Frequent Orthoptera Species (Caelifera: Acrididae) in the Middle Atlas of Morocco. *Indian Journal of Entomology* 1–13. https://doi.org/10.55446/IJE.2023.1133

Badih, A. & F. Pascual (1998). Données préliminaires sur les Célifères du nord du Maroc (Orthoptera, Caelifera). *Nouvelle Revue d'Entomologie* 131–150.

Baur, B., H. Baur, C. Roesti & D. Roesti (2006). Die Heuschrecken der Schweiz. Haupt Verlag, Bern, Stuttgart, Wien: 1–352.

Bent, A.M., T.C. Ings & S.L. Mowles (2018). Anthropogenic noise disrupts mate searching in *Gryllus bimaculatus*. *Behavioral Ecology* 29: 1271–1277. https://doi.org/10.1093/beheco/ary126

Benrima, A. (1990). La biologie de la faune Orthoptérologique de la région de Kolea. Mémoire Ingénieur Agronome, Univ. Sci. Techn. Blida, 77p.

Bidau, C.J. (2014). Patterns in Orthoptera biodiversity. I. Adaptations in ecological and evolutionary contexts. *Journal of Insect Biodiversity* 2(20): 1–39. https://doi.org/10.12976/jib/2014.2.20

Brouwers, N.C. & A.C. Newton (2008). Habitat requirements for the conservation of wood cricket (*Nemobius sylvestris*) (Orthoptera: Gryllidae) on the Isle of Wight, UK. *Journal of Insect Conservation* 13: 529–541. https://doi.org/10.1007/s10841-008-9199-5

Brouwers, N.C., A.C. Newton & S. Bailey (2011). The dispersal ability of wood cricket (*Nemobius sylvestris*) (Orthoptera: Gryllidae) in a wooded landscape. *European Journal of Entomology* 108(1): 117–125. https://doi.org/10.14411/eje.2011.015

Bronwyn, A.E. (2013). Culturally and Economically Significant Insects in the Blouberg Region, Limpopo Province, South Africa. Dissertation, University of Limpopo, South Africa. Thesis (PhD. (Zoology)), University of Limpopo.

Chopard, L. (1936). Contribution à l'étude de la faune des Orthoptères du Maroc. *Bulletin de la Société des Sciences Naturelles du Maroc* 16: 151–179.

Chopard, L. (1943). Contribution to the study of orthoptera, North Africa (4th grade). *France Review Entomology* 144–146.

Chopard, L. (1949). Note sur les Orthopteroïdes du Sahara marocain. Bulletin de la Société des Sciences naturelles du Maroc XXV-XXVII : 191-199.

Cigliano, M.M., H. Braun, D.C. Eades & D. Otte (2022). Orthoptera Species File. Version 5.0/5.0.

Dakhel, W.H., S.T. Jaronski & S. Schell (2020). Control of pest grasshoppers in North America. *Insects* 11: 566. https://doi.org/10.3390/insects11090566

Defaut, B. (1999). Synopsis des Orthoptères de France. Matériaux Entomocénotiques, n° hors-série, deuxième édition, révisée et augmentée, 87 pp.

Defaut, B. & A. François (2019). Premières données sur les synusies Orthoptériques de l'Oriental marocain. *Matériaux Orthoptériques et Entomocénotiques* 26: 151–201.

Defaut, B. & A. Francois (2018). Evaluation densitaires des Orthoptères en moyenne-Moulouya (Maroc oriental) (Ensifera, Caelifera, Mantodea). *Matériaux Orthoptériques et entomocénotiques* 23: 149–168.

Defaut, B. & A. Francois (2020). Taxons orthoptériques nouveaux ou peu connus du Maroc oriental. *Matériaux Orthoptériques et entomocénotiques* 27: 21–41

Defaut, B. & H. Benmammar-Hasnaoui (2016). Pré-inventaire des Orthoptéroïdes des monts de Tlemcen et des environs immédiats (Algérie nord-occidentale) (Orthoptera, Mantodea, Phasmida. *Matériaux Orthoptériques et Entomocénotiques* 21: 5–33

Defaut, B. & A. Francois (2021). Premières données sur les synusies orthoptériques de l'Oriental marocain. *Matériaux Orthoptériques et entomocénotiques* 26: 151–201.

Defaut, B. (2022). Récolte de topotypes d'Orthoptères au Maroc: détails de ce projet avorté. *Matériaux orthoptériques et entomocénotiques* 27: 155–161

Donoughe, S. & C.G. Extavour (2016). Embryonic development of the cricket *Gryllus bimaculatus. Developmental Biology* 411: 140–156. https://doi.org/10.1016/j.ydbio.2015.04.009

Douadi, B. (1992). Contribution à l'étude bioécologique des peuplements Orthoptérologique dans la région de Guerrara (Ghardaia) - Développement ovarien chez Acrotylus patruelis (Herrich- Schaeffer, 1838). Mémoire d'ingénieur agronome, INA, El Harrach, Alger, 75 pp.

El Alami-Idrissi, N. (2013). La faune de la litière de la suberaie de la Mamora. *Revue Marocaine des Sciences Agronomiques et Vétérinaires* 2: 50–57.

El Ghadraoui, L., D. Petit & J. El Yamani (2003). Le site Al Azaghar (Moyen Atlas, Maroc) : un foyer grégarigène du criquet marocain *Dociostaurus maroccanus* (Thunb., 1815). *Bulletin de l'Institut Scientifique Rabat*, 25: 83–88.

El Ghadraoui, L., D. Petit, R. Mokhles, A. Azouzi & A. Lazraq (2008). Situation du criquet marocain "*Dociostaurus maroccanus* Thunb, 1815" par rapport aux différentes espèces acridiennes : morphométrie et capacités de déplacements. *Revue Internationale des Sciences et Technologie* 4(1): 125–137.

El Harche, H., S. El Hassouni, M. Fadli & J. Dahmani (2023). Spatial, seasonal variation and impacts of anthropogenic factors on insect assemblages (Arthropoda: Insecta) in Northwest Morocco. *Biodiversitas* 24(10): 5368–5375. https://doi.org/10.13057/biodiv/d241019

El Harche, H., G. Chavanon, J. Dahmani, I. Bedoui, K. Kaioua & M. Fadli (2022). Biological and ecological traits of terrestrial arthropods in North-West Morocco. *Journal of Ecological Engineering* 23(1): 252–263. https://doi.org/10.12911/22998993/143907

Essakhi, D., M. Benjelloun, N. Errabhi, H. El Harchli & L. El Ghadraoui (2014). *Locusts Grasshoppers* species richness of the Moroccan Middle Atlas. *Bulletin de l'Institut Scientifique, Rabat, Section Sciences de la Vie* 36: 41–48.

Faucheux, M.J., M.B. Agnas & Y. El Wabi (2013). Orthoptères Caelifères du Maroc atlantique : Prospections 2001–2012, étude de quelques espèces. I-Pyrgomorphidae, Pamphagidae, Cyrtacanthacridinae, Acridinae. *Bulletin de la Société de Sciences Naturelles Ouest de la France, nouvelle série* 35(1) : 15–40.

Fellaouine, R. (1989). Bioécologie des Orthoptères de la région de Sétif. Thèse magister, INA, El Harrach, Algérie, 81 pp.

Gawałek, M., K. Dudek, G.A. Ekner, Z. Kwieciński & J. Sliwowska (2014). Ecology of the field cricket (Gryllidae: Orthoptera) in farmland: the importance of livestock grazing. *North-Western Journal of Zoology* 10: 325–332.

Gueciqueur, L. (1990). Bioécologie de la faune Orthoptérologique de trois stations à Lakhdaria. Mémoire Ingénieur Agronome. INA, El-Harrach, Alger, 71 pp.

Gorochov, A.V. & V. Llorente (2001). Estudio taxonómico preliminar de los Grylloidea de España (Insecta, Orthoptera). *Graellsia* 57: 95–139.

Guerrero, A., M. Coca-Abia & C. Quero (2017). The Moroccan Locust *Dociostaurus Maroccanus* (Thunberg): Biology, Economic Impact and Control, pp 14–57. In: Jenkins, O.P. (ed.). Advances in Animal Science and Zoology. Nova Science Publishers Inc., New York.

Hamdi, H. (1989). Contribution à l'étude de la bioécologie des peuplements Orthoptéroloqiques de la région medio septentrionale de l'Algérie et de la région de Gabès (Tunisie). Mémoire Ingénieur Agronome, INA, El Harrach, 127 pp.

Havyarimana, F., M.J. Bigendako, T. Masharabun, F. Bangirinama, J. Lejoly, Y.S.S. Barima, C. De Cannière. J. Bogaert (2013). Diversité et distribution d'abondances des plantes d'un écosystème protégé dans un paysage anthropisé: cas de la Réserve Naturelle Forestière de Bururi, Burundi. *Tropicultura* 31: 28–35.

Hernández y, F. & J.J. Presa (1985). Los Ortópteros de la Huerta de Murcia (S.E. Espana): Tettigonoidea, Tetrigoidea y Acridoidea (Orth.). *The Boletín de la Asociación española de Entomología*. 9 : 299–316.

Hochkirch, A. & F. Adorf (2007). Effects of prescribed burning and wildfires on Orthoptera in Central European peat bogs. *Environmental Conservation* 34(3): 225–235.

Latchininsky, A.V. & M.H. Launois-Luong (1992). Le Criquet Marocain, *Dociostaurus Maroccanus* (Thunberg, 1815), dans la Partie Orientale de son Aire Distribution. Etude Monographique Relative à l'ex-URSS et aux Pays Proches; Cirad-Gerdat-Prifas: Montpellier, France; Saint Petersburg, Russia, p. xix + 270.

Latchininsky A., G.A. Sword, M.G. Sergeev, M.M. Cigliano & M. Lecoq (2011). Locusts and grasshoppers: Behavior, ecology and biogeography. *Psyche* 2011: 578327. https://doi.org/10.1155/2011/578327

Latchininsky, A.V. (1998). Moroccan locust *Dociostaurus maroccanus* (Thunberg, 1815): a faunistic rarity or an important economic pest? *Journal of Insect Conservation* 2: 167–178

Mabrouki, Y., A.F. Taybi & D.P. Petit (2021). New data on the distribution of Orthoptera (Caelifera, Ensifera) from eastern Morocco with notes on chorology. *Annales de la Société entomologique de France* (N.S.) 57: 523–538. https://doi.org/10.1080/00379271.2021.1984307

Martín-Vega, D., A. Aguirre-Segura, P. Barranco, A. Baz & B. Cifrián (2013). Necrophagy in crickets, katydids and grasshoppers? Orthoptera collected in carrion-baitedtraps in central Spain. Annales de la Société entomologique de France (N.S.) 49: 91–99. https://doi.org/10.1080/00379271.2013.769320

O'Neill, K.M. Olson, B.E. Rolston, M.G. Wallander, R. Larson & C.E. Seibert (2003). Effects of livestock grazing on rangeland grasshopper (Orthoptera: Acrididae) abundance. *Agriculture, Ecosystems & Environment* 97(1–3): 5164.

Panagiotopoulou, H., M. Baca, K. Baca, P. Sienkiewicz, P. Slipinski & M. Zmihorski (2016). Genetic identification of a non-native species introgression into wild population of the field cricket *Gryllus campestris* (Orthoptera: Gryllidae) in Central Europe. *European Journal of Entomology* 113: 446–455. https://doi.org/10.14411/eje.2016.058

Popova, E.N. & I.O. Popov (2009). Harmful acridids of Southern Russia and climatic factors, regulating their breeding and distribution. *Problems of Ecological Monitoring and Modeling of Ecosystems* 22: 124–146.

Quesada-Moraga, E. & C. Santiago-Álvarez (2001). Assessment of sexual maturation in the Moroccan locust *Dociostaurus maroccanus* (Thunberg). *Journal of Orthoptera Research* 10(1): 1–8.

Rodriguez-Munoz, R., A. Bretman, J. Slate, C.A. Walling & T. Tregenza (2010). Natural and Sexual Selection in a Wild Insect Population. *Science* 328: 1269–1272. https://doi.org/10.1126/science.1188102

Song, H. (2011). Density-Dependent Phase Polyphenism in Nonmodel Locusts: A Minireview. *Psyche: A Journal of Entomology* 2011: 1–16. https://doi.org/10.1155/2011/741769

Song, H. (2018). Biodiversity of Orthoptera. pp. 245–279. In: R.G. Foottit and P. H. Adler (eds), Insect Biodiversity. Science and Society. Volume 2. Hoboken: Wiley. https://doi.org/10.1002/9781118945582.ch10

Vahed, K. (2020). The life cycle of the Atlantic Beach-Cricket, *Pseudomogoplistes vicentae* Gorochov, 1996. *Journal of Insect Conservation* 24: 473–485. https://doi.org/10.1007/s10841-019-00187-1

Victorovich, D.M. & B.V. Zlatanov (2020). An Ecological Niche Model for *Dociostaurus maroccanus,* Thunberg, 1815 (Orthoptera, Acrididae): The Nesting Environment and Survival of Egg-Pods. *Biosis: Biological Systems* 1(1): 08–24. https://doi.org/10.37819/biosis.001.01.0048

Vrenozi, B. & A. Uchman (2020). Burrows of the common field-cricket *Gryllus campestris* Linnaeus, 1758 (Orthoptera: Gryllidae) from Dajti Mountain, Albania. *Ichnos* 28: 46–55. https://doi.org/10.1080/10420940.2020.1843455

Watanabe, T., S. Noji & T. Mito (2017). Genome Editing in the Cricket, *Gryllus bimaculatus*. *Methods in molecular biology* 1630: 219–233. https://doi.org/10.1007/978-1-4939-7128-2_18

Witzenberger, K.A. & A. Hochkirch (2008). Genetic consequences of

animal translocations: A case study using the field cricket, *Gryllus campestris* L. *Biological Conservation* 141: 3059–3068. https://doi.org/10.1016/j.biocon.2008.09.017

Woo, B. (2022). *Nemobius sylvestris* (Orthoptera, Trigonidiidae, Nemobiinae) in North America. *Journal of Orthoptera Research* 31(1): 47–53. https://doi.org/10.3897/jor.31.72082

Yadav, R.S. & D.Kumar (2017). Biodiversity of pyrgomorphid grasshoppers from eastern uttar Pradesh. *Journal of Experimental Zoology of India* 20(1): 1467–1470.

Zergoun, Y. (1991). Contribution à l'étude bioécologique des peuplements Orthoptérologique dans la région de Ghardaïa. Mémoire d'ingénieur agronome Institut National d'Agronomique d'El-Harrach, Algeria, 73 pp.

Zergoun, Y. (1994). Bioécologie des Orthoptères dans la région de Ghardaïa et régime alimentaire d'Acrotylus patruelis (Herrich – Schaeffer, 1838) [Orthoptera Acrididae]. Thèse de Magister, Institut National d'Agronomie d'El-Harrach, Algeria, 110 pp.

Zhang, L., M. Lecoq, A. Latchininsky & D. Hunter (2019). Locust and grasshopper management. *Annual Review of Entomology* 64: 15–34. https://doi.org/10.1146/annurev-ento-011118-112500

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25545–25570

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

https://doi.org/10.11609/jott.8824.16.7.25545-25570

#8824 | Received 14 November 2023 | Final received 01 June 2024 | Finally accepted 05 July 2024

OPEN ACCESS

ARTICLE

Impact of root harvest on *Decalepis hamiltonii* Wight & Arn. population across habitats in Savandurga Reserve Forest, Karnataka, India

M. Sathya Sangeetha [1], Kaliamoorthy Ravikumar [2] & H.C. Chetan [3]

[1,2,3] Centre for Conservation of Natural Resources, The University of Trans-disciplinary Health Sciences and Technology (TDU), Foundation for Revitalisation of Local Health Traditions (FRLHT), 74/2, Jarakabande Kaval, Attur Post, Via Yelahanka, Bengaluru, Karanataka 560064, India.

[1] sathya.sangeetha@tdu.edu.in (corresponding author), [2] k.ravikumar@tdu.edu.in, [3] chetan.hc@tdu.edu.in

Abstract: *Decalepis hamiltonii* Wight & Arn., is a woody climber, endangered due to the destructive harvest of fragrant roots and substituted for *Hemidesmus indicus* (L.) R.Br. (Nannari). We assessed the density, size class, distribution across habitat types, disturbance types, and environmental variables that influence the *D. hamiltonii* population in the Savandurga Reserve Forest (SRF). Method: The entire forest was divided into 1 km² grids, with 10 plots of 5 x 5 m established in each of the 24 grids, totaling 240 plots. Disturbances were categorized as low, medium, and high, while plots were classified into dense, mixed, and rocky outcrop habitats. Results: *D. hamiltonii* density ranged from 0.1 ± 0.32 to 5.2 ± 2.66 per 25 m² across the grids with an overall mean density of 675 ± 455 stems per ha. The size class distribution showed a typical inverted "J" curve, with fewer saplings (3.01–6.0 cm class), indicating potential future population instability. Stem density was lower in dense vegetation and higher in mixed vegetation and rocky outcrops, with greater densities in areas of higher disturbance. Adult density was mainly influenced by harvesting (78% variation), saplings by NDVI (2.09%) & altitude (18.72%), and seedlings by aspect (4.44%), increasing from the south to the north. **Conclusion:** Strict monitoring and periodic assessment of the population are essential to protect the seedlings to the sapling stage, regulation of selective harvesting of the adults, and control of the herders feeding the leaves. Encouragement of local and large-scale cultivation to reduce pressure on the wild source and to improve livelihood. Capacity and confidence building of the community with citizen science reporting of destructive harvesting will help the forest department to save the declining population.

Keywords: Aspect, density, inverted "J" curve, MPCA, NDVI, Nannari sharbat, NTFP, root harvesting, size class, woody climber.

Editor: Amit Kumar, Wildlife Institute of India, Dehradun, India.

Date of publication: 26 July 2024 (online & print)

Citation: Sangeetha, M.S., K. Ravikumar & H.C. Chetan (2024). Impact of root harvest on *Decalepis hamiltonii* Wight & Arn. population across habitats in Savandurga Reserve Forest, Karnataka, India. *Journal of Threatened Taxa* 16(7): 25545–25570. https://doi.org/10.11609/jott.8824.16.7.25545-25570

Funding: Supported by Infosys Foundation.

Competing interests: The authors declare no competing interests.

Author details: M. Sathya Sangeetha (MSS,) is currently a Ph.D. scholar in Transdisciplinary University (TDU, Bengaluru) guided by Dr K. Ravikumar. She has been working with TDU (FRLHT) as research officer and Co principal investigator for various projects on conservation. Her experience and interests are medicinal plants ecology, species-distribution & conservation, ENM, GIS & geospatial-databases with five publications. Dr K. Ravikumar, (KRK) is an eminent systematic botanist, who has conducted botanical surveys across India. He is working as emeritus professor in TDU. He has guided five Doctoral candidates, published eight books, described 25 new plant taxa and 110 research papers on plant-taxonomy, ethnobotany, medicinal plants conservation and sea grasses. Dr Chetan H.C., (CHC) is an ecologist, working as associate professor in TDU. He worked as a teacher educator at Azim Premji Foundation and University. He has Ph.D. from Manipal University, guided many M.Sc. students and has 20+ research publications. His research interests are restoration ecology, environmental studies, policy interventional research, natural resources management & sustainability.

Author contributions: Funding support: MSS, conceptualization, field survey: MSS & KRK. Data curation, photography, GIS, remote sensing & geospatial analysis: MSS. Sampling design, methodology & statistical analysis: MSS & CHC. All authors provided equally to the writing and editing of the original draft.

Acknowledgements: The authors are thankful to Late Shri D.K. Ved, retd. I.F.S., TDU, and Shri Darshan Shankar, vice chancellor, TDU, for the fund supported by Infosys grant. We thank D.K. Ved for his staunch conservation concern and support for encouraging research on *D. hamiltonii* and Savandurga Reserve Forest. We are thankful to one anonymous expert for the constant guidance and critical inputs from conceptualisation to completion, design of sampling. We are grateful to Dr. Dhatchanamurthy, TDU, for his expertise in plant taxonomy which helped us in the field identification of the associated diversity of all life forms. Special thanks to Karnataka Forest Department for granting research permit Ref. No.: APCCF (R&U.A1.RAC/CR-37/2014-15, Dated: 03-10-2018). Complete field work took place for 2 years, population sampling was done between April to September 2019. I am grateful to Ramanagara and Magadi Forest Department Staff for the cooperation extended during the research period. Thanks to all watchers especially Doddaya for his support throughout the fieldwork. We are thankful for the guidance, expertise, logistics, and local support extended by Shri Jayadevaiah from Kalyan Devara Matha, Savandurga.

INTRODUCTION

In India, over 1,178 medicinal plants are commercially demanded for raw drugs. Of these 53% of plants are destructively harvested by collecting roots, wood, bark, or the entire plant (Goraya & Ved 2017). The concern is among the non-timber forest product (NTFP), harvesting of roots, whole stems, bulbs, and bark, especially in perennials is usually lethal or fatally weakens the plant species, and further achieving sustainability becomes difficult (Davenport & Ndangalasi 2002; Ticktin 2004; Hernandez et al. 2015). Of the 242 species in high commercial demand, 72% are sourced from the wild and they lack information on the impact of harvesting on the wild population (Fuller 1991; Cunningham 1993a; Ticktin 2004; Goraya & Ved 2017). These conditions make ecological conservation even more critical when there are increased collections. Research from the perspective of assessing the threats and the impact of harvesting of climbers are less studied compared to other life forms likewise there is a dearth of information on root-harvested plants also (Ticktin 2004; Stanley et al. 2012). Most of the studies on woody climbers have focused on community level analysis, in fact, generally climbers are neglected and less included in ecological studies (Gerwing 2004; Pandi et al. 2022). *Decalepis hamiltonii* is a woody climber, a medicinal non-timber forest product (NTFP), destructively harvested for fragrant roots, coupled with habitat loss the population is declining (IUCN ver. 3.1, Ravikumar & Ved 2000). We focus on studying *D. hamiltonii* which is harvested for roots and quantify the density, size class, and distribution of the population from the perspective of harvesting impact which is fairly unique. This attempt enhances our understanding of the status and also from the literature by touching upon studies related to woody climbers as well as root harvested plants.

For sustainable management of resources Shankar et al. (1996), emphasize the need for information on extraction and productivity levels per unit area which are unknown for most of the species being harvested. Studies have demonstrated that both natural and anthropogenic disturbances are crucial for the sustainability of the population of many such species (Mandle & Ticktin 2012; Mandle et al. 2013; McKechnie & Sargent 2013). Illegal collections have driven certain species population to an endangered status (Pfab & Scholes 2004). Destructive practises of harvesting plant parts such as bark, foliage, fruit, pith, seeds, and cone have led to population decline (Ticktin 2004; Stanley et al. 2012; Krishnamurthy et al. 2013). Best lessons have also been adopted from traditional ecological knowledge for root harvesting methods, life history & mode of reproduction to sustain the population from studies conducted on *Dichelostemma capitatum, Harpagophytum procumbens, Nardostachys grandiflora* and *Neopicrorhiza scrophulariiflora* (Anderson & Rowney 1999; Ticktin & Johns 2002; Stewart & Cole 2005; Ghimire et al. 2008; Ticktin et al. 2012). Trade and demand for roots affected the population of *Rauwolfia serpentina* as the gatherers were offered high prices at the retail level, which led to a sixfold increase in the harvesting rate of immature stages of the rhizomes and roots (Mishra 2001). *Asparagus racemosus* (Satawari), *Chlorophytum borivilianum* (Safed Musli), and *Cyperus rotundus* (Nagarmotha) are some of the well-known tubers /rhizomes facing destructive harvesting. Unsustainable harvesting practices like uprooting plants at the immature stage, not placing them back in the soil with proper coverage, or the entire primary /core root cut reduces the chances of survival. Root harvested plants remain exposed to sunlight leading to death and collection done throughout the year, roots/tubers of all age groups being harvested are highly unsustainable. Such activities reduce the quality and quantity, and pose a challenge to the survival and sustenance of the individuals (Mishra 2000; Prasad et al. 2002; Mishra & Kotwal 2003, 2007; Mishra et al. 2003).

Excessive harvesting has resulted in a typical population with many resprouts (small diameter sizes) but very few mature stems in both disturbed and severely disturbed sites (Hall & Bawa 1993; Ndangalasi et al. 2006). Over collections of fragrant medicinal roots of *Mondia whitei,* and other species under trade led to the extermination of the population locally in South Africa (Cunningham 1993b). Extraction likely impacts negatively on plant population leading to changes in population structure found in perennials, e.g. some trees and climbers (Ganesan & Setty 2004; Bitariho & Emmanuel 2019; Soumya et al. 2019b). *Loeseneriella apocynoides* is a slow-growing woody climber and its whole plant stem is harvested, so it takes over 20 years to reach a harvestable size (Muhwezi 1997). Long-term harvesting had a strong impact on reducing the root size over a period of time and noted changes in the biology of *Philodendron corcovandense* population (Valente & Negrelle 2011). *Coscinium fenestratum* is another woody climber species that is harvested for both stem and roots (Ved & Goraya 2007). The study by Thriveni et al. (2015) across disturbance levels found that none of the *C. fenestratum* individuals recorded a diameter of more than 3.5 cm, but the forest department records

suggested the existence of individuals that were larger than 25.0 cm diameter indicating the intense effect of harvesting which has resulted in a smaller size class representation. Likewise, McGeoch (2004) found *Mondia whitei* roots preferentially harvested for adults and juveniles which had led to disjunct patches of over or under abundance of size class representation with very few fruiting individuals. Since the root is an organ available in the plant from the initial growth stage found in all size classes, it is not a part like flowers/leaves/fruits which are produced, every year to shed. Rather the role of a root is on a long term for storage, transport, anchoring, developing new shoots after disturbance and much more. Unless the marketable size is specific to only a certain size or quality, demand for the material can lead to harvest of all size classes.

Woody climbers grow well in forest edges, gaps and disturbed habitats compared to undisturbed forest which is one of their characteristic features (Schnitzer & Bongers 2002). It is observed in *C. fenestratum* population tolerating a wider range of light levels, and was found to have lowest survival under the lowest light treatment (Kathriarachchi et al. 2004). Similarly, McGeoch (2004), found *Mondia whitei* growing well in all habitats as it is a wind dispersed species and germinated very well in disturbed areas. Light levels (sunflecks) effected the local demography in root harvested ginseng *Panax quinquiefolius* (Wagner & McGraw 2013). Lack in information on over-harvesting and quantification of the resources leads to decline of the population and could lead to conflicts among the stakeholders (Homma 1992; Chamberlain et al. 1998; Dovie 2003).

According to the International Union for Conservation of Nature (IUCN ver. 3.1), *Decalepis hamiltonii* Wight & Arn. (Apocynaceae) is assessed as endangered due to destructive root harvesting and habitat loss (Molur & Walker 1997; Ved et al. 2015). It is endemic to the Deccan plateau, found wild in Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, and Kerala, within an altitudinal range of 1,200 m (Ravikumar & Ved 2000; Reddy & Murthy 2013). It is a woody *climber* found in seasonally dry forests, mixed and dry deciduous forests, and semi-evergreen forests (Muthumperumal & Parthasarathy 2010; Anburaja et al. 2012; Rao & Reddy 2022; Pandi et al. 2022). Roots of this plant are traded nationally at 100–200 MT (Goraya & Ved 2007) and traders have reported a decrease in availability through the years which is a forewarning (Goraya & Ved 2017). Roots are medicinal, aromatic and substituted for *Hemidesmus indicus,* and it is known as "Makaliberu" in Kannada, "Magali kizhangu" in Tamil, "Maredu kommulu" or "Nannari kommulu" in Telugu, and Swallow root in English. Collectors prefer *D. hamiltonii*'s stout and thicker tuberous roots, which yield 40–45 kg per plant, over those of *H. indicus*. To meet the demand for roots, other *Decalepis* species like *D. arayalpathra* and *D. salicifolia* are also used as substitutes. However, both species are narrow endemics with limited ecological range and small populations, making them vulnerable to extinction (Mishra et al. 2015, 2017; Rodrigues et al. 2021). Sourced largely from the wild but origin of collection sources in the wild are not known. Unfortunately, there is no large-scale cultivation to meet the demands for the future or reduce the pressure on wild resource except for few farmers.

Studies have reported that the *D. hamiltonii* root extracts have the potential to cure many diseases, it has insecticidal, antifungal, and antioxidant properties (Reddy & Murthy 2013; Sharma & Shahzad 2014; Pradeep et al. 2016; Kharat & Mokat 2020; Ahmad et al. 2022). Potentially a new ecofriendly bioinsecticide and grain protectant of natural origin for agriculture (Mohana et al. 2008; Rajshekhar et al. 2010). Phytochemical investigations find a cocktail of active principles (Srivastava & Shivanandappa 2009) and researchers consider it to be an inspiration for discovering new herbal drugs and active compounds to treat many incurable diseases in the future (Naveen & Khanum 2010). It is considered as a wild food resource in the diet of tribal communities for enhancing nutrients, therapeutic practices, and strengthening their relationship by sharing the tubers frequently among themselves (Harisha et al. 2021). Roots are of multiple uses, required for Ayurvedic formulations, pickling and beverage industries, and to prepare traditional health drinks such as *Nannari Sharbat* or *Rayalseema sharbat* (Raju & Ramana 2009). Sold in local vegetable markets for pickling in households, the recent increase in people's preference is for 'makali' root juice and tea recipes are naturally drawing crowds at local food festivals (Vedavathy 2004). Naturally, the tubers of this endangered plant are highly exploited for medicinal, culinary, and confectionary uses and applications through destructive harvesting methods. Hence, its conservation in the wild is crucial. There is a need for alternative methods to meet the growing demand and reduce the pressure on wild resources through local or mass cultivation. Recent increase in the awareness of this plant for natural flavor extracts has created huge interest and its commercial cultivation by farmers can provide scope for looking at unexplored R&D avenues of *D. hamiltonii* (Shankar 2022).

The scope for demand increases because these roots are 10 times stronger than a 20-fold Vanila Bourbon concentration (John et al. 2007). The plant's tuberous roots possess a characteristic vanillin-like aroma due to the compound 2-hydroxy-4-methoxybenzaldehyde (2HMB) (Nagarajan et al. 2001). Biotechnological approaches are reviewed and recommended to mass multiply, and produce this vanillin flavour in tubers naturally in large scale (Shankar 2022). Globally vanillin biosynthesis is essentially becoming a need to meet the growing demand for natural vanillin productivity in a sustainable and efficient way (Xu et al. 2024). Though, there are several methods extensively reviewed (Reddy & Murthy 2013; Shankar 2022) plant tissue culture is also one of the methods to have demonstrated the scope to increase the yield of tubers. Increasing the vanillin and vanillic acid (Matam et al. 2017; Xu et al. 2024) and field transfer in rooted plantlets have been successful (Giridhar et al. 2003, 2004, 2005). Shoot multiplication and elongation methods have produced 40–48 plants from a single explant within four months followed by transfer from green house to field which resulted in survival of approximately 80–90% of the plantlets (Giridhar et al. 2003). Further, a higher yield in tuber biomass and maintenance of relative content of flavour compounds was also observed (Kamireddy 2017; Shankar et al. 2022). These studies provide evidences that can contribute towards local and mass cultivation and reduce pressure on the wild resource.

Field studies on *D. hamiltonii* revealed several issues related to its population and ecology. For instance, Raju & Ramana (2009) identified bottlenecks in sexual reproduction and seedling establishment. Meanwhile, in the Bili Giri Rangan hills (BR hills), root extraction experiments showed that the population is sensitive to even small intensities of 25% harvest and recommended the need for curtailment of wild collection (Murali 2008). A population estimation study in the Seshachalam hills using Adaptive Cluster Sampling utilized decadal data from the Girijan Co-operative Corporation (GCC), and aimed to estimate productivity (Mishra & Naidu 2014). The focus was on quantification of the root yield but not population status, structure or rotation period and the study recommended a long-term monitoring to suggest sustainable harvesting practices. Apart from species specific focus there are studies specific to climbers where the presence of *D. hamiltonii* has been recorded from various sites (Muthumperumal & Parthasarathy 2010; Anburaja et al. 2012; Pandi et al. 2022; Rao & Reddy 2022).

Conditions for *D. hamiltonii's* inadequate regeneration is reported to be the impeding factors such as the hard seed coat, and the short viability of seeds and the need for a good aerated substrate (Anandalakshmi & Prakash 2010). Factors regulating the population size of *D. hamiltonii* in natural areas are found to be extended flowering pattern, pollinator limitation, self-incompatibility, abortion of a considerable percentage of seedlings prior to establishment and absence of seed dormancy (Raju & Ramana 2009). The tuberous roots of *D. hamiltonii* are over exploited prior to reproductive maturity due to their economic and medicinal values and this is the main cause for the gradual decline of population (Anandalakshmi & Prakash 2010; Shankar 2022). As it is a tropical species, it requires higher alternate temperature of 20/30 ° C or 30° C rather than low temperature for germination and it was observed that among the three tests seed germination showed better results for the ones kept in between the paper than placing it on top of the paper or in the cocopeat (Navya et al. 2019). Similarly, soaking in hot water (60°C) for 24 h significantly improved the germination percentage from 83% to 98% on moist filter paper than on sand (Anandalakshmi & Prakash 2010). Storage of seeds at lower temperature of 15° C, having at least 8% moisture results in maintenance of seed viability and longevity (Navya et al. 2019). Storage of seeds at ambient temperature probably favored the increase of those enzymes, which positively affected germination.

Novelty in research information was found to exhibit significant variations observed in the quantity of phenolics, flavonoids in the tubers that were collected from different natural habitats which showed 10–16 % difference in the content of 2H4MB, Biligiri Rangaswamy Temple (BRT) being the highest, followed by Mysore, Tirumala, Kurnool, Trichy, and Palakkad (Pradeep et al. 2019). A similar study on *Ichnocarpus frutescens demonstrated* variations between the two phytogeographical zones and also within the same zone, as they were affected by various edaphic factors which is indicating that the micro-environment of the location plays a considerable impact on the yield of secondary metabolite contents in plants (Nirala et al. 2024). The composition of secondary metabolites is influenced by a range of biotic and abiotic factors, diverse environmental conditions that significantly impact the composition of medicinal plants (Li et al. 2020). Since roots serve as the primary channel for nutrient uptake from the external environment to the plant's internal system, edaphic conditions mainly play a pivotal role in metabolite production (Liu et al. 2022). Recent findings on *D. hamiltonii* study revealed that compared to the

first stage (12 months old) tuber there was a decrease in the expression of vacuolar transporters at second stage of the tubers (48 months old), indicating that the normal functioning of vacuoles in first stage transforms into a storage organ/tuber for 2HMB accumulation in the second stage (Kamireddy et al. 2021). It is indicative of the accumulation of fragrant compound in *D. hamiltonii* gradually increasing at the older stage of 48 months, than the first stage and this information is helpful in avoiding root harvesting of small size class individuals and it can also be chosen as a parameter for standardizing root harvesting. It is evident from the study that *D. hamiltonii* plants may adapt to various ecological / microclimatic conditions in the habitat and vary in accumulation of secondary metabolites.

Around 150 ha area in SRF has been designated as medicinal plant conservation area (MPCA) for in situ conservation of medicinal plants which includes *D. hamiltonii* population also (Somashekhar 2013). The botanical survey resulted in 355 medicinal plants including *D. hamiltonii* (Ved et al. 2004) and Dhatchanamoorthy et al. (2021) studied exclusively grasses. Trainings have been imparted to the community on conservation and sustainable harvesting methods of medicinal plants which includes root harvesting of *D. hamiltonii* also (Kinhal & Jagannatha 2006; Kinhal et al. 2006; Jagannatha & Kinhal 2008). However, attempts have not been made so far to assess the species-specific population size, density, demography, threats/disturbances for the complete landscape of SRF. Hence, addressing this primary need of assessing and quantifying the population status will be helpful in formulating management plans, assessment of Red List status, sustenance and conservation of the population in the wild.

The major objective of this study was to understand the population status of *D. hamiltonii* with key research questions such as (a) what is the density and size class distribution of the *D. hamiltonii* population in Savandurga RF?, (b) what is the differences in *D. hamiltonii* densities and regeneration across different habitats?, (c) Does the density and regeneration vary across harvesting regimes?, (d) What are the environmental variables influencing the density and demography of *D. hamiltonii*? Therefore, in the current study we aim to understand sustainable use and suggest conservation strategies to save its population.

MATERIALS AND METHODS

Study area

The SRF is situated approximately 70 km west of Bengaluru and 12 km from Magadi town in Karnataka, India. The largest monolith in the area, the Savandurga hill, stands at 1226 m, and is part of the Deccan plateau. The hill comprises two peaks, the black hill (Karigudda) and the white hill (Biligudda), separated by a deep valley. The scrub, dry deciduous natural forest vegetation in the area is characterized by large bald rocky surfaces. The rocks include the Closepet granite series, peninsular gneiss, granites, basic dykes, and laterites. The forest type is classified as a shrub and tree savanna type comprising the *Anogeissus latifolia* - *Chloroxylon swietenia* - *Albizia amara* series (Champion & Seth 1968; Pascal & Ramesh 1996). Accepted name of *Anogeissus latifolia* is *Terminalia anogeissiana Gere & Boatwr. as per* POWO (2024). The forest between 750 m and 1,200 m has a sparser distribution of trees such as *Wrightia tinctoria*, *Wrightia arborea*, *Holarrhena pubescens*, *Polyalthia cerasoides* (Accepted name–*Huberantha cerasoides*) *Albizia amara*, *Terminalia anogeissiana*, and *Pterocarpus marsupium.* However, SRF is invaded by weeds such as *Lantana camara*, *Chromolaena odorata,* and *Pterolobium hexapetalum*, which affect the vegetation distribution. The forest's vegetation, combined with factors such as altitude, slope, sunlight, and edaphic factors, create a habitat for species growth, leading to three main vegetation categories: dense vegetation (closed canopy, no sunlight), rocky vegetation (open canopy, extreme sunlight), and mixed vegetation (sparse vegetation with sunlight penetration) at the boundary between the two types. The dense and mixed vegetation comprises loamy soil mixed with rocks and open rocky areas that receive sunlight have patches of soil deposited on the rocky slopes.

Population sampling

To assess the population size, distribution, and habitat characteristics of *D. hamiltonii*, sampling was conducted between April end to September 2019 in the SRF. Considering the financial constraints, accessibility issues, manpower constraints, and the wind dispersal of this climber species, fixed area plots were adopted as a sampling design. First, the forest boundary was digitized using Google Earth, and the entire area was divided into 1 × 1 km grids with QGIS. Only grids with over 50% forest coverage were selected for sampling, while those located in fringe forest areas were excluded from the analysis. Consequently, the study included 24

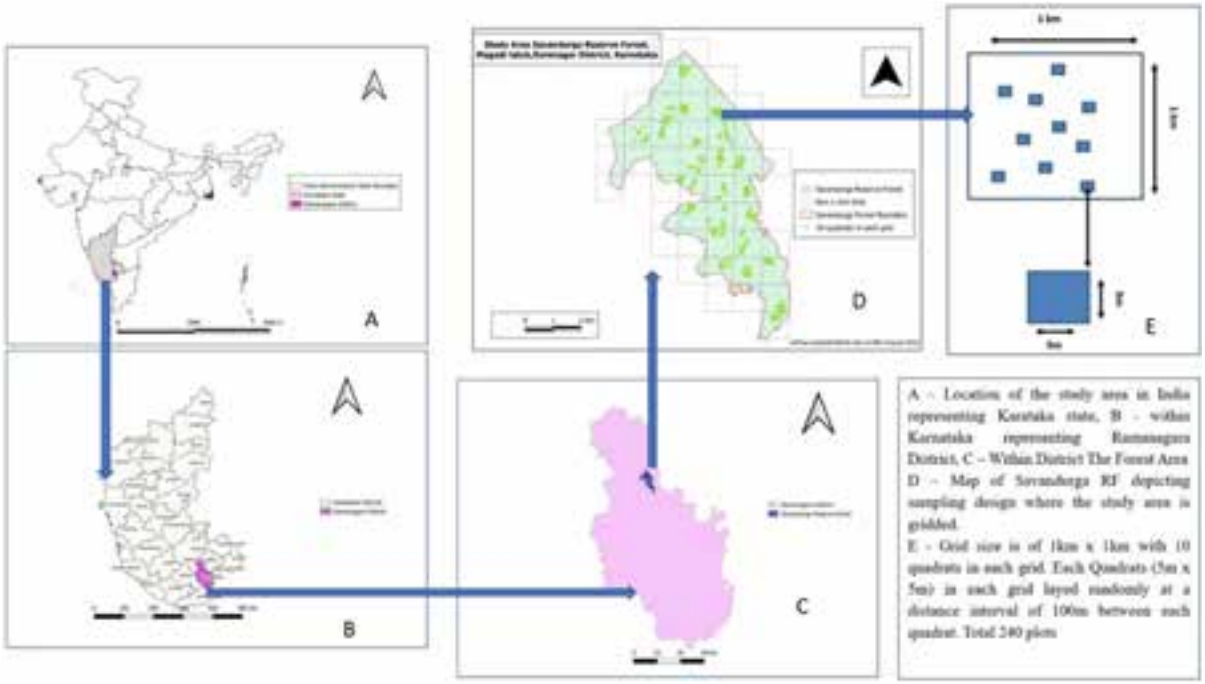


Figure 1. Study area and schematic representation of sampling quadrants of 5 × 5 m within 1 × 1 km grids (Total 24 grids).

Table 1. List of study sites selected for sampling *Decalepis hamiltonii* in Savandurga Reserve Forest.

No.	Grid	Site Code	No.	Grid	Site Code
1	G10	KTK	13	G39	IKB
2	G16	ITM	14	G40	DAD
3	G17	GKM	15	G45	NK
4	G18	BKM	16	G46	KOH
5	G22	ITG	17	G47	DBO
6	G23	ITE	18	G53	HCG
7	G24	SFH	19	G54	MST
8	G25	MPCA	20	G60	MR1
9	G31	AAS	21	G61	MR2
10	G32	DGK	22	G62	MR3
11	G33	VBD	23	G69	KPN
12	G38	VTK	24	G76	KPS

grids measuring 1 × 1 km, covering around 2,300 ha of forest area (Table 1). In each grid, 10 sample quadrants measuring 5 × 5 m were established randomly (Figure 1). Each 5 × 5 m quadrant was surveyed to identify and enumerate all stems of *D. hamiltonii*. The girth was measured at 1.3 m from the rooting point, referred to as the point of measurement (POM) (Gerwing et al. 2006). However, Gerwing et al. (2006) recommends a minimum diameter limit of 0.5 cm for density, species richness, regeneration, and succession studies to help accurate representation of stem size. Smaller diameter classes can capture the dynamics of the community, including growth, mortality, and recruitment. If the seedlings were small and not yet established, they were measured using digital vernier callipers, otherwise, big ones were measured with a measuring tape. Each quadrant's reproductive status was recorded, and its habitat was evaluated and classified as dense, mixed, or rocky. Elevation, latitude, longitude was recorded for each plot by using the Garmin GPS (map 64) instrument.

Climber inventories generally captured evidence from a community perspective but with variations in research objectives, methods, plot sizes, and stem diameter. Studies enumerated stems ≥1 cm dbh (Proctor et al. 1983; Putz & Chai 1987; Chalmers & Turner 1994; Rice et al. 2004; Burnham 2004; Muthuramkumar et al. 2006; Reddy & Parthasarathy 2003, 2006; Campanello et al. 2007; Ding & Zang 2009) studies enumerating stems ≥1.6 cm dbh (Padaki & Parthasarathy 2000). However, it is important for identifying small-sized regeneration of climbers to know the consequences of forest dynamics (Gerwing et al. 2006), but such studies received little attention (Chazdon 2003). Some studies enumerating smaller stems to mention are ≥0.5 cm dbh studied by Dewalt et al. (2000), Yuan et al. (2009), and much lesser stem girth of ≥0.2 cm dbh by Mascaro et al. (2004), Cai et al. (2009), and Chettri et al. (2010). The above differences considered in the studies make comparison of data across the tropics difficult. In the present study,

we have considered all size classes beginning from 0.5 cm onwards to capture the population of all size classes. Though, studies by Gerwing (2004), Schnitzer et al. (2004), and Anbarashan & Parthasarathy (2013) show a positive correlation between disturbance and climber abundance, lower climber densities in more disturbed areas have been observed by Rice et al. (2004). No relationship between disturbance and climber abundance was observed by Mascaro et al. (2004). However, Hall & Bawa (1993), emphasize the importance that monitoring an annual species for which the entire individual is harvested requires a completely different sampling design from monitoring a large tree species from which only fallen fruits are harvested. Likewise, sampling designs may differ based on the life form, history, method, and plant part harvested. The sampling design chosen here is on a targeted woody climber species and the attempt here is to capture the type of disturbances, habitats, and the influencing factors that determine the population density. Our study is from the perspective of a single climber species population disturbed by root harvest, which is unique.

Description of stages of plants and size-class distribution

The stems were classified based on their girth size, with adults having a GBH ≥6 cm onwards, saplings having a GBH between 3 cm and 6 cm, and seedlings having a GBH >3 cm (0.5 to 3cm). The measurements for all *D. hamiltonii* stems followed the protocol of Schnitzer et al. (2006) and Gerwing et al. (2006).

Seedlings: Seedlings range in size from 0.5 cm to 3 cm, they stand stiff without support up to 30–40 cm in height (Image 1a). Leaves may wither due to deciduous nature, grazing, or other disturbances like small fires. 1 cm stem girth corresponds to at least 750 g of underground roots (Sathya Sangeetha: Unpublished Thesis). As stem girth increases from 2 to 3 cm, climber length increases by 1 to 1.5 m, falling on taller grasses, herbs, and nearby shrubs. Between 0.5 cm to 3 cm the un-established seedlings (height <1 m) and established seedlings (height >1 m) are included.

Saplings: Individuals with stem girths ranging from 3.1 to 6 cm experience growth in length but do not exhibit flowering (Image 1b). Increase in length is noted in the stem between the two nodes and are found to be greenish pink in colour. It was observed from the overall survey that the flowering and fruiting started above 5 or 6 cm onwards. At this stage, climbers establish support through multiple hosts as they grow typically, the plant twines onto from the nearby grasses, herbs, and shrubs ascending onto the nearest branch extension of the host tree, choosing the shortest distance towards light. If no hosts are found, the stems lie on rock boulders.

Adults: Individuals with stem girths more than 6.1 cm are considered adults, as they flower and fruit (Image 1d). At this stage, the plant has 4–5 branches with flowers in terminal and axillary cymose inflorescences. Each branch has about 15–20 inflorescences and increases based on the stem size and length of the branch. After pollination, fruits develop, with each weighing around 40–50 g and measuring 20–35 g when dried. The number of branches, flowers, and fruits increases with stem size. The colour of the stem varies from greenish pink, to maroon and as they grow old the colour turns to dark brown and finally blackish grey with prominent lenticels (Image 1g & h).

Overall, the stem girth size was divided into 11 size classes with equal intervals of 3 cm ranging from 0.5 to 31 cm. The size classes are as follows: a) 0.5–3 cm; b) 3.01–6 cm; c) 6.01–9 cm; d) 9.01–12 cm; e) 12.01–15 cm; f) 15.01–18 cm; g) 18.01–21 cm; h) 21.01–24 cm; i) 24.01–27 cm; j) 27.01–30 cm; k) 30.01–33 cm (Figure 7; Image 1). The largest size class of one or two adult stems was observed in closed canopy areas, where they were found within the large trees in dense forests. These stems were identified by the presence of fruits hanging above the closed canopy. (Note–0.5 cm, 0.8 cm, 0.9 cm stems are placed within the 0.5–3 cm range).

Associated vegetation was also recorded from each plot. Trees, shrubs, climbers, herbs, and grasses were identified in the field, and the doubtful species were compared with the authentic specimens in FRLH herbarium and also the field images. The herbarium specimen was deposited in FRLH Herbarium (Voucher specimen number: 122072, Date: 25.05.2019, Location: Savandurga MPCA). All trees measuring >10 cm DBH and the stems of shrubs (ranging from 1 to 10 cm DBH) were counted, and the species were identified. Disturbances affecting the *D. hamiltonii* population in the SRF were recorded through field observations and each of the 24 grids was categorized based on the number of stems harvested, uprooted or had branches chopped, as well as the occurrence of fire, grazing (Image 2 a–g), presence of weeds and distance from each site to villages and roads (Appendix 1).

Habitat variables

To investigate the potential factors that may be influencing the distribution and abundance of *D. hamiltonii*, the study selected eight habitat variables (Table 2). Normalized Difference Vegetation Index (NDVI), elevation, slope, aspect, hill shade illumination,

Image 1. Sampling *Decalepis hamiltonii* population in Savandurga Reserve Forest. a—Seedling | b—Sapling | c—Measuring the stem girth of an adult plant | d—Adult climber supported on *Euphorbia antiquorum* | e&f—Laying sample plots and assigning plot numbers | g—Large adults–woody climber | h—Adult plant grown luxuriously on rocks and surrounding grasses, herbs, and shrubs. © M. Sathya Sangeetha.

associated species, and the distance from the forest boundaries, as well as two categorical variables: habitat types and harvesting regimes. The NDVI, elevation, slope, aspect, and hill shade illumination variables were obtained from satellite imagery, namely LANDSAT-8 (Scene ID LC81440512019104LGN00; acquired in 2019; http://glovis.usgs.gov/) and elevation data from ALOS (JAXA Global ALOS portal; scene ALPSMLC30-N014E077–

Image 2. *Decalepis hamiltonii* population facing anthropogenic pressure and other disturbances: a—Large adult plant from rocky area extracted for roots by breaking the rock slope into pieces | f—Large adult plant roots extracted from loamy soil by digging and twilting the rock boulders | b—Fire set only to the sample plot where *D. hamiltonii* sapling was killed (note the assigned plot no 55) | c—Fruiting branches pulled and chopped by herders for feeding goats | d—Goat eating the leaves of *D. hamiltonii* which was growing near the *Euphorbia antiquorum* plant | e—Supporting plant *E. antiquorum* branches chopped while root harvesting observed in the interior most site which is the peripheral edge of SRF | g—Small mud roads created inside the forest by clearing the vegetation. © M. Sathya Sangeetha.

Table 2. Summary of the eight environmental variables included for the regression analyses, apart from the two categorical variables (Habitat types and harvesting regimes).

Variable	Mean	Median	Range
Elevation (m)	844.7	847	754.0–960.0
Slope (Sexagecimal degree)	0.9246	10.0301	0.5072–30.1230
Eastness	-0.1384	-0.3698	-0.9997–0.9994
Northness	0.05566	0.04859	-0.99925–0.99992
Hill shade illumination	170.6	172	79.0–236.0
NDVI	0.14757	0.14377	0.07176–0.33512
Associated species	21.18	21	1.00–57.00
Distance to forest boundary (m)	563.7	530	70.0–1700.0

DSM) and Google Earth (http://earth.google.com). The NDVI values for vegetation quadrants were derived from the Landsat image with a 30 m resolution, using Band 4 (Red) and Band 5 (NIR). The NDVI was validated in the field. In the SRF, the NDVI ranged -0.1–0 for water bodies, 0.1–0.17 for bare soil and rock regions, 0.18–0.2 for sparse vegetation, and 0.2–0.4 for less dense vegetation up to the closed canopy. The topographical variables, including slope, elevation, aspect, and hill shade illumination, were extracted from the digital elevation model (DEM) raster with 30 m resolution. These variables represent the basic elements used when analyzing and visualizing ecological problems related to forest and wildlife habitat suitability site analyses (Al-Kindi et al. 2017). The aspect was transformed into a linear north-south gradient (Northness) and an east-west gradient (Eastness) by performing cosine and sine transformations, respectively, to facilitate statistical analysis. Northness ranged from -1 (south-facing) to 1 (north-facing), while Eastness ranged from -1 (west-facing) to 1 (east-facing). The values were extracted using the ARCGIS 10.2, 3D analyst tool/raster surface option, and Q GIS 3.10.2 and ArcMap 10.2 were used for data extractions. Furthermore, surrogates of disturbance such as settlements, villages, and the distance from quadrants to villages and roads were also mapped. Distribution of plant species on a landscape depends on surface soil moisture balance, moisture holding capacity of the soil which is related to topographical variables like elevation, aspect, slope, hillside position, curvature (Franklin et al. 2000). Soil moisture is strongly correlated with the amount of radiation received on the Earth's surface and the sun's radiation is described often by aspect (Najafifar et al. 2019). Aspect plays an important role in evaporation, temperature change and solar radiation these conditions create micro niches for the plant's establishment and survival period.

Environmental variables

A total of 10 environmental variables were considered: NDVI, altitude, slope, northness, eastness, habitat types, harvesting intensities, hill shade illumination, associated species, and the distance from the forest boundaries (Table 2). Prior to regression analysis, collinearity among predictor variables was assessed using Pearson's cross-correlations (Figure 2) and the variance inflation factor (VIF) (Neter et al. 1996). The VIF measures the increase in variance of an estimated regression coefficient due to collinearity. Whenever high collinearity was observed (Pearson's r ± 0.40 and VIF >10) (Neter et al. 1996), ecologically more relevant predictors were retained, while others were discarded. Therefore, the final set of explanatory variables consisted of nine variables, excluding habitat types, as they were highly correlated with the NDVI (Figure 3).

Although the quantile-quantile plots and Shapiro-Wilk test for normality indicated non-normal variance in all the response variables, the approach by Chapagain et al. (2019) was employed to address the large number of zeros in the datasets. Moreover, the best-fitting multiple regression model was determined based on the lowest value of the bias-corrected Akaike's Information Criterion for small samples (AICc; Burnham & Anderson 2002) among all potential regression models (equation X).

$$AICc = AIC + \frac{2k\,(k+1)}{n-k-1} \text{ equation} X$$

where, AICc is the lowest value of the bias corrected AIC,

n is the sample size,

AIC is Akaike's Information Criterion, and is given as:

$$AIC = 2k - 2ln\,(L)$$

where, k is the number of parameters in the statistical model,

L is the maximum value of the likelihood function for the estimated model.

The resultant best predicted variables were used to explain the variations observed in the *D. hamiltonii* distributions across SRF.

Data analysis

The data analysis focused on comparing the densities and relative densities of *D. hamiltonii* across three habitat types (rocky vegetation, mixed vegetation, dense

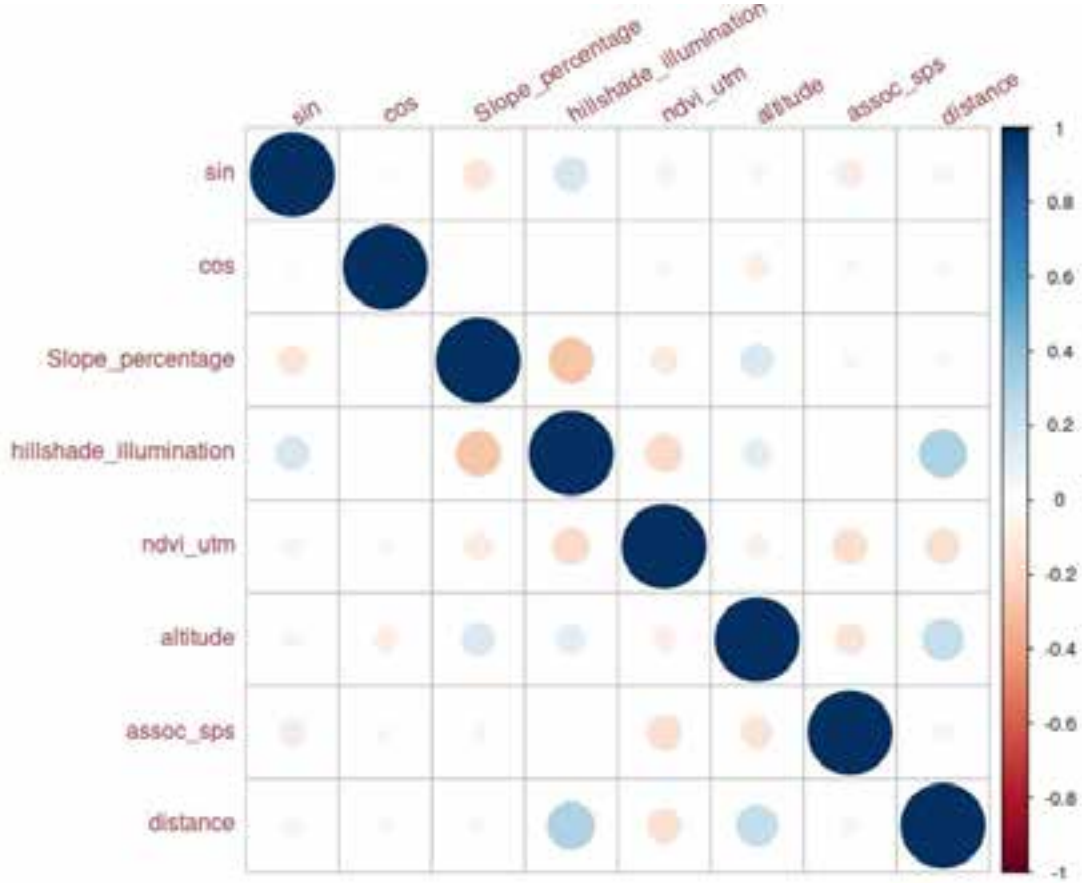


Figure 2. Correlation plots for environmental variables as part of the multidisciplinary test.

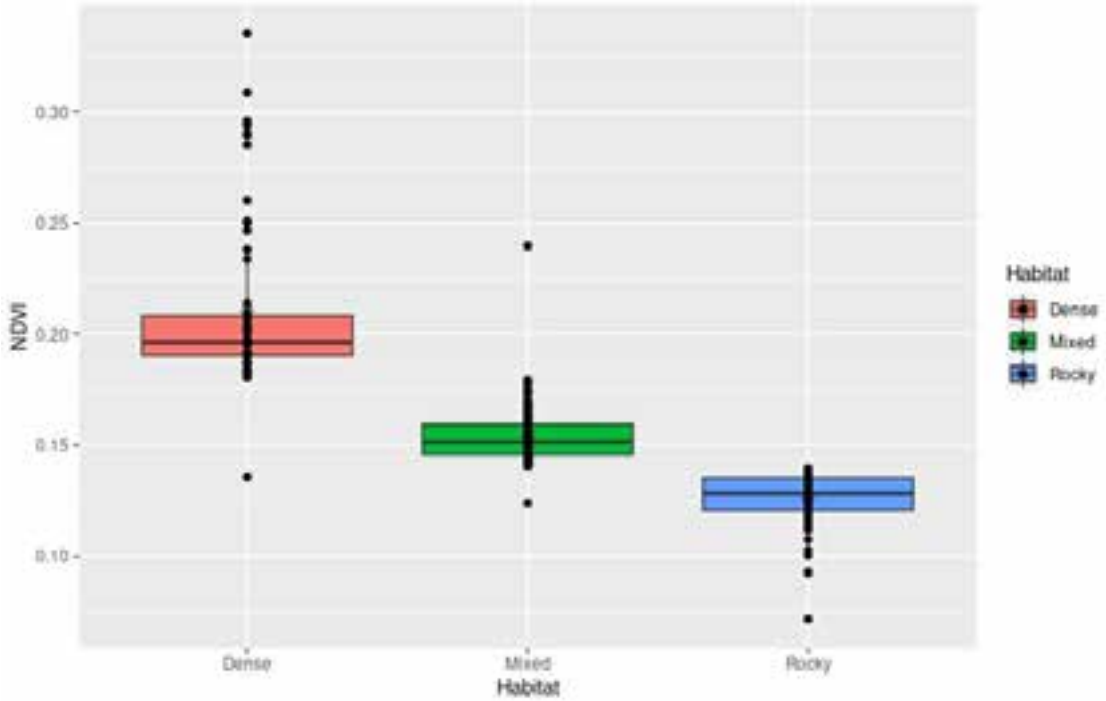


Figure 3. Box plots for comparing the mean NDVI values across the habitat classification in Savandurga Reserve Forest.

vegetation) and three different harvesting intensities (low, medium, high) to identify any variations due to these factors. Since density (D) and population size (N) are related, with N = D x Area, we estimated the density for the sample and used it to compute the total population. We used the formula D(p) = N/A, where D(p) represents population density, N represents the number of stems (population size), and A represents the area. The quadrat and environmental data were analysed using R software version 3.6.3 (R Core Team 2020).

Next, we standardized the densities of *D. hamiltonii* adults, saplings, and seedlings per hectare for all sites in the SRF. We then compared the relative densities of *D. hamiltonii* across habitat types and harvesting intensities. We used the Wilcoxon test to calculate pairwise comparisons between group levels, with corrections for multiple testing. We also plotted population structure curves using the GBH-based size class distribution of *D. hamiltonii* stems. The smallest stems were 0.5 cm which was placed between 0.1 to 3 cm class. We formed 15 size classes ranging 0.1–45 cm with an equal interval of 3 cm and statistically compared the relative densities and size classes using non-parametric ANOVA (Kruskal-Wallis test). Whenever the Kruskal-Wallis test resulted in a significant difference, we performed pairwise Wilcoxon rank sum tests.

To compare the densities and relative densities, we derived four datasets from the *D. hamiltonii* database: (1) entire *D. hamiltonii* stems across SRF; (2) adults; (3) saplings; and (4) seedlings. We attempted a regression analysis to examine the impact of various environmental factors on the distribution and abundance of *D. hamiltonii* in SRF. We initially considered the eight habitat and two categorical variables as predictor variables, and after checking for collinearity among them, we used a final set of nine explanatory variables for regression, excluding habitat types due to high correlation with NDVI.

RESULTS

From the 240 sample plots, total 405 stems of the *D. hamiltonii* species were enumerated from 6000 m^2 (5 x 5 m = 25 m^2 x 240 plots = 6000 m^2). Adults made up the largest portion of them (188 stems, or 46%), followed by seedlings (152 stems, or 37%), and saplings (65 stems, or 16%). Among the 24 grids density ranged from lowest 0.1 ± 0.32/25 m^2 (Mean ± S.D.) to the highest 5.2 ± 2.66/25 m^2 (Mean ± S.D.). The estimated densities of the *D. hamiltonii* per plot (25 m^2) and for each grid were the highest in DBO, KOH, KPN, MPCA, and MST (Table 3), while the grids SFH and JKB had the least densities. The density of the adults was highest (Mean ± S.D.: 313 ± 210 stems/ha, N = 24), followed by the density of the

Table 3. Estimated densities per hectare and per sampled plot (25 m2) for *Decalepis hamiltonii*.

Grids	Density / 25 m^2 (Mean ± S.D)	Density / ha
AAS	1.3 ± 0.95	520
BKM	0.9 ± 1.20	360
DAD	2.4 ± 1.35	960
DBO	2.8 ± 2.30	1120
DGK	1.5 ± 0.71	600
GKM	1.4 ± 0.97	560
HCG	2 ± 2.98	800
ITE	0.8 ± 1.03	320
ITG	1.5 ± 1.65	600
ITM	1.6 ± 1.43	640
JKB	0.5 ± 0.85	200
KOH	2.8 ± 2.39	1120
KPN	3.5 ± 4.62	1400
KPS	1.9 ± 1.97	760
KTK	1.1 ±2.13	440
MPCA	5.2 ± 2.66	2080
MR1	0.8 ± 1.75	320
MR2	0.8 ± 1.03	320
MR3	1.5 ± 1.65	600
MST	2.8 ± 2.86	1120
NK	1.9 ± 2.60	760
SFH	0.1 ± 0.32	40
VBD	0.4 ± 0.52	160
VTK	1 ± 0.67	400

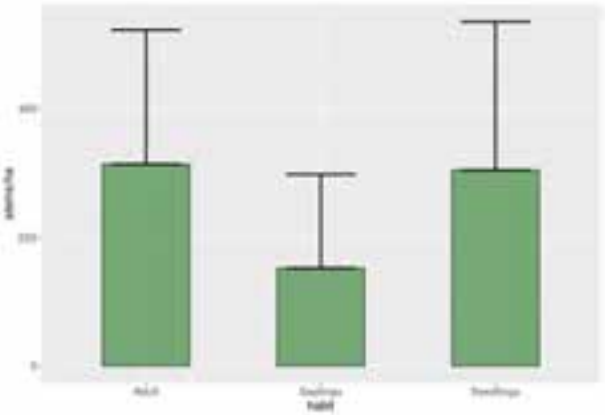


Figure 4. Distribution of the *D. hamiltonii* adult, sapling, and seedling densities per hectare across the Savandurga Reserve Forest.

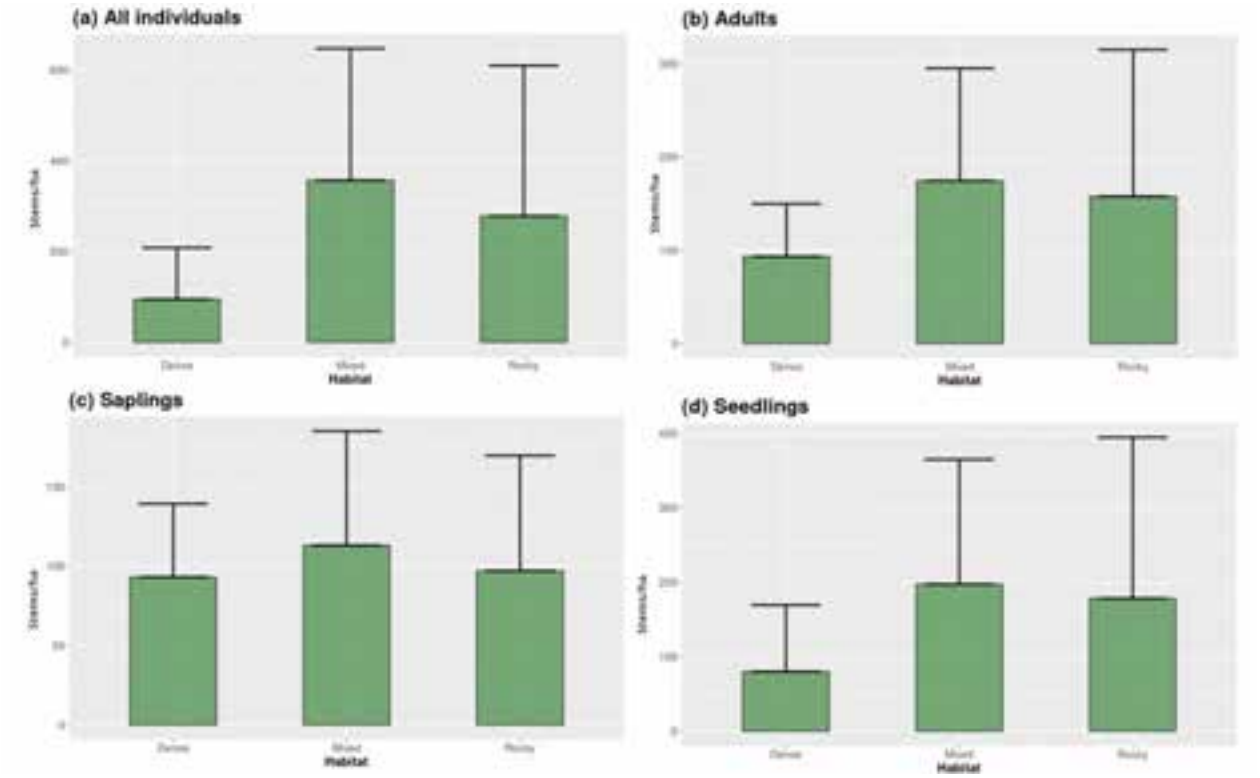


Figure 5. Comparison of the Mean ± S.D. in the *D. hamiltonii* stems from the sites across the three habitat types (dense vegetation, mixed vegetation, rocky outcrops) for: (a)—all the stems | (b)—adults | (c)—saplings | (d)—seedlings.

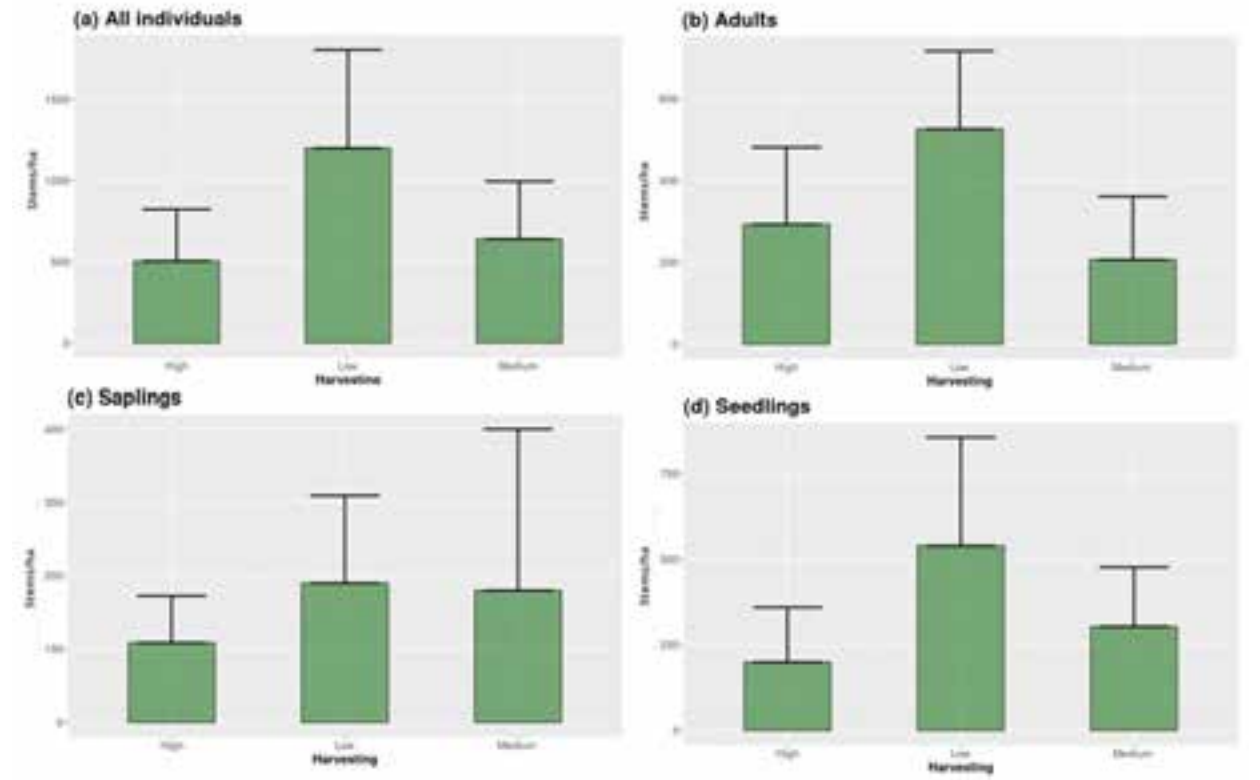


Figure 6. Comparison of the Mean ± S.D in the *D. hamiltonii* stems from the sites across the harvesting regimes (low, medium, high) for: (a)—all the stems | (b)—adults | (c)—saplings | (d)—seedlings.

Table 4. Nonparametric ANOVA results for the comparison of adults, saplings, and seedlings of *Decalepis hamiltonii* compared among sites under different harvesting regimes (high, medium, and low).

Response variable	Harvesting intensity			Kruskal-Wallis ANOVA	*P* value
	High	Medium	Low		
	Mean ± S.D. (N) stems/250 m²	Mean ± S.D. (N) stems/250 m²	Mean ± S.D. (N) stems/250 m²		
Adults	293 ± 188 (15)	206 ± 154 (6)	470 ± 247 (4)	χ2(2,23) = 3.291	0.19
Saplings	108 ± 64 (7)	180 ± 220 (6)	190 ± 119 (4)	χ2(2,15) = 1.003	0.6
Seedlings	200 ± 160 (12)	304 ± 77 (5)	540 ± 317 (4)	χ2(2,19) = 5.880	0.06

Table 5. Multiple linear regression models based on the AIC model selection for (a) total stems, (b) adults, (c) saplings, and (d) seedlings.

Response variable	Predictors	parameter estimate	T	*P*- value	AIC values
All stems	Harvest_high	0.822	1.924	0.056	720.075
	Harvest_medium	1.264	2.803	<0.01	
	Harvest_less	2.585	5.649	<0.0001	
	Associated species	0.038	2.344	<0.05	
Adults	Harvest_high	1.529	13.686	<0.0001	225.13
	Harvest_medium	1.193	8.327	<0.0001	
	Harvest_less	1.682	13.503	<0.0001	
Saplings	NDVI	3.257	1.161	0.2503	241.227
	Altitude	0.001	2.609	<0.05	
Seedlings	Northness	-0.655	-2.006	<0.05	384.043

seedlings (Mean ± S.D. :304 ± 232 stems/ha; N = 20) and density of the saplings (Mean ± S.D.: 153 ± 144 stems/ha, N = 17). Overall mean density (Mean ± S.D.) observed was 675 ± 455 stems/ha in SRF.

When the total number of *D. hamiltonii* individuals at each site was compared, the sites that are subjected to high harvesting had, on average, the fewest individuals (less than ten), with the exception of sites AAS (13 individuals), GKM (14 individuals), KTK (11 individuals), and VTK (10 individuals). The areas that had medium levels of harvesting had a comparatively greater number of plants to begin with (10–20 individuals per site). And the locations that had the fewest plants harvested had more than 20 individuals per site; the site that was protected by the MPCA had the largest number of plants (52 individuals). When compared to the mature plants in the less harvested sites, the medium and highly harvested sites had a much lower number of individuals, with most having fewer than 10 individuals, while the less harvested sites had more than 10 individuals.

When the densities of adults, saplings, and seedlings were compared across different sites in SRF, significant differences were found (Figure 4; Kruskal-Wallis ANOVA: $\chi^2_{(2,21)} = 14.09$; P <0.001). According to the results of the pair wise comparison tests, the sapling densities were substantially lower compared to those of the adults (P <0.001), as well as those of the seedlings (P <0.05). On the other hand, there was no significant difference in the densities of the adults and the seedlings (P = 0.2032).

From the Figure 5a, the densities of the *D. hamiltonii* were significantly less in the dense vegetation (Mean±S.D.: 95 ± 113, N = 16) as compared to the mixed vegetation (Mean±S.D.: 356 ± 290, N = 24) and the rocky outcrops (Mean±S.D.: 278 ± 331, N = 22). This was confirmed using Kruskal-Wallis ANOVA ($\chi^2_{(2,59)} = 13.728$; P <0.01). Furthermore, the pair wise comparison tests revealed that the abundance in the dense vegetation were significantly lower compared to that in the mixed vegetation (P <0.01) and the rocky outcrops (P <0.05). However, there was no differences in the densities of the *D. hamiltonii* in the mixed vegetation and the rocky outcrops (P = 0.22).

When the adult populations were compared across the different types of habitats (Figure 5b), the densities were relatively higher in the mixed vegetation (Mean ± S.D.: 174 ± 120, N = 22) and the rocky outcrops (Mean ± S.D.: 158 ± 157, N = 18) than they were in the dense vegetation (Mean ± S.D.: 93 ± 56, N = 9). However, the

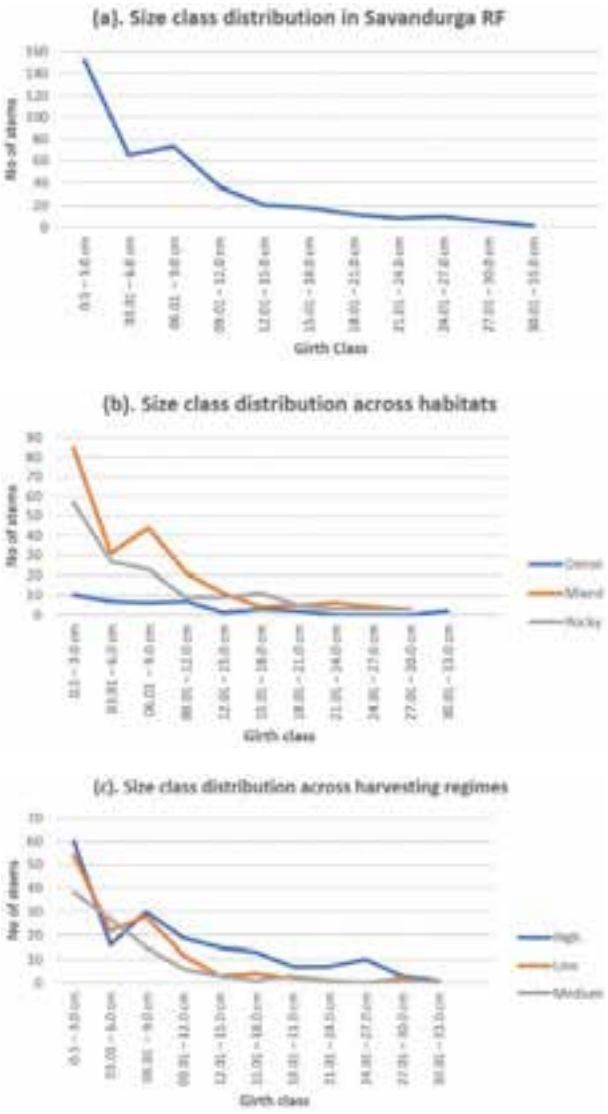


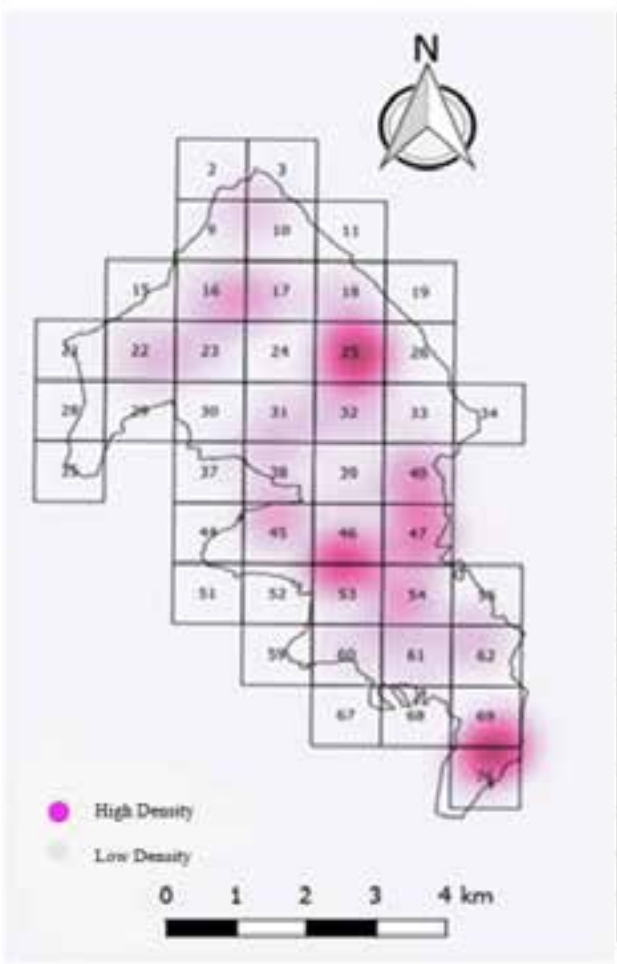
Figure 7. Comparison of the size class distributions of the *D. hamiltonii* stems for: (a)—entire SRF | (b)—across habitat types | (c)—across harvesting regimes.

statistical differences between the populations were not significant (Kruskal-Wallis ANOVA: $\chi^2_{(2,46)}$ = 3.282; P = 0.19). The densities of the saplings were comparable across all three habitat types (Figure 5c; dense vegetation: Mean±S.D.: 93 ± 46, N = 3; mixed vegetation: Mean ± S.D.: 113 ± 72, N = 12; and rocky outcrops: Mean±S.D.: 96 ± 68, N = 9, and the differences between the three habitat types were not statistically significant (Kruskal-Wallis ANOVA: $\chi^2_{(2,21)}$ = 0.032; P = 0.85). In a manner analogous to that of the saplings, the densities of the seedlings did not vary across the three different habitat types (Figure 5d; dense vegetation: Mean ± S.D.: 80 ± 89, N = 5; mixed vegetation: Mean ± S.D.: 197 ± 167, N = 17; and rocky outcrops: Mean±S.D.: 178 ± 216, N = 13, and the differences were not statistically significant (Kruskal-Wallis ANOVA: $\chi^2_{(2,32)}$ = 2.544; P = 0.28).

According to Figure 6a, the densities of *D. hamiltonii* were lower in the sites that were highly harvested (Mean±S.D.: 5483 ± 342, N = 15) and moderately harvested (Mean ± S.D. : 640 ± 554, N = 6) as compared to the sites that had less harvesting which had densities of (Mean ± S.D. : 1280 ± 355, N = 4) The Kruskal-Wallis analysis of variance ($\chi^2_{(2,22)}$ = 8.04; P <0.05) provided evidence in support of this hypothesis. According to the results of the pair wise comparison tests, the mean densities of *D. hamiltonii* were substantially lower in heavily harvested sites in contrast to those in less harvested areas (P <0.01). However, there was no difference in the mean densities of *D. hamiltonii* between highly harvested sites and moderately harvested sites (P = 0.32), nor was there a difference between moderately harvested sites and less harvested sites (P = 0.06). When the densities of adults, saplings, and seedlings were examined across the three harvesting regimes, similar patterns were found; however, the Kruskal-Wallis ANOVA revealed that there were no statistically significant differences (Table 4).

Size class distributions

The size class distribution for the *D. hamiltonii* exhibited close to a typical inverted "J" curve (Figure 7a); however, it can be inferred that the size class distributions for the entire population of *D. hamiltonii* in SRF is unstable due to the lowest densities of the saplings (size class: 3.01–6.0 cm). In a similar manner, when the size class distributions were analyzed across the various habitat types (Figure 7b), it was discovered that the populations are unstable as a result of the decreased abundance of the saplings. Compared to the thick vegetation and the mixed vegetation the rocky outcrops had a greater recruitment into the populations than the dense vegetation. The Kruskal-Walli's analysis of variance revealed very significant differences between the three habitat types ($\chi^2_{(14,42)}$ = 34.576; P <0.01). Furthermore, when the size class distributions were examined among the different harvesting regimes (Figure 7c), it was observed that the populations are unstable due to lower abundance of the saplings. However, the sites subjected to high harvesting pressure had higher recruitment into the populations than compared to that in the sites with moderate and less harvesting pressure. Statistical analysis of size classes reflected high significant differences between the three harvesting regimes (Kruskal-Wallis ANOVA: $\chi^2_{(14,42)}$ = 36.741; P <0.001). On the contrary to our expectations, the sites with higher harvesting pressure had a greater



Grid	Site code	Density/25 m² (Mean ± S.D.)
G31	AAS	1.3 ± 0.95
G18	BKM	0.9 ± 1.20
G40	DAD	2.4 ± 1.35
G47	DBO	2.8 ± 2.30
G32	DGK	1.5 ± 0.71
G17	GKM	1.4 ± 0.97
G53	HCG	2 ± 2.98
G23	ITE	0.8 ± 1.03
G22	ITG	1.5 ± 1.65
G16	ITM	1.6 ± 1.43
G39	JKB	0.5 ± 0.85
G46	KOH	2.8 ± 2.39
G69	KPN	3.5 ± 4.62
G76	KPS	1.9 ± 1.97
G10	KTK	1.1 ±2.13
G25	MPCA	5.2 ± 2.66
G60	MR1	0.8 ± 1.75
G61	MR2	0.8 ± 1.03
G62	MR3	1.5 ± 1.65
G54	MST	2.8 ± 2.86
G45	NK	1.9 ± 2.60
G24	SFH	0.1 ± 0.32
G33	VBD	0.4 ± 0.52
G38	VTK	1 ± 0.67

Figure 8. *D. hamiltonii* population density in SRF for 24 grids with IDs.

number of adults with girth ranging 6–33 cm (Figure 7c).

Influencing variables determining the adult, sapling and seedling distribution

The regression analysis based on AIC model selection indicated that the adult *D. hamiltonii* distribution in the sampled sites of the SRF was determined by harvesting alone with 78% variation explained ($F_{(3,120)}$ = 146.3; P <0.001). Contrary to expectations, the coefficients for the adult plant abundance were more in high and less sites than in moderately harvested sites (Table 5). The sapling distributions in the SRF were mostly determined by the NDVI (2.09% variation explained), a surrogate for habitat type, along with altitude (18.72% variation explained) that explained a total variation of 56.58%. Furthermore, the NDVI and altitude positively correlated with the sapling abundance (Table 5). The seedling distributions in the SRF was determined by the transformed aspect variable–cosine or the northing. The cosine or the northing variable negatively correlated with the seedling abundance suggesting that the densities increased as one travels from north to south in SRF. However, the directional variable explained a mere 4.44% variation observed in the seedling distribution (Table 5).

DISCUSSION

This study serves as the first baseline to assess *D. hamiltonii* population density and size class across habitats and disturbance levels for the entire landscape of SRF, Karnataka, India. The focus on a specific climber species is also fairly unique since most studies of have focused on community-level analysis (Gerwing 2004). Climbers in life forms and root-harvested plants are rarely attempted for research from the perspective of harvesting and its impact on the population is less known (Ticktin 2004; Stanley 2012). Totally, 405 stems were enumerated from the sampled area of 6,000 m² and the density ranged from lowest (Mean ± S.D.: 0.1 ± 0.32/25 m²) to the highest mean density of (Mean ± S.D.:

5.2 ± 2.66/25 m^2) across 24 grids. The overall estimated mean density/ha of *D. hamiltonii* in SRF is (Mean ± S.D.: 675 ± 455 stems/ha) and details for each grid/site is provided in Table 3.

Though the adults are represented in all grids we found that in SFH except for one adult individual none of the other classes was spared as it was a highly disturbed area. Sites such as DGK have the maximum number of adult plants, while others BKM and VBD, are inaccessible peripheral portions of the MPCA having less density. Though, all grids have some kind of disturbances categorized into low, medium, and high levels based on signs of being chopped, uprooted, hanging dead stems, uncovered dug pits, and drying of collected roots, some of these peripheral grids are part of the MPCA which is interior and inaccessible but requires protection for recouping of the population naturally. Seedlings were missing in four grids, which could eventually be the result of harvesting adults, leading to a reduction in fruits or in seed quality which is not germinating well. The second reason is goat herders cutting / pulling the branches with fruits to feed the goat with leaves. This is a matter of concern as it causes great loss by wasting the reproductive effort and material of the plant. Usually, the goat feeds only on the leaves there is no threat to the survival of the plant as the roots are intact.

One would expect that areas of high adult density would also have high sapling and seedling densities since most of the adult plants' have wind-dispersed seeds which place the seeds in open rocky, and dense areas indiscriminately. Grids facing harvest compared with no harvest helps in distinguishing between the varying levels of harvesting intensities and the effects of harvesting on population dynamics (Hall & Bawa 1993). The density map depicts most of the peripheral grids being disturbed and exhibiting unequal patchy density either over-representation or under-representation of size classes and this could have been a result of harvesting largely or due to other kind of disturbances happening over a period of years now affecting the central, interior portions of the forest. Similar patches of disjuncture alternatively, representing areas where adults or seedlings have been preferentially harvested, leaving an overabundance and an under abundance of one size class was observed in *Mondia whitei* harvested for roots in Kakamega forest (McGeoch 2004). It is evident from the study that the highest number of 52 stems were found from the sample plots laid in the MPCA (Grid no 25), with a (Mean ± S.D.: 5.2 ± 2.66/25 m^2). It is worth mentioning that this area had all size classes spread naturally which are not captured in our plots and such population was not observed in any other grids. This is an indication of management effort and a restricted gated area or 'hands off' or 'no harvest area' where the central portion of MPCA is not disturbed, unlike the peripheral grids. The central portion of the MPCA is the only grid with a healthy population representing all size classes. Strict monitoring and regulations are required to support the natural regeneration of the population to support the in situ conservation area as well as throughout the landscape.

Size class distribution exhibits close to a typical inverted "J" curve with lower densities of the saplings (class: 3.01–6.0 cm) compared to seedlings and adults. The abundance of seedlings is an indicator of good regeneration but the low density of the saplings stage poses a future bottleneck (Bitariho & Emmanuel 2019). Reasons for the low density of the sapling class could be due to low recruitment or mortality of the individuals or both. Savandurga RF is a site where sustainable harvesting methods have been trained by the experts and implemented by the community for harvesting *D. hamiltonii* individuals and this could be one of the reasons contributing to the presence of a greater number of adult class (Kinhal & Jagannatha 2006; Kinhal et al. 2006). Unscientific, premature, unregulated root harvesting or uprooting of size classes like saplings do have good yield but may not be able to withstand the intensity of harvest and survive like the adults but rather lead to mortality or delay in their growth progress to reproduction (Image 1b&e). Reduction in sapling class is considered a forewarning as it indicates an unstable population generally observed in tropical forests and reasons could be many factors. One prominent factor to mention is fire which is almost an annual occurrence could also kill the seedlings and saplings (Sukumar et al. 2005). Studies by Parthasarathy (2000), Parren (2003), and Rai et al. (2016) also showed the inverse "J" pattern generally observed in climber communities. Bitariho & Emmanuel (2019) have studied harvested climber populations and found a similar inverted "J" curve pattern in five species whereas other climbers represented different patterns in population structure depending on the intensity of harvest. Similar to our findings in *D. hamiltonii* observations made in perennials like trees for ex *Phyllanthus emblica* population had higher mortality of the sapling size class, as well as *Boswellia serrata* (Ganesan & Setty 2004; Soumya et al. 2019a). These outcomes show similarity in the methods of representing the size class and also representing the negative consequences of the harvested perennials leading to poor representation of size classes, in a dry

tropical ecosystem. Contrary to our finding's density of saplings in *C. fenestratum* was positively associated with the adults and exhibited a healthy population but, during the survey they did not find size class above 3.5 cm (Thriveni et al. 2015). In case of climbers like *Mondia whitei* people harvest roots before fruit development and such premature harvesting disturbs the growth of the plant and because of this it is very hard to find adult fruiting plants (McGeoch 2004). As a result of intense stem harvesting in both areas of very disturbed and less disturbed sites there was a prevalence of small diameter sizes in the *Loeseneriella apocynoides* which is typical of a population with many resprouts but very few mature stem (Ndangalasi 2006; Hall and Bawa 1993; Bitariho et al. 2006). The studies mentioned above shows the intensity of harvest on the climber population in *M. whitei* (roots), *L. apocynoides* (stem) and *C. fenestratum* (stem & roots) where only small diameter classes were present but with the absence of adult size classes and very few fruiting individuals. These studies mentioned above and our results, invariable of life form indicate that a species-specific scientific approach unfolds more insights about the population and size classes. Hall & Bawa (1993) emphasize that the method of representing size class distribution is useful to identify the poorly represented size classes and it may differ based on habitats or due to various level of harvesting intensities. Considering the effect of harvesting on different life forms (herbs, shrubs, climbers, trees) the life history (annual, biennial and perennial) or plant parts being harvested (leaf, flower fruits, bark, resin and root) the negative consequence of harvesting is expressed in the process at different life stages. Invariable of the life forms, the plant parts are stored carbon resources for the plants to continue the life cycle, and removal of those parts hampers their growth process.

Harvesting history of the forest is of consideration (Ticktin 2004) because SRF is an area where sustainable harvesting methods for root harvesting of *D. hamiltonii* has been imparted to the community (Kinhal & Jagannatha 2006; Kinhal et al. 2006; Jagannatha & Kinhal 2008). These practices may ensure and support survival of the adult plants after harvest but to what extent the methods are still followed?, how frequently each stem is harvested?, how healthy and productive are the harvested plants?, do the adult plants have their roots intact or lost due to harvest?, are points necessarily to be investigated. Saplings were not found in seven grids and found less in other grids compared to adults and seedlings. This scenario is indicating that the root harvesting is not restricted to only mature adults (>6.1 cm onwards) but being collected from smaller size classes also. This type of harvests may not allow the harvested stems to reach reproductive maturity and eventually recruit (Hall & Bawa 1993). The quantity of root available, for e.g., in a six-month-old plant, i.e., a seedling has minimum 500 g of root below ground. A sapling size class (3–6 cm stem girth) will have, not less than 2–3 kg of roots (minimum). Increased demand and pressure on the collectors, less equipped or unskilled harvesters, plants grown in favorable soil conditions which could be easily harvested are possible options for collecting roots from smaller size class. From the perspective of root harvest and its impact on the growth, survival, duration required to reproduce flower, fruits and potential seeds again are topics for further investigations. Unless monitored, managed and regulated spatially it is difficult to save premature harvest and selective harvest of adults.

Less number of stems is found in the dense vegetation, abundant in mixed vegetation and rocky outcrops. More in areas with higher disturbance which is a characteristic feature of climbers. Density of adults are determined by harvesting alone (78% variation), saplings by NDVI (2.09% variation) a surrogate for habitat type correlating along with altitude (18.72% variation). Seedlings were determined by directional variable (aspect) - 4.44%. (densities increased as one travels from south to north) adult stems had the highest density, followed by seedlings and saplings. The sites with high levels of harvesting had the fewest stems on average, while the protected site had the largest number of plants. The impact of harvesting on the population densities of *D. hamiltonii* was found to be significant, with heavily harvested sites having significantly lower densities compared to less harvested areas.

The densities of *D. hamiltonii* were significantly lower in areas with dense vegetation compared to areas with mixed vegetation and rocky outcrops. Interestingly the dense vegetation had less density but *D. hamiltonii* stems had attained higher diameter like single stems with gbh ≥28 cm to 30 cm. Reason is that some portion of forest fragments have not faced disturbance for a longer period of time and secondly in such dense vegetation these stems are not visible to the human eyes, so in such places the plants have attained higher stem diameters. Likewise, we found stems in undisturbed rocky areas also of gbh ≥20 cm single stems fallen on the rock without host. Similar results have been observed and confirmed in undisturbed, unaffected forests for long periods and also in old growth forests depicting dbh ≥30 cm in climber community studies (Dewalt et al. 2000;

Anbarashan & Parthasarthy 2013).

The destructive root harvesting of *Swertia chirayita* is another example of a habitat-specific species facing similar threats (Pradhan & Badola 2015). Studies have shown that the quality of the microhabitat significantly affects the availability of the *Swertia chirayita* population, with more stems observed in open habitats and on open grassy slopes, possibly due to lower interspecific competition for sunlight, and fewer stems observed in wetland habitats. *Houttuynia cordata* is restricted to specialized moist habitats in Assam (Bhattacharyya & Sarma 2010). Many medicinal plants which are root harvested are habitat-specific for example *Picrorhiza kurroa* (Kutki) grows only in moist rocks and steep slopes at an altitude of 3,500 m (Chandra et al. 2020). *Nardostachys grandiflora* (Accepted name - *Nardostachys jatamansi*) prefers rocky steep areas on the southeast slopes and in alpine grasslands, it is found on southwest facing slopes (Ghimire et al. 2005). In the case of *D. hamiltonii*, it is a wind-dispersed species that can colonize all three habitats in the SRF, but its adaptability to microsite habitat determines its survival as an adult.

Plant density, recruitment and survival rates are found to be more in less harvested areas than high harvest area with decreased densities (Ghimire et al. 2005; Bhattacharyya & Sarma 2010; Chandra et al. 2020). It was observed in *Coscinium fenestratum* population that they survive and regenerate naturally in disturbed habitats compared to undisturbed forest (Kathriarachchi 2004). The larger adults of *D. hamiltonii* were found in dense vegetation and seedlings within the canopy gaps and all classes were found in open areas, rocky outcrops and mixed vegetation in our study. Similarly, *Mondia whitei* also germinates well specifically in disturbed areas and forest gaps, also they are able to survive in all extreme conditions of Kakamega forests (McGeoch et al. 2008).

The mixed vegetation in SRF features an open canopy that allows sunlight to penetrate through exposed rocky areas and gaps in the foliage. *D. hamiltonii* is commonly found in this habitat alongside other plant species such as bamboo and *Sterculia urens*. The species also shows regeneration in the dense vegetation of the forest, particularly in canopy gaps and rock gaps where sunlight can reach. Climbing plants like *D. hamiltonii* often grow on shorter trees such as *Wrightia* spp. (in fact all size classes) and also large trees like *Albizia* spp. Additionally, *Euphorbia antiquorum* which thrives in barren rock fissures and depressions, provides a suitable habitat for *D. hamiltonii for regenerating seeds* by offering protection from grazing and support up to a large adult stage. Rocky outcrops serve as favorable habitats for *D. hamiltonii* as they act as water filters, improving soil moisture. Moreover, the hair-like appendages connected to the seeds aid in wind dispersion, allowing the species to propagate and renew populations in rocky patches.

Apart from cattle grazing, *D. hamiltonii* leaves are extensively browsed by goats of course no damage to the roots. Shepherds also chop down the large climbers with flowers and fruits to feed the goats which is a loss to the population. Similar cases could be found in *Hydrastis canadensis* population, though overharvesting lead to severe decline, browsing of white-tailed deer also was an additional cause (Mulligan & Gorchov 2004). *D. hamiltonii* density is primarily impacted by destructive root harvesting practices. Flat and low-lying regions face higher levels of anthropogenic pressure compared to higher elevations, which results in a decrease in pressure as elevation increases. The reduced recruitment and density are likely due to the prevalent harvesting strategy and the chopping of the climbers that flower and fruit, used for feeding goats. This decrease in recruitment and higher mortality of seedlings and saplings will make it difficult to replace the existing adult population in the future. Although there is a higher number of adult population every other plant has been harvested in previous years, and the adults are preferred by the harvesters due to their potential for producing the highest yield.

The results of this study have clear management implications, primary focus is to mitigate destructive extraction pressure and save the remaining population in SRF by enforcing laws to control harvesting for the entire landscape. The management strategy should prioritize the protection of early life stages (seedlings to saplings stage) to avoid premature harvest and regulate selective harvesting of the adult stems. Goat herders, pulling the fruiting branches to feed the goat should be restricted. It would be worthwhile to protect the adjacent grids surrounding the MPCA also which harbor good density. The area within the MPCA needs protection to support natural regeneration and sustenance of the gene pool. Most of the peripheral grids are disturbed and needs proper planning to restore the species in open and disturbed areas provided protection is ensured (Figure 4. Density Map).

The entire landscape is worth protection as it is one of the best habitats for conserving *D. hamiltonii* population due to the natural design of the topography and supporting associated species. It provides open areas, gap vegetation and rock crevices, slopes, aspect,

hillocks which create innumerable micro niches. These micro niches ensure seedling establishment and forms vegetation patches with host species which can provide shelter from seedling to adult stage. Studies deepening the role of these variables will be useful for future studies. These micro niches make this habitat a refuge site for the population to establish, recover and sustain in spite of disturbances.

Our results underscore the necessity of long-term studies to monitor the population at different stages and develop appropriate management plans (Nakazono et al. 2004). The effect of harvesting on different size classes and their response to survival, growth, yield and reproduction necessitates investigation to tease apart the effects and enlighten future research on climbers as well as root harvesting species. All plant species are threatened by changes in temperature, rainfall, disruption of associated species, pests, pathogens, anthropogenic influence, habitat fragmentation, destructive harvesting, which could be the causes to push the populations to extinction. World scientists warning to humanity highlights the fact that medicinal plant species are often harvested unsustainably, when combined with the above pressures the stress level increases and the responses can result in decline in biomass, changes in chemical content affecting the quality and safety of medicinal plants. (Applequist et al. 2020). *D. hamiltonii* is holding a cocktail of medicinal properties and expected to be a potential source for more discoveries to unfold in the future, and so it is of high importance which needs to be conserved.

Harvesting *D. hamiltonii* roots can be one of the reasons which disturbs the host as well as the surrounding associated species because these activities enable gaps and create scope for growth of *Lantana camara* and *Hyptis suaveolens* (Accepted name- : *Mesophaerum suaveolens*) bushes accommodating the area. The post effect of disturbance after roots of *D. hamiltonii* is harvested needs investigation.

Though rocky areas encourage regeneration, long and thick roots, in our study the big size stems were found to be growing very well in undisturbed dense forest and also in loamy soil. This information needs to be shared with the stakeholders to grow/cultivate and reduce the pressure from the wild. It is recommended that future studies focus on identifying similar suitable areas to grow, reintroduce, restore *D. hamiltonii* by using technological tools like Ecological niche modelling. Secondly, monitor the effect of harvest on different size classes.

Encouragement of cultivation locally as well as at large-scale can be provided for the farmers through loans or under the NMPB subsidy schemes. Connecting the product to market will ensure livelihoods and reduce pressure from the wild (Homma et al. 1992). Periodic training on sustainability for harvesters, certification of the raw material and programs to monitor the population involving all the stake holders is essential.

Consequences of root harvested plants are difficult to be traced because the loss is below ground and scope of enquiry is invisible and difficult to gauge the population unless monitored periodically. The results from SRF may serve as an example to encourage more such studies across the distribution range, trigger research on root harvested climber species and compare the evidences across the sites. Such efforts would help in formulation of management plans, assessment of its Red List status and help in sustenance of the remaining endemic population.

The presence of many native species like *Wrightia tinctoria, Albiza amara, Psydrax dicoccos*, and *Euphorbia antiquorum* are potential hosts which supports the growth of *D. hamiltonii* at all stages in the forest. *Wrightia tinctoria* is present in all size classes supporting *D. hamiltonii* abundance both naturally as well as through management efforts. These plants can be used for supporting the climbers while planting or domesticating. Conservation organisations and citizen groups alike must foster a collective responsibility towards preserving this habitat and the species by engaging communities and raising awareness about it. Preserving the habitat is not just a matter of ecological conservation but also a means of securing a sustainable future for both the environment and the communities.

Confidence and capacity building among local people (Rist et al. 2016), citizen science reporting of harvesting/ disturbances, will help the Forest Department to save the population. Field demonstration plots on how *D. hamiltonii* can be grown with interpretation units for surrounding villages, schools and panchayats needs to be encouraged. This effort will be useful to disseminate the value of the resource, habitat and engage community.

CONCLUSION

The high and increasing demand for roots, place undue pressures on the wild population and dynamics of *D. hamiltonii.* The management strategy should prioritize the protection of early life stages (seedlings to saplings stage) to avoid premature harvest, equally regulate selective harvesting of the adult stems and

mitigate grazing by strict monitoring and periodic assessment of the population. The impact of root harvest on the reproduction and yield needs to be investigated and monitored on a long-term basis. Intensifying the protection for the MPCA towards the peripheral grids to help natural regeneration and restoring of the population outside the MPCA is highly recommended. Encouragement of local plus large-scale cultivation is inevitable and local citizen science awareness and reporting mechanism of destructive root harvesting will help the forest department to take action and save the remaining population in the wild. It is submitted that the results of this study are based on one site (Savandurga RF) only, hence comparative studies carried out on a regional scale that include both social and ecological analyses will allow to gain better insight into the current population status of *D. hamiltonii*. More collection from the wild and missed conservation actions from the stakeholders at this juncture will lead to depletion of the population in this landscape.

REFERENCES

Ahmad, Z., A. Shahzad, A. Emamverdian, M. Ramakrishnan & Y. Ding (2022). Genus *Decalepis*: Biology, importance and biotechnological interventions. *Agronomy* 12(4): 855. https://doi.org/10.3390/agronomy12040855

Al-Kindi, K.M., P. Kwan, N. Andrew & M. Welch (2017). Impact of environmental variables on Dubas bug infestation rate: A case study from the Sultanate of Oman. *PLoS ONE* 12(5): e0178109. https://doi.org/10.1371/journal.pone.0178109

Anbarashan, M. & N. Parthasarathy (2013). Diversity and ecology of lianas in tropical dry evergreen forests on the Coromandel Coast of India under various disturbance regimes. *Flora* 208: 22–32. https://doi.org/10.1016/j.flora.2012.12.004

Anburaja, V., V. Nandagopalan, S. Prakash & A.L. Prabha (2012). A report of the threatened plant *Decalepis hamiltonii* Wight & Arn. (Asclepiadaceae) from the mid elevation forests of Pachamalai Hills of the Eastern Ghats, Tamil Nadu, India. *Journal of Threatened Taxa* 4(15): 3447–3449. https://doi.org/10.11609/JoTT.o3053.3447-9

Anderson, M.K. & D.L. Rowney (1999). The edible plant *Dichelostemma capitatum*: its vegetative reproduction response to different indigenous harvesting regimes in California. *Restoration Ecology* 7(3): 231–240. https://doi.org/10.1046/j.1526-100X.1999.72016.x

Applequist, W.L., J.A. Brinckmann, A.B. Cunningham, R.E. Hart, M. Heinrich, D.R. Katerere & T. van Andel (2020). Scientists' warning on climate change and medicinal plants. *Planta Medica* 86(01): 10–18. https://doi.org/10.1055/a-1041-3406

Bhattacharyya, N. & S. Sarma (2010). Assessment of availability, ecological feature, and habitat preference of the medicinal herb *Houttuynia cordata* Thunb. in the Brahmaputra Valley of Assam, India. *Environmental Monitoring and Assessment* 160: 277–287. https://doi.org/10.1007/s10661-008-0694-7

Bitariho, R. & A. Emmanuel (2019). Harvesting of wild climbers, food security and ecological implications in Bwindi impenetrable National Park. BMCT, 35 pp.

Burnham, K.P. & D.R. Anderson (2002). *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach* 2nd Edition, Springer Science & Business Media, 488 pp. https://doi.org/10.1007/b97636

Burnham, R.J. (2004). Alpha and beta diversity of lianas in Yasuni, Ecuador. *Forest Ecology and Management* 190: 43–55. https://doi.org/10.1016/j.foreco.2003.10.005

Cai, Z.Q., S.A. Schnitzer, B. Wen, Y.J. Chen & F. Bongers (2009). Liana communities in three tropical forest types in xishuangbanna, South-West China. *Journal of Tropical Forest Science* 21: 252–264.

Campanello, P.I., J.F. Garibaldi, M.G. Gatti & G. Goldstein (2007). Lianas in a subtropical Atlantic Forest: Host preference and tree growth. *Forest Ecology and Management* 242: 250–259. https://doi.org/10.1016/j.foreco.2007.01.040

Chalmers, A.C. & J.C. Turner (1994). Climbing plants in relation to their supports in a stand of dry rainforest in the Hunter Vally, New South Wales. *Proceedings of the Linnaean Society of New South Wales* 114: 73–89. https://biostor.org/reference/67581

Chamberlain, J., R. Bush & A.L. Hammett (1998). Non-timber forest products: the other forest products. *Forest Product Journal* 48: 10–19.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of The Forest Types of India*. Manager of publications, Government of India, Delhi, 404 pp.

Chandra, N., G. Singh, S. Lingwal, M.P.S. Bisht & L.M. Tewari (2020). Habitat preference and availability of medicinal and aromatic plants in alpine meadows of Kumaun Himalaya, Uttarakhand, India. *ENVIS Bulletin Himalayan Ecology* 28: 4.

Chapagain, D.J., H. Meilby & S.K. Ghimire (2019). Plant density and life history traits of *Aconitum spicatum* in North-central Nepal: effects of elevation and anthropogenic disturbances. *Peer Journal* 7: e7574. https://doi.org/10.7717/peerj.7574

Chazdon, R.L. (2003). Tropical forest recovery: Legacies of human impact and natural disturbances. *Perspectives of Plant Ecology, Evolution and Systematics* 6: 51–71. https://doi.org/10.1078/1433-8319-00042

Chettri, A., S.K. Barik, H.N. Pandey & M.K. Lyngdoh (2010). Liana diversity and abundance as related to microenvironment in three forest types located in different elevational ranges of the Eastern Himalayas. *Plant Ecology & Diversity* 3: 175–185. https://doi.org/10.1080/17550874.2010.495140

Cunningham, A.B. (1993a). African medicinal plants. United Nations Educational, Scientific and Cultural Organization: Paris, France, 50 pp.

Cunningham, A.B. (1993b). African Medicinal Plants - Setting Priorities at the Interface between Conservation and Primary Health Care. Working Paper 1, WWF/UNESCO/Kew People and Plants Initiative. Paris, France; UNESCO.

Davenport, T.R.B. & H.J. Ndangalasi (2003). An escalating trade in orchid tubers across Tanzania's Southern Highlands: assessment, dynamics and conservation implications. *Oryx* 37(1): 55–61. https://doi.org/10.1017/S0030605303000127

DeWalt, S.J., K. Ickles, R. Nilus, K.E. Harms & D.F. Burslem (2006). Liana habitat association and community structure in a Bornean lowland tropical forest. *Plant Ecology* 186: 203–216. https://doi.org/10.1007/s11258-006-9123-6

DeWalt, S.J., S.A. Schnitzer & J.S. Denslow (2000). Density and diversity of lianas along a chrono sequence in a central Panamanian lowland forest. *Journal of Tropical Ecology* 16: 1–19. https://doi.org/10.1017/S0266467400001231

Dhatchanamoorthy, N., S. Sangeetha, K. Ravikumar & N.S. Begum (2021). Studies on Grass flora of Savandurga forest from Karnataka India. *Species* 22(70): 187–199.

Ding, Y. & R.G. Zang (2009). Effects of Logging on the Diversity of Lianas in a Lowland Tropical Rain Forest in Hainan Island, South China. *Biotropica* 41: 618–624. https://doi.org/10.1111/j.1744-7429.2009.00515.x

Dovie, D.B.K. (2003). Rural economy and livelihoods from the non-timber forest products trade. Compromising sustainability in southern Africa? *International Journal of Sustainable Development and World Ecology* 10: 247–262. https://doi.

org/10.1080/13504500309469803

Franklin, J., P. McCullough & C. Gray (2000). Terrain variables used for predictive mapping of vegetation communities in Southern California, pp. 331–353. In: Wilson, J.P. & J.C. Gallant (eds.). *Terrain Analysis: Principles and Applications*. John Wiley & Sons, New York, 516 pp.

Fuller, D. (1991). *Medicine from the Wild: An Overview of the Native Medicinal Plant Trade and its Conservation Implications*. TRAFFIC, World Wildlife Fund, 85 pp.

Ganesan, R. & R.S. Setty (2004). Regeneration of "Amla", an Important Non-Timber Forest Product from Southern India. *Conservation and Society* 2(2): 365–375.

Gerwing, J.J. (2004). Life history diversity among six species of canopy lianas in an old-growth forest of the eastern Brazilian Amazon. *Forest Ecology and Management* 190: 57–72. https://doi.org/10.1016/j.foreco.2003.10.006

Gerwing, J.J., S.A. Schnitzer, R.J. Burnham, F. Bongers, J. Chave, S.J. DeWalt, C.E.N. Ewango, R. Foster, M. Martínez-Ramos, M. Parren, N. Parthasarathy, D.R. Pérez-Salicrup, F.E. Putz & D.W. Thomas (2006). A standard protocol for liana censuses. *Biotropica* 38: 256–261. https://doi.org/10.1111/j.1744-7429.2006.00134.x

Ghimire, S.K., D. McKey & Y. Aumeeruddy-Thomas (2005). Conservation of Himalayan medicinal plants: Harvesting patterns and ecology of two threatened species, *Nardostachys grandiflora* DC. and *Neopicrorhiza scrophulariiflora* (Pennell) Hong. *Biological Conservation* 124(4): 463–475. https://doi.org/10.1016/j.biocon.2005.02.005

Ghimire, S.K., O. Gimenez, R. Pradel, D. McKey & Y. Aumeeruddy-Thomas (2008). Demographic variation and population viability in a threatened Himalayan medicinal and aromatic herb *Nardostachys grandiflora*: matrix modelling of harvesting effects in two contrasting habitats. *Journal of Applied Ecology* 45: 41–51. https://doi.org/10.1111/j.1365-2664.2007.01375.x

Gianoli, E., A. Saldana, M. Jimenez-Castillo & F. Valladares (2010). Distribution and abundance of vines along the light gradient in a southern temperate rain forest. *Journal of Vegetation Science* 21: 66–73. https://doi.org/10.1111/j.1654-1103.2009.01124.x

Giridhar, P., D.V. Ramu, B.O. Reddy, T. Rajasekaran & G.A. Ravishankar (2003). Influence of phenylacetic acid on clonal propagation of *Decalepis hamiltonii* wight & ARN: an endangered shrub. In Vitro Cellular & Developmental Biology-Plant 39: 463–467. https://doi.org/10.1079/IVP2003448

Giridhar, P., T. Rajasekaran, S. Nagarajan & G.A. Ravishankar (2004). Production of 2-hydroxy-4-methoxybenzaldehyde in roots. of tissue culture raised and acclimatized plants of *Decalepis hamiltonii* Wight & Arn., an endangered shrub endemic to Southern India and evaluation of its performance vis-a-vis plants from natural habitat. *Indian Journal of Experimental Biology* 42(1): 106–10.

Giridhar, P., T. Rajasekaran & G.A. Ravishankar (2005). Improvement of growth and root specific flavour compound 2-hydroxy-4-methoxy benzaldehyde of micro propagated plants of *Decalepis hamiltonii* Wight & Arn., under triacontanol treatment. *Scientia horticulturae* 106(2): 228–236. https://doi.org/10.1016/j.scienta.2005.02.024

Goraya, G.S. & D.K. Ved (2017). Medicinal plants in India: an assessment of their demand and supply. Dehradun: Ministry of AYUSH. Government of India. Dehradun: New Delhi and Indian Council of Forestry Research and Education.

Gururaj, H.B., P. Giridhar & G.A. Ravishankar (2004). Efficient clonal propagation method for *Decalepis hamiltonii,* an endangered shrub, under the influence of phloroglucinol. *Indian Journal Experimental Biology* 42: 424–428.

Hall, P. & K. Bawa (1993). Methods to Assess the Impact of Extractions of Non-Timber Tropical Forest Products on Plant Population, *Economic Botany* 47: 234-47. https://doi.org/10.1007/BF02862289

Harisha, P.R., R. Gowthami & R.S. Setty (2021). Vocal to local: indigenous dietary practices and diversity of wild food plants in Malai Mahadeswara wildlife sanctuary, South India. *Ethnobotany Research and Applications* 22: 1–27. https://doi.org/10.32859/era.22.22.1-27

Hernandez, B.J.C., N.P. Anten & M. Martínez-Ramos (2015). Sustainable harvesting of non-timber forest products based on ecological and economic criteria. *Journal of Applied Ecology* 52(2): 389–401. https://doi.org/10.1111/1365-2664.12384

Homma, A.K.O. (1992). The dynamics of extraction in Amazonia: a historical perspective. *Advances in Economic Botany* 9: 23–32.

Jagannatha R.R. & G.A. Kinhal (2008). In Ed Adaptive Management of Medicinal Plants and Non-Timber Forest Products: Sustainable harvesting of medicinal plants/ non timber forest products–-adaptive planning and Management, BSMPS, Dehra Dun.

John, T., M. Gunasekar, G. Conklin & M. Dewis (2007). U.S. Patent Application No. 11/329,006.9

Kamireddy, K., P. Matam, P.S. Priyanka & G. Parvatam (2017). Biochemical characterization of a key step involved in 2H4MB production in *Decalepis hamiltonii*. *Journal of Plant Physiology* 214: 74–80. https://doi.org/10.1016/j.jplph.2017.04.006

Kamireddy, K., P.P. Sonbarse, S.K. Mishra, L. Agrawal, P.S. Chauhan, C. Lata & G. Parvatam (2021). Proteomic approach to identify the differentially abundant proteins during flavour development in tuberous roots of *Decalepis hamiltonii* Wight & Arn. *3 Biotech* 11: 1–19. https://doi.org/10.1007/s13205-018-1388-7

Kathriarachchi, H.S., K.U. Tennakoon, C.V.S. Gunatilleke, I.A.U.N. Gunatilleke & P.M.S. Ashton (2004). Ecology of two selected liana species of utility value in a lowland rain forest of Sri Lanka: implications for management. *Conservation and Society* 2(2): 273–288.

Kharat, T.D. & D.N. Mokat (2020). Pharmacognostic and phytochemical studies on *Hemidesmus indicus* and its substitute *Decalepis hamiltonii* - Review. *International Journal of Botany Studies* 5: 224–231.

Kinhal, G.A., R. Jagannatha & L. Anna (2006). A temImage participatory planning and designing for sustainable harvesting of medicinal plants, pp. 147–157. In: Miththapala, S. (ed.). Conserving Medicinal Species: securing a healthy future. IUCN: Ecosystems and Livelihoods Group, Asia, 184 pp.

Kinhal, G.A. & R. Jagannatha (2006). Conservation and Sustainable Management of Medicinal Plants in India, Foundation for Revitalization of Local Health Tradition (FRLHT). Karnataka. http://nbaindia.org/uploaded/docs/ncb_jan_06_17.pdf

Krishnamurthy, V., L. Mandle, T. Ticktin, R. Ganesan, C.S. Saneesh & A. Varghese (2013). Conservation status and effects of harvest on an endemic multi-purpose cycad, *Cycas circinalis* L., Western Ghats, India. *Tropical Ecology* 54(3): 309–320.

Lambert, J., J. Srivastava & N. Vietmeyer (1997). Medicinal plants: rescuing a global heritage (Vol. 355). World Bank Publications. https://doi.org/10.1596/0-8213-3856-0

Mabeluanga, T., A.V.D. Kumar, A. Gayathri & A. Krishnan (2016). Influence of Elephant-human interactions on agrarian communities in the Bengaluru-Bannerghatta landscape–A perspective survey. *Gajah* 45: 28–32.

Mandle, L. & T. Ticktin (2012). Interactions among fire, grazing, harvest and abiotic conditions shape palm demographic responses to disturbance. *Journal of Ecology* 100: 997–1008. https://doi.org/10.1111/j.1365-2745.2012.01982.x

Mandle, L., T. Ticktin, S. Nath, R.S. Setty & A. Varghese (2013). A framework for considering ecological interactions for common non-timber forest product species: a case study of mountain date palm (*Phoenix loureiroi* Kunth) leaf harvest in South India. *Ecological Processes* 2: 1–9. https://doi.org/10.1186/2192-1709-2-21

Mascaro, J., S.A. Schnitzer & W.P. Carson (2004). Liana diversity, abundance, and mortality in a tropical wet forest in Costa Rica. *Forest Ecology and Management* 190: 3–14. https://doi.org/10.1016/j.foreco.2003.10.002

Matam, P., G. Parvatam & N.P. Shetty (2017). Enhanced production of vanillin flavour metabolites by precursor feeding in cell suspension cultures of *Decalepis hamiltonii* Wight & Arn., in shake flask culture 3 Biotech, 7, 376 pp. https://doi.org/10.1007/s13205-017-1014-0

McGeoch, L., I. Gordon & J. Schmitt (2008). Impacts of land use, anthropogenic disturbance, and harvesting on an African medicinal

liana. *Biological Conservation* 141(9): 2218–2229. https://doi.org/10.1016/j.biocon.2008.06.021

McGeoch, L. (2004). Plant Ecology in a Human Context: *Mondia whytei* in Kakamega Forest, Kenya. Undergraduate Thesis. Brown University 81 pp.

McGraw, J.B. & M.A. Furedi (2005). Deer browsing and population viability of a forest understory plant. *Science* 307: 920–922. https://doi.org/10.1126/science.110703

McKechnie, I.M. & R.D. Sargent (2013). Do plant traits influence a species' response to habitat disturbance? A meta-analysis. *Biological Conservation* 168: 69–77. https://doi.org/10.1016/j.biocon.2013.09.023

Mishra, M. (2000). Harvesting practices and management of two critically endangered medicinal plants in the natural forests of central India, pp. 335–341. In: Harvesting of Non-wood Forest Products. FAO-ECE-ILO, Menemen-Izmir, Turkey, 432 pp.

Mishra, M., S. Teki & R.P. Mishra (2003). Sustainable harvesting, value addition and marketing of selected Non timber forest products: A case study of Koraput, Malkangiri Districts, Orissa. Indian Institute of Forest Management, Bhopal (M.P), 120 pp.

Mishra, C.K. & G.R. Naidu (2014). Inventory of non-timber forest products through adaptive cluster sampling. *Indian Forester* 140(1): 1–10.

Mishra, M. & P.C. Kotwal (2003). Sustainable management of some critically endangered species of medicinal plants in central India. Draft Research Project report submitted to Indian Institute of Forest Management, Nehru Nagar, Bhopal (M.P.). India, 105 pp.

Mishra, M. & P.C. Kotwal (2007). Harvesting decline and economics of Baichandi (*Dioscorea daemona*) in the natural forests of central India. *Flora and Fauna* 13(2): 243–248.

Mishra, P., A. Kumar, G. Sivaraman, A.K. Shukla, R. Kaliamoorthy, A. Slater & S. Velusamy (2017). Character-based DNA barcoding for authentication and conservation of IUCN Red listed threatened species of genus *Decalepis* (Apocynaceae). *Scientific Reports* 7(1): 14910. https://doi.org/10.1038/s41598-017-14887-8

Mishra, P., L.D. Kumar, A. Kumar, S. Gokul, K. Ravikumar, A.K. Shukla & V. Sundaresan (2015). Population dynamics and conservation implications of *Decalepis arayalpathra* (J. Joseph & V. Chandras.) Venter., a steno endemic species of Western Ghats, India. *Applied Biochemistry and Biotechnology* 176: 1413–1430. https://doi.org/10.1007/s12010-015-1654-7

Mishra, M. (2011). Immature collection of Baibirang (*Embelia tsjeriam-cottam*) fruits and its impact on raw material quality: a case of Katni district, Madhya Pradesh. *Life Sciences Leaflets* 12: 384–395.

Molur, S. & S. Walker (1997). Report on Conservation Assessment and Management Plan Workshop (C.A.M.P. III) for Selected Species of Medicinal Plants of Southern India. Foundation for Revitalization of Local Health Traditions, Zoo Outreach Organization & CBSG, India Medicinal Plants Specialist Group, SSC, IUCN. Bangalore, 16–18 January 1997, 145 pp.

Muhwezi, O. (1997). The Biology, Use and Impact of Harvesting on the Afromontane Liana (*Loeseneriella apocynoides*) in and around Bwindi Impenetrable National Park, Uganda. M.Sc. Thesis, Makerere University, Kampala, Uganda.

Mulligan, M.R. (2003). Population loss of Goldenseal, *Hydrastis canadensis* L. (Ranunculaceae), in Ohio. M. Sc Thesis, Department of Botany, Miami University, Oxford, Ohio. https://doi.org/10.2307/4126936

Mulligan, M.R. & D.L. Gorchov (2004). Quantifying population loss of goldenseal, *Hydrastis canadensis* L. in Ohio. (Environmental Poster Session). *The Ohio Journal of Science* 103(1): A-12. https://doi.org/10.2307/4126936

Murali, K.S. (2008). Impact of extraction on *Decalepis hamiltonii* Wight & Arn. -an experiment from BR hills, Karnataka, pp. 49. In: Kinhal, G.A. & J.R. Rao (eds.). Adaptive Management of Medicinal Plants and Non-Timber Forest Products: Strategies, Implications and Policy, Dehradun, 49 pp.

Muthumperumal, C. & N. Parthasarathy (2010). A large-scale inventory of liana diversity in tropical forests of South Eastern Ghats, India. *Systematics and Biodiversity* 8(2): 289–300. https://doi.org/10.1080/14772001003723546

Muthuramkumar, S. & N. Parthasarathy (2000). Alpha diversity of lianas in a tropical evergreen forest in the Anamalais, Western Ghats, India. *Diversity and Distributions* 6: 1–14. https://doi.org/10.1046/j.1472-4642.2000.00057.x

Muthuramkumar, S., N. Ayyappan, N. Parthasarathy, D. Mudappa, T.R.S. Raman, M.A. Selwyn & L.A. Pragasan (2006). Plant community structure in tropical rain forest fragments of the Western Ghats, India. *Biotropica* 38: 143–160. https://doi.org/10.1111/j.1744-7429.2006.00118.x

Mohana, D.C., K.A. Raveesha & K.M.L. Rai (2008). Herbal remedies for the management of seed-borne fungal pathogens by an edible plant *Decalepis hamiltonii* (Wight & Arn). *Archives of Phytopathology and Plant Protection* 41(1): 38–49. https://doi.org/10.1080/03235400600654902

Nagarajan, S., L.J.M. Rao & K.N. Gurudutt (2001). Chemical composition of the volatiles of *Decalepis hamiltonii* (Wight & Arn). *Flavour and Fragrance Journal* 16(1): 27–29.

Najafifar, A., J. Hosseinzadeh & A. Karamshahi (2019). The role of hill shade, aspect, and topo shape in the woodland dieback of arid and semi-arid ecosystems: A case study in Zagros woodlands of Ilam province, Iran. *Journal of Landscape Ecology* 12(2): 79–91.

Nakazono, E.M., E.M. Bruna & R.C.G. Mesquita (2004). Experimental harvesting of the non-timber forest product *Ischnosiphon polyphyllus* in central Amazonia. *Forest Ecology and Management* 190: 219–225. https://doi.org/10.1016/j.foreco.2003.10.013

Nantel, P., D. Gagnon & A. Nault (1996). Population viability analysis of American ginseng and wild leek harvested in stochastic environments. *Conservation Biology* 10: 608–621. https://doi.org/10.1046/j.1523-1739.1996.10020608.x

Naveen, S. & F. Khanum (2010). Antidiabetic, antiatherosclerotic and hepatoprotective properties of *Decalepis hamiltonii* in streptozotocin-induced diabetic rats. *Journal of Food Biochemistry* 34(6): 1231–1248. https://doi.org/10.1111/j.1745-4514.2010.00361.x

Navya, B.L., G.R. Smitha, H.S. Yogeesha, P.E. Rajasekharan, Vishnuvardhan & H.M. Pallavi (2019). Seed germination and storage studies in *Decalepis hamiltonii* Wight and Arn.: A threatened medicinal plant. *Medicinal Plants* 11(4): 464–474. https://doi.org/10.5958/0975-6892.2019.00061.3

Ndangalasia, H.J., R. Bitarihob, B.K. Delali & Dovie (2006). Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. *Biological Conservation* 134(2007): 242–250. https://doi.org/10.1016/j.biocon.2006.06.020

Neter, J., M.H. Kutner, C.J. Nachtsheim & W. Wasserman (1996). *Applied Linear Statistical Models*. 4th Edition, WCB McGraw-Hill, New York.

Nirala, V.K., A. Srivastava, M.K. Chaudhary & S. Srivastava (2024). Effect of edaphic factors on phenolic contents in the natural population of *Ichnocarpus frutescens* (L.) R. Br. collected from Central India and Eastern Ghats. *Biochemical Systematics and Ecology* 112: 104759. https://doi.org/10.1016/j.bse.2023.104759

Padaki, A. & N. Parthasarathy (2000). Abundance and distribution of lianas in tropical lowland evergreen forest of Agumbe, central Western Ghats, India. *Tropical Ecology* 41: 143–154.

Pandi, V., K.N. Babu, M. Anbarashan, C.S. Reddy, J. Borgohain, K. Shynyan, A.M. Achamma, H. Rakshith, J. Joseph & V.N. Kennedy (2022). Taxonomic estimates of climbing plants in India: How many species are out there? *Ecoscience 29*(4): 325–343. https://doi.org/10.1080/11956860.2022.2094631

Parren, M.P.E. (2003). Lianas and logging in West Africa PhD thesis, Wageningen University, Wageningen, The Netherlands, 180 pp.

Pascal, J.P. & B.R. Ramesh (1996). *Notes on the sheet Bangalore-Salem*. Institut Français de Pondichéry, 66 pp.

Peres, C.A., C. Baider, P.A. Zuidema, L.H.O. Wadt, K.A. Kainer, D.A.P. Gomes-Silva, R.P. Salomão, L.L. Simões, E.R.N. Franciosi, F.C. Valverde, R. Gribel, G.H. Shepard., M. Kanashiro, P. Coventry, D.W. Yu, A.R. Watkinson & R.P. Freckleton (2003). Demographic threats

to the Sustainability of Brazil Nut Exploitation. *Science (American Association for the Advancement of Science)* 302: 2112–2114. https://doi.org/10.1126/science.1091698

Pfab, M.F. & M.A. Scholes (2004). Is the collection of *Aloe peglerae* from the wild sustainable? An evaluation using stochastic population modelling. *Biological Conservation* 118(5): 695–701. https://doi.org/10.1016/j.biocon.2003.10.018

POWO (2024). "Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://www.plantsoftheworldonline.org/Retrieved 29 May 2024."

Pradeep, M., N.P. Shetty & P. Giridhar (2019). HPLC and ESI-MS analysis of vanillin analogue 2-hydroxy-4-methoxy benzaldehyde in swallow root–the influence of habitat heterogeneity on antioxidant potential. *Acta Scientiarum Polonorum Hortorum Cultus* 18(2): 21–28. https://doi.org/10.24326/asphc.2019.2.3

Pradhan, B.K. & H.K. Badola (2015). *Swertia chirayta*, a threatened high-value medicinal herb: Microhabitats and conservation challenges in Sikkim Himalaya, India. *Mountain Research and Development* 35(4): 374–381. https://doi.org/10.1659/MRD-JOURNAL-D-14-00034.1

Prasad, R., P.C. Kotwal & M. Mishra (2003). Harvesting practices of *Buchanania lanzan* fruits and its impact on the fruit and seed quality. *Van ki Sandesh* 27(4): 9–24.

Prasad, R., P.C. Kotwal & M. Mishra (2002). Harvesting practices of Safed Musli (*Chlorophytum* spp.) and its ecological impact on the natural forests of central India. *Journal of Tropical Forestry* 18(1): 9–24.

Premalatha, K., S. Gokul, A. Kumar, P. Mishra, P. Mishra, K. Ravikumar & A. Kalra (2015). Molecular profiling of fungal assemblages in the healthy and infected roots of *Decalepis arayalpathra* (J. Joseph & V. Chandras) Venter, an endemic and endangered ethnomedicinal plant from Western Ghats, India. *Annals of Microbiology* 65(2): 785-797. https://doi.org/10.1007/s13213-014-0919-7

Proctor, J., J.M. Anderson, P. Chai & H.W. Vallack (1983). Ecological studies in four contrasting lowland rain forests in Gunung Mulu National Park, Sarawak. I. Forest environment, structure and floristics. *Journal of Ecology* 71: 273–260. https://doi.org/10.2307/2259731

Putz, F.E. (1983). Liana biomass and leaf area of a 'terra firme' forest in the Rio Negro Basin, Venezuela. *Biotropica* 15: 185–189.

Putz, F.E. (1984) The natural history of Lianas on Barro Colorado Island, Panama. *Ecology* 65: 1713–1724. https://doi.org/10.2307/1937767

Putz, F.E. & P. Chai (1987). Ecological studies of lianas in Lambir National Park, Sarawak, Malaysia. *Journal of Ecology* 75: 523–531. https://doi.org/10.2307/2260431

Putz, F.E. & H.A. Mooney (eds.). (1991). *The Biology of Vines*. Cambridge University Press, 512 pp.

R Core Team (2020). R Core Team R: a language and environment for statistical computing. Foundation for Statistical Computing.

Raju, A.S. & K.V. Ramana (2009). Traditional preparation of a health drink Nannari Sharbat from the root extract of *Decalepis hamiltonii* Wight & Arn. *Indian Journal of Natural Products and Resources* 2(1): 121–124.

Rajashekar, Y., N. Gunasekaran & T. Shivanandappa (2010). Insecticidal activity of the root extract of *Decalepis hamiltonii* against stored-product insect pests and its application in grain protection. *Journal of Food Science and Technology* 47: 310–314.

Rai, A., A. Chettri, A. Pradhan, S.K. Rai, A.K. Rai & N.T. Lepcha (2016). Diversity of climbing plants in 'Gadi' sacred grove of Central Pendam in East Sikkim, India. *Pleione* 10(1): 97–107. https://doi.org/10.5897/JMPR2013.5099

Rao, P.S. & M.S. Reddy (2022). Study on frequency distribution of lianas on trees in dry deciduous forests of Guvvalacheruvu, Southern Eastern Ghats, Andhra Pradesh, India. *Indian Journal of Ecology* 49(4): 1283–1286.

Ravikumar, K. & D.K. Ved (2000). Illustrated Field Guide to 100 Red Listed Medicinal Plants of Conservation Concern in Southern India. Foundation for Revitalisation of Local Health Traditions, Bangalore, India.

Reddy, M.S. & N. Parthasarathy (2003). Liana diversity and distribution in four tropical dry evergreen forests on the Coromandel coast of south India. *Biodiversity and Conservation* 12: 1609–1627. https://doi.org/10.1023/A:1023620901624

Reddy, M.S. & N. Parthasarathy (2006). Liana diversity and distribution on host trees in four inland tropical dry evergreen forests of peninsular India. *Tropical Ecology* 47: 109–123.

Reddy, M.C. & K.S.R. Murthy (2013). A review on *Decalepis hamiltonii* Wight & Arn. *Journal of Medicinal Plants Research* 7(41): 3014–3029. https://doi.org/10.5897/JMPR2013.5099

Rice, K., N. Broka & J. Thompson (2004). Liana abundance in a Puerto Rican Forest. *Forest Ecology and Management* 190: 33–41. https://doi.org/10.1016/j.foreco.2003.10.004

Rist, L., C.M. Shackleton, L. Gadamus, F.S. Chapin, C.M. Gowda, R.S. Setty, R. Kannan & R.U. Shaanker (2016). Ecological knowledge among communities, managers and scientists: bridging divergent perceptions to improve forest management outcomes. *Environmental Management* 57: 798–813. https://doi.org/10.1007/s00267-015-0647-1

Robbins, C.S. (2000). Comparative analysis of management regimes and medicinal plant trade monitoring mechanisms for American ginseng and goldenseal. *Conservation Biology* 14: 1422–1434. https://doi.org/10.1046/j.1523-1739.2000.99100.x

Rodrigues, V., A. Kumar, S. Gokul, A.K. Shukla, K. Ravikumar & V. Sundaresan (2021). *Decalepis salicifolia* (Bedd. ex Hook. f.) Venter: A steno-endemic and critically endangered medicinal and aromatic plant from Western Ghats, India. *Journal of Biosciences* 46(2): 44. https://doi.org/10.1007/s12038-021-00162-6

Sardeshpande, M. & C. Shackleton (2019). Wild edible fruits: a systematic review of an under-researched multifunctional NTFP (non-timber forest product). *Forests* 10(6): 467. https://doi.org/10.3390/f10060467

Schnitzer, S.A, S.A. Mangan, J.W. Dalling, C.A. Baldeck, S.P. Hubbell, A. Ledo, H. Muller-Landau, M.F. Tobin, S. Aguilar, D. Brassfield & A. Hernandez (2012). Liana Abundance, Diversity, and Distribution on Barro Colorado Island, Panama. *PLoS ONE* 7(12): e52114. https://doi.org/10.1371/journal.pone.0052114

Schnitzer, S.A. (2005). A mechanistic explanation for global patterns of liana abundance and distribution. *American Naturalist* 166: 262–276. https://doi.org/10.1086/431250

Schnitzer, S.A. & F. Bongers (2002). The ecology of lianas and their role in forests. *Trends in Ecology and Evolution* 17: 223–230. https://doi.org/10.1016/S0169-5347(02)02491-6

Schnitzer, S.A. & W.P. Carson (2001). Treefall gaps and the maintenance of species diversity in a tropical forest. *Ecology* 82: 913–919. https://doi.org/10.1890/0012-9658(2001)082[0913:TGATMO]2.0.CO;2

Schnitzer, S.A., J.W. Dalling & W.P. Carson (2000). The impact of lianas on tree regeneration in tropical forest canopy gaps: evidence for an alternative pathway of gap-phase regeneration. *Journal of Ecology* 88: 655–666.156. https://doi.org/10.1046/j.1365-2745.2000.00489.x

Schnitzer, S.A., M.E. Kuzee & F. Bongers (2005). Disentangling above- and below-ground competition between lianas and trees in a tropical forest. *Journal of Ecology* 93: 1115–1125. https://doi.org/10.1111/j.1365-2745.2005.01056.x

Schnitzer, S.A., M.P.E. Parren & F. Bongers (2004). Recruitment of lianas into logging gaps and the effects of pre-harvest climber cutting in a lowland forest in Cameroon. *Forest Ecology and Management* 190: 87–98. https://doi.org/10.1016/j.foreco.2003.10.008

Schnitzer, S.A. & F. Bongers (2002). The ecology of lianas and their role in forests. *Trends in Ecology and Evolution* 17(5): 223–230. https://doi.org/10.1016/S0169-5347(02)02491-6

Schnitzer, S.A., S.J. DeWalt & J. Chave (2006). "Censusing and Measuring Lianas: A Quantitative Comparison of the Common Methods" Biological Sciences Faculty Research and Publications, 792 pp. https://epublications.marquette.edu/bio_fac/792

Shackleton, C.M., G. Guthrie & R. Main (2005). Estimating the potential role of commercial over-harvesting in resource viability: a case study of five useful tree species in South Africa. *Land Degradation &*

Development 16(3): 273–286. https://doi.org/10.1002/ldr.652

Shackleton, C.M., A.K. Pandey & T. Ticktin (2015). *Ecological sustainability for Non-Timber Forest Products: Dynamics and Case Studies of Harvesting*. Routledge, New York, USA, 280 pp. https://doi.org/10.4324/9781315851587

Shankar, D. & D.K. Ved (2003). A balanced perspective for management of Indian medicinal plants. *Indian Forester* 129(2): 275–288.

Shankar, K.U., P. Matam & G. Parvatam (2022). In vitro-derived plants grown from low nitrate medium produced quality tubers in *Decalepis hamiltonii* Wight & Arn. 3 *Biotech* 12: 200. https://doi.org/10.1007/s13205-022-03256-6

Shankar, K.U. (2022). Biotechnological approaches for enhancement of bio-actives in tubers of *Decalepis hamiltonii.* PhD Thesis. Department of Plant Cell Biotechnology, CSIR-Central Food Technological Research Institute.

Sharma, S. & A. Shahzad (2014). An overview on *Decalepis*: a genus of woody medicinal climbers. *Journal of Plant Science and Research* 1(1): 104.

Singh, M., M. Singh, H.N. Kumara, S. Kumar, S.D. Gnanaolivu & R. Sasi (2021). A review of research on the distribution, ecology, behaviour, and conservation of the Slender Loris *Loris lydekkerianus* (Mammalia: Primates: Lorisidae) in India. *Journal of Threatened Taxa* 13(11): 19540–19552. https://doi.org/10.11609/jott.7562.13.11.19540-19552

Somashekhar, B.S. (2013). Conservation of Medicinal Plants in Karnataka: Initiatives so far, Gaps and Challenges ahead, Sahyadri newsletter, Issue 36. Accessed on 19 March 2024. http://wgbis.ces.iisc.ernet.in/biodiversity/sahyadri_enews/newsletter/issue36/article/index.html

Soumya, K.V., C.M. Shackleton & S.R. Setty (2019a). Harvesting and local knowledge of a cultural non-timber Forest product (NTFP): gum-resin from *Boswellia serrata* Roxb. in three protected areas of the Western Ghats, India. *Forests* 10(10): 907. https://doi.org/10.3390/f10100907

Soumya, K.V., C.M. Shackleton & S.R. Setty (2019b). Impacts of gum-resin harvest and *Lantana camara* invasion on the population structure and dynamics of *Boswellia serrata* in the Western Ghats, India. *Forest Ecology and Management* 453: 117618. https://doi.org/10.1016/j.foreco.2019.117618

Srivastava, J., J. Lambert & N. Vietmeyer (1996). *Medicinal Plants: An Expanding Role in Development (English)*. World Bank-Technical papers, Washington, DC, 320 pp.

Srivastava, A. & T. Shivanandappa (2009). *Decalepis hamiltonii* roots boost antioxidant status of rat liver and brain. *Journal of the Science of Food and Agriculture* 89(14): 2461–2466.

Stanley, D., R. Voeks & L. Short (2012). Is non-timber forest product harvest sustainable in the less developed world? A systematic review of the recent economic and ecological literature. *Ethnobiology and Conservation* 1: 1–39. https://doi.org/10.15451/ec2012-8-1.9-1-39

Stewart, K.M. & D. Cole (2005). The commercial harvest of devil's claw (*Harpagophytum* spp.) in southern Africa: The devil's in the details. *Journal of Ethnopharmacology* 100(3): 225–236. https://doi.org/10.1016/j.jep.2005.07.004

Sukumar, R., H.S. Suresh, H.S., Dattaraja, S. Srinidhi & C. Nath (2005). Dynamics of a tropical dry forest at Mudumalai (India): climate, fire, elephants and the evolution of life history strategies, pp. 510–529. In: Burslem, D., M. Pinard & S. Hartley (eds.). *Biotic Interactions in the Tropics*. Cambridge University Press, UK, 572 pp.

Thriveni, H.N., V.G. Srikanth, H.N.R. Babu & R. Vasudeva (2015). Ecological niche modelling, population status and regeneration of *Coscinium fenestratum* Colebr. (Menispermaceae): a medicinally important liana of the central Western Ghats. *Tropical Ecology* 56(1): 101–110.

Ticktin, T. & T. Johns (2002). Chinanteco management of *Aechmea magdalenae*: Implications for the use of TEK and TRM in management plans. *Economic Botany* 56(2): 177–191. https://doi.org/10.1663/0013-0001(2002)056[0177:CMOAMI]2.0.CO;2

Ticktin, T. (2004). The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology* 41(1): 11–21. https://doi.org/10.1111/j.1365-2664.2004.00859.x

Ticktin, T., R. Ganesan, M. Paramesha & R.S. Setty (2012). Disentangling the effects of multiple anthropogenic drivers on the decline of two tropical dry forest trees. *Journal of Applied Ecology* 49(4): 774–784. https://doi.org/10.1111/j.1365-2664.2012.02156.x

Murali, K.S., U. Shankar, R.U. Shaanker, K.N. Ganeshaiah & K.S. Bawa (1996). Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP Extraction on Regeneration, Population Structure, and Species Composition. *Economic Botany* 50(3): 252–269. https://doi.org/10.1007/BF02907329

Valente, T.P. & R.R.B. Negrelle (2011). Harvesting of cipo´-preto (roots of *Philodendron corcovadense* Kunth) in the south of Brazil. *Forest Trees and Livelihoods* 20: 2–3. https://doi.org/10.1007/BF02907329

Ved, D.K., S.N. Begum, K. Ravikumar, R.V. Sankar & R. Karthikeyan (eds.) (2004). *Medicinal Plants of Karnataka State, India: presence across 13 MPCAs. Conservation Research Group*. Foundation for Revitalisation of Local Health Traditions (FRLHT), Bengaluru.

Ved, D.K. & G.S. Goraya (2007). *Demand and Supply of Medicinal Plants in India*. National Medicinal Plants Board, BSMPS, New Delhi, xviii + 211 pp.

Ved, D.K., D. Saha, K. Ravikumar & K. Haridasan (2015). *Decalepis hamiltonii*. The IUCN Red List of Threatened Species 2015: e.T50126587A50131330. https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T50126587A50131330.en. Accessed on 31 May 2024.

Vedavathy, S. (2004). *Decalepis hamiltonii* - An endangered source of indigenous health drink. *Natural Product Radiance* 3(1): 1–60.

Wagner, A. & J.B. McGraw (2013). Sunfleck effects on physiology, growth, and local demography of American Ginseng (*Panax quinquefolius* L.). *Forest Ecology and Management* 291: 220–227. https://doi.org/10.1016/j.foreco.2012.11.038

Xu, L., F. Liaqat, J. Sun, M.I. Khazi, R. Xie & D. Zhu (2024). Advances in the vanillin synthesis and biotransformation: A review. *Renewable and Sustainable Energy Reviews* 189(part A): 113905. https://doi.org/10.1016/j.rser.2023.113905

Yuan, C.M., W.Y. Liu, C.Q. Tang & X.S. Li (2009). Species composition, diversity, and abundance of lianas in different secondary and primary forests in a subtropical mountainous area, SW China. *Ecological Research* 24: 1361–1370. https://doi.org/10.1007/s11284-009-0620-7

Appendix 1. Disturbance scoring and conservation implications of Savandurga Reserve Forest (24 sites/grids) with site description.

Grid	Site	Fire	Invasive plants	Collection of fruits, green, etc.	Grazing, chopping	Herbivory	Transport-frequency	Pathways	People Footfalls	Adventure sports	Distance from villages	Drying of roots	Roots removal	Disturbance score	Dist. code
G10	KTK	1	3	0	0	0	0	1	0	0	1	1	4	11	**High**
G17	GKM	1	2	0	0	0	0	1	1	0	1	1	4	11	**High**
G18	BKM	0	1	0	0	0	0	0	0	0	1	10	4	16	**High**
G23	ITE	0	1	1	1	1	0	1	1	0	3	0	2	11	**High**
G24	SFH	0	3	0	1	1	3	2	2	4	4	0	3	23	**High**
G31	AAS	1	2	1	3	1	3	2	2	4	4	0	3	26	**High**
G33	VBD	0	1	0	0	1	0	0	0	0	3	2	4	11	**High**
G38	VTK	0	3	1	1	1	3	2	2	4	4	0	4	25	**High**
G39	JKB	1	1	0	1	0	0	1	0	0	4	0	4	12	**High**
G60	MR1	1	3	1	1	0	1	1	0	0	4	0	4	16	**High**
G61	MR2	0	1	1	1	1	2	0	0	0	4	0	4	14	**High**
G25	MPCA	0	1	0	0	0	0	0	0	0	0	0	0	1	**Less**
G40	DAD	0	1	0	0	0	0	0	0	0	4	0	0	5	**Less**
G46	KOH	0	1	0	0	0	0	0	0	0	2	0	2	5	**Less**
G47	DBO	0	1	0	1	0	0	1	0	0	2	0	0	5	**Less**
G53	HCG	0	1	0	0	0	1	0	0	0	3	0	0	5	**Less**
G54	MST	0	1	0	0	0	0	0	0	0	4	0	0	5	**Less**
G69	KPN	0	1	0	0	0	0	0	1	0	3	0	0	5	**Less**
G16	ITM	1	2	0	0	0	0	1	1	0	1	0	0	6	**Medium**
G22	ITG	1	1	1	1	0	0	1	0	0	1	0	1	7	**Medium**
G32	DGK	0	1	0	0	0	0	0	0	0	4	0	2	7	**Medium**
G45	NK	0	1	0	0	0	0	1	0	0	4	0	4	10	**Medium**
G62	MR3	0	1	0	0	1	2	0	0	0	3	0	0	7	**Medium**
G76	KPS	0	1	0	1	0	1	0	0	0	3	0	1	7	**Medium**

Criteria for disturbance level calculated for each grid/site level based on field observation.
Site disturbance scores were obtained by assessing all 24 grids/sites which include the following:

1. Resource removal, roots harvested by different methods–- uprooted, chopped up to the stem, no of uprooted holes vary–- absent–- 0, partially harvested–- 1, completely harvested, uprooted chopped (>5 ind.), 5–- 10 stems dug in that area–- 3, more than 10 stems harvested–- 4

2. Accessibility at a Minimum Distance of nearby villages.–- 500m–- 4, 1000m–- 3, 1500 m- 2, 2000 m- 1.

3. Pathway–- Road absent–- 0, Mud Road–- 1, Tar Road–- 2.

4. People footfalls–- Absent- 0, interior small worship places visited rarely once in a year by very few families–- 1, regular visit to main temples- 2. The main temples of SRF are visited frequently weekly (rare-frequently).

5. Adventure habits–- rock climbing, nature park, trekking. Trekking, birding, boating camps on the other side of the hill i.e., near the Manchanabele waters.

6. Herbivory observed–- Porcupines–- 1, Wild boar–- 2.

7. Fire–- Low- level fires to clear the weeds.–- observed fire–- yes–- 1, no–- 0.

8. Grazing and chopping of *D. hamiltonii* climbers–- Absent–- 0, cattle–- 1, goats–- 2.

9. Invasive species–- 1–- less, 2–- medium, 3–- high.

10. Drying roots–- absent- 0, evidence of people staying to process the roots–- 5, cooking also–- 10, (high weightage has been given this point).

11. Collection of other NTFPs or medicinal plants–- Bela (*Feronia elephantum*), Soppu (Greens), Genasu (Tubers), medicinal plants–- yes–- 1, no–- 0.

12. Transport frequency–- absent–- 0, adventure cycles and two- wheelers- 4, weekend 2 wheelers, & four wheelers–- 3, local autos and transport–- 2, Govt vehicles–- 1.

Overall Disturbance score of each site–Values ranging from 0–- 5 as Less Disturbed, 6–- 10 as Medium Disturbed, and above 10 onwards - Highly Disturbed.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25571–25576

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

https://doi.org/10.11609/jott.9122.16.7.25571-25576

#9122 | Received 01 May 2024 | Final received 02 July 2024 | Finally accepted 08 July 2024

OPEN ACCESS

COMMUNICATION

Small Wild Cats Special Series

Rare encounters: Jungle Cat *Felis chaus* Schreber, 1777 (Mammalia: Carnivora: Felidae) in the lower reaches of the Jordan River, Jordan

Ehab Eid [1] & **Mohammad Farid Alayyan** [2]

[1] Lutfi Queder Street, Al-Yadodah 11610, Amman, Jordan.
[2] Ghzaleh Street, Khelda Um Alsummaq, Amman, Jordan.
[1] eha_jo@yahoo.com (corresponding author), [2] blueberrytradingest@gmail.com

Abstract: The Jungle Cat *Felis chaus* is classified as critically endangered in Jordan due to its limited distribution and presumed population decline. We present new evidence for its presence in the lower Jordan River region, where it was recorded opportunistically during a monitoring program focused on the Golden Jackal *Canis aureus*. Five photographs of the Jungle Cat were obtained between June 2020 and February 2022, primarily during night-time and early morning hours. In view of these findings, we recommend urgent implementation of conservation measures, including other effective area-based conservation measures, particularly in military-controlled zones with limited accessibility where confirmed sightings occurred.

Keywords: Bycatch, camera trap, citizen science, habitats suitability, human-induced threats, northern ghor, other effective conservation measures, private farms, riverbed, threatened species.

تم تصنيف قط الغابات في الأردن كنوع مهدد بالانقراض بشكل حرج نظراً لتوزيعه الجغرافي المحدود والانخفاض المحتمل في أعداد جموعه. نقدم في هذا البحث أدلة جديدة تثبت وجود هذا النوع في المناطق السفلية من نهر الأردن، حيث تم تصويره بشكل انتهازي خلال برنامج مراقبة لحيوانات ابن آوى. تم التقاط خمس صور لقط الغابات في ساعات الليل والصباح الباكر في الفترة الواقعة ما بين شهر حزيران للعام 2020 وشهر شباط من العام 2022. في ضوء هذه النتائج، نوصي بتطبيق تدابير عاجلة أخرى لحماية المناطق بفعالية، لا سيما تلك المناطق التي تخضع لإدارة القوات المسلحة الأردنية والتي توفر ملاذات للأنواع لمحدودية إمكانية الوصول إليها.

Editor: Angie Appel, Wild Cat Network, Germany.

Date of publication: 26 July 2024 (online & print)

Citation: Eid, E. & M.F. Alayyan (2024). Rare encounters: Jungle Cat *Felis chaus* Schreber, 1777 (Mammalia: Carnivora: Felidae) in the lower reaches of the Jordan River, Jordan. *Journal of Threatened Taxa* 16(7): 25571–25576. https://doi.org/10.11609/jott.9122.16.7.25571-25576

Funding: This project is self-funded by the authors.

Competing interests: The authors declare no competing interests.

Author details: Mr. Ehab Eid is a steering committee member in the IUCN SSC, vice chair for West Asia, and an editorial board member at IUCN, with over 22-years of experience in terrestrial and marine biodiversity conservation and protected areas management in the Middle East. Mr. Mohammad Farid Alayyan has worked with INGOs such as OXFAM and managed a family agriculture venture focused on citrus. His experience in this private enterprise at a migration stopover site has enriched his knowledge of species and conservation efforts.

Author contributions: E.E and M.F.A participated in research design and data collection. E.E. analyzed data and wrote the manuscript. E.E and M.F.A reviewed the article and gave final approval for publication.

Acknowledgements: We extend our gratitude to all farmers for their support and cooperation during the survey. We also appreciate the valuable suggestions and comments from the reviewers and Angie Appel, which significantly enhanced the content of the manuscript.

INTRODUCTION

Consensus across various red list assessments indicates a decline in the Jungle Cat *Felis chaus* population at national, regional, and global levels, in addition to the paucity of available information. It has been assessed as Least Concern on the IUCN Red List, and the global population is thought to be declining (Gray et al. 2016). However, regional assessments in West Asia vary. It is classified as Data Deficient in the Mediterranean Region and the Arabian Peninsula (Temple & Cuttelod 2009; Jdeidi et al. 2010; Mallon et al. 2023), but Critically Endangered in Jordan due to limited occupancy and presumed population decline (Eid et al. 2020).

The Jungle Cat is distributed across a wide range, from the Anatolian region in Turkey (Gerngross 2014; Ünal & Eryilmaz 2020) southward to the Nile River valley in Egypt (Basuony 2000). In the Levant, it occurs in southern Lebanon, Palestine and western Jordan (Qumsiyeh 1996; Amr 2000; Tohme & Tohme 2000). To the east of the Levant, its range extends to the Euphrates and Tigris Rivers in Syria and Iraq (Masseti 2009; Al-Zubaidi et al. 2017; Mallon et al. 2023), the Iranian Plateau and the Caucasus (Sanei et al. 2016; Askerov et al. 2022) to central, southern, and southeastern Asia (Gray et al. 2016).

The Jungle Cat is considered rare in Jordan, with a limited distribution mainly confined to the country's northwestern region (Eid et al. 2020). Information about it is scarce, possibly due to restricted access to the Jordan River, designated as a military zone with limited access for people (Abu Baker et al. 2003). The only known records are two deceased specimens found on 10 February 1998 in Al–Baqurah within the Yarmouk River Valley (Abu Baker et al. 2003; Eid et al. 2020). Since then, there have been no further records on its status or potential distribution in Jordan. Abu Baker et al. (2003) suggested that its range might extend to the lower regions of the Jordan River and its main tributaries.

Here we report photographic evidence of the continued presence of the Jungle Cat in Jordan obtained during a monitoring survey targeting the Golden Jackal *Canis aureus* in northwestern Jordan.

Study area

Our survey was conducted in the lower reaches of the Jordan River between the Sea of Galilee and the Dead Sea in Jordan (Ibrahim et al. 1976; Katz 2022). The study area encompassed a 9.9 ha private farm in Sheikh Hussein, northern Ghor (Figure 1), cultivating citrus varieties using irrigation, fertilization, and herbicide control. The farm boundaries extend to the Jordan River, and the farm's landscape features riparian vegetation dominated by Common Reed *Phragmites communis*, Cattail *Typha domingensis,* and Athel Tree *Tamarix aphylla*. Additionally, various shrubs and herbs thrive, including Sieber's Wormwood *Artemisia sieberi*, Christ's Thorn Jujube *Ziziphus spina-christi*, Arabian Fagonia *Fagonia arabica,* and Common Mallow *Malva sylvestris*. The farm serves as a sanctuary for migratory birds such as ducks, herons, egrets and storks. Despite this, the dense reed may pose a fire hazard, prompting farmers to actively manage it through removal, controlled burning or herbicide application to maintain a sustainable farming environment.

MATERIALS AND METHODS

We deployed four Dark Ops HD MAX Browning camera traps that were set to a trigger speed of 0.6 seconds with a trigger delay of one second. The cameras were active for 24 hours at the same locations during the entire study period and were checked monthly. They were fastened to iron sticks anchored in the riverbed and positioned approximately 40–50 cm above ground in both south and north directions to avoid false records during sunrise and sunset. No bait was used to ensure neutral data collection. Their locations were determined using a Garmin eTrex 20x device set to datum WGS84.

RESULTS

Our total survey effort covered 2,548 camera trap days at four locations from 1 June 2020 to 28 February 2022. We obtained five photographs of solitary Jungle Cats at all four camera trap locations. Four records occurred during late-night or early-morning hours and one in the afternoon. In 2021, the Jungle Cat was photographed on 12 January at 1258 h, 17 January at 2133 h, 11 April at 2135 h, and 3 September at 2241 h. The only record in 2022 occurred on 30 January at 0212 h (Image 1).

During the survey, several other species were recorded, including the Golden Jackal *Canis aureus*, Egyptian Mongoose *Herpestes ichneumon*, Wild Boar *Sus scrofa*, Red Fox *Vulpes vulpes*, various rodent and numerous bird species.

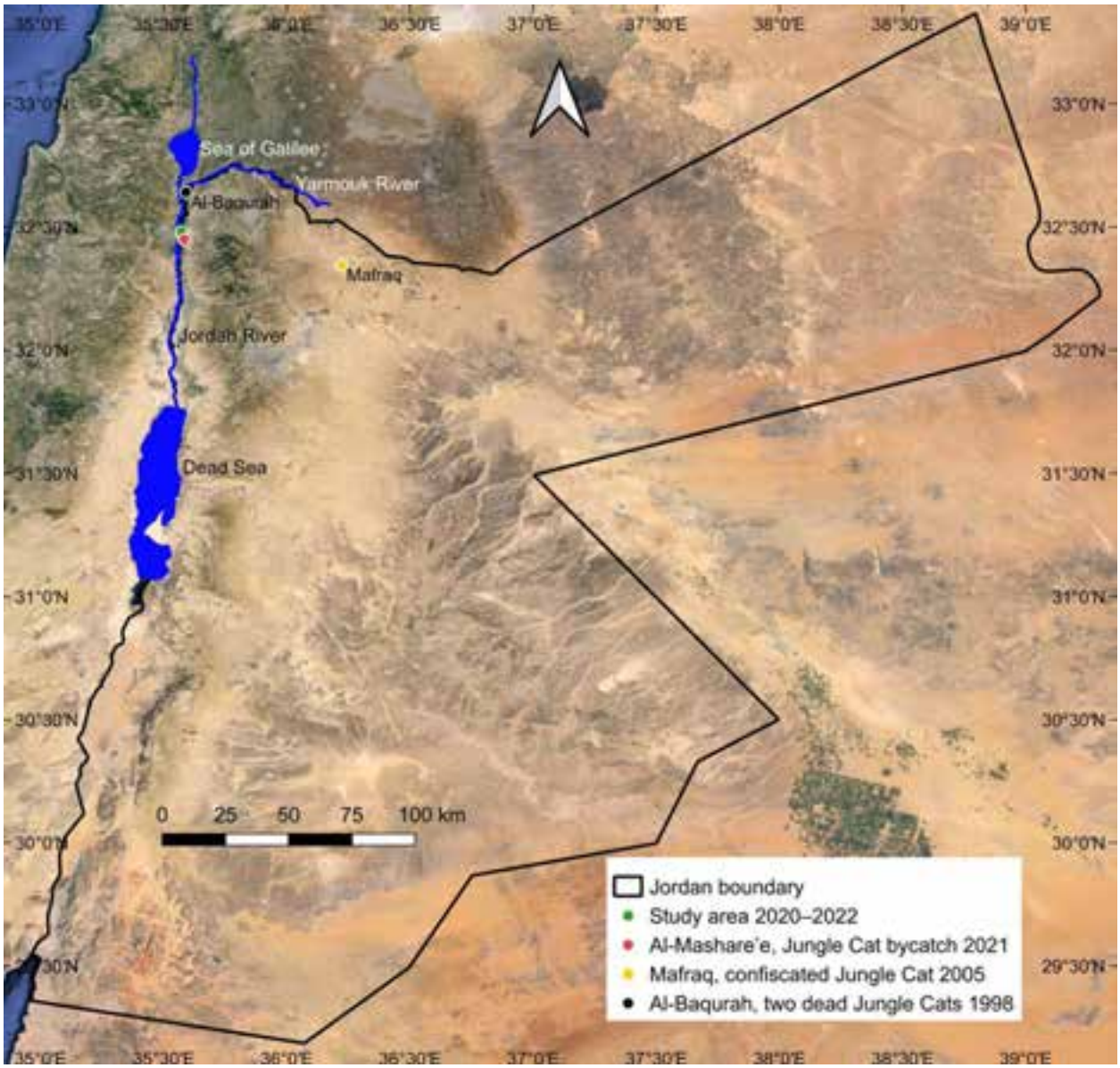


Figure 1. Map showing study area and locations where Jungle Cats were encountered between February 1998 and January 2022 in Jordan.

DISCUSSION

Our survey is the first camera-trapping study in the Jordan River basin. Our results confirm the continued presence of the Jungle Cat in the lower reaches of the Jordan River nearly 22 years after two dead specimens were found near the Yarmouk River, a tributary of the Jordan River (Abu Baker et al. 2003). However, the limited number of photographs did not allow to determine the number of individuals in our study area.

We consider the agricultural setting of our study area and its surroundings to represent a suitable habitat for the Jungle Cat. Thick and dense riparian vegetation along riverbeds has been suggested to provide ideal hiding and movement spaces (Abu Baker et al. 2003; Masseti 2009; Sanei et al. 2016; Eid et al. 2020; Mishra et al. 2020; Desai et al. 2022). As documented by our survey, the area also hosts abundant rodents, which constitute the most important prey items of the Jungle Cat (Mukherjee et al. 2004; Majumder et al. 2011; Rostro-García et al. 2021).

The camera traps frequently documented four feral dogs *Canis familiaris* on the farm, which the owner kept after rescuing them. Despite more than 18 months of study duration, the Jungle Cat was recorded rather infrequently. The low detection rate can be attributed to the dense growth of reed plants, which significantly hindered visibility, affected the quality of photographs

Image 1. Jungle Cats photographed in the study area between 12 January 2021 and 30 January 2022. © Ehab Eid.

and resulted in numerous photographs of plants swaying in the wind. This situation required considerable effort to repeatedly remove reed growth. Active agricultural operations of workers, roaming feral dogs, Golden Jackals and other wildlife using the same habitat day and night added complexity to the recording environment. However, this challenging setting might also benefit the Jungle Cats, allowing them to manoeuvre quietly through dense vegetation (Abu Baker et al. 2003) and avoid encounters with humans, feral dogs and other competitors. The low detection rate of the Jungle Cat can also be attributed to the exceedingly small population within our study area and its surroundings.

We identified several human-induced threats to the Jungle Cat population, consistent with findings by other scholars (Abu Baker et al. 2003; Eid et al. 2020, 2022). These threats include habitat alteration, fragmentation and degradation due to agricultural expansion,

the burning of wetland reeds, prey depletion from widespread pesticide use, and bycatch. An incident of bycatch involved the capture of an adult Jungle Cat in November 2021 in the Al-Mashare'e area, approximately 6 km south of our study area. The cat was caught in a net intended for chicken protection but escaped after being video-recorded. Further investigations using citizen science may reveal more instances of accidental or incidental hunting of the Jungle Cat, potentially challenging literature that suggests no hunting of this species occurs in Jordan (Abu Baker et al. 2003; Eid & Handal 2018). Elsewhere in its range, the Jungle Cat is threatened by the conversion of natural wetlands to agricultural lands, excessive destruction and burning of reeds, pollution due to extensive pesticide use, and poaching (Ogurlu et al. 2010; Gray et al. 2016; Sanei et al. 2016; Barkat et al. 2021).

Furthermore, the restricted niche where wild and domestic species coexist exacerbates the threat to the Jungle Cat. This was confirmed through species distribution models assessing suitable habitats for the Jungle Cat in Jordan, which revealed a significant decline in these habitats. Projections indicate a 33% reduction by 2050 and a staggering loss of 90% by 2070 under the Representative Concentration Pathways (RCP) 2.6 scenario. Even under the RCP 8.5 scenario, an 84% habitat loss is forecasted by 2070 (Eid et al. 2022). These alarming trends emphasize the need for conservation efforts to protect the Jungle Cat from extinction. It was not documented in Jordan's trade or folk medicine (Eid et al. 2011; Aloufi & Eid 2016). A single individual, claimed to be brought from Syria, was confiscated at a private farm in Mafraq city in eastern Jordan in 2005 (Ehab Eid, unpublished data).

The designation of Yarmouk protected area in 2010 in the Yarmouk River valley and the military control of border areas may be beneficial for the conservation of the Jungle Cat, in view of historical records of dead specimens in this area (Abu Baker et al. 2003). No sightings have been recorded within the protected area to date (Sufian Al-Yahya, pers. comm. 3 February 2024). This absence of sightings may be due to restricted site access or limited survey efforts. Therefore, targeted research and collaboration with the military are essential to determine the Jungle Cat's status.

Despite the Jungle Cat being listed in Appendix I of the Wildlife Protection of the Agricultural Law Number 13 of 2015, based on Regulation Number 43 of 2008, enforcing these legal instruments in Jordan is ineffective. Mitigating threats and preventing species extinction requires a thorough review and development of the legal framework associated with effective implementation.

The Jungle Cat's presence within this limited access protected zone underscores the critical need for targeted conservation measures. The Jordanian government, particularly the Ministry of Environment and conservation organizations such as the Royal Society for the Conservation of Nature, should explore establishing Other Effective Area-Based Conservation Measures (OECMs). Farhadinia et al. (2022) recommended this approach to meet post-2020 biodiversity targets in Asia, noting that achieving the ambitious 2030 goal requires a substantial increase in protected area coverage. Currently, the riverbeds of the Yarmouk and Jordan Rivers are under army protection, presenting a valuable opportunity for species and habitat conservation and implementing OECMs, especially in view of the area's limited accessibility. Specifically, implementing OECMs through strategic partnerships with military units along the Yarmouk and Jordan rivers is essential to safeguard the Jungle Cat population and prevent its potential extinction in Jordan.

The results of this study are highly significant as they pave the way for further research into the status of the Jungle Cat across the entire Jordan River basin and its tributaries, extending northward to include the Yarmouk River. Establishing effective communication and collaboration with military units will facilitate and support the implementation of surveys. Regional cooperation with the West Bank in Palestine and southeastern Syria adjacent to the Yarmouk River valley is crucial, as it will likely yield important insights into the Jungle Cat's status and habitat use. Understanding the regional context will aid conservation efforts, particularly during species Red Listing and considering the rescue effect. These findings highlight the need for a coordinated approach to wildlife management and conservation, enhancing our understanding and enabling more effective protection measures for the Jungle Cat.

REFERENCES

Abu Baker, M., K. Nassar, L. Rifai, M. Qarqaz, W. Al-Melhim & Z. Amr (2003). On the current status and distribution of the Jungle Cat *Felis chaus*, in Jordan (Mammalia: Carnivora). *Zoology in the Middle East* 30: 5–10. https://doi.org/10.1080/09397140.2003.10637982

Aloufi, A. & E. Eid (2016). Zootherapy: A study from the Northwestern region of the Kingdom of Saudi Arabia and the Hashemite Kingdom of Jordan. *Indian Journal of Traditional Knowledge* 15(4): 561–569.

Al-Zubaidi, A.A., M.K. Mohammad & M.J. Rasheed (2017). The importance of geodiversity on the animal diversity in Huwaiza marsh and the adjacent areas, southeastern Iraq. *Bulletin of the Iraq Natural History Museum* 14(3): 235–249. https://doi.org/10.26842/binhm.7.2017.14.3.0235

Amr, Z.S. (2000). *Jordan Country Study on Biological Diversity: Mammals of Jordan*. United Nations Environment Programme (UNEP), Amman, 100 pp.

Askerov, E., S.A. Trepet, T.G. Eskina, K.V. Bibina, A.I. Narkevich, A.B. Pkhitikov, N. Zazanashvili & K. Akhmadova (2022). Estimation of the population densities of species prey or competitor to the Leopard (*Panthera pardus*) in Hyrcan National Park, Azerbaijan. *Biology Bulletin* 49(7): 953–960. https://doi.org/10.1134/S1062359022070020

Barkat, A.I., F.T. Liza, S. Akter, A.R. Shome & M.F. Rabbe (2021). Wildlife hunting practices of the Santal and Oraon communities in Rajshahi, Bangladesh. *Journal of Threatened Taxa* 13(11): 19484–19491. https://doi.org/10.11609/jott.7260.13.11.19484-19491

Basuony, M.I. (2000). *Ecological Survey of Burullus Nature Protectorate: Mammals*. Nature Conservation Sector, Egyptian Environmental Affairs Agency, Cairo, Egypt, 32 pp.

Desai, S., C. Gosai & N. Dharaiya (2022). Notes on Jungle Cat nesting site in agricultural areas and associated threats. *Cat News* 76: 34.

Eid, E. & R. Handal (2018). Illegal hunting in Jordan: Using social media to assess impacts on wildlife. *Oryx* 52(4): 730–735. https://doi.org/10.1017/S0030605316001629

Eid, E., A. Soultan & H. Elalqamy (2022). Habitat suitability modelling for feline species in Jordan: A tool for climate-responsive conservation planning. *Journal of Wildlife and Biodiversity* 6(3): 26–53. https://doi.org/10.22120/jwb.2022.290322.1452

Eid, E., I. Al Hasani, T. Al Share, O. Abed & Z. Amr (2011). Animal Trade in Amman Local Market, Jordan. *Jordan Journal of Biological Science* 4(2): 101–108.

Eid, E., M. Abu Baker & Z. Amr (2020). *National Red Data Book of Mammals in Jordan*. Amman, Jordan: IUCN Regional Office for West Asia, Amman, vi + 122 pp. https://doi.org/10.2305/IUCN.CH.2020.12.en

Farhadinia, M.S., A. Waldron, Ż. Kaszta, E. Eid, A. Hughes, H. Ambarlı, H. Al-Hikmani, B. Buuveibaatar, M.A. Gritsina, I. Haidir & Z.U. Islam (2022). Current trends suggest most Asian countries are unlikely to meet future biodiversity targets on protected areas. *Communication Biology* 5: 1221. https://doi.org/10.1038/s42003-022-04061-w

Gerngross, P. (2014). Recent records of Jungle Cat in Turkey. *Cat News* 61: 10–11.

Gray, T.N.E., R. Timmins, D. Jathana, J.W. Duckworth, H. Baral & S. Mukherjee (2016). *Felis chaus*. The IUCN Red List of Threatened Species: e.T8540A50651463. Downloaded on 15 February 2024. https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T8540A50651463.en

Ibrahim, M., A. Sauer & K. Yassine (1976). The East Jordan Valley Survey, 1975. *Bulletin of the American Schools of Oriental Research* 222(1): 41–66.

Jdeidi, T., M. Masseti, I. Nader, K. de Smet & F. Cuzin (2010). *Felis chaus* (Mediterranean assessment). The IUCN Red List of Threatened Species 2010: e.T8540A12915840. Downloaded on 28 April 2024. https://www.iucnredlist.org/species/8540/12915840

Katz, D. (2022). Basin management under conditions of scarcity: The transformation of the Jordan River basin from regional water supplier to regional water importer. *Water* 14(10): 1605. https://doi.org/10.3390/w14101605

Majumder, A., K. Sankar, Q. Qureshi & S. Basu (2011). Food habits and temporal activity patterns of the Golden Jackal *Canis aureus* and the Jungle Cat *Felis chaus* in Pench Tiger Reserve, Madhya Pradesh, India. *Journal of Threatened Taxa* 3(11): 2221–2225. https://doi.org/10.11609/JoTT.o2713.2221-5

Mallon, D.P., C. Hilton-Taylor, G. Amori, R. Baldwin, P.L. Bradshaw & K. Budd (2023). *The Conservation Status and Distribution of the Mammals of the Arabian Peninsula*. IUCN, Gland, Switzerland, and Environment and Protected Areas Authority, Sharjah, United Arab Emirates, 164 pp. https://doi.org/10.2305/WBGQ3886

Masseti, M. (2009). Carnivores of Syria. In: Neubert, E., Z. Amr, S. Taiti & B. Gümüs (eds.) *Animal Biodiversity in the Middle East*. Proceedings of the First Middle Eastern Biodiversity Congress, Aqaba, Jordan, 20–23 October 2008. *ZooKeys* 31: 229–252. https://doi.org/10.3897/zookeys.31.170

Mishra, R., B. Gautam, S.K. Shah, N. Subedi, C.P. Pokheral & B.R. Lamichhane (2020). Opportunistic records of Jungle Cat (*Felis chaus*) and their activity pattern in Koshi Tappu Wildlife Reserve, Nepal. *Nepalese Journal of Zoology* 4(1): 50–55. https://doi.org/10.3126/njz.v4i1.30673

Mukherjee, S., S.P. Goyal, A.J.T. Johnsingh & M.L. Pitman (2004). The importance of rodents in the diet of Jungle Cat (*Felis chaus*), Caracal (*Caracal caracal*) and Golden Jackal (*Canis aureus*) in Sariska Tiger Reserve, Rajasthan, India. *Journal of Zoology* 262(4): 405–411. https://doi.org/10.1017/S0952836903004783

Ogurlu I., E. Gundogdu & I.C. Yildirim (2010). Population status of Junge Cat (*Felis chaus*) in Egirdir Lake, Turkey. *Journal of Environmental Biology* 31: 179–183.

Qumsiyeh, M.B. (1996). *Mammals of the Holy Land*. Texas Tech University Press, Lubbock, 389 pp.

Rostro-García, S., J.F. Kamler, C. Minge, A. Caragiulo, R. Crouthers, M. Groenenberg, T.N. Gray, V. In, C. Pin, P. Sovanna & M. Kéry (2021). Small cats in big trouble? Diet, activity, and habitat use of Jungle Cats and Leopard Cats in threatened dry deciduous forests, Cambodia. *Ecology and Evolution* 11(9): 4205–4217. https://doi.org/10.1002/ece3.7316

Sanei, A., M. Mousavi., K. Rabie., M.S. Khosravi., L. Julaee., F. Gudarzi., B. Jaafari & M. Chalani. (2016). Distribution, characteristics and conservation of the Jungle Cat in Iran. *CAT News Special Issue* 8: 51–55.

Temple, H.J. & A. Cuttelod (Compilers) (2009). *The Status and Distribution of Mediterranean Mammals*. IUCN, Gland, Switzerland and Cambridge, UK, 32pp. https://doi.org/10.2305/IUCN.CH.2009.19.en

Tohme, G. & H. Tohme (2000). Quelques nouvelles données sur le statut actuel des Felidae au Liban et plus particulièrement du Chat des Marais *Felis chaus* Güldenstädt, 1776. *Mammalia* 64(2): 247–249.

Ünal, Y. & A. Eryilmaz (2020). Jungle Cat (*Felis chaus* Schreber, 1777) population density estimates, activity pattern and spatiotemporal interactions with humans and other wildlife species in Turkey. *Applied Ecology & Environmental Research* 18(4): 5873–5890. https://doi.org/10.15666/aeer/1804_58735890

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25577–25583

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

https://doi.org/10.11609/jott.8523.16.7.25577-25583

#8523 | Received 13 May 2023 | Final received 30 September 2023 | Finally accepted 16 January 2024

OPEN ACCESS

COMMUNICATION

Diversity of bird species in Ebpanan Marsh, Maguindanao del Norte, Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), Philippines

Gindol Rey A. Limbaro [1], Benito Anthony A. Pingoy [2] & Peter Jan D. de Vera [3]

[1] Forestry Department, College of Forestry and Environmental Studies, Mindanao State University-Maguindanao, Dalican, Datu Odin Sinsuat, 9601 Maguindanao del Norte, BARMM, Philippines.

[2] Department of Biology, Davao Medical School Foundation, Davao City, 8000 Davao del Sur, Philippines.

[3] Natural Sciences Department, College of Arts and Sciences, Mindanao State University-Maguindanao, Dalican, Datu Odin Sinsuat, 9601 Maguindanao del Norte, BARMM, Philippines.

[1] galimbaro@msumaguindanao.edu.ph, [2] bapingoy@email.dmsf.edu.ph, [3] peterjandevera0302@gmail.com (corresponding author)

Abstract: Wetland areas such as the marsh provide vital habitats for birds. However, marshes in the Philippines have been threatened by anthropogenic disturbances and may be further degraded. This study conducted a rapid bird assessment in Ebpanan Marsh located in Maguidanao del Norte within the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) on 06–12 March 2022. A total of 36 bird species belonging to 24 families were recorded during the rapid assessment. Among the bird species recorded, two species— *Anas luzonica* and *Streptopelia dusumieri* are considered as Vulnerable, while *Padda oryzivora* is considered 'Endangered' in the IUCN Red List of Threatened Species. Eight of the bird species recorded are endemic and are observed in the remaining freshwater swamp forest of the Ebpanan Marsh. Despite habitat degradation and anthropogenic disturbance, the Ebpanan Marsh can still accommodate threatened and endemic bird species. Increasing the number of observation sites and extending the sampling duration of bird assessment will be required in order to complete the list of birds on the Marsh and understand the spatial and temporal variation in bird populations in the area.

Keywords: Anthropogenic disturbance, conservation assessment, endemic birds, freshwater swamp forest, habitat degradation, rapid assessment, species richness, threatened bird species, wetland conservation.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

Date of publication: 26 July 2024 (online & print)

Citation: Limbaro, G.R.A., B.A.A. Pingoy & P.J.D. de Vera (2024). Diversity of bird species in Ebpanan Marsh, Maguindanao del Norte, Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), Philippines. *Journal of Threatened Taxa* 16(7): 25577–25583. https://doi.org/10.11609/jott.8523.16.7.25577-25583

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Gindol Rey A. Limbaro is a licensed forester and a college instructor from Southern Mindanao Island, Philippines. His studies primarily focus on dendrology and conservation biology. Benito Anthony T. Pingoy is a college instructor at Davao Medical School Foundation. He is a bird enthusiast and a wildlife photographer. His research is focused on bird and ecosystem conservation. Peter Jan D. De Vera is a college instructor and an early career researcher from Maguindanao del Norte, Philippines. His research interests are on environment and wildlife conservation.

Author contributions: GRAL—paper conceptualization, data collection, writing and editing the manuscript. BATP—data collection and writing the manuscript. PJDDV—research design, paper conceptualization, data collection, writing and editing the manuscript, and corresponding journal submission.

Acknowledgements: The authors would like to extend their gratitude to the local officials and residents for assisting us during the conduct of the rapid bird survey in the area.

INTRODUCTION

A wetland is an area of land that is either covered by water or saturated with water (PAWB-DENR 2013). These areas are varied and include lakes, rivers, marshes, swamps, and reservoirs (Lopez-Calderon & Riosmena-Rodriguez 2016). The Philippines has about 216 lakes, 421 principal rivers, and 22 marshes, swamps, and reservoirs (Scott 1989). Several studies have been conducted highlighting the importance of wetland areas in the country in providing refuges for birds (van Weerd & van der Ploeg 2004; Villamor 2006; Lador & Seronay 2020). These ecosystems provide critical habitats for a wide range of bird species. However, wetland areas in the country, such as marshes, are considered to be one of the threatened ecosystems as the result of changes in land use, pollution, and climate change (Sespeñe et al. 2016). Marsh, a wetland ecosystem mostly dominated by grasses (Keddy 2010), provides a habitat for a rich diversity of flora and fauna, especially birds (Raj et al. 2010; Mohan et al. 2023).

Currently, in the Mindanao Island of the Philippines, there are around 455 species of birds documented of which 49 are globally threatened and 39 are endemic (Avibase 2023). The diversity of bird species has been noted to be a good bio-indicator of ecosystems (Datta 2011; Roshnath & Shruthi 2015), especially in wetland areas (Khadka et al. 2017; Studholme et al. 2022). However, in the Philippines' wetland areas, the diversity of birds is declining due mostly to anthropogenic pressures particularly the conversion of wetland areas for agricultural purposes (Haribon Foundation 2014).

Ebpanan marsh is a wetland area that stretches along different municipalities in Maguindanao del Norte and Maguindano del Sur provinces, and is part of the largest marsh in the country by area, the Ligawasan marsh. The Ligawasan marsh has been considered an Important Bird Area (IBA) and key biodiversity site and this warrants the need to for regular monitoring and updates of the bird composition in the area (Donald et al. 2018). This study provides a list of bird species recorded during the rapid bird assessment conducted in one of the conglomerates of the Ligawasan Marsh, the Ebpanan Marsh located within the Kabuntalan municipality, Maguindanao del Norte. Data from this study may contribute to the knowledge of the current list of birds in Ebpanan Marsh and is possibly the first published report of birds in the area. Government agencies, private stakeholders, and local communities may benefit from this study as this may serve as the basis for crafting conservation and protection policies for Ebpanan Marsh.

METHODS

Study area

The localized rapid bird assessment was conducted in the Ebpanan marsh (7.1451, 124.3391) that is located in Barangay Lower Taviran, Kabuntalan, Maguindanao del Norte, BARMM. The surveyed area for rapid bird assessment was approximately 64.23 hectares and is at least 5 km away from the national road. The marsh is one of three marshes, including the Ebpanan Marsh, Libungan Marsh, and Ligawasan Marsh proper, that collectively form the Ligawasan Marsh, one of the largest wetland areas in the Philippines. The southern to the western portion of the marsh is surrounded by concrete roads and residential areas, making the area easily accessible. The northern portion of the marsh is bordered by the Libungan Marsh while the lower eastern portion is bordered by the Ligawasan Marsh proper. Perennial agroforestry plants such as coconut *Cocos nucifera,* mango *Mangifera indica* and cashew *Anacardium occidentale* are common within the residential areas of the marsh. The study area also included marsh habitats, such as freshwater swamp forests and herbaceous swamp habitats. The presence of *Terminalia catappa* 'Talisay', *Terminalia copelandii* 'Lanipau', *Antidesma ghaesembilla* 'Binayuyo', and *Pterocarpus indicus* 'Narra' was common in the freshwater swamp forest while Water Hyacinth *Eichhornia crassipes,* Water Lettuce *Pistia stratioides*, and Duckweed *Lemna pauciflora* were present in the herbaceous swamp habitat. Most of the residents along the Ebpanan marsh depend heavily on its aquatic resources for food and as a source of income, evidenced by the presence of fish pens and nets. Furthermore, when the dry season arrives and floodwater recedes, certain swamp areas are utilized for cultivating watermelon *Citrullus lanatus* providing the residents with an alternative source of income.

Bird Sampling Technique

Localized rapid bird assessment was conducted between 06–12 March 2022 through the 'look and see', point count, and oppurtunistic listing methods in the Ebpanan marsh located in Barangay Lower Taviran, Kabuntalan municipality, Maguindanao del Norte. Field reconnaissance was conducted to explore the area and to establish the observation sites. Observation sites were established based on accessibility and safety. 10 strategic observation sites were established in the study area (5 in freshwater swamp forest, and 5 in herbaceous swamp habitat). Observation of birds was done from 0600–0900 h and 1500–1730 h by three field observers. Bird

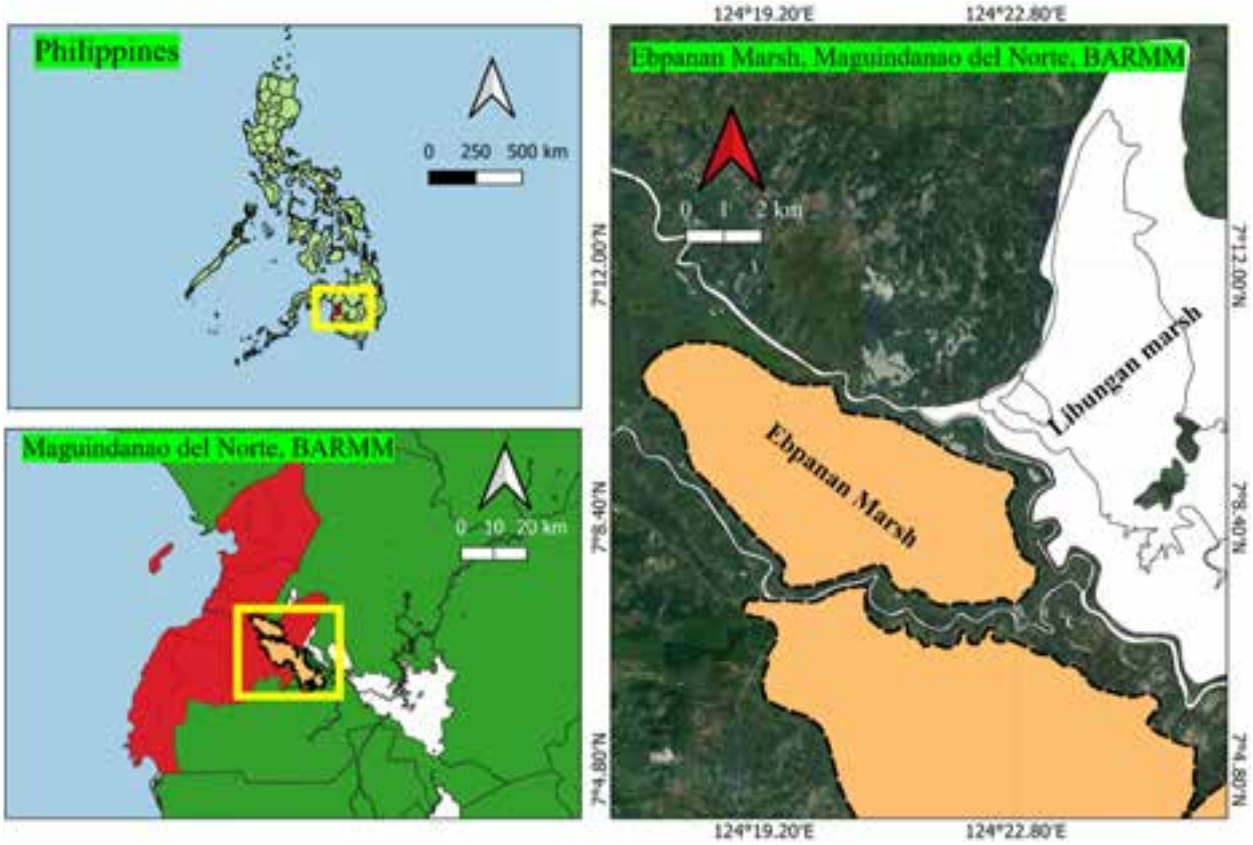


Figure 1. Map of Ebpanan Marsh, Maguindanao del Norte, Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), Philippines (QGISv.3). The map on the upper left shows the map of the Philippines. The map on the lower left is the subset of the yellow polygon in the Philippines map, which is the Ebpanan Marsh located in the province of Maguindanao del Norte in Bangsamoro Autonomous Region in Muslim Mindanao (BARMM). The map on the right is the is the subset of the yellow polygon from the map of Maguindanao del Norte, BARMM. The part of Ebpanan Marsh located in the Barangay Lower Taviran, Kabuntalan municipality (7.1451, 124.3391) was the study area.

documentation was carried out using field notebooks, binoculars, and a DSLR camera. Identification of birds and their respective spatial distribution and habitat range used different available reference materials such as 'Birds of the Philippines' (Allen 2020), eBird (2023), and Birdlife International (2023). The weather was generally sunny during the rapid bird assessment.

RESULTS AND DISCUSSION

Thirty-six species of birds belonging to 24 families were documented during the rapid bird assessment conducted in the Ebpanan Marsh (Table 1). Among the documented species, Ardeidae was the most represented family with seven species. The results of this study show a similar trend in terms of bird species richness in Agusan Marsh (Ardeidae = 13 species) in which species belonging to this family are also abundant. Bird species from this family prefer still open water habitats (Choi et al. 2007) which is common in the marsh. Anecdotal reports mentioned that in some cases the residents of the Ebpanan Marsh hunt egrets for food. Although most of the species of the family Ardeidae are listed as of Least Concern, continuous hunting may threaten their population (Benitez-Lopez et al. 2017). On the other hand, 22% of the bird species documented in Ebpanan Marsh are classified as endemic. This number is low compared to Agusan Marsh (ASEAN Centre for Biodiversity 2023) thus increasing the number of bird surveys may significantly improve the list of birds in the marsh.

Among the 36 bird species recorded, two bird species—the Philippine duck *Anas luzonica* and the Philippine Collared Dove *Streptopelia dusumieri*—are considered 'Vulnerable' and *Padda oryzivora* as 'Endangered' as per the IUCN Red List of Threatened Species (Figure 2). The nearest sightings of *A. luzonica* from the Ebpanan Marsh are in Timaco Hill, Cotabato City (de Vera et al. 2023). Locals in the Ebpanan Marsh hunt and trap the *A. luzonica* along with the Common Moorhen *Gallinula chloropus* for food, thus further

Table 1. List of birds recorded at Ebpanan Marsh, Kabuntalan, Maguindanao del Norte, BARMM.

Family	Scientific name	Common name	Endemism*	Conservation status**
Accipitiridae	*Elanus caerulus*	Black-winged Kite	Resident	Least Concern
	Haliastur indus	Brahminy Kite	Resident	Least Concern
Acrocephalidae	*Acrocephalus stentoreus*	Clamorous Reed Warbler	Resident	Least Concern
Alcedinidae	*Alcedo atthis*	Common Kingfisher	Migrant	Least Concern
	Todiramphus chloris	Collared Kingfisher	Resident	Least Concern
Anatidae	*Anas luzonica*	Philippine Duck	Endemic	Vulnerable
Ardeidae	*Ardea alba*	Great White Egret	Resident	Least Concern
	Ardea intermedia	Intermediate Egret	Resident	Least Concern
	Ardea purpurea	Purple Heron	Resident	Least Concern
	Ardeola speciosa	Javan Pond Heron	Resident	Least Concern
	Bulbucus ibis	Cattle Egret	Resident	Least Concern
	Butorides striatus	Green-backed Heron	Resident	Least Concern
	Egretta garzetta	Little Egret	Resident	Least Concern
Artamidae	*Artamus leucorynchus*	White-breasted Woodswallow	Resident	Least Concern
Columbidae	*Geopelia striata*	Zebra Dove	Resident	Least Concern
	Streptopelia dusumieri	Philippine Collared Dove	Endemic	Vulnerable
Cuculidae	*Centropus viridis*	Philippine Coucal	Endemic	Least Concern
	Eudynamis scolopaceus	Asian Koel	Resident	Least Concern
Dicaeidae	*Dicaeum austral*	Red-keeled Flowerpecker	Endemic	Least Concern
Estrildidae	*Lonchura atricapilla*	Chestnut Munia	Resident	Least Concern
	Padda oryzivora	Java Sparrow	Introduced	Endangered
Laniidae	*Lanius cristatus*	Brown Shrike	Migrant	Least Concern
Laridae	*Gelochelidon nilotica*	Gull-billed Tern	Resident	Least Concern
Locustellidae	*Megalurus palustris*	Striated Grassbird	Resident	Least Concern
Nectariniidae	*Cinnyris jugularis*	Olive-backed Sunbird	Resident	Least Concern
Oriolidae	*Oriolus chinensis*	Black-naped Oriole	Resident	Least Concern
Passeriformes	*Passer montanus*	Eurasian Tree Sparrow	Resident	Least Concern
Psittacidae	*Bolbopsittacus lunulatus*	Guaiabero	Endemic	Least Concern
Psittaculidae	*Loriculus philippensis*	Philippine Hanging Parrot/ Colasisi	Endemic	Least Concern
Pycnonotidae	*Hypsipetes phillipinus*	Philippine Bulbul	Endemic	Least Concern
Rallidae	*Gallinula chloropus*	Common Moorhen	Resident	Least Concern
	Amauronis cinerea	White-browed Crake	Resident	Least Concern
Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt	Migrant	Least Concern
Rhipiduridae	*Rhipidura nigritorquis*	Philippine Pied- Fantail	Endemic	Least Concern
Scolopacidae	*Gallinago gallinago*	Common Snipe	Migrant	Least Concern
Sturnidae	*Aplonis panayensis*	Asian Glossy Starling	Resident	Least Concern

*—eBird Cornell Laboratory for Ornithology (2023) | **—IUCN Red List of Threatened Species (2023).

making them vulnerable to population decline (BirdLife International 2023). The Philippine Collared Dove is classified as Vulnerable due to its rapid decrease in population in Luzon, Philippines mainly attributed to competition from the Red-collared Dove *Streptopelia tranquebarica* and Spotted Dove *Streptopelia chinensis* (BirdLife International 2023). Informing the locals of the status of *A. luzonica* and *S. dusumieri*, and establishing key protected areas, are actions that should prevent further population declines (Nori et al. 2020).

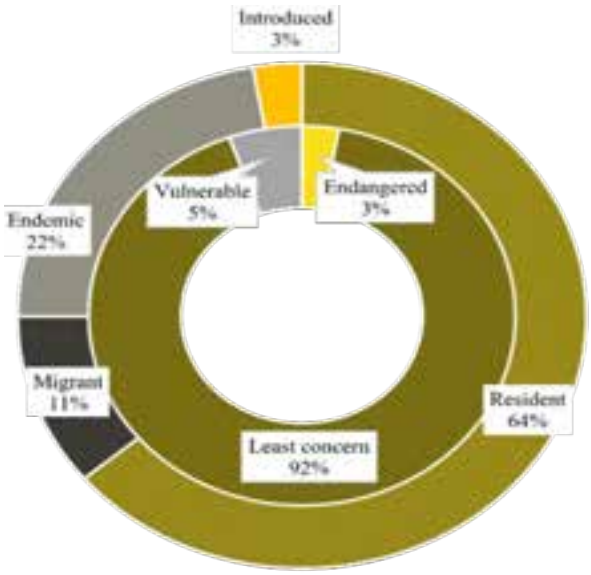


Figure 2. Endemism* and conservation status of birds documented in Ebpanan Marsh, Maguindanao del Norte, BARMM (*eBird 2023; **International Union for Conservation of Nature Red List of Threatened Species 2022).**

The introduced Java Sparrow *Padda oryzivora* was recorded during the rapid bird assessment in Ebpanan Marsh. A flock was recorded near the rice field within the study area. This bird species was considered to be a pest in rice crops. Eight out of the 36 recorded bird species in Ebpanan marsh were classified as endemic. Twenty-three of the 36 species were classified as a resident, four bird species were migrants, and one bird species as introduced (Figure 2). All endemic birds recorded in this study were observed in freshwater swamp forests. Despite the presence of residential areas and the conversion of some areas to agricultural land, the marsh can still harbor endemic bird species. Unfortunately, during the conduct of rapid bird assessment in the area, one *G. chloropus* was trapped and captured, however, this was later freed by local inhabitants. They also mentioned that, based on their observations, there was a decline in the number of bird species and their frequency in the Ebpanan Marsh, and they attributed this to climate change and bird hunting. Aside from bird hunting, another threat that the birds in Ebpanan Marsh are facing is the conversion of freshwater swamp forests into agricultural land. Thus, conservation measures, such as hunting regulations and identifying protected areas within the marsh, are recommended (Dudley 2008).

MANAGEMENT RECOMMENDATIONS

This study recorded a total of 36 bird species from the Ebpanan Marsh. Despite the area being degraded, it still harbors important endangered, vulnerable, and endemic bird species and this underlines the importance of the marsh as an important habitat for birds. Immediate conservation measures should be developed and implemented to prevent further degradation, particularly in the remaining freshwater swamp forest, where all the endemic bird species were recorded. Raising the awareness of the locals regarding the conservation status of the documented birds in the Ebpanan Marsh is deemed necessary to conserve the presence and population of the endangered, vulnerable, and endemic bird species in the area. The data presented in this study provides an indication of the total number of bird species in the Ebpanan Marsh. Therefore, it is recommended that the number of observation sites be increased and the sampling duration extended to permit a complete list of birds to be obtained and more fully understand the spatial and temporal variation of birds in the area.

REFERENCES

Allen, D. (2020). *Birds of the Philippines*. Lynx Editions, Barcelona, 400 pp.

ASEAN Centre for Biodiversity (2023). Agusan Marsh Wildlife Sanctuary. https://asean.chm-cbd.net/agusan-marsh-wildlife-sanctuary

Avibase (2023). The World Bird Database. https://avibase.bsc-eoc.org/avibase.jsp. Electronic version accessed 15 April 2023.

Benitez-Lopez, A., R. Alkemade, A.M. Schipper, D.J. Ingram, P.A. Verweij, J.A.J. Eikelboom & M.A.J. Huijbregts (2017). The impact of hunting on tropical mammal and bird populations. *Science* 356(6334): 180–183. https://doi.org/10.1126/science.aaj1891

BirdLife International (2023). Important Bird Areas factsheet: Philippines. Downloaded on 01 May 2023

Choi, Y.S., I.K. Kwon & J.C. Yoo (2007). Foraging habitat preferences of herons and egrets. *Journal of Ecology and Field Biology* 30(3): 237–244.

Datta, T (2011). Human interference and avifaunal diversity of two wetlands of Jalpaiguri, West Bengal, India. *Journal of Threatened Taxa* 3(12): 2253–2262. https://doi.org/10.11609/JoTT.o2739.2253-62

De Vera, P.J.D., J.P.C. Catipay, M.D.T. Tagoon, E.M. Delima-Baron & A.B. Pingoy (2023). Avian sanctuary within the city in Timaco Hill, Cotabato City, Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), Mindanao Island, Philippines. *Biodiversitas* 24(2): 1004–1009. https://doi.org/10.13057/biodiv/d240240

Department of Environment and Natural Resources [DENR] (2004). The Wetland Component for Ligawasan Marsh Project. A Project of the Department of Environment and Natural Resources (DENR) supported with a grant from the Global Environmental Facility (GEF) and the World Bank, with supervision of the United Nations Development Programme (UNDP). December 2004, v + 63 pp. https://faspselib.denr.gov.ph/sites/default/files//Publication%20Files/Volume%20III%20-%20Project%20Brief.pdf

Image 1. Birds found in Ebpanan Marsh, in Ebpanan Marsh, Maguindanao del Norte, BARMM: A—Clamorous Reed Warbler *Acrocephalus stentoreus* | B—Collared Kingfisher *Todiramphus chloris* | C—Chestnut Munia *Lonchura atricapilla* | D—Brown Shrike *Lanius cristatus* | E—Purple Heron *Ardea purpurea* | F—Philippine Pied Fantail *Rhipidura nigritorquis* | G—Philippine Duck *Anas luzonica* | H—Olive-backed Sunbird *Cinnyris jugularis* | I—Javan Pond Heron *Ardeola speciosa* | J—Guaiabero *Bolbopsittacus lunulatus* | K—Little Egret *Egretta garzetta* | L—Red-keeled Flowerpecker *Dicaeum australe* | M—White-breasted Woodswallow *Artamus leucorynchus* | N—Philippine Collared-Dove *Streptopelia dusumieri* | O—Black-winged Stilt *Himantopus himantopus* | P—Philippine Hanging-Parrot/Colasisi *Loriculus philippensis*. © B.A. Pingoy & G.R. Limbaro.

Donald, P.F., L.D. Fishpool, A. Ajabge, L.A. Bennun, G. Bunting, I. Burfield, S.M. Butchart, S. Capellan, M.J. Crosby, M.P. Dias, D. Diaz, M.I. Evans, R. Grimmet, M. Heath, V.R. Jones, B. G. Lascelles, J.C. Merriman, M. O'brien, I. Ramirez, Z. Waliczky & D.C. Wege (2018). Important bird and biodiversity areas (IBAs): the development and characteristics of a global inventory of key sites for biodiversity. *Bird Conservation International* 29(2): 177–98. https://doi.org/10.1017/S0959270918000102

Dudley, N. (Ed.) (2008). *Guidelines for Applying Protected Area Management Categories*. IUCN, Gland, Switzerland, x + 86 pp.

eBird (2023). Cornell Lab of Ornithology. http://www.ebird.org. Accessed on 01 May 2023.

Haribon Foundation (2014). The State of the Philippine Birds. Haribon Foundation for the Conservation of Natural Resources Inc. Quezon City, Philippines., 45 pp.

Khadka, B.B., P.M. Acharya & S.L. Rajbhandari (2017). Population status and species diversity of wetland birds in the Rapti and Narayan rivers and associated wetlands of Chitwan National Park, Nepal. *Journal of Threatened Taxa* 9(6): 10297–10306. https://doi.org/10.11609/jott.2364.9.6.10297-10306

Keddy, P.A. (2010). *Wetland Ecology: principles and conservation. 2nd edition*. Cambridge University Press, Cambridge, United Kingdom, 497 pp.

Lador, R.P. & R.A. Seronay (2020). Avifaunal diversity of Lake Mainit watershed, Caraga region, Philippines. *Journal of Ecosystem Sciences and Eco-Governance* 2(1): 13–24.

Lopez-Calderon, J.M. & R. Riosmena-Rodriguez (2016). Wetlands, pp.738–741. In: Kennish, M.J. (ed.). *Encyclopedia of Estuaries*. Springer, Dordrecht, 760 pp. https://doi.org/10.1007/978-94-017-8801-4

Mohan, S.K., R. Anjitha & K.M. Rodrigues (2023). The avian diversity of Chemmattamvayal wetlands and adjacent areas of Kasaragod district, Kerala, India. *Journal of Threatened Taxa* 15(4): 23047–23060. https://doi.org/10.11609/jott.5246.15.4.23047-23060

Nori, J., R. Loyola & F. Villalobos (2020). Priority areas for conservation of and research focused on terrestrial vertebrates. *Conservation Biology* 34(5): 1281–1291. https://doi.org/ 10.1111/cobi.13476

PAWB-DENR (2013). The National Wetlands Action Plan for the Philippines 2011–2016. Protected Areas and Wildlife Bureau-Department of Environment and Natural Resources.

Raj, P.P.N., J. Ranjini, R. Dhanya, J. Subramanian, P.A. Azeez & S. Bhupathy (2010). Consolidated checklist of birds in the Pallikarani wetlands, Chennai, India. *Journal of Threatened Taxa* 2(8): 1114–1118. https://doi.org/10.11609/JoTT.o2220.1114-8

Roshnath, R. & V. Shruthi (2015). Habitat utilization by wetland birds of Munderikadavu, a proposed bird sanctuary in northern Kerala, India. *Journal of Threatened Taxa* 7(12): 7870–7878. https://doi.org/10.11609/JoTT.o3999.7870-8

Scott, D.A. (ed.) (1989). *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland and Cambridge, United Kingdom, xiv + 1189 pp.

Senarillos, T.L.P., K.M.F. Pitogo & J.C. Ibañez (2020). Bird observations in the Busa Mountain Range, Sarangani Province, Philippines. *Philippine Journal for Science* 150(S1): 347–362. https://doi.org/10.56899/150.S1.25

Sespeñe, S. M. Maniquiz-Redillas, M. Kim, L.H. & Y. Choo (2016). Characteristics, threats, and management of Philippine wetlands. *Journal of Wetland Research* 18(3): 250–261. https://doi.org/10.17663/JWR.2016.18.3.250

Studholme, K.R., L.M. Tranquilla, L.E. Berrigan, L.M. Achenbach & D.C. Tozer (2022). Land cover habitat associations of breeding marsh birds and priority waterfowl differ in eastern Canada. *Avian Conservation and Ecology* 17(1): 33. https://doi.org/10.5751/ACE-02110-170133

van Weerd, M. & J. van der Ploeg (2004). Surveys of wetlands and waterbirds in the Cagayan Valley, Luzon, Philippines. *Folktail* 20(2004): 33–39.

Villamor, G.B. (2006). A survey and study on food habits of migratory waterbirds along Naujan Lake, Oriental Mindoro Province, Philippines. *Journal of Tropical Biology and Conservation* 2(1): 1–8. https://doi.org/10.51200/jtbc.v1i2.81

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25584–25589

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

https://doi.org/10.11609/jott.9129.16.7.25584-25589

#9129 | Received 05 May 2024 | Final received 21 June 2024 | Finally accepted 02 July 2024

OPEN ACCESS

COMMUNICATION

Heleocoris stephanus (Heteroptera: Naucoridae: Laccocorinae), a new species of creeping water bug from Kallada River, Kerala, India

Dani Benchamin [1], **R. Sreejai** [2] & **M.S. Arya** [3]

[1–3] Zoology Research Centre, St. Stephen's College, Pathanapuram, University of Kerala, Thiruvananthapuram, Kerala 695034, India.
[1] danibenchamin93@gmail.com (corresponding author), [2] sreejaiksbb@gmail.com, [3] aryamadhussc@gmail.com

Abstract: A new species of *Heleocoris*, Stål (1876) was collected from the upstream Kallada River in Kerala, southwestern India. This discovery brings the number of described species for this genus in India to twelve. This species can be diagnosed by the overall body coloration and distinct morphological & genital features. Descriptions including a habitus photograph, ecology, and diagnostic comparisons among congeners are provided.

Keywords: Coloration, congeners, genitalia, morphology, upstream, Urukunnu.

Malayalam: ഹെലിയോകോറിസ് ജനുസ്സിൽ പെട്ട ഒരു പുതിയ സ്പീഷീസിനെ ഇന്ത്യയുടെ തെക്കുപടിഞ്ഞാറൻ സംസ്ഥാനമായ കേരളത്തിലെ കല്ലട നദിയിൽ നിന്ന് കണ്ടെത്തി. ഈ കണ്ടെത്തലോടു കൂടി ഇന്ത്യയിൽ ഈ ജനുസ്സിലെ സ്പീഷീസുകളുടെ എണ്ണം പന്ത്രണ്ടായി. ശരീരത്തിലെ വ്യത്യസ്തരീതിയിലുള്ള ആകമാന നിറവും അടയാളങ്ങളും രൂപശാസ്ത്രപരവും ജനനേന്ദ്രിയ സംബന്ധമായ മറ്റു സവിശേഷതകളുമാണ് ഈ പുതിയ സ്പീഷീസിനെ മറ്റു സ്പീഷീസുകളിൽ നിന്നും വ്യത്യസ്തമാക്കുന്നത്. വിശദമായ വിവരണങ്ങളും അനുബന്ധ ചിത്രങ്ങളും താരതമ്യ പഠനങ്ങൾ ഉൾപ്പെടെയുള്ള വിവരണങ്ങളും ഈ പ്രസിദ്ധീകരണത്തിൽ നൽകിയിരിക്കുന്നു.

ZooBank: urn:lsid:zoobank.org:pub:8F58793E-3BD5-4EB6-A07B-3DB1BF7A63D7

Editor: Hasko Nesemann, Central University of Bihar, Patna, India. **Date of publication:** 26 July 2024 (online & print)

Citation: Benchamin, D., R. Sreejai & M.S. Arya (2024). *Heleocoris stephanus* (Heteroptera: Naucoridae: Laccocorinae), a new species of creeping water bug from Kallada River, Kerala, India. *Journal of Threatened Taxa* 16(7): 25584–25589. https://doi.org/10.11609/jott.9129.16.7.25584-25589

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author details: Dr. Dani Benchamin, a former PhD scholar, Postgraduate and Research Department of Zoology, St. Stephen's College has research interests in freshwater ecology and biomonitoring. Sreejai R serves as an assistant professor and research guide at the Postgraduate and Research Department of Zoology, St. Stephen's College, Pathanapuram, and Dr. Arya MS, a former PhD scholar of the same department has a research interest in estuarine ecology and planktonology.

Author contributions: DB and AMS carried out fieldwork, identification and manuscript preparation, SR reviewed the manuscript.

Acknowledgements: All glory, honor and praise to my Lord and Savior Jesus Christ. We are grateful to the authorities of St. Stephen's College, Pathanapuram, University of Kerala, for providing laboratory facilities for this discovery. We extend our gratitude to our friend, Sreenish S., for his assistance in the field. We remember our parents and family members for their prayers and love. The research stipend for first and third authors has been provided by the University of Kerala.

INTRODUCTION

The creeping water bugs are subaquatic, but some species are present in the water covering a rock surface (hygropetric). Most Indian species present adjacent to the streams. The genus *Heleocoris* Stål (1876) was first included in the division Laccocoraria, which later was raised to the subfamily Laccocorinae, Montandon (1897). *Heleocoris* contains 29 species, of which 11 are known from India (Polhemus & Polhemus 2013). The recent decade witnessed the discovery of a new species: *Heleocoris mcphersoni,* Sites and Vitheepradit, 2011 from Thailand. Globally, the Naucoridae consists of 401 species while the Indian sub-region consists of 20 species under seven genera (Chandra et al. 2017). There are few taxonomic records of *Heleocoris* in the southern part of India, and faunal surveys in waterfalls, streams of mountain ranges, and forests are still required. *Heleocoris stephanus* sp. nov. from Kollam District of Kerala state, is described as new to science in the present paper. This species was generally found associated with plant debris on the edge of the rivers. A diagnosis and comparison with congeners in Kerala, Tamil Nadu and other states congeners is presented..

MATERIALS AND METHODS

Bug samples were collected by hand-picking with either fingers or soft forceps and use of an aquatic net to sweep through submerged vegetation and organic debris along shorelines of river Urukunnu, Kerala (Image 1). Specimens were placed into vials with 90% ethyl alcohol and brought to the laboratory of Zoology Research Centre, St. Stephen's College, Pathanapuram. Morphological terminology in the description mostly follows that of Xie & Liu (2015) and Sites & Vitheepradit (2011). All measurements are given in mm. Olympus CX33 and Weswox SZM-105 microscopes were used to obtain images and followed by its preparation with Photoshop CS5 (Adobe Systems Inc., San Jose, CA). The holotype (ZSI/WGRC/I.R.-INV.26976) was deposited in the Zoological Survey of India, Western Ghats Regional Centre (WGRC), Kozhikode, Kerala, India. Paratypes (SSCDZ/Hem01/2024 and SSCDZ/Hem02/2024) were deposited in the Department Museum, Zoology Research Centre, St. Stephen's College, Pathanapuram.

RESULTS

Heleocoris stephanus sp. nov.
(Image 2)

urn:lsid:zoobank.org:act:D01E304C-38E9-412A-A296-09DFEB97BE86

Material examined: Holotype (ZSI/WGRC/I.R.-INV.26976): 07 October 2023, macropterous male, India: Urukunnu station, Kollam District, Kerala, 8.5905 ^{0}N & 77.0124 ^{0}E, 45 m, upstream Kallada River, coll. Dani & Arya, Paratypes (SSCDZ/Hem01/2024 and SSCDZ/

Image 1. Urukunnu Station in the upstream of Kallada River, Kollam District, Kerala, India, the type locality of *Heleocoris stephanus* sp. nov.

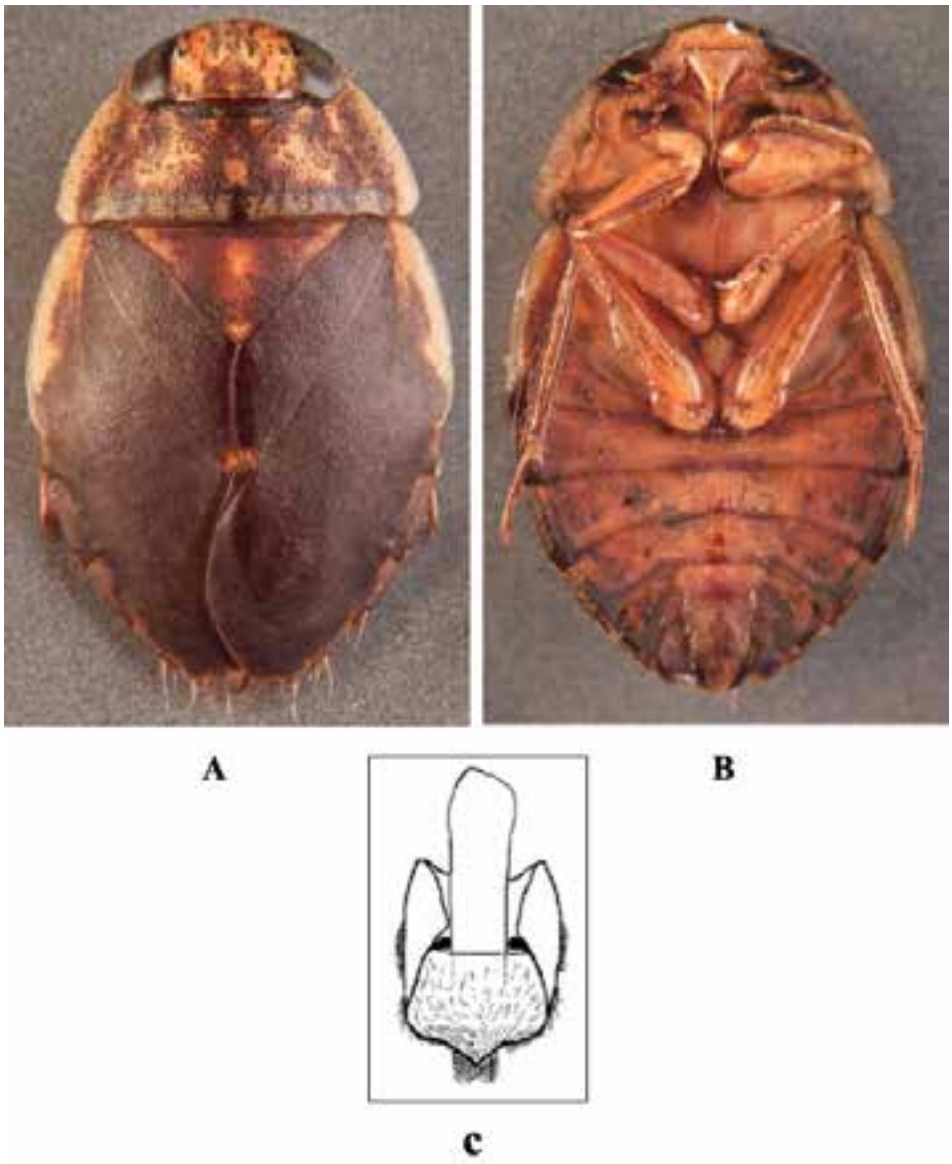


Image 2. Diagnostic features of *Heleocoris stephanus* sp. nov. (holotype): A—dorsal habitus | B—ventral habitus | C—phallotheca. © Dani Benchamin.

Hem02/2024): same data as primary type.

Description: Macropterous male. Holotype, length 9.78; width 6.20. Paratypes (n = 4), length 9.44–9.88 (mean = 9.69); maximum width 6.09–6.29 (mean = 6.17). General shape is ovate, slightly flattened; widest across embolia. Description of *Heleocoris stephanus* sp. nov. and other congeners are presented in Table 1.

Coloration: Overall body color is anteriorly yellowish with black mottling, scutellum dark brown with irregular yellow apex, yellowish, and thick median longitudinal patch. Head with black spotting, generally over the entire yellowish dorsal surface; patterns coalescent at the posterior margin, reducing anteriorly as black spots adjoining anterior margin, eyes blackish with pale yellowish anterolateral margin, rostrum last two segments dark brownish. Pronotum with black markings scattered over the entire dorsal surface; laterally reduced to a few black spots; black coalescent patches in the mid-anterior region; a yellowish transverse band with irregular black blotches at the posterior margin. Hemelytra black. Forelegs and hindlegs are dorsally brownish and ventrally pastel yellowish. Connexiva yellowish-brown antero-posterior, showing checkered appearance (Image 2B). Ventrally yellowish cephalothorax, brownish abdomen, and pygophore (Image 2B).

Head*:* Densely punctured with black. Single sclerite at posterior corner of eye, directed ventrad, anterior

end simple. Dome-shaped, blackish spot on the base of the head in between the eyes. Compound eyes blackish, convergent anteriorly, convex on lateral posterior margin. Broad semi-circular labrum, rostrum short with three visible segments, first segment partially covered with labrum, each following segment progressively narrower, reaching to near anterior prothoracic coxae. Antennae, thickened and hairy: not extending to lateral margin of head.

Thorax: Pronotum broad and maximum width at rounded posterolateral corners; tuft of setae in anterior end, transverse sulcus band ending at anterior end of clavus with ventral tuft of setae; ventro-lateral margins with blackish punctations; tuft of elongate sensory setae on anterior surface behind eye. Scutellum is finely granulose, tumescent, and elevated above level of wings; sinuated lateral margins. Well-developed hind-wings. Hemelytron blackish-brown; largely yellowish embolium with black spots.

Legs: Foreleg with large femur, strongly widened antero-basally, lateral margins with thick bunch of setae; tibia narrow, with bunch of setae at lateral margins; tarsus bristled and two-segmented with two razor shaped claws. Hindleg with wide femur have small bulbous projections at its posterior end, tibia narrow with a profusion of swimming hairs; tarsus with small dorsal bristles and ventral elongated tuft of setae.

Abdomen: Abdomen ventrally covered with appressed hair; large blackish spots; ventrally with heavy marginal spines on laterotergites III–VI and elongate light-coloured hair.

Genitalia: Pygophore brownish and hairy, posterior margin acuminated with dense brush**;** parameres reduced, blackish, and symmetrical; phallosoma elongate, linear, widest & rounded triangular at apex (Image 2C).

Female: Unknown

Diagnosis: *Heleocoris stephanus* sp. nov. is similar to the congener *H. vicinus* (Montandon, 1910)*,* by size, and overall coloration. However, *H. stephanus* is notably different from *H. vicinus* by the finely granulose, dark brown scutellum with irregular yellow apex and thick median longitudinal yellowish patch. *H. majusculus* (Montandon, 1908) and *H. rotundatus* (Montandon, 1908) are other congeners reported from the neighbouring state of Tamil Nadu. The former drastically differs from *H. stephanus* by its entirely black scutellum and overall body size, while the latter differs from *H. stephanus* by its black coloured body beneath with greyish pilose and body size. *H. breviceps* (Montandon, 1897) is another congener reported from the Indian states such as Andhra Pradesh, Himachal Pradesh, Maharashtra, and Tamil Nadu. This congener differs from *H. stephanus* by largely blackish abdomen beneath and brownish scutellum. As the name implies, *H. elongatus* (Montandon, 1897) differs from *H. stephanus* by its body shape. Additionally, *H. elongatus* can be distinguished from *H. stephanus* by its entirely yellowish body beneath. *H. elongatus* was reported from the Indian states Bihar, Madhya Pradesh, Maharashtra, and West Bengal. *H. acutus* (Spinola, 1837) was reported only from Maharashtra and it can be distinguished from *H. stephanus* by its distinct acute posterior angles of pronotum. *H. bengalensis* (Montandon, 1910) was reported from the central states such as Madhya Pradesh, Uttar Pradesh, and West Bengal. *H. stephanus* can be distinguished from this congener by the distinct characteristics of genitalia such as brownish & hairy pygophore, posterior margin acuminated with dense brush, and blackish & reduced parameres. *H. bergrothi* (Montandon, 1897), reported from the southern Indian states of Karnataka, Kerala, and Tamil Nadu is similar to *H. stephanus* in a few characteristics such as body size, shape, and v-shaped discal spot in scutellum. *H. stephanus* differs from *H. bergrothi* by its distinct colouration of scutellum, such as, dark brown with irregular yellow apex, thick & yellowish median longitudinal patch, and distinct black mottling of head & pronotum. Lastly, the closest congener *H. indicus* (Montandon, 1897) shares a few similar features with *H. stephanus* like flavescent with brown punctures on head and pronotum, overall coloration, and v-shaped discal spot in scutellum. *H. indicus* has a number of contrasting characteristics such as entirely yellowish underbody, pronotum with blackish transverse colouration on the posterior margin, while the *H. stephanus* has a ventrally yellowish cephalothorax, brownish abdomen and pygophore, pronotum with irregular black blotches on the posterior transverse margin, embolium of the hemelytra yellowish with distinct blackish colouration, and abdomen with appressed hairs and large blackish spots, heavy marginal spines on laterotergites III–VI, and elongate light-colored hair.

Etymology: This specific epithet “stephanus” refers to the Institution where this significant research was conducted at the Zoology Research Centre, St. Stephen’s College, Pathanapuram. St. Stephen’s College was founded in 1964 after the name of St. Stephen, one of the first seven ordained Deacons and the first Martyr of Christianity.

Table 1. Comparison among the congeners in the genus *Heleocoris* reported from Kerala, Tamil Nadu, and central states of India.

Taxon	Size	Shape	Head	Pronotum	Scutellum	Hemelytron	Abdomen
H. bergrothi	Length 9.7; width 6.8 mm	Oval	Palely yellow with indistinct brown spots	Colouration same as head, the lateral margins arcuate, the lateral posterior angles acute, the surface densely and finely punctate	Black with yellow apex, very finely granulose, with a yellow v-shaped discal spot	Blackish-brown with largely yellowish embolium	Connexivum, abdomen, and legs entirely pale yellowish
H. vicinus	Length 9–10	Oval	Twice as broad at base between eyes, rounded in front, ochraceous with black speckles	Ochraceous with black speckles, the lateral margins pale ochraceous, distinctly subampliate, the posterior margin a little paler than the disk	Black with ochraceous apex	Black, lateral margin of corium pale ochraceous with two blackish macular suffusions	Connexivum pale ochraceous with the posterior margins black; abdomen and legs pale ochraceous, left sixth ventral laterotergite is completely flat
H. breviceps	Length 9.5; width 6.5 mm	Oval	Ochraceous; intraocular area marked on each side by two small foveations	Ochraceous	Blackish-brown with the disk narrowly yellow	Hemelytra brownish; embolium ochraceous	Abdomen beneath largely blackish with yellowish apex; legs entirely yellow
H. indicus	Length 8; width 5 mm	Oval	Brown punctures more or less dense forming small ill-defined shadings	Colouration same as head	Dark brown with a median longitudinal line.	Embolium yellowish with a medial brown spot on its inner margin and another spot at its apex	Connexivum yellow, very narrowly darkened on the outer edge of the posterior angles of each segment; underside of body entirely yellowish
H. majusculus	Length 13; width 8.8 mm	Oval	Surface superficially punctate, two impressions, one before the other on each side near the eyes	Very transverse, yellowish, finely granulose, punctured on all the surface, with the anterior margin obtusely sinuate on each side behind the eyes	Entirely black; claval commissure nearly as long as the scutellum	Embolium very much dilated behind	Connexivum yellow, with the posterior angles of the segments a little acuminate; underside of body pitchy brown
H. rotundatus	Length 12; width 9.4 mm	Oval	Thick, finely granulose, brownish-ochraceous, centrally blackish	Brownish-ochraceous much suffused with blackish except on the lateral margin areas which are distinctly rounded	Black with apex ochraceous, strongly and mostly transversely wrinkled; clavalsuture longer than scutellum and apically spotted with ochraceous	Black, thick, finely punctate, lateral margins of embolium ochraceous.	Connexivum ochraceous; under side of the body blackish; legs ochraceous; abdomen beneath with a central longitudinal series of black spots, the lateral margins ochraceous.
H. acutus		Oval		Shape is not perceptibly "flange" with no marginal furrow, the posterior angles acute			
H. elongatus	Length 8; width 4.5 mm	Oval	Clear yellow tint densely punctured with black	Colouration same as head; lateral margins very slightly arcuated nearly straight, the lateral posterior angles rounded, not prominent behind, the posterior edge straight	Brownish; claval suture a little longer than half the length of the scutellum	Embolium little enlarged and largely yellowish and along the outer margin, the yellow margin bisinuated at its inner edge by two brown spots	Connexivum yellow, with a straight transverse brown fascia on the posterior margins of the segments; underside of the body entirely yellow

Taxon	Size	Shape	Head	Pronotum	Scutellum	Hemelytron	Abdomen
H. bengalensis	Length 8 mm	Oval	Posterior margin with brown punctures coalescent and dark punctuation and associated maculation denser	Dark punctuation and associated maculation denser; posterior margin with longitudinal marks		Large yellow patch on embolium.	Abdomen laterally slightly surpassing hemelytra in males; ventral laterotergites II–VII each light anteriorly, dark posteriorly
H. stephanus sp. nov.	Length 9.78; width 6.20 mm	Oval	Densely punctured with black. Single sclerite at posterior corner of eye, directed ventrad, anterior end simple. Goblet shaped black colouration in the dorsal surface	Finely granulose, broad and maximum width at rounded posterolateral corners; tuft of setae in anterior end, transverse sulcus band ending at anterior end of clavus with ventral tuft of setae	Finely granulose, tumescent and elevated above level of wings, sinuated lateral margins.	Blackish-brown, largely yellowish embolium with distinct black colouration	Abdomen ventrally covered with appressed hairs; heavy marginal spines on laterotergites III–VI and brush of elongate light-coloured hairs; legs brownish with setae and bristles.

DISCUSSION

This species was found in the upstream of Kallada River, Kerala, India. The type locality is located in the Western Ghats of the southwestern region of the country. The sampling area of the present investigation was characterized by partially decomposed plant parts. Studies on saucer bugs are scanty in our country, and the sampling area is an undisturbed and unexplored area of Kallada River. There were no detailed recent taxonomical reports on creeping water bugs from the freshwater ecosystems of Kerala. As part of our macroinvertebrate sampling, we explored several ignored parts of the upstream forested area of Kallada River with a rich diversity of creeping water bugs. No additional *Heleocoris* species were collected. Males of this species are most similar to *H. bergrothi* and *H. indicus* based on some external features like coloration pattern, though, these species are clearly distinct from *H. stephanus* in several aspects. Previously, 11 species were reported in India. The present discovery brings the total number of *Heleocoris* species in India to 12.

CONCLUSION

Heleocoris stephanus sp. nov. shows close morphological similarity with *H. bergrothi,* and *H. indicus*; The latter species are differentiated by distinctive morphological and genital features.

REFERENCES

Chandra, K., K.C. Gopi, D.V. Rao, K. Valarmathi & J.R.B. Alfred (2017). Chapter 23: Insecta: Hemiptera, pp. 357–378. In: Basu, S. & K.A. Subramanian (eds.). *Current Status of Freshwater Faunal Diversity in India*. Zoological Survey of India, Kolkata.

Montandon, A.L. (1897). Hemiptera cryptocerata. Fam. Naucoridae.–Sous.-fam. Laccocorinae. Verhhandlungen der kaiserlich-königlichen zoologisch-botanischen Gesellschaft in Wien 47: 435–454.

Montandon, A. L., (1908). *Heleocoris rotundatus*, La Rivers, Dcc. Pap Bioi. Soc Nevada, 38: 12.

Montandon, A.L. (1910). Espécies nouvelles ou peu connues d'Hydrocorises de l'Inde. *Bulletin de la Société des Sciences de Bucharest–Roumanie* 19: 652–658.

Polhemus, D.A. & J.T. Polhemus (2013). Guide to the aquatic Heteroptera of Singapore and Peninsular Malaysia. Xi. Infraorder Nepomorpha--families Naucoridae and Aphelocheiridae. *Raffles Bulletin of Zoology* 61(2): 665–686.

Sites, R.W. & A. Vitheepradit (2011). *Heleocoris* (Heteroptera: Naucoridae: Laccocorinae) of Thailand, with description of a new species. *Zootaxa* 2736(1): 1–16. https://doi.org/10.11646/zootaxa.2736.1.1

Stål, C. (1876). Enumeratio Hemipterorum, Bidrag till en förteckning öfver alla hitills kända Hemiptera, jemtes systematicameddelanden. 5. *Kongliga Svenska Vetenskaps-Akademiens Handlingar* 14(4): 1–162.

Xie, T.Y. & G.Q. Liu (2015). The creeping water bugs (Hemiptera: Heteroptera: Naucoridae) of China, with description of a new species. *Zootaxa* 3911(4): 571–580. https://doi.org/10.11646/zootaxa.3911.4.6

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25590–25597

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

https://doi.org/10.11609/jott.8134.16.7.25590-25597

#8134 | Received 05 August 2022 | Final received 12 May 2024 | Finally accepted 23 June 2024

OPEN ACCESS

COMMUNICATION

Incidence and risk factors associated with parasitic infections in captive wild mammals and birds in Indian zoos

Nikita Das [1], P.D. Pawar [2], P.P. Mhase [3], V.G. Nimbalkar [4], R.V. Jadhav [5], V.S. Dhaygude [6], Gavin Furtado [7] & L.D. Singla [8]

[1–7] Department of Veterinary Parasitology, KNP College of Veterinary Science, Shirwal, Satara District, Maharashtra 412801, India.
[8] Department of Veterinary Parasitology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab 141004, India.
[1] dasnikita5@gmail.com, [2] prashant_vet@yahoo.co.in (corresponding author), [3] prashantmhase@gmail.com,
[4] vgnimbvet2002@yahoo.com, [5] rajivgandhizoo@punecorporation.org, [6] drvitthalp@gmail.com, [7] furtado.gavin2@gmail.com,
[8] ldsingla@gmail.com

Abstract: Present study was conducted to record the seasonal incidence and worm burden (eggs per gram of faeces) of helminthic infections and to evaluate the efficacy of deworming protocols followed for control of parasitic infections in captive animals (including birds) at the zoo. Freshly voided faecal samples were collected during winter, monsoon and summer from 150 captive animals including wild mammals (n = 95) and birds (n = 55) between 1–15 years of age kept at Rajiv Gandhi Zoo and Wildlife Research Centre Karaj, Pune (Zoo-I) and Nisargakavi Bahinabai Chaudhary Zoo, Pimpri Chinwad (Zoo-II) in Maharashtra, India. Samples were processed and examined by standard sedimentation and floatation methods to assess the prevalence of helminth infections. Faecal samples of positive animals were collected pre and post-treatment, and the efficacy of the drugs used was evaluated based on faecal egg count reduction test (FECRT). The overall seasonal prevalence of gastro-intestinal parasitic infection in mammals varied among seasons with the highest prevalence (29.50 %) in monsoon followed by winter (26.30 %) and lowest in summer (8.40 %), while the same was found non-significant in birds. Of 19 bird species screened, 25 % of peafowl were positive for *Ascardia* spp., 25 % of crested eagles for *Capillaria* spp., and 50% of brown fish owls for *Strongyloides* spp. Among mammals, 75 % of Black Buck, 50 % of Leopards and 25 % of Giant Malabar Squirrels were positive for *Strongyloides* spp., while all four Bonnet Macaques were positive for *Balantidium coli*. The range of eggs per gram (EPG) of faeces recorded was 50–300 in mammals and 100–350 in birds. At Zoo I (Rajiv Gandhi Zoo and Wildlife Research Centre Karaj, Pune), there was 85.89 and 77.36 per cent reduction in egg counts after treatment with fenbendazole @5 mg/kg in herbivores and birds, respectively. While in carnivoresthe reduction was 69.93 % after treatment with a drug combination@10 mg/kg (Praziquantel 50 mg + Pyrantelembonate 144 mg + fenbantel 150 mg). In Zoo II (Nisargakavi Bahinabai Chaudhary Zoo, Pimpri Chinwad) the reduction in EPG was 72.35 % in carnivores with drug combination @10 mg/kg (Praziquantel 50mg + pyrantelembonate 144 mg + fenbantel 150 mg) and 68.98% in birds with albendazole @10 mg/kg.

Keywords: FECRT, helminthic infections, prevalence, preventive management, worm.

Editor: Alok Kumar Dixit, College of Veterinary Science & A.H., Rewa, India. **Date of publication:** 26 July 2024 (online & print)

Citation: Das, N., P.D. Pawar, P.P. Mhase, V.G. Nimbalkar, R.V. Jadhav, V.S. Dhaygude, G. Furtado & L.D. Singla (2024). Incidence and risk factors associated with parasitic infections in captive wild mammals and birds in Indian zoos. *Journal of Threatened Taxa* 16(7): 25590–25597. https://doi.org/10.11609/jott.8134.16.7.25590-25597

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author details: Nikita Das (M.V.Sc scholar), P.D. Pawar (sectional head Department of Veterinary Parasitology), P.P. Mhase (assistant professor Department of Veterinary Microbilogy), V.G. Nimbalkar (farm manager Livestock farm complex), R.V. Jadhav (director Katraj Zoological Park, Pune), V.S. Dhaygude (sectional head Department of Veterinary Pathology), Gavin Furtado (veterinary officer) & L.D. Singla (director and professor, Human Resource, GADVASU, Ludhiana).

Author contributions: Nikita Das (collection processing of samples along with history), P.D. Pawar (planning and execution of research plan as per objective), P.P. Mhase (compilation of all data), V.G. Nimbalkar (statical analysis of data), R.V. Jadhav (permission and support during collection of samples), V.S. Dhaygude (writing of manuscript), Gavin Furtado (help in collection of history and schedule deworming plan) & L.D. Singla (help in analysis of results and corrections in the manuscript).

Acknowledgements: Authors sincerely acknowledge the support provided by the Rajiv Gandhi Zoo and Wild life Research Centre Karaj, Pune and NisargakaviBahinabai Chaudhary Zoo, PimpryChinwad, and Department of Veterinary Pathology, KNP College of Veterinary Science, Shirwal, Maharashtra.

INTRODUCTION

India is the World's 8th most bio-diverse region with a 0.46 BioD score on the diversity index, including 1,02,718 species of fauna (ZSI 2021). The nation is unique in having immense natural beauty, rich, and diverse wildlife comprising mixed species of different types of animals. Many countries including India in different parts of the world have adopted the strategy to protect wild animals via the use of parks and the construction of zoological gardens (Parasani et al. 2001). The zoological gardens display wild animals for aesthetic, recreational, educational, and conservation purposes (Varadharajan & Pythal 1999). Wild mammals and birds act as reservoirs and amplifiers of emerging human and domestic livestock pathogens (including parasites) of public health significance which has gained considerable attention in recent years (Moudgil et al. 2015).

The mortality in animals in captivity has been reported to be at a higher rate due to a variety of factors, including various bacterial, viral, fungal, and parasitic infections (Rao & Acharjyo 1984). Knowledge on parasitic diseases of wildlife is still in infancy in India, and data is on the baseline to understand the epidemiology of parasitic diseases in wild fauna kept in Indian zoos (Singh et al. 2009). Only a few researchers have carried out basic work on the prevalence of parasites in captive wild animals in India (Singh et al. 2006; Gupta et al. 2011; Jaiswal et al. 2014; Mir et al. 2016) except for recent comprehensive studies on animals (Moudgil et al. 2020a,b) from Punjab state.

The parasitic control and prevention programs for wildlifemainly depend on different factors like financial resources, public health structures, reduction of parasitic load, action on the animal reservoirs & vectors, improved diagnostic tools, environmental & ecological changes, human behaviours, education of the people that are involved in the wildlife, and domestic animal chain (Chomel 2008).

Though we can achieve better animal health in zoological gardens by quarantining newly inducted animals, improving hygiene practices and enforcing policy for not allowing visitors to feed animals (Singh et al. 2006), however, the most important part is the implementation of strategic prevention and control programs for prevalent parasitic species in wild animals based on parasitological analysis. The present study was planned to record the seasonal incidence of helminthic infections, assess the worm burden based on estimation of the eggs per gram (EPG) of faeces, and evaluate the efficacy of regular scheduled anthelmintic treatment administered in zoo mammals and birds.

MATERIALS AND METHODS

Area of the study

The study was conducted in two zoos located at Pune, Maharashtra, India (18.5204 °N & 73.8567 °E),the first zoo (Zoo I) was Rajiv Gandhi Zoological Park and Wildlife Research Center (RGZP) andthe second zoo (Zoo II), Nisargakavi Bahinabai Chaudhary Zoo, Pimpri Chinchwad. Freshly voided faecal samples of 150 wild animals including Indian Peafowl (6), Pariah Kite (6), Brown Fish Owl (1), Shikra (2), Flying Fox (1), Eagle Owl (1), Brown Owl (1), Long-billed Vulture (2), Black Kite (2), Ring-neck Dove (1), Great Horn Owl (1), Painted Stork (1), Crested Eagle (2), LaggarFalcon (2), Amazon Parrot (4), African Grey Parrot (4), Plum-headed Paraket (1), Spot-billed Duck (4), Rose Ring Parakeet (1), Budgerigar (2), Cockatiel (2), Tiger (7), Leopard (6), Jungle Cat (16), Indian Wolf (1), Lion (2), Hyena (2), Jackal (5), Sloth Bear (2), Black Buck (4), Chinkara (2), Four- horned Antelope (5), Gaur (4), Indian Elephant (2), Barking Deer (2), Sambar (3), Spotted Deer (5), Blue Bull (4), Malabar Giant Squirrel (4), Bonnet Macaque (4), Rhesus Macaque (4), Trinket Snake (2), Bamboo Pit Viper (5), Reticulated Python (1), King Cobra (3), Common Krait (1), Banded Racer (1), Earth Boa (4), Indian Rat Snake (1), and Star Tortoise (1) were collected and examined.

A total of 450 faecal samples were collected during three different seasons, 150 each time (110 samples from Zoo I and 40 samples from Zoo II) throughout 2021. Along with the faecal sample, individual data regarding age, sex, and captivity were recorded separately. The data regarding the drug used for deworming, dose and period of deworming was also noted separately. Fresh faecal samples were collected randomly and pooled together from enclosures premises.

Coprological evaluations

The faecal samples were subjected to detailed parasitological analysis to confirm parasitic eggs /oocysts by direct smear examination. These samples were also subjected to standard sedimentation and floatation techniques (Soulsby 1982). Positive samples were further analysed quantitatively to indirectly calculate the parasitic load by eggs per gram of faeces (Gupta & Singla 2012).

Treatment given

The treatment at Zoo I was carried with fenbendazole

for herbivores @5 mg/kg body weight (BW) for two days (Table 7). The carnivores and reptiles were treated with a combination of praziquantel 50 mg, pyrantel-embonate 144 mg and fenbantel 150 mg @10 mg/kg BW for three days. Whereas, for the birds fenbendazole was given orally @5 mg/kg body weight (with restricted feed) once and repeated after 14 days during the study period.

The deworming zoo II in birds was carried out with albendazole@ 10 mg/kg as a single dose orally. The carnivores were treated with a combination of praziquantel 50 mg, pyrantel-embonate 144 mg and febantel 150 mg) @ 10 mg/kg BW for three days (Table 8).

The faecal samples of positive animals were collected before treatment and 14th day post-treatment. The efficacies of the above drugs were assessed based onthe faecal egg count reduction test (FECRT).

$$\text{Percent efficacy (FECRT)} = \frac{\text{(Pre-treatment mean EPG -Post-treatment mean EPG)}}{\text{Pre-treatment mean EPG}} \times 100$$

Statistical analysis

The data was processed in Microsoft Excel, and descriptive analysis was done using SPSS statistic software for Windows, Version 20 developed by IBM Company, USA. Parametric and non-parametric statistical tests including the Chi-square test, student t-test and faecal egg count reduction test was used to interpret the final results.

RESULTS AND DISCUSSION

Overall seasonal prevalence

The seasonal prevalence of gastro-intestinal parasitic infection in mammals varied significantly (P<0.01) with a higher prevalence (29.50%) in monsoon followed by winter (26.30%) and summer (8.40%). At the same time, the same was found non-significant in birds with a prevalence rate of 21.80, 20.00, and 18.80% in monsoon, winter, and summer, respectively (Table 1). During monsoon season, high humidity and suitable environmental temperatures can prolong the survival of infective parasitic stages (Singh et al. 2009) resulting in higher prevalence rate. Mammals had a higher overall prevalence (21.50%, CI: 16.8–26.6) than birds (18.80%, CI: 13.10–25.60). The findings are similar to Moudgil et al. (2020a), who reported a 25.5% prevalence of gastrointestinal parasitism in zoo animals. In contrast, Muraleedharan et al. (1990) and Singh et al. (2006) recorded a higher prevalence of gastrointestinal parasites. Similarly, in other previous studies, higher prevalence had been recorded from different states of India, i.e., Bihar (51.90%; Modi et al.1997a), Andhra Pradesh (46.59%; Kumar & Rao 2003), and Punjab (32.98%; Moudgil et al. 2020b). Comparatively lower prevalence in the present study could be associated with the adoption of better management practices including balanced feeding, regular deworming, regular screening and treatment of positive animals and daily cage and premises cleaning.

Prevalence based on sex and location

Sex and location (Table 2) based variation in prevalence rate was found non-significant during all three seasons. However, Kumar & Rao (2003) found a higher prevalence of parasitic infection in males than females kept in the different zoological gardens of Andra Pradesh (India) and Nekede Owerri (Southeast Nigeria).

Species based seasonal prevalence

All the omnivores were positive for gastrointestinal parasites during the winter (Table 3) followed by 28.60 % prevalence in herbivores, 16.70 % in reptiles, and 5.04 % (2/37) in carnivores. The observations are similar to Thawait et al. (2014). The prevalence was significantly higher (p<0.01) in omnivores during the winter and monsoon season. The prevalence during summer

Table 1. Overall seasonal prevalence of gastrointestinal parasitic infections in mammals and birds.

	Season	Examined (mammals + birds)	Positive mammals	Prevalence (%)	Positive birds	Prevalence (%)
1	Winter	150 (95+55)	25	26.30 (CI 17.8–26.30)	11	20.00 (CI 10.40–33.0)
2	Summer	150 (95+55)	8	8.40 (CI 3.70–15.90)	8	14.50 (CI 6.50–26.70)
3	Monsoon	150 (95+55)	28	29.50 (CI 20.60–39.90)	12	21.80 (CI 11.80–35.00)
	Overall	450 (285+165)	61	21.50 (CI 16.80–26.60)	31	18.80 (CI 13.10–25.60)
	$\chi 2$		20.86**		1.033^{NS}	

CI—95% Confidence Interval | *—significant at P<0.05 | **—significant at P <0.01 | NS—non-significance.

among different species was found lower than the other seasons, contrary to the studies from southeastern Nigeria that reported higher infections in the summer season in wild cats (Okoye et al. 2014). The hot and dry climate in the study region and clean surroundings on the premises might have attributed to the low parasitic infections during the summer season.

In the monsoon season, 10.80% of carnivores were found positive for gastrointestinal parasites. *Balantidium coli* cysts were most commonly found in lions (Image 5) and strongyle eggs and *Strongyloides* larvae in Hyena (Image 6). Among herbivorous animals, gaurs and blackbucks (Image 3 & 4) were found positive for *Strongyloides* species, whereas chinkara and nilgai were positive for *Trichuris* eggs (Image 1) and *B. coli* (Image 2), respectively. Similar findings were previously recorded by Cook et al. (1979). Among omnivores, *B.coli* cysts were seen in Bonnet macaque (Image 8) and *Strongyloides* species larvae in Malabar Giant Squirrel (Image 7). Prevalence was found higher in monkeys as they were kept in cages, which could have led to excessive stress, further leading to a 100% infection rate of gastrointestinal parasites. Thawait et al. (2014) also recorded a similar observation where the prevalence of different gastrointestinal parasites was found higher in monkeys (60%), followed by herbivores (45.6%) and carnivores (45.2%). In python, *Strongyloides* species eggs (Image 13) were abundant, whereas *B. coli* cysts were seen in Star back tortoise (Image 14). Similar observations were reported in Kerala by Akhila et al. (2018), i.e., overall *Strongyloides* species larvae were most prominently found accounting for 25.7%of all infections, followed by *Capillaria* species (22.8%) and strongyles (20.00%) in captive snakes.

Table 2. Seasonal prevalence of gastrointestinal parasites based on sex and location in different animals.

Variables	Sex		Location	
	Female	Male	Zoo I	Zoo II
Winter	8/29 (27.00)	4/25 (16.00)	24/85(28.20)	1/10(10.00)
χ2	8.38^{NS}		3.74^{NS}	
Summer	0/29(0)	4/25(16.0)	7/85(8.20)	1/10(10.00)
χ2	4.62^{NS}		0.48^{NS}	
Monsoon	9/29(31.00)	9/25(36.00)	26/85(30.60)	2/10(20.00)
χ2 value	1.05^{NS}		0.48^{NS}	

^{NS}—non-significance | Figures in parentheses indicate percentages | Zoo I—Rajiv Gandhi Zoological Park and Wildlife Research Center | Zoo II—NisargakaviBahinabaiChaudhary Zoo.

Seasonal prevalence in birds

In the monsoon season, adult birds showed a significant higher prevalence of gastrointestinal parasites compared to young birds. (Table 4). Similarly, a highly significant difference was observed in males during the monsoon season. The presence of *Ascaridia galli* was

Table 3. Seasonal prevalence of gastrointestinal parasites found in different species of animals.

Variables	Carnivores	Herbivores	Omnivores	Reptiles	χ2 Value
Winter	2/37(5.40)	8/28(28.60)	12/12(100)	3/18(16.70)	25.232**
Summer	2/37(5.40)	2/28(7.10)	2/12(16.70)	2/18(11.20)	1.72^{NS}
Monsoon	4/37(10.80)	8/28(28.60)	12/12(100)	4/18(22.20)	35.380**

*—Significant at P<0.05 | **—significant at P <0.01 | ns—non-significance. Figures in parenthesis indicates percentages

Table 4. Age, sex, location wise seasonal prevalence of gastrointestinal parasites in birds.

Variables /season	Age		Sex		Location	
	Adult	Young	Female	Male	Zoo I	Zoo II
Winter	11/40 (27.50)	1/15 (6.70)	4/18 (22.20)	2/14 (14.30)	8/25 (32.0)	4/30 (13.0)
χ2 value	2.77^{NS}		0 .71^{NS}		2.78^{NS}	
Summer	9/40 (22.50)	2/15 (13.30)	2/18 (11.10)	4/14 (26.60)	7/25 (28)	4/30 (13.0)
χ2 value	0.57^{NS}		1.57^{NS}		1.83^{NS}	
Monsoon	6/40 (15.00)	2/15 (13.30)	3/18 (16.70)	3/14 (21.40)	3/25 (12.0)	5/30 (16.70)
χ2 value	17.39**		46.54**		47.43**	

*—significant at P<0.05 | **—significant at P <0.01 | ^{NS}—non-significance. Figures in parenthesis indicates percentages.

commonly observed in peafowl (Image 9) and African Grey Parrots (Image 11), followed by *Capillaria* in Long-billed Vultures (Image 10) and Great Horn Owls (Image 12). Such observation is more or less similar to the findings of Parsani et al. (2007) in birds in Ahmedabad. Sahoo et al. (2010) reported a prevalence of 29.5%from Orissa at Nandankanan Zoo in wild birds. The birds in the zoo are often subjected to the stress of caged captivity, overcrowding and environmental conditions favorable for the development of parasites. As a result, the birds in captivity generally harbor more parasitic infections than their freely living counterparts.

Captivity based prevalence

Captivity based prevalence found significantly higher in herds (groups), i.e., 33.30% (95% CI = 25.60–41.80), followed by birds 18.80% (95% CI = 13.10–25.60) and individually enclosed animals 9.72% (95% CI = 5.40–15.80) (Table 5). At the beginning of the study, the birds showed the highest prevalence in monsoon, i.e., 32% (95% CI = 14.90–53.50), followed by winter with 28% (95% CI = 12.10–49.40) and summer with 12% (95% CI = 2.50–31.20) at Zoo I. The parasitic gastrointestinal infections in the mammals kept in herds (groups) were highest (45.70%) in the monsoons (95% CI = 30.90–61.00) followed by winter (45.60%) (95% CI = 30.90–61.00) and summer (8.7%) (95% CI = 2.40–61). Initially, in Zoo II, the captivity-based prevalence in birds and herds during the season of monsoon was 13.3% (95% CI = 3.80–30.70) and 100% (95% CI = 2.5–100), respectively. That could be because of overcrowding and competition for food and water, causing stress and lowered immunity, making them more vulnerable to parasitic illnesses (Dhoot et al. 2002; Singh et al.2009). The individual enclosed animals had a significantly lower prevalence than herd animals and birds, as they might get special care, management and appropriate anthelmintic treatment throughout the year (Table 5). Similar observations have been reported by Moudgil et al. (2020a) from Punjab from different zoos.

Seasonal EPG recorded in both mammals and birds

The mean EPG of mammals of both zoos during the pre-monsoon season was the highest (183.9±16.00). The EPG recorded in the positive herbivores was moderate (50–100) while it was more in carnivores (100–300).The mean EPG observed in the pre-winter and pre-summer seasons was (156±13) and post-winter andpost-summer was(20± 6.40) (Table 6). Similar results were shown by Modi et al. (1997b) from Bihar; Kumar & Rao (2003) from Andhra Pradesh and Moudgil et al. (2014) from Punjab, where the monsoon season has the highest prevalence,

Table 5.Prevalence of gastrointestinal parasites based on captivity.

Overall/ Captivity	Frequency of positive samples	Prevalence (%)	χ2
Birds	31/165	18.80 (CI 13.10–25.60)	24.858**
Individual enclosed	14/144	9.70 (CI 5.40–15.80)	
Groups (herds)	47/141	33.30 (CI 25.60–41.80)	

CI—95% Confidence Interval | *—significant at P<0.05 | **—significant at P <0.01 | NS—non-significance.

followed by winter while the summers had the lowest prevalence. During the study period, the intensity of parasitic infection was also recorded in captive birds at both zoos. The mean EPG recorded in birds was highest in the winter season (265±18.30), followed by monsoon (200±26.10) and summer (181.2±32.60).

Drug-wise efficacy study

The treatment was carried out for positive animals and birds in the present investigation as per Table 7 and 8. The faecal samples were collected two times (pre and post treatment) for the study from different animals and birds. At Zoo I (Rajiv Gandhi Zoo and Wildlife Research Centre Karaj, Pune), there was 85.89% and 77.36% reduction in eggs counts after treatment with fenbendazole @5mg/kg in herbivores and birds, respectively. In carnivores, the reduction was 69.93% after treatment with drug combination @10 mg/kg (Praziquantel 50mg + Pyrantelembonate 144mg + fenbantel 150 mg) (Table 7). In Zoo II (Nisargakavi Bahinabai Chaudhary Zoo, Pimpri Chinwad) the reduction in EPG was 72.35% in carnivores with drug combination@10mg/kg (Praziquantel 50mg + pyrantelembonate 144mg + fenbantel 150mg) and 68.98% in birds with albendazole @10mg/kg.

The drugs used were able to eliminate the development stages of the parasites in herbivores, carnivores as well as birds. Cent-percent efficacy was observed against *Trichuris* species and strongyle parasites for herbivores and carnivores, as eggs of these two species of parasites were not detected in the faeces post-treatment. Similarly, in birds, both albendazole and fenbendazole were able to eliminate *Ascaridia* sp., parasites, as no eggs of *Ascaridia* species were seen in the faeces post-treatment.

In the Nisargakavi Bahinabai Chaudhary Zoo, the faecal egg count reduction in mammals was 66.60–100 %. The average reduction in carnivores was 72.35%. The fecal egg count reduction in EPG birds was 76.20–56.30 % with an average of 68.98%. A highly significant reduction in the faecal egg count when compared to pre and post-

Table 6. Seasonal EPG recorded in both mammals and birds.

EPG	Mammals (Range)	Mean ± SE	Birds(Range)	Mean± SE
Pre-winter	50–300	156 ±13.00	150–350	265±18.30
Post-winter	0–100	20 ± 6.40	0–150	60±16.30
Pre-summer	50–300	156±13.00	100–300	181.2±32.60
Post-summer	0–100	20±6.40	0–150	56.2±17.50
Pre-monsoon	50–300	183.9±16.00	100–300	200±26.10
Post-monsoon	0–150	55.30±11.30	0–150	83.3±16.60

Table 7. Species-wise drug and dosing used for deworming at Zoo I.

	Species	drug used (contents)	Dosing	Pre- treatment EPG	Post-treatment EPG	Percentage reduction in EPG
1	Herbivores	5% suspension containing fenbendazole	@ 5mg/kg body weight once a day for 2 days.	156 ±13.00	20 ± 6.40	85.89%
2	Carnivores	Praziquantel 50mg + Pyrantelembonate 144mg +fenbantel 150 mg	@10mg/kg body weight for 3 days.	183.9±16.00	55.30±11.30	69.93%
3	Birds	5% suspension containing fenbendazole	@5mg/kg body weight for 1 day	265±18.30	60±16.30	77.36%

Table 8. Species-wise drug and dosing used for deworming at Zoo II.

	Species	Content of the drug used for deworming	Dosing	Pre- treatment EPG	Post-treatment EPG	percentage reduction in EPG
2	Carnivores	Praziquantel 50mg + pyrantelembonate 144mg + fenbantel 150 mg	@10mg/kg body weight for 3 days.	200±26.10	55.30±11.30	72.35%
3	Birds	Albendazole	@ 10mg/kg. body weight for 1 day	181.2±32.60	56.2±17.50	68.98%

treatment egg counts in both zoos may be due to proper dosing of drugs in animals according to body weight, good hygienic management practices, and individual care of wild animals and birds. It has been observed that confinement of wild animals in the zoo makes them prone to different parasitic infections despite providing adequate attention to feed, water, and maintenance of hygiene in captivity (Barmon et al. 2014). Despite regular deworming practices, the prevalence of parasitic infections varying from 25–95 % has been reported in zoo birds at various locations in India (Parasani et al. 2007). Besides proper dosing with specific and recommended drugs, in animals according to their body weight, good hygienic management practices and individual care of wild animals and birds in captivity is required for the management of these infections.

SUMMARY AND CONCLUSION

Climatic conditions during different seasons and captivity play a major role in the prevalence of parasitic infections in zoo animals. Captivity enhances the repeated exposure of the animals to the environment contaminated by the infective stages of the parasites. Furthermore, such environmental conditions can be favourable to the parasites' developmental stages being propagated as a result and the enclosure being contaminated. It is possible to infer from the study's findings that appropriate control methods, such as periodical examination, following the collection of faecal samples, and successful treatment is administered with anthelmintic. It may be suggested that cleaning the premises and proper disposal of excreta and refusals may minimize/avoid the associated losses.

Eggs of parasites observed in herbivores:

Image 1. *Trichuris* sp. (40X) in Chinkara.

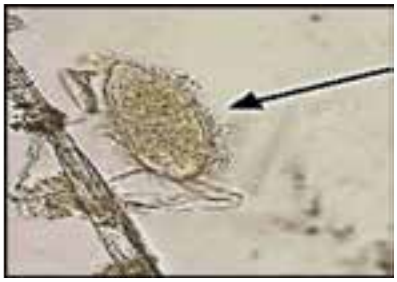


Image 2. *Balantidium coli* (40X) in Nilgai.

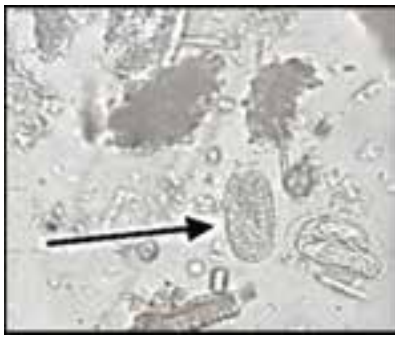


Image 3. *Strongyloides* (40X) in Gaur.

Image 4. *Strongyloides* (40X) in Black Buck.

Eggs of parasites observed in carnivores:

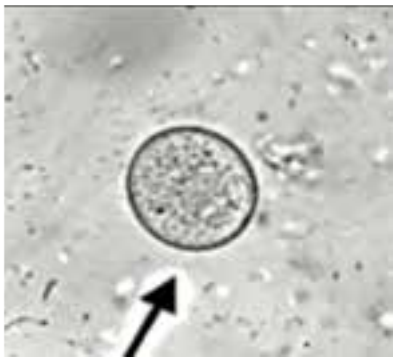


Image 5. Balantidium coli (40X) in African Lion.

Image 6. *Strongyloides* (40X) in Spotted Hyena.

Eggs of parasites observed in omnivores:

Image 7. *Strongyloides* (40X) in Giant Malabar Squirrel.

Image 8. *Balantidum coli* (40X) Bonnet Macaque.

REFERENCES

Akhila, S., V.S. Sukanya, A. Anto & S. Karunakaran (2018). Prevalence of endoparasites in captive snakes of Kerala, India. *Annals of Parasitology* 64(2): 129–135. https://doi.org/10.17420/ap6402.144

Barmon, B.C., N. Begum, S.S.Labony, U.K. Kundu, A.R. Dey & T.R. Dev (2014). Study of gastrointestinal parasites of deer at Char Kukri Mukri in Bhola district. *Bangladesh Journal of Veterinary Medicine* 12(1): 27–33.

Chomel, B.B. (2008). Control and prevention of emerging parasitic zoonoses. *International Journal for Parasitology* 38(11): 1211–1217. https://doi.org/10.1016/j.ijpara.2008.05.001

Cook, T.W., B.T. Ridgeway, R. Androeid & J. Hodge (1979). Gastrointestinal helminths in White-tailed Deer of Illinois. *Journal of Wild Diseases* 15(3): 405–407.

Dhoot, V.M., S.V.Upadhye&S.W.Kolte (2002). Prevalence of parasitism in wild animals and birds of Maharajbag Zoo, Nagpur. *Indian Veterinary Journal* 79(3): 225–227.

Gupta, A., A.K. Dixit, P. Dixit, C. Mahajan & A.B. Shrivastava (2011). Incidence of gastro-intestinal parasites in wild ruminants around Jabalpur, India. *Journal of Threatened Taxa* 3(11): 2226–2228. https://doi.org/10.11609/JoTT.o2431.2226-8.

Gupta, S.K. & L.D. Singla (2012). Diagnostic trends in parasitic diseases of animals, pp. 81–112. In: Gupta, R.P., S.R. Garg, V. Nehra & D. Lather (eds.). *Veterinary Diagnostics: Current Trends.* Satish Serial Publishing House, Delhi.

Jaiswal, S., P. Fontanillas, J. Flannick, A. Manning, P.V. Grauman, B.G. Mar & B.L. Ebert (2014). Age-related clonal hematopoiesis associated with adverse outcomes. *New England Journal of Medicine* 371(26): 2488–2498. https://doi.org/10.1056/NEJMoa1408617

Kumar, B.V. & A.N. Rao (2003). Influence of age on the prevalence of parasitic infections among the felids in Animal Reserve Centre at Vizag Zoo, Vishakhapatnam, Andhra Pradesh. *Zoo's Print* 18(10): 11.

Mir, A.Q., K. Dua, L.D. Singla, S. Sharma & M.P. Singh (2016). Prevalence of parasitic infection in captive wild animals in BirMotiBagh mini zoo (Deer Park), Patiala, Punjab. *VeterinaryWorld* 9(6): 540–543. https://doi.org/10.14202/vetworld.2016.540-543

Modi, G.S., B.N. Prasad & B.K. Sinha (1997a). Seasonal effect on the prevalence of parasitic zoonotic diseases among zoo

Eggs of parasites observed in birds:

Image 9. *Ascaridiagalli* (40X) in Indian Peafowl.

Image 10. *Capillaria* spp.(40X) in Long-billed Indian Vulture.

Image 11. *Ascaridiagalli* (40X) in African Grey Parrot.

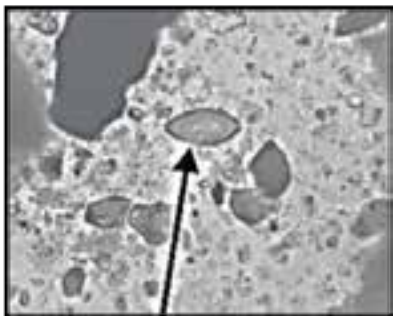


Image 12. *Capillaria* spp. (40X) in Great Horn Owl.

Eggs of parasites in reptiles:

Image 13. *Strongyloides* (40X) in Reticulated Python.

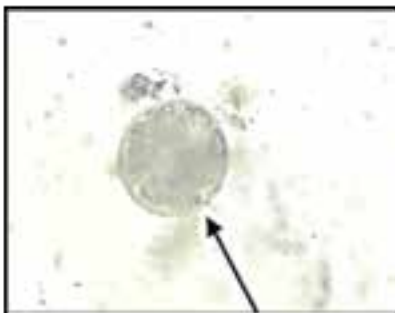


Image 14. *Balantidium coli* (40X) in Star Back Tortoise.

animals in Bihar. *Zoo's Print* 12: 8–11.

Modi, G.S., B.N. Prasad & P.K. Sinha (1997b). Effect of age on the prevalence of intestinal parasitism among zoo animals in Bihar. *Indian Veterinary Journal* 74: 351–353.

Moudgil, A.D., L.D. Singla & M.P. Singh (2014). First report on molecular identification and fenbendazole resistance against *Baylisascaris transfuga* infection in *Melursus ursinus* (Sloth Bear). *Helminthologia* 51(4): 262–268. https://doi.org/10.2478/s11687-014-0239-2

Moudgil, A.D., L.D. Singla & Pallavi (2015). Parasitosis in wild felids of India: an overview. *Journal of Threatened Taxa* 7(10): 7641–7648. https://doi.org/10.11609/JoTT.o4236.7641-8

Moudgil, A.D., L.D. Singla & M.P. Singh (2020a). Seasonal coprological survey for assessment of risk factors associated with gastrointestinal parasitism in zoo-housed animals of Punjab, India. *Biological Rhythm Research* 51(8): 1273–1287. https://doi.org/10.1080/09291016.2019.1571706

Moudgil, A.D., L.D. Singla & M.P. Singh (2020b). Seasonal variation in gastrointestinal parasitism of zoo-housed birds of Punjab, India. *Biological Rhythm Research* 51(8): 1075–1086. https://doi.org/10.1080/09291016.2019.1576284

Muraleedharan, K., V. Iswaraiah, K.S. Ziauddin & K. Srinivasan (1990). A survey of gastro-intestinal parasites of animals of zoological gardens at Mysore. *Mysore Journal of Agricultural Science* 24(2): 250–256.

Okoye, I.C., N.R. Obiezue, F.N. Okoh & E.C. Amadi (2014). Descriptive epidemiology and seasonality of intestinal parasites of cats in Southeast Nigeria. *Comparative Clinical Pathology* 23(4): 999–1005.https://doi.org/10.1007/s00580-013-1734-4

Parsani, H.R., R.R. Momin, M.G. Maradia & V. Singh (2001). A survey of gastrointestinal parasites of captive animals at Rajkot municipal corporation zoo, Rajkot, Gujarat. *Zoos' Print Journal* 16(10): 604–606. https://doi.org/10.11609/JoTT.ZPJ.16.10.604-6

Parsani, H.R. Momin & V. Singh (2007). Prevalence of parasitic infections in captive zoo birds in Gujarat. *Journal of Veterinary Parasitology* 21(2): 129–131.

Rao, A.T. & L.N. Acharjyo (1984). Diagnosis and classification of common hoofed wild life in North America. *Mid-American Agriculture Research in Veron* 53: 593–594.

Sahoo, N., M. Dehuri, K.M.N. Bharti, P.K. Roy, A. Das & R.K. Samantaray (2010). Prevalence of endoparasitic infection in birds of Nandankanan Zoo. *Journal of Veterinary Parasitology* 24(1): 95–96.

Singh, P., M.P. Gupta, L.D. Singla, N. Singh & D.R. Sharma (2006). Prevalence and chemotherapy of gastrointestinal helminthic infections in wild carnivores in Mahendra Choudhury Zoological Park, Punjab. *Journal of Veterinary Parasitology* 20(1): 17–23.

Singh, P., L.D. Singla, M.P. Gupta, S. Sharma & D.R. Sharma (2009). Epidemiology and chemotherapy of parasitic infections in wild omnivores in the Mahendra Choudhury Zoological Park, Chhat Bir, Punjab. *Journal of Threatened Taxa* 1(1): 62–64. https://doi.org/ 10.11609/JoTT.o1767a.62-4

Soulsby, E.J.L. (1982). *Helminths. Arthropods and Protozoa of Domesticated Animals, 7th Edition*, ELBS, Bailliere Tindall, London, 809 pp.

Thawait, V.K., S.K. Maiti & A.A.Dixit (2014). Prevalence of gastro-intestinal parasites in captive wild animals of Nandan Van Zoo, Raipur, Chhattisgarh. *Veterinary World* 7(7): 448–451. https://doi.org/10.14202/vetworld.2014.448-451

Varadharajan, A. & C. Pythal (1999). Incidence of gastro intestinal parasitism in free living Feral Bonnet Macaque (*Macacaradiata* L). Zoo's *Print Journal* 14(6): 41–42. https://doi.org/10.11609/JoTT.ZPJ.14.6.41-2

ZSI (2021). India adds 557 new species to its fauna: Zoological Survey of India. Archived 13 September 2021 at the Wayback Machine, *The Hindu*, 27 Aug 2021.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25598–25603

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

https://doi.org/10.11609/jott.8154.16.7.25598-25603

#8154 | Received 21 August 2022 | Final received 29 June 2024 | Finally accepted 12 July 2024

OPEN ACCESS

COMMUNICATION

Bryophyte diversity of Berinag (Pithoragarh District) in Kumaun Himalaya, Uttarakhand, India

D. Dhami [1] & P. Chaturvedi [2]

[1,2] Department of Biological Sciences, College of Basic Sciences & Humanities, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand 263145, India.

[1] deekshadhami@gmail.com, [2] an_priti@yahoo.co.in (corresponding author)

Abstract: This study reports the diversity of bryophytes of Berinag (Dist. Pithoragarh), Uttarakhand (India). In the investigation, a total of 33 species were reported, out of which eight were liverworts and 25 were mosses. Majority of the taxa were terricolous and corticolous. Liverwort species belonged to six genera of five families and two orders whereas mosses belonged to 24 genera of 17 families and eight orders. Out of the 10 orders dealt in the present work, Hypnales was the largest consisting of seven families, nine genera, and nine species followed by Dicranales and Marchantiales both consisting of three families, five, and four genera, respectively. In mosses, Bryaceae was the dominant family consisting of three genera and four species followed by Calymperaceae, Leucobryaceae, Anomodontaceae, Leskeaceae, and Polytrichaceae. Out of 25 mosses, 15 were acrocarpous and 10 were pleurocarpous. Aytoniaceae was dominant among liverworts. *Marchantia*, *Frullania*, and *Bryum* were the dominant genera of the region.

Keywords: Acrocarpous, bryoflora, corticolous, hornworts, hypnales, liverworts, Marchantiales, mosses, pleurocarpous, Pottiaceae.

Editor: Anonymity requested.

Date of publication: 26 July 2024 (online & print)

Citation: Dhami, D. & P. Chaturvedi (2024). Bryophyte diversity of Berinag (Pithoragarh District) in Kumaun Himalaya, Uttarakhand, India. *Journal of Threatened Taxa* 16(7): 25598–25603. https://doi.org/10.11609/jott.8154.16.7.25598-25603

Funding: No funding was received from any agency for this work.

Competing interests: The authors declare no competing interests.

Author details: Deeksha Dhami completed her M.Sc. thesis on diversity of bryophytes in Berinag. Her research interests include different aspects of bryophytes and medicinal plants. Dr. P. Chaturvedi is currently professor & head, Department of Biological Sciences, G.B. Pant University of Agriculture & Technology, Pantnagar. For the last 25 years, she has been working on biodiversity and bioprospecting of bryophytes and conservation biology of threatened medicinal flora of Uttarakhand.

Author contributions: DD collected the samples, prepared the herbarium specimens and wrote the first draft. PC conceptualized and designed the study and prepared the final draft.

Acknowledgements: Both the authors are highly grateful to Dr. S.D. Tewari, retired professor, I.P.G.P.C.C. Haldwani for providing generous support to conduct this study. Authors are also thankful to the dean, CBSH and G.B. Pant University of Agriculture & Technology, Pantnagar for providing the necessary lab facilities.

INTRODUCTION

India is one of the mega diverse countries blessed with four global diversity hotspots, home to more than 49,000 species of plants, bestowed with 18,800 species of Angiosperms, 82 species of Gymnosperms, 1,307 species of Pteridophytes, 7,434 species of Algae, 2,786 species of Bryophytes, and 2,917 species of Lichens. According to Plant Mao et al. (2020), bryophytes constitute 5.57 % of total plants of India.

State-wise distribution list of liverworts and hornworts in India (Singh et al. 2016) suggested that the state of Uttarakhand ranked second in the country holding 47 families of liverworts and hornworts. The state is home to 84 genera and 259 species and infraspecific taxa of liverworts and hornworts ranking fourth and fifth in the country, respectively, for number of genera and species. There are 339 species belonging to 129 genera of mosses in Uttarakhand (Suman et al. 2010).

Luxuriant forests, varied topography, and suitable climatic conditions made Kumaun Himalaya of Uttarakhand, very rich in bryophyte diversity. Pithoragarh is the easternmost district in the Kumaun region of Uttarakhand. The study area (29.781–29.778 °N & 80.045–80.048 °E), Berinag, is a hill station and one of the six administrative subdivisions (tehsil) of Pithoragarh famous for tea estates (Figure 1). It is located at an elevation of 2,540–1,674 m (source: Google Earth). It got its name from Naga Devta temple locally called 'Bedinag' situated at the top of Berinag Hill. Limestone, sandstone, slate, gneiss, and granite rocks are very common in the region. It has a humid and cold climate. Earlier, most of the land was covered by the forest, however, due to rapid urbanization, biodiversity of this area is under threat. Today, various types of new projects like electricity production from pine needles, tourism and small-scale industries are flourishing in this area, however, threat to the biodiversity remains unaddressed. For the biodiversity conservation of the area, a complete taxonomic data of the region is essential. In the ongoing decade of ecosystem restoration (www.unep.org), diversity of the pioneers of vegetation needs to be assessed for getting the up-to-date health profile of the fragile mountain ecosystems. The present study, attempts to document the bryophytic flora of Berinag and prepare a preliminary checklist based on this.

MATERIAL AND METHODS

The present work is the outcome of several plant surveys done in the study area by the first author (DP) from September 2018 to June 2019. Systematic collection of bryoflora was done from the various localities. Plants from different terrestrial habitats were collected, air dried and were kept in paper packets (15 x 10 cm). Field data such as name, locality from where the collection was done, date of collection, habitat, substratum, collector's name, associated species were written on the paper packets followed by the identification of collected samples using the available monographs of Gangulee (1969–1980), Chopra (1975), & Aziz & Vohra (2008) for mosses and Kashyap (1929), Watson (1968), Singh & Singh (2009), & Dey & Singh (2012) for liverworts. Bryonet and bryophyte experts were also consulted to confirm the identity of some confusing taxa. Standard abbreviations of authors' names have been followed according to Brummit & Powell (1992). The collected samples have been deposited in Cryptogam section of Herbarium of G.B. Pant University of Agriculture & Technology, Pantnagar (GBPUH). Enumeration is done in accordance with the classification given by Crandall-Stotler et al. (2009) for liverworts and Goffinet et al. (2009) for mosses. Orders and families have been arranged as per adopted classifications. The genera within each family and the species within each genus have been arranged alphabetically. All species were verified against TROPICOS data base (www.tropicos.org), The Plant List 2013 (www.theplantlist.org), and Catalogue of Life (CoL 2021).

RESULTS

Increased tourism activities, unabated biological resource usage and unrestricted infrastructure development in the hills have been the major factors responsible for diminishing plant diversity of the region. Bryophytes along with pteridophytes and herbaceous angiosperms form the major ground flora of the hill forests. Besides, the miniature cryptogams also adorn the tree barks and rocky surfaces. Habitat preference of bryophytes itself signifies their role as an important indicator of ecosystem health. To recreate and restore diminishing health of fragile ecosystems of mountainous tourist spots, bryofloristic assessment and conservation is essential. Bryophytes of Berinag along with their local distribution, information about their substratum and taxonomic hierarchies of species are listed in Table 1. Out

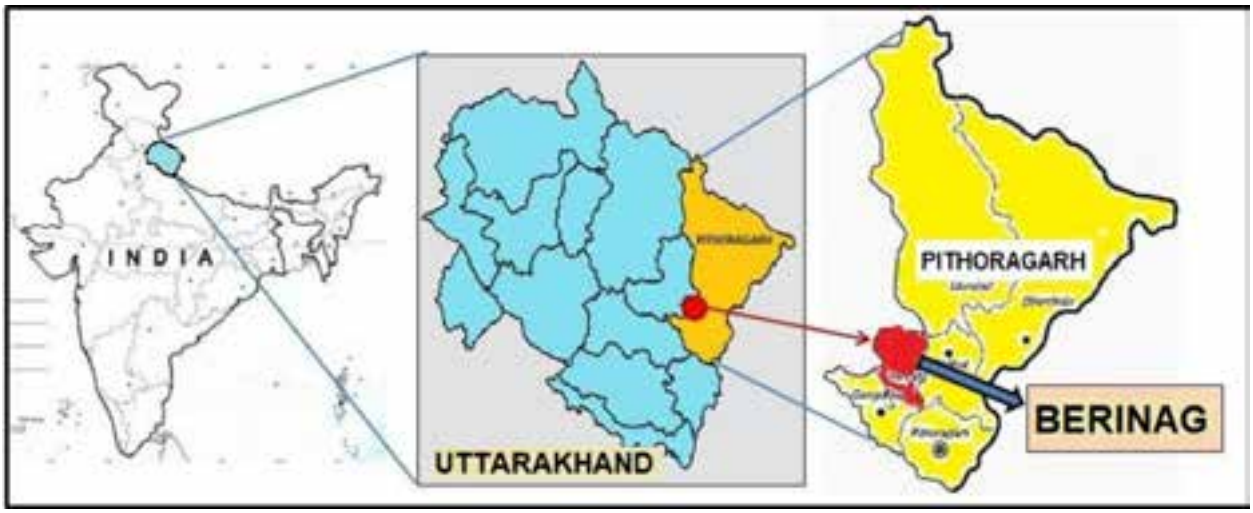


Figure 1. Map of study site in Uttarakhand, India.

of the 33 taxa reported in the region, eight taxa belonged to liverworts and remaining 25 were mosses. Hornworts were not found in the study area. This accounted for 1.18% of total bryophytes in just around 0.0002% of total geographic area of the country. Substratum details give the idea of dominance of terrestrial and corticolous forms of bryophytes in Berinag (Figure 2). Out of 25 mosses, 15 were acrocarpous mosses and 10 mosses were pleurocarpous making acrocarpous growth forms most dominant amongst mosses (Figure 3).

Hypnales and Marchantiales were the most dominant orders with representation of seven and three families respectively. *Bryum*, *Frullania*, and *Marchantia* were represented by two species each in the study area. A preliminary checklist enlisting 51 taxa has earlier been reported by Alam et al. (2012) from Dharchula and Munsyari tehsils of Pithoragarh wherein, Hypnales was the most dominant order represented by seven families followed by Bryales and Dicranales representing three families each among mosses. Marchantiales was the most dominant order among liverworts representing eight families. According to the moss checklist of western Himalaya (India) by Alam (2013), there are 745 species of mosses belonging to 230 genera and 55 families. Hypnales is the most diversified order of mosses followed by Pottiales and Bryales. In the present study also, Hypnales was the most dominant group of mosses followed by Dicranales.

Family wise comparison of distribution of collected genera and species in the world, in western Himalaya, in Uttarakhand, in Pithoragarh District and in the study area (Berinag) is provided in the Table 2. According to The Plant List (2013), a total of 1,822 plant genera in 177

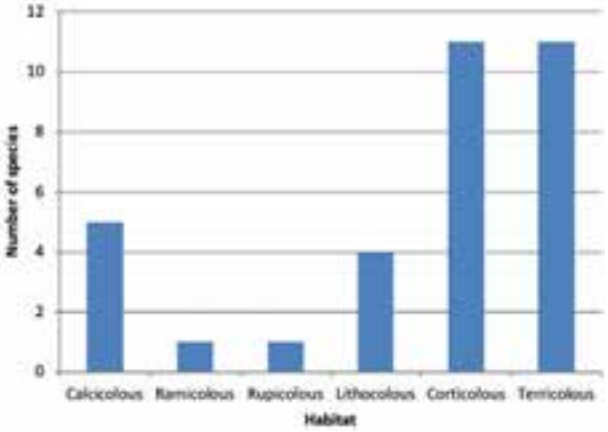


Figure 2. Distribution of mosses on the basis of their habitat.

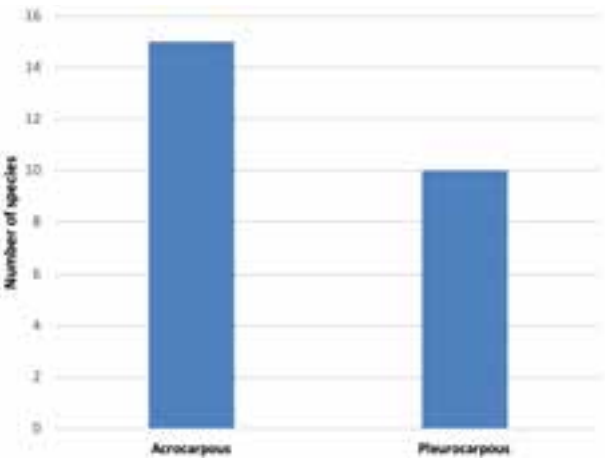


Figure 3. Total number of investigated species of pleurocarpous and acrocarpous mosses.

Table 1. Bryophytes of Berinag (Pithoragarh District), Uttarakhand.

	Family	Species	Local distribution	Substratum
A)	**LIVERWORTS**			
1	Aytoniaceae	*Plagiochasma appendiculatum* Lehm. & Lindenb.	New Bazar Berinag, 29.778°N, 80.053°E	Cemented wall
2		*Reboulia hemisphaerica* (L.) Raddi	New Bazar Berinag, 29.778°N, 80.053°E	Cemented wall
3	Dumortieraceae	*Dumortiera hirsuta* (Sw.) Nees	Kanera (Site rich in water) 29.672°N, 80.055°E	Stone
4	Marchantiaceae	*Marchantia papillata* Raddi	Degree College Berinag, 29.775°N, 80.050°E	Cemented wall
5		*Marchantia polymorpha* L.	Naula Berinag, 29.778°N, 80.053°E	Stone
6	Frullaniaceae	*Frullania ericoides* Nees (Mont).	Kanera, 29.672°N, 80.055°E	Bark of *Quercus leucotricophora* A.Campus and *Mangifera indica* L.
7		*Frullania muscicola* Steph.	Kalibinayak, 29.704°N, 80.054°E	Bark of *Q. leucotricophora* A.Campus
8	Porellaceae	*Porella caespitans* (Steph.) S.Hatt.	Kanera, 29.672°N, 80.055°E	Bark of *Q. leucotricophora* A.Campus
B)	**MOSSES**			
9	Bartramiaceae	*Philonotis mollis* (Dozy & Molk.)	Forest of Berinag, 29.780°N, 80.055°E	Soil
10	Bryaceae	*Bryum argenteum* Hedw.	Berinag Main Market, 29.778°N, 80.053° E	Humus mixed soil
11		*Bryum mildeanum* Jur.	Berinag forest 29.780°N, 80.055°E	Soil
12		*Ptychostomum capillare* (Hedw.) Holyoak & N.Pedersen.	Berinag forest, 29.780°N, 80.055°E	Soil
13		*Rhodobryum roseum* (Hedw.). Limpr.	Berinag forest, 29.780°N, 80.060°E	Soil
14	Mniaceae	*Mnium integrum* Bosch & Sande Lac.	Berinag forest, 29.780° N, 80.055° E	Soil
15	Calymperaceae	*Octoblepharum albidum* Hedw.	Kanera, 29.672°N, 80.055°E	Bark of *Q. leucotricophora* A.Campus
16		*Syrrhopodon gardneri* (Hook.) Schwagr	Kalibinayak, 29.704°N, 80.055°E	Bark of *Q. leucotricophora* A.Campus and *Q. glauca* Thunb.
17	Ditrichaceae	*Ditrichum heteromallum* (Hedw.)	Forest of Berinag, 29.780° N, 80.060° E	Rock
18	Leucobryaceae	*Brothera leana* (Sull.) Müll.	Kalibinayak, 29.704° N, 80.054°E	Bark of *Q. leucotricophora* A.Campus
19		*Thysanomitrion involutum* (Mull.Hal.) P.de la Varde	Degree College Berinag, 29.775°N, 80.050°E	Stone
20	Funariaceae	*Funaria hygrometrica* Hedw.	Forest of Berinag, 29.780°N, 80.055°E	Soil
21	Anomodontaceae	*Anomodon minor* (Hedw.) Lindb.	Kanera, 29.672°N, 80.055°E	Bark of *Toona ciliata* M.Roem.
22		*Herpetineuron toccoae* (Sull. & Lesq.) Cardot.	Dhanouli, 29.761°N, 80.053°E	Bark of *Q. leucotricophora* A.Campus and *Q. glauca* Thunb.
23	Brachytheciaceae	*Oxyrrhynchium vagans* (A.Jaeger) Ignatov & Huttunen.	Kanera, 29.672°N, 80.055°E	Soil
24	Entodontaceae	*Entodon concinnus* °	Kanera, 29.672°N, 80.055°E	Cemented wall
25	Leskeaceae	*Haplocladium schimperi* Ther.	Kanera, 29.672°N, 80.055°E	Bark of *T. ciliata* M.Roem. and *M. indica L.*
26		*Rozea pterogonioides* (Harv.) A. Jaeger	Kanera, 29.672°N, 80.055°E	Soil
27	Meteoriaceae	*Trachypodopsis serrulata* (P. Beauv.) M. Fleisch.	Naula site Berinag, 29.778°N, 80.053°E	Cemented wall
28	Neckeraceae	*Neckeropsis exserta* (Hook. ex Schwagr.) Broth.	Kanera, 29.672°N, 80.055°E	Wood of *M. indica* L
29	Thuidiaceae	*Thuidium tamariscellum* (Mull. Hal.) Bosch & Sande Lac.	Dhanouli, 29.761°N, 80.053°E	Stone
30	Orthotrichaceae	*Macromitrium moorcroftii* (Hook. & Grev.) Schwagr.	Kalibinayak,29.704°N, 80.054°E	Branch of *Q. leucotricophora* A.Campus
31	Polytrichaceae	*Atrichum obtusulum* (Mull. Hal.) A.Jaeger.	Berinag forest, 29.780°N, 80.055°E	Soil
32		*Pogonatum aloides* (Hedw.) P.Beauv.	Berinag forest,29.780°N, 80.055°E	Soil
33	Pottiaceae	*Hyophila involuta* (Hedw.) P.Beauv.	Kanera, 29.672°N, 80.055°E	Soil

Table 2. Family wise comparison of distribution of genera and species in the world, in India, in western Himalaya, in Uttarakhand and in the study area.

Family	Number of genera and species													
	In the World (The Plant List 2013)		In India (Dandotiya et al. 2011)		In western Himalaya (Alam 2013)		In Uttarakhand (Suman et al. 2010)		In Pithoragarh (Sahu & Asthana 2015)		In Pithoragarh (Alam et al. 2012)		In Berinag (Dhami 2019)	
	G	S	G	S	G	S	G	S	G	S	G	S	G	S
Aytoniaceae	10	115	6	30	-	-	7	22	-	-	3	6	2	2
Dumortieraceae	-	-	1	1	-	-	-	-	-	-	1	1	1	1
Marchantiaceae	7	50	3	24	-	-	3	5	-	-	1	3	1	2
Frullaniaceae	-	-	1	42	-	-	1	7	-	-	-	-	1	2
Porellaceae	5	134	1	24	-	-	1	16	-	-	1	1	1	1
Bartramiaceae	14	686	8	48	7	28	4	12	1	2	1	1	1	1
Bryaceae	43	2108	09	103	6	45	6	32	5	9	4	5	3	4
Mniaceae	13	222	7	64	7	38	3	20	2	3	1	1	1	1
Ditrichaceae	34	347	9	30	4	12	4	9	1	1	-	-	1	1
Calymperaceae	19	417	7	35	2	4	3	4	-	-	-	-	2	2
Leucobryaceae	-	-	8	69	2	5	5	9	-	-	-	-	2	2
Pottiaceae	138	3223	38	207	32	116	17	60	6	8	3	4	1	1
Funariaceae	24	452	4	47	3	15	3	11	2	2	2	2	1	1
Anomodontaceae	-	-	5	17	-	-	3	8	-	-	1	1	2	2
Brachytheciaceae	62	1117	9	66	-	-	7	19	2	3	1	1	1	1
Entodontaceae	13	314	3	19	3	3	5	15	1	3	1	2	1	1
Leskeaceae	22	383	10	35	12	30	5	17	1	1	-	-	2	2
Meteoriaceae	30	650	21	80	11	21	4	5	4	5	3	4	1	1
Neckeraceae	37	827	19	93	8	21	6	12	1	1	-	-	1	1
Thuidiaceae	33	504	3	27	5	27	1	4	5	6	1	-	-	1
Orthotrichaceae	44	1265	13	64	1	18	2	4	1	1	1	1	1	1
Polytrichaceae	31	536	5	55	5	24	4	18	2	3	2	2	2	2

-—indicates that respective species is not included in the source | G—number of genera | S—number of species.

families of bryophytes are present in the world out of which maximum number of genera and species belong to family Pottiaceae (138 genera, 3,223 species) followed by Bryaceae (43 genera, 2,108 species). Dandotiya et al. (2011) reported total 1,786 species of mosses in 355 genera and 675 species of liverworts in 121 genera in India, out of which maximum number of taxa belonged to family Pottiaceae (38 genera, 207 species) followed by Lejeuneaceae and Notothyladaceae. Sahu & Asthana (2015) reported 72 moss taxa belonging to 24 families from Pithoragarh and adjoining areas with Bryaceaee being the most diverse family represented by nine genera. The present bryofloristic study of Berinag also reports maximum number of species belonging to Bryaceae but with a lesser representation, i.e., three genera and four species only (Tables 1 & 2). According to Alam (2013), maximum diversity of mosses in western Himalaya (India) is represented by family Pottiaceae which included 116 species belonging to 32 genera. Unlike the general trend in western Himalaya or India or Uttarakhand, in the present study, Bryaceae is having maximum diversity. This may be due to dominance of mixed pine-oak forests in the region. Bryaceae members prefer shade and lower temperature while Pottiaceae is more common in comparatively drier and open areas. Habitat preference of the bryophytic vegetation suggests the dominance of both terricolous and corticolous forms represented by 11 species each. Habitat wise distribution of bryophytic vegetation of district Nainital and selected mineralized localities of Almora and Pithoragarh districts of Kumaun Himalaya have earlier been reported by Tewari and Pant (1994).

REFERENCES

Alam, A. (2013). Moss flora of Western Himalayas, India- an updated checklist. *Archive for Bryology* 168: 1–28.

Alam, A., V. Sharma, S.C. Sharma & A. Tripathi (2012). Bryoflora of Munsyari and Dharchula Tehsil of Pithoragarh, Uttarakhand, Western Himalayas, India. *Archive for Bryology* 140: 1–11.

Aziz, M.N. & J.N. Vohra (2008). *Pottiaceae (Musci) of India*. Bishen Singh and Mahendra Pal Singh, Dehra Dun, India, 366 pp.

Brummitt, R.K. & C.E. Powell (eds.) (1992). *Authors of plant names. A list of authors of scientific names of plants, with recommended standard forms of their names, including abbreviations*. Kew, 732 pp.

Chopra R.S. (1975). *Taxonomy of Indian Mosses*. CSIR Publications, New Delhi, India, 631 pp.

CoL (2021). Species 2000 & ITIS Catalogue of Life, 2021-05-07. Digital resource at www.catalogueoflife.org. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858. Accessed on 4 July 2021.

Crandall-Stotler, B., R.E. Stotler & D.G. Long (2009). Phylogeny and classification of the Marchantiophyta. *Edinburgh Journal of Botany* 66(1): 155–198. https://doi.org/10.1017/S0960428609005393

Dandotiya, D., H. Govindapyari, S, Suman & P.L. Uniyal (2011). Checklist of the bryophytes of India. *Archive for Bryology* 88: 1–126.

Dey, M. & D.K. Singh (2012). *Epiphyllous Liverworts of Eastern Himalaya*, Botanical Survey of India, Kolkata, 415 pp. https://doi.org/10.14719/pst.2016.3.2.228

Dhami, D. (2019). Diversity of Bryophytes in Berinag (Uttarakhand), Kumaun Himalaya. M.Sc. Thesis. Department of Biological Sciences, G.B. Pant University of Agriculture and Technology, Pantnagar, 100 pp.

Gangulee, H.C. (1969–1980). *Mosses of Eastern India and adjacent regions*. Fascicles 1–8. Books and Allied Limited, Calcutta, 2145 pp.

Goffinet, B., W.R. Buck & A.J. Shaw (2009). Morphology, anatomy and classification of the Bryophyta, pp. 55–138. In: Goffinet, B. & A.J. Shaw (eds.). *Bryophyte Biology*. 2nd edition. Cambridge University Press, Cambridge, 565 pp. https://doi.org/10.1017/CBO9780511754807.003

Kashyap, S.R. (1929). *Liverworts of the Western Himalaya and Punjab Plain Part 1*. The University of Panjab, Lahore, 129 pp.

Mao, A.A., S.S. Dash & S. Kumar (2020). Plant Discoveries 2019. Botanical Survey of India, Kolkata.

Sahu, V. & A.K. Asthana (2015). Diversity in mosses of Pithoragarh and its neighbouring areas, western Himalaya, India. *Indian Forester* 141(11): 1183–1191. https://doi.org/10.36808/if/2014/v140i4/48020

Singh, D.K., D. Singh & S.K. Singh (2016). *Liverworts and Hornworts of India: An Annotated Checklist.* Botanical Survey of India, Kolkata, 439 pp.

Singh, S.K. & D.K. Singh (2009). *Hepaticae and Anthocerotae of Great Himalayan National Park and Its Environs (H.P.), India*. BSI, Kolkata, 466 pp.

Suman, S., Sanavar & P.L. Uniyal (2010). Bryophytes of Uttarakhand, pp. 197–276. In: Uniyal, P.L., B.P. Chamola & D.P. Semwal (eds.). *The Plant Wealth of Uttarakhand*. Jagdamba Publishing House, New Delhi, 436 pp.

Tewari, S.D. & G. Pant (1994). *Bryophytes of Kumaun Himalaya*. Bishen Singh Mahendra Pal Singh Dehradun. India, 240 pp.

Watson, E.V. (1968). *British Mosses and Liverworts*. Cambridge University Press. 2nd edition, 495 pp.

The Plant List (2013). Version 1.1. Published on the internet. http://www.the plantlist.org/ (accessed several times in 2019)

http://www.tropicos.org. Missouri Botanical Garden. Accessed on 19 August 2022.

http://www.unep.org. Accessed several times in 2022, 2023.

http://www.Bryonet.org. Accessed several times in 2022, 2023.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25604–25608

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

https://doi.org/10.11609/jott.8859.16.7.25604-25608

#8859 | Received 28 November 2023 | Final received 29 June 2024 | Finally accepted 03 July 2024

OPEN ACCESS

SHORT COMMUNICATION

The opportunistic feeding behaviour of *Schistura notostigma* (Teleostei: Nemacheilidae) in tropical mountain streams in Sri Lanka

J. Bandara [1], M.P. Gunawardena [2] & R.T.P Jayasuriya [3]

[1,2,3] Faculty of Science, Horizon Campus, Knowledge City Malabe, KCM Drive, Off Millennium Road, Malabe, 10115, Sri Lanka.
[2] Biodiversity Educational Research Initiative (BERI), LE CUBE, No. 130, High Level Road, Colombo 06, 00600, Sri Lanka.
[2] Thema Collection, LE CUBE, No. 130, High Level Road, Colombo 06, 00600, Sri Lanka.
[1] janaminabandara@gmail.com (corresponding author), [2] medhisha@gmail.com, [3] ravishkajayasuriya@gmail.com

Abstract: *Schistura notostigma* is a bottom-dwelling freshwater fish endemic to Sri Lanka. In this study, we document an opportunistic feeding behavior exhibited by this loach species in close association with *Garra ceylonensis* and *Plesiopuntius bimaculatus* in the streams of high-elevation headwater regions of the Knuckles Mountain Range and Piduruthalagala Mountain Range in Sri Lanka.

Keywords: Feeding ecology, behavioural ecology, coexistence, commensalism

Schistura notostigma (Bleeker, 1863) is a small, bottom-dwelling freshwater fish endemic to Sri Lanka. It features an elongated, moderately cylindrical body that is ventrally flattened and slender, and possesses three pairs of small barbels, which characteristics are shared by many benthic freshwater fishes (Pethiyagoda 1991; Sundarabarathy et al. 2001; Herath 2009; Shirantha 2021). In this study, we document instances of opportunistic feeding behavior exhibited by this loach. These behaviors were observed frequently in the close association with two species of the family Cyprinidae, *Garra ceylonensis* (Bleeker, 1863) and *Plesiopuntius bimaculatus* (Bleeker, 1863), in streams situated in high elevation headwater regions of the Knuckles Mountain Range (KMR) and Piduruthalagala Mountain Range (PMR).

Schistura notostigma (Image 1A) is one of the few freshwater fishes found at elevations exceeding 1,000 m in Sri Lanka, along with *Garra ceylonensis* (Image 01B), *Plesiopuntius bimaculatus* (Image 01C) and *Devario* spp. (Pethiyagoda & Sudasinghe 2021). Although *S. notostigma* can sometimes be found at elevations above 1,300 m, the other species mentioned generally inhabit elevations up to 1,000 m, albeit with rare exceptions (Pethiyagoda & Sudasinghe 2021; Sudasinghe et al. 2021, 2023). Despite our observations indicating that *S. notostigma* could occasionally be the sole freshwater fish in high-elevation habitats, however, it exhibits a notable inclination to associate closely with *G. ceylonensis* when present in the ichthyo-community as associates.

Editor: Rohan Pethiyagoda, Australian Museum, Sydney, Australia. **Date of publication:** 26 July 2024 (online & print)

Citation: Bandara, J., M.P. Gunawardena & R.T.P Jayasuriya (2024). The opportunistic feeding behaviour of *Schistura notostigma* (Teleostei: Nemacheilidae) in tropical mountain streams in Sri Lanka. *Journal of Threatened Taxa* 16(7): 25604–25608. https://doi.org/10.11609/jott.8859.16.7.25604-25608

Funding: This research was supported by funding from BERI and Thema Collection, Sri Lanka.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are grateful to Rohan Pethiyagoda for reviewing an earlier version of the manuscript draft, and to Hiranya Sudasinghe for providing constructive comments and reviewing the current version of the manuscript. The authors also thank Madura De Silva for permitting the use of his photographs in this paper.

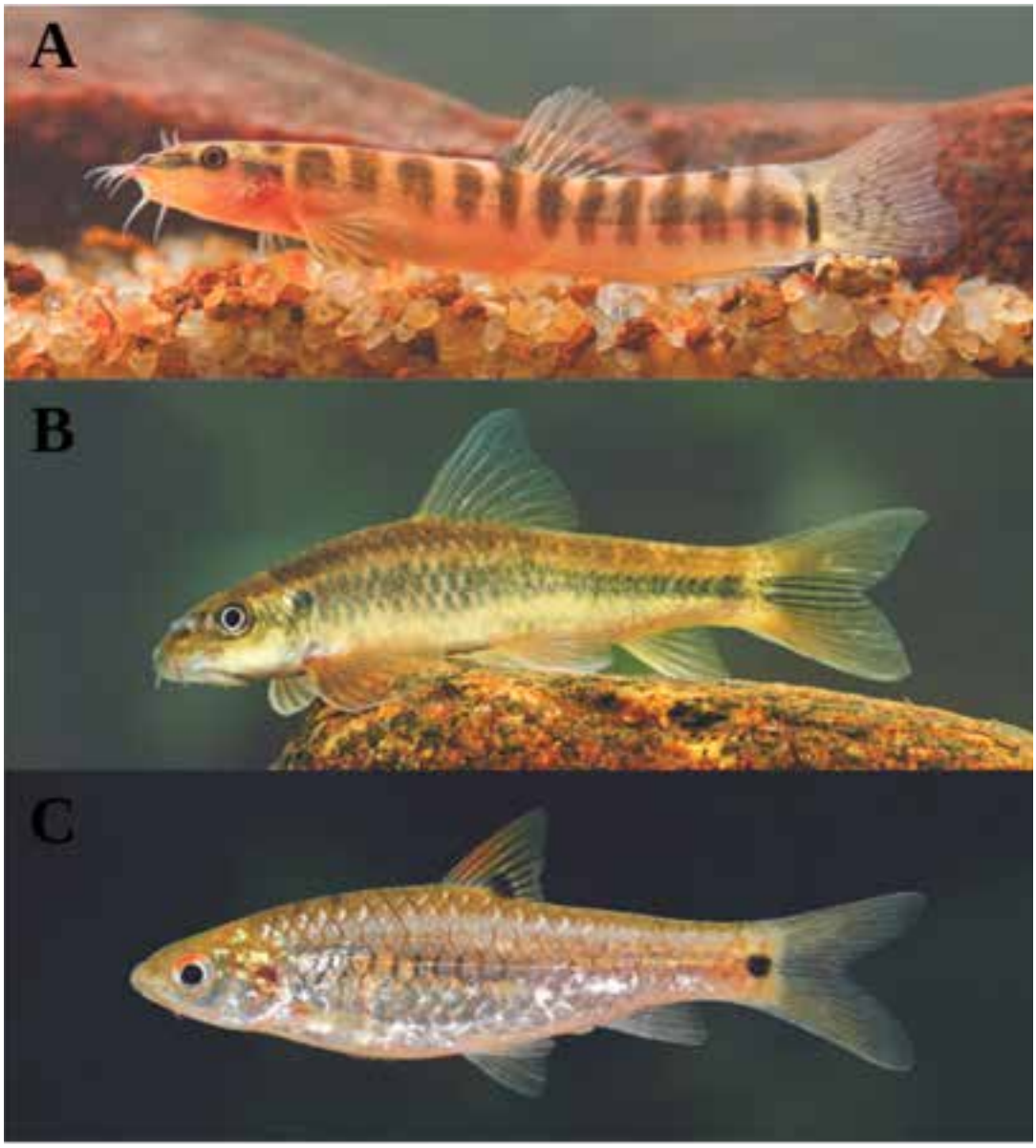


Image 1. Three benthic co-existing species from tropical mountain streams of Sri Lanka: A—Banded Mountain Loach *Schistura notostigma* | B—Ceylon Stonesucker *Garra ceylonensis* | C—Red-side Barb *Plesiopuntius bimaculatus*. © Madura De Silva & Wildlife Conservation Society, Galle (WCSG).

Materials and Methods

The present study was conducted as part of an ongoing research project on Sri Lankan freshwater fishes. The study was carried out in Mandaramnuwara, situated on the eastern slopes of PMR at an elevation of 1,000 m. PMR study site is a circular area with a 5-km radius centered on coordinates 7.0638^{0}N, 80.7652^{0}E, situated in the Belihul Oya (river) headwaters, near Kalu Palama Ella, and in Medadumbara, on the southern flank of KMR at 590 m. KMR study site is a circular area of 5-km radius, centered at 7.3475^{0}N, 80.8202^{0}E in the Heel Oya and Galmal Oya headwater regions (Figure 1). Five points were arbitrarily selected for observation from each site within the specified range. These observations spanned a 12-month period from November 2022 to October 2023. Observations were made monthly (five days per month from 0700–1800 h) using remote underwater video footage (GoPro Hero 9 action camera) and snorkelling. Fish identification was performed in the field using the latest field guides (De Silva et al. 2015; Shirantha 2021) and later confirmed by reference to recent publications (Sudasinghe 2017, 2018). During the species identification process, fishes were captured using a scoop-net and immediately released to their

Figure 1. The locations of the study sites in Sri Lanka. KMR—Knuckles Mountain Range | PMR—Piduruthalagala Mountain Range.

original habitats.

Observations and Discussion

Garra ceylonensis and *Schistura notostigma* (at an elevation range of 590–1,350 m in KMR and PMR) exhibit a close association and a commensalism relationship as follows: *G. ceylonensis* was observed grazing on algae on the rocky substrate, using its sucker mouth (Sudasinghe et al. 2021), causing small invertebrates and other food particles to be detached. The opportunistic species *S. notostigma* then exploits this disturbance by browsing on the dislodged food particles (see Image 2A,B).

Analysis of diets, notwithstanding different degrees of selectivity for various food categories, showed both species to be omnivorous (confirmed through gut content analysis in prior studies and references in: Moyle & Senanayake 1984; Wikramanayake & Moyle 1989; Sundarabarathy et al. 2001, 2005; Shirantha 2004; Pethiyagoda & Sudasinghe 2021). However, *S. notostigma* was found to primarily feed on a variety of small invertebrates, especially caddisfly larvae (Trichoptera: Hydropsychidae and Rhyacophilidae) and small mayfly larvae (Ephemeroptera: Leptophlebeidae) (Moyle & Senanayake 1984). Furthermore, Moyle & Senanayake (1984) suggest carnivory as the dominant mode of feeding for this loach, highlighting the short intestine (less than 1 × body length) and the observed willingness of *S. notostigma* to attack small benthic prey. On the other hand, *G. ceylonensis* is mentioned as a benthic algae feeder in Sudasinghe (2021) by referring to Lujan & Conway (2015) and Kottelat (2020). Moreover, Moyle & Senanayake (1984) also showed *G. ceylonensis* to be primarily a detritus and diatom feeder, based on a gut content analysis in Costa & Fernando (1967). Furthermore, studies conducted by Wikramanayake & Moyle (1989) and Moyle & Senanayake (1984) in rainforest streams and lowland wet zone streams show that there is no statistically significant dietary overlap among *G. ceylonensis* and *S. notostigma*. Therefore, based on the diet and behaviour, we hypothesize this association as a commensal relationship, in which *S. notostigma* benefits substantially more, rather than a mutualism in which both species benefit.

A similar set of observations were also recorded with schools of *Plesiopuntius bimaculatus* in the KMR during the study period (recorded in five occasions specifically during March 2023 and April 2023), which also confirmed the opportunistic feeding behaviour of *S. notostigma*. Here, *S. notostigma* followed the schools of foraging *Pl. bimaculatus*, feeding on food particles sinking to the substrate.

In this case of *S. notostigma*, given the absence of any recorded negative interactions up to date, whether of a predatory or competitive nature between these species (*G. ceylonensis* and *S. notostigma* or *Pl. bimaculatus* and *S. notostigma*), we suggest that opportunistic feeding behaviours and close associations may enable these species to access food sources more easily and with less competition. This becomes especially pertinent in high-elevation tropical mountain regions, where co-evolved fishes and other vertebrate species are recognized to have a high degree of adaptation to their environments, as described in Abell et al. (2008).

In addition to *S. notostigma*, similar opportunistic feeding behaviours have been observed in other benthic loach species, including *Misgurnus anguillicaudatus* (Cantor, 1842) as documented by VanHaitsma (2020) and McNair et al. (2023), *Misgurnus fossilis* (Linnaeus, 1758) as reported by Pyrzanowski et al. (2019), and *Barbatula barbatula* (Linnaeus, 1758) as noted by Andrei et al. (2015) and Worischka et al. (2015). Furthermore,

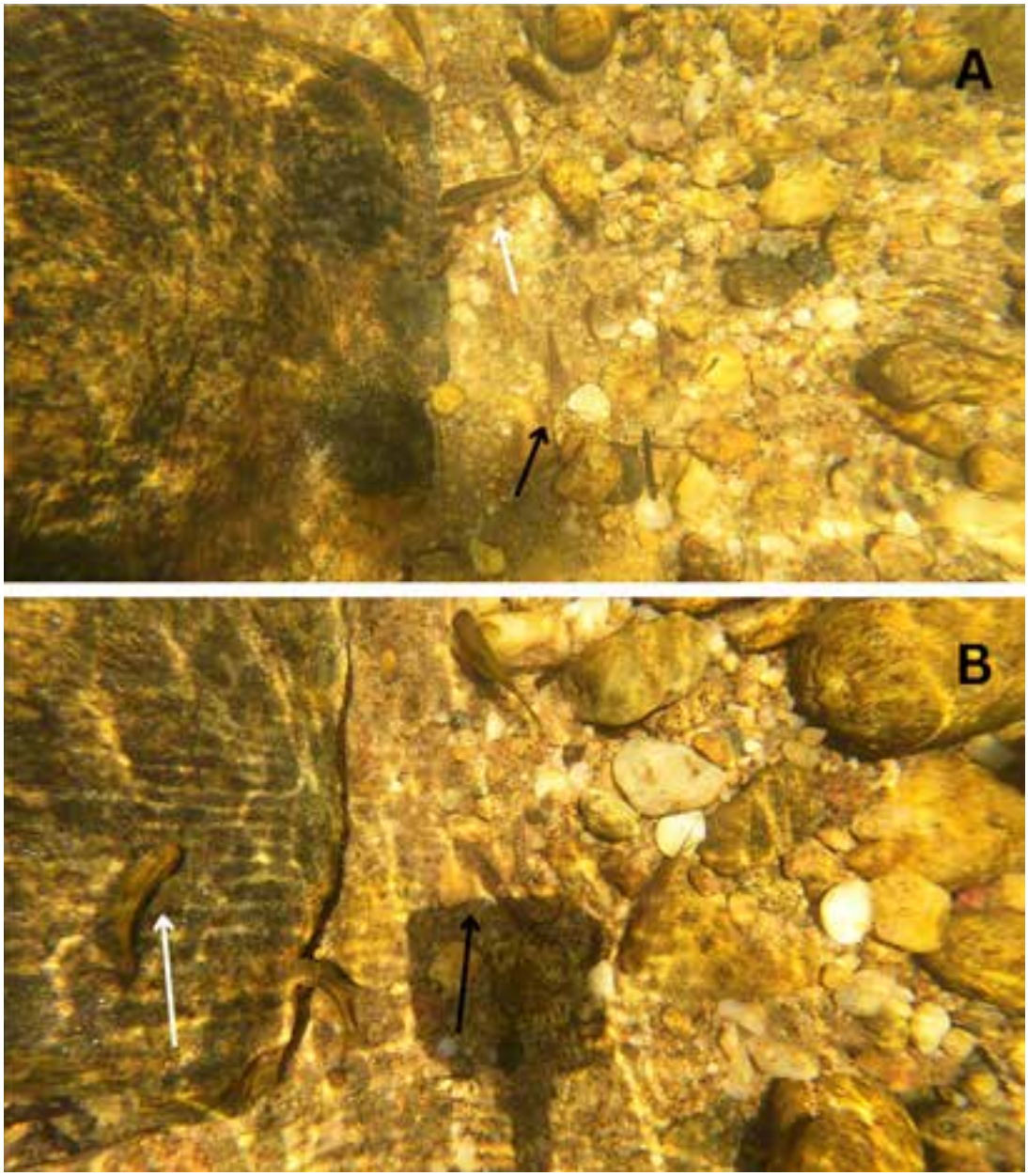


Image 2A,B. Close association of *Garra ceylonensis* (GC) and *Schistura notostigma* (SN) recorded frequently in Heel Oya, southern flank of Knuckles Mountain Range, Sri Lanka. GC pointed by the white arrowheads and SN by the black arrowheads. © Janamina Bandara.

Rice et al. (2019) too, make reference to several unique benthic feeding behaviours of fishes.

Pethiyagoda & Sudasinghe (2021) also make reference to a similar set of ecological interactions among Sri Lankan freshwater fishes, originally documented by Schut et al. (1984). These interactions involve *Rohanella titteya* (Deraniyagala, 1929) and *Pl. bimaculatus*, as well as juvenile *Dawkinsia fillementosa* (Valenciennes, 1844) and adult *Pethia cumingii* (Günther, 1868). These associations can be succinctly summarized as optimizations of dietary habits and the avoidance of shared predators.

Apart from *G. ceylonensis*, *S. notostigma*, and *Pl. bimaculatus*, only *Devario malabaricus* (Jerdon, 1849) and *Poecilia reticulata* (Peters, 1859) were found inhabiting the high-elevation regions in KMR (600 m) (Pethiyagoda & Sudasinghe 2021; Bandara & Gunawardena 2023a,b). No other freshwater fishes were recorded in headwaters of the PMR study site, except for *G. ceylonensis* and *S. notostigma*. Generally, it shows a lower fish diversity in high-elevation tropical freshwater fish assemblages recorded above 1,000 m elevation, when compared to

lowland assemblages in the island's south west wet zone (Sumith et al. 2011; Pethiyagoda & Sudasinghe 2021; Sudasinghe et al. 2023). In this case we believe that the opportunistic feeding of *S. notostigma* reported here could be a common behaviour with the co-occurring benthic species *G. ceylonensis* and *Pl. bimaculatus*.

Conclusion

In conclusion, frequent occurrences of the aforementioned ecological associations and interactions provide insight into the feeding behaviours of this benthic loach species. Moreover, these records also offer vital information that can be used to understand the ecological structure of tropical freshwater fish assemblages in high-elevation mountain streams (1,000 m) in Sri Lanka.

References

Abell, R., M. Thieme, C. Revenga, M. Bryer, M. Kottelat, N. Bogutskaya, B. Coad, N. Mandrak, S. Balderas, W. Bussing, M. Stiassny, P. Skelton, G. Allen, P. Unmack, A. Naseka, R. Ng, N. Sindorf, J. Robertson, E. Armijo & P. Petry (2008). Freshwater ecoregions of the World: a new map of biogeographic units for freshwater biodiversity conservation. *BioScience* 58: 403–414. https://doi.org/10.1641/B580507

Andrei, R.Ă.U.M., G. Plavan, Ș.A. Strungaru, M. Nicoară, I. Moglan & D. Ureche (2015). Feeding ecology of two sympatric fish species in a river ecosystem. *Biologie Animală* LXI: 11–18

Bandara, J. & M.P. Gunawardena (2023a). A new locality of guppy, *Poecilia reticulata* (Cyprinodontiformes: Poeciliidae) on the border zone of Knuckles Forest Reserve, Sri Lanka. In Proceedings of the Third International Conference of the Centre for Environmental Sustainability 2023, University of Peradeniya, Sri Lanka.

Bandara, J. & M.P. Gunawardena (2023b). Freshwater ichthyofauna in Medadumbara, the Southern flank of Knuckles Mountain Range Sri Lanka. In Proceedings of the Wildlanka International Symposium 2023, Department of Wildlife Conservation, Sri Lanka.

Costa, H.H. & E.C.M. Fernando (1967). The food and feeding relationships of the common meso and macrofauna in the Maha oya, a small mountainous stream at Peradeniya, Ceylon. *Ceylon Journal of Science (Biological Sciences)* 7: 54–90.

De Silva, M., N. Hapuarachchi & T. Jayarathne (2015). *Sri Lankan Freshwater Fishes, 1st Edition*. Wildlife Conservation Society, Galle, 391 pp.

Herath, H.M.J.C.B. (2009). Preliminary Observations on the Banded Mountain Loach Schistura Notostigma. Second Annual Research Sessions 2009, Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihinthale.

Kottelat, M. (2020). Ceratogarra, a genus name for *Garra cambodgiensis* and *G. fasciacauda* and comments on the oral and gular soft anatomy in labeonine fishes (Teleostei: Cyprinidae). *Raffles Bulletin of Zoology* 35: 156–178.

Lujan, N.K. & K.W. Conway (2015). Life in the fast lane: a review of rheophily in fishes. In: Riesch, R., M. Tobler & M. Plath (eds.). Extremophile fishes - ecology and evolution of teleosts in extreme environments. Springer, Switzerland, pp. 107–136.

Moyle, P.B. & F.R. Senanayake (1984). Resource partitioning among the fishes of rainforest streams in Sri Lanka. *Journal of Zoology* 202(2): 195–223.

McNair, S.F., W.L. Gerrin, J.L. Shelton, A. Musolf, B. Amman & R. Byrne (2023). Approach of the Loach: Weather Loaches (*Misgurnus anguillicaudatus*) in Georgia. Warnell School of Forestry and Natural Resource, University of Georgia.

Pethiyagoda, R. (1991). *Freshwater Fishes of Sri Lanka*. Wildlife Heritage Trust of Sri Lanka, Colombo, Sri Lanka, 362 pp.

Pethiyagoda, R. & H. Sudasinghe (2021). *The Ecology and Biogeography of Sri Lanka: A Context for Freshwater Fishes.* WHT Publications (Private) Limited, Colombo, 258 pp.

Pyrzanowski, K., G. Zięba, M. Dukowska, C. Smith & M. Przybylski (2019). The role of detritivory as a feeding tactic in a harsh environment – a case study of weatherfish (*Misgurnus fossilis*). *Scientific Reports* 9(1): 8467. https://doi.org10.1038/s41598-019-44911-y

Shirantha, R.R.R.A. (2021). *A Field Guide to the Fishes in Freshwaters of Sri Lanka*. Department of Wildlife Conservation, Colombo, 520 pp.

Rice, S., A. Pledger, J. Toone & K. Mathers (2019). Zoogeomorphological behaviours in fish and the potential impact of benthic feeding on bed material mobility in fluvial landscapes. *Earth Surface Processes and Landforms* 44(1): 54–66. https://doi.org/10.1002/esp.4541

Schut, J., S.S. De Silva & K. Kortmulder (1984). Habitat, associations and competition of eight *Barbus* (= *Puntius*) species (Pisces, Cyprinidae) indigenous to Sri Lanka. *Netherlands Journal of Zoology* 34(2): 159–181.

Shirantha, R.R.A.R. (2004). Some aspects of biology and population dynamics of selected endemic freshwater fish species inhabiting two river basins Sri Lanka. MPhil thesis. Department of Zoology, University of Kelaniya.

Sudasinghe, H. (2017). *Schistura madhavai*, a new species of hill-stream loach from Sri Lanka, with redescription of *S. notostigma* (Teleostei: Nemacheilidae). *Zootaxa* 4311(1): 96–110. https://doi.org/10.11646/zootaxa.4311.1.6

Sudasinghe, H. (2018). A new species of *Schistura* (Teleostei: Nemacheilidae) from the south-western lowlands of Sri Lanka. *Zootaxa* 4422(4): 478–492. https://doi.org/10.11646/zootaxa.4422.4.2

Sudasinghe, H., T. Ranasinghe, N. Dahanukar, R. Raghavan, L. Rüber, R. Pethiyagoda & M. Meegaskumbura (2023). Biogeography and evolutionary history of Puntius sensu lato (Teleostei: Cyprinidae) in Sri Lanka. *Scientific Reports* 13(1): 18724.

Sumith, J., R. Munkittrick & N. Athukorale (2011). Fish assemblage structure of two contrasting stream catchments of the Mahaweli river basin in Sri Lanka: Hallmarks of human exploitation and implications for conservation. *The Open Conservation Biology Journal* 5(1): 25–44. https://doi.org/10.2174/1874839201105010025

Sundarabarathy, T. & U. Edirisinghe & M. Dematawewa (2005). Breeding and larval rearing of threatened, endemic fish stonesucker, *Garra ceylonensis* (Bleeker). *Aquaculture Research* 36: 196–201. https://doi.org/10.1111/j.1365-2109.2004.01212.x

Sundarabarathy, T.V., U. Edirisinghe, C.M.B. Dematawewa & K.G. Nandasena (2001). Morphology and some biological aspects of Common spiny or lesser loach (*Lepidocephalichthys thermalis*) and Banded Mountain loach (*Schistura notostigma*) of Sri Lanka. *Tropical Agricultural Research* 13: 411–420.

VanHaitsma, A. (2020). Impact Analysis on the Invasive Oriental Weather Loach (*Misgurnus anguillicaudatus*) in the Grant Creek and Prairie Creek Watersheds at Midewin National Tallgrass Prairie. Pence-Boyce STEM Student Scholarship 16.

Wikramanayake, E.D. & P.B. Moyle (1989). Ecological structure of tropical fish assemblages in wet-zone streams of Sri Lanka. *Journal of Zoology* 218(3): 503–526.

Worischka, S., S.I. Schmidt, C. Hellmann & C. Winkelmann (2015). Selective predation by benthivorous fish on stream macroinvertebrates: The role of prey traits and prey abundance. *Limnologica* 52: 41–50.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25609–25612

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

https://doi.org/10.11609/jott.8233.16.7.25609-25612

#8233 | Received 20 October 2022 | Final received 05 June 2024 | Finally accepted 09 July 2024

OPEN ACCESS

SHORT COMMUNICATION

First record of *Pieris napi* L. (Lepidoptera: Pieridae) from Kashmir Valley, India

Firdousa Rasool [1] & **Altaf Hussain Mir** [2]

[1,2] Entomology Research Laboratory, Department of Zoology, University of Kashmir, Srinagar, Jammu & Kashmir 190006, India.
[1] firdousabintirasool@gmail.com (corresponding author), [2] draltaf_786@yahoo.com

Abstract: *Pieris napi*, a well-studied butterfly species distributed throughout the world, has remained undiscovered from Kashmir Himalaya to date. The present study reports the *Pieris napi* for the first time from Kashmir. This paper describes the diagnostic features and distribution patterns of the butterfly species in this region. It also includes specimen photographs and a distribution map of the species.

Keywords: Dachigam National Park, distribution, general hosts, *Geranium* sp., green-veined white butterfly, new record, Pir Panjal range, preservation, *Rubus* sp., *Stellaria media*, Zabarwan Range.

There are 34 different *Pieris* species reported in the world (Kirti et al. 2020). *Pieris napi* is found in the Himalayan region, including the northeastern states of India such as Arunachal Pradesh, Manipur, Assam, Himachal Pradesh, Meghalaya, Mizoram, Nagaland, and Uttarakhand, as well as Bhutan, Myanmar, China, Japan, North America, and Japan (Geiger & Shapiro 1992; Shaoji 2009; Gogoi 2013; Lodh & Agarwal 2015; Tadokoro 2015; Tadokoro 2017). The geographic distribution of the *Pieris napi* comprises the cool-temperate to cold wooded biomes of the Northern Hemisphere (Geiger & Shapiro 1992). In Russia, *Pieris napi* is present in the Caucasus; middle Siberia, and southwestern Siberia. It is a polymorphic species represented by a complex set of forms (Nuzhnova & Vasilevskaya 2013). The permanence of habitat and the oviposition on different hosts of the *P. napi* were studied by Ohsaki & Sato (1999). However, some researchers considered them as individual species, while others do not discriminate between various *Pieris* species such as *P. bryoniae*, *P. pseudorapae*, *P. euorientis*, *P. persis*, *P. narina*, *P. bowdeni*, *P. dulcinea*, *P. ocshenheimeri*, and *P. tomariana*, instead, they view the *P. napi* complex as a superspecies in a broad sense. The *P. napi* has been considered as a separate species by many authors and has provided distinguishing characteristic features (Richards 1940; Ohsaki & Sato 1999; Rayor et al. 2007; Bibi et al. 2022). Richards (1940) studied in detail the structural differences in eggs, pupae, larvae, and the hosts of *Pieris rapae* and *Pieris napi.* The *Pieris napi,* a multivoltine butterfly is widely spread in Europe at elevations below 200 m. Females of *Pieris napi* produce few large eggs, tend to be sedentary, and usually select those plants whose locations are long-lasting (Ohsaki & Sato 1990). As per Ohsaki (1979) *Pieris napi* lays eggs only on *Arabis* plants in the shade in the Kyoto area, Western Japan.

Since only five *Pieris* species have been reported in the Union Territory of Jammu and Kashmir—*Pieris brassicae*, *Pieris canidia*, *Pieris rapae*, *Pieris ajaka*, and *Pieris deota*—this survey focused on the Kashmir Valley.

Editor: Kushal Choudhury, Bodoland University, Kokrajhar, India.

Date of publication: 26 July 2024 (online & print)

Citation: Rasool, F. & A.H. Mir (2024). First record of *Pieris napi* L. (Lepidoptera: Pieridae) from Kashmir Valley, India. *Journal of Threatened Taxa* 16(7): 25609–25612. https://doi.org/10.11609/jott.8223.16.7.25609-25612

Funding: The current study was funded by Maulana Azad National Fellowship (MANF) and is a component of my Ph.D. work.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are thankful to the Department of Zoology, University of Kashmir- Srinagar, for providing lab facilities.

It also included high-altitude forest areas like the Pir Panjal Range, Dachigam National Park, and various vegetable-growing regions of Kashmir.

Materials and Methods

Study area: The present study was conducted in high-altitude forest areas such as the Pir Panjal Range, Dachigam National Park, and various vegetable-growing regions of Kashmir, UT Jammu & Kashmir. The Dachigam National Park is a part of the Zabarwan range of the western Himalaya located at 34.1547°N & 74.9155°E and altitude 1634.36 m (Image 1).

Survey and collection: The current study highlighted all *Pieris* species of different regions of Kashmir from 2020 to 2021. Random surveys were conducted fortnightly in different months of the year depending on the prevailing weather conditions and butterfly activity. The survey was done twice a month and conducted near water sources, damp patches in the forest areas, open sunny areas, and blossoming flowers. Adult butterflies were collected with the help of an insect collecting net. After collection, the butterflies were kept in jars and killed with ethyl-acetate. Thereafter, these specimens were then shifted in the relaxing chamber with wet sand for at least 24 hours and were properly labelled bearing (i) sample number, (ii) date of collection, (iii) name of the place, and (iv) name of the collector. The collected specimens were stretched on an insect stretching board by passing an entomological pin of size 4 through the thorax. The wings were spread in such a manner that the lower margin of the fore-wing was at a right angle to the body and the antenna in front of the head.

Preservation: After proper spreading, the specimens were left for about 2 to 4 days at room temperature inside the Entomology Research Laboratory, Department of Zoology, and were then shifted to wooden insect-storing boxes (Image 4). Each specimen was labelled bearing the same information as was written on the relaxing chamber previously. In order to protect the collected specimens from pests and fungus, cotton balls dipped in ethyl acetate vapours or benzene-dipped papers were periodically inserted in these boxes. The storage

Image 1. A—Map of India in the world map | B—Sampling sites in different districts of Kashmir Valley (prepared with ArcGIS, version, 10.8.1) | C—Study site map- Dachigam National Park, Srinagar (source: Wikipedia).

Image 2. *Pieris napi* spotted in Dachigam National Park, resting on: 1—Flowers of *Stellaria media* | 2—Leaves of *Geranium* sp. | 3 — Leaves of *Rubus* sp. | 4—Eggs on the leaves of *Cardamine flexuosa*.

boxes were kept in clean and shadow places, away from direct sunlight as per the technique adopted by Borror et al. (1976), Kunte et al. (2020), and Wynter-Blyth (1957). The specimens were identified later by using the identification keys of Evans (1932).

Results and Discussion

Material examined: 4♂, 1♀, Dachigam National Park along Dagwan River, 20.iv.2022, 34.154°N 74.915°E, 1634.36 m, insect collection nets, coll. Firdousa Rasool.

Diagnosis: The upper side of both Male and female is white coloured, veins conspicuously green or black, the base of the forewing is dusted with black scales, the apex and terminal border is black down to vein 2, and a black spot is present in the outer half of interspace 1. Hindwing with a black sub-costal spot. Under side veins are margined with black, the apex of the forewing and the whole surface of the hindwing are tinged with yellow, base of the costa of the hindwing is bright yellow. The female is much darker than the male, all the markings are broader. The upper side of the body is black with whitish hairs (Image 3).

Pieris napi was observed to fly inside Dachigam National Park and mostly rested on the flowers of *Stellaria media*, leaves of *Geranium* sp., and the leaves of *Rubus* sp. (Image 1, 2). A total of 5 specimens were collected from the same site with insect collection nets. Out of 30 different sampling sites, *P. napi* was spotted and trapped only in Dachigam National Park as it typically occurs in moist habitats, favours shaded or partly shaded woodland edges in a cool, moist environment as also suggested by (Howe & Bauer 1975). The present study revealed that *P. napi* exhibited the narrowest range of distribution being confined to only Dachigam National Park; outside the Dachigam National Park, no specimen

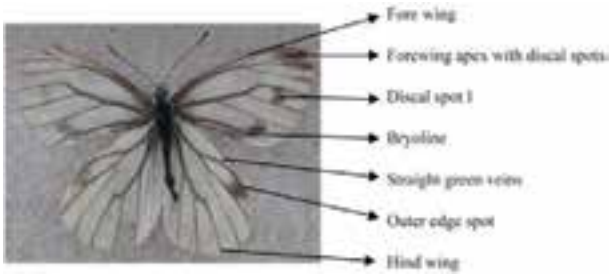


Image 3. *Pieris napi* of Kashmir, captured at Dachigam National Park, Srinagar, J & K, India

Image 4. Preservation of *Pieris napi* in Entomological Research Laboratory, Department of Zoology, University of Kashmir.

was collected. The *P. napi* and its narrowest natural distribution within forest edge habitat have also been proved in an experiment conducted by Ohsaki & Sato (1999) in the northern city of Kyoto, Japan. *P. napi* eggs and larvae were found on the plants of the Brassicaceae family like *Cardamine flexuosa*, acting as the host of the *P. napi* in the Dachigam National Park (Image 2(4)), and the same results were obtained by (Chew & Watt 2006; Friberg & Wiklund 2019). *Pieris napi* was very difficult to trap as it was flying high and fast. The species was captured at an elevation of 1676 m (5,500 ft) above sea level. The same results were documented by Shreeve (1981) as *Pieris napi* can fly high and cover large distances. *Pieris napi* trapped in Kashmir is not too much white but has long parallel green veins and broad discal spots that may be due to the variation in morphology due to the effect of latitude and altitude. According to Espeland et al. (2007) and Valimaki & Kaitala (2007), the morphology and life history of *P. napi* vary with latitude. *P. napi* is predominantly white at low elevations and low latitudes in Scandinavia; however, at higher elevations and latitudes, it is darker and more melanized and is frequently known as *Pieris bryoniae* (Ochsenheimer 1808; Kirby 1896) in central Europe and *Pieris napi adalwinda* (Fruhstorfer, 1909) in Scandinavia (Porter et al. 1997). Richards (1940) found that the proboscis sheath of *p. napi* projects only a very short distance in pupae, with its eggs and larvae being found on cabbage very rarely.

References

Bibi, M., S. Bibi, N. Akhtar, Z. Ullah, M.F. Khan & I.Z. Qureshi (2022). Butterfly (Order: Lepidoptera) species Richness, diversity and distribution in different localities of Battagram, Pakistan. *Saudi Journal of Biological Sciences* 29: 1853–1857.

Borror, D.J., D.M. DeLong & C.A. Triplehorn (1976). *An Introduction to The Study of Insects*. 4th. Edition. Holt Reinehart and Wiston, New York, XII + 852pp.

Kirti, J.S., M. Kaur, A.V. Sidhu & N. Singh (2020). Taxonomic revision of the Genus *Pieris* Schrank (Lepidoptera: Pieridae) from India. *Journal of applied and Natural Sciences* 12(3): 328–343.

Chew, F.S. & W.B. Watt (2006). The Green-veined White (*Pieris napi* L.), its Pierine relatives, and the systematics dilemmas of divergent character sets (Lepidoptera, Pieridae). *Biological Journal of the Linnean Society* 88(3): 413–435.

Espeland, M., K. Aagaard, T. Balstad & K. Hindar (2007). Ecomorphological and genetic divergence between lowland and montane forms of the *Pieris napi* species complex (Pieridae, Lepidoptera). *Biological Journal of the Linnean Society* 92(4): 727–745.

Evans, W.H. (1932). The identification of Indian Butterflies. (Second edition revised). Bombay Natural History Society, 454 pp.

Friberg, M. & C. Wiklund (2019). Host preference variation cannot explain microhabitat differentiation among sympatric *Pieris napi* and *Pieris rapae* butterflies. *Ecological Entomology* 44(4): 571–576. https://doi.org/10.1111/een.12728

Fruhstorfer, H. (1909). *Parnassius* Latr., pp. 109–112. In: Seitz, A. (ed.). *Die Groß-Schmetterlinge der Erde. Dictado AustralischeTagtalter*. Stuttgart, Lehmann Vrlg.

Geiger, H. & A.M. Shapiro (1992). Genetics, systematics and evolution of holarctic *Pieris napi* species group populations (Lepidoptera, Pieridae). *Journal of Zoological Systematics and Evolutionary Research* 30(2): 100–122.

Gogoi, M.J. (2013). Book Review: Butterflies of the Garo Hills. *Journal of Threatened Taxa* 5(10): 4527–4528. https://doi.org/10.11609/jott.902.4527-4528

Howe, W.H. & D.L. Bauer (1975). *The Butterflies of north America*. Doubleday, Garden City, NY, 633 pp.

Kirby, W.F. (1896). *A Hand Book to the Order Lepidoptera*. Lloyds Natural History, London, I(II), 147– 150 pp.

Kunte, K., P. Churi, A. Bora & S. Debnath (2020). *Pieris canidia* (Linnaeus, 1768) - Asian Cabbage White. Kunte, K., S. Sondhi & P. Roy (Chief Editors). Butterflies of India, v. 2.87. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/876/ Pieris-canidia.0/

Lodh, R. & B.K. Agarwala (2015). Inventory of butterfly fauna (Lepidoptera: Rhopalocera) of Tripura, India, in the Indo-Myanmar biogeographical zone, with records of threatened taxa. *Check List* 11(2): 1–37. https://doi.org/10.15560/11.2.1591

Nuzhnova, O.K & N.V. Vasilevskaya (2013). The effect of colour preferences on the foraging behaviour of the Green-veined White Butterfly (*Pieris napi* L.). *Contemporary Problems of Ecology* 6(1): 45–50. https://doi.org/10.1134/S1995425513010113

Ohsaki, N. (1979). Comparative population studies of three *Pieris* butterflies, *P. rapae, P. melete* and *P. napi,* living in the same area. Ecological requirements for habitat resourses in the adults. *Researches on Population Ecology* 20: 278–296.

Ohsaki, N. & Y. Sato (1999). The role of parasitoids in evolution of habitat and larval food plant preference by three *Pieris* butterflies. *Population Ecology* 41(1): 107–119.

Porter, A. H., R. Wenger, H. Geiger, A. Scholl & A.M. Shapiro (1997). The Pontia daplidice-edusa hybrid zone in northwestern Italy. *Evolution* 51(5): 1561–1573.

Rayor, L.S., L.J. Mooney & J.A. Renwick (2007). Predatory behaviour of *Polistes dominulus* wasps in response to Cardenolides and Glucosinolates in *Pieris napi* Caterpillars. *Journal of Chemical Ecology* 33: 1177–1185.

Richards, O.W. (1940). The biology of the small white butterfly (*Pieris rapae*) with special reference to the factors controlling its abundance. *Journal of Animal Ecology* 9(2): 243–288.

Shaoji, H. (2009). Preliminary field survey of butterflies on Xishan Hill (Kunming, Yunnan Province, China). *Journal of Research on the Lepidoptera* 41: 60–69.

Shreeve, T.G. (1981). Flight patterns of butterfly species in woodlands. *Oecologia* 51(2): 289–293.

Tadokoro, T. (2015). Taxonomic status of *Pieris* (napi) *nesis* Fruhstorfer, 1909 (Lepidoptera, Pieridae). *Lepidoptera Science* 66(3-4): 104–108.

Tadokoro, T., S. Wangchuk, S. Wangdi, K. Wangdi, R. Wangdi, S. Drukupa & M. Yago (2017). Description of a new subspecies of *Pieris erutae* Poujade, 1888 from Eastern Bhutan, with taxonomic notes on the *Pieris napi* group from the Himalayas (Lepidoptera, Pieridae). *Lepidoptera Science* 68: 3–4. https://doi.org/10.18984/LEPID.68.3-4_81

Valimaki, P. & A. Kaitala (2007). Life history tradeoffs about the degree of polyandry and developmental pathway in *Pieris napi* (Lepidoptera, Pieridae). *Oikos* 116(9): 1569–1580.

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

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25613–25616

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

https://doi.org/10.11609/jott.8311.16.7.25613-25616

#8311 | Received 07 December 2022 | Final received 10 June 2024 | Finally accepted 16 July 2024

OPEN ACCESS

SHORT COMMUNICATION

Reassessment of *Strobilanthes recurva* (Acanthaceae), an endangered plant from Manipur, India

Rajkumari Jashmi Devi [1] & **Biseshwori Thongam** [2]

[1,2] Plant Systematics and Conservation Laboratory, Plant Bioresources Division, Institute of Bioresources and Sustainable Development (IBSD), Takyelpat, Imphal West, Manipur 795001, India.

[1] rajkumjas@gmail.com, [2] b_thongam07@yahoo.com (corresponding author)

Abstract: The presence and status of *Strobilanthes recurva* C.B.Clarke (Acanthaceae) in Manipur, northeastern India is re-assessed with a brief description and illustration. Photographs and their conservation status are also provided. The values of Extent of Occurrence (EOO) and Area of Occupancy (AOO) calculated as 16,313.797 km2 (VU), and 20.000 km2 (EN) respectively predicted *S. recurva* as Vulnerable and Endangered. Therefore, we proposed to treat this threatened species, *S. recurva* as Endangered (EN) until further information becomes available.

Keywords: Biodiversity, description, eastern himalaya, exploration, flora, northeastern India, rare, red list, taxonomy, threatened.

The genus *Strobilanthes* Blume of the family Acanthaceae consists of around 463 species (POWO 2024). It is distributed mostly in Asia, extending to Japan and Korea in the north, Afghanistan and Pakistan in the west, and northern Australia in the south. It is most diverse in the Indian subcontinent, southern China, and mainland southeastern Asia, but many species have also been reported to occur on the islands of southeastern Asia (Wood & Scotland 2021). Most species under the genus *Strobilanthes* are recorded as rare and localized in their distribution (Wood & Scotland 2009). Species belonging to the genus *Strobilanthes* of peninsular India, the Himalaya, and hills of northeastern India are recorded to be varied and have no connection (Wood 1994). About 65 species were reported from peninsular India, and approximately 85 species were reported from hills of northeastern India (Wood & Scotland 2021). The *Strobilanthes* of the whole Himalayan region were discussed by Wood (1994), however, southwestern China, upper Burma, and the hills on the Indo-Burmese border were excluded from the study. It is reported that there is no comprehensive study on the *Strobilanthes* species of the hills on the Indo-Burmese border, which include the Indian states of Meghalaya, Nagaland, and Manipur.

Manipur is one of the states of the northeastern region of India. It lies between 23.83'–25.68'N and 94.31'–94.78'E and falls under the Indo-Burma Biodiversity Hotspot (https://www.cepf.net/our-work/biodiversity-hotspots/indo-burma). In the Flora of Manipur, no species of *Strobilanthes* was previously recorded (Singh et al. 2000). However, a total of six species—*Strobilanthes affinis* Terao ex J.R.I.Wood &

Editor: Asok Ghosh, The University of Burdwan, West Bengal, India.

Date of publication: 26 July 2024 (online & print)

Citation: Devi, R.J. & B. Thongam (2024). Reassessment of *Strobilanthes recurva* (Acanthaceae), an endangered plant from Manipur, India. *Journal of Threatened Taxa* 16(7): 25613–25616. https://doi.org/10.11609/jott.8311.16.7.25613-25616

Funding: M K Bhan Young Researcher Fellowship Programme (BT/HRD/MK-YRFP/50/15/2021), Department of Biotechnology, Government of India.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors express gratitude to professor Pulok Kumar Mukherjee, director, Institute of Bioresources and Sustainable Development (IBSD), Imphal, India. Heartfelt gratitude to John R.I. Wood, Department of Plant Sciences, University of Oxford, UK for all valuable suggestions and species confirmation. We extend our gratitude to Dr. N. Odyuo, scientist e, Botanical Survey of India, Eastern Regional Centre, Shillong, India for his kind cooperation. We are also grateful to the local communities of Mao Songsong, Senapati, Manipur, India, and laboratory members, Plant Systematic and Conservation Laboratory of IBSD, Imphal, India. This work is funded by the M.K. Bhan Young Researcher Fellowship Programme, Department of Biotechnology, Government of India.

J.R.Bennett, *S. asymmetrica* J.R.I.Wood & J.R.Benn., *S. auriculata* Nees, *S. clarkei* J.R.I.Wood, *S. cusia* J.R.I.Wood & J.R.Benn., and *S. torrentium* Benoist—were recorded by Ningombam (2012), of which *S. auriculata* is reported to have an eight-year plietesial cycle in Manipur (Devi et al. 2021). In addition, *S. frondosa* J.R.I.Wood was also reported to be rediscovered in Manipur (Wood et al. 2003). Among the other *Strobilanthes* species collected in the 19th century from Manipur, a newspaper article reported photographic evidence for the presence of *S. recurva* at Sadu chiru water fall Kangpokpi District, Manipur (https://easternmirrornagaland.com/coneflower-photographed-in-wild-after-73-years-in-manipur/). *Strobilanthes recurva*, a rare species, was also collected from Mt. Tiyi in Wokha, Nagaland, India by N. Odyuo and D. Roy. Herbaria specimens are present at Botanical Survey of India, Eastern Regional Center in Shillong bearing numbers 096495 and 096496. However, these vouchers lack information on the altitude, habitat, and geographical coordinates (latitude and longitude). John R.I. Wood, an expert on the genus *Strobilanthes*, confirmed another collection of *S. recurva* from Chittagong, Bangladesh (Collector: Mr. Mohammed Uddin). No record on the description and illustration of these new collections of *S. recurva* are available on public domain.

A plant specimen of *S. recurva* was collected by the present author(s) from Mao Songsong, Senapati District, Manipur, India in February 2022 and the species was authenticated by J.R.I. Wood. Plants were growing at an altitude of 1,835 m on a shaded streamside at the hill slope of an open forest. Although not plentifully distributed, the collection site recorded 20–30 mature individuals. Voucher specimens were deposited in the Institute of Bioresources and Sustainable Development (IBSD), Imphal with accession number IBSD/M-279. In this study, the presence of *Strobilanthes recurva* C.B.Clarke (Acanthaceae) in Manipur, northeastern India is re-assessed with a brief description and illustration. Photographs and their conservation status are also provided below.

Results and Discussion

Strobilanthes recurva C.B.Clarke

J. Linn. Soc., Bot. xxv. (1889: 53).

Type: INDIA, Naga Hills, Kohima, alt 4,500 ft (1,360 m), Clarke C.B. 41379, 30.x.1885, (Holotype K000883138!).

Description: Isophyllous to weakly anisophyllous undershrub, 0.6–0.8 m height. Stem quadrangular, swollen at the base of the node. Leaves petiolate, ovate, pubescent on both sides, 7.8–9.9 × 3.0–4.5cm, margin crenate, apex broadly acuminate, base attenuate. Inflorescence of terminal and axillary bracteates spikes, 3.5–3.7 × 1.1–1.3 cm. Bracts imbricate, broadly ovate, persistent, green, glandular-pilose, 1.3–1.7 × 0.7–1.1 cm. Bracteoles 2, linear, obtuse, 7–8 mm. Calyx 5-parted, glandular hairs present, linear, obtuse, lobes unequal in length, 0.8 ¬ 0.9cm. Corolla 5-lobed, curved, funnel-shaped. Corolla tube short, white, 1.5–2 × 0.2 cm, gradually widened at the mouth., purple. Stamens 4, fertile, didynamous, longer filament 2.2 cm, shorter filaments 0.3–0.4 cm; anthers included, 0.2–0.3 cm long. Style pilose, curved, 2.1 cm. Ovary 0.9 cm, hirsute at the apex. Capsule oblong, hairy at the apex 1.0–1.2 cm. 4-seeded; seeds lenticular, villous, 0.2–0.3 cm (Image 1).

Specimen examined: INDIA, Manipur, Senapati, Mao Songsong, 1,835 m, 09.ii.2022, RJ Devi & B.Thongam, M-279 (IBSD) (Image 2).

Other specimens of *S. recurva* recorded so far.

India: hills of Kohima, alt 4,500 ft (1,360 m), C.B.Clarke 41379, 30.x.1885 (Holotype K000883138!) (http://specimens.kew.org/herbarium/K000883138); India: Manipur, 14.i.1882, Watt G. 5156, E00133469 (https://data.rbge.org.uk/herb/E00133469); India: Sirhoi, alt 6,500 ft (1,970 m), 15.iv.1948, F. Kingdon-Ward 17292 (NY2652219!) (http://sweetgum.nybg.org/science/vh/specimen-details/?irn=3451210); India: Mt. Tiyi, Wokha, Nagaland, N. Odyuo and D. Roy, 17.iv.2016, 096495! and 096496; Chittagong, Bangladesh (photographs by Mr Mohammed Uddin).

Conservation Status

No earlier evaluation was made to assess the conservation status of this species. Since its type specimen collection was made in the year 1885, this species is presently known from only four locations of northeastern India, viz.: Kohima & Wokha of Nagaland State; Ukhrul & Senapati District of Manipur State; and another one from Chittagong, Bangladesh. Records available so far may indicate the confinement of this species in the higher altitudinal hills of the Indo-Burma border. Geographical coordinates are not available for the locations from where *Strobilanthes* species are collected so far except for the present study. Therefore, the standard Geospatial Conservation Assessment Tool (Bachman et al. 2011) was used for automatic assessment of IUCN Red Listing. The extent of occurrence (EOO) and area of occupancy (AOO) were calculated as 16,313.797 km², and 20,000 km², respectively.

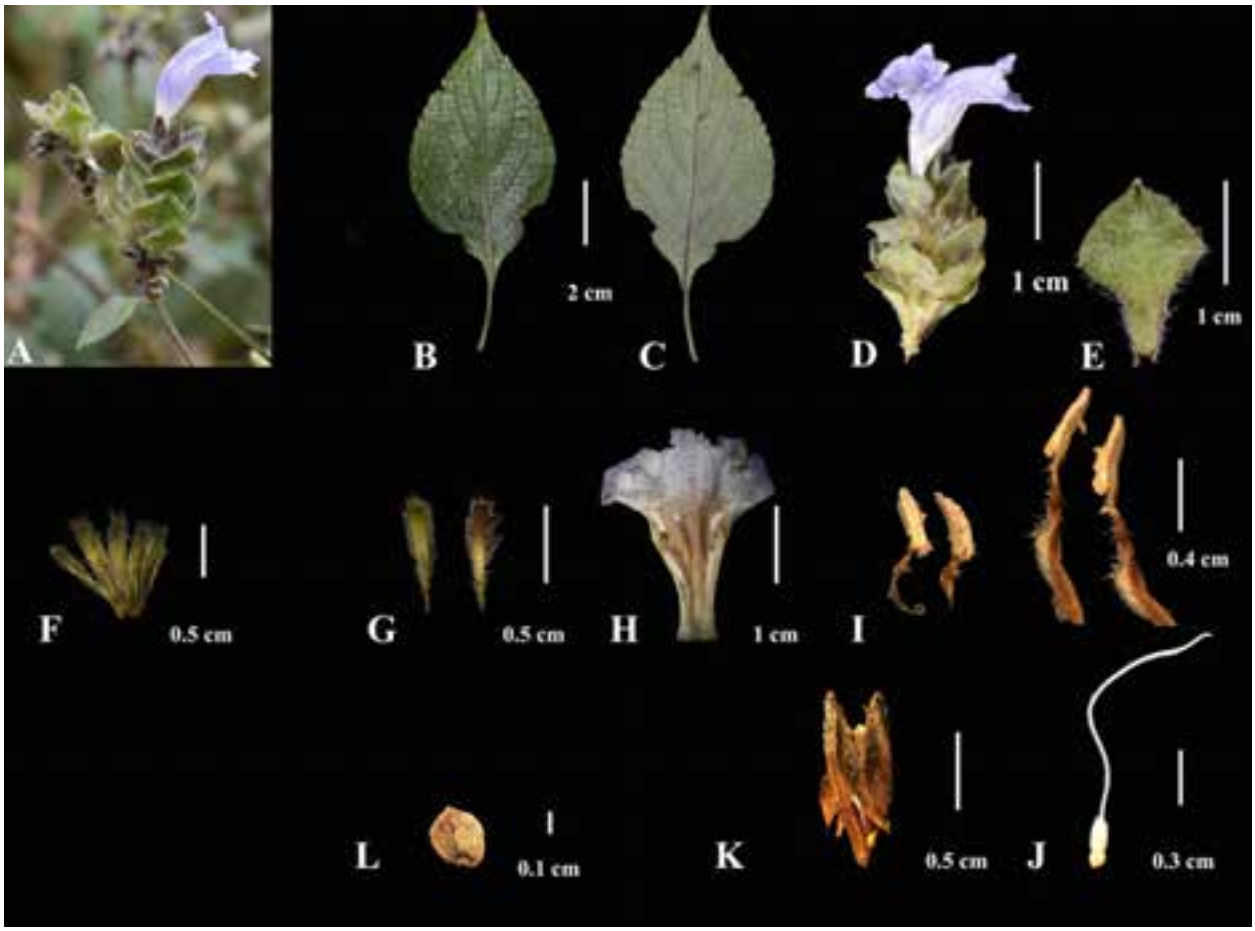


Image 1. *Strobilanthes recurva*: A—A twig with inflorescences | B—leaf adaxial | C—leaf (abaxial) | D—inflorescence | E—bract | F—calyx split open | G—bracteoles | H—corolla (split opened from curvy side) | I—Stamens | J—carpel | K—capsule | L—seed | © M. Aldrin & R.J. Devi.

Keys to species of *Strobilanthes* recorded from Manipur, India

1a. Inflorescence short terminal spike; Leaves petiolate; Bracts obovate – subspathulate; Bracteoles oblanceolate subspathulate; Corolla lobe pale sulphur or white ..... *S. aymmetrica*
1b. Inflorescence axillary or terminal spike; Leaves subsessile; Bracts obovate or elliptic obovate; Bracteoles oblanceolate or subacute; Corolla lobe white or purple 2
2a. Inflorescence small axillary & terminal panicle; Bracts obovate; calyx lobe equal; Corolla lobe glossy violet, curved ..... *S. clarkei*
2b. Inflorescence terminal or axillary spikes; Bracts obovate to oblanceolate or leaflike imbricate; Calyx unequal; Corolla not glossy, slightly bent to curved, lobe pale blue to purple colour 3
3a. Anisophyllous, subsessile; Inflorescence short, nodding subcapitate spike on simple or sparsely branched axillary branchlets; Bracts elliptic-obovate with scattered gland dots; Corolla straight, lobe pale blue colour ..... *S. frondosa*
3b. Isophyllous to weakly anisophyllous, subsessile or petiolate; Inflorescence terminal or axillary spike; Bracts leaflike imbricate or obovate or oblanceolate; Corolla straight to slightly bent or highly curved, lobe blue colour 4
4a. Leaves oblong, ovate, elliptic, glabrous or pilose; Cystolith absent 5
4b. Leaves ovate to elliptic, pubescent; Cystolith present 6
5a. Leaves sessile, lanceolate, oblong, cordate, both surface pilose; Bracts imbricate broadly ovate to obovate spathulate; Corolla funnel shape, lobe pale purple ..... *S. auriculata*
5b. Leaves petiolate, elliptic, ovate, glabrous or pubescent; Bracts leaflike imbricate broadly ovate or oblanceolate to obovate; Corolla straight to slightly bent or highly curved, lobe blue colour 7
6a. Leaves both surface sparsely stringose, densely covered with subulatecystoliths; Bracts imbricate broadly obovate, rhomboidal or elliptic; Corolla purplish-blue to violet, curved ..... *S. affinis*
6b. Leaves adaxially sparsely pubescent, numerous cystolith; Bracts obovate to subrhombic, distinctly angled; corolla blue to violet, curved ..... *S. torrentium*
7a. Isophyllous to weakly anisophyllous; Leave glabrous; Bracts oblanceolate to obovate; Corolla straight to slightly bent, lobe blue ..... *S. cusia*
7b. Isophyllous; Leaves pubescent on both sides; Bracts broadly ovate; Corolla curved, funnel shaped, lobe purple ..... *S. recurva.*

Image 2. Image of the herbarium specimen of *Strobilanthes recurva* deposited at IBSD (IBSD/M-279).

References

Bachman, S., J. Moat, A.W. Hill, J. de la Torre & B. Scott (2011). Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *ZooKeys* 150: 117–126. https://doi.org/10.3897/zookeys.150.2109

Clarke, C.B. (1889). On the Plants of Kohima and Muneypore. *The Journal of Linnean Society Botany* 25: 53. https://www.biodiversitylibrary.org/page/180613

Devi, R.J., D. Khuraijam & B. Thongam (2021). *Strobilanthes auriculata* Nees: a lesser known pliestesial flora from Manipur, North East India. *Current Science* 121: 0745–46.

Ningombam, D.S. (2012). Systematic study of the plant species under Acanthaceae family in the valley districts of Manipur. PhD. thesis, Manipur University, Manipur, India. http://hdl.handle.net/10603/150270

POWO (2024). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet: http://www.plantsoftheworldonline.org/ Electronic version accessed on 02 May 2024.

Singh, N.P., A.S. Chauhan & M.S. Mondal (2000). *Flora of Manipur, Vol 1.* Botanical Survey of India, Kolkata, India.

Wood, J.R.I. & R.W. Scotland (2009). New and little known species of *Strobilanthes*(Acanthaceae) from India and South East Asia. *Kew Bulletin* 64: 3–47. https://doi.org/10.1007/s12225-009-9098-2

Wood, J.R.I. & R.W. Scotland (2021). A *Strobilanthes* (Acanthaceae) miscellany. *Kew Bulletin* 76: 827–840. https://doi.org/10.1007/s12225-021-09990-z

Wood, J.R.I. (1994). Notes relating to the flora of Bhutan: XXIX. Acanthaceae, with special reference to *Strobilanthes*. *Edinburgh Journal of Botany* 51: 175–274. https://doi.org/10.1017/S0960428600000871

Wood, J.R.I., J.R. Bennett & R.W. Scotland (2003). Notes on *Strobilanthes*: the Sympagis group. *Kew Bulletin* 58: 131–173. https://doi.org/10.2307/4119358

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25617–25622

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

https://doi.org/10.11609/jott.8972.16.7.25617-25622

#8972 | Received 15 February 2024 | Final received 17 May 2024 | Finally accepted 27 June 2024

OPEN ACCESS

SHORT COMMUNICATION

New distribution record of Slender Wild Basil *Clinopodium gracile* (Benth.) Kuntze (Lamiaceae: Nepetoideae: Mentheae) for the flora of Himachal Pradesh, India

Rimjhim Chandra [1] & **Mamita Kalita** [2]

[1] Department of Botany, Government Degree College, Chamba, Himachal Pradesh 171005, India.
[2] Department of Botany, Digboi College, Digboi, Assam 786171, India.
[1] rimjhimchandra6@gmail.com, [2] mamita.bot@gmail.com (corresponding author)

Abstract: *Clinopodium gracile* (Benth.) Kuntze has been recorded for the first in the Chamba district of Himachal Pradesh. The study provides descriptions, illustrations, and photographs to aid in the identification of the species. The new distribution record has been entrenched upon investigation based on observation and verification obtained from herbarium, literature, and plant web databases.

Keywords: Calamint, distribution, flora, identification, keys, native.

The mint family *Lamiaceae* Martinov (also known as *Labiatae* Juss.) has profound distribution, confining 232 accepted genera. According to Angiosperm Phylogeny Group (APG IV), the genus `*Clinopodium*´ is bound within the sub-family *Nepetoideae* (Dumortier) Luerssen and tribe *Mentheae* Dumortier (Stevens 2001 onwards). *Clinopodium* L. comprises about 20 species in Asia and Europe (Li & Hedge 1994). In accord with Plants of World Online (POWO 2024), *Clinopodium* has nativity in tropical and sub-tropical regions with 186 species. The genus is commonly known as Calamint (Weakley 2010) due to the inclusion of *Calamintha* Mill. members. Doroszenko (1985) served *Clinopodium* as a section of *Calamintha.* However, the latter remains as a synonym for the former genus due to the priority of *Clinopodium* (1753) over *Calamintha* (1754). According to the database of POWO, *Clinopodium* is native to India and portrayed by seven species: *Clinopodium capitellatum* (Benth.) Kuntze, *C. gracile* (Benth.) Kuntze, *C. hydaspidis* (Falc. ex Benth.) Kuntze, *C. javanicum* (Blume) I.M.Turner, *C. piperitum* (D.Don) Murata, *C. umbrosum* (M.Bieb.) K.Koch., and *C. vulgare* L. The species `*Clinopodium gracile*´ is native to Asia (Weakley 2010). It can be allocated from China, Indonesia, Japan, Jawa, Korea, Laos, Malaysia, Myanmar, Taiwan, Thailand, Vietnam, and India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, & Tripura). It commonly flourishes near river banks, wild/semi-wild areas, and alongside forest margin sites (Li & Hedge 1994). In accord with Cantino & Wagstaff (1998), the species is associated with a morphologically diverse and taxonomically complex group called the `clinopodioid complex´. The species retain a 2n = 18 chromosomes number and distinct in possessing one vascular bundle in its petiole (Hsieh & Huang 1998).

Clinopodium gracile is known as slender wild Basil (Zomlefer et al. 2011). According to Mao & Dash (2020), *Clinopodium* is represented by three species in Himachal Pradesh: *Clinopodium capitellatum*, *C. umbrosum*, and *C. vulgare.* However, in accord with POWO (2024), three additional species *C. hydaspidis*, *C. javanicum* and *C. piperitum* can also be found. The presently

Editor: K. Haridasan, Palakkad, Kerala, India.

Date of publication: 26 July 2024 (online & print)

Citation: Chandra, R. & M. Kalita (2024). New distribution record of Slender Wild Basil *Clinopodium gracile* (Benth.) Kuntze (Lamiaceae: Nepetoideae: Mentheae) for the flora of Himachal Pradesh, India. *Journal of Threatened Taxa* 16(7): 25617–25622. https://doi.org/10.11609/jott.8972.16.7.25617-25622

Funding: None.

Competing interests: The authors declare no competing interests.

examined `*Clinopodium gracile*' is the seventh addition of *Clinopodium* species to the flora of Himachal Pradesh.

Materials and Methods

The first author collected the plant specimen from Gajnoi region during a field trip in Chamba district, Himachal Pradesh. Field photographs, and GPS location were recorded and flowering plant parts were collected for further investigations. The morphological attributes, including stem, leaves, inflorescence, bract, flowers, calyx, corolla, androecium, and gynoecium have been studied. The vegetative and reproductive features have been examined and the species was identified as *Clinopodium gracile* (Benth.) Kuntze. Further, the species identity was confirmed based on microfilms of herbarium records as furnished in specimen examined section. The voucher specimen of the presently examined species has been deposited in GUBH. The map showing the precise location of *Clinopodium gracile* in the Chamba district of Himachal Pradesh has been laid out (Figure 1). Also, a photoplate (Image 1) and an illustration (Figure 2) displaying the vegetative and reproductive parts have been presented.

Taxonomic treatment

***Clinopodium gracile* (Benth.) Kuntze** Revis. Gen. Pl. 2:514.1891. —*Clinopodium confine* (Hance) Kuntze Gen. Pl. 2:515.1891; Hara In: Jour. Jap. Bot. 101:14.1935. —*Clinopodium gracile* (Benth.) Matsum Index. Pl. Jap. 2:538.1912 (isonym). —*Calamintha gracilis* Benth. In: DC. Prodr. 12:232.1848. —*Calamintha moluccana* Miq. Fl. Ned. Ind. 2:968.1859. —*Calamintha confinis* Hance In: Journ. Bot. 6:331.1868. —*Calamintha radicans* Vaniot Bull. Acad. Geogr. Bot. 14:182.1904. —*Calamintha argyi* H.Lév. In: Repert. Spec. Nov. Regni Veg. 8:423.1910. —*Satureja gracilis* (Benth.) Nakai In: J. Coll. Sci. Univ. Tokyo. 31:149.1911; Bailey In: Gent. Herb. 1:43.1920. —*Satureja confinis* (Hance) Kudô Mem. Fac. Sci. Taihoku Imp. Univ. 2:100.1929.

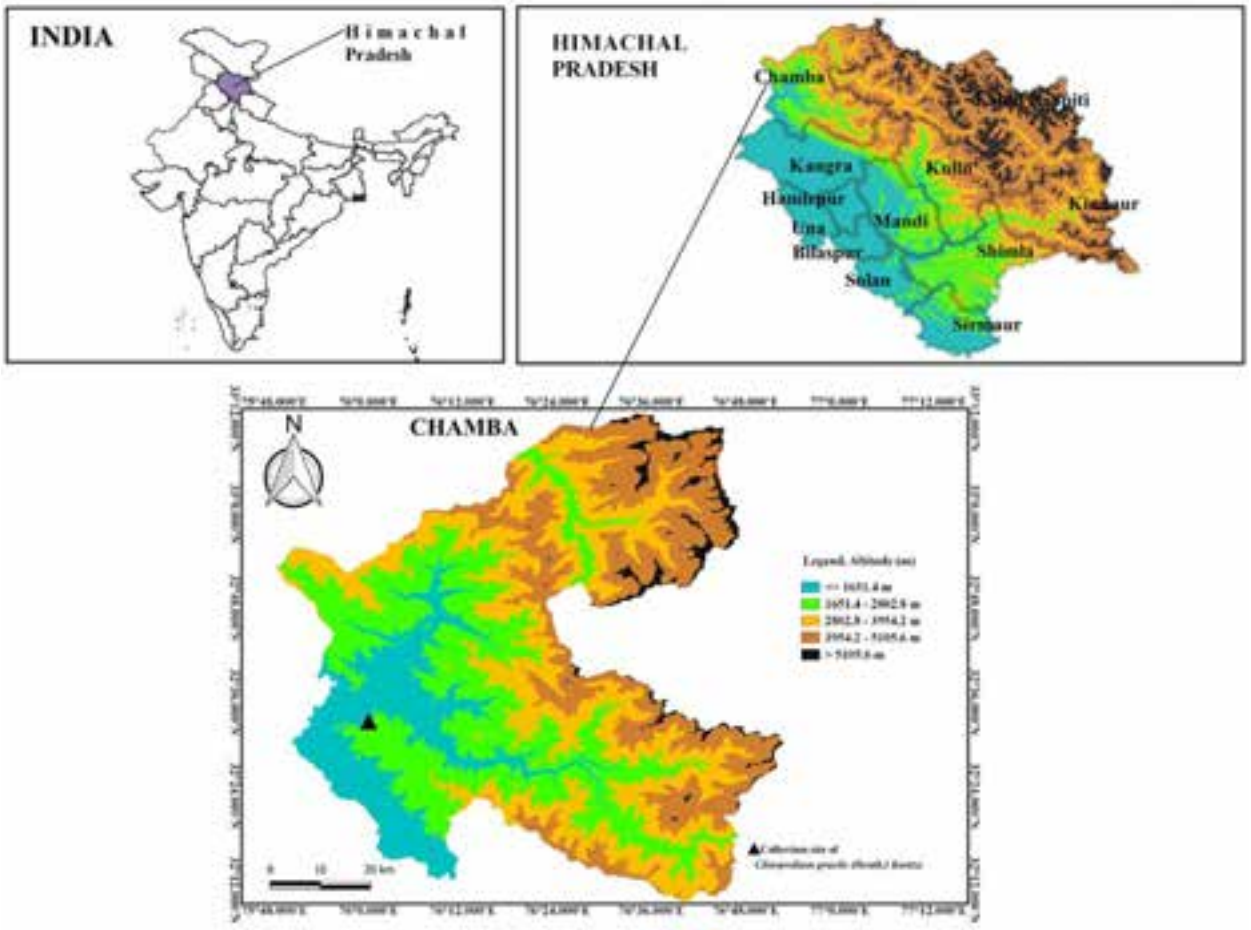


Figure 1. Map showing geographical location of *Clinopodium gracile* (Benth.) Kuntze in Chamba District of Himachal Pradesh (Map prepared through QGIS software).

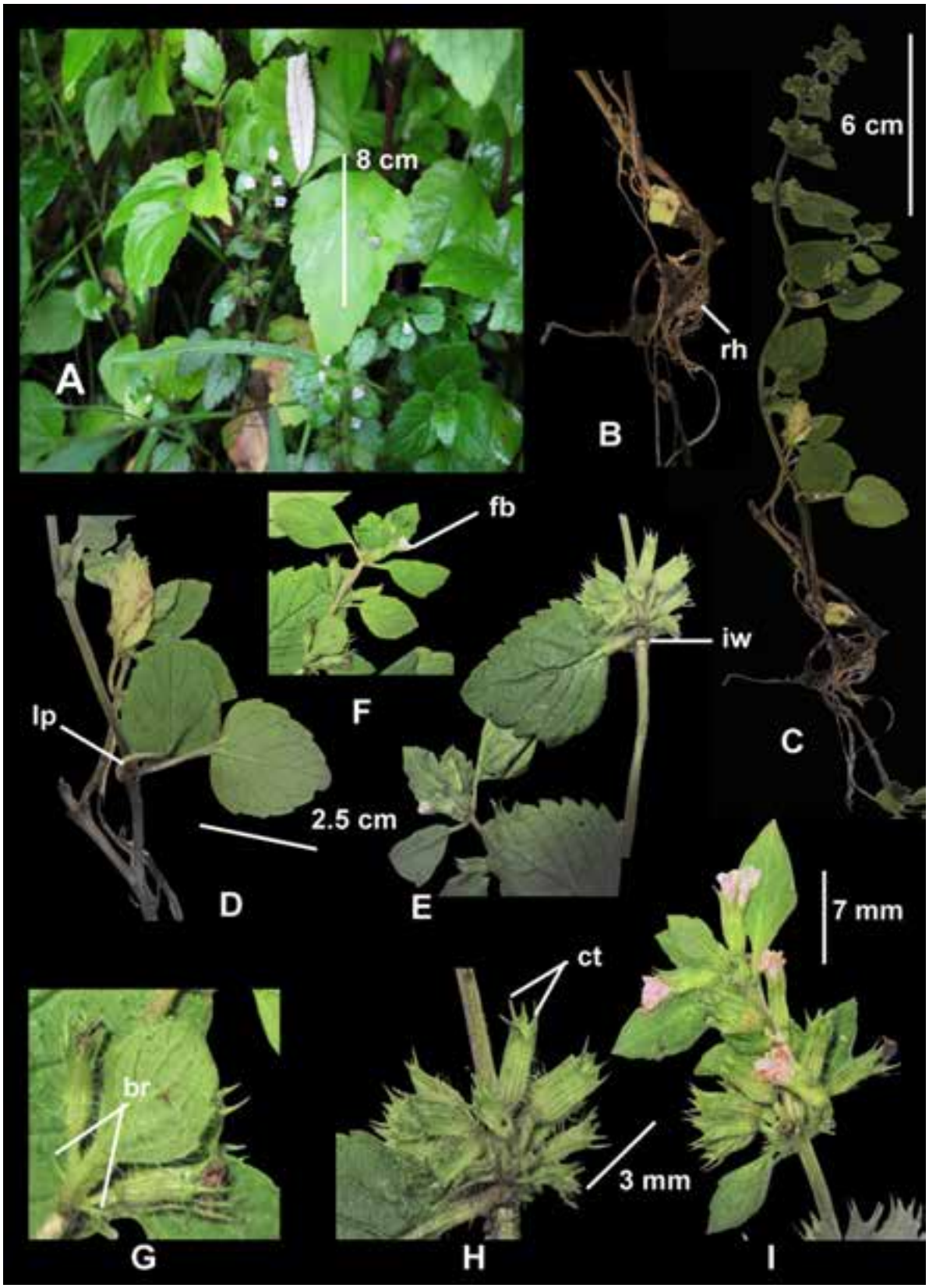


Image 1. ***Clinopodium gracile*** **(Benth.) Kuntze: A—Habit of the plant | B—Stoloniferous root showing root hair (rh) | C—Whole plant revealing its vegetative and reproductive parts | D—Abaxial surface of leaf with leaf petiole (lp) | E—Adaxial surface of leaf and inflorescence whorl (iw) | F—Young shoot displaying floral bud (fb) | G—Base of pedicel manifesting bract (br) | H—Calyx portraying its tooth (ct) | I—Verticillaster inflorescence exhibiting flower arrangement. © Rimjhim Chandra.**

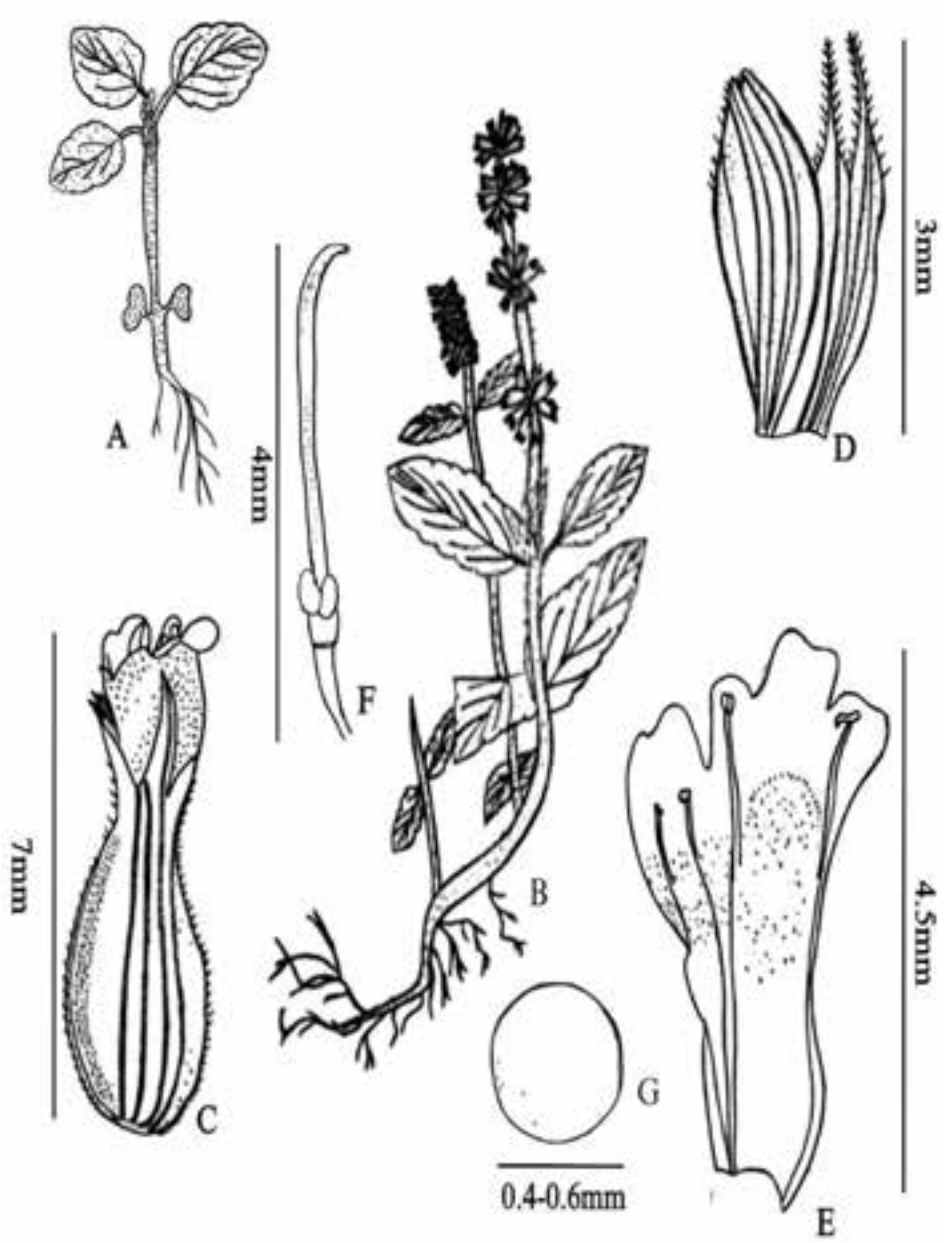


Figure 2. ***Clinopodium gracile*** **(Benth.) Kuntze. A—Young sapling | B—Habit of the plant | C—A complete flower | D—Dissected view of the calyx | E—Corolla showing epipetalous stamens | F—Gynoecium | G—Nutlet. © Rimjhim Chandra.**

Description

Small perennial herb, slender, stoloniferous; Stem quadrangular, numerous, tufted, erect or procumbent at the base, ascending, 8–30 cm, retrorse, pubescent; Leaves opposite, basal leaves circular-ovate, 1.2–1.5 × 1–1.1 cm, base rounded, apex obtuse, margin remotely crenate, lower and mid stem leaves ovate, 1.5–2.5 × 1–1.5 cm, papery, sub-glabrous, abaxially sparsely hispid on veins, apex obtuse, base rounded to cuneate, margin remotely dentate or crenate-serrate, petioles 0.3–1 cm; Inflorescence verticillaster, few flowered (5–10), lax or dense, crowded in short terminal raceme, floral leaves ovate-lanceolate, 0.5–1 × 0.3–0.8 cm, margin serrate, acute; Bract linear, acute, puberulous, much shorter than pedicel; Flower rose-pink, 5–7 × 3–4 mm, pedicel 1–3 mm; Calyx tubular, base rounded, ca. 3–5 mm and declinate in fruit, puberulent or subglabrous, minutely hispid on veins, throat sparsely fine pilose, teeth ciliate, lower two subulate, upper three triangular, reflexed in fruit; Corolla ca. 4.5 mm, puberulent; nutlets ovoid, smooth 0.4–0.5 mm (Image 1 and Figure 2).

Common name: Calamint, Savory, Slender Wild Basil,

Key to four species of *Clinopodium* L.

1. Calyx with glandular hairs
   2. Calyx teeth ciliate; leaves ovate; verticillate flowers crowded nearby; corolla rose-pink; nutlets ovoid; stoloniferous ..... ***Clinopodium gracile***
   2. Calyx teeth long; leaves sub-obtuse; verticillate flowers distantly cyme; corolla purplish; nutlets ellipsoid; woody rootstock ..... *Clinopodium capitellatum*

1. Calyx with eglandular hairs
   3. Calyx with bristly hairs; leaves sharply toothed margin; many (30–40) flowered whorls; lower corolla with notched centre lobe ..... *Clinopodium vulgare*
   3. Calyx with wooly hairs, leaves toothless or shallowly toothed; few (10–20) flowered whorls; lower corolla with smooth centre lobe ..... *Clinopodium umbrosum*

Tower Flower.

Flowering: The flowering has been observed in July.

Habitat: Stream sides, open grasslands, forest margin, and thickets.

Specimen examined

China: Si-chu-shan, C. Sampson, i.1968, coll. No. 13045, K000193480! Indonesia: Bakh; Brink, 27.vii.1920, coll. No. 4839, K000193477! Japan: Pref. Chiba, Nokogiriyama, Yoshihiro Asai, 3.v.1959, coll. No. 8518, NY 02706540! USA: Florida, J.R. Burkhalter, 30.iv.1980, coll. No. 6908, 149957! Louisiana, S.R. Hill, 20.iv.1998, coll. No. 29989, 278039! South Carolina, K.A. Bradley, 22.vi.2016, altitude 165 m, coll. No. 4693, 295537! Florida, Tallahassee, Loran C. Anderson, 25.v.2017, 30.44718 N 84.25225 W, coll. No. 30676, NY 04416374! Louisiana, Iberia Parish, Roland M. Harper, 16.vii.1934, NY 03030120! India: Himachal Pradesh, Jot Chamba, Gajnoi, Rimjhim Chandra, 27.vii.2023, 32.4868 N 76.0593 E, altitude 2,880 m, coll. No. 103.

Taxonomic note

The specific epithet '*gracile*' (Latin–gracilis) suggests the slender and delicate habit of the species. *Calamintha gracilis* Benth. is the basionym for *Clinopodium gracile* (Benth.) Kuntze. Bentham (1848) showed uncertainty about the species kinship to the genus '*Clinopodium*'. He further considered *Clinopodium gracile* features somewhere between *Clinopodium debilis* (*C. debile*) and *Clinopodium umbrosa* (*C. umbrosum*). Ohwi (1965) mentioned four varieties of *Clinopodium gracile* viz. *C. gracile* var. *latifolium* (H.Hara) Ohwi, *C. gracile* var. *minimum* (H.Hara) Ohwi, *C. gracile* var. *multicaule* (Maxim.) Ohwi, *C. gracile* var. *sachalinense* (F. Schmidt) Ohwi. However, these remain as synonyms of *C. latifolium*, *C. multicaule* var. *yakusimense*, *C. multicaule*, *C. micranthum* var. *sachalinense* respectively. No infra-specific ranks are available for *Clinopodium gracile* (POWO 2024).

Discussion

Chen et al. (2013) reported 34 essential oil compounds in *Clinopodium gracile* with higher content of sesquiterpenoids followed by monoterpenoids. Thus, the species occurring in the Himachal Pradesh region can also act as a potent therapeutic plant. The species can be efficacious in floristic, biodiversity, and conservation studies. The present examined species is similar in morphological description provided by Weakley (2010).

Conclusion

The perennial herb *Clinopodium gracile,* was collected from natural habitat of Gajnoi, Chamba district of Himachal Pradesh. The location site was specified with 12 numbers of *C. gracile* plants, growing in deteriorated broad-leaved oak and pine forest. Few other species flourishing along with *C. gracile* were *Ageratum conyzoides* L., grasses being *Cynodon* sp., *Stachys* sp., ferns such as *Diplazium* sp., and *Matteuccia* sp. The species might be a prospective for multitude of medicative activities. The findings can further assist in exploring the extended distribution of *C. gracile* in the western Himalayan belt.

References

Bentham, G. (1848). *Lamiaceae,* pp. 27–603. In: de Candolle, A.P. *Prodrumus Systematis Naturalis Regni Vegetabilis*, *Volume 12*. Parisii, Sumptibus Sociorum Treuttel et Würtz., 232 pp. https://doi.org/10.5962/bhl.title.286

Cantino, P.D. & S.J. Wagstaff (1998). A re-examination of North American *Satureja* s.l. (*Lamiaceae*) in light of molecular evidence. *Brittonia* 50: 63–70. https://doi.org/10.2307/2807719

Chen. X.B., X.C. Liu, L. Zhou & Z.L. Liu (2013). Essential oil composition and larvicidal activity of *Clinopodium gracile* (Benth.) Matsum (*Labiatae*) aerial parts against the *Aedes albopictus* mosquito. *Tropical Journal of Pharmaceutical Research* 12(5): 799–804. https://doi.org/10.4314/tjpr.v12i5.21

Doroszenko, A. (1985). Taxonomic studies on the *Satureja* complex (*Labiatae*). Doctoral Thesis. Edinburgh University, Biological Sciences thesis and dissertation collection, Edinburg Research Archives. http://hdl.handle.net/1842/13694

Hsieh, T. & T. Huang (1998). Notes on the Flora of Taiwan-Revision on the genus *Clinopodium* L. in Taiwan, *Taiwania* 43(2): 108–115.

Li, X.W. & I.C. Hedge (1994). *Clinopodium,* pp. 228–231. In: Wu, Z.Y. &

P.H. Raven (eds.). *Flora of China Volume 17*: *Verbenaceae* through *Solanaceae*. Science Press, Beijing, China.

Mao, A.A. & S.S. Dash (2020). *Flowering Plants of India: An Annotated Checklist, Volume 2: Dicotyledons.* Botanical Survey of India, 705 pp.

Ohwi, J. (1965). *Flora of Japan: combined, much revised and extended translation.* Washington D.C. Smithsonian Institution, 1067 pp.

POWO (2024). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet. Retrieved on 5 January 2024. https://powo.science.kew.org/

Stevens, P.F. (2001 onwards). Angiosperm Phylogeny Website, Version 14. http://www.mobot.org/MOBOT/research/APweb/. Accessed on 10 January 2024.

Weakley, A.S. (2010). *Flora of the Southern and Mid-Atlantic States*. United States: University of North Carolina Herbarium, North Carolina Botanical Garden, University of North Carolina, Chapel Hill, 744 pp.

Zomlefer, W.B., D.E. Giannasi, M.W. Denslow, D.B. Poindexter, P. Ball, W.B. Zomlefer, D.E. Giannasi, A. Reynolds & K. Heiman (2011). Noteworthy Collections: Georgia. *Castanea* 76(2): 187–189. https://doi.org/10.2179/10-043.1

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25623–25626

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

https://doi.org/10.11609/jott.9070.16.7.25623-25626

#9070 | Received 04 April 2024 | Final received 02 July 2024 | Finally accepted 10 July 2024

OPEN ACCESS

NOTE

Small Wild Cats Special Series

Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in the semi-natural subterranean habitat in Karnataka, India

Shirish Manchi [1], Goldin Quadros [2], Dipika Bajpai [3], Shomita Mukherjee [4], Suma Haleholi [5], Mahesh Marennavar [6], Sangmesh Neeralagi [7], Prakash Ganiger [8], Suresh Lamani [9] & Nikhil Kulkarni [10]

[1,2,4] Sálim Ali Centre for Ornithology and Natural History, South India Centre of Wildlife Institute of India, Anaikatty, Coimbatore, Tamil Nadu 641108, India.

[3,5,6,7,8,9] c/o Deputy Conservator of Forests, Gadag Division, Binkadkatti, Gadag, Karnataka 582103, India.

[10] Gadag Zoo, Binkadakatti, Gadag, Karnataka 582103, India.

[1] ediblenest@gmail.com (corresponding author), [2] goldinq@gmail.com, [3–9] dcfconservatorgadag@gmail.com, [4] shomita.sacon@wii.gov.in, [10] zoorfogadag@gmail.com

On 29 March 2023, we conducted a rapid survey in three abandoned gold mines in Kappatagudda Wildlife Sanctuary in Gadag, Karnataka, India (Image 1) to explore the biological diversity in these artificial subterranean habitats. The habitat around these mines is characterised by dry grasslands interspersed with thorn scrub forests (Image 2). Due to the presence of groundwater, our survey of the mines was limited to the upper strata. While surveying one of the mines in Jalligeri village of Shirahatti taluka in Gadag district, we observed pug marks of a small mammal. Approximately 85 m from the tunnel's entrance, we found the carcass of a male Rusty-spotted Cat *Prionailurus rubiginosus* (Image 3).

The carcass was taken to Gadag Zoo for further examination (Image 4). The cat measured 68.58 cm in total length, 35.56 cm in body length, with a 10.16 cm head, 22.86 cm long tail, 22.86 cm in height, and chest girth of 35.56 cm, indicating that it was an adult. The gut contained a partly digested unidentified bat species (Microchiroptera) (Image 5). The dissection examination of the carcass revealed exophthalmia of eyeballs, gelatinisation of subcutaneous fat, paleness and friable nature of kidneys, half-digested food, severe congestion in the right lobe of the lung, passed off rigour mortis, and initiation of the secondary flaccidity. We therefore estimated that the time of death was within 48–72 hours prior to the collection (Sastry 2020). The cause of death could not be determined.

Rusty-spotted Cat predation on bats is evident from at least one instance in Gujarat (Devkar et al. 2016). Other studies on Rusty-spotted Cat diet indicate that rodents form its primary prey (Mukherjee et al. 2016; Bora et al. 2020; Chaudhary et al. 2022; Mukherjee et al. 2024). This individual possibly visited this cave for hunting, as caves have a rich presence of bats and rodents (Busch et al. 2000). The Rusty-spotted Cat is claimed to also use caves and crevices in other parts of India (Patel 2011; Vyas & Upadhyay 2014).

Editor: Angie Appel, Wild Cat Network, Germany.

Date of publication: 26 July 2024 (online & print)

Citation: Manchi, S., G. Quadros, D. Bajpai, S. Mukherjee, S. Haleholi, M. Marennavar, S. Neeralagi, P. Ganiger, S. Lamani & N. Kulkarni (2024). Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in the semi-natural subterranean habitat in Karnataka, India. *Journal of Threatened Taxa* 16(7): 25623–25626. https://doi.org/10.11609/jott.9070.16.7.25623-25626

Funding: Karnataka Forest Department, Government of Karnataka.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are grateful to the Karnataka Forest Department, Government of Karnataka for providing budgetary and logistical support to organise visits to the study sites. We extend hearty appreciation to the director of the Wildlife Institute of India for his encouragement and for permitting a team of SACON scientists to visit the study sites. The study area map has been prepared by Dhanusha Kawalkar, for which we are grateful for her efforts and timely support.

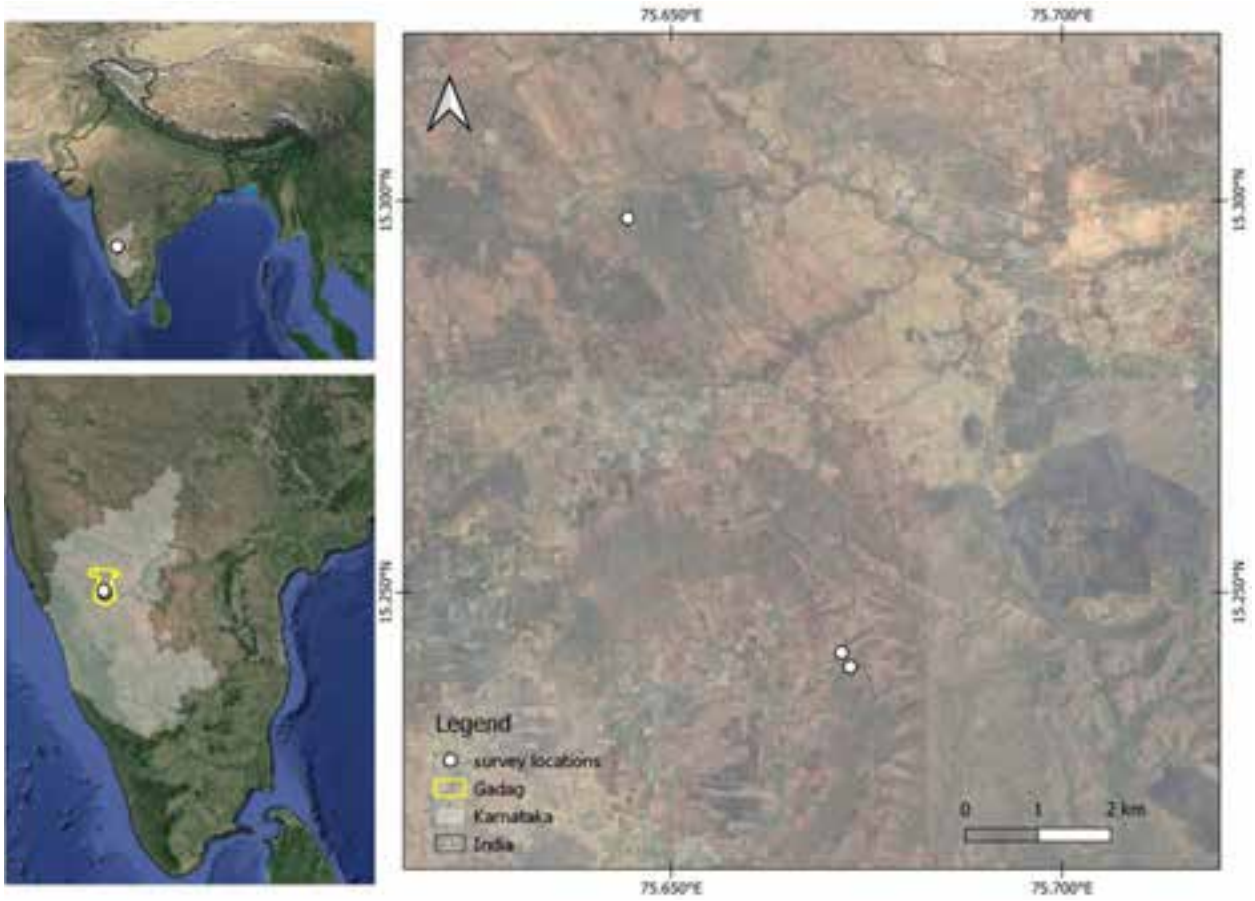


Image 1. Map showing the location of the surveyed human-made subterranean spaces in Kappatagudda Wildlife Sanctuary, Karnataka, India.

Image 2. The habitat around the abandoned gold mine. © Shirish Manchi.

Between 1900 and 1922, horizontal tunnels were dug in Indian forests for gold mining, but they have been abandoned since mining ceased in the early 1990s. The mines have varying lengths and structures with several subterranean water patches. Due to infiltration from rainwater, these tunnels are inaccessible for most part

Image 3. The carcass of the Rusty-spotted Cat found in the abandoned gold mine, Kappatagudda Wildlife Sanctuary. © Shirish Manchi.

Image 4. Measuring the morphometric characteristics of the dead Rusty-spotted Cat found in the abandoned gold mine. © Shirish Manchi.

Image 5. A bat (Microchiroptera) was recovered from the gut of the carcass of the Rusty-spotted Cat. © Shirish Manchi.

of the year. Horizontal branching tunnels could only be reached via wet ground and shallow water ditches. The oligotrophic subterranean habitat harboured several amphibians, sustained mainly by organic matter from the bats inhabiting the roof and dropping their guano.

Our observations suggest that the subterranean habitats are possible additional important areas of use for the Rusty-spotted Cat, especially given the availability of prey such as bats. The Rusty-spotted Cat possibly contributes to the food chain of this semi-natural subterranean habitat, both as a top predator and as an additional energy source to this oligotrophic ecosystem. Further investigation on this aspect is necessary to uncover the extent of its contribution to this ecosystem.

Ecologically, subterranean habitats are still poorly understood (Wynne et al. 2021). They contain unique and specialised biozones of high scientific interest and conservation potential (Stone et al. 2005). Abandoned mines are semi-natural habitats and complex ecosystems (Lenart et al. 2022).

The presence of a Rusty-spotted Cat, a Near Threatened (Mukherjee et al. 2016) and Schedule-I species (Ministry of Law and Justice 2022), in a human-made subterranean habitat demonstrates the high conservation value of this habitat and calls for additional research to explore underground ecosystems in the cat's range. We urge local, state and national governments and other stakeholders to safeguard and oversee both human-made and natural underground habitats in order to maintain and preserve these under-researched crucial habitats for a multitude of identified and unidentified species that rely on them.

References

Bora, J.K., N. Awasthi, U. Kumar, S. Goswami, A. Pradhan, A. Prasad, D.R. Laha, R. Shukla, S.K. Shukla, Q. Qureshi & Y.V. Jhala (2020). Assessing the habitat use, suitability and activity pattern of Rusty-spotted Cat *Prionailurus rubiginosus* in Kanha Tiger Reserve, India. *Mammalia* 85: 459–468. https://doi.org/10.1515/mammalia-2019-0032

Busch, C., C.D. Antinuchi, J.C. del Valle, M.J. Kittlein, A.I. Malizia, A.I. Vassallo & R.R. Zenuto (2000). Population ecology of subterranean rodents, pp. 183–226 in: Lacey E.A., J.L. Patton & G. Cameron (eds.) *Life underground: the biology of subterranean rodents*. The University of Chicago Press, Chicago, Illinois, 449 pp.

Chaudhary, R., Z. Nazneen, M. Azra & A.K. Jamal (2022). Status, activity pattern and habitat use of Rusty-spotted Cat (*Prionailurus rubiginosus*) in Gir Protected Area, Gujarat, India. *International Journal of Ecology and Environmental Sciences* 48: 747–753. https://doi.org/10.55863/ijees.2022.674

Devkar, R., R. Bhatt & K. Upadhyay (2016). Rusty-spotted Cat predating on bats. *Cat News* 64: 27–28.

Lenart, J., K. Schuchová, M. Kašing, L. Falteisek, Š. Cimalová, J. Bílá, M. Ličbinská & J. Kupka (2022). The abandoned underground mine as a semi-natural ecosystem: The story of Flaschar's Mine (Czechia). *Catena* 213: 106178. https://doi.org/10.1016/j.catena.2022.106178

Ministry of Law and Justice (2022). The Wild Life (Protection) Amendment Act, 2022, No. 18 of 2022. The Gazette of India. Registered No. DL—(N)04/0007/2003—22.

Mukherjee, S., A.R. Gawari, K. Pillai, P. Koparde, P.V. Karunakaran & N. Khanolkar (2024). Diet of Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Sanjay Gandhi National Park, Mumbai, India. *Journal of Threatened Taxa* 16(5): 25129–25136. https://doi.org/10.11609/jott.8898.16.5.25129-25136

Mukherjee, S., J.W. Duckworth, A. Silva, A. Appel & A. Kittle (2016). *Prionailurus rubiginosus*. The IUCN Red List of Threatened Species 2016: e.T18149A50662471. Downloaded on 23 July 2023. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T18149A50662471.en

Patel, K. (2011). Preliminary survey of small cats in Eastern Gujarat, India. *Cat News* 54: 8–11.

Sastry, G.A. (2020). Veterinary Pathology. CBS Publishers & Distributors, India, 782pp.

Stone, F.D., F.G. Howarth, A. Hoch & M. Asche (2005). Root communities in lava tubes, pp. 447-484. In White W. B. & D.C. Culver (eds.), Encyclopaedia of caves. Elsevier Academic Press, Burlington, San Diego, London, 945 pp.

Vyas, R. & K. Upadhyay (2014). Sightings and distribution of Rusty-spotted Cat in Gujarat State, India. *Cat News* 61: 26–29.

Wynne, J.J., F.G. Howarth, S. Mammola, R.L. Farreira, P. Cardoso, T.D. Lorenzo, D.M.P. Galassi, R.A. Medellin, B.W. Miller, D. Sánchez-Fernández, M.E. Bichuette, J. Biswas, C.W. BlackEagle, C. Boonyanusith, I.R. Amorim, P.A.V. Borges, P.J. Boston, R.N. Cal, N. Cheeptham, L. Deharveng, D. Eme, A. Faille, D. Fenolio, C. Fišer, Z. Fišer, S.M. 'Ohukani'ōhi'a Gon III, F. Goudarzi, C. Griebler, S. Halse, H. Hoch, E. Kale, A.D. Katz, Ľ. Kováč, T.M. Lilley, S. Manchi, R. Manenti, A. Martínez, M.B. Meierhofer, A.Z. Miller, O.T. Moldovan, M.L. Neimiller, S.B. Peck, T.G. Pellegrini, T. Pipan, C.M. Phillips-Lander, C. Poot, P.A. Racey, A. Sendra, W.A. Shear, M.S. Silva, S. Taiti, M. Tian, M.P. Venarsky, S.Y. Pakarati, M. Zagmajster & Y. Zhao (2021). A conservation roadmap for the subterranean biome. *Conservation Letters*: e12834. https://doi.org/10.1111/conl.12834

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25627–25629
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8856.16.7.25627-25629
#8856 | Received 26 November 2023 | Final received 11 June 2024 | Finally accepted 09 July 2024
OPEN ACCESS
NOTE

First record of Scaly-breasted Munia *Lonchura punctulata* (Linnaeus, 1758) (Aves: Passeriformes: Estrildidae) from Kashmir, India

Shazia Shafayat [1], Fayaz Ahmad Ahanger [2], Tariq Ahmad [3], Bilal A. Bhat [4] & Zakir Hussain Najar [5]

[1,3,4,5] Department of Zoology, University of Kashmir, Hazratbal, Srinagar, Jammu & Kashmir 190001, India.
[2] Department of Zoology, Government Degree College Ganderbal, Jammu & Kashmir 191201, India.
[1] ssshafayat006@gmail.com, [2] ahangerfayaz@gmail.com, [3] drtariqento@kashmiruniversity.ac.in, [4] bilalwildlife@gmail.com, [5] zakirnajar1@gmail.com (corresponding author)

Scaly-breasted Munia *Lonchura punctulata* is a small-sized bird from the family Estrildidae, commonly known as waxbills, grass finches, or the munia family. Scaly-breasted Munia is also sometimes referred to as Spotted Munia. This bird is indigenous to Asia with a broad geographic range, including India, China, Bangladesh, Afghanistan, Bhutan, Cambodia, Indonesia, Nepal, Singapore, Sri Lanka, Thailand, and Vietnam (Arigela et al. 2020; Bird Life International 2023). It has been introduced to Australia, Hawaii, Puerto Rico, Florida, Japan, and California. In Oahou and Hawaii this introduction has led to the establishment of wild populations that compete with other munia species, such as Tricolored Munias *Lonchura malacca,* which were also introduced at the same time (Moulton et al. 1992; Payne 2020). Scaly-breasted Munias live in wet and high grasslands, often with other munias. They eat grass seeds, berries, algae, and insects (Payne 2020). They roost in bushes, trees, and cycas plants. In southern India and Indonesia, they are considered crop pests.

Current literature reports Scaly-breasted Munia in Jammu province of the Union Territory of Jammu & Kashmir, India which is ecologically different from Kashmir (Grimmet et al. 2011; Suhail et al. 2020). Here we present Scaly-breasted Munia from Kashmir province with photographic evidence (Image 1–4). During our field surveys, Scaly-breasted Munia, was observed at three locations, viz., Kaman post Uri, Salamabad Uri, and Ladoora area in Baramulla District along the river Jhelum (Image 5). Initially the bird was sighted at Kaman post (34.100°N & 74.022°E) on 2 September 2022, at 1022 h perching on the transmission wires. During a second visit on 17 June 2023 in the Salamabad area (34.095°N & 74.022°E), a flock of Scaly-breasted Munias was sighted at 1430 h near the hydropower project dam. The third sighting took place at the Ladoora (34.252°N & 74.401°E) area of Baramulla on 21 July 2023 at 1500 h. The bird was observed near a footbridge, perching on an electric wire, and feeding on grass. The first author is investigating riverine bird diversity, conducting comprehensive bird surveys in the area to identify, and document bird species. As munias are popular cage birds, the birds seen in Kashmir could be escapees. As munias have been successfully introduced in many countries, they are hardy enough to establish wild populations by the escaped birds from the cages.

Editor: Carol Inskipp, Bishop Auckland Co., Durham, UK. **Date of publication:** 26 July 2024 (online & print)

Citation: Shafayat, S., F.A. Ahanger, T. Ahmad, B.A. Bhat & Z.H. Najar (2024). First record of Scaly-breasted Munia *Lonchura punctulata* (Linnaeus, 1758) (Aves: Passeriformes: Estrildidae) from Kashmir, India. *Journal of Threatened Taxa* 16(7): 25627–25629. https://doi.org/10.11609/jott.8856.16.7.25627-25629

Funding: This research received no specific grant from any funding agency.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are highly thankful to Department of Wildlife Protection, Jammu and Kashmir, for granting the necessary permission to carry out work in north Kashmir. A special thanks go out to Deputy Commissioner Baramulla for granting permission in sensitive zones.

Image 1–2. Scaly-breasted Munia *Lonchura punctulata* at Kaman Post and Salamabad Uri, Baramulla, Kashmir. © Shazia Shafayat.

Image 3–4. Scaly-breasted Munia *Lonchura punctulata* at Ladoora, Baramulla, Kashmir. © Shazia Shafayat.

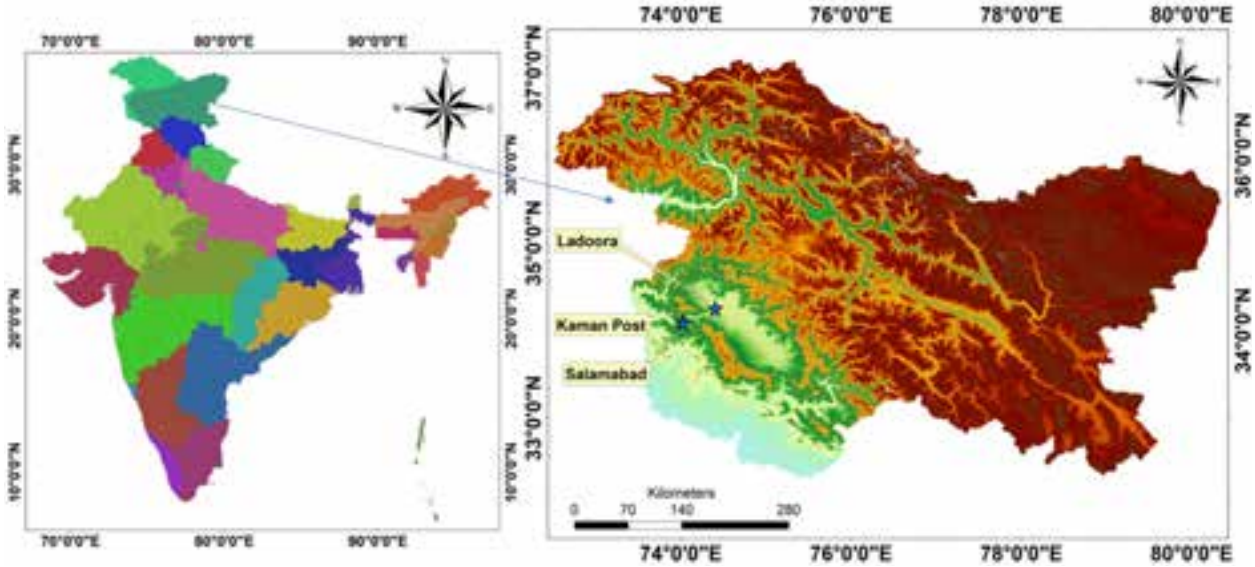


Image 5 . Map showing sighting locations of Scaly-breasted Munia in Kashmir, India.

Many times, people become tired of their pet birds and release them. Most do not survive, but many species (e.g., munias, parakeets, mynas) survive and establish wild populations.

The bird is characterized by its rich reddish-brown plumage, notably darker on the chin, and throat (Image 1–4). The breast and belly display a striking contrast, appearing white with black feather edges that create a scaled pattern which distinguishes the bird from other munias. The mantle, back, and wings exhibit a slightly paler and duller hue, adorned with subtle barring, and occasionally more prominent pale shaft streaks. The bird's eyes have a dark brown to brownish-red iris, the bill is blackish, and the lower mandible may exhibit a paler bluish-grey shade. The rump showcases distinctive dark brown and whitish or yellowish bars, while the upper tail coverts feature a subdued golden-yellow to orange-brown coloration. The species was identified using Grimmett et al. (2011).

The bird is a new member to the avifaunal diversity of Kashmir, India. There is limited scientific investigation into the avian diversity inhabiting the northern Kashmir, which needs scientific attention in the form of intensive surveys.

References

Arigela, R.K., N. Siddabathula, K. Prasad & R.K. Singh (2020). Preferent wild grasses of Scaly-breasted Munia *Lonchura punctulata* in Andhra Pradesh, Tamil Nadu and Telangana. *NeBIO* 11(1): 13–17.

Birdlife International (2023). Downloaded on 15/06/2021. Species factsheet: *Lonchura punctulata*. http://datazone.birdlife.org/species/factsheet/scaly-breasted-munia-lonchura-punctulata

Grimmett , R., C. Inskipp & T. Inskipp (2011). *Helm Field Guides Birds of the Indian Subcontinent.* Oxford University Press, New Delhi, 528 pp.

Moulton, M.P., L.J. Allen & D.K. Ferris (1992). Competition, resource use and habitat selection in two introduced Hawaiian Mannikins. *Biotropica* 1: 77–85.

Payne, R.B. (2020). Scaly-breasted Munia *Lonchura punctulata*, version 1.0. In: del Hoyo, J.A., J. Elliott, J. Sargatal, D.A. Christie & E. de Juana (eds.). *Birds of the World*. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.nutman.01

Suhail, I., R. Ahmad & K. Ahmad (2020). Avifaunal diversity in Jammu and Kashmir State, pp. 897–831. In: Dar, G.H. & A.A. Khuroo (eds.). *Biodiversity of the Himalaya: Jammu and Kashmir State, Topics in Biodiversity and Conservaton*. Springer Nature, Singapore, 1100 pp. https://doi.org/10.1007/978-981-32-9174-4_35

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25630–25631
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.9225.16.7.25630-25631
#9225 | Received 19 June 2024 | Final received 27 June 2024 | Finally accepted 01 July 2024
OPEN ACCESS
NOTE

First record of *Proszynskia diatreta* (Simon, 1902) (Araneae: Salticidae) from Gujarat, India

Manisha P. Patel [1] & **Dhruv A. Prajapati** [2]

[1] Department of Zoology, Navyug Science College, Rander Road, Surat, Gujarat 395009, India.
[2] Web of Nature (WON) Research Foundation, Ahmedabad, Gujarat 380058, India.
[1] dr.manishappatel@gmail.com, [2] dhruvspidy215@gmail.com (corresponding author)

The genus *Proszynskia* Kanesharatnam & Benjamin, 2019 was established with *Proszynskia diatreta* (Simon, 1902) as its type species (Kanesharatnam & Benjamin 2019; World Spider Catalog 2024). *P. diatreta* is presently known from India and Sri Lanka (Kanesharatnam & Benjamin 2019). In India, the species has been documented only from two localities in Tamil Nadu (Caleb 2016). In this study, we report the discovery of *P. diatreta* in Gujarat, making it the northernmost distributional record of this species.

The specimen was hand-collected and studied under a Leica M205 A stereomicroscope and microphotographic images were taken by a Leica DFC2900 digital camera attached to the stereomicroscope and enabled with the software package Leica Application Suite (LAS), version 4.5.0. Left palp was studied and photographed by placing in a cavity block filled with ethanol. The species was identified based on Kanesharatnam & Benjamin (2019). The examined specimen has been deposited in the reference collection of the Web of Nature (WON) Research Foundation, Gujarat, India (curator: Dhruv A. Prajapati).

Family Salticidae Blackwall, 1841
Genus *Proszynskia* Kanesharatnam & Benjamin, 2019
Type species: *Viciria diatreta* Simon, 1902

***Proszynskia diatreta* (Simon, 1902)** (Images 1–3)
Viciria diatreta Simon, 1902: 366
Viciria diatreta Prószyński, 1984: 433, figs 42–43
Viciria diatreta Caleb & Mathai, 2014: 65, figs 38–46
Phintella diatreta Caleb, 2016: 274
Proszynskia diatreta Kanesharatnam & Benjamin, 2019: 54, figs 23E-H, 24A-E, 25A-E, 26A-D

Material examined: WON102495A, 3.viii.2016, 1 male, India, Gujarat, Ahwa village in Dang district (20.7488 °N, 73.6916 °E), 461 m, leg. D. Prajapati.

Diagnosis: The species can be easily identified by the short, straight and robust embolus directed at 12 o'clock position ventrally (Image 2); tegulum with significant prolateral proximal lobe (Image 2); retrolateral tibial apophysis bent at the tip and directed at 10 o'clock position (Image 3).

Distribution: India and Sri Lanka (Simon 1902; Kanesharatnam & Benjamin 2019) (Figure 1).

Distribution in India: Tamil Nadu (Simon 1902) and Gujarat.

Editor: John T.D. Caleb, SIMATS, Saveetha University, Chennai, India. **Date of publication:** 26 July 2024 (online & print)

Citation: Patel, M.P. & D.A. Prajapati (2024). First record of *Proszynskia diatreta* (Simon, 1902) (Araneae: Salticidae) from Gujarat, India. *Journal of Threatened Taxa* 16(7): 25630–25631. https://doi.org/10.11609/jott.9225.16.7.25630-25631

Funding: Crowd funding.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are thankful to Mrs Priyal Patel (WON Research Foundation, Ahmedabad) for her generous help in preparation of images.

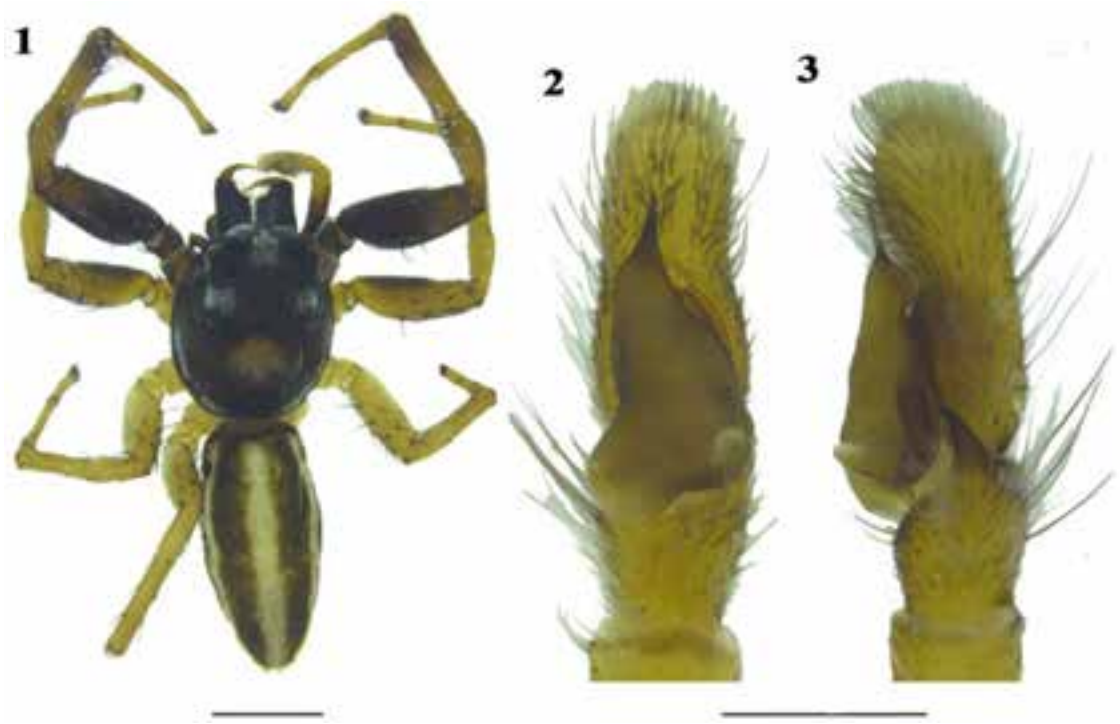


Image 1–3. Male *Proszynskia diatreta* (Simon, 1902) from Gujarat, India: 1—habitus, dorsal view | 2—left pedipalp, ventral view | 3—same, retrolateral view. Scale bars: 2 mm (1), 0.5 mm (2–3). © WON Research Foundation.

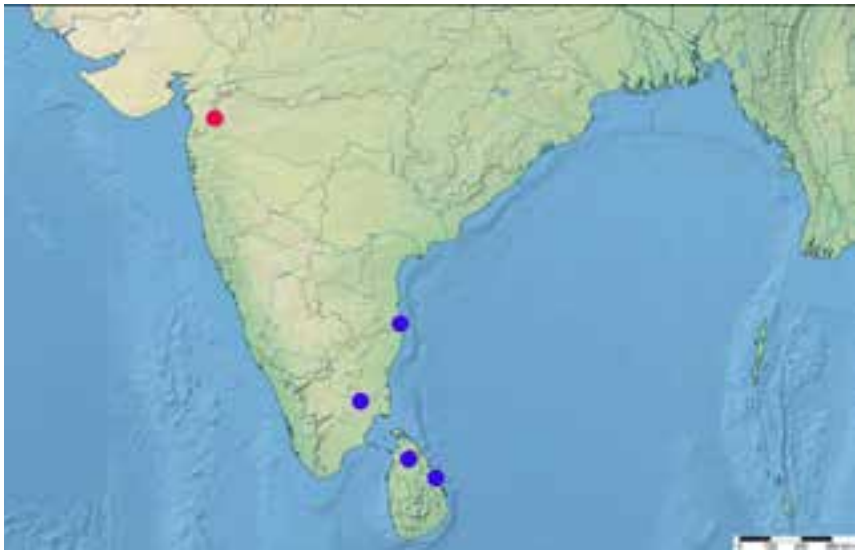


Figure 1. Distribution of *Proszynskia diatreta* (Simon, 1902). (pink circle—new record; blue circles—previous records)

References

Caleb, J.T.D. (2016). New data on the jumping spiders (Araneae: Salticidae) from India. *Arthropoda Selecta* 25(3): 271–277. https://doi.org/10.15298/arthsel.25.3.06

Kanesharatnam, N. & S.P. Benjamin (2019). Multilocus genetic and morphological phylogenetic analysis reveals a radiation of shiny South Asian jumping spiders (Araneae, Salticidae). *ZooKeys* 839: 1–81. https://doi.org/10.3897/zookeys.839.28312

Prószyński, J. (1984). Remarks on *Viciria* and *Telamonia* (Araneae, Salticidae). *Annales Zoologici, Warszawa* 37: 417–436.

Simon, E. (1902). Description d' arachnides nouveaux de la famille des Salticidae (Attidae) (suite). *Annales de la Société Entomologique de Belgique* 46: 24–56, 363–406.

World Spider Catalog (2024). World Spider Catalog. Version 25. Natural History Museum Bern. http://wsc.nmbe.ch. Accessed on 31 March 2024. https://doi.org/10.24436/2

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25632–25636
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8906.16.7.25632-25636
#8906 | Received 08 January 2024 | Final received 02 June 2024 | Finally accepted 28 June 2024
OPEN ACCESS
NOTE

Medicago monantha (Fabaceae) and *Euphorbia jodhpurensis* (Euphorbiaceae) as new additions to the flora of Maharashtra State, India

Praveen V. Kale [1] & **Rajendra D. Shinde** [2]

[1,2] Department of Botany, St. Xavier's College (Autonomous), Mumbai, 5, Mahapalika Marg, Mumbai, Maharashtra 400001, India.
[1] praveen.kale@xaviers.edu (corresponding author), [2] rajendra.shinde@xaviers.edu

Abbreviations: BLAT—Blatter Herbarium, St. Xavier's College (Autonomous), Mumbai, Maharashtra 400001 | BSJO—Botanical Survey of India, Arid Zone Circle, Jodhpur, Rajasthan, India | CAL—Botanical Survey of India, Central National Herbarium, Howrah, West Bengal, India | LE—The Komarov Botanical Institute of RAS, Saint Petersburg, Russia.

During the recent (2019–2022) botanical survey of Daund Tehsil in Pune District of Maharashtra State, two plant specimens belonging to the genera *Medicago* L. and *Euphorbia* L. were collected. On the thorough scrutiny of the literature (Bentham 1839; Trautvetter 1840; Baker 1879; Hooker 1890; Blatter & Hallberg 1920; Ali 1977; Purohit et al. 2019), they have been identified as *Medicago monantha* (C.A. Mey.) Trautv. (1840, Fabaceae) and *Euphorbia jodhpurensis* Blatt. & Hallb. (1920, Euphorbiaceae), which were hitherto not reported from the Maharashtra State. The herbarium specimens (Image 1B & 1C) of the plant species reported herein are deposited at the Blatter Herbarium (BLAT), St. Xavier's College (Autonomous), Mumbai. The detailed descriptions, distribution, and photographs of both species are provided herein for their easy identification.

Systematic treatment

Fabaceae

Medicago monantha (C.A. Mey.) Trautv., Index Seminum [Kiev] 1840: vi, adnot. No. 4. 1840; Mishra et al., Indian J. Plant Sci. 4(3): 70. 2015; Mishra et al., Int. J. Herb. Med. 3(4): 11. 2015; Mishra et al., Indian J. Plant Sci. 4 (4): 92. 2015; Pandey et al., J. Med. Plants Stud. 5(5): 53. 2017; Kaur et al., J. Threat. Taxa 9(8): 10556. 2017; Sanjappa & Ambrish in Dar & Khuroo, Biodivers. Himal.: Jammu & Kashmir State: 640. 2020; Sharma, Int. J. Innov. Res. Sci. Eng. 11(5): 6098. 2022; Sharma, Int. J. Innov. Res. Sci. Eng. 11(7): 9623. 2022; Choudhary et al., Int. Res. J. Modern. Eng. Technol. Sci. 5(8): 565–569. 2023. *Trigonella monantha* C.A. Mey., Verz. Pfl. Casp. Meer.: 137. 1831. *Trigonella polyceratia* auct. non. L. (1753): Baker in Hook. f., Fl. Brit. India 2: 87. 1879; Duthie, Fl. Gangetic Plain 1(1): 209. 1903; Bamber, Pl. Punjab.: 554. 1916; Babu, Herb. Fl. Dehradun: 168. 1977; Sharma & Dhakre, Fl. Agra Distr.: 96. 1995. *Trigonella incisa* Royle ex Benth., Ill. Bot. Himal. Mts.: 197. 1839; Aitchison, Cat. Pl. Punjab and Sindh: 38. 1869; Maheshwari, Fl. Delhi: 115. 1963; Nair, Rec. Bot. Surv. India 12(1): 101. 1978; Sanjappa, Legumes of India: 265. 1992; Bhellum

Editor: V. Sampath Kumar, Botanical Survey of India, Coimbatore, India.

Date of publication: 26 July 2024 (online & print)

Citation: Kale, P.V. & R.D. Shinde (2024). *Medicago monantha* (Fabaceae) and *Euphorbia jodhpurensis* (Euphorbiaceae) as new additions to the flora of Maharashtra State, India. *Journal of Threatened Taxa* 16(7): 25632–25636. https://doi.org/10.11609/jott.8906.16.7.25632-25636

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to the Management of St. Xavier's College (Autonomous), Mumbai for supporting the present research work. Authors express their gratitude to Mr. Anand R. Chordia, Director, Technology & Innovations, Pravin Masalewale, and Founder, The Eco Factory Foundation, Pune, Maharashtra, India for permitting us to carry out our botanical survey in their factory premises located at the village Yawat, Taluka Daund, District Pune, Maharashtra. The authors are also grateful to the Directors at the Blatter Herbarium (BLAT), Botanical Survey of India, Arid Zone Circle (BSJO), Central National Herbarium (CAL), and the Komarov Botanical Institute of RAS (LE) for providing high-resolution digital images important to comparing and confirming the identity of the specimens reported herein.

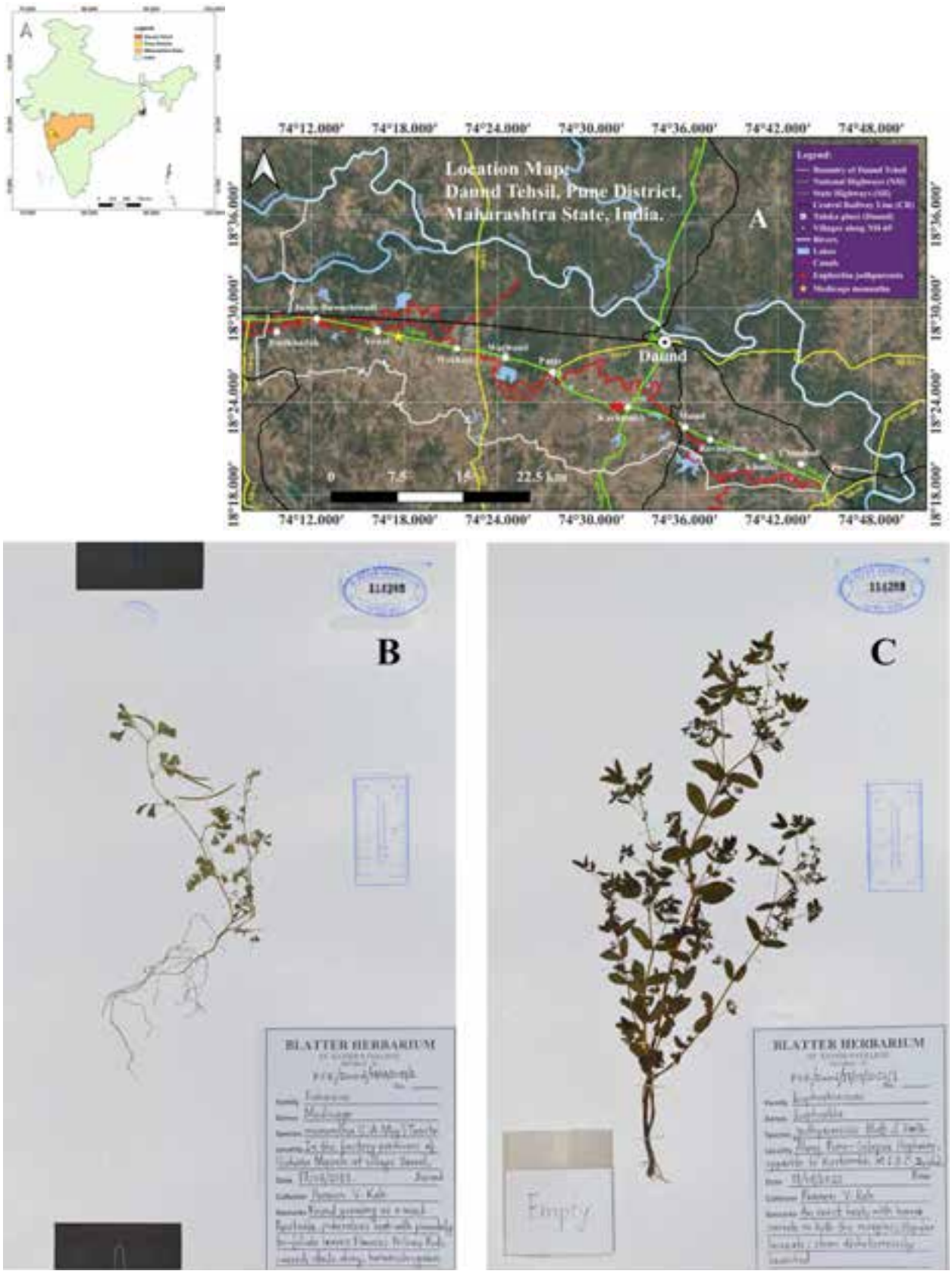


Image 1. A—Location Map | Herbarium specimens deposited at BLAT: B—*Medicago monantha* (C.A. Mey.) Trautv. | C—*Euphorbia jodhpurensis* Blatt. & Hallb. © The Director, Blatter Herbarium, St. Xavier's College (Autonomous), Mumbai.

& Magotra, J. Plant Biol. Res. 1(2): 7. 2012. *T. monantha* ssp. *incisa* (Benth.) Ali in Nasir & Ali, Fl. W. Pakistan, Papilionaceae 100: 294. 1977; Singh in Shetty & Singh, Fl. Rajasthan 1: 269. 1987. (Image 2H–J).

Annual, silvery-puberulous herb with prostrate to ascending slender stem. Leaves pinnately 3-foliolate, strongly nerved; petioles 1–1.5 cm long; leaflets 5–10 × 3–7 mm, obovate-oblong, retuse at apex, cuneate at base, toothed mainly in upper part, sub-glabrous above, sparsely silvery-puberulous beneath; lateral nerves 5–8, conspicuous; petiolules of lateral leaflets are very short, those of terminal leaflets 1–1.5 cm long. Stipules are linear-subulate, puberulous, 3–6mm long, single-nerved. Inflorescence axillary, sessile or pedunculate, 1–3-flowered in axillary sub-umbellate clusters; peduncles 0.5–1.5 cm long, puberulous; bracts linear-subulate, puberulous, 1–2 mm long; pedicels less than 1mm long. Calyx campanulate, linear-lanceolate, very acute, 3–5 mm long, puberulous outside; teeth 5, sub-equal. Corolla yellow; standard 5–7 × 2–2.5 mm, obovate, narrow towards base, retuse; wings 3.5–4 × 1 mm, oblong-obovate, obtuse, claw 2.0–2.3 mm long, upper auricle 0.5–1 mm long; keels 3.5–4 × 1 mm, oblong-obovate, slightly curved towards apex, rounded, claw 2 mm long, flat, upper auricle minute. Stamens glabrous; vexillary filaments 2.3–3 mm long, flat; staminal sheath 2.5–4 mm long; free filaments 0.5–0.7 mm long, sub-equal; anthers minute. Ovary 2.7–3.3 × 0.5 mm, narrowly oblong, ovules many, very minute hairs present along dorsal side when young, densely sericeous at maturity; style 0.5 mm long, subulate, flat, curved, glabrous, persistent; stigma capitate, glabrous. Pods greyish-green, 2.7–5.5 × 0.1–0.2 cm, linear-cylindrical, somewhat compressed, straight or slightly falcate, apiculate, reticulately veined, 12–15-seeded; seeds brownish-green.

Flowering & Fruiting: March–May.

Habitat & associates: In the garden premises of Pravin Masalewale (Suhana Masala) factory unit located along the Pune–Solapur Highway Road, found growing as a weed together with *Medicago polymorpha* L., *Solanum nigrum* L., *Dactyloctenium aegyptium* (L.) Willd., *Eragrostis tenella* (L.) P. Beauv. ex Roem. & Schult. and *Setaria verticillata* (L.) P. Beauv.

Distribution in India: So far has been reported from Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Rajasthan, Uttarakhand, and Uttar Pradesh. The present collection from Yawat village, Daund tehsil, Pune district, Maharashtra State, India (Image 1A), forms its first report for the State.

Specimens examined: Maharashtra, Suhana Masale Factory Premises, Yawat, Daund tehsil, Pune district, 18.469 ^{0}N, & 74.294 ^{0}E, 17.iii.2019, coll. P. V. Kale, P.V.K./ Daund/17/03/2019/2 (BLAT Accession number 114280).

Euphorbiaceae

Euphorbia jodhpurensis Blatt. & Hallb., J. Bombay Nat. Hist. Soc. 26(4): 971. 1920; Bhandari, Fl. Ind. Desert: 342. 1978; Parmar in Shetty & Singh, Fl. Rajasthan 2: 781. 1991; Binojkumar & Balakrishnan in Balakrishnan et al., Fl. of India 23: 291. 2012; Purohit et al., Euphorbia World 15(3): 18–22. 2019; Kotiya et al., Fl. Rajasthan: 441. 2020. *Euphorbia clarkeana* var. *erecta* Hook.f., Fl. Brit. India 5: 254. 1890. *Chamaesyce jodhpurensis* (Blatt. & Hallb.) Raju & Rao, Phytologia 40(5): 392. 1978. (Image 2A–G).

Annual, about 15–60 cm high, glabrous, filiform; stem straw-coloured, erect, simple, or branched from base. Leaves opposite, 12–15 × 3–4.5 mm, obliquely linear-oblong, base almost auricled on one side, margins usually spinulose-serrate, apex obtuse or sub-acute, coriaceous, often crowded at end of branchlets; petioles very short. Stipules lacerate. Cyathia solitary, axillary, less than 1 mm long, campanulate, glabrous; involucral lobes 5, lanceolate, triangular, toothed; glands 4, minute, rounded with pinkish-white orbicular appendages. Male flowers 3–4, pedicels ca 0.5 mm long; anthers sub-globose, transversely dehiscing. Female flower solitary, pedicels ca 1 mm long, glabrous; ovary sub-globose, ca 1 mm across; style 3, ca 1.2 mm long, free from base, each bifurcated up to base; stigma capitate. Capsules yellowish-green with a reddish tinge, sub-globose 1.5–1.7 mm in diam., glabrous, obtusely keeled, cocci somewhat cornet; seeds rose-brownish, 1–2 mm long, 4-angled, attenuated and obtuse at apex, distinctly transversely rugose, delicately foveolate.

Flowering & Fruiting: September–December.

Habitat & associates: In sandy soils near the Kurkumbh M.I.D.C. along the Pune–Solapur Highway Road, found growing together with *Euphorbia hirta* L., *Tridax procumbens* L., and *Alternanthera pulchella* Kunth.

Distribution in India: The present collection of specimens of *E. jodhpurensis* collected from Kurkumbh village, Daund Tehsil, Pune District, Maharashtra State, India (Image 1A) forms its extended distribution to Maharashtra State from Rajasthan.

Specimens examined: Maharashtra, Along Pune–Solapur Highway opposite to Kurkumbh M.I.D.C, Kurkumbh, Daund Tehsil, Pune District, 18.395 ^{0}N & 74.525 ^{0}E, 17. ix.2022, coll. P. V. Kale, P.V.K./ Daund/17/09/2022/1 (BLAT Accession number 114283).

Image 2. ***Euphorbia jodhpurensis*** **(A–G): A—Habit | B—Lacerate stipules | C—Leaves showing margins spinulose-serrate | D—Inflorescence | E—Male flowers | F—Cyathium showing male & female flowers | G—Seeds.** ***Medicago monantha*** **(H–J): H—Habit | I—Single flower | J—Pods.**

IUCN Red List status: Purohit & Kulloli (2022) listed *Euphorbia jodhpurensis* as 'Endangered' under criteria B2ab(iii), D.

References

Ali, S.I. (1977). *Trigonella monantha* subsp. *incisa* (Benth.) Ali, p. 294. In: Nasir, E. & S.I. Ali (eds.). *Flora of West Pakistan, Vol. 100 (Papilionaceae).* Department of Botany, University of Karachi, Karachi, 389 pp.

Baker, J.G. (1879). Genus Medicago, pp. 89–91. In: Hooker, J.D. (ed.). *Flora of British India Vol. 2 (Sabiaceae to Cornaceae)*. L. Reeve & Co., London, 792 pp.

Bentham, G. (1839). Himalayan *Leguminosae* of European and Siberian Forms, pp. 197–201. In: Royle, J.F. (ed.). *Illustrations of the Botany and other branches of Natural History of the Himalayan Mountains, and of the Flora of Cashmere. Vol. 1.* WM. H. Allen & Co., London, 472 pp.

Blatter, E. & F. Hallberg (1920). The Flora of the Indian Desert. (Jodhpur and Jaisalmer). *Journal of the Bombay Natural History Society* 26(4): 968–987**.**

Hooker, J.D. (1890). *Flora of British India Vol. 5* (*Chenopodiaceae* to *Orchideae*). L. Reeve & Co., London, 910 pp.

Purohit, C.S., R. Kulloli & A. Bharti (2019). *Euphorbia jodhpurensis* Blatt. & Hallb., An endemic plant from the Indian desert and its range extension from Todgarh-Raoli Wildlife Sanctuary, Rajasthan. *Euphorbia World* 15(3): 18–22.

Purohit, C.S. & R.N. Kulloli (2022). *Euphorbia jodhpurensis*. The IUCN Red List of Threatened Species 2022: e.T177962845A177969097. Accessed on 18 November 2023. https://doi.org/10.2305/IUCN.UK.2022-2.RLTS.T177962845A177969097.en

Trautvetter, E.R. von (1840). *Medicago monantha* (C.A. Mey.) Trautv. *Delectus seminum in horto botanico Kioviensi Universitatis Caesareae St. Vladimiri anno 1840 collectorum: vi*, adnot. no. 4.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25637–25638
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.9324.16.7.25637-25638
#9324 | Received 10 July 2024
OPEN ACCESS

BOOK REVIEW

All eyes on the island

A book review of The Great Nicobar Betrayal

Lakshmi Ravinder Nair

Jalvayu Towers, NGEF Layout, Baiyyappanahalli, Bengaluru, Karnataka 560038, India.
lakshmigd@gmail.com

I tried to stifle a yawn as my monotonic Physics teacher read out the formula of displacement from her notes.

Thrust force = p x v x g

"Where ρ is the density of the liquid, V is the volume of liquid displaced and g is the acceleration due to gravity." I wrote it down in my notebook and tried assigning a mnemonic to commit it to memory.

As the seasons changed and my interest in environmental matters grew stronger, I learnt a new formula for displacement that involved different terms.

Displacement was now the sum total of a Transshipment port, an International Airport, a Power plant, and a Township; all coming together as the Great Nicobar mega project.

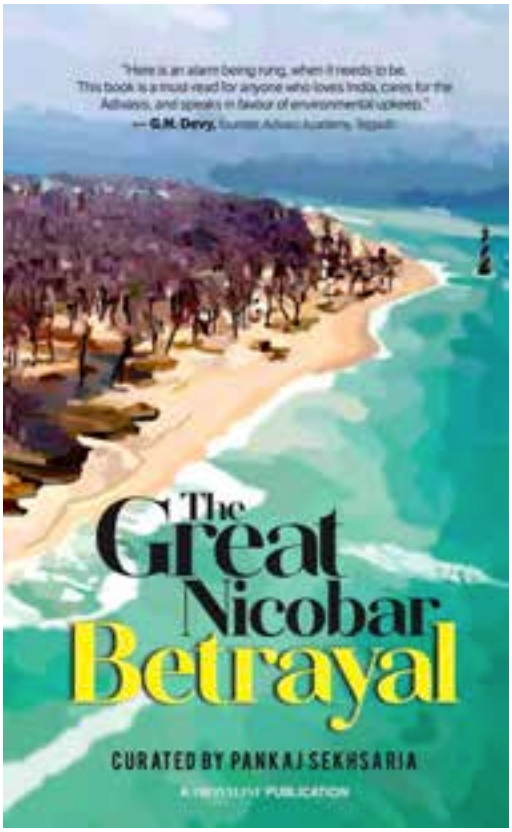
This is one formula that needs to be committed to public memory.

On Google Maps, one has to zoom in at least thrice for a clear view of the Andaman and Nicobar Islands. Tucked away in a remote corner of our planet, a few regions of the Indian archipelago are still home to pristine natural ecosystems due to the sea barrier and island conditions that limit mass entry and proliferation. The biodiversity that these islands hold is like no other. Its flora and fauna have deeply complex relationships with the island tribes and is one of the rarest places on Earth where there is an instinctive respect and understanding between humans, wildlife, and forests.

However, a series of decisions taken in mainland India threaten to throw this sacred connection off the course. The proposed site of the mega project in Great Nicobar sits on a zone that is prone to earthquakes, tsunamis and worst of all, apathy.

For those keen on understanding the effects of capitalism on natural ecosystems, **The Great Nicobar Betrayal** is a great place to start. It is a timely book of curated articles on the repercussions of the Great

Publisher: Frontline Publication (2024); Frontline, Chennai.
Paperback: 123 pages
ISBN-10: 9393875863
ISBN-13 : 978-9393875860



Date of publication: 26 July 2024 (online & print)

Citation: Nair, L.R. (2024). All eyes on the island: A book review of The Great Nicobar Betrayal. *Journal of Threatened Taxa* 16(7): 25637–25638. https://doi.org/10.11609/jott.9324.16.7.25637-25638

Nicobar mega project, weaved together masterfully by Pankaj Sekhsaria. The book explores multiple viewpoints of the project's impact from researchers, journalists, ecologists, and scientists. The story comes together like pieces of a jigsaw puzzle to give the reader a full view of the havoc that is about to be inflicted on the island.

The Government of India through NITI Aayog had proposed the mega project in 2021 in a scale that appears humungous for the mainland itself. The project envisions port connectivity, infrastructural development, and employment opportunities for the inhabitants of the Great Nicobar Island, the last land mass in the Andaman and Nicobar archipelago. The project is priced at INR 72,000 crores with grand plans that would require around 130 sq.km of primary forests to be cleared.

It seems like the apocalypse is not a single event; it is a string of careless verdicts like these. Pankaj Sekhsaria introduces the islands, the project and throws light on the absurdities of the environmental assessments, convenient legal loopholes and criminal leniencies in forest and land clearances procured.

Most earthquakes originate in the margins of Great Nicobar. *'Following building codes is one thing but going ahead and building on a fault line is reckless',* the authors, Janki Andharia, V Ramesh and Ravinder Dhiman point out.

To the sane, this is a risky proposition and the fault lines are not just wobbly tectonic plates.

A planned influx of around 3,50,000 people to an island that strains to meet demands of 8,000 people is sure to drive local tribals to extinction. Marooned on an island of worry, the Particularly Vulnerable Tribal Group – the Shompens and other tribes like the Nicobarese are left to fend for themselves. Manish Chandi shares snippets of his interactions with tribal leaders and families that have been displaced post the tsunami. Some tribal members lament that they have been lied to about the scope of the project and the damage from it is expected to be worse.

The articles in the book have been arranged in a such a way that they help the reader understand the linkages between them. For example, the irrationality of compensatory afforestation in Haryana is mentioned in the earlier chapters by Sekhsaria with some authors like Ishika Ramakrishna driving the point home through further explanation. The outlined areas for forest diversion to the mainland include habitats of the Nicobar Long-Tailed Macaque and many other endemic species like the Nicobar Treeshrew. The forests themselves date back to the Pleistocene period and reducing them to a safari park in mainland India would be deplorable.

The frustrations of the authors are evident in the words that are peppered throughout their articles. Words like *absurdity, monumental folly, flawed judgment, economic peril, misadventure, lethal, disastrous, marginalised, misunderstood* and their variations feature across the book.

I tried to pick holes in the presentation of the book however this subject aligned with my confirmation bias on the predictability of decisions taken by people who wield power. Once this bias was recognised and kept aside, I felt that more stories on displaced tribal communities could have made the book more impactful to the uninitiated and moved them closer to the epicentre of the issue since displacement is fairly relatable. The concerns on ecological damage could have followed once a strong case on the irreversible loss of ancestral land was set. Each chapter could have also had their associated image for quicker visualization instead of placing them all towards the end of the book.

The format in which the book is presented with various angles to the issue seems like an ideal blueprint for understanding the total effects of infrastructural projects, mostly built with taxpayer money. **The Great Nicobar Betrayal** should find a good audience amongst those holding the slightest interest in environmentalism and one can positively hope that the book will bring the required focus to the issue of displacement of Great Nicobar's natural ecosystems and their custodians – the Shompens and Nicobarese.

Lastly, the timing of the book release is commendable. It works like an out-of-breath town crier arriving in the crowded places of our minds and city spaces to inform us of the happenings in our beloved archipelago.

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) 5.64

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa

www.threatenedtaxa.org

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

July 2024 | Vol. 16 | No. 7 | Pages: 25495–25638
Date of Publication: 26 July 2024 (Online & Print)
DOI: 10.11609/jott.2024.16.7.25495-25638

Articles

Communications

Short Communications

Notes

Book Review

Publisher & Host

WILD zoOreach
Zoo Outreach Organisation

Threatened Taxa