Building evidence for conservation globally

Journal of Threatened Taxa

Open Access

10.11609/jott.2022.14.3.20703-20810
www.threatenedtaxa.org

26 March 2022 (Online & Print)
14(3): 20703–20810
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

No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti,
Coimbatore, Tamil Nadu 641035, 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: Rufous-headed Hornbill *Rhabdotorrhinus waldeni* © Philip Godfrey C. Jakosalem.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20703–20712

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

https://doi.org/10.11609/jott.6178.14.3.20703-20712

#6178 | Received 17 May 2020 | Final received 20 January 2022 | Finally accepted 27 February 2022

OPEN ACCESS

ARTICLE

Distribution and habitat-use of Dhole *Cuon alpinus* (Mammalia: Carnivora: Canidae) in Parsa National Park, Nepal

Santa Bahadur Thing [1], Jhamak Bahadur Karki [2], Babu Ram Lamichhane [3], Shashi Shrestha [4], Uba Raj Regmi [5] & Rishi Ranabhat [6]

[1,4] Ministry of Forests, Environment and Soil Conservation, Lumbini Province, Nepal.
[2] Kathmandu Forestry College (KAFCOL), Amarawati Marga, Koteshwor, Kathmandu, P.O. Box 1276, Nepal.
[3] National Trust for Nature Conservation, Lalitpur, POB 3712, Kathmandu, Nepal.
[5] Former Joint Secretary at Department of National Parks and Wildlife Conservation, Babarmahal, P.O. Box 860, Kathmandu, Nepal.
[6] Department of National Parks and Wildlife Conservation, P.O. Box 860, Kathmandu, Nepal.
[1] sonam.lama200@gmail.com (corresponding author), [2] jbkarki@gmail.com, [3] baburam@ntnc.org.np,
[4] shrestha.shashi2015@gmail.com, [5] ubrajregmi@hotmail.com, [6] ranabhatrishi@gmail.com

Abstract: Dhole *Cuon alpinus* is one of the top predators in Asian forests but is one of the least studied species of carnivores. We surveyed an area of 499 km^2 of Parsa National Park (PNP) during the winter (November–January) of 2016–17 using camera-traps to determine the spatial distribution and habitat-use patterns of Dhole. We overlaid 2 x 2 km^2 grid cells (n= 126) across the study area and set up a pair of motion sensor cameras in each grid cells for 21 days. We modeled the habitat-use by Dholes as a function of sampling covariates and fine-scale habitat covariates using single species single season occupancy models. We estimated the parameters in two steps. First, we defined a global model for probability of habitat-use and modeled detection probability (p) either as an intercept-only model or as a function of covariates. Second, we modeled the habitat-use probability (Ψ) incorporating the top-ranked model for probability of detection (p) in the first step. A total effort of 2,520 camera-trap-nights resulted in 63 independent detections of dholes at 27 locations in PNP. The naïve occupancy estimate of Dholes in PNP was 0.21. The estimated probability of habitat-use (Ψ) and detection (p) were 0.47±0.27 and 0.24±0.05, respectively. Grassland availability (β_G= 8.00±3.09), terrain ruggedness index (β_{TRI}= 0.73±0.34), and Sambar (prey) presence (β_S= 1.06±0.51) strong positive association, whereas, stream/exposed surfaces (β_{SES}= -0.45±0.43) had negative association with the habitat use by Dholes. Similarly, detection probability was positively associated with presence of Sambar (β_S= 2.44±1.02) but negatively associated with streams/exposed surfaces (β_{SES}= -0.99±0.32) and terrain ruggedness (β_{TRI}= -0.09±0.23). Our study provides quantitative information on the ecology of Dholes with potential applications for improving their conservation efforts in Nepal.

Keywords: Asiatic Wild Dogs, camera-traps, conservation, ecology, occupancy, social carnivores, spatial scale.

Editor: Mewa Singh, University of Mysore, Mysuru, India. **Date of publication:** 26 March 2022 (online & print)

Citation: Thing, S.B., J.B. Karki, B.R. Lamichhane, S. Shrestha, U.R. Regmi & R. Ranabhat (2022). Distribution and habitat-use of Dhole *Cuon alpinus* (Mammalia: Carnivora: Canidae) in Parsa National Park, Nepal. *Journal of Threatened Taxa* 14(3): 20703–20712. https://doi.org/10.11609/jott.6178.14.3.20703-20712

Funding: (1) National Trust for Nature Conservation, Biodiversity Conservation Center, Sauraha, Chitwan; (2) ZSL Nepal and Panthera; (3) WWF Nepal, Hariyo Ban Program, Baluwatar, Kathmandu.

Competing interests: The authors declare no competing interests.

Author details: See end of this article.

Author contributions: SBT, JBK & BRL designed the survey; SBT & BRL analysed the data, SBT wrote the first manuscript and all authors revised the manuscript.

Acknowledgements: I deeply appreciate and would like to thank to Prof. Balram Bhatta (PhD) and Prof. Basudev Pokharel for their intellectual guidance, constructive comments and supports. I also acknowledge DNPWC and PNP for providing me permission to conduct this research and also for providing relevant data for this study. I would like to express gratitude to National Trust for Nature Conservation, Biodiversity Conservation Center, Sauraha, Chitwan, ZSL Nepal/ Panthera and WWF Nepal, Hariyo Ban Program, Kathmandu for the financial support. I also would like to thank ZSL Nepal and Panthera for providing me camera trap records. I heartily would like to thank Dr. Kanchan Thapa, Mr. Sujan Khanal and Mr. Gopal Khanal for their help in data collection, processing and analyzing.

Faculty of Forestry (FOF)
Agriculture and Forestry University (AFU)

INTRODUCTION

Patterns of spatial distribution and fine-scale habitat-use by species are important aspects to understand their ecology and to initiate conservation measures to ensure population stability (Law & Dickman 1998; Phillips et al. 2004; Abrahms et al. 2016; Massara et al. 2018). Habitat components such as topography, canopy cover, water sources, prey species availability, proximity of habitat edges, and anthropogenic activities have significant roles in shaping the occurrence of a species (Durbin et al. 2004; Grassman et al. 2005; Jenks et al. 2012; Srivathsa et al. 2014; Aryal et al. 2015; Ferreguetti et al. 2016; Ferreguetti et al. 2017; Punjabi et al. 2017). Some species are habitat specialists with narrow niche requirements in specific habitats while others are habitat generalists occurring in a variety of habitats (Thorpe & Thorpe 2019). Within this behavioural diversity, it is hard to manage any species without information on its distribution and ecology (Aryal et al. 2015). Such information is a prerequisite for planning and developing species conservation strategies (Guisan & Zimmermann 2000; Halstead et al. 2010; Aryal et al. 2014, 2012; Lee et al. 2012).

The Dhole *Cuon alpinus* is a habitat generalist and a social carnivore that lives in packs of 3–20 adults (Valkenburgh 1991; Iyengar et al. 2005; Reddy et al. 2019). Dholes occur in a variety of habitats, occupying a wide distribution range across central Asia, southern Asia, and southeastern Asia (Lekagul & Mc Neely 1977; Johnsingh 1985; Srivathsa et al. 2014; Kamler et al. 2015). They are also found on the islands of Sumatra and Java (IUCN 2015). In Nepal, they are distributed from southern lowland protected areas of Bardia, Chitwan, and Parsa national parks (Thapa et al. 2013; Yadav et al. 2019) to the northern high mountain protected areas of Kanchanjunga Conservation Area, Makalu Barun National Park, and Dhorpatan Hunting Reserve (Jha 2003; Khatiwada 2011; Aryal et al. 2015). Despite their wide geographical distribution, they are endangered because of low population density and continued population decline caused by prey depletion, disease, habitat loss, and persecution (Kamler et al. 2015; Reddy et al. 2019). The Dhole is categorized as 'Endangered' in the IUCN Red List and placed in Appendix II of CITES (Kamler et al. 2015; CITES 2017). In spite of its endangered status, there have been relatively few quantitative studies throughout its range (Khatiwada 2011; Aryal et al. 2015) and very little is known about its distribution and ecology in Nepal (Thapa et al. 2013). Our study documents the influence of various ecological factors on the habitat-use patterns of dholes at a fine spatial scale in Parsa National Park Nepal. This study generates baseline information about dholes in Parsa with potential applications for improving dhole conservation efforts in Nepal.

Image 1. Camera trap photograph of Dholes *Cuon alpinus* in Parsa National Park (X:279520, Y:3015710). (© DNPWC/NTNC/ZSL Nepal/ Panthera).

MATERIALS AND METHODS

Study Area

The study was conducted between 2016 and 2017 in Parsa National Park (PNP) in south-central Nepal (27.25–27.55 N, 84.68–84.96 E) covering an area of 499 km^2 (area of PNP before extension). PNP was established in 1984 as a wildlife reserve, which was extended eastward to 627.37 km^2 in 2015 (Figure 1), and was upgraded to a national park in 2017. Parsa is the easternmost protected area of the trans-boundary Terai Arc Landscape (Lamichhane et al. 2018). The park was established primarily to preserve the unique sub-tropical dry ecosystem and to protect habitats of resident Asian Elephant *Elephus maximus* populations. However, it also provides good habitat for Dholes as they have been frequently recorded in camera-traps (PNP 2020) and directly sighted (Thapa et al. 2013). The reduced anthropogenic pressure, improved security and good prey base (Thapa et al. 2013; Thapa & Kelly2016; Lamichhane et al. 2018) have made the landscape suitable for Dholes.

PNP has many carnivore species including the Tiger *Panthera tigris*, Leopard *Panthera pardus*, Striped Hyaena *Hyaena hyaena,* Clouded Leopard *Neofelis nebulosa*, and Golden Jackal *Canis aureus*. The park also supports populations of a wide range of herbivore

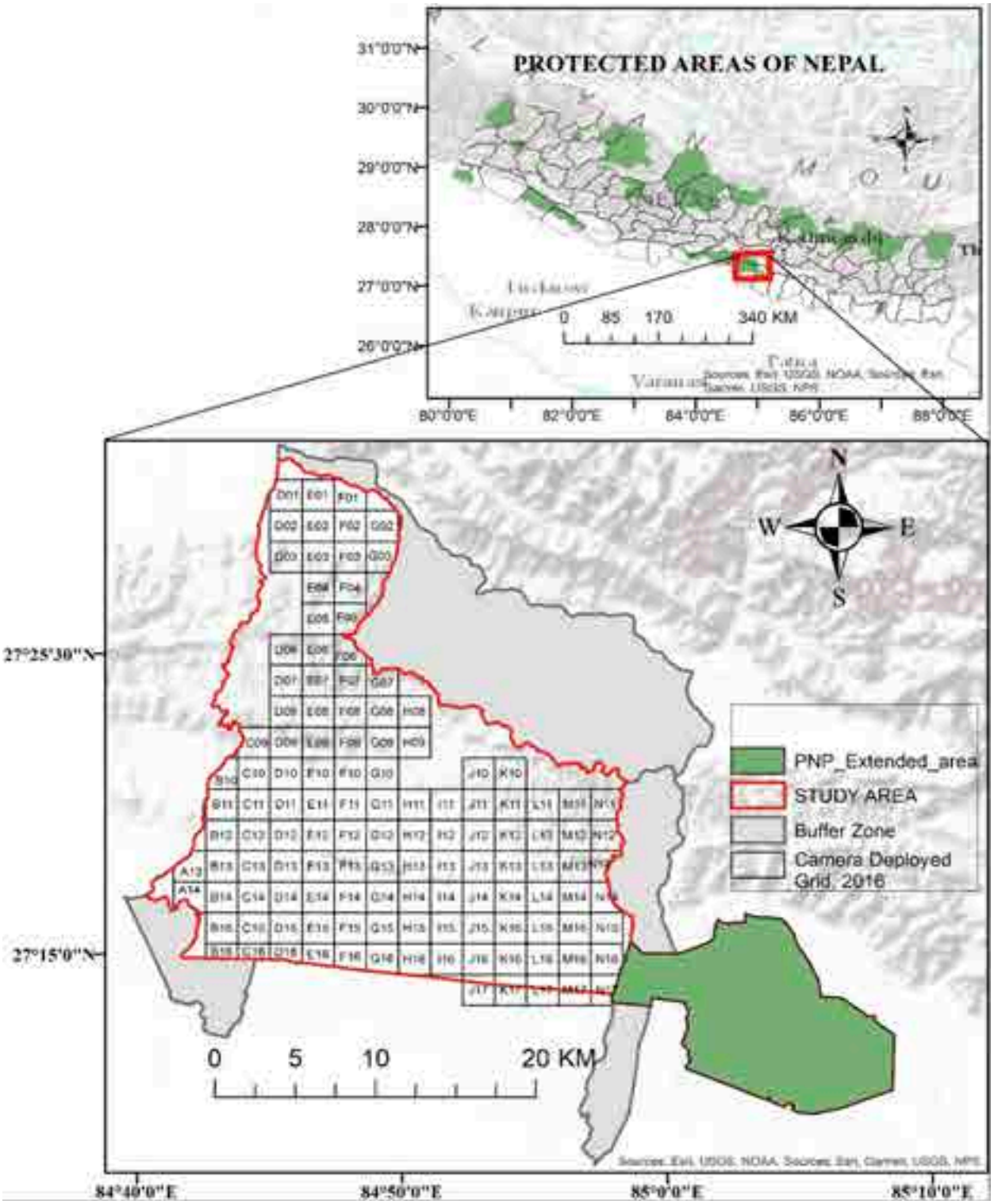


Figure 1. Map of the study area showing camera deployed grids in Parsa National Park, Nepal.

species such as Greater One-horned Rhinoceros *Rhinoceros unicornis*, Gaur *Bos gaurus*, Sambar *Rusa unicolor*, Nilgai *Boselaphus tragocamelus*, Spotted Deer *Axis axis*, Barking Deer *Muntiacus vaginalis*, and Wild Pig *Sus scrofa* (Thapa et al. 2013). Parsa has a fragile geology and highly porous alluvial substrate. The streams running off the Churia Hills permeate the porous sediment and flow underground, reappearing

south of the park and restricting water availability in >70% of PNP throughout the dry months (Lamichhane et al. 2018). Besides its biodiversity conservation value, PNP also serves the vital needs of the large human population living south of the park by conserving water sources and reducing the soil erosion in the Siwalik Hills (Bhattarai et al. 2018). PNP includes mainly sub-tropical forests of the Siwalik and Bhabar physiographic regions of Parsa, Makwanpur, and Bara districts. The vegetation is mainly dominated by Sal *Shorea robust* forest (90%). However, the forests are dominated by Khote salla *Pinus roxburghii* on the southern slope of the Siwalik Hills (60%). The riverbeds and flood plains are covered by riverine species including Khair *Acacia catechu*, Simal *Bombax ceiba*, Kans *Saccharum spontaneum*, and Cogon Grass *Imperata cylindrica* (Chhetri 2003; PNP 2020).

Field Survey

We overlaid 2 x 2 km^2 grid cells on 499 km^2 area of PNP and set up a pair of automatic motion sensor digital cameras (Panthera V4 and V5) in each grid cell selecting the best possible locations. The paired cameras were positioned 45 cm above ground, perpendicular to, and 5–7 m apart, on either side of game trails, grassland, forest roads and riverbeds with higher probability of detecting carnivores (Figure 1). The camera-traps were kept for 21 days within each grid cell. Camera-traps were installed in the field during the winter season (November–January) of 2016–17. Due to limited camera-traps availability, the entire area was divided into two blocks and surveyed sequentially. The camera-traps pictures were sorted species-wise, and all the Dhole photographs were obtained in a separate folder. Dhole photographs obtained from a location at 30 minutes apart were considered as independent detections (Silver et al. 2004; Di Bitetti et al. 2006; Thapa et al. 2013).

Data Analysis

The estimated home-range of dhole is ~85 km^2 (Srivathsa et al. 2017) which exceeded our sampling unit 4 km^2, so we described occupancy as a measure of 'habitat-use' instead of 'true occupancy' (Sunarto et al. 2012; Srivathsa et al. 2014; Thapa & Kelly 2016). We constructed the detection history of dholes in each grid. We considered 24 hours as a sampling occasion, so that each grid had 21 sampling occasions. We then grouped five consecutive sampling occasions to obtain four temporal replicates in each location (discarding first camera-trap day) to avoid redundancy in data transformations that might arise from zero counts (Kafley et al. 2016; Wolff et al. 2019). The final detection history of Dholes in each grid therefore included four independent sampling occasions (replicates). We coded detection of Dholes in each replicate as '1' and non-detection as '0'. We estimated the detection probability and habitat-use following MacKenzie et al. (2002). We estimated the probability of detection, p based on the two possible outcomes for each survey occasion, namely, (1) the animal was detected, p, and (2) the animal was not detected, $1–p$. Consequently, the probability of habitat-use based on the detectability was translated as follows: (1) the site was occupied and the species was detected, $\Psi x p$; (2) the species was present but not detected, $\Psi x(1- p)$; or (3) the species was not present and, hence, not detected, $(1-\Psi)$. We used single season single species occupancy models (MacKenzie et al. 2006) to estimate the relative effect of land cover (forest cover, grassland and streams/exposed surfaces), terrain ruggedness index, distance to the nearest settlement, and prey species covariates at a fine-scale on the probability of Dholes habitat-use and distribution. We used the prey species (Sambar) captured on the same camera-traps as sample covariate and others as site covariates (Karanth & Sunquist 1995; Andheria et al. 2007; Punjabi et al. 2017). Areas of different habitat types, i.e., forest cover, grassland, and stream/exposed surfaces were obtained from supervised classification of Landsat satellite images and were used as site covariates (Lillesand et al. 2004). Similarly, we calculated average terrain ruggedness index (TRI) values for each grid cell from the digital elevation model (DEM) of ASTER Global DEM at 30 m resolution by using a "DOCELL" command in ArcGIS 10.3. We calculated the distance of each grid from its center to the nearest settlements using ArcGIS 10.3 and used this as a surrogate of disturbance index. We assumed farther the distance from settlements, lower is the disturbance and higher is the occupancy and vice-versa. All predictor variables were standardized (z-transformations) so that the model coefficients could be directly interpreted as effect sizes. We tested auto-correlation between the predictor variables using Pearson's coefficients. We constructed covariate combinations such that highly correlated predictors (Pearson's $|r| > 0.70$) did not appear in the same model. For example, grassland and streams/exposed surfaces were not used together within the same model due to high correlation between the variables (Pearson's $|r| = 0.74$). We performed all analyses on program PRESENCE Version v2.12.32 and selected the best model based on minimum Akaike Information Criteria (Burnham & Anderson 2002). We estimated parameters in two steps. First, a general structure for habitat-use was

defined as a function of forest cover Fc, grassland G, streams/exposed surfaces SES, terrain ruggedness index TRI, distance to the nearest settlements D and prey species S i.e. Ψ (Fc+G+SES+TRI+D+S) as global model Ψ (Global) and modeled detection probability (p) either as an intercept-only modelor as a function of individual covariates and their combinations (Table 1). Second, the habitat-use probability (Ψ) was modeled incorporating the top ranked model for probability of detection in the first step (Table 2). Influence of different covariates on habitat-use was again modeled either individually or additively combining covariates in different biologically plausible combinations. Models with ΔAIC of <2 were considered to be strongly supported by the data. We used estimated β-coefficients to assess the strength of association of each covariate with habitat-use probability. Model fit was assessed for over-dispersion in the global model by running 1,000 bootstrap iterations (Burnham & Anderson 2002). The global models with c-hat>4 were considered structurally inadequate (Burnham & Anderson 2002) and excluded from further analyses. A total of seven candidate models (Table 2) were run for determining factors influencing habitat-use by Dholes.

RESULTS

Distribution of Dholes

With a total survey effort of 2,520 trap-nights at 126 camera-traps locations, we obtained 63 independent pictures of Dholes in PNP. Dholes were photographed at least once in 27 different locations (21.43% of the surveyed grids) with the naïve occupancy estimate of 0.21. Dholes were recorded primarily in the Churia hill forest (59.26%) followed by the forest in plains (29.63%), grassland (7.41%), and stream/exposed area (3.70%). Most photo-captures were in the western and northwestern part of the park bordering Chitwan National Park with a few records on the southern border (Figure 2).

Detection probability of Dhole

Streams/exposed surfaces (SES), terrain ruggedness index (TRI), and Sambar (S) affected the detection probability (p)in the top ranked model (Table 1, Figure 3). The estimated detection probability (p) was found to be 0.24±0.05. The top model indicated that dhole detection probability was positive for prey species Sambar (β_S= 2.44±1.02) but was negative for streams/exposed surfaces (β_{SES}= -0.99±0.32) and terrain ruggedness index (β_{TRI}= -0.09±0.23) as shown in the Table 1.

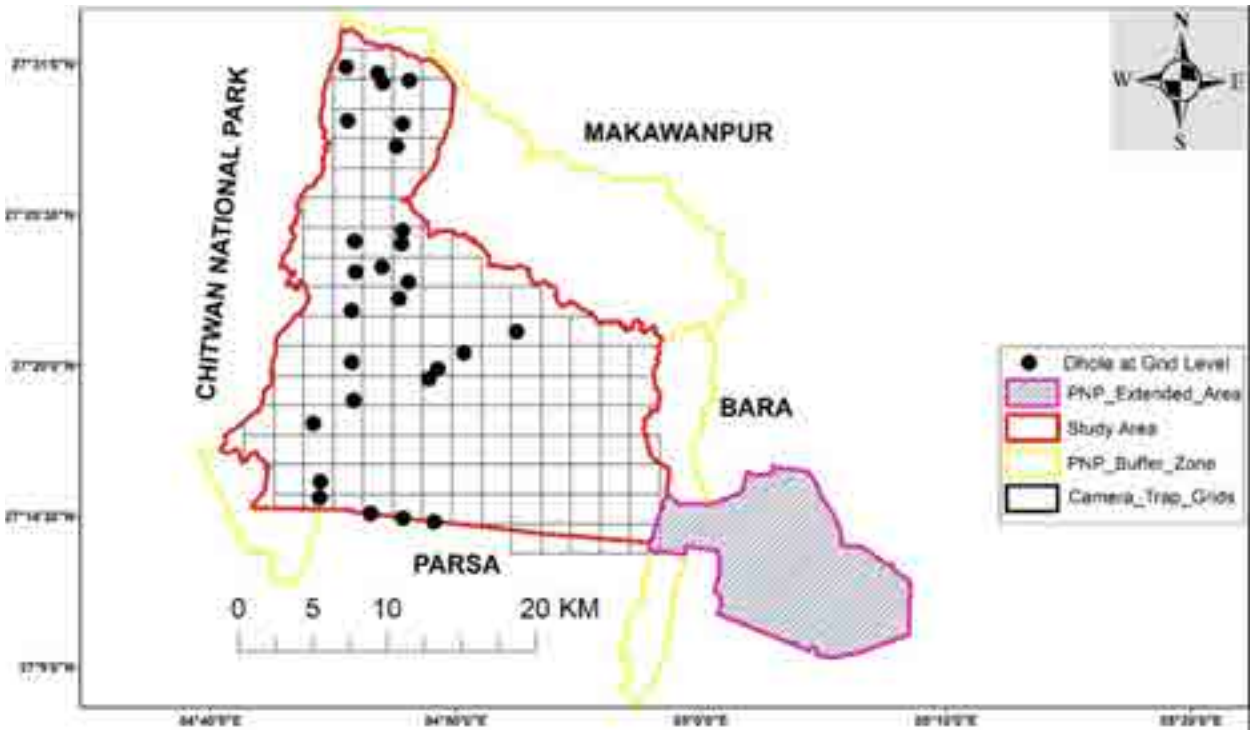


Figure 2. Photo-captured locations of Dhole in Parsa National Park.

Table 1. Summary of β-coefficient parameter estimates and associated standard errors (SE) of covariates from top models used to explain Dhole detection (p) in PNP. Given are intercept (Int.), stream/exposed surfaces (SES), terrain ruggedness index (TRI), Sambar presence (S), grassland availability (G), distance to the nearest settlements (D), Akaike Information Criteria (AIC), relative difference in AIC(ΔAIC), and AIC model weight (W).

Model (M)	$\beta_{Int.}$±SE	β_{SES}±SE	β_{TRI}±SE	β_{S}±SE	β_{G}±SE	β_{D}±SE	AIC	ΔAIC	W
Ψ (Global),*p*(SES+TRI+S)	-2.29±0.15	-0.99±0.32	-0.09±0.23	2.44±1.02	-	-	256.03	0	0.46
Ψ (Global),*p*(TRI+S)	-1.29±0.11	-	-0.25±0.16	0.47±0.21	-	-	257.42	1.39	0.23
Ψ (Global),*p*(S)	0.31±0.14	-	-	0.50±0.25	-	-	257.64	1.61	0.21
Ψ (Global),*p*(SES)	0.51±0.78	-0.30±0.13	-	-	-	-	260.53	4.50	0.05
Ψ (Global),*p*(G+S+TRI+D)	1.13±0.71	-	-0.22±0.17	0.41±0.11	-0.48±0.16	-0.19±0.13	261.23	5.20	0.03
Ψ (Global),*p*(.)	2.13±1.45	-	-	-	-	-	262.20	6.17	0.02

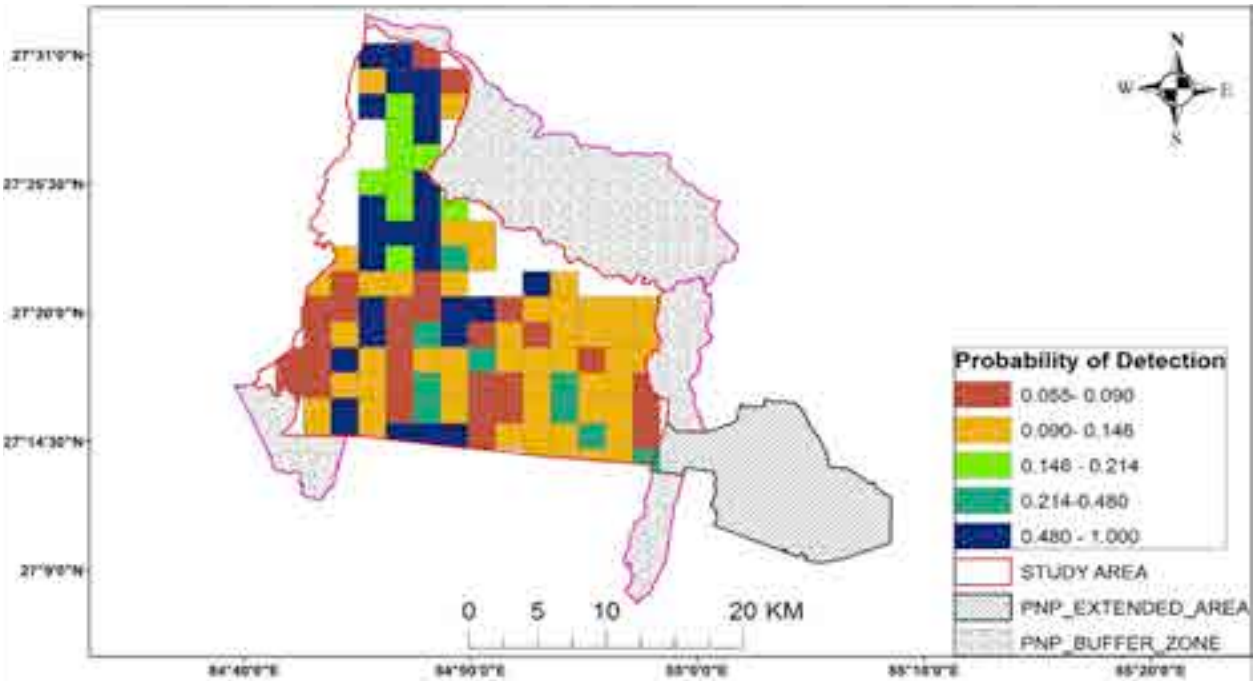


Figure 3. Detection probability of Dholes in Parsa National Park at grid level.

Table 2. Summary of β-coefficient parameter estimates and associated standard errors (SE) of covariates from top models used to explain dhole habitat use (Ψ) in PNP. Given are intercept (Int.), grassland availability (G), terrain ruggedness index (TRI), Sambar presence (S), stream/ exposed surfaces (SES), Akaike Information Criteria (AIC), relative difference in AIC(ΔAIC), and AIC model weight (W).

Model (M)	$\beta_{Int.}$±SE	β_{G}±SE	β_{TRI}±SE	β_{S}±SE	β_{SES}±SE	AIC	ΔAIC	W
Ψ (G+TRI),*p*(SES+TRI+S)	0.91±0.37	8.00±3.09	0.73±0.34	-	-	251.54	0.00	0.49
Ψ (G+S),*p*(SES+TRI+S)	-1.19±0.23	0.21±0.09	-	1.06±0.51	-	252.56	1.02	0.29
Ψ (G),*p*(SES+TRI+S)	0.63±0.09	0.29±0.16	-	-	-	254.86	3.32	0.09
Ψ (Global),*p*(SES+TRI+S)	-0.61±0.47	8.78±2.81	-3.70±1.15	2.31±1.20	-3.70±1.151	254.97	3.43	0.09
Ψ (SES+S),*p*(SES+TRI+S)	-1.26±0.24	-	-	0.39±0.51	-0.45±0.43	258.09	6.55	0.02
Ψ (S),*p*(SES+TRI+S)	-1.19±0.22	-	-	0.38±0.51	-	260.70	9.16	0.01
Ψ (.),*p*(.)	0.29±0.16	-	-	-	-	262.20	10.66	0.00

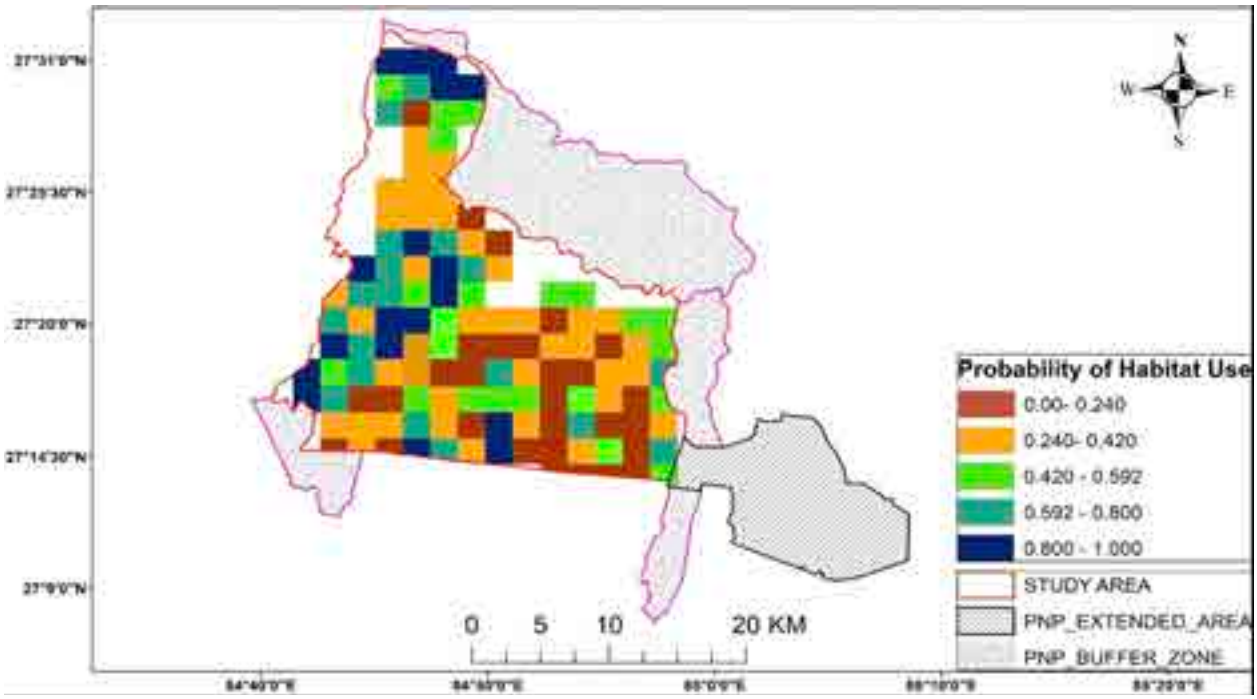


Figure 4. Map showing the probability of habitat-use by Dholes in Parsa National Park at grid level.

Probability of habitat-use

We used top ranked model for detectability, *Ψ* (Global) *p* (SES+TRI+S) to model fine-scale habitat-use (*Ψ*). Among a set of seven candidate occupancy models, the model with *Ψ* as a function of grassland and terrain ruggedness index, *Ψ* (G+TRI) and *p* as a function of stream/exposed surfaces, terrain ruggedness index and Sambar, *p* (SES+TRI+S) best fit the data. Our model estimate of the probability of habitat-use (*Ψ*) was 0.47±0.27, more than double the naïve occupancy estimate. The model indicated that the habitat-use was strongly associated with grassland availability (β_G= 8.00±3.09), terrain ruggedness index (β_{TRI}= 0.73±0.34) and prey species (Sambar) presence (β_S= 1.06±0.51) but had strong negative association with streams/exposed surfaces (β_{SES}= -0.45±0.43) as shown in Table 2. We model averaged across a set of models for estimating probability of habitat-use (Figure 4).

DISCUSSION

Our study provides insights into the factors affecting spatial distribution and habitat-use by Dholes at a fine spatial scale in PNP, Nepal using camera-trap data. The survey was conducted primarily to monitor Tigers. Hence, probable bias in camera-traps placement towards Tigers cannot be denied. However, the camera-traps also produced a good number of Dhole detections (n= 63), which were used in this study. It provides an opportunity to obtain information on Dhole but our results may have underestimated the probability of habitat-use and detection of Dholes in PNP due to the bias in the placement of camera traps. Positive association of Dholes with grassland can be explained by the availability of prey species in higher density and ease of predation in grasslands. Prey populations of large carnivores occur in a wide range of habitats including grasslands (Karanth et al. 2009; Wegge et al. 2000; Dinerstein 1980, 1979; Schaller 1967). Our findings are similar to those reported by Jenks et al. (2012) and Grassman et al. (2005) in Thailand. The inter-specific competition like tigers and leopards, both of which typically prefer lowland areas, may have pushed the dholes in rugged areas in Siwalik hills (Reddy et al. 2019; Dhakal et al. 2014; Venkataraman 1995; Johnsingh 1983; Wood 1929). Another reason may be due to year-round availability of their preferred prey species (Sambar) in these hills (Thapa & Kelly 2016; Shrestha 2004; McKay & Eisenberg 1974). Moreover, the rugged areas (Churia hills) of Parsa are generally distant from settlements and hence there is comparatively less disturbance. We also found strong positive association between Dhole habitat-use and Sambar presence similar to the findings of Jenks et al. (2012). This is probably because Sambar is one of the most preferred prey species of Dholes (Hayward et

al. 2014; Acharya et al. 2007). In Parsa, there are many streams flowing from the Siwalik hills towards south with large amount of sediments deposited in the streambeds. The streambeds are wide and remain dry most of the time (except flash floods during rainy season). Avoiding these streambeds and exposed surfaces by dholes can be linked to the low density of prey species and difficulty in predation as prey species can easily spot Dholes from a distance. Previous studies documented the Dhole habitat use increasing with an increasing distance from forest edge but we did not find the effect of distance to forest edge (Durbin et al. 2004; Punjabi et al. 2017; Aryal et al. 2015; Srivathsa et al. 2014; Khatiwada 2011). In a nutshell, our results show that dholes prefer rugged areas with grasslands and prey (Sambar). In addition to these findings, obtaining information on their population size and viabilities in the Terai Arc Landscape (that PNP is a part of) would be important from a conservation standpoint.

REFERENCES

Abrahms B., S.C. Sawyer, N.R. Jordan, J.W. Mcnutt, A.M. Wilson & J.S. Brashares (2016). Does wildlife resource selection accurately inform corridor conservation? *Journal of Applied Ecology* 54(2): 412–422. https://doi.org/10.1111/1365-2664.12714

Acharya, B. (2007). The Ecology of the Dhole or Asiatic Wild Dog (*Cuon alpinus*) In Pench Tiger Reserve, Madhya Pradesh. PhD Thesis. Saurashtra University, Rajkot, Gujarat.

Andheria, A.P., K.U. Karanth & N.S. Kumar (2007). Diet and prey profiles of three sympatric large carnivores in Bandipur Tiger Reserve, India. *Journal of Zoology* 273(2): 169–175. https://doi.org/10.1111/j.1469-7998.2007.00310.x

Aryal, A., W. Ji, Raubenheimer & D. Brunton (2012). Blue sheep in the Annapurna Conservation Area, Nepal: habitat-use, population biomass and their contribution to the carrying capacity of Snow Leopards. *Integrative Zoology* 9(1): 34–45. https://doi.org/10.1111/1749-4877.12004

Aryal, A., D. Brunton, W. Ji, D. Karmacharya, T. McCarthy, R. Bencini & D. Raubenheimer (2014). Multipronged strategy including genetic analysis for assessing conservation options for the snow leopard in the central Himalaya. *Journal of Mammalogy* 95(95): 871–881. https://doi.org/10.1644/13-MAMM-A-243

Aryal, A., S. Panthi, R.K. Barraclough, R. Benchi, K. Adhikari, W. Ji & D. Raubenheimer (2015). Habitat selection and feeding ecology of dhole (*Cuon alpinus*) in the Himalayas. *Journal of Mammalogy* 96(1): 47–53. https://doi.org/10.1093/jmammal/gyu001

Barber-Meyer, S.M., S.R. Jnawali, J.B. Karki, P. Khanal, S. Lohani, B. Long, D.I. MacKenzie, B. Pandav, N.M.B. Pradhan, R. Shrestha, N. Subedi, G. Thapa, K. Thapa & E. Wikramanayake (2013). Influence of prey depletion and human disturbance on tiger occupancy in Nepal. *Journal of Zoology* 289(1): 10–18. https://doi.org/10.1111/j.1469-7998.2012.00956.x

Bhattarai, S., C.P. Pokharel, B.R. Lamichhane, U.R. Regmi, A.K. Ram & N. Subedi (2018). Amphibians and Reptiles of Parsa National Park, Nepal. *Amphibians & Reptile Conservation* 12(1): 35–48 (e155).

Burnham, K.P. & D.R. Anderson (2002). *Model Selection and Multimodel Inference*. A Practical Information-Theoretic Approach. Springer-Verlag New York, Inc., 175 Fifth Avenue, New York, NY 10010, USA.

Chetri, M. (2003). Food habits of gaur *Bos gaurus gaurus* Smith, 1827 and livestock (cows and buffaloes) in Parsa Wildlife Reserve, Central Nepal. *Himalayan Journal of Sciences* 1(1): 31–36. https://doi.org/10.3126/hjs.v1i1.183

Convention on International Trade in Endangered species of wild Fauna and Flora (2017). www.cites.org

Dhakal, M., M. Thapa, S.R. Jnawali, N. Subedi, N.M.B. Pradhan, S. Malla, B.R. Lamichhane, C.P. Pokheral, G.J. Thapa, J. Oglethorpe, S.A. Subba, P.R. Bajracharya & H. Yadav (2014). Status of tigers and prey in Nepal Department of National Park and Wildlife Conservation. Kathmandu, Nepal.

Di Bitetti, M.S., A. Paviolo & C. De Angelo (2006). Density, habitat-use and activity patterns of ocelots *Leopardus pardalis* in Asiatic Forest of Misiones, Argentina. *Journal of Zoology* 270(1): 153–163. https://doi.org/10.1111/j.1469-7998.2006.00102.x

Dinerstein, E. (1979). An ecological survey of the royal Karnali-Bardia Wildlife Reserve, Nepal. Part I: vegetation, modifying factors, and successional relationships. *Biological Conservation* 15(2): 127–150. https://doi.org/10.1016/0006-3207(79)90030-2

Dinerstein, E. (1980). An ecological survey of the Royal Bardia Wildlife Reserve, Nepal. Part III: Ungulate Populations. *Biological Conservation* 18(1): 5–37. https://doi.org/10.1016/0006-3207(80)90063-4

Durbin, L.S., A. Venkataraman, S. Hedges & W. Duckworth (2004). Dhole (*Cuon alpinus*), pp. 210–219. In: Sillero-Zubiri, C., M. Hoffmann & D.W. Macdonald (eds.). *Canids: foxes, wolves, jackals and dogs. Status survey and conservation action plan*. IUCN/ SSC Canid Specialist Group, Gland, Switzerland.

Ferreguetti, C.A., M.W. Tomas & G.H. Bergallo (2015). Density and niche segregation of two armadillo species (Xenarthra: Dasypodidae) in the Vale Natural Reserve, Brazil. *Mammalian Biology* 81(2): 138–145. https://doi.org/10.1016/j.mambio.2015.10.007

Fox, M.W. (1984). *The Whistling Hunters. Field Studies of the Asiatic Wild Dog* (*Cuon alpinus*). State University of New York Press, New York.

Grassman, J.R. (2005). Spatial ecology and diet of the dhole Cuon alpinus (Canidae,carnivore) in north central Thailand. *Mammalia* 69(1): 11–20. https://doi.org/10.1515/mamm.2005.002

Guisan, A. & N.E. Zimmermann (2000). Predictive habitat distribution models in ecology. *Ecological Modelling* 135(2–3): 147–186. https://doi.org/10.1016/S0304-3800(00)00354-9

Halstead, B.J., G.D. Wylie & M.L. Casazza (2010). Habitat suitability and conservation of the giant gartersnake (*Thamnophis gigas*) in the Sacramento Valley of California. *Copeia* 2010(4): 591–599. https://doi.org/10.2307/40962955

Hayward, W.M., S. Lyngdoh & B. Habib (2014). Diet and prey preferences of the dhole *Cuon alpinus*: dietary competition within Asia's apex predator guild. *Journal of Zoology* 294(4): 255–266. https://doi.org/10.1111/jzo.12171

Hines, J.E. (2006). PRESENCE-software to estimate patch occupancy and related parameters. https://www.mbr.pwrc.usgs.gov/software/presence.shtml.

Hines, J.E., J.D. Nichols & J.A. Collazo (2014). Multi season occupancy models for correlated replicate surveys. *Methods in Ecology and Evolution* 5(6): 583–591. https://doi.org/10.1111/2041-210X.12186

IUCN (2010). IUCN Red List of Threatened Species. Version 2010.4. Downloaded on 26 December 2010.

Iyengar, A., V.N. Babu, S. Hedges, N.M. Venkataraman & P.A. Morin (2005). Phylogeography, genetic structure, and diversity in the dhole (*Cuon alpinus*). *Molecular Ecology* 14(8): 2281–2297. https://doi.org/10.1111/j.1365-294X.2005.02582.x

Jackson, R.M., J.D. Roe, R. Wangchuk & D.O. Hunter (2006). Estimating snow leopard population abundance using photography and capture-recapture techniques. *Wildlife Society Bulletin* 34(3): 772–781. https://doi.org/10.2193/00917648(2006)34[772:ESLPAU]2.0.CO;2

Jenks, K.E., S. Kitamura, A.J. Lynam, D. Ngoprasert, W. Chutipong, R. Steinmetz, R. Sukmasuang, L.I. Grassman Jr., P. Cutter,

N. Tantipisanuh, N. Bhumpakphan, G.A. Gale, D.H. Reed, P. Leimgruber & N. Songsasen (2012). Mapping the distribution of dholes, *Cuon alpine* (Canidae, Carnivora), in Thailand. *Mammalian* 76(2): 2011–2063. https://doi.org/10.1515/mammalia-2011-0063

Jha, S.G. (2003). Linkages between Biological and Cultural Diversity for Participatory Management: Nepal's experiences with Makalu-Barun National Park and Buffer Zone. *Journal of National Science Foundation Sri Lanka* 31(1–2): 41–56.

Johnsingh, A.J.T. (1983). Large Mammalian Prey-Predators in Bandipur. *Journal of the Bombay Natural History Society* 80(1): 1–57.

Johnsingh, A.J.T. (1985). Distribution and status of dhole *Cuon alpinus* Pallas, 1811 in South Asia. *Mammalia* 49(2): 203–208. https://doi.org/10.1515/mamm.1985.49.2.203

Kafley, H., E.M. Gompper, M. Sharma, B.R. Lamichhane & R. Maharjan (2016). Tigers (*Panthera tigris*) respond to fine spatial-scale habitat factors: occupancy-based habitat association of tigers in Chitwan National Park, Nepal. *Journal of Wildlife Research* 43(5): 398–410. https://doi.org/10.1071/WR16012

Kamler, J.F., N. Songsasen, K. Jenks, A. Srivathsa, L. Sheng & K. Kunkel (2015). *Cuon alpinus*. The IUCN Red List of Threatened Species 2015. Accessed on June 15, 2020. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T5953A72477893.en

Karanth, K.U. & M.E. Sunquist (1995). Prey selection by tiger, leopard and dhole in tropical forests. *Journal of Animal Ecology* 64(4): 439–450. https://doi.org/10.2307/5647

Karanth, K.U. & J.D. Nichols (1998). Estimation of tiger densities in India using photographic captures and recaptures. *Ecology* 79(8): 2852–2862. https://doi.org/10.1890/0012-9658(1998)079[2852:EOTDII]2.0.CO;2

Karanth, K.K., J.D. Nichols, J.E. Hines, K.U. Karanth & N.L. Christensen (2009). Patterns and determinants of mammal species occurrence in India. *Journal of Applied Ecology* 46(6): 1189–1200. https://doi.org/10.1111/j.1365-2664.2009.01710.x

Khatiwada, A.P. (2011). Status and Habitat Preference of Dhole*Cuon alpinus* in Kangchenjunga Conservation Area. M.Sc. Thesis, Tribhuvan University, Institute of Forestry, Pokhara, Nepal.

Lamichhane, B.R., C.P. Pokheral, S. Poudel, D. Adhikari, S. Giri, S. Bhattarai & N. Subedi (2018). Rapid recovery of tigers *Panthera tigris* in Parsa Wildlife Reserve, Nepal. *Oryx* 52(1): 16–24. https://doi.org/10.1017/S0030605317000886

Law, B.S. & C.R. Dickman (1998). The use of habitat mosaics by terrestrial vertebrate fauna: implications for conservation and management. *Biodiversity and Conservation* 7(3): 323–333.

Lee, J.H., D. Park & H.C. Sung (2012). Large-scale habitat association modeling of the endangered Korean ratsnake (*Elapheschrenckii*). *Zoological Science* 29: 281–285.

Lekagul, B. & J. McNeely (1977). *Mammals of Thailand*. Association for the Conservation of Wildlife, 758 pp.

Lillesand, T.M., R.W. Kiefer & J.W. Chipman (2004). *Remote Sensing and Image Interpretation. 5th Ed*. John Wiley & Sons Ltd.

MacKenzie, D.I. (2012). PRESENCE User Manual. Proteus Wildlife Research Consultants http://www.proteus.co.nz.

MacKenzie, D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A. Royle & C.A. Langtimm (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83(8): 2248–2255. https://doi.org/10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2

MacKenzie, D.I., J.D. Nichols, J. Royle, K. Pollock, L. Bailey & J. Hines (2006). *Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence*. Academic Press, New York.

Wolff, M., N. Ferreguetti, A.C. Tomas, W. Moraes & H.G. Bergallo (2019). Population density, activity pattern and habitat-use of the ocelot *Leopardus pardalis* in an Atlantic Forest protected area, southeastern Brazil. *Hystrix, the Italian Journal of Mammalogy* 30(2): 120–125. https://doi.org/10.4404/hystrix-00214-2019

Massara, R.L., A.M.D.O. Paschoal, L. Bailey, Jr P. Doherty, A. Hirsch & A.G. Chiarello (2018). Factors influencing ocelot occupancy in Brazilian Atlantic Forest reserves. *Biotropica* 50(1): 125–134. https://doi.org/10.1111/btp.12481

McKay, G. & J. Eisenberg (1974). Movement patterns and habitat utilization of ungulates in Ceylon the behavior of ungulates and its relation to management. IUCN Publication, Morges.

Morris, D.W. (1987). Spatial scale and the cost of density-dependent habitat selection. *Evolutionary Ecology* 1(4): 379–388. https://doi.org/10.1007/BF02071560

Phillips, S.J., M. Dudík & R.E. Schapire (2004). A maximum entropy approach to species distribution modeling, pp. 655–662. In: Proceedings of the 21st International Conference on Machine Learning, ACM Press, New York

PNP (2020). https://parsanationalpark.gov.np/index.php/flora-fauna

Punjabi, G.A., A. Edgaonkar, A. Srivathsa, S. Ashtaputre & M.K. Rao (2017). Distribution of the dhole in its northern range limits in the WesternGhats, India. *Canid Biology & Conservation* 20(3): 7–13. https://www.canids.org/CBC/20/dhole_in_western_ghats.pdf.

Reddy, C.S., R. Yosef, G. Calvi & L. Fornasari (2019). Inter-specific competition influences apex predator-prey populations. *Wildlife Research* 46(7): 628–638. https://doi.org/10.1071/WR19011

Schaller, G.B. (1967). *The Deer and the Tiger – A Study of Wildlife in India*. The University of Chicago Press, Chicago.

Shrestha, M. (2004). Relative ungulate abundance in fragmented landscape: implication for tiger conservation. PhD Dissertation, University of Minnesota, St Paul..

Silver, S.C., L.E.T. Ostro, L.K. Marsh, L. Maffei, A.J. Loss, M.J. Kelly, R.B. Wallance, H. Gomez & G. Ayala (2004). The use of camera-trapss for estimating jaguar abundance and density using capture/recapture analysis. *Oryx* 38(2): 148–154. https://doi.org/10.1017/S0030605304000286

Smithers, R.H.N. (1983). The mammals of the southern African subregion. University of Pretoria, Pretoria, South Africa.

Srivathsa, A., K.K. Karanth, D. Jathanna, N.S. Kumar & K.U. Karanth (2014). On a Dhole trail: examining ecological and anthropogenic correlates of dhole habitat occupancy in the western ghats of India. *PLoS ONE* 9(6): e98803. https://doi.org/10.1371/journal.pone.0098803

Srivathsa, A., S.N. Kumar & K.U. Karanth (2017). Home range size of the dhole from camera-trap surveys. *Canid Biology & Conservation* 20(1): 1–4. https://www.canids.org/CBC/20/dhole_home_range.pdf.

Sunarto, S., M.J. Kelly, K. Parakkasi, S. Klenzendorf, E. Septayuda, H. Kurniawan (2012). Tigers need cover: multi-scale occupancy study of the big cat in Sumatran forest and plantation landscapes. *PLoSONE*7(1): e30859. https://doi.org/10.1371/journal.pone.0030859.

Tempa, T., M. Hebblewhite, L.S. Mills, R. Tshewang, N. Norbu, T. Wangchuk, T. Nidup, P. Dendup, D. Wangchuk, Y. Wangdi & T. Dorji (2013). Royal Manas National Park, Bhutan: a hot spot for wild felids. *Oryx* 47(02): 207–210. https://doi.org/10.1017/S0030605312001317

Thapa, K. & M.J. Kelly (2016). Prey and tigers on the forgotten trail: high prey occupancy and tiger habitat-use reveal the importance of the understudied Churia habitat of Nepal. *Biodiversity Conser*vation 26(3): 593–616. https://doi.org/10.1007/s10531-016-1260-1

Thapa, K., M.J. Kelly, J.B. Karki & N. Subedi (2013). First camera-traps record of pack hunting dholes in Chitwan National Park, Nepal. *Canid Biology & Conservation* 16(2): 4–7.

The United States Geological Survey (2016). Science for a changing world. Retrieved from the United States Geological Survey website: Accessed on Aug 3, 2019. https://earthexplorer.usgs.gov/

Thorpe, E. & S. Thorpe (2019). Geography and Environmental Ecology. Pearson India Education Services Pvt. Ltd., Uttar Pradesh, India.

Valkenburgh, V.B. (1991). Iterative evolution of hypercarnivory in canids (Mammalia: Carnivora): evolutionary interactions among sympatric predators. *Paleobiology* 17(4): 340–362.

Venkataraman, A.B., R. Arumugam & R. Sukumar (1995). The foraging ecology of Dholes (*Cuon alpinus*) in Mudumalai Sanctuary, southern India. *Journal of Zoology* 237(4): 543–561. https://doi.org/10.1111/j.1469-7998.1995.tb05014.x

Wang, S.W. & D.W. Macdonald (2009). Feeding habits and niche

partitioning in a predator guild composed of tigers, leopards and dholes in a temperate ecosystem in central Bhutan. *Journal of Zoology* 277(4): 275–283. https://doi.org/10.1111/j.1469-7998.2008.00537.x

Wegge, P., T. Storaas, M. Odden & S.R. Jnawali (2000). Ungulates in heterogenous landscapes: how spatialgradients affect tigers and their prey in lowland Nepal. In: Ecology and management of ungulates: integrating across spatial scales international conference, British Columbia, Canada, August 1999.

Wood, H.S. (1929). Observations on the wild dog. *Journal of Bengal Natural History Society* 4: 7–15.

Yadav, S.K., B.R. Lamichhane, N. Subedi, R.K. Thapa, L.P. Poudyal & B.R. Dahal (2019). Dhole *Cuon alpinus* (Mammalia: Carnivora: Canidae) rediscovered in Bardia National Park, Nepal. *Journal of Threatened Taxa* 11(12): 14582–14586. https://doi.org/10.11609/jott.4714.11.12.14582-14586

Author details: Santa Bahadur Thing—recently involving in the Provincial level Forest and Wildlife conservation related policy formulation activities. He is Interested in Wildlife Management outside the Protected areas and its bottlenecks, Sustainable Tropical Forest management. Habitat suitability modeling of threatened group of flora and fauna. Jhamak Bahadur Karki, PhD—interested in Habitat (Grassland wetland) management of tiger and prey base, Ramsar convention implementation in Nepal focusing Himalayan wetland. Involved in Policy formulation process for conservation. Babu Ram Lamichhane, PhD—in-charge of the NTNC's Biodiversity Conservation Center, Chitwan. He is interested in study of large mammals and human-wildlife interactions. Mrs. Shashi Shrestha—completed her B.Sc. Forestry degree in 2016 from Institute of Forestry, Hetauda under Tribhuvan University, Nepal. Currently, involving in the Provincial level Forest and Wildlife conservation policy formulation activities. She is interested in Community Based Sustainable Forest Management, Gender equality and social inclusion (GESI) in forestry sector. Mr. Uba Raj Regmi—the former Joint secretary under the Ministry of Forests and environment. He is recently involving in community based conservation practices. He is interested in studying Wildlife ecology and Protected area management. Rishi Ranabhat—Member of Asian rhino specialist group, Species survival commission of IUCN. He is interested in Rhino conservation and habitat management, also Involving in Wildlife conservation policy formulation.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20713–20720

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

https://doi.org/10.11609/jott.7261.14.3.20713-20720

#7261 | Received 06 April 2021 | Finally accepted 08 March 2022

OPEN ACCESS

COMMUNICATION

Habitat preference and population density of threatened Visayan hornbills *Penelopides panini* and *Rhabdotorrhinus waldeni* in the Philippines

Andrew Ross T. Reintar [1], Lisa J. Paguntalan [2], Philip Godfrey C. Jakosalem [3], Al Christian D. Quidet [4], Dennis A. Warguez [5] & Emelyn Peñaranda [6]

[1,2,3] Philippines Biodiversity Conservation Foundation, Inc., Door 1 Roma Apartments, 12th Street Lacson, Bacolod City, 6100 Negros Occidental, Philippines.

[4,5] Department of Biological Sciences, College of Science and Mathematics, Mindanao State University-Iligan Institute of Technology, Andres Bonifacio Ave, Iligan City, 9200 Lanao del Norte, Philippines.

[6] Conservation and Development Division, Department of Environment and Natural Resources - Region VI, DENR Region VI, Pepita Aquino Street, Port Area, Iloilo City, 5000 Iloilo, Philippines.

[1] andrewrossreintar@philbio.org.ph (corresponding author), [2] lisapaguntalan@philbio.org.ph, [3] godo.jakosalem@philbio.org.ph, [4] alchristianquidet20@gmail.com, [5] dennis.warguez@g.msuiit.edu.ph, [6] emelyn_penaranda@yahoo.com

Abstract: The habitat preference and population density of the Critically Endangered Rufous-headed Hornbill *Rhabdotorrhinus waldeni* and Endangered Visayan Tarictic Hornbill *Penelopides panini* were studied in the Central Panay Mountain range in Panay Island, western Visayas. Point counts were established to survey for hornbills and habitat variables were measured in a 30 x 30 m plot at each point. *P. panini* was recorded in primary and secondary forest, while records of *R. waldeni* were mostly in primary forest, with only one record in secondary forest. Spearman's rank order correlation and stepwise multiple regression showed that *R. waldeni* is positively correlated to density of large trees (>70cm DBH), with the Visayan Tarictic Hornbill showing moderate correlation with density of medium-sized trees (31–70 cm DBH). Central Panay Mountains is the largest remaining forests block in western Visayas. It is the stronghold area of *R. waldeni* and other western Visayas threatened species, supporting the need to declare the site a protected area.

Keywords: Critically Endangered, Endangered, Panay, Rufous-headed Hornbill, Tarictic Hornbill, western Visayas.

Editor: Anonymity requested.

Date of publication: 26 March 2022 (online & print)

Citation: Reintar, A.R.T., L.J. Paguntalan, P.G.C. Jakosalem, A.C.D. Quidet, D.A. Warguez & E. Penaranda (2022). Habitat preference and population density of threatened Visayan hornbills *Penelopides panini* and *Rhabdotorrhinus waldeni* in the Philippines. *Journal of Threatened Taxa* 14(3): 20713–20720. https://doi.org/10.11609/jott.7261.14.3.20713-20720

Funding: United Nations Development Programme (UNDP) through the UNDP – Biodiversity; Partnership Project; Biodiversity Management Bureau (BMB); Global Environment Facility (GEF); Local Government Unit of Culasi; Local Government Unit of Sebaste

Competing interests: The authors declare no competing interests.

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

Acknowledgements: We are grateful on the support from several highly committed individuals and institutions, specifically, the United Nations Development Programme - Global Environment Facility through the Biodiversity Partnership Project of the Department of Environment and Natural Resources - Biodiversity Management Bureau, William Oliver Student Research Grant, Virginia Zoo and DENR Region 6. We thank CENR Officer Cynthia Blancia and CDS Chief Gloria Decena, Director Mundita S. Lim, BPP Manager Jose Regunay, Former DENR-6 RD Jim Sampulna, Former DENR-6 RTD Carlo Custodio, Melba Salditos, MSU-IIT Chancellor Sukarno Tanggol, Mayor Jose Christopher Varona and Alma Lisay Sandig; to Mayor Jose Jeffrey Lomugdang. To our field technicians: Pedro Villarta and Jaime Getaruelas; volunteers: Ecel Mae Lagudas, Erl Pfian Maglangit, Ronnie Jann Ian Mabitasan; to our field guides: Junjun, Roland, Elliser, Pato, Edmund, Almond, Renz, Jomari, Lito, Arnel, Ranti, Alex, Sonny, Charlie, Sonny and Benjamin.

INTRODUCTION

There are 62 species of hornbills in the world, of which 10 species and six subspecies are endemic to the Philippines (Gonzalez et al. 2013; Poonswad et al. 2013). All Philippine hornbills occur in lowland forests below 1,200 m (Gonzalez et al. 2013), but forest loss in the lowlands may have pushed species to the upper limit of up to 1,500 m elevation (Poonswad et al. 2013). Of the 10 species in the Philippines, two are classified as Critically Endangered, two as Endangered, and six as Vulnerable (IUCN 2020). The Ticao Hornbill *Penelopides panini ticaensis,* subspecies of the Visayan Tarictic Hornbill was declared Extinct (Poonswad et al. 2013) because of habitat loss. The Rufous-headed Hornbill *Rhabdotorrhinus waldeni* and *P. panini* are restricted-range species found only in the islands of Negros and Panay in western Visayas, where they inhabit lowland forest (Image 1 & 2). With continuing lowland forest loss, populations have been assessed by BirdLife and the International Union for the Conservation of Nature (IUCN) as decreasing. BirdLife International (2020) and the IUCN (2020) estimate the Panay population at 1,800 individuals, with 1,200 mature individuals, and declared the Negros population as possibly extinct.

Currently, only three protected areas (PAs) exist in Panay: Northwest Panay Peninsula Protected Landscape, Sibalom Natural Park, and Bulabog-Putian Natural Park. Despite ongoing conservation efforts, the largest remaining forest and stronghold of hornbill populations is in the Central Panay Mountains, and remains unprotected. This paper presents information on the habitat, abundance and conservation status of *P. panini* and *R. waldeni* in CPM. Conservation initiatives primarily led by local government units and Department of Environment and Natural Resources (DENR) are also presented. This research was undertaken as part of the Philippine Hornbills Conservation Programme of Philippines Biodiversity Conservation Foundation Inc.

Image 1. Visayan Tarictic Hornbill *Penelopides panini*

Image 2. Rufous-headed Hornbill *Rhabdotorrhinus waldeni*

METHODS

Study area

The Central Panay Mountain (CPM) refers to the chain of mountains that stretches and divides Panay Island into four provinces: Iloilo, Antique, Aklan, and Capiz (Klop et al. 2000; Mallari et al. 2000). The mountainous spine of CPM encompasses the largest forest area of montane and lowland forests. Survey for hornbill population and habitat preference was conducted in Mt. Camantra,

Figure 1. Map of northern Central Panay Mountain Range, showing location of sampling sites.

Sebaste, Antique from 25 July 2016 – 3 August 2016 and from 4–9 August 2016 for Mt. Igpako, Culasi in Central Panay Mountains. At the onset of the field surveys, severe tropical storm Nida affected the weather conditions in the country including Panay Island. Field research was authorized by DENR Region VI through a gratuitous permit issued to Philippines Biodiversity Conservation Foundation Inc. (PhilBio).

Mt. Camantra (11.544778°N & 122.148408°E)

The Mt. Camantra is located in the municipality of Sebaste (Figure 1) with elevation range of 444–996 m. The primary forest covers steep ridges and gullies. The average height of trees was 25 m and majority have more than 30 cm diameter at breast height. Canopy cover ranges 60–100% forest cover. Thick and tall undergrowth cover the trail and some areas were almost inaccessible with fallen dead trees and decaying logs. Forest trails were hardly visible indicating limited human-related activities. The secondary lowland forest habitat (11.544139° N & 122.147083° E) was located at 419 m. Majority of the trees have heights ranging 10–15 m with average diameter at breast height of 30 cm (n= 41 plots). The trails were visible following rivers, streams, and mountain ridges. The canopy cover ranged from 40–80 %. Abandoned agricultural clearings and presence of pineapple and coconut plantations were observed in the lower sections of the forests closer to the town and lower reaches of rivers and streams.

Mt. Igpako (11.466167°N & 122.1355°E)

The Mt. Igpako site is located in the municipality of Culasi (Figure 1) with primary lowland forests reaching up to 631 m. The forest understory was thick with *Pandanus* sp. and few climbing bamboo species. Large uprooted trees from recent typhoons were encountered. Canopy cover ranges 60–90% with patches of openings created from uprooted trees. In elevations above 900 m, moss cover thickly covered the forest floor and barks of trees.

Hornbill distribution and abundance: point-count sampling

Twenty-four-point count stations were established and surveyed, 15 located in the primary lowland forests of Mt. Camantra, Sebaste (5 points) and Mt. Igpako, Culasi (10 points), and nine in the secondary lowland forest in Mt. Camantra, Sebaste. Each sampling point was at least 250 m apart and the observation record bands are 100 m radius. Bird observations were conducted from 0600 h to 1100 h. Two to three observers recorded the distance of the hornbill from the center of the point station as well as the number of individuals seen or heard. Distance of the hornbill was recorded only through estimate. Observation per point was around 10

minutes. 8 x 42 and 10 x 42 roof-type binoculars were used during the survey.

We identified forest type following the definition from the Convention on Biological Diversity (CBD): Primary forest is a forest that has never been logged and has developed following natural disturbances and under natural processes. Secondary forest is a forest that has been logged and has recovered naturally or artificially.

Habitat assessment

Twenty-four 30 x 30 m plots were established in each of the 24 sampling points to determine habitat characteristics (Table 1). Canopy cover was measured using an improvised densiometer, and a tape measure was used in acquiring diameter at breast height (DBH). Understory cover percentage was measured through visual estimate. Garmin GPS was used to measure elevation and coordinates.

Data analyses

Hornbill density was acquired by calculating the average number of hornbills per point and dividing it by the total area sampled (3.14 hectares/point * number of point count stations) (Raman & Mudappa 2003). Density and population estimate using DISTANCE program was not used due to insufficient number of encounters for both species of hornbill.

Mann-Whitney U-test was used to compare the habitat variables between primary and secondary forest. Spearman's rank-correlations and multiple linear regression (stepwise) were used to identify relationship between habitat variables and hornbill abundance.

RESULTS

Hornbill distribution and records

We recorded a total of 12 detections (22 individuals) of *P. panini* and 31 detections (94 individuals) of *R. waldeni*. *P. panini* was recorded four times in primary forest and eight times in secondary forest while 99% of the records of *R. waldeni* were in primary forest. There were 13 *R. waldeni* positively identified as female and 18 as males and the rest were heard in groups. The highest number of individuals observed in a cluster was 25 (eight females, 13 males and four immature) while the average number of individuals encountered in a flock was 10. In the case of *P. panini,* three were positively identified as males and four were females.

We observed *R. waldeni* in secondary forests feeding on fruiting native trees together with *P. panini,* Pink-bellied Imperial Pigeon *Ducula poliocephala,* Green Imperial Pigeon *Ducula aenea,* Philippine Cuckoo dove *Macropygia tenuirostris* and other fruit-eating species.

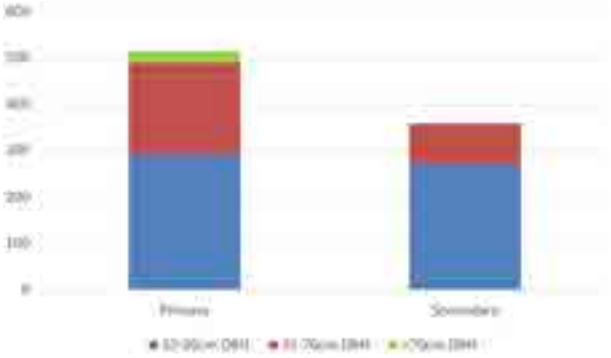


Figure 2. Tree densities per hectare between primary and secondary forest, with the three diameter at breast height (DBH) size classes.

Hornbill habitat preference

The primary lowland and secondary forests in CPM varied across sites. There were more large and tall trees in the primary and secondary forests of Mt. Camantra in Sebaste than in Mt. Igpako in Culasi. We tested for significant differences between primary and secondary forests using Mann-Whitney U-tests. Trees with a range of 16–20 m tall and trees with 31–70 and >70cm DBH varied significantly between primary and secondary forests (Table 1; Figure 2). This difference influenced the abundance of the hornbills. The *R. waldeni* was significantly correlated to the density of trees with 31–70cm DBH (r_s= 0.614, P= 0.001) and trees greater than 70cm DBH (r_s= 0.618, P= 0.001). This species was recorded almost strictly to primary forest with only one record in secondary forest. There was no significant correlation between habitat variable and *P. panini,* abundance. *P. panini* was recorded in both primary and secondary forest with most of the records in the latter.

Stepwise multiple regression showed that *P. panini* abundance was positively correlated with understory cover (R^2= 0.127, P= 0.049, Table 3) while the *R. waldeni*, abundance was positively related with presence of trees with >70cm DBH (adjusted R^2= 0.340, P= 0.002).

DISCUSSION

The forests in Sebaste and Culasi still contain significant lowland tropical rainforests. Both hornbills were encountered in primary and secondary lowland forest. Undisturbed forests with tall and large trees were

Table 1. Mean values and Mann-Whitney U-test results of habitat variables between primary and secondary forest.

Habitat variable	Primary forest	Secondary forest	U	p
Elevation	646.7	266.8	135	0.000
Density of 10–15 m tall trees (no./ha)	369	257		
Density of 16–20 m tall trees (no./ha)	126	71	103	0.035
Density of >20 m tall trees (no./ha)	45	33		
Canopy cover (%)	67.3	70		
Understory cover (%)	67.3	53.5		
Density of trees with 10–30 cm DBH (no./ha)	291	272		
Density of trees with 31–70 cm DBH (no./ha)	200	87	116.5	0.007
Density of trees with >70 cm DBH (no./ha)	24	0	112.5	0.005
Standing dead tree (no./ha)	20	6.3		

Table 2. Stepwise multiple regression analysis of hornbill abundance with significant habitat variables and values.

Species	Variables	Standard error (SE)	Standardized coefficient Beta	p
Visayan Tarictic Hornbill	Constant	1.077		0.296
	Understory cover	0.017	0.406	0.049
Rufous-headed Hornbill	Constant	0.596		0.233
	Density of trees with >70 cm DBH	0.331	0.607	0.002

Table 3. Estimates of forest in Panay and Negros island.

Name of area	Size (ha)	Estimated forest cover	Forest <1,200 m (ha)
Northwest Panay Peninsula Protected Landscape	12,009	8,000	5,000
Central Panay Mountain Range	105,200	105,200	30,049
Sibalom Natural Park	5,511.47	672	672
Northern Negros Natural Park	70,826.16	24,000	~10,000
Mt. Kanlaon Natural Park	24,388	8,000	~2,500
Balinsasayao Twin Lakes Natural Park	8,016.05	3,000	~2,500
Cuernos de Negros Mountains	4,096	2,000	~500

Source: Condeno (2018); Schade (2018); NAMRIA (2010); DENR FMB (2013); de Alban et al. (2004); Quimpo et al. (2014); PBCFI – BMB (2019).

positively correlated with the occurrence of the hornbill. The CPM remains as the main population stronghold of the Critically Endangered *R. waldeni* as it retains the largest lowland tropical rainforest on the island.

In 2017, the Haribon Foundation estimated 2,960–3,700 individuals remaining in Panay (Condeno 2018), slightly higher than the 2014 estimates of 2,880–3,600 (Quimpo et al. 2014). Based on the estimates, *R. waldeni* appears to have maintained its population since 2007 (Alabado et al. 2009; Quimpo et al. 2014; Condeno 2018). BirdLife International (2016) estimated population of *R. waldeni* at 1,000–2,499 mature individuals with total number of individuals at 1,500–4,000. From this study, we acquired a density of 0.2 individuals/hectare (20 individuals/km2) for the *P. panini* and 0.47 individuals/hectare (47 individuals/km2) for the *R. waldeni*. This is a crude estimate from our field observations and basic density calculation from number of recorded hornbills and the sampled area and accuracy can be improved with more data particularly on adjacent forest areas and to run the analysis in the DISTANCE program.

Mynott et al. in 2021 estimated the population density of *P. panini* in Northwest Panay Peninsula Natural Park (NWPPNP) through DISTANCE analysis to be at 17.8 individuals/km^2 (0.178 individuals/ha) in primary forests and 3.7 individuals/km^2 (0.037 individuals/ha).

Though we were not able the acquire density estimates using DISTANCE analysis and per forest type our crude estimate of 20 individuals/km^2 (0.2 individuals/ha) was close with their primary forest density estimate. In terms of encounters between forest types, we detected the *P. panini* more in the secondary forest (8 encounters) than the primary forest (4 encounters) while Mynott et al. in 2021 encountered more *P. panini* in primary forest (31 encounters) than in secondary forest (12 encounters). We suspect that this was the case for the sites we surveyed in CPM because of the presence of *R. waldeni*, which we observed to be more abundant and dominant particularly in the primary forests. *R. waldeni* is almost certainly extirpated in NWPPNP (Birdlife International 2022) and its presence needs to be confirmed. With that, there is lesser competition for space and resources for the *P. panini* in NWPPNP, most significantly in the primary forests. Though the two species of hornbills co-exist and form flocks, there will be competition for nesting trees during breeding season. The *P. panini* having a broader habitat preference, requiring less pristine conditions than the *R. waldeni*, were able to occupy the secondary forests if competition for resources ensues.

P. panini shows preference to areas with medium-sized trees (30–70 cm DBH) which could be one of their minimum requirement for nesting. This was similar to the results of Klop et al. (2000) in their study of nest site characteristics, where the mean DBH of nesting trees of *P. panini* was 34 cm. Klop et al. (2000) only measured one nesting tree of *R. waldeni* that was 90 cm. These results indicate that *P. panini* has a wider range of habitat preference, and thus it is able to survive in secondary forests and tolerate some level of disturbance. *R. waldeni* on the other hand has a narrow preferred habitat range, requiring large trees and undisturbed forests. Among the sites in Panay, CPM holds the largest lowland forest cover in Panay followed by Northwest Panay Peninsula Protected Landscape and Sibalom Natural Park.

Hornbill distribution

The past distribution of *P. p. panini* was on Negros, Panay, Masbate, Sicogon, Pan de Azucar and Guimaras Islands. However, it is now extinct on the latter three and only survives in small forest fragments on Negros and Panay (Poonswad et al. 2013; Paguntalan et al. 2002, 2004). It is uncertain if populations still remain on Masbate Island although locals have reported the presence of the species in small forest fragments in Milagros and Mobo watershed in 2013. The loss of forests, combined with hunting, have threatened the survival of the bird in the wild, exemplified by the extinction of Ticao hornbill (Klop et al. 2000; Poonswad et al. 2013).

R. waldeni was known to occur on Negros, Panay and Guimaras Island. It is now extinct on Guimaras and survives in lowland forests in Negros and Panay. There were very few records of the species in the last 30 years in Negros (Poonswad et al. 2013). We have encountered two females and two males in Northern Negros Natural Park on 20 March 2013 and two females and five males in 16 February 2017. A lone female was observed from the viewing deck in Balinsasayao Twin Lakes Natural Park last on 22 June 2017 while a group of three individuals composed of one female and two males were seen on 19 August 2019.

The two threatened hornbills are reported to occur in at least five Protected Areas in Panay and Negros. Of the five, two are in Panay (Sibalom Natural Park and Northwest Panay Peninsula Protected Landscape) and three in Negros (Northern Negros Natural Park, Mt. Kanlaon Natural Park and Balinsasayao Twin Lakes Natural Park) (Table 4). Two of the significant forest blocks (Cuernos de Negros Mountain Range in Negros and the Central Panay Mountain Range in Panay) remain unprotected. With the known forest areas where the *R. waldeni* exists, of which there are few, the CPM is the stronghold and the most important sanctuary for the species.

Threats

The primary lowland forests in Sebaste and Culasi are still relatively undisturbed. Part of the reason for this is the topography of the area. The forests are found on steep mountain ridges and gullies that are difficult to access. Trails follow the rivers and streams and bisect steep slopes to reach the mountain ridges. The lower reaches and areas close to the villages showed evidence of disturbances while the forest interior remained relatively pristine. As one moves farther away from the villages and rivers, less disturbance in forests was encountered.

In areas close to the villages and towns, habitat destruction and hunting remain as the main threats to hornbill populations. Large trees were observed being selectively logged for timber needed to make boats and houses or sold as lumber in the nearby town. Clearings were then planted with subsistence crops. Locals were also reportedly using marble guns for hunting birds and other animals for protein and for sport.

During the survey, two of the six known nesting trees of *R. waldeni* in Mt. Camantra were uprooted by previous typhoons. We also recorded two additional

nesting holes suspected to be that of *R. waldeni* based on the size of the tree, location and size of the nesting hole and the larger seeds found at the base of the tree trunk directly below the nest hole. Locals have also reported this nest as that of *R. waldeni.*

Conservation efforts

The national threatened status of *R. waldeni* remained at Critically Endangered status, but *P. panini* was changed from Endangered to Critically Endangered status in the recent revision of the National List of Threatened Fauna and their categories in the Department Administrative Order 2019 – 19 (BMB DENR 2020).

The enactment of the Expanded National Integrated Protected Areas System (ENIPAS) Act of the Philippines effectively legislated into law the declaration of two Protected Areas in Negros (Balinsasayao Twin Lakes Natural Park and Northern Negros Natural Park) and two in Panay (Northwest Panay Peninsula Protected Landscape and Sibalom Natural Park). Mt. Kanlaon Natural Park has its own Republic Act declaring it as a protected area in 2002.

The DENR Region VI initiated the protected area suitability assessment (PASA) last December 2020–January 2021 as the first step in declaring Central Panay Mountain Range as a protected area. This was in response to the resolution passed by the Regional Development Council of Region VI in 2018. There were several attempts in the past to declare the CPMR as a nationally declared protected area, but only local legislations were enacted.

MANAGEMENT RECOMMENDATIONS

Declaration of Central Panay Mountains as Protected Area – The Regional Development Council of Region VI and the Department of Environment and Natural Resources (DENR) Region VI had initiated the process of declaring Central Panay Mountains as a protected area last October 2018. The move to declare CPM as PA started in the early 1990s and with millions of funds poured in the last two decades, this has remained a suggestion. Local Government Units (LGU) of all four provinces should seriously investigate securing the very mountains that provided its life support system: freshwater.

Collaboration with LGUs and stakeholders in monitoring protected areas – average annual national budget allocations for monitoring PAs is US $581 while class A local government units have annual funds of at least US $19,380 for environmental programs including monitoring PAs. The Protected Areas Management Board of each PA, DENR and LGU within Key Biodiversity Areas (KBAs) should institutionalize the conduct of synchronized bio-monitoring and hornbill count in each Protected Area and KBA using improved line-point and DISTANCE analysis.

Surveys on threatened hornbills of western Visayas – Surveys are needed in the other identified forests patches, e.g., Northwest Panay Peninsula Protected Landscape, Sibalom Natural Park, Cuernos de Negros Mountain Range, Sta. Catalina forest, Masbate Island, to determine the presence of surviving populations.

REFERENCES

BirdLife International (2021). Species factsheet: *Penelopides panini*. Available from http://www.birdlife.org. Accessed on February 26, 2016.

BirdLife International (2021). Species factsheet: *Rhabdotorrhinus waldeni.* Available from http://birdlife.org. Accessed on February 26, 2016.

BirdLife International (2022). Species factsheet: *Rhabdotorrhinus waldeni*. Available from http://birdlife.org. Accessed on http://www.birdlife.org on 25/03/2022.

Collar, N.J., N.A.D. Mallari & B.R.J. Tabaranza (1999). *Threatened birds of the Philippines: the Haribon Foundation/ BirdLife International Red Data Book*. Bookmark, Makati City.

Condeno, R. (2018). Biodiversity Change in the Panay Mountain Range 2014–2017. Forest and Climate Protection in Panay - Phase II. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Dilliman, Quezon City.

Curio, E., M. Kauth, S.L. Engel & L.L. Lastimoza (1998). Observations on the Breeding Biology of the Writhed-billed Hornbill (*Aceros waldeni*) in the Philippines. *Journal of Ornithology* 139: 475–483.

de Alban, J.D., R. Condeno, M. Gonzales, N. Resureccion & J. Jalbuena (2004). Sibalom Natural park, Antique: Integrating Forest Conservation with Local Governance: Technical Report. Haribon Foundation Inc.

Department of Environment and Natural Resources – Forest Management Bureau (2013). Philippine Forest Facts and Figures. DENR – FMB. Quezon City, Philippines.

Department of Environment and Natural Resources – Forest Management Bureau (2017). Philippine Forest at a Glance. Forest Policy, Planning and Knowledge Management Division, FMB. Diliman, Quezon City.

Gonzalez, J.C., B. Sheldon, N.J Collar & J. Tobias (2013). A comprehensive molecular phylogeny for the hornbills (Aves: Bucerotidae). *Molecular Phylogenetics and Evolution* 67(2): 468–483. https://doi.org/10.1016/j.ympev.2013.02.012

Kemp, A. (1995). *The Hornbills: Bucerotiformes*. Oxford University Press Inc., New York, x+302 pp.

Kemp, A.C. (2001). Family Bucerotidae (Hornbills), pp. 436–523. In: del Hoyo, J., A. Elliott & J. Sargatal (eds.). *Handbook of the Birds of the World - 3.* Lynx Edicions, Barcelona, Spain.

Kennedy, K.S., P.C. Gonzales, E.C. Dickinson, H.C.J. Miranda & T.H. Fisher (2001). *A Guide to the Birds in the Philippines*. Oxford University Press, New York, 540pp+72 color plates.

Kinnaird, M.F. & T.G. O'Brien (2007). *The Ecology and Conservation of Asian Hornbills; Farmers of the Forest*. Chicago. University of Chicago Press.

Klop, E., E. Curio & L. Lastimoza (2000). Breeding Biology, Nest Site Characteristics and Nest Spacing of the Visayan Tarictic Hornbill

Penelopides panini panini on Panay, Philippines. *Bird Conservation International* 10: 17–27.

Mynott, H.I., D.C. Lee, R.A. Santillan, C.J. Schwarz, B. Tacud, A.D. Fernandez & D. Kerhoas (2021). Population assessment and habitat associations of the Visayan Hornbill (*Penelopides panini*) in Northwest Panay, Philippines. *Avian Research* (2021) 12: 67.

National Mapping and Resource Information Authority (2010). Department of Environment and Natural Resources. Taguig City.

Negros Island Biodiversity Strategy and Action Plan (2018). DENR-BMB and Philippines Biodiversity Conservation Foundation Inc., Bacolod City.

Paguntalan, L.M.J., J.C.T. Gonzalez, M.J.C. Gadiana, A.T.L. Dans, M.dG. Pedregosa, A. Cariño & C.N. Dolino (2002). Birds of Ban-Ban, Central Negros, Philippines: threats and conservation status. *Silliman Journal* 43(1): 110–136.

Paguntalan, L.M.J., P.G.C. Jakosalem, M. dG. Pedregosa, M.J.G. Catacutan & R. Bueno (2004). Conservation Status of Forest Birds in Isolated Forest R. Patches in Masbate, Philippines. *Silliman Journal* 45(2): 222–236.

Philippines Biodiversity Conservation Foundation and Biodiversity Management Bureau (2018). *Negros Island Biodiversity Strategy and Action Plan*. Impress Printing Press, Bacolod, 64 pp.

Poonswad, P. (1991). Hornbill, pp. 63–73. In: *Insight Guide: Southeast Asia Wildlife*. APA publication (HK) Ltd., 430 pp.

Quimpo, J.D.G., B.R.J. Tabaranza, R.C. Martinez, G. Azarez, N.A. Resurrecion, A.A. Alabado, J. Espiritu, J.K. Panopio, K.C. Artiaga & M.C. Bueno (2014). Central Panay Mountain Ranges (CPMR). Panay Island Biophysical survey technical report for Cluster 1 municipalities (Pandan, Sebaste, Culasi, and Tibiao). ForClim Project 2010–2014.

Raman, T.R.S. & D. Mudappa (2003). Correlates of hornbill distribution and abundance in rainforest fragments in the Southern Western Ghats, India. *Bird Conservation International* 13: 199–212.

Schade, J. (2018). Forest Cover and Carbon Monitoring in the Panay Mountain Range. Manila Philippines. Deutsche Gesselschaft für Internationale Zusammenarbeit (GIZ). Technical Report.

Author Details: Andrew Ross T. Reintar - Filipino. An ornithologist and the Field Operations Officer of Philippines Biodiversity Conservation Foundation. Recently conducted a conservation project on the Critically Endangered Cebu flowerpecker and is currently involved in Sulu hornbill and Tawi-tawi biodiversity conservation, working on population and ecological study, education, capacity development and community-based forest protection. Lisa J. Paguntalan - Filipino. An ornithologist and the Executive Director of Philippines Biodiversity Conservation Foundation. She's been doing conservation work for more than two decades focusing on threatened species and habitats in the Philippines. Currently overseeing the Sulu hornbill and Tawi-tawi biodiversity conservation program of PhilBio and other core conservation programs. Philip Godfrey C. Jakosalem - Filipino. Is an ornithologist and the Field Operations Manager of Philippines Bioversity Conservation Foundation (PhilBio). He's been doing conservation work on for two decades, working on bird conservation and ecology. Currently one of the lead of the Sulu hornbill and Tawi-tawi biodiversity conservation program and waterbirds research of PhilBio. Al Christian D. Quidet - Filipino. Currently a medical student of Xavier University in Mindanao. Previously involved in biodiversity research during his undergraduate thesis with particular focus on Visayan hornbills. Dennis A. Warguez - Filipino. An associate professor of Mindanao State University-Iligan Institute of Technology, is currently enrolled as a Ph.D. student at De La Salle University-Manila. He had recently conducted herpetological surveys organized by Herp Watch Pilipinas in Antique, Samal Island, Mt. Apo Protected Area, and Mt. Hamiguitan Range Wildlife Sanctuary. Emelyn Peñaranda - Filipino. Development Management Officer of the Department of Environment and Natural Resources Region 6. She is now actively engaged in the implementation of conservation and development programs and projects concerning protected areas, biodiversity, forest, coastal and marine and urban ecosystems as well as climate change and gender and development.

Author contributions: ARTR—Manuscript writing. Survey and data gathering. Performed the analysis and map making of the study. Conceptualization of the study. Arrangements and preparations of the survey expedition. LJP—Manuscript writing and review. Conceptualization, development and realization of the study and survey expedition. Fund sourcing for the project. PGCJ—Conducted survey and data gathering. Conceptualization and development of the study. ACDQ—Survey and data gathering. Conceptualization of the study. DAW—Survey and data gathering. Conceptualization of the study. Arrangements and preparations of the survey expedition. EP—Arrangements and preparations of the survey expedition. Manuscript review.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20721–20732

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

https://doi.org/10.11609/jott.7748.14.3.20721-20732

#7748 | Received 09 November 2021 | Final received 25 January 2022 | Finally accepted 05 March 2022

OPEN ACCESS

COMMUNICATION

Nest colonies of Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) on overhead power transmission cables in the agricultural landscape of Cuddalore and Villupuram districts (Tamil Nadu) and Puducherry, India

M. Pandian

No. F1901, AIS Housing Complex, Natesan Nagar West, Virugambakkam, Chennai, Tamil Nadu 600092, India.
pandian.m14@gmail.com

Abstract: Nesting habits of Baya Weaver *Ploceus philippinus* with specific reference to overhead power transmission cables was studied between April and November 2021 in the agrarian landscape of 10 villages covering Cuddalore and Villupuram districts (Tamil Nadu), and Puducherry. A total of 408 nests of various stages (wad stage-35, ring stage-21, helmet stage-227, egg-chamber closed stage-49, complete nests-22, and abnormal nests-54) and 411 birds were enumerated on 25 nest colonies. The number of nests in each colony ranged from 1 to 82. Baya Weavers had selected power cables as nesting sites despite the availability of three nest-supporting trees (n= 2,255), such as *Cocos nucifera*, *Borassus flabellifer*, and *Phoenix sylvestris* within 500 m of nesting cables. Birds used leaves of sugarcane *Saccharum officinarum*, Indian Date Palm *Phoenix sylvestris*, and Narrow-leaf Cattail *Typha angustifolia* as a source of fibres for the construction of nests. Twenty-three out of 25 nest colonies were found on power cables running over sugarcane crops. Abnormal nests constituted 13.23% (n= 54) of the total nests and 92.91% (n= 223) helmet stage nests had clay deposits on the inner walls. A total of 285 fallen nests in various stages of development were scattered on the ground. There were opportunistic sightings of avian predators, such as House Crow *Corvus splendens*, Large-billed Crow *Corvus macrorhynchos*, Rufous Treepie *Dendrocitta vagabunda*, and Shikra *Accipiter badius* found perched on power cables bearing nests and caused damages to eight nests.

Keywords: Abnormal nests, clay deposit, nest development, nest predation, threats.

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

Date of publication: 26 March 2022 (online & print)

Citation: Pandian, M. (2022). Nest colonies of Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) on overhead power transmission cables in the agricultural landscape of Cuddalore and Villupuram districts (Tamil Nadu) and Puducherry, India. *Journal of Threatened Taxa* 14(3): 20721–20732. https://doi.org/10.11609/jott.7748.14.3.20721-20732

Funding: None.

Competing interests: The author declares no competing interests.

Author details: M.Pandian has completed MSc., PhD., in Botany and BLIS from University of Madras and Bachelor of Education (BEd) from Annamalai University, Chidambaram and now serves in Tamil Nadu Police Department. His area of interest is ecology and nesting biology of birds and published a few papers on House Sparrows, Baya Weavers, Munias, Ring-necked Parakeets, and Indian Flying Fox.

Acknowledgements: I thank D. Balaji (Mailam), K. Sriram (Rettanai) for assistance in the collection of data and photography, A. Giridharan (Minnal), P. Logeswaran (Minnal), T. Selvapandian, and P. Poornima (Odisha) for data analysis/ preparation of maps.

INTRODUCTION

Ploceidae is a family of small passerine birds, called weavers or bishops. They are native to the Old World, particularly Africa and tropical Asia. The genus *Ploceus* contains 64 species, of which four—*P. philippinus*, *P. manyar*, *P. benghalensis*, and *P. megarhynchus*—occur in India (Craig 2010; Gill & Donsker 2010). Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) (Aves: Passeriformes: Ploceidae) is a social, polygamous, colonial nester and occurs in the Indian subcontinent (Ali et al. 1956), Java, Malacca, Sumatra (Blyth 1845; Wood 1926), China, Indonesia, Laos, Myanmar, Singapore, Thailand, and Vietnam (BirdLife International 2016). The IUCN Red List of Threatened Species has classified Baya Weaver under organisms of 'Least Concern' (Birdlife International 2016). In India, the breeding season of Baya Weaver is from May to November (Ali & Ripley 1987; Rasmussen & Anderton 2005). Baya Weavers select a variety of trees for nesting but prefer tall, unbranched trunks and long-swaying foliage of palm trees to keep away predators and provide convenient leaf strips for building nests (Davis 1974). Baya Weavers prefer *Cocos nucifera* along the west coast of the Indian peninsula, *Borassus flabellifer* along the east coast, and *Acacia nilotica* in the arid northwestern region (Sharma 1989). Dense canopies of nest-bearing trees possibly provide safety from predators and weather-related problems (Sharma 1991). The breeding biology of this bird was studied by Ali (1931), Ali & Ambedkar (1956), Ambedkar (1964), and Mathew (1977). Several workers have reported construction of abnormal nests (Ali & Ambedkar 1956; Ambedkar 1964; Crook 1964; Sharma 1989; Pandian 2018). Nests of Baya Weavers were found attached to telegraph lines along the Chittoor-Chandragiri routes (Kirkpatrick 1952), Kumaon Terai region of Nainital District (Uttarakhand) (Ambedkar 1969), and between Bangalore and Madras where sugarcane crops predominate (Subramanya 1982). Nests of Baya Weavers were recorded on electric cables in Assam and Tamil Nadu (Davis 1974). A total of 135 nests were observed on four power cables in Villupuram district, Tamil Nadu (Pandian 2018). Apart from these, no other detailed studies are available on the nesting of this bird on power cables in Tamil Nadu and Puducherry. Hence, the present study was carried out to fill this gap.

In this paper, I sought answers to questions relating to the choice of power cables for nest construction by Baya Weaver, with specific reference to Cuddalore and Villupuram districts (Tamil Nadu) and Puducherry. The following objectives were kept in mind in the study: (1) extent and pattern of selection of power cables for nesting, (2) features of nest building including sources of nesting materials, stages of nest developments, plastering of clay on inner walls, and abnormalities, and (3) threats faced by the birds.

MATERIALS AND METHODS

Study Area

The present study was carried out in 10 villages covering Cuddalore and Villupuram northeastern districts of the state of Tamil Nadu and the Union Territory of Puducherry from the first week of April to the second week of November 2021. The study area spreads over 5,897 km^2, with a human population of c. 5,630,000 (2011 Census). Agriculture is the primary occupation of the people. The major crops of the area are paddy *Oryza sativa*, sugarcane *Saccharum officinarum*, followed by jowar Sorghum *bicolor*, pearl millet *Pennisetum glaucum*, finger millet *Eleusine coracana*, foxtail millet *Setaria italica*, groundnut *Arachis hypogaea*, and green gram *Vigna radiata*. Flower and vegetable cultivations also occur. The maximum and minimum temperatures in the districts are 36 °C and 20 °C, respectively. The average annual rainfall is 1,060 mm (Figure 1).

Methods

With help from field assistants/informants (2), I identified villages having definite populations of Baya Weaver and their nests on overhead power transmission cables and nest-supporting palms, such as *C. nucifera, B. flabellifer*, and *Phoenix sylvestris* in the agricultural lands in 10 villages in Cuddalore and Villupuram districts (Tamil Nadu) and Puducherry. The nests attached to all the power cables between two poles including solitary nests and nests observed on tree crown were considered a single nest colony. These nesting colonies were surveyed on daily basis between April and November 2021 without causing any disturbance to the nests and inhabiting birds. The observations were carried out from 0600 h to 1200 h and 1500 h to 1800 h when the birds were found active. The heights of the cables from the ground were ascertained from the details written on power transmission poles while heights between overhanging nests and crops, and the distance between the overhanging nests from bunds/pathways were measured using a dried bamboo stick. The sources of nesting materials and the type of cultivating crops underneath the overhanging power cables were recorded. Every 250 trips of males carrying

Figure 1. Study area map: a—India map showing Tamil Nadu and study site | b—Villupuram, Cuddalore district, and Puducherry map showing villages and locations of nest colonies. List of villages: (1) Sundaripalayam, (2) V. Agaram, (3) A.K. Kuchipalayam, (4) Kallipattu, (5) Varinjipakkam, (6) Poondi, (7) Kandrakottai, (8) Mozhiyanur, (9) Madurapakkam, and (10) Kunichampet.

fibres to power cables and nest-supporting trees were observed using binoculars and analysed the type nest materials carried by them. The locations of all the cables that bore nests/nest colonies were determined using GPS (Gramin Etrex 20x). The nests, their developmental stages including abnormal nests on power cables and nesting trees were recorded. Deposits of clay on the inner walls of helmet stage nests, damages to nests, and sightings of avian predators near nest colonies were observed by maintaining c. 30 m distance using Super Zenith 20 x 50 field binoculars, without disturbing nests and their residents. Fallen nests under the overhanging nest colonies were counted. Each nest colony was observed uninterruptedly for 60 min and the maximum number of birds observed in that colony was counted. To assess the proportions of three types of palms (*C. nucifera*, *B. flabellifer,* and *P. sylvestris*) used by Baya Weavers as nesting substrata within 500 m radii from nesting cables, all the individuals of three palms bearing nests and without nests were enumerated and preference assessed. The correlation between variables such as the total number of birds and nests observed on power cables was calculated using Pearson's Correlation Coefficient test. Utmost care was taken not to disturb the nests or birds and a minimum distance of c. 30 m was maintained during observations. No live nests, eggs, chicks, or adult birds were disturbed, and only fallen nests were examined during the study period. Nikon P 1000 digital camera was used for photography and videography. Collected data were tabulated, analyzed and shown as graphs.

RESULTS AND DISCUSSION

Males started to visit power cables carrying plant fibres during the third week of May 2021, and commenced nest construction. In total 408 nests of various developmental stages and 411 adult birds were enumerated on power cables/nest colonies at 25 sites. The number of nests in each colony ranged from 1 to 82, and three nest colonies with solitary nests were also recorded (Table 1). An average of 16.3 nests and 16.4 birds were counted on each nest colony. At 22 sites, the nesting power cables were found passing over sugarcane crops, while one passed over foxtail millet *Setaria italica* crop, guava *Psidium guajava* orchard, and Narrow leaf Cattail *T. angustifolia* reed (Image 1). The study also revealed that grain crops such as paddy, jowar, sorghum, finger millets, and foxtail millets were being cultivated within a 1-km radius of nest colonies. It indicates that the birds had chosen nesting sites on power cables

Image 1. Images showing overhanging nest colonies: a—Nest colony over Sugarcane crop field | b—Nest colony over Foxtail millet crop field | c—Nest colony over Guava orchard | d—Nest over Cattail reed area. © M. Pandian

running adjacent to grain crops, probably for forage for adult birds. Pearson's correlation coefficient test was conducted between the number of nests and the number of birds enumerated on the power cables bearing nests. The test indicated a strong positive correlation (0.939) between the number of nests and the number of birds observed on power cables (Figure 2).

Power cables as nesting substratum

Baya Weaver used power cables as nesting sites and constructed nests attached to these power cables. Electricity poles rose c. 5.6 m above the ground, while the cables were 5.2 m above the ground, with a distance of 60 m between two poles. A total of 408 nests in 25 nest colonies were observed. Within 500 m radii from the power cables bearing nest colonies, there were 2,296 nest-supporting trees, such as *C. nucifera* (*n*= 1,856), *B. flabellifer* (*n*= 409), and *P. sylvestris* (*n*= 31) in 10 villages. The birds had utilized only 1.78% (n= 41) of those nest-supporting trees and the remaining 98.22% nest-supporting trees (n= 2,255) of those three palm species (Arecaceae) were found not utilized by the birds for the construction of nests. A total of 727 nests of various developmental stages were enumerated on those 41 nest-supporting trees. Out of 2,296 available nest supporting trees, the birds had proportionately utilized 1.78 % of *C. nucifera* trees (*n*= 33), 1.47% of *B. flabellifer* trees (*n*= 6), and 6.45% of *P. sylvestris* trees (*n*= 2). It reveals that the birds had proportionately preferred *P. sylvestris*, followed by *C. nucifera*, and *B. flabellifer* trees (Table 2). The utilization of only 41 trees out of 2,296 trees indicate that Baya Weavers selected power cables as nesting sites in the study area despite the availability of abundant nest-supporting trees (n= 2,255) around the power cables bore nests.

Colonization of Baya Weavers on telegraph and power lines has been reported earlier in Kumaon Terai region of Nainital District, Uttarakhand (Ambedkar 1969), Chittoor and Chandragiri regions (Kirkpatrick 1952), Tamil Nadu, and Assam (Davis 1974). Subramanya (1982) observed the presence of nests of Baya Weavers on telegraph wires between Bangalore and Madras (Chennai) regions. The occurrence of nest colonies on the power cables in the present study area corroborates the

Table 1. Details of villages, GPS coordinates of a nest bearing power cables, number of individuals of Baya Weaver and nests in the study area as on fourth week of September 2021.

	District	Name of the Village	GPS coordinates of power cables bearing nests	Crops underneath the power cables	Total no. of birds counted	Total no. of nests	Developmental stages of nests					
							Wad stage	Ring stage	Helmet stage stage	Egg chamber closed stage	Complete nests	Abnormal nests
1	Cuddalore	Sundaripalayam	11.896° N–79.549°E	Sugarcane	6	16	0	0	6	7	1	2
			11.887°N–79.548°E	Sugarcane	10	3	0	0	2	1	0	0
		V. Agaram	11.882° N–79.549°E	Sugarcane	7	5	0	0	3	0	0	2
			11.882° N–79.549°E	Sugarcane	48	29	5	4	12	3	2	3
		AK Kuchipalayam	11.860° N–79.550°E	Sugarcane	64	52	3	3	23	9	7	7
			11.859°N–79.551°E	Foxtail millet	22	20	2	4	9	5	0	0
			11.859°N–79.551°E	Sugarcane	5	5	0	0	4	0	1	0
			11.858° N–79.551°E	Sugarcane	4	3	0	0	2	1	0	0
			11.857°N–79.556°E	Sugarcane	62	54	1	0	30	6	4	13
		Kallipattu	11.855°N–79.553° E	Narrow leaf Catttail	1	3	1	0	2	0	0	0
			11.852°N–79.552°E	Sugarcane	1	1	0	0	0	0	0	1
		Varinjipakkam	11.816°N–79.530°E	Guava	3	10	0	0	6	1	0	3
		Poondi	11.825°N–79.530° E	Sugarcane	6	6	3	0	1	0	0	2
			11.825°N–79.531°E	Sugarcane	1	1	0	0	1	0	0	0
			11.825°N–79.530°E	Sugarcane	2	2	0	0	1	0	0	1
		Kandrakottai	11.834° N–79.557°E	Sugarcane	10	10	0	1	5	0	0	4
2.	Villupuram	Mozhiyanur	12.132°N–79.570°E	Sugarcane	6	2	0	0	2	0	0	0
			12.134° N–79.571°E	Sugarcane	9	8	0	0	8	0	0	0
			12.130° N–79.569° E	Sugarcane	1	1	0	0	1	0	0	0
		Madurapakkam	11.999°N–79.606° E	Sugarcane	38	57	0	0	41	9	4	3
			12.000° N–79.606° E	Sugarcane	12	16	8	4	4	0	0	0
			12.001°N–79.606° E	Sugarcane	17	17	0	0	11	3	0	3
			11.996°N–79.624°E	Sugarcane	68	82	12	5	48	4	3	10
			11.995° N–79.607° E	Sugarcane	4	3	0	0	3	0	0	0
3.	Puducherry	Kunichampet	11.999°N–79.625°E	Sugarcane	4	2	0	0	2	0	0	0
	Total	10 villages	25 sites	25 crop sites	411	408	35	21	227	49	22	54

Table 2. Details of proportions of nest-supporting trees selected from available trees around 500m radii from nest bearing cables.

Nest-supporting trees	Total no. of trees found within 500 m radii from nest bearing cables	Total no. of trees selected for nesting	The proportion of trees selected for nesting (%)
Cocos nucifera	1856	33	1.78
Borassus flabellifer	409	6	1.47
Phoenix sylvestris	31	2	6.45
Total	2296	41	-

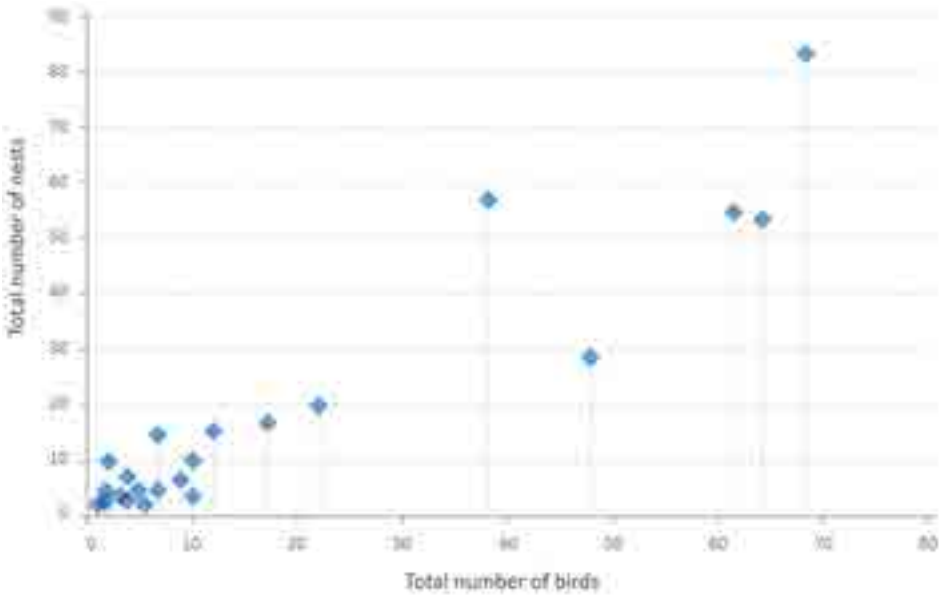


Figure 2. Pearson's correlation coefficient graph shows a relationship between the total number of birds and nests in the study area.

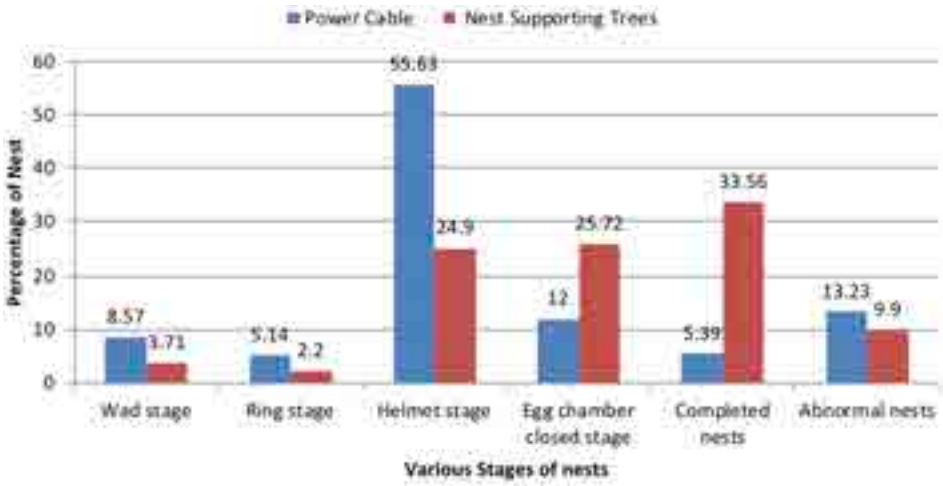


Figure 3. Comparison of various developmental stages of nests of Baya Weaver on power cables and potential nest-supporting trees in the study area.

findings of Ambedkar (1969), Kirkpatrick (1952), Davis (1974), and Subramanya (1982). Baya Weavers showed a preference for telegraph wires in the Bangalore–Madras regions where sugarcane and paddy crops predominate (Subramanya 1982). Similarly in the present study area, Baya Weavers used power cables as substrata for the construction of nests that passed over sugarcane crops (22 out of 25 sites). Birds have been found to have made nests at odd places like electric transmission cables when other suitable nesting sites were scarce (Toland 1990; Chace & Walsh 2006). However, in the present study area, it was found that despite availability of a sufficient number of nest-supporting palm trees (n= 2,255) within a 500 m radius, the birds chose power cables, indicating that in this instance it was not the absence of traditional nesting sites that led birds to choose power cables, as found by Toland (1990) and Chace & Walsh (2006).

Subramanya (1982) put forward several reasons for birds preferring power cables overhanging sugarcane crops: (i) safety from terrestrial predators like snakes and lizards, (ii) availability of sugarcane crops throughout the breeding season, (iii) availability of paddy crops, and (iv) sugarcane crops serve as roosting sites during the non-breeding season. From the present we can add: (i)

abundant nesting materials, i.e., sugarcane leaves were available beneath 22 power cables and nearby (330–700 m) to another three power cables throughout the breeding season; (ii) availability of foraging grain crops such as paddy, pearl millet, finger millet, and foxtail millet, found within 500–1,000 m of nest colonies, and (iii) fewer anthropogenic disturbances like frequent climbing of palm trees by humans for fruits, leaves, and toddy, pruning of leaves bearing nests, and nest predation by humans. Hence, the present observations partially match the suggestions of Subramanya (1982). Also, the availability of a clear line of sight in all directions afforded by free-hanging cables may allow birds to detect the approach of predators.

Colony size

The number of nests in each colony varied 1–82 nests per colony were observed on power cables, whereas 1–73 nests were observed on nest-supporting trees; 12% of nest colonies (n= 3) observed on power cables were solitary nests, as were 4.8% (n= 2) of nests observed on trees. Sharma (1989) had recorded 1–250 nests in Rajasthan, 5–24 nests in South Goa (Borkar & Komarpant 2003), 1–30 nests in Nanded (Achegawe et al. 2016), and 1–61 nests in Vellore district, Tamil Nadu (Pandian 2021a) and hence, the present observations of 1–82 nests on power cables and 1–73 nests on potential nest-supporting trees concur with the findings of previous studies (Pandian 2021a). This indicates that there exists no major variation in the number of nests in a colony either on power cables or nest-supporting trees.

Distance with crop bunds

The distances between nest colonies (n= 25) and bunds in the vicinity were: one colony was directly over a bund in Madurapakkam village (11.999°N–79.606°E); nine colonies were 1–2 m away from the bunds; six colonies at 3–4 m distance; five colonies at 5–6 m; four colonies at >6 m. This indicates that the birds preferred power cables away from bunds/pathways for construction of nests, probably to avoid any human disturbances because nests on power cables were found hanging 4–4.5 m above the ground. The distance from bunds seems not to apply to potential nest-supporting trees, because all such trees occurred on crop bunds and nests were attached to palm fronds above 10 m from the ground.

Source of fibres

A study of the source of nest materials revealed that male Baya Weavers plucked fibres from leaves of sugarcane, Indian date palm, and narrow leaf cattail, made incisions on the leaf margins near the bases and tore off fine fibres toward the distal ends and then carried them to the power cables. They selected young leaves found around the terminal buds and avoided dried and partly dried old leaves. The study on 250 trips of males on power cables revealed that males brought fibres from sugarcane leaves in 241 trips, seven trips from Indian date palm, and two trips from narrow leaf cattail. The study on 250 trips of males on nest-supporting trees revealed that the males used fibres from Sugarcane (112 trips) and Indian date palm (138 trips) for the construction of nests. However, no instance of carrying fibre from narrow leaf cattail to nest-supporting trees was observed. This indicates that the birds used more fibres of sugarcane for the construction of nests on power cables, whereas more fibres of Indian date palm *were* used for the construction of nests on nest-supporting tees. Baya Weavers were found to have used leaves of *Phoenix* sp., coarse grass and paddy leave for the construction of nests in Kolaba district, Maharashtra (Ali 1931). In the present study, Baya Weavers used fibres from leaves of sugarcane, Indian date palm, and narrow leaf cattail, rather than fibres of grass, or paddy as observed by Wood (1926) and Ali (1931). The birds' preferential use of more fibres of Sugarcane on power cables and more fibres of Indian date palm on potential nest-supporting trees for the construction of nests require further studies.

Developmental stages of nests

In the present study, out of a total of 408 nests counted on power cables, various stages of nests included: wad stage nests—8.6% (n= 35), Ring stage—5.2% (n= 21), helmet stage nests—55.6% (n= 227), egg-chamber closed stage nests—12% (n= 49), 5.4% complete nests—5.4% (n= 22), and abnormal nests—13.2% (n= 54). An average of 16.3 nests/nest colony was found on power cables. Various stages of nest developments are given in Image 2 and Figure 3.

On 41 potential nest-supporting plants, various stages of nests included: wad stage nests—3.71% (n= 27), Ring stage—2.2% (n= 16), helmet stage nests—24.9% (n= 181), egg-chamber closed stage nests—25.7% (n= 187), complete nests—33.6% (n= 244), and abnormal nests—9.9% (n= 72). An average of 17.7 nests/nest colony was observed on nesting trees (Image 2). Since further development of helmet stage nests depends on pairing, it was presumed that after being paired with a female, active breeding occurs in egg-chamber

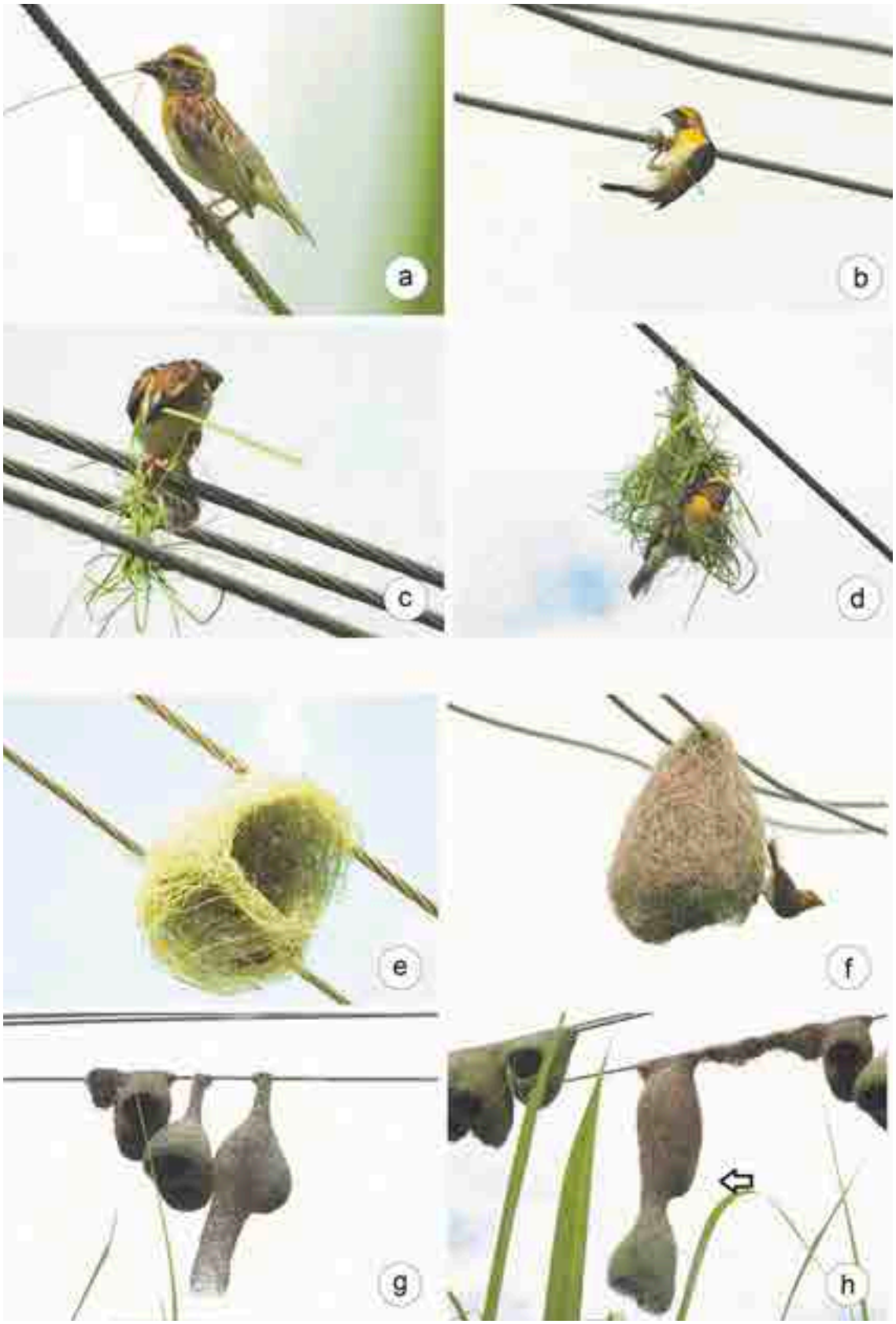


Image 2. Images showing various stages of nest developments: a—Male carries plant fibres | b—Male attempts to plait a knot | c—Male strengthens a knot | d—Ring stage nest | e—Helmet stage nest | f—Egg-chamber closed stage nest | g—Complete nest | h—An abnormal nest. © M. Pandian

closed stage nests and complete nests. Based on that assumption, active breeding would occur in 17.4 % of nests (n= 71) attached to power cables, whereas active breeding would occur in 59.3% of nests (n= 432) on potential nest-supporting trees. It indicates that a proportionately less number of active nests were found on power cables when compared to nest-supporting trees as both occur in the same vicinity, i.e., within 500 radii. Proportionately, reducing the number of active nests (egg-chamber closed & complete nests) attached to power cables than the potential nest-supporting trees in the same area during the same breeding period requires further studies.

Abnormal nests

Abnormal nests constituted 13.2% (n= 54) of the total nests (n= 408) and among them, 94.4% (n= 51) of abnormal nests were found overhanging sugarcane crops and the remaining 5.6% abnormal nests (n= 3) overhanging a Guava orchard, Foxtail millet crop, and narrow leaf cattail (Image 2h). Eight different types of abnormal nests were noticed: 35.2% (n= 19) abnormal nests belonged to 1+1/2 storeyed type, followed by 22.2% (n= 12) 1+1 storeyed type, 16.6% (n= 9) mixed abnormal types, 9.3% (n= 5) ½+½ storeyed, 7.4% (n= 4) fused nests, 5.6% (n= 3) ½+1 storeyed, one multi-stalked, and one chain-storeyed nest.

Some other species of the genus *Ploceus* also construct abnormal nests. Black-breasted Weaver *Ploceus benghalensis* constructs an abnormal entrance tube with more than 1-m length (Mishra 2004). Spectacled Weaver *Ploceus ocularis* constructs an abnormal entrance tube two meters in length in southern Africa (Maclean 1985). African Black-headed Weaver *Ploceus cucullatus* constructs kidney-shaped nests with abnormal supernumerary antechamber or with bottomless nests in Africa (Collias & Collias 1962). Southern Masked Weaver *Ploceus velatus* constructs one of the most abnormal nests among the weaver birds in South Africa, Angola, Zambia, and Mozambique. Streaked Weaver *Ploceus manyar* constructs abnormal nests with short entrance tubes in India and long entrance tubes in Java (Delacour 1947). Sakalava Weaver *Ploceus sakalava* constructs nests with shorter entrance tubes in the arid habitats and long entrance tubes in the other parts of Madagascar. In India, the abnormal nests of Baya Weaver were studied by Ali et al. (1956) and Ambedkar (1958, 1980) in Pune, Maharashtra, and Sharma (1985, 1988, 1995) in Rajasthan. Thirteen distinct types of abnormal nests were recorded in South Goa (Borkar & Komarpant 2003). Two-storeyed and three-storeyed types of nests were studied in Nanded, Maharashtra (Achegawe et al. 2016). Fifteen types of abnormal nests were recorded in Villupuram district, Tamil Nadu (Pandian 2018). But in the present study area, only eight different types of abnormal nests were observed on power cables.

Deposition of clay in the nests

The males have the habit of plastering wet clay on the inner walls of helmet stage nests, and such plastering of clay takes place immediately after the construction of helmet stage nests and before the arrival of females to select such nests. Observation on 240 helmet stage nests attached to power cables using binoculars revealed that clay deposits were found on 92.9% (n= 223) nests and the remaining 7.1% (n= 17) nests were free of clay deposits. It was not possible to view and ascertain clay deposits in the remaining 168 nests. Dissection of two fallen nests (helmet stage-1 and egg-chamber closed-1) revealed that patches of clay were observed on either side of the nests. No females were seen carrying wet clay to the nests.

Plastering of inner walls of the nest with wet clay is done when the nest construction reaches the helmet stage before pairing with females (Dewar 1909; Ali 1931; Ambedkar 1969; Borkar & Komarpant 2003). Wood (1926) had suggested that plastering of clay helps to stabilize the nest in strong winds. The mud on either side of the nest may stabilize the swinging nest in high winds (Crook 1963). He added that female was never found bringing mud. In the present study also, 7.1% (n= 17) helmet stage nests do not have clay deposits, and hence this matches with the findings of Davis (1974). The habits of smudging of clay in the nests were common in three species of Asian weavers (*P. manyar, P. benghalensis,* and *P. philippinus*) and not found in African Weaver (Crook 1963; Davis 1974). Hence, the observance of clay deposits in the present study corroborates the findings of the above authors. Davis (1973) had recorded that about 18.3% of nests did not show the presence of mud blobs on the inner walls of nests in South Goa. In the present study also 7.1% of nests did not show traces of clay and hence it matches with the observations of Davis (1974) (Image 3ab).

Fallen nests

A total of 285 nests in various developmental stages (wad stage-63, ring stage-48, helmet stage-86, egg-chamber closed stage-30, and complete nests-58) had fallen from the nest colonies, and were found scattered on the ground in sugarcane and other crop fields. Among the fallen nests, six complete nests contained 11

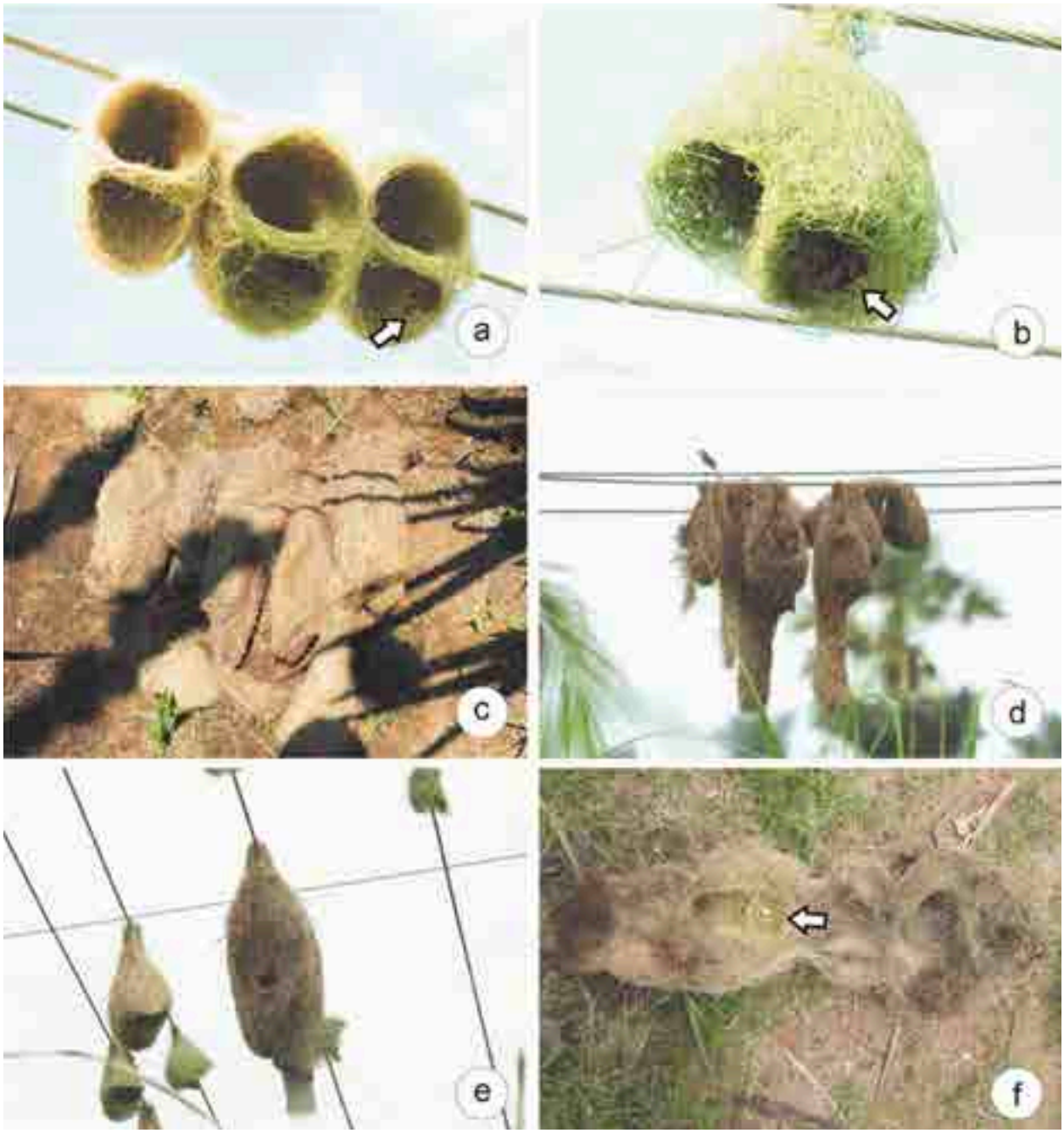


Image 3. Pictures showing clay deposits in helmet stage nests, fallen nests, and nest damage: a & b—Deposits of clay on the inner wall of helmet stage nests | c & d—Fallen nests | e—Damaged nests | f—Dissected fallen nests containing damaged egg. © M. Pandian

Table 3. Details of avian predators were observed in the vicinity of nesting colony in the study area.

	Name of the predator	No. of sightings noted	Damages caused to nests
1	House Crow	45	2
2	Large-billed Crow	21	5
3	Shikra	5	0
4	Rufous Treepie	6	1
	Total	77	8

damaged eggs (Image 3cf). Rivalry exists among males during the earlier stages of nest construction and some males had cut down the nests of other males in Poona City, Maharashtra (Ali et al. 1956). They also stated that many completed nests were blown down due to recurring spells of bad weather during June–August in the Bombay area causing mortality to nest colonies. Pandian (2021a) had recorded 458 fallen nests of various developmental stages under the nest-supporting plants in 26 villages

in Arakkonam taluk, Tamil Nadu due to various biotic and abiotic factors. A male Baya Weaver had cut down its nest by lacerating the stalk in Villupuram district (Pandian 2021b). Hence, the observations of 285 fallen nests in the study area might be due to various biotic/abiotic factors like slippery nature of aluminium cables, plaiting of weak knots, south-west monsoon, or cutting down of nests by rival male Baya Weavers as stated by Ali et al. (1956) and Pandian (2021a,b).

Predation threats

Opportunistic sightings of predatory birds, such as House Crow *Corvus splendens*, Large-billed Crow *Corvus macrorhynchos*, Rufous Treepie *Dendrocitta vagabunda*, and Shikra *Accipiter badius* were made in the vicinity of nest colonies attached to power cables during the study period. But no incident of predation of adult birds was observed. Whenever predators landed on nest-bearing power cables, all the birds deserted the nesting sites to roost on adjacent sugarcane crops or *Prosopis juliflora* trees. Eight incidents of nest damages by three avian predators, viz., House Crow, Large-billed Crow, and Rufous Treepie were observed during the study period. Rufous Treepie made puncture by creating a circular hole near the brood chamber of one complete nest and it was not possible to ascertain whether Rufous Treepie predated eggs/chicks or not (Image 3de). Among 408 nests, 32 nests (egg-chamber closed stage-9, complete nests-16, and abnormal nests-7) in the colonies were found damaged. Ali (1931) had stated that agitated behaviours of birds were observed when Crow Pheasants *Centropus sinensis* appeared in close proximity of nesting bearing trees in Kolaba district, Maharashtra, and also observed Shikra making an unsuccessful stoop on nest colony. In the present study also individuals of Baya Weaver had exhibited agitated behaviour when House Crows, Large-Billed Crow, Shikra, and Rufous Treepie visited nesting sites as stated by Ali (1931). Nest predation by the treepie was reported in Arakkonam Taluk, Tamil Nadu (Pandian 2021a). Hence, the present observation of agitated behaviour of birds when sighting avian predators and 32 damaged nests including a hole on the egg-chamber matches with the observations of Ali (1931) and Pandian (2021a) (Table 3).

CONCLUSION

This is the first systematic study on the preference of Baya Weaver towards power transmission cables as nesting substrata, stages of nests, abnormal nests, and probable threats to the nests on such cables in the study area. The survey revealed that Baya Weavers preferred electric cables and avoided readily available species of palms, such as *B. flabellifer*, *C. nucifera*, and *P. sylvestris* for nesting. Among the three palm species, the birds proportionately preferred *P. sylvestris* over the other two palms. However, this species seems to be in low availability in the study area. Hence it is suggested that planting more *P. sylvestris* and preventing felling the same can create more habitats for Baya Weavers. These three palms are an integral part of rural areas and they are also associated with rural cottage industries. Increasing urbanization by conversion of cultivated lands into residential areas, industrialization, widening of roads along with indiscriminate felling of these principal nest-supporting plants that are vital for Baya Weaver is a conservation issue in this landscape. The increasing practice of monoculture of *Casuarina*, sugarcane, vegetables, and flower crops, declining areas of cultivation of cereals and millets cause a shortage of food grains to adult birds. Destruction of viable nests due to various anthropogenic factors and abiotic factors (monsoon winds and rains) also causes severe stress on the breeding of Baya Weaver. They preferred power cables away from bunds/pathways in the croplands for the construction of nests probably to avoid any human disturbances. Abnormal nests constituted 13.2% of total nests and 92.9% of helmet stage nests contained clay depots on inner walls. House Crow, Large-billed Crow, and Rufous Treepie had damaged nests of Baya Weaver. The breeding period of this bird was found varied on power cables and potential nest-supporting trees. The survey is limited to 10 villages, but this is part of a larger geographical area that has a potential for a high nesting population of Baya Weaver which, however, faces threats from the changing rural landscape. Local communities, particularly landholders, agricultural workers, and school students should be sensitized to understand the need to preserve the populations of this species.

REFERENCES

Ali, S. (1931). The nesting habits of the Baya (*Ploceus philippinus*). *Journal of the Bombay Natural History Society* 4(4): 947–964.

Ali, S. & V.C. Ambedkar (1956). Notes on the Baya Weaver Bird *Ploceus philippinus* Linn. *Journal of the Bombay Natural History Society* 53: 381–389.

Ali, S., Vijayakumar & C.V. Ambedkar (1956). Notes on the Baya weaver Bird. *Journal of the Bombay Natural History Society* 53: 381–389.

Ali, S. & S.D. Ripley (1987). Birds of India and Pakistan. Oxford University Press, New Delhi, 737 pp.

Ambedkar, V.C. (1958). Notes on the Baya breeding season. *Journal of*

the Bombay Natural History Society 55(1): 100–106.

Ambedkar, V.C. (1964). Some Indian weaver birds: a contribution to their breeding biology, University of Bombay, Bombay.

Ambedkar, V.C. (1969). Notes on the Baya, " *Ploceus philippinus*" (Linnaeus) on telegraph wires. *Journal of the Bombay Natural History Society* 66(3): 624.

Ambedkar, V.C. (1980). Abnormal nests of the Baya Weaver Bird *Ploceus philippinus* (Linn.). *Journal of the Bombay Natural History Society* 75(supplement): 1205–1211.

BirdLife International (2016). *Ploceus philippinus*: The red list of threatened species. Accessed on 05 August 2021. https://doi.org/10.2305/IUCN-UK.2016-3.RLTS.T22719005A94606190.en

Blyth (1845). Notices and descriptions of various new or little known species of birds. *Journal of the Asiatic Society of Bengal*. Vol. XIV, Part-II, Bishop's College Press, Calcutta, 553 pp.

Borkar, M.R. & N. Komarpant (2003). Observations on the nesting ecology of Baya Weaver bird (*Ploceus philippinus* Linn.) in South Goa, with notes on aberrant nest designs. *Ecology, Environment and Conservation* 9(2): 217–227.

Chace, J.F. & J.J. Welsh (2006). Urban efforts on native avifauna: a review. *Landscape Urban Plane* 74: 46–99.

Collias, N.E. & E.C. Collias (1962). An experimental study of the mechanisms of nest building in a weaverbird. *The Auk* 79: 568–595.

Craig, A.J.F.K. (2010). Family Ploceidae (Weavers), pp. 73–197. In del Hoyo, J., A. Elliott & D.A. Christie (eds). *Handbook of the Birds of the World Warblers*. Lynx Edicions, Barcelona, Spain.

Crook, J.H. (1963). A Comparative Analysis of Nest Structure in the Weaver Birds (Ploceinae). *Ibis* 105: 238–262.

Crook, J.H (1964). Field experiments on the nest construction and repair behavior of certainWeaver birds. *Proceedings of the Zoological Society*, London 142: 217–255.

Dawar, T.A. (1974). Selection of nesting trees and the frequency of nest visits by Baya Weaver birds. *Journal of the Bombay Natural History Society* 71(3): 356–366.

Delacour, J. (1947). *Birds of Malasia*. The Macmillan Company, New York, 382 pp.

Devas, D. (1909). The nesting habits of Baya. *Journal of the Bombay Natural History Society* 19(3): 627–634.

Gill, F & D. Donsker (2010). Old World Sparrows, snow finches, weavers. World bird list version 8.2. International Ornithologists Union. Accessed on 22 January 2022.

Kirkpatrick, K.M. (1952). Baya (*Ploceus philippinus* Linnaeus) nests on telegraph wires. *Journal of the Bombay Natural History Society* 52: 657.

Maclean, G.L. (1985). Roberts' Birds of Southern Africa, Cape Town: John Voelter Bird Book Fund.

Mathew, D.N. (1971). Ecology and biology of the Baya Weaver Bird *Ploceus philippinus*. Ph.D. Dissertation, University of Bombay, Bombay.

Mathew, G. (1977). A Sporadic Bird Pest, *Ploceus philippinus* (Linnaeus) attacking paddy plants at Mannuthy, Kerala. *Research Journal of Kerala* 15(1): 96.

Mishra, N. (2004). Abnormal nest of the Black-breasted weaver *Ploceus benghalensis*. *Newsletter for Ornithologists* 1(3): 45.

Pandian, M. (2018). Baya Weaver Bird: Nest colonies and abnormal nests of *Ploceus philippinus* in Tindivanam Taluk, Villupuram District, Tamil Nadu, India. Bird-o-Soar 24. In: *Zoo's Print* 33(12): 15—27.

Pandian, M. (2021a). Nesting habits of Baya Weaver *Ploceus philippinus* (Linnaeus, 1776) in rural Arakkonam Taluk, Vellore district, Tamil Nadu, India. *Journal of the Bombay Natural History Society* 118: 03—17.

Pandian, M. (2021b). Incidences of White-rumped Munia occupying the nest of Baya Weaver in Villupuram District, Tamil Nadu. Bird-o-soar 65, In: *Zoo's Print* 36 (1): 07–09.

Rasmussen, P.C. & J.C. Anderton (2005). The Birds of South Asia: The Ripley Guide, 2 Volumes, Smithsonian Institute, Washington, D. C. & Lynx Edicions, Barcelona.

Sharma, S.K. (1985). A study on qualitative aspects of abnormal nesting in Baya WeaverBird *Ploceus philippinus* Linn. *Journal of the Bombay Natural History Society* 60: 50–54.

Sharma, S.K. (1988). Buttressed nest of Baya Weaver Bird *Ploceus philippinus* (Linn.). *Journal of the Bombay Natural History Society* 85(2): 432.

Sharma, S.K. (1989). Host plants used by Baya Weaver Bird *Ploceus philippinus* (L.) for nesting
in Udaipur district, Rajasthan. *Journal of the Bombay Natural History Society* 86: 453–454.

Sharma, S.K. (1991). Nests of Baya Weaver Birds *Ploceus philippinus* and wintering
Arthropods. *Journal of the Bombay Natural History Society* 88(2): 289 –290.

Sharma, S.K. (1995). A study of abnormal nests of Baya Weaver bird *Ploceus philippinus* (L.) in
Rajasthan. *Journal of the Bombay Natural History Society* 92: 1205–1211.

Subramanya, S. (1982). Baya nests on telegraph wires *Newsletter for Birdwatchers* 22(6): 3–4.

Toland, B. (1990). Use of power poles for nesting by Red-Tailed Hawks in SC Florida. *Florida Field Naturalist* 18: 52–55.

Wood, C.A. (1926). The nest of the Baya Weaver bird. *The Auk* 43(3): 295—302.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20733–20739

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

https://doi.org/10.11609/jott.7575.14.3.20733-20739

#7575 | Received 16 July 2021 | Final received 09 March 2022 | Finally accepted 12 March 2022

OPEN ACCESS

COMMUNICATION

Status and distribution of Mugger Crocodile *Crocodylus palustris* in the southern stretch of river Cauvery in Melagiris, India

Rahul Gour [1], Nikhil Whitaker [2] & Ajay Kartik [3]

[1] Kenneth Anderson Nature Society, No.9/2, HCF Post, Mathigiri, Hosur, Tamil Nadu 635110, India.
[1] Department of Ecology & Environmental Sciences, School of Life Sciences, Pondicherry University, Puducherry 605014, India.
[2,3] Madras Crocodile Bank Trust and Centre for Herpetology, 4, Mamallapuram, Tamil Nadu 603104, India.
[1] rahulkgour@gmail.com (corresponding author), [2] nikhil@madrascrocodilebank.org, [3] ajaykartik88@gmail.com

Abstract: A study was conducted to examine the population estimate and spatial distribution of Mugger Crocodile in the southern stretch of river Cauvery, Hosur Forest Division from February 2019 to May 2019. In total, 53 basking sites and 45 Muggers were encountered by direct sighting in the 24-km river stretch using daytime ground based survey approach. N-mixture models estimated an average Mugger density of 2.05 individuals per kilometre for daytime survey. A night spotlight survey across the seven segments of river stretch was also conducted which yielded direct sightings of 54 Muggers with an average encounter rate of 2.25 individuals per kilometre. Two crocodile nests with hatched egg shells were also observed on the sand banks of the river. We concluded that a potential healthy and breeding population of Mugger inhabits the studied stretch of the river. Multiple corresponding analysis was also performed, which demonstrated that Mugger responds to sandy banks alongside deep water pools for basking in contrast to river segments with shallow depth and dense riparian cover.

Keywords: Basking sites, conservation, Hosur Forest Division, nest, night spotlight survey, N-mixture models.

Editor: Raju Vyas, Vadodara, Gujarat, India.

Date of publication: 26 March 2022 (online & print)

Citation: Gour, R., N. Whitaker & A. Kartik (2022). Status and distribution of Mugger Crocodile *Crocodylus palustris* in the southern stretch of river Cauvery in Melagiris, India. *Journal of Threatened Taxa* 14(3): 20733–20739. https://doi.org/10.11609/jott.7575.14.3.20733-20739

Funding: The present work received no external funding.

Competing interests: The authors declare no competing interests.

Author details: Rahul Gour recently graduated from Pondicherry University with a master's degree in ecology and environmental sciences. He has associated with Kenneth Anderson Nature Society on various conservation projects in Melagiris. He is particularly interested in learning about the behavioural ecology of reptiles and megafauna. Nikhil Whitaker is a curator at the Madras Crocodile Bank Trust and Centre for Herpetology. He has studied environmental science and wildlife management at Charles Darwin University in Australia. An editor at journals including Taprobanica, Journal of Contemporary Herpetology, and Herpetological Review, and a member of the IUCN/SSC Crocodile Specialist group and Tortoise and Freshwater Turtle Specialist Group. Ajay Kartik is a herpetologist with a keen interest in the behavioural ecology of reptiles. He has worked with diverse species across several landscapes of India and is an invited member of the IUCN/SSC Crocodile Specialist group and Tortoise and Freshwater Turtle Specialist Group.

Authors contribution: RG—contributed to the fieldwork and manuscript writing; NW—contributed to the work design, technical guidance and review of the manuscript; AJ—contributed to the field support and review of the manuscript.

Acknowledgements: On behalf of Kenneth Anderson Nature Society and Madras Crocodile Bank Trust and Centre for Herpetology, we thank Mr. Deepak Bilgee IFS, district forest officer, Hosur Forest Division, Tamil Nadu Forest Department for granting necessary permissions and supporting us during the course of this study. We are thankful to the range forest officers and field staff of Anchetty and Urigam ranges for helping us conduct the surveys. We thank Arvind Adhi, Laxmeesha Acharya, Prem Kumar Aparanji, Prasanna Vyanatheya, and Jason Gerard for leading multiple surveys during the course of the study. We also thank the students of College of Forestry, Kerala and members of Kenneth Anderson Nature Society for volunteering for the surveys. We are also thankful to George Tom for helping with the illustrations (Image 2 & 3) and reviewing an early draft of this paper.

INTRODUCTION

The Marsh or Mugger Crocodile *Crocodylus palustris* (Lesson, 1831) (Image 1), is an apex predator and can be found in different forms of freshwater environment including rivers, ponds, reservoirs, marshes, and also inhabits estuarine habitats (Whitaker 1987; Whitaker & Whitaker 1989). Its range extends from southern Iran to the Indian subcontinent and is one of the most adaptable crocodilian species in India (Da Silva & Lenin 2010). The Mugger is legally protected in India under Schedule I of the Wildlife Protection Act, 1972, and categorized as 'Vulnerable' under the IUCN Red List of Threatened Species (Choudhury & De Silva 2013). Awareness about crocodile distribution and the ecosystem services provided by them is essential to better conserve the species and their habitats. An increasing number of studies have focused on the distribution of Mugger in various parts of India (Rao & Choudhury 1993; Singh 1999; Vyas 2012). Here we present the distribution and population status of Muggers in the small stretch of Cauvery river that runs through dense riparian forests of Tamil Nadu and Karnataka.

MATERIALS AND METHODS

Study site

Cauvery (also known as Kaveri) is a perennial river that originates in the Brahmagiri range of the Western Ghats, Karnataka. The river enters Tamil Nadu through the Hosur Forest Division in Krishnagiri district leading to the flat plains where it meanders. A continuous river stretch of 24 km was chosen to conduct the survey starting from Dabaguli (12.205N, 77.545E) upstream to Moslaemaduvu (12.149N, 77.748E) downstream (Figure 1). The region comes under the Melagiri Hill ranges which is an important wildlife habitat between the Western and Eastern Ghats (Daniel & Ishwar 1994; Tiwari & Kaliamoorthy 2018). This region has a semi-arid climate. The average temperature during winter reaches a minimum of 16°C and a maximum of 40°C during summer. It receives rainfall mainly during the north-east monsoon (October–December) and low rainfall from south-west monsoon (June–September), which ranges 750–800 mm (Shenoy et al. 2006). The study section of the river flows through valleys and forests, with the Cauvery Wildlife Sanctuary, Karnataka in the south and the dense reserve forests under Hosur Forest Division, Tamil Nadu in the north. Vegetation along the river section mainly consists of dry deciduous forest and southern tropical dry thorn riverine forests (Baskaran et al. 2011).

Method

The entire survey which included reconnaissance and preliminary surveys followed by replication surveys for daytime and night spotlight surveys, were conducted over the course of four months (February–May 2019) during the dry season.

Reconnaissance and preliminary survey: These surveys were carried out over the 24-km river stretch to explore site characteristics and to collect adequate data for planning and survey design.

Daytime survey: The 24-km stretch of the river was divided into seven segments (Table 1) that served as seven different sites for temporal replicated surveys. Out of the 24-km of total river section, a 4.2-km segment was not surveyed due to insufficient water level in the river to row the coracle (a small, rounded lightweight boat) and lack of accessibility for the survey team to walk due to dense thorn forest along the river. Hence, the survey was carried out at the remaining six replicated sites (six river segments). Each site was surveyed on five occasions. The daylight survey was taken place with a minimum of seven days and a maximum of 10 days' time space between each survey occasion. The surveys were carried out on foot along the river and by rowing coracle where riverbanks are inaccessible on foot. Teams of two to three observers recorded direct basking counts during maximum basking activity times, 0700–1000 h and 1500–1800 h (Venugopal & Prasad 2003). The survey team also searched for potential nests and nesting activities such as digging, presence of eggs or shells along the river banks. The locations of direct and indirect signs (scat,

Image 1. Mugger Crocodile *Crocodylus palustris*.

Figure 1. Cauvery river section (red box in inset map of India) where the study took place during February–May 2019.

spoor, basking and nest sites) of Muggers were recorded by using a GPS instrument (Garmin eTrex 20x). Animals were observed with Olympus binocular (10 x 50) and wherever possible images of Mugger and their habitat were recorded using a digital camera. The number of individuals detected in a given site were counted using standard monitoring techniques.

Spotlight survey: After completion of daytime replicated surveys, the same six sites (river segments) were used for conducting a night spotlight survey using coracles. All the six sites were surveyed at the same time by six different survey teams. Available spotlight survey procedure was carried out to perform night surveys (Messel et al. 1981; Bayliss 1987; Lentic & Connors 2006). At each segment of the river, all coracles were operated between 2000 h and 2300 h. Coracles were operated at about 2 m from and parallel to the shoreline, and one observer was stationed at the front in each coracle in addition to a fellow observer to record the data. A speed of 5–8 km/hr was maintained. A high-powered (1000+ lumen) searchlight was used by the observer during the survey, which produced a readily detectable eye shine up to a distance of approximately 100 m. When an eye shine was spotted, the Mugger was approached closer to obtain a size estimate. We assigned four size classes to the Muggers based on Andrews (1999): hatchlings (<0.5 m TL), small/juveniles (0.5–1.0 m TL), medium/subadults (1.0–1.5 m TL), and large/adults (>1.5 m TL). Unknown size classes when only eye shine was visible were categorized as eyes only (EO).

Measure of abundance: Appropriate measure of abundance was chosen instead of a total population count as not all mugger crocodiles present in the area were observed for the each survey. For the daytime survey, N-mixture models were employed to estimate abundance based on repeated counts in a given site (Royle 2004; Dail & Madsen 2011). Since capture and manipulating of individuals are not required in N-mixture models and they also allow collecting abundance information over larger areas compared to traditional techniques (Kéry et al. 2009; Griffiths et al. 2015). The lengths of the river segments (sites) were considered as a site level covariate, and the sampling hours were considered as observational covariates which were recorded during each survey occasion for each site. We used R package 'unmarked' for N-mixture modelling to estimate abundance (Fiske & Chandler 2011). However, because the night spotlight survey was conducted only once at all sites, we considered the total spotted individuals as a relative index of abundance for night spotlight survey (Bayliss 1987; Cherkiss et al. 2006; Fukuda et al. 2012).

Association and correlation: Multiple correspondence analysis (MCA) was carried out to measure the association among the habitat features and occurrence of Muggers. It is an adaptation of corresponding analysis to a data table containing more than two categorical variables (Greenacre & Blasius 2006). MCA can also

be seen as a generalisation of principal component analysis (PCA) when the variables to be analysed are categorical instead of quantitative (Abdi & Williams 2010). We specifically selected 10 categorical variables which were most dominant habitat features found in each river segment during the daytime surveys. We used R packages 'FactoMineR' for the MCA analysis and 'factoextra' for ggplot2-based visualization (Le et al. 2008; Wickham 2009; Kassambara & Mundt 2020).

All the map layouts were created using QGIS and Google Earth. Abundance and association measurements were carried out using open source software R v3.6.2 (R Core Team 2021).

RESULTS

We found 53 potential basking sites along the river section based on the frequent and numerous indirect signs, mainly spoors. During five repeated counts, we encountered a total of 45 Mugger Crocodiles by direct sighting which includes 12 adults (>1.5 m TL), nine sub-adults (1.0–1.5 m TL), 15 juveniles (0.5–1.0 m TL), and nine without any concrete size estimate. In N-mixture models, we selected the model with Poisson error, as it showed AIC values lower than the respective zero-inflated Poisson (ZIP) model (86.97 vs. 88.98). Assuming homogeneous density in the survey area, N-mixture models estimated an average mugger crocodile density of 2.05 individuals per kilometre. During daytime ground based surveys two nests were also observed very close to the riverbank on the sandy substrate (Image 2). At

Table 1. Type of association observed for Mugger Crocodiles with respect to the habitat.

River segment	Segment length (km)	Topography	Habitat type	Type of association*
Dabaguli–Dolamathi	3.6	Semi-boulders, mud and sparse riparian cover	Runs, pools and cascades	+
Dolamathi–Uganiyam	2.7	Boulders, semi boulders, sand, leaf litter, and riparian cover	Runs, pools and riffles	+
Uganiyam–Thumbaguli	3.7	Semi-boulders, Sand, and sparse riparian cover	Runs, pools and riffles	–
Thumbaguli–Upstream Raasimanal (Unsurveyed segment)	4.2	Boulders, bed rock, leaf litter, and dense riparian cover	Shallow river depth with cascades and rapids	NA
Upstream–Raasimanal	1.7	Semi-boulders, bed rock, mud, and riparian cover	Runs, pools and riffles	+
Raasimanal–Biligundlu	5.7	Semi-boulders, sand, mud, leaf litter, and dense riparian cover	Shallow river depth with runs and riffles	–
Biligundlu–Moslaemaduvu	2.4	Boulders, semi-boulders, mud, and less riparian cover	Runs, pools and cascades	+
Total	**24**			

'+' shows positive and '–' shows negative association

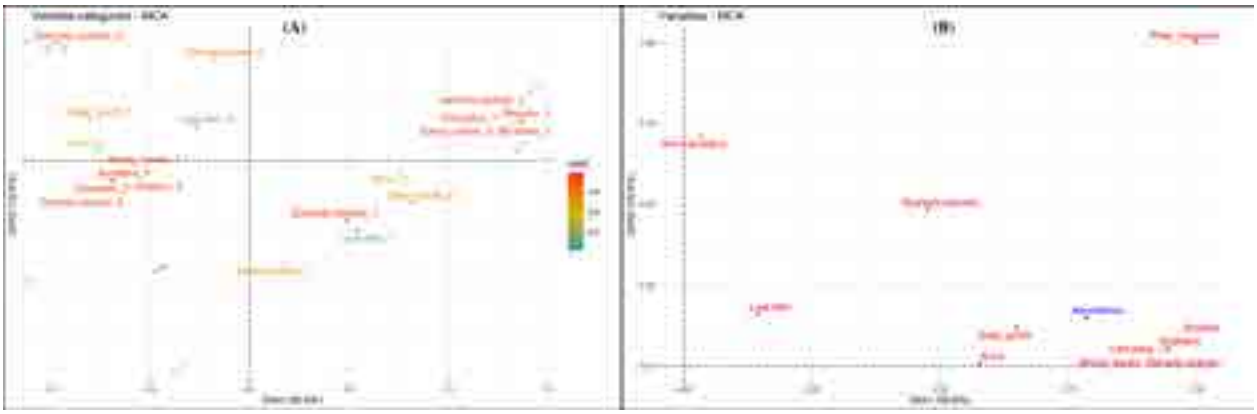


Figure 2. A—Quality of representation (squared cosine – cos²) showing the degree of association between variable categories | B—Correlation between variables and MCA principal dimensions.

Image 2. Spatial distribution of direct and indirect sightings of Mugger Crocodiles with the nesting sites recorded during day time survey.

Image 3. Spatial distribution of Mugger Crocodiles during night time spotlight survey.

the first nest, 13 empty eggshells, of which two had failed to hatch were observed. Near the first nest, three hatchlings (<0.5 m TL) were also observed in water and at the second nest, 11 freshly hatched eggs shells, and five hatchlings with an adult crocodile were spotted in the river. It should be borne in mind that all the available nests in the study site are not represented in our nesting observations, as search effort for nests was not standardized among the river section and observers.

Night spotlight survey yielded direct sightings of 54 Muggers which includes 14 adults, seven sub-adults, five juveniles, and 28 with eyes only (EO) recorded in the targeted river section (Image 3). A relative abundance of 2.25 individuals per kilometre was obtained during

spotlight survey, comparatively higher than the daytime survey. We also observed the basking banks with deep-water river segments as the key determinant explaining the relatively high occurrences of mugger crocodiles. MCA biplots also displayed greater squared cosine values for deep pools, sandy banks and runs which shows the higher quality of representation (Figure 2A). And while comparing the river segments with shallow depth and dense riparian cover, the availability of sandy banks for basking alongside deep water pools revealed a substantially higher abundance as shown in Figure 2B, which also complemented with our field observations.

In addition to Muggers various other threatened species like Smooth-coated Otter *Lutrogale perspicillata*, Leith's Softshell Turtle *Nilssonia leithii*, Asian Elephant *Elephas maximus*, Sloth Bear *Melursus ursinus*, and Lesser Fish Eagle *Icthyophaga humilis* were also observed a few occasions in the study area. Most of the river stretch was facing unrestricted fishing pressure. Human activities and livestock along the river stretch appeared to negatively influence the use of areas by Muggers. During the entire study period, no crocodile attacks were observed.

DISCUSSION

The present study with successful nesting and hatching records suggested the presence of a potential breeding population of Mugger along the targeted stretch of the river. It also demonstrated that Muggers preferred river sections with a wider width and greater depth while avoiding shallow regions with high rapids. Spotlight survey was found to be more effective out of the two survey strategies adopted in this study, yet the detection probability of hatchlings/ yearlings and animals resting in vegetation along the riverbank reduced significantly when compared with the daylight surveys (Woodward & Marion 1978; Bayliss 1987). However, the study shows that the spotlight survey can be an effective tool for monitoring crocodilian populations over the long term (Messel et al. 1981; Hutton & Woolhouse 1989; Webb et al. 2000; Fujisaki et al. 2011; Fukuda et al. 2012). It is expected that more systematic surveys will detect more populations across the Cauvery river ecosystem. An earlier study by Whitaker & Andrews (2003) also showed a stable population of Muggers in upper region (around 150 km upstream from the present study site) of river Cauvery in Ranganathittu Bird Sanctuary, Karnataka. A systematic multiscale study of Muggers, associated species, and their habitat in the entire stretch of river will yield valuable information regarding the population dynamics and ecology of the species in the Cauvery river ecosystem. There is also a need to have local awareness campaigns focusing on the vulnerability and ecological values of crocodiles (Brito et al. 2011).

REFERENCES

Abdi, H. & L.J. Williams (2010). Principal Component Analysis. *Wiley Interdisciplinary Reviews: Computational Statistics* 2: 433–459.

Andrews, H.V. (1999). Status and Distribution of the Mugger Crocodile in Tamil Nadu. *ENVIS Bulletin: Wildlife & Protected Areas* 2(1): 38–43.

Baskaran, N., K. Senthilkumar & M. Saravanan (2011). A new site record of the Grizzled Giant Squirrel *Ratufa macroura* (Pennant, 1769) in the Hosur forest division, Eastern Ghats, India and its conservation significance. *Journal of Threatened Taxa* 3(6): 1837–1841. https://doi.org/10.11609/jott.o2632

Bayliss, P. (1987). Survey methods and monitoring within crocodile management programmes, pp. 157–175. In: Webb, G.J.W., S.C. Manolis & P.J. Whitehead (eds.). *Wildlife Management: Crocodiles and Alligators*. Surrey Beatty and Sons Pty, Sydney.

Brito, J.C., F. Martínez-Freiría, P. Sierra, N. Sillero & P. Tarroso (2011). Crocodiles in the Sahara Desert: An Update of Distribution, Habitats and Population Status for Conservation Planning in Mauritania. *PloS ONE* 6(2): e14734. https://doi.org/10.1371/journal.pone.0014734

Cherkiss, M.S., F.J. Mazzotti & K.G. Rice (2006). Effects of shoreline vegetation on visibility of American crocodiles (*Crocodylus acutus*) during spotlight surveys. *Herpetological Review* 37(1): 37–40.

Choudhury, B.C. & A. de Silva (2013). *Crocodylus palustris*. 2013 IUCN Red List of Threatened Species: e.T5667A3046723. Downloaded on 14 July 2021. https://doi.org/10.2305/IUCN.UK.2013-2.RLTS.T5667A3046723.en

Da Silva, A. & J. Lenin (2010). Mugger Crocodile *Crocodylus palustris*. In: Manolis S.C. & C. Stevenson (eds.). *Crocodiles. Status Survey and Conservation Action Plan*. 3rd Edition. Crocodile Specialist Group, Darwin, Australia.

Dail, D. & L. Madsen (2011). Models for estimating abundance from repeated counts of an open metapopulation. *Biometrics* 67: 577–587. https://doi.org/10.1111/j.1541-0420.2010.01465.x

Daniels, R.J.R. & N.M. Ishwar (1994). Rarity and the herpetofauna of the Southern Eastern Ghats, India. *Cobra* 16: 2–14.

Fiske, I. & R. Chandler (2011). unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance. *Journal of Statistical Software* 43(10): 1–23. http://www.jstatsoft.org/v43/i10/

Fujisaki, I., F.J. Mazzotti, R.M. Dorazio, K.G. Rice, M. Cherkiss & B. Jeffery (2011). Estimating trends in alligator populations from nightlight survey data. *Wetlands* 31: 147–155. https://doi.org/10.1007/s13157-010-0120-0

Fukuda, Y., W. Saalfeld, G. Webb, C. Manolis & R. Risk (2012). Standardised method of spotlight surveys for crocodiles in the tidal rivers of the Northern Territory, Australia. *Northern Territory Naturalist* 24(1): 14–32.

Greenacre, M. & J. Blasius (eds.) (2006). *Multiple Correspondence Analysis and Related Methods*. Chapman and Hall/CRC, New York, 354pp. https://doi.org/10.1201/9781420011319

Griffiths, R.A., J. Foster, J.W. Wilkinson & D. Sewell (2015). Science, statistics and surveys: a herpetological perspective. *Journal of Applied Ecology* 52: 1413–1417. https://doi.org/10.1111/1365-2664.12463

Hutton, J.M. & M.E.J. Woolhouse (1989). Mark-recapture to assess factors affecting the proportion of a Nile crocodile population seen during spotlight counts at Ngezi, Zimbabwe, and the use of spotlight counts to monitor crocodile abundance. *Journal of Applied Ecology*

26(2): 381–395. https://doi.org/10.2307/2404068

Kassambara, A. & F. Mundt (2020). factoextra: Extract and Visualize the Results of Multivariate Data Analyses. R package version 1.0.7.

Kéry, M., R.M. Dorazio, L. Soldaat, A. Van Strien, A. Zuiderwijk, & J.A. Royle (2009). Trend estimation in populations with imperfect detection. *Journal of Applied Ecology* 46: 1163–1172. https://doi.org/10.1111/j.1365-2664.2009.01724.x

Lentic, M. & G. Connors (2006). Changes in the distribution and abundance of saltwater crocodiles (*Crocodylus porosus*) in the upstream, freshwater reaches of rivers in the Northern Territory, Australia. *Wildlife Research* 33(7): 529–538. https://doi.org/10.1071/WR05090

Le, S., J. Josse & F. Husson (2008). FactoMineR: An R Package for Multivariate Analysis. *Journal of Statistical Software* 25(1): 1–18.

Messel, H., G.C. Vorlicek, A.G. Wells & W.J. Green (1981). *Surveys of Tidal River Systems in the Northern Territory of Australia and their Crocodile Populations*. Monograph: Volume 1. The Blyth-Cadell River Systems Study and the Status of *Crocodylus porosus* in Tidal Waterways of Northern Australia. Methods for Analysis, and Dynamics of a Population of *C. porosus*. Pergamon Press, Sydney.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rao, R.J. & B.C. Choudhury (1993). Sympatric distribution of Gharial *Gavialis gangeticus* and Mugger *Crocodylus palustris* in India. *Journal of the Bombay Natural History Society* 89(3): 312–315.

Royle, J.A. (2004). N-mixture models for estimating population size from spatially replicated counts. *Biometrics* 60: 108–115.

Shenoy, K., S. Varma & K.V.D. Prasad (2006). Factors determining habitat choice of the smooth-coated otter, *Lutra perspicillata* in a South Indian river system. *Current Science* 91(5): 637–643.

Singh, L.A.K. (1999). Significance and achievements of the Indian Crocodile Conservation Project. *ENVIS Bulletin: Wildlife & Protected Areas* 2(1): 10–16.

Tiwari, U. & R. Kaliamoorthy (2018). Floristic Diversity and Vegetation Analysis of Plants from Various Forest Types in Hosur Forest Division, Tamil Nadu, Southern India. *Notulae Scientia Biologicae* 10(4): 597–606.

Venugopal, D. & K.V.D. Prasad (2003). Basking Behavior and Survey of Marsh Crocodiles *Crocodylus palustris* in Ranganthittu Bird Sanctuary, Karnataka, India. *Hamadryad* 27(2): 241–247.

Vyas, R. (2012). Current status of Marsh Crocodiles *Crocodylus palustris* (Reptilia: Crocodylidae) in Vishwamitri River, Vadodara City, Gujarat, India. *Journal of Threatened Taxa* 4(14): 3333–3341. https://doi.org/10.11609/jott.o2977

Webb, G.J.W., A.R.C. Britton, S.C. Manolis, B. Ottley & S. Stirrat (2000). The recovery of Crocodylus porosus in the Northern Territory of Australia: 1971–1998, pp. 195–234. In: Crocodiles. Proceedings of the 15th Working Meeting of the IUCN-SSC Crocodile Specialist Group, IUCN, Gland, Switzerland.

Whitaker, R. (1987). The management of crocodilians in India, pp. 63–72. In: Webb, G.J.W., S.C. Manolis & P.J. Whitehead (eds.). *Wildlife Management: Crocodiles and Alligators*. Surrey Beatty and Sons Pty, Sydney.

Whitaker, R. & H.V. Andrews (2003). Crocodile conservation, aestern Asia region: An update. *Journal of the Bombay Natural History Society* 100: 432–445.

Whitaker, R. & Z. Whitaker (1989). Ecology of Mugger Crocodile, pp. 276–297. In: *Crocodiles. Their Ecology, Management and Conservation*. Crocodile Specialist Group. IUCN, Gland, Switzerland.

Wickham, H. (2009). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

Woodward, A.R. & W.R. Marion (1978). An evaluation of factors affecting night-light counts of alligators. Proceedings of the Annual Conference South eastern Association Fish and Wildlife Agencies 32: 291–302.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20740–20746

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

https://doi.org/10.11609/jott.7306.14.3.20740-20746

#7306 | Received 05 April 2021 | Final received 29 November 2021 | Finally accepted 13 January 2022

OPEN ACCESS

COMMUNICATION

Dragonflies and damselflies (Insecta: Odonata) of Jabalpur, Madhya Pradesh, India

Ashish Tiple [1], Vivek Sharma [2] & Sonali V. Padwad [3]

[1] P.G. Department of Zoology, Vidyabharti College, Seloo, Wardha, Maharashtra 442104, India.
[2] Departments of Zoology, Govt. Model Science College, Jabalpur, Madhya Pradesh 482003, India.
[3] B1/8 Savitri Vihar, Somalwada, Wardha Road Nagpur, Maharshtra 440025, India.
[1] ashishdtiple@gmail.com (corresponding author), [2] vrks1007@gmail.com, [3] sonalipadwad@yahoo.co.in

Abstract: The present study was carried out to reveal the odonate diversity in Jabalpur city and its surrounding area in Madhya Pradesh, central India. During the study period of 2008–2019 a total of 75 species of odonates belonging to two suborders and nine families were recorded. Twenty-one new species were recorded for Jabalpur district and four for Madhya Pradesh; 37% (28) species were abundant or very common, 19% (14) were common, 16% (12) were frequent, 24% (18) rare, and 4% (3) very rare. The maximum number of odonates were found in family Libellulidae (n= 32), followed by Coenagrionidae (n= 17), Gomphidae (n= 09), Platycenemididae (n= 06), Aeshnidae (n= 05), Lestidae (n= 03), Macromiidae (n= 02), and Chlorocyphidae (n= 01). Of 75 species recorded from Jabalpur city, 72 come under the IUCN Red List. Among them, *Indothemis carnatica* come under Near Threatened (NT) category, 65 species come under Least Concern (LC) Category, six species under Data Deficient (DD), and three species remain not assessed. The study supports the value of the city area in providing habitat for Odonata.

Keywords: Central India, checklist, conservation, distributional gaps, diversity, habitat, IUCN Red List, new records, Odonata.

वर्तमान अध्ययन मध्य भारत के मध्य प्रदेश में जबलपुर शहर और इसके आसपास के क्षेत्र में ओडोनेट विविधता को प्रकट करने के लिए किया गया था।2008-2019 की अध्ययन अवधि के दौरान दो उपसमूहों और नौ परिवारों से संबंधित ओडोनेट्स की कुल 75 प्रजातियों को दर्ज किया गया था।जबलपुर जिले के लिए इक्कीस और मध्य प्रदेश के लिए चार नई प्रजातियां दर्ज की गईं; 37% (28) प्रजातियां प्रचुर या बहुत आम थीं, 19% (14) आम थीं, 16% (12) अक्सर दिखाई देने वाली, 24% (18) दुर्लभ और 4% (3) अति दुर्लभ थीं।लिबेलुलिडे (संख्या=32) परिवार में ओडोनेट्स की अधिकतम संख्या पाई गई, उसके बाद अन्य परिवार जिनमें प्रजातियाँ दर्ज की गई वे संख्या के क्रमांक में इस प्रकार हैं- कोएनाग्रियोनिडे (संख्या=17), गोम्फिडे (संख्या=09), प्लैटीसीनेमिडीडे (संख्या=06), एशनिडे (संख्या=05), लेस्टिडे (संख्या=03), मैक्रोमिडी (संख्या=02), और क्लोरोसाइफिडे (संख्या=01)। जबलपुर शहर से दर्ज 75 प्रजातियों में से 72 आईयूसीएन रेड लिस्ट में आती हैं।उनमें से, इंडोथेमिस कार्नाटिका नियर थ्रेटंड (एनटी) श्रेणी के अंतर्गत आती है, 65 प्रजातियां लीस्ट कंसर्न (एलसी) श्रेणी के अंतर्गत आती हैं, छह प्रजातियां डेटा डेफिसिएंट (डीडी) के अंतर्गत आती हैं, और तीन प्रजातियों का मूल्यांकन नहीं किया जाता है।प्रस्तुत अध्ययन ओडोनाटा के लिए आवास प्रदान करने में शहर के क्षेत्र के महत्व का समर्थन करता है।

Editor: K.A. Subramanian, Zoological Survey of India, Chennai, India.

Date of publication: 26 March 2022 (online & print)

Citation: Tiple, A., V. Sharma & S.V. Padwad (2022). Dragonflies and damselflies (Insecta: Odonata) of Jabalpur, Madhya Pradesh, India. *Journal of Threatened Taxa* 14(2): 20740–20746. https://doi.org/10.11609/jott.7306.14.3.20740-20746

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Dr. Ashish D. Tiple is a wildlife biologist with field experience in Central India. He has more than 18 years of research experience. His prime research focuses on Butterfly biodiversity; taxonomy; behavior; population dynamics; molecular ecology and insect tissue culture; In addition, he is also a keen Odonatologist, interested in dragonfly diversity and behavior. He also maintains an active interest in Conservation at the grassroots level with respect to bureaucracy, community involvement and related activities. He has 70 International/ National papers, 09 books and 1 ebook in his credit on an extensive range of ecological, behavioral and biogeographically research of central Indian fauna. Vivek Sharma is actively working on snakes of India and has been part of 20 publications on snakes. His aim is to innovate and build bridges to facilitate citizen-science projects on wildlife and environment. Presently he is working as a freelance biologist to provide solutions on the education of snakes and snakebites and occasionally shows his interest in wild mammals and the Odonate diversity of central India. Sonali V. Padwad is involved in extensive research in the field of Biotechnology and insect ecology. She has 14+ years of research and teaching experience and published 12 research papers in reputed journals. In addition, she is also interested in dragonfly and Butterfly diversity and behavior.

Author contributions: ADT and SVP designed the study, carried out the fieldwork, analyzed the data and prepared a draft; VS carried out the fieldwork and revised the final draft. ADT, SVP and VS helped with the preparation of the manuscript and revised the draft.

Acknowledgements: Thanks to Dr. K.C. Joshi and Dr. Nitin Kulkarni, senior scientists, Tropical Forest Research Institute, Jabalpur for valuable suggestions and providing facilities.

INTRODUCTION

Odonates (damselflies and dragonflies) are an ancient insect order with origins in the Carboniferous era about 250 million years ago. They probably mark the first time that evolution experimented with the ability to hover in the air over an object of interest (Andrew et al. 2008). They are beautifully coloured, primarily aquatic in their pre-adult stages, and closely tied to freshwater ecosystems such as rivers, streams, lakes, marshes, and rice fields. Species are usually highly specific to habitats, but some have adapted to using man-made water bodies (Tiple & Chandra 2013). Odonates are important for water-rich habitats such as wetlands, lakes and rainforests, and they are also significant for habitats where water is scarce. Thus the Odonata are regarded as vital to the survival of life (Dijkstra 2007). Odonates are economically significant and act as useful biocontrol agents, since adults prey on mosquitoes, flies, moths, aphids, termites, and small beetles, while larvae feed on mosquito larvae and other soft-bodied aquatic invertebrates. Odonata are reliable indicators of overall ecosystem health, since they are highly sensitive to environmental changes (Dijkstra & Lewington 2006; Andrew et al. 2008).

Globally, 6,356 species in 693 genera of odonates have been reported (Schorr & Paulson 2022), of which 498 species and 27 Subspecies in 154 genera and 18 families are known from India (Subramanian & Babu 2020; Joshi & Sawant 2020; Bedjanič et al. 2020; Payra et al. 2020, 2021; Dawn 2021). Fraser (1933–1936) published three volumes on Odonata in the 'Fauna of British India' and included 536 species and subspecies of Odonata from India, including Bangladesh, Bhutan, Myanmar, Nepal, Pakistan, and Sri Lanka and included many species from Madhya Pradesh. After Fraser's work, some additions were made by Bhasin (1953), Prasad & Ghosh (1988), Mitra (1988, 1995), Srivastava & SuriBabu (1997), Prasad & Varshney (1995), and Mishra (2007). Many additions have been made to the fauna of Madhya Pradesh by Tiple et al. (2011, 2012) with the latest updated checklist being Tiple & Chandra (2013) revealing 106 species under 53 genera and 12 families with 14 new records from Madhya Pradesh and Chhattisgarh. Recently Tiple & Payra (2020) reported *Epophthalmia frontalis* as a new record for Madhya Pradesh. Though the diversity of Odonata had been well documented from Madhya Pradesh, no consolidated checklist of Odonata of Jabalpur city and its surrounding areas is available and hence the present one with an objective of exploring the diversity and abundance.

MATERIALS AND METHODS

Opportunistic sampling and photo documentation were conducted in selected areas of Jabalpur city and its surrounding areas. Surveys were carried out from 2008 to 2019. Most of the samplings were done between 1000 h and 1400 h, when odonates control their body temperature in sunlight (Subramanian 2009; Koli et al. 2014; Payra & Tiple 2019). Identification of odonates was primarily made directly in the field from specimens collected with handheld aerial sweep nets and subsequently released without harm. Photographs of specimens taken from various angles aided their identification using field guides (Andrew et al. 2008; Subramanian 2009; Nair 2011). Specimens that were difficult to identify in the field were collected and preserved in 70% alcohol or acetone, and carried to the laboratory for further identification with the help of taxonomic keys (Fraser 1933, 1934, 1936; Mitra 2002). All scientific names follow Kalkman et al. (2020). The species were categorized on the basis of number of sightings in the Jabalpur city as: VC very common (>100 sightings), C common (50–100 sightings), FC frequently common (15–50 sightings), R rare (2–15 sightings), VR very rare (<2 sightings) (Tiple et al. 2008).

Study area

Jabalpur is one of the largest and the most crowded cities in Madhya Pradesh, located in the north-center region of India at 23.16°10'7.57''N & 79.93°55'54.64''E. It is situated on the Deccan Plateau at an altitude of 411 m and is surrounded on all sides by ancient basalt rocks and forests. Jabalpur consists of a long, narrow plain running from south-west to north-east flanked by the Bhanrer and Kaimur ranges of the Vindhyan system on the west and the various hills of the Mahadeo range and Maikal range on the east. The Bhitrigarh range and a few subsidiary hills intrude upon in the middle of the district and practically join the Vindhyan and the Satpura systems, which together form the great central watershed of India. It lies in the catchment of the longest river of central India, the Narmada, along with its tributaries, Hiran, Gour, Ken, and Sone. Jabalpur city is surrounded by low, rocky, and barren hillocks, which include Kariapathar hillock to the north-east, SitaPahad and Kandhari hills to the east and Madan Mahal hills to the south-west (Chandra 2008; Flora et al. 2020).

Jabalpur city has a humid subtropical climate, having three main seasons: June/July wet monson and its aftermath from June till October, the cool dry winter from October/November to February/March and the

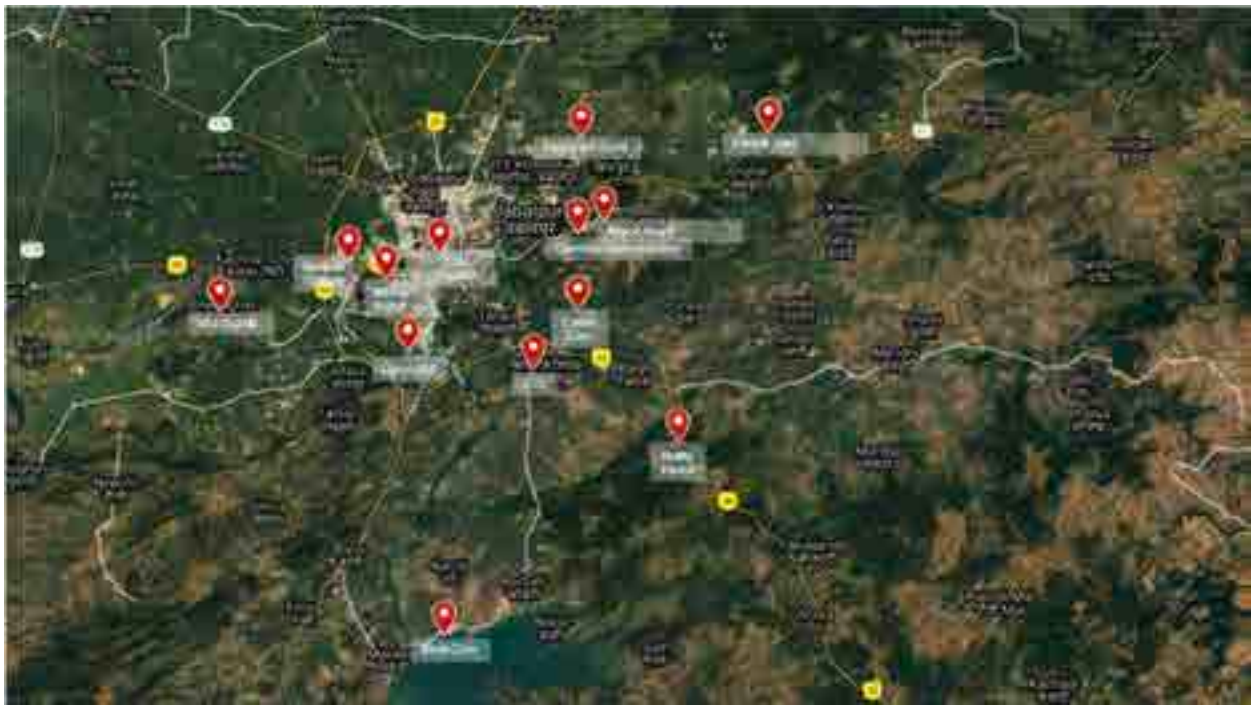


Figure 1. Map of the surveyed localities of Jabalpur City. Source: Google Earth

hot dry season from April till the onset of rains. The temperature of the city ranges from minimum of 10–25 °C to maximum 30–45 °C with a relative humidity 10–15 % to 60–95 %. Annual precipitation is 1,386 mm.

Survey sites

All the study sites were within and around Jabalpur city within a radius of 20 km. Odonates were surveyed in Dumna Nature Reserve (includes Kakartala), Dhobi Reserve Forest, Lower Gaur Reserve Forest, City Gardens, Tropical Forest Research Institute (TFRI), Airport Road, Vijaynagar, Garha, Adhartal, Medical College Campus, Bhedaghat, Pariyat Tank, Narrai forest, Parashuram Kund, Madan Mahal Hills (includes Thakurtal, Pisanhaari Temple and SangramSagar), areas adjacent to River Narmada, Bargi dam, temporary and permanent flowing or still water bodies, and rivers (Figure 1).

RESULTS AND DISCUSSION

Seventy-five species of Odonata belongings to nine families were recorded. The present study adds 21 new species recorded for Jabalpur district, and four species for Madhya Pradesh. Of the total, 37% (28) species were abundant or very common, 19% (14) were common, 16% (12) were frequently common, 24% (18) rare and 4% (03) very rare (i.e., *Aethriamanta brevipennis*, *Agriocnemis pieris*, *Caconeura ramburi*). The observed and identified species, their status in and around of Jabalpur city are listed in Table 1.

The highest number of odonates belonged to the family Libellulidae (32 species) with 10 new records (i.e., *Aethriamanta brevipennis*, *Diplacodes lefebvrii*, *Diplacodes nebulosa*, *Indothemis carnatica*, *Neurothemis fulvia*, *Orthetrum chrysis*, *Rhodothemis rufa*, *Tramea limbata*, *Rhyothemis triangularis*, *Urothemis signata*), followed by Coenagrionidae (17 species) with one new record (*Pseudagrion hypermelas)*, Gomphidae (09 species) with five new records (i.e., *Cyclogomphus ypsilon*, *Cyclogomphus wilkinsi*, *Ictinogomphus distinctus*,*Ictinogomphus angulosus*, *Microgomphus torquatus*), Platycenemididae (06 species) with three new records (i.e., *Caconeura ramburi*, *Elattoneura nigerrima*, *Onychargia atrocyana*), Aeshnidae (05 species) with one new record (*Anax indicus*), Lestidae (03 species), Macromiidae (02 species) with one new record (*Macromia cingulata*) and Chlorocyphidae (1 species) (see Figure 2). *Ictinogomphus distinctus*, *Rhyothemis triangularis, Onychargia atrocyana*, and *Anax indicus* are recorded for the first time in Madhya Pradesh. *I. distinctus* has been reported from Santragachi, Howrah, West Bengal (Image 1). *R. triangularis*is a widely distributed species; it was recorded only from Assam, Karnataka, Kerala, Tamil Nadu states (Dow & Sharma 2010) (Image 4). *O. atrocyana* is a widely distributed

Table 1. Checklist of Odonata of Jabalpur city: OS—Occurrence status | TS—Threat status as assigned from IUCN (2014). NA—Not available | LC—Least concern | DD—Data deficient | VU—Vulnerable | NT—Near Threatened. The species recorded for the first time from the Jabalpur are asterisked by (*), and those which were previously unrecorded in the Madhya Pradesh state are marked by #.

	Scientific name	OS	TS
Suborder: Anisoptera (Dragonflies)			
Family: Aeshnidae (05)			
1	*Anax guttatus* (Burmeister, 1839)	VC	LC
2	*Anax immaculifrons* (Rambur, 1842)	C	LC
3	*Anax indicus* Lieftinck, 1942*#	R	LC
4	*Anax ephippiger* (Burmeister, 1839)	FC	LC
5	*Gynacantha bayadera* Selys,1891	C	LC
Family: Gomphidae (09)			
6	*Burmagomphus pyramidalis* Laidlaw,1922	R	NA
7	*Cyclogomphus ypsilon* Selys, 1854*	R	NA
8	*Cyclogomphus wilkinsi* Fraser, 1926*	R	DD
9	*Ictinogomphus distinctus* Ram, 1985*#	R	DD
10	*Ictinogomphus angulosus* (Selys,1854)*	R	LC
11	*Ictinogomphus rapax* (Rambur, 1842)	VC	LC
12	*Macrogomphus annulatus* (Selys,1854)	FC	DD
13	*Microgomphus torquatus* Selys, 1854*	R	DD
14	*Paragomphus lineatus* (Selys,1850)	C	LC
Family:Libellulidae (32)			
15	*Acisoma panorpoides* Rambur, 1842	C	LC
16	*Aethriamant abrevipennis* (Rambur, 1842)*	VR	LC
17	*Brachydiplax sobrina* (Rambur, 1842)	FC	LC
18	*Brachythemis contaminata* (Fabricius,1793)	VC	LC
19	*Bradinopyga geminate* (Rambur, 1842)	VC	LC
20	*Crocothemis servilia* (Drury, 1770)	VC	LC
21	*Diplacodes lefebvrii* (Rambur,1842)*	R	LC
22	*Diplacodes nebulosa* (Fabricius, 1793)*	R	LC
23	*Diplacodes trivialis* (Rambur,1842)	VC	LC
24	*Indothemis carnatica* (Fabricius, 1798)*	R	NT
25	*Neurothemis fulvia* (Drury, 1773)*	C	LC
26	*Neurothemis intermedia* (Rambur, 1842)	VC	LC
27	*Neurothemis tullia* (Drury, 1773)	C	LC
28	*Orthetrum Sabina* (Drury, 1773)	VC	LC
29	*Orthetrum chrysis* (Selys, 1891) *	FC	LC
30	*Orthetrum glaucum* (Brauer, 1865)	VC	LC
31	*Orthetrum luzonicum* (Brauer, 1868)	VC	LC
32	*Orthetrum pruinosum* (Burmeister, 1839)	VC	LC
33	*Orthetrum taeniolatum* (Schneider,1845)	VC	LC
34	*Pantalaflavescens*(Fabricius, 1798)	VC	LC
35	*Potamarcha congener* (Rambur, 1842)	VC	LC
36	*Rhodothemis rufa* (Rambur, 1842) *	R	LC
37	*Rhyothemis variegate* (Linnaeus, 1763)	VC	LC
38	*Rhyothemis triangularis* Kirby, 1889*#	R	LC
39	*Tholymis tillarga* (Fabricius, 1798)	C	LC
40	*Tramea basilaris* (Palisot de Beauvois, 1807)	C	LC
41	*Tramea limbata* (Desjardins, 1832) *	C	LC
42	*Trithemis aurora* (Burmeister, 1839)	VC	LC
43	*Trithemis festiva* (Rambur, 1842)	VC	LC
44	*Trithemis kirbyi* Selys, 1891	FC	LC
45	*Trithemis pallidinervis* (Kirby, 1889)	VC	LC
46	*Urothemis signata* Rambur, 1842*	FC	LC
Family: Macromiidae (02)			
47	*Epophthalmia vittata* Burmeister, 1839	C	LC
48	*Macromia cingulata* Rambur, 1842*	C	LC
Suborder: Zygoptera (Damselflies)			
Family: Chlorocyphidae (01)			
49	*Libellago lineate* (Burmeister, 1839)	C	LC
Family: Coenagrionidae (17)			
50	*Aciagrion pallidum* (Selys,1891)	FC	LC
51	*Aciagrion occidentale* Laidlaw, 1919	C	LC
52	*Agriocnemis splendidissima* Laidlaw	FC	NA
53	*Agriocnemis femina* (Brauer, 1868)	R	LC
54	*Agriocnemis pygmaea* (Rambur, 1842)	VC	LC
55	*Agriocnemis pieris* Laidlaw,1919	VR	LC
56	*Paracercion calamorum* (Ris,1916)	R	LC
57	*Ceriagrion coromandelianum* (Fabricius, 1798)	VC	LC
58	*Amphiallagma parvum* (Selys,1876)	R	LC
59	*Ischnura aurora* (Brauer, 1865)	VC	LC
60	*Ischnura senegalensis* (Rambur, 1842)	VC	LC
61	*Pseudagrion spencei* Fraser, 1922	FC	LC
62	*Pseudagrion decorum* (Rambur, 1842)	VC	LC
63	*Pseudagrion hypermelas* (Selys,1876)*	R	LC
64	*Pseudagrion microcephalum* (Rambur, 1842)	C	LC
65	*Pseudagrion rubriceps* (Selys, 1876b)	VC	LC
66	*Ischnura nursei* (Morton,1907)	FC	LC
Family: Lestidae (03)			
67	*Lestes elatus* Hagen in Selys,1862	FC	LC
68	Lestes concinnus Hagen in Selys, 1862	VC	LC
69	*Lestes viridulus* Rambur, 1842	VC	LC
Family: Platycnemididae (06)			
70	*Copera marginipes* (Rambur, 1842)	VC	LC
71	*Caconeura ramburi* (Fraser, 1922) *	VR	DD
72	*Disparoneura quadrimaculata* (Rambur,1842)	VC	LC
73	*Prodasineura verticalis* (Selys,1860)	FC	LC
74	*Elattoneura nigerrima* (Laidlaw, 1917)*	R	DD
75	*Onychargia atrocyana* (Selys, 1865)*#	R	LC

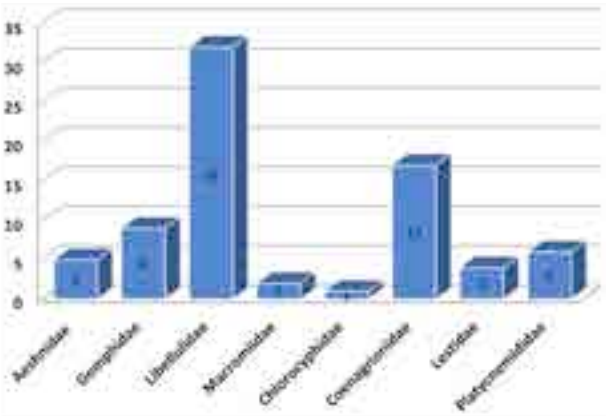


Figure 2. The number of odonate species encountered in different families in the Jabalpur city.

species; it was recorded only from forested areas of Western Ghats, Bengal, and northeastern states (Image 3). These species are recorded for the first time in central India. *A. indicus* is a widely distributed species in India. There are gaps in its known distribution but these are likely to be due to under sampling and misidentification as the closely related *A. guttatus*, with which it has been frequently confused (Image 2).

Among the 75 odonates recorded from Jabalpur city, 72 species are listed in the IUCN Red List of Threatened Species. Among them *Indothemis carnatica* is 'Near Threatened', 65 species are 'Least Concern', the six species are 'Data Deficient' (*Cyclogomphus wilkinsi*, *Ictinogomphus distinctus*, *Macrogomphus annulatus*, *Microgomphus torquatus, Caconeura ramburi*, and *Elattoneura nigerrima*), and three not listed. The family Gomphidae is also represented by the highest number of Data Deficient species (Table 1). The members of this family are fast moving insects and may have crepuscular habits. These insects are difficult to observe or collect. Many gomphids are already rare. Therefore, there are high chances of not detecting them during surveys (Tiple & Koparde 2015).

During monsoon and post-monsoon seasons, *Pantala flavescens* is very abundant, as a result of mass emergence and migration. However, species like *Aethriamanta brevipennis*, *Agriocnemis pieris*, *Caconeura ramburi, Onychargia atrocyana, Elattoneura nigerrima, Ictinogomphus angulosus*, and *Rhyothemis triangularis* were rarely encountered. Abundance of *Brachythemis contaminata*, *Orthetrum Sabina*, and *Diplacodes trivialis* was high in contaminated water bodies. Species of Gomphidae, Macromiidae, Chlorocyphidae, and Platycnemididae were not found in contaminated water but found to occur in unpolluted

Image 1. ***Ictinogomphus distinctus***

IImage 2. ***Onychargia atrocyana***

Image 3. ***Anax indicus***

Image 4. ***Rhyothemis triangularis***

wetlands.

Odonates are an indicator group and conservation activities must be acknowledged, especially for tropical odonates (Samways & Steytler 1996; Suhling et al. 2004). Zones in and around urban regions which consist of rivers, lakes, dams, rainwater puddles, marshes, urban parks, and gardens are excellent and rich sites of Odonata, and thus should be conserved and kept pollution free. Emerging urbanization affects odonate populations because of destruction and contamination of their natural habitats. Regions like the Narmada River and Bargi dam, which are home to large numbers of migratory birds, should be monitored and kept pollution free. Thorough analyses of their population in these habitats may act as role model for the evaluation of environmental health and quality. Observations from the present investigation may end up being significant as a reference for biodiversity managers in assessing changes in environmental conditions in the study area.

To conserve the suitable habitats of these ecologically important insects, public awareness is required. Anthropogenic activities (cutting logs, expansion of agricultural fields in lake surroundings), siltation, and eutrophication are among the major causes for increasing deterioration rate of the suitable habitats of odonates. However, presence of forest streams, waterfalls, rivers, lakes, and temporary & permanent flowing or still water bodies with dense shrubs & tree vegetations are most likely the major attractions for the Odonata. The observations recorded in the present study may prove valuable as a reference for assessing the changes due to the environmental conditions in the locality in the future.

The suborder Anisoptera was abundant in comparison to Zygoptera, and found in all the water bodies that were sampled. This corroborates the findings of earlier reports (Williams 1997; Lawler 2001; Suhling et al. 2004). Our findings agree with Keize & Kalkman (2009), who concluded that Coenagrionidae and Libellulidae are the dominant Odonata fauna in standing water worldwide. Tiple (2008) studied the Odonata fauna of Nagpur city and observed that the Libellulidae dominated with 30 species followed by Coenagrionidae (16 species). In central India too, odonate fauna is mostly dominated by the Libellulidae and Coenagrionidae (Tiple & Chandra 2013). Andrew (2013) observed similar findings with the Odonata of Chatri Lake in Amravati and Zilpi Lake in Nagpur, respectively. Tiple et al. (2013) gave a detailed compilation of odonates of Vidarbha region of Maharashtra with 82 species under 47 genera and nine families, and revealed that the Libellulidae is the dominant one (38 species). The present study also corroborates this as Libellulidae (32 species), the most dominant, followed by Coenagrionidae.

Tiple & Chandra (2013) reported 106 species of Odonata from Madhya Pradesh and Chhattisgarh States. The present study on the Odonata of Jabalpur city revealed the presence of 75 species which account 71% of total species reported in Madhya Pradesh and Chhattisgarh States. The Jabalpur city and surrounding area seems to be having rich Odonate diversity of 75 varieties of species in small city area. Probably due to the presence of rivers (Narmada, Hiran, Gour, Ken, and Sone), lakes, and temporary & permanent flowing or still water bodies with dense shrub & tree vegetation a major attraction to the odonate species. The observations recorded in the present study supports the value of the Jabalpur city area in providing valuable resources for Odonata and it may prove as a reference for assessing the changes due to the environmental conditions in the locality in the future.

REFERENCES

Andrew, R.J. (2013). Odonates of Zilpi Lake of Nagpur (India) with a note on the emergence of the Libellulidae dragonfly, *Trithemis pallidenervis*. *Journal of New Biological Report* 2: 177–187.

Andrew, R.J., K.A. Subramaniam, & A.D. Tiple (2008). *A Handbook on Common Odonates of Central India.* South Asian Council of Odonatology, 65 pp.

Bedjanič, M., V. Kalkman & K.A. Subramanian (2020) A new species of Orthetrum Newman, 1833 (Odonata: Libellulidae) from the Andaman Islands, India. *Zootaxa* 4779(1): 91–100.

Bhasin, G.D. (1953). A systematic catalogue of main identified collection at Forest Research Institute, Dehra Drun. Pt. 12. Order Odonata. *Indian Forest Leaflet* 121(3): 63–78.

Chandra, K. (2008). *Faunal Diversity of Jabalpur District, Madhya Pradesh.* Zoological Survey of India, Kolkata, 417 pp.

Dawn, P. (2021). A new species of *Cephalaeschna* Selys, 1883 (Odonata: Anisoptera: Aeshnidae) from Neora Valley National Park, West Bengal, India, with notes on C. acanthifrons Joshi & Kunte, 2017 and *C. viridifrons* (Fraser, 1922). *Zootaxa* 4949(2): 371–380.

Dijkstra, K.D.B. (2007). Gone with the wind: westward dispersal across the Indian Ocean and island speciation in *Hemicordulia* dragonflies (Odonata: Corduliidae). *Zootaxa* 1438: 27–48.

Dijkstra, K.D.B. & R. Lewington (2006). *Field Guide to the Dragonflies of Britain and Europe*. British Wildlife Publishing, 320 pp.

Dow, R.A. & G. Sharma (2010). *Rhyothemis triangularis*. The IUCN Red List of Threatened Species 2010: e.T169123A6570098. https://doi.org/10.2305/IUCN.UK.2010-4.RLTS.T169123A6570098.en

Flora, J.S., A.D. Tiple, A. Sengupta & S.V. Padwad (2020). Butterfly (Lepidoptera: Rhopalocera) fauna of Jabalpur City, Madhya Pradesh, India. *Journal of Threatened Taxa* 12(11): 16607–16613. https://doi.org/10.11609/jott.4168.12.11.16607-16613

Fraser, F.C. (1933). *Fauna of British India Odonata1*. Taylor and Francis Ltd. London, 423 pp.

Fraser, F.C. (1934). *Fauna of British India Odonata 2.* Taylor and Francis Ltd. London, 398 pp.

Fraser, F.C. (1936). *Fauna of British India Odonata 3.* Taylor and Francis Ltd. London, 461 pp

Joshi, S. & D. Sawant (2020). Description of *Bradinopyga konkanensis*

sp. nov. (Odonata: Anisoptera: Libellulidae) from the coastal region of Maharashtra, India. *Zootaxa* 4779(1): 65–78.

Kalkman, V.J., R. Babu, M. Bedjanič, K. Conniff, T. Gyeltshen, M.K. Khan, K.A. Subramanian, A. Zia & A.G. Orr (2020). Checklist of the dragonflies and damselflies (Insecta: Odonata) of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. *Zootaxa* 4849(1): 1–84.

Keize, J. and V. Kalkman (2009). Records of dragonflies from Kabupaten Merauke, Papua, Indonesia collected in 2007 and 2008 (Odonata). *Suara Serangga Papua* 4(2): 40–45.

Koli, V.K., C. Bhatnagar & D.S. Shekhawat (2014). Diversity and species composition of odonates in southern Rajasthan, India. *Proceedings of the Zoological Society* 68: 202–211.

Lawler, S.P. (2001). Rice fields as temporary wetlands: a review. *Israel Journal of Zoology* 47: 513–528.

Mishra, S.K. (2007). Fauna of Madhayapardesh (Odonata: Insecta). State Fauna Series, Zoological Survey of India, Kolkata 15(1): 245–272.

Mitra, T.R. (1988). Note on the odonata fauna of Central India. *Records of the Zoological Survey of India* 83: 69–81.

Mitra, T.R. (1995). Insecta: Odonata including a new species from Central India, pp. 31–34. In: *Fauna of Indravati Tiger Reserve*. Fauna of Conservation Areas, Zoological Survey of India, 117 pp.

Mitra, T.R. (2002). Geographical distribution of Odonata (Insecta) of Eastern India. *Memoirs of the Zoological Survey of India* 19(1): 1–208.

Nair, M.V. (2011). *Dragonflies & Damselflies of Orissa and Eastern India*. Wildlife Organization, Forest & Environment Department, Government of Orissa, 252 pp.

Payra, A. & A.D. Tiple (2019). Odonata fauna in adjoining coastal areas of Purba Medinipur District, West Bengal, India. *Munis Entomology & Zoology* 14(2): 358–367.

Payra, A., K.A. Subramanian, K. Chandra & B. Tripathy (2020). A first record of *Camacinia harterti* Karsch, 1890 (Odonata: Libellulidae) from Arunachal Pradesh, India. *Journal of Threatened Taxa* 12(8): 15922–15926. https://doi.org/10.11609/jott.4653.12.8.15922-15926

Payra, A., P. Dawn, K. A. Subramanian, C. K Deepak, K. Chandra & B. Tripathy (2021). New record of *Megalestes gyalsey* Gyeltshen, Kalkman & Orr, 2017 (Zygoptera: Synlestidae) from India, with first description of female and larva. *Zootaxa* 4938(2): 233–242.

Prasad, M. & S.K. Ghosh (1988). A contribution on the EastuarineOdonata of East India. *Record of Zoological Survey of India* 85(2): 197–216.

Prasad, M. & A. Singh (1995). Fauna of conservation areas series 5. Rajaji National Park: Odonata. *Records of the Zoological Survey of India* 195–215.

Samways, M.J. & N.S. Steytler (1996). Dragonfly (Odonata) distribution patterns in urban and forest landscapes, and recommendations for riparian management. *Biological Conservation* 78: 279–288.

Schorr, M. & D. Paulson (2021) World Odonata List. https://www.pugetsound.edu/academics/academic-resources/slater-museum/. Accessed 12 January 2022.

Srivastava, V.K. & B. SuriBabu (1997). Annotations on the Damselfly collection from Sagar, Central India. *Fraseria* 4: 13–15.

Subramanian, K.A. (2009). *Dragonflies and Damselflies of Peninsular India - A Field Guide*. VigyanPrasar, Noida, India, 168 pp.

Subramanian, K.A. & R. Babu (2020). *Dragonflies and damselflies (Insecta: Odonata) of India*, pp. 29–45. In: Ramani, S., M. Prrashanth & H.M. Yeshwanath (eds.). *Indian Insects Diversity and Science.* CRC Press, Taylor & Francis.

Suhling, F., K. Schenk, T. Padeffke & A. Martens (2004). A field study of larval development in a dragonfly assemblage in African desert ponds (Odonata). *Hydrobiologia* 528: 75–85

Tiple A.D. & A. Payra (2020) First Record of *Epophthalmia frontalis* from Central India (Insecta: Odonata: Macromiidae). *Travaux du Muséum National d'Histoire Naturelle "Grigore Antipa"* 63(2): 127–130. https://doi.org/10.3897/travaux.63.e52897

Tiple, A.D. & P. Koparde (2015). Odonata of Maharashtra, India with Notes on Species Distribution. *Journal of Insect Science* 15(1): 1–10. https://doi.org/10.1093/jisesa/iev028

Tiple, A.D. & K. Chandra (2013) Dragonflies and Damselflies (Insecta, Odonata) of Madhya Pradesh and Chhattisgarh States, India. *Care 4Nature* 1(1): 2–11.

Tiple, A.D., N. Kulkarni & K.C. Joshi (2011). Diversity of Odonata in Kanha National Park, Madhya Pradesh, India. *Indian Journal of Forestry* 34(3): 329–332.

Tiple, A.D., R.J. Andrew, K.A. Subramanian & S.S. Talmale (2013). Odonata of Vidarbha region, Maharashtra state, central India. *Odonatologica* 42: 237–245.

Tiple, A.D., S. Paunikar & S.S. Talmale (2012). Dragonflies and Damselflies (Odonata: Insecta) of Tropical Forest Research Institute, Jabalpur, Madhya Pradesh, central India. *Journal of Threatened Taxa* 4(4): 2529–2533. https://doi.org/10.11609/JoTT.o2657.2529-33

Tiple, A.D., A.M. Khurad & R.J. Andrew (2008). Species Diversity of Odonata in and Around Nagpur City, Central India. *Fraseria* 7: 41–45.

Williams, D.D. (1997). Temporary ponds and their invertebrate communities. *Aquatic Conservation: Marine and Freshwater Ecosystems* 7: 105–117.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20747–20757

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

https://doi.org/10.11609/jott.7165.14.3.20747-20757

#7165 | Received 06 February 2021 | Final received 26 November 2021 | Finally accepted 10 March 2022

OPEN ACCESS

COMMUNICATION

Spatial and temporal variation in the diversity of malacofauna from Aripal stream of Kashmir Himalaya, India

Zahoor Ahmad Mir [1] & **Yahya Bakhtiyar** [2]

[1,2] Fish Biology and Limnology Research Laboratory, Department of Zoology, University of Kashmir, Srinagar, Jammu & Kashmir 190006, India.

[1] mirzahoor88@gmail.com, [2] yahya.bakhtiyar@gmail.com (corresponding author)

Abstract: This paper presents the spatial and temporal variation in the diversity of malacofauna in relation to the water chemistry of the Aripal stream of Kashmir Himalaya. A total of 12 species were reported which belong to four families, Lymnaeidae, Physidae, Planorbidae, and Bithyniidae from class Gastropoda, and two families, Cyrenidae and Pisidiidae from class Bivalvia. The family Planorbidae contributed 34% to the total annual molluscan population followed by Lymnaeidae (28%) and Bithyniidae (18%). During the collection, *Gyraulus* sp., *Planorbis* sp., and *Bithynia tentaculata* were prevalent at all sites, with predominance of *Bithynia tentaculata*. Species richness and abundance were observed maximum at site A3 (down-stream) and minimum at site A1 (up-stream) while in the case of temporal variation, species richness and abundance were maximum in summer and minimum in winter. Shannon-Wiener index, Simpson index, Margalef index, and Pielou evenness index were used to calculate the diversity, dominance, richness, and evenness of molluscan species, respectively. Physico-chemical parameters revealed a non-significant spatial variation (P >0.05) except pH, total hardness, and alkalinity while a significant temporal variation (P <0.05) was observed in the physico-chemical parameters except dissolved oxygen. A significant positive correlation was seen between the molluscan species and total hardness. In the present study, the stone mining, channel morphology of stream, habitat heterogeneity, and physico-chemical parameters were also found to promote the spatial and temporal diversity of malacofauna.

Keywords: Abundance, classification, distribution, freshwater ecosystems, macrobenthic invertebrates, molluscs, Pearson's correlation, physico-chemical parameters, richness.

Editor: N.A. Aravind, Ashoka Trust for Research in Ecology and the Environment, Bengaluru, India. **Date of publication:** 26 March 2022 (online & print)

Citation: Mir, Z.A. & Y. Bakhtiyar (2022). Spatial and temporal variation in the diversity of malacofauna from Aripal stream of Kashmir Himalaya, India. *Journal of Threatened Taxa* 14(3): 20747–20757. https://doi.org/10.11609/jott.7165.14.3.20747-20757

Funding: None, all expenses were borne by Zahoor Ahmad Mir, PhD Research Scholar, Department of Zoology, University of Kashmir.

Competing interests: The authors declare no competing interests.

Author details: Zahoor Ahmad Mir—PhD Research Scholar, Department of Zoology, University of Kashmir is currently working in the Fish Biology and Limnology Research Laboratory of the Department and has a keen interest in the taxonomy and diversity of macrobenthic invertebrates along with the limnology of Kashmir Himalayan streams. Dr. Yahya Bakhtiyar—Assistant Professor, Department of Zoology, University of Kashmir is currently working in the Fish Biology and Limnology Research Laboratory of the Department and his focus of research is fish population dynamics, fish reproductive biology, zooplankton, macrobenthic invertebrates, biomonitoring, and limnology of the waterbodies of Jammu and Kashmir.

Author contributions: ZAM—field survey, data collection, identification, photography, statistical analysis, and manuscript preparation. YB—research supervision, drafting of research problem, and manuscript preparation.

Acknowledgements: The authors are highly thankful to the Head, Department of Zoology, University of Kashmir for providing all the necessary laboratory and library facilities while conducting this research work.

INTRODUCTION

Molluscs serve as sources of food for fishes, birds and mammals (Wosu 2003). Molluscs also act as intermediate hosts to helminth parasites that cause diseases such as schistosomiasis and fascioliasis in humans and livestock (Mostafa 2009; Alhassan 2020; Silva et al. 2020). Freshwater molluscs, being detritus feeders, play a significant role in improving water quality (Martin 1991; Reddy 1995). Freshwater bodies are inhabited by two classes of molluscs: Gastropoda and Bivalvia, with the Gastropoda forming the largest group (Lydeard et al. 2004). Both gastropods and bivalves are diverse in aquatic ecosystems such as lakes, ponds, wetlands, springs, streams, and rivers, which act as models for ecological studies (APHA 1998). Ecological parameters like temperature, nature of substratum, type of vegetation, and water chemistry play significant role in the occurrence, distribution, and density of freshwater molluscs (Bournard et al. 1987; Boulton & lake 1992; Linke et al. 1999). Temperature has a major impact on the seasonal distribution and abundance of freshwater molluscs (Biggs et al. 1990). Bottom substrate such as boulders, cobbles, pebbles, gravel, and sand provide a suitable habitat for the colonization and establishment of molluscs in streams (Hynes 1970; Habib & Yousuf 2012). Growth of vegetation such as macrophytes and periphyton along and within the stream increases the density, distribution, and diversity of molluscs (Nelson et al. 1990; Bilby & Ward 1991; Ghani et al. 2017). Water chemistry parameters (viz., pH, alkalinity, hardness) influence the abundance and richness of molluscs (Peeters & Gardeniers 1998). The spatial and temporal variation in both biotic and abiotic parameters change the adaptation strategies along with the composition, distribution, and diversity of mollusc communities (Rosillon 1987; Poff & Ward 1989). The freshwater molluscs are facing threats from various sources such as water pollution, habitat destruction through dams and channelization, and climate change (Peeters & Gardeniers 1998; Primack 2002). The studies on Indian Himalayan malacofauna is meager compared to other parts of India (Blanford & Godwin-Austen 1908; Rao 1993; Aravind et al. 2010; Sharma et al. 2010) and in Kashmir Himalaya, a well-documented work has been carried out on the diversity of benthic molluscan fauna (Qadri et al. 1981; Dhar et al. 1985; Pandit et al. 2002; Yousuf et al. 2006; Bhat & Pandit 2010; Habib & Yousuf 2014; Allaie et al. 2019). Despite the work carried out in the field of limnology, there is still a lack of knowledge and fragmentary information regarding habitat heterogeneity and changing riparian land use patterns along the hill streams. These aspects have a profound impact on the occurrence, abundance, and richness of benthic fauna and have been considered during the present study on the spatial and temporal variation in the diversity of malacofauna from the Aripal stream of Tral, Kashmir Himalaya.

MATERIALS AND METHODS

Description of the study area

The present study has been carried out from the Aripal stream, located in the Tral town, between geographic coordinates 33.93°N and 75.10°E with an altitude of 1,662 m in the district Pulwama, Kashmir valley. The stream originates in the northern ridge of Greater Himalaya and forms one of the important tributaries of the Jhelum river in the district. The town is situated 11 km away from NH 44 Awantipora and nearly about 40 km from Srinagar city. The Aripal watershed covers an area of 380 km^2 in the sub-district and provides various ecosystem services such as a source of drinking water and irrigation for horticulture and agriculture purposes and also forms an opportunity for trout culture in the area. The stream forms an important reservoir of construction materials such as boulders, cobbles, pebbles, gravel, and sand, which boost the rural economy (Mir & Saleem 2016). During the survey, three sites were selected from the stream, on the basis of distance, altitudinal distribution, riparian land-use types, and stream heterogeneity. The sites were marked as site A1 at Aripal (up-stream), 34.01˚N & 75.04˚E, 1,902 m, site A2 at Chandrigam (mid-stream), 33.55˚N & 75.05˚E, 1,607 m, and site A3 at Kadelbal (down-stream), 33.53˚N & 75.02˚E, 1,583 m (Image 1). The geographical representation of the Aripal watershed along with sampling sites was created through Arc-GIS software (Figure 1).

Sampling, processing, and identification

Sampling was carried out on monthly basis from June 2018 to May 2019. The molluscan samples were collected by using standard bottom samplers (EU-WFD implemented) Surber net and D-net (HYDRO-BIOS) with 0.9 m^2 area and 0.5 mm mesh size (Rosenberg & Resh 1993; Barbour et al. 1999; Hayslip & Gretchen 2007). Wader and synthetic rubber gloves were used during wading in each sampling reach. A systematic method was followed to cover the different microhabitats in each sampling site (Peck et al. 2002). A standard operating

Image 1. Sample collection sites of Aripal stream with habitat heterogeneity. © Zahoor Ahmad Mir

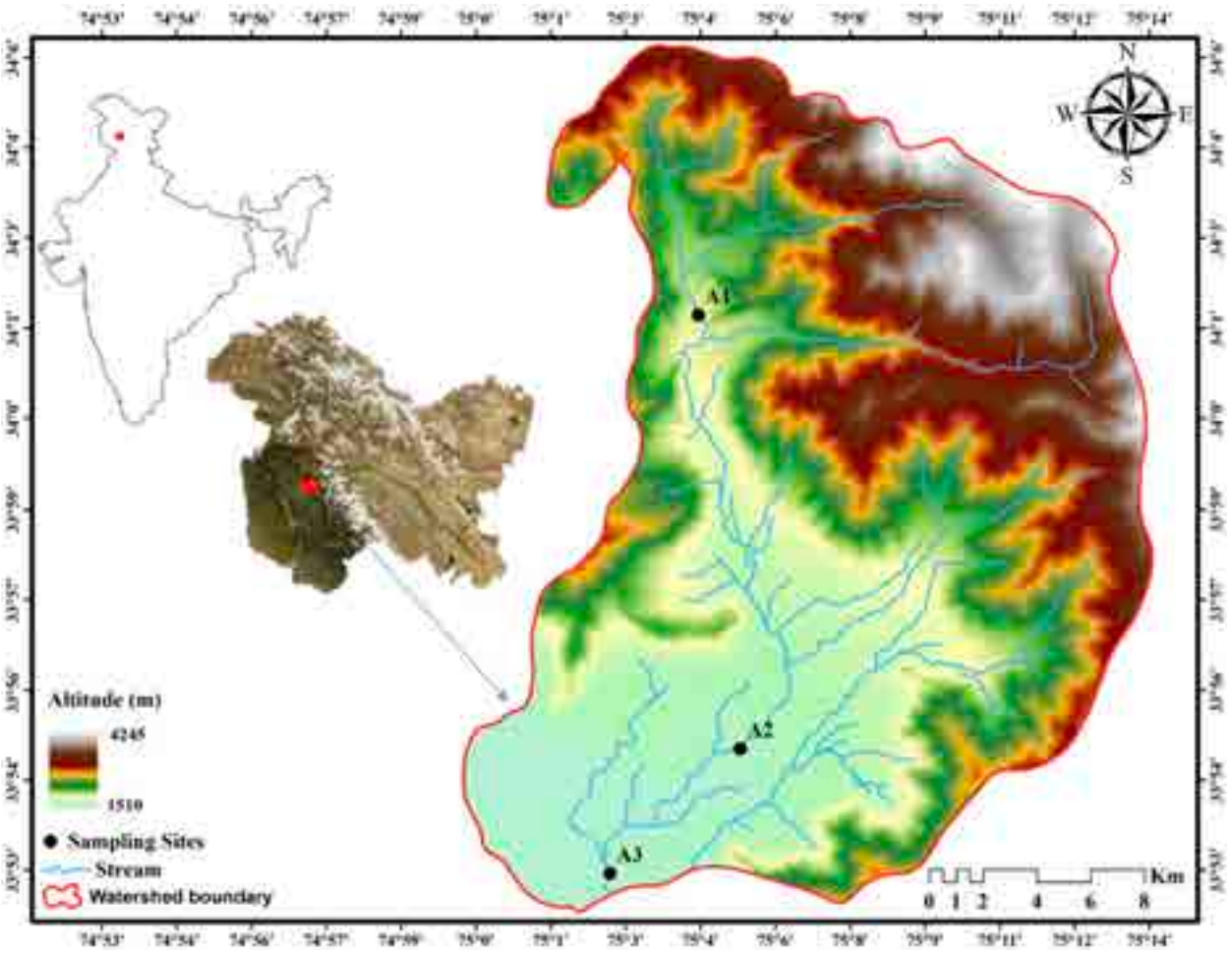


Figure 1. Geographical representation of sampling sites of Aripal stream, Tral, Kashmir Himalaya.

method in benthic macroinvertebrate sampling, developed by Moultan et al. (2000) and Carter & Resh (2001) was followed for filtration, sieving, removing, and sorting of molluscs and extraneous material from the sample. During processing, samples were fixed with 4% formalin and preserved with 70% ethanol. The identification was done with the help of dissecting stereo zoom microscope (Magnus MS 24) with Magcam DC 10 camera following taxonomic keys (Edmondson 1959; Rao 1989; Ramakrishna & Dey 2007).

Physico-chemical parameters

The physico-chemical parameters of water, viz., dissolved oxygen (DO), alkalinity (Alk), total hardness (TH), air temperature (AT), water temperature (WT), pH, electrical conductivity (EC), and total dissolved solids (TDS) were measured by following standard methods (APHA 1998).

Statistical analysis

Statistical analysis of data was performed by using MS excel 2016, SPSS 20, and Past 4 software. Shannon-Wiener index (1949), Simpson dominance index (1949), Margalef index (1958) and Pielou evenness index (1966) were used to calculate the diversity, dominance, richness, and evenness of molluscan species with the use of Past 4 software. Spatial and temporal data of physico-chemical parameters were subjected for one-way ANOVA followed by Duncan's multiple range test and the relationship with molluscan species was determined through two-tailed Pearson's correlation with the help of SPSS 20 software.

RESULTS

Molluscan diversity

During the present study, 1,509 individuals were collected from three different sites of the Aripal stream throughout the year. A total of 12 species were reported from six families and two classes. Gastropoda represented 10 species that belong to four families, Lymnaeidae, Physidae, Planorbidae, and Bithyniidae while the class Bivalvia was represented by two species belonging to two families, Cyrenidae and Pisidiidae (Table 1). The identified Gastropoda were *Radix auricularia*, *Lymnaea stagnalis*, *Pseudosuccinea columella*, *Racesina luteola*, *Physella acuta*, *Segmentina* sp., *Indoplanorbis exustus*, *Gyraulus* sp., *Planorbis* sp., and *Bithynia tentaculata.* The Bivalvia species were *Corbicula cashmirienses* and *Pisidium casertanum* (Table 1; Image 2). During the collection, *Gyraulus* sp., *Planorbis* sp., and *Bithynia tentaculata* were present at all the sites, while *Physella acuta* was observed only at site A2 (mid-stream) and *Lymnaea stagnalis, Segmentina* sp. *and Indoplanorbis exustus* were present only at site A3 (down-stream). *Radix auricularia, Pseudosuccinea columella*, *Racesina luteola*, *Corbicula cashmirienses* and *Pisidium casertanum* were reported from site A2 and site A3 of the stream (Table 2).

The class Gastropoda and Bivalvia contributed 82% and 18% to the total annual molluscan population (Figure 2). The family Planorbidae contributed 34% followed by Lymnaeidae (28%), Bithyniidae (18%), Cyrenidae (11%), Pisidiidae (7%), and Physidae (2%) to the total annual molluscan population (Figure 3). The species *Bithynia tentaculata* contributed 18% followed by *Gyraulus* sp. (16%), *Pseudosuccinea columella* (12%), *Radix auricularia* (10%), *Corbicula cashmiriensis* (10%), *Planorbis* sp. (8%), *Indoplanorbis exustus* (7%), *Pisidium casertanum* (7%), *Lymnaea stagnalis* (4%), *Racesina luteola* (3%), *Segmentina* sp. (3%), and *Physella acuta* (2%) to the total annual molluscan population (Figure 4).

The diversity was observed highest at site A3 (2.25) and lowest at site A1 (1.04), dominance was recorded highest at site A1 (0.37) and lowest at site A3 (0.12), species richness was observed highest at site A3 (1.47) while lowest at site A1 (0.41) and evenness was recorded highest at sites A1 & A3 (0.94) while lowest at site A2 (0.78) (Figure 5).

In the temporal variation of malacofauna, the diversity was observed highest in summer season (2.33) while lowest in winter season (2.06), dominance was recorded maximum in winter season (0.14) while minimum in summer season (0.11), species richness was observed maximum in summer season (1.74) while minimum in winter season (1.45) and evenness was recorded maximum in spring season (0.89) while minimum in summer season (0.86) (Figure 6).

Physico-chemical parameters

During the study, a total of eight physico-chemical parameters were recorded. The air temperature (AT) ranged from 4–25 ˚C with a mean value of 16.3±7.5 ˚C, water temperature (WT) ranged from 7.67–19 ˚C with mean value of 13.2±3.7 ˚C, dissolved oxygen (DO) ranged from 8.13–14.33 mg/L with mean value of 11.1±1.8 mg/L, pH ranged from 7.33–8.47 with mean value of 7.8±0.4, electrical conductivity (EC) ranged from 126.67–368.67 µs cm^{-1} with mean value of 256.3±84.4 µs cm^{-1}, total dissolved solids (TDS) ranged from 62–184.33 mg/L with mean value of 121.6±42.1 mg/L, total hardness

Table 1. The systematic list of malacofauna from Aripal stream.

Phylum	Class	Order	Family	Genus/Species
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Radix auricularia*
				Lymnaea stagnalis
				Pseudosuccinea columella
				Racesina luteola
			Physidae	*Physella acuta*
			Planorbidae	*Segmentina* sp.
				Indoplanorbis exustus
				Gyraulus sp.
				Planorbis sp.
		Mesogastropoda	Bithyniidae	*Bithynia tentaculata*
	Bivalvia	Veneroida	Cyrenidae	*Corbicula cashmiriensis*
			Pisidiidae	*Pisidium casertanum*

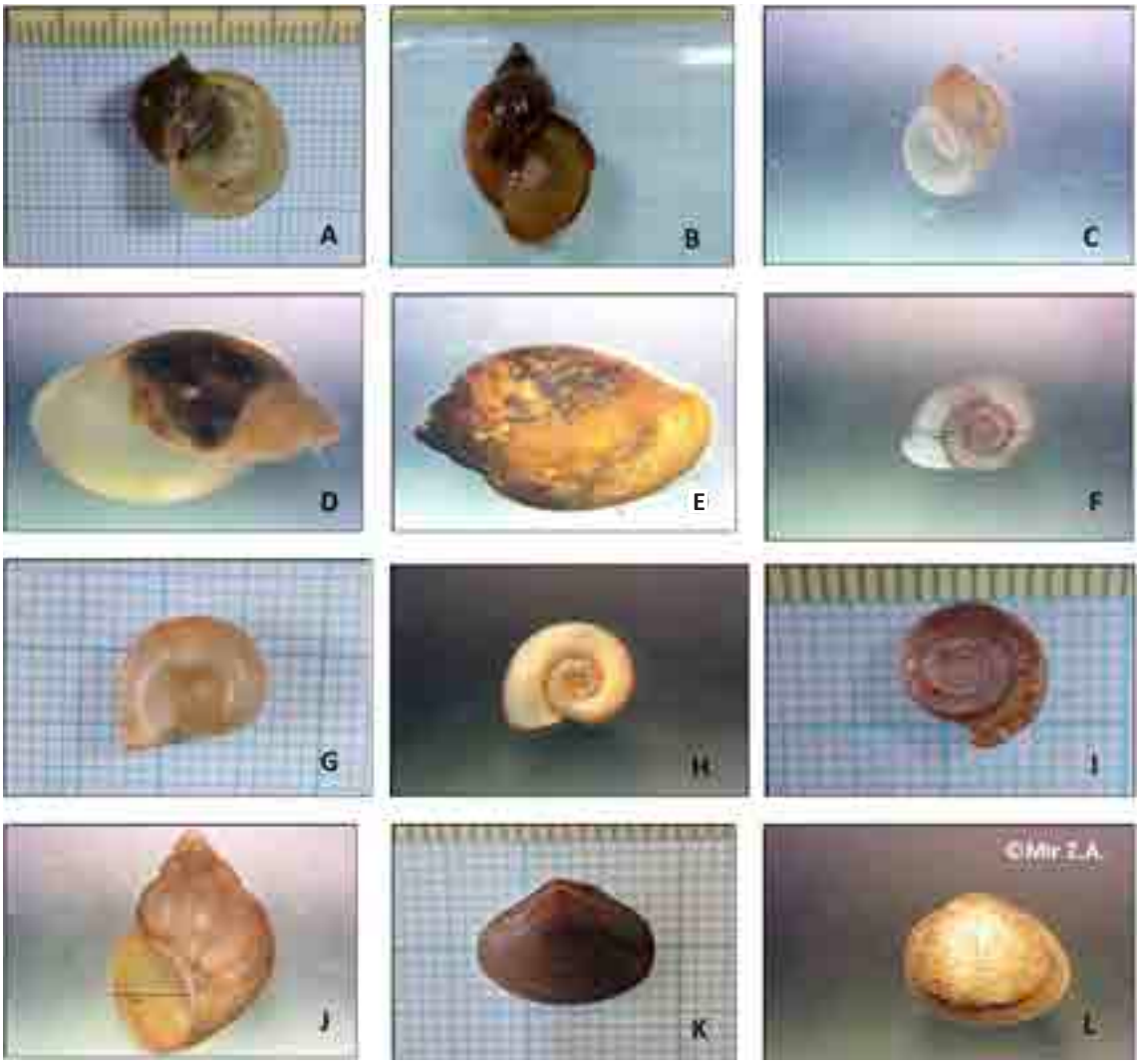


Image 2. Collected and identified molluscan species from Aripal stream: A—*Radix auricularia* | B—*Lymnaea stagnalis* | C—*Pseudosuccinea columella* | D—*Racesina luteola* | E—*Physella acuta* | F—*Segmentina* sp. | G—*Indoplanorbis exustus* | H—*Gyraulus* sp. | I—*Planorbis* sp. | J—*Bithynia tentaculata* | K—*Corbicula cashmirienses* | L—*Pisidium casertanum*. © Zahoor Ahmad Mir

Table 2. Species composition of malacofauna at different sites of Aripal stream.

	Genus/Species	Site A1	Site A2	Site A3
1	*Radix auricularia*	-	+	+
2	*Lymnaea stagnalis*	-	-	+
3	*Pseudosuccinea columella*	-	+	+
4	*Racesina luteola*	-	+	+
5	*Physella acuta*	-	+	-
6	*Segmentina* sp.	-	-	+
7	*Indoplanorbis exustus*	-	-	+
8	*Gyraulus* sp.	+	+	+
9	*Planorbis* sp.	+	+	+
10	*Bithynia tentaculata*	+	+	+
11	*Corbicula cashmiriensis*	-	+	+
12	*Pisidium casertanum*	-	+	+

(+) presence; (-) absence

Table 3. Range and mean values of physico-chemical parameters from Aripal stream.

	Parameters	Min	Max	Mean±SD
1	AT (°C)	4	25	16.3±7.5
2	WT (°C)	7.7	19	13.2±3.7
3	DO (mg/L)	8.1	14.3	11.1±1.8
4	pH	7.3	8.5	7.8±0.4
5	EC (µs cm^{-1})	126.7	368.7	256.3±84.4
6	TDS (mg/L)	62	184.3	121.6±42.1
7	TH (mg/L)	35.7	161.7	94.8±32.9
8	Alk (mg/L)	61.3	137	94.2±21.5

Min—minimum | Max—maximum | SD—standard deviation.

(TH) ranged from 35.7–161.67 mg/L with mean value of 94.8±32.9 mg/L and alkalinity (Alk) ranged from 61.33–137 mg/L with mean value of 94.2±21.5 mg/L (Table 3).

The descriptive analysis in the physicochemical parameters of the Aripal stream on spatial and seasonal scale is presented in the Table 4 & 5, respectively.

A relationship between the molluscan species and physico-chemical parameters of the Aripal stream showed a significantly positive correlation with the total hardness. The *Radix auricularia*, *Racesina luteola*, *Gyraulus* sp., *Planorbis* sp., and *Corbicula cashmirienses* revealed a very significant positive correlation (P <0.01) with total hardness while the *Lymnaea stagnalis*, *Pseudosuccinea columella*, *Segmentina* sp., *Indoplanorbis exustus*, and *Pisidium casertanum* revealed a significant positive correlation (P <0.05) with total hardness. Besides the *Pseudosuccinea columella*

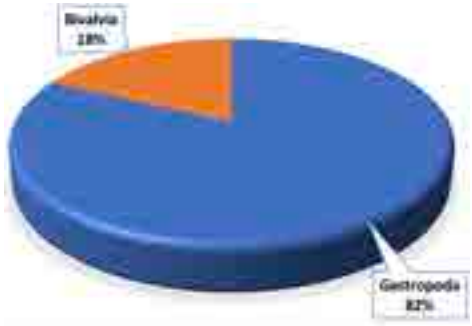


Figure 2. The annual percent contribution of Gastropoda and Bivalvia to the total molluscan population.

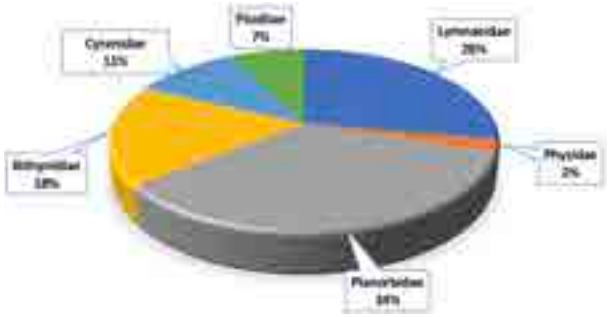


Figure 3. The annual percent contribution of different families to the total molluscan population.

and *Pisidium casertanum* showed a significant positive correlation (P <0.05) with water temperature and pH. The *Planorbis* sp. showed a very significant positive correlation (P <0.01) with air temperature and water temperature. The *Bithynia tentaculata* revealed a very significant positive correlation (P <0.01) with air temperature and water temperature while a negative significant correlation (P <0.05) with alkalinity (Table 6).

DISCUSSION

The ecology of a place and the seasons of a year play an important role in the distribution and abundance of organisms. During the present study, the distribution and abundance of freshwater molluscs were monitored in the Aripal stream of Kashmir Himalaya, where 12 species were reported which belong to six families and two classes. Out of 12 species, 10 species belong to class Gastropoda, and the remaining two species belong to class Bivalvia. The family Planorbidae showed a high contribution to the total molluscs at all the selected sites of the stream, followed by the Lymnaeidae and Bithynidae. Sharma et al. (2010) observed similar results regarding the diversity and distribution of

Table 4. Spatial variation in the physico-chemical parameters from Aripal stream.

Parameters	Site A1	Site A2	Site A3
AT (°C)	15.4±6.5^{a}	16.5±8^{a}	16.8±8.1^{a}
WT (°C)	12.4±2.8^{a}	14.2±4.7^{a}	13.1±3.5^{a}
DO (mg/L)	10.7±1.2^{a}	11.6±2.1^{a}	10.8±2.2^{a}
pH	7.6±0.3^{b}	7.9±0.4^{a}	7.9±0.3^{a}
EC (µs cm^{-1})	226±90.3^{a}	258.9±80.7^{a}	283.9±82.2^{a}
TDS (mg/L)	108.4±44.8^{a}	122.8±39.8^{a}	133.8±41.5^{a}
TH (mg/L)	78.3±32.8^{b}	94.6±29^{ab}	111.5±36.9^{a}
Alk (mg/L)	80.9±20.1^{b}	92.1±19.4^{ab}	109.5±25^{a}

Parameter sharing the same superscript among the sites are nonsignificant (P >0.05); one-way ANOVA applied followed by Duncan's multiple range test.

Table 5. Seasonal variation in the physico-chemical parameters from Aripal stream.

Parameters	Summer	Autumn	Winter	Spring
AT (°C)	24.1±1.3^{a}	17.4±5^{b}	6.7±2.5^{c}	16.9±5.4^{b}
WT (°C)	17.4±2.9^{a}	12.8±3.3^{b}	9.7±1.5^{c}	13±2.2^{b}
DO (mg/L)	10.2±2.1^{a}	11.1±1.9^{a}	11.7±1.8^{a}	11.2±1.6^{a}
pH	7.7±0.3^{b}	8±0.6^{a}	7.6±0.2^{b}	7.9±0.1^{ab}
EC (µs cm^{-1})	183.8±68.5^{b}	315.7±55.6^{a}	335.1±32^{a}	190.6±38.2^{b}
TDS (mg/L)	87.7±31.6^{b}	156.8±30^{a}	150.1±24.8^{a}	92±26.4^{b}
TH (mg/L)	108.1±51.1^{a}	90±19.1^{ab}	71.8±24.4^{b}	109.3±26.6^{a}
Alk (mg/L)	78±17.7^{b}	87.6±17.7^{b}	120.1±25.9^{a}	91±12.1^{b}

Parameter sharing the same superscript among the seasons are nonsignificant (P >0.05); one way ANOVA applied followed by Duncan's multiple range test.

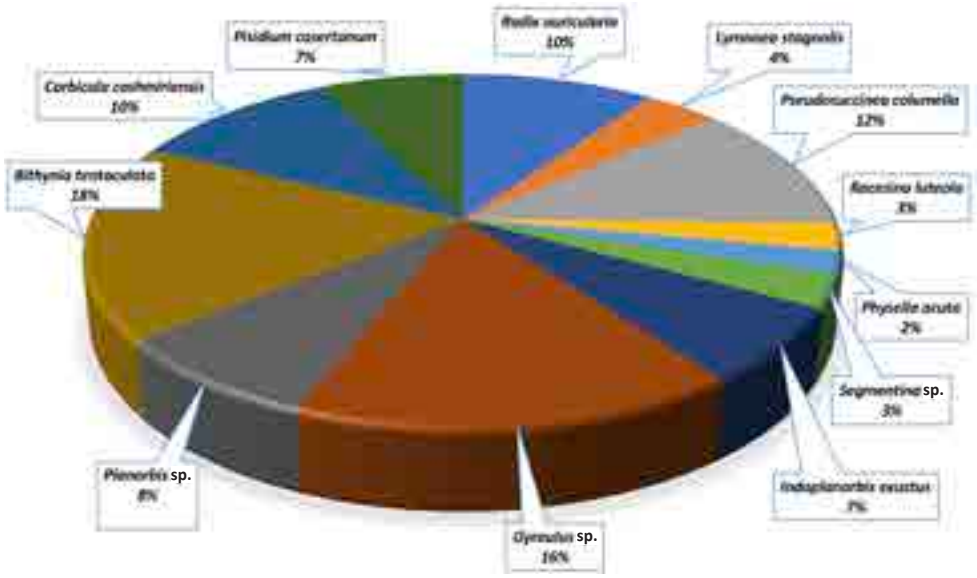


Figure 4. The annual percent contribution of different species to the total molluscan population.

Table 6. Correlation between the molluscan species and physico-chemical parameters from Aripal stream.

Malacofauna	AT	WT	DO	pH	EC	TDS	TH	Alk
Radix auricularia	0.48	0.5	-0.28	0.4	-0.06	-0.06	0.82**	0.15
Lymnaea stagnalis	0.16	0.06	-0.28	0.29	0.08	0.09	0.68*	0.39
Pseudosuccinea columella	0.48	0.61*	0.01	0.60*	0.01	0.02	0.65*	0.14
Racesina luteola	0.55	0.56	-0.20	0.46	-0.10	-0.05	0.81**	-0.01
Physella acuta	0.13	0.23	0.51	0.43	0.07	0.13	0.06	-0.19
Segmentina sp.	0.20	0.13	-0.32	0.16	0.18	0.14	0.62*	0.38
Indoplanorbis exustus	0.31	0.20	-0.37	0.24	0.11	0.10	0.68*	0.28
Gyraulus sp.	0.42	0.33	-0.38	0.24	-0.06	-0.07	0.78**	0.18
Planorbis sp.	0.72**	0.74**	-0.33	0.43	-0.26	-0.24	0.79**	-0.18
Bithynia tentaculata	0.90**	0.95**	-0.38	0.24	-0.57	-0.50	0.50	-0.70*
Corbicula cashmiriensis	0.23	0.29	-0.02	0.50	0.12	0.11	0.73**	0.43
Pisidium casertanum	0.46	0.61*	0.03	0.61*	-0.11	-0.08	0.67*	0.07

'*' significant correlation at P <0.05; '**' highly significant correlation at P <0.01; two-tailed Pearson's coefficient of correlation (r) applied.

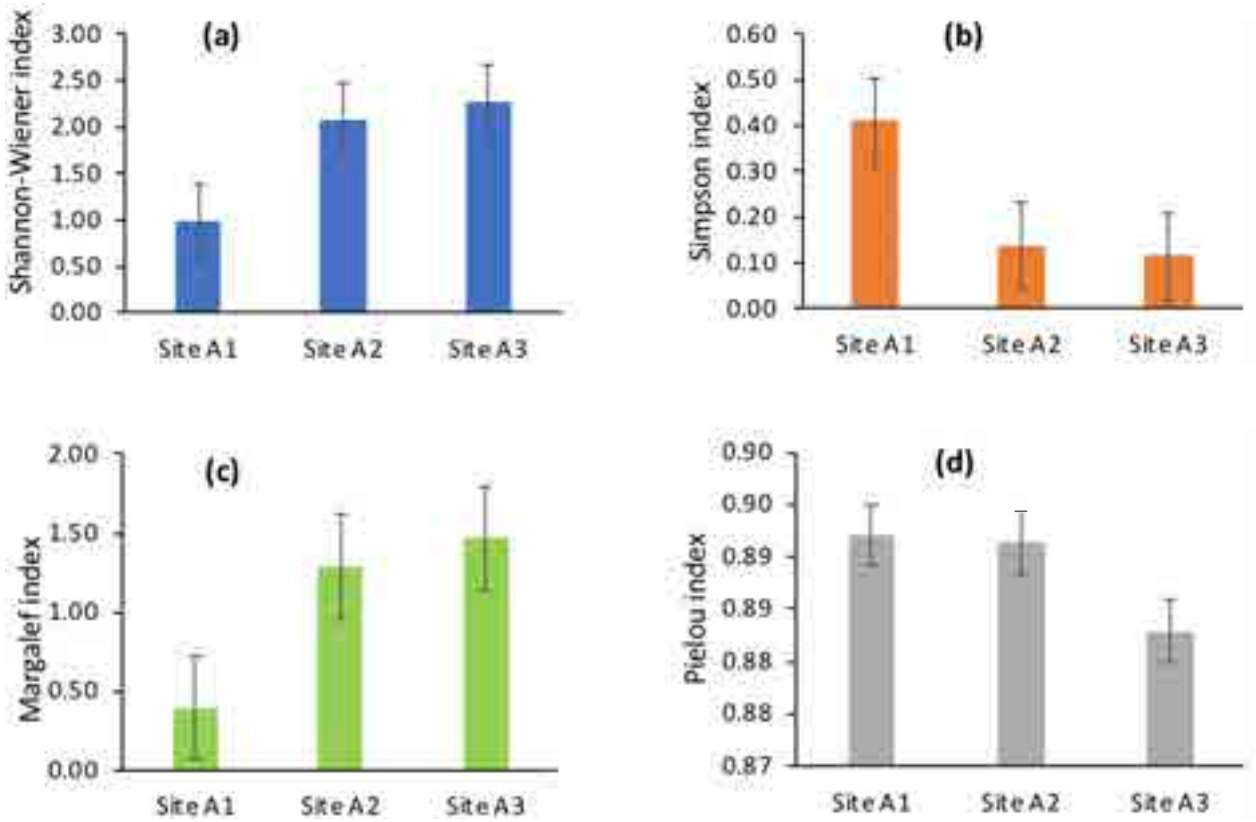


Figure 5. Spatial variation in the diversity of malacofauna from Aripal stream.

Gastropoda. Hora et al. (1955) observed the prevalence of *Gyraulus* sp., *Indoplanorbis exustus*, and *Valvata* sp. in the Kashmir valley. However, in our case, *Gyraulus* sp., *Planorbis* sp., and *Bithynia tentaculata* were recorded from all the sites which may be attributed to the availability of food and shelter in the form of leaf litter, aquatic macrophytes, periphyton, and organic-rich bottom sediments of different sites. The high prevalence of *Bithynia tentaculata* in the stream may be due to the better capability of utilizing the organic matter available in the bottom substrate. The presence of *Lymnaea stagnalis*, *Segmentina* sp., and *Indoplanorbis exustus* with the increase in electrical conductivity and total dissolved solids at site A3 may act as bioindicator of pollution. Wagh et al. (2019) noticed similar results with respect to freshwater molluscs in the Amravati district of Maharashtra, India. The selected sites along the stream face various types of disturbances. The site A1 is disturbed due to stone mining, floods, and land-use changes, site A2 is disturbed mainly from washing clothes and domestic sewage and site A3 receives the agricultural runoff from surrounding agricultural land. The presence of few species at site A1 (up-stream) may be the key cause of stone mining, occasionally torrential flow during floods, and change in land-use patterns which may cause habitat instability and result negative impacts upon the molluscan fauna. However, the species number increased abruptly towards the downstream which may be attributed to the reduction in the stream slope, low velocity, stability of bottom substrate, the inflow of nutrients from surrounding agricultural land, and sedimentation of fine organic matter. Further high diversity, richness, and evenness were observed at site A3 (down-stream) and low values at site A1 (up-stream). The high diversity, richness, and evenness in the downstream may reflect the stability of bottom substrate due to downward serpentine flow, formation of pool-rich stretches, and presence of different microhabitats by the introduction of woody debris and growth of periphyton and submerged macrophytes. The findings are validated by Strzelec & Krolczyk (2004) who reported that sandy bottom, vegetation, and organic sedimentation are the most suitable substrate for rich molluscan fauna. The richness of the molluscan species at site A2 and site A3 may also be attributed to the combined effect of higher values of alkalinity, pH, total hardness, and total dissolved solids. During the present study, majority of molluscan species showed a significant positive

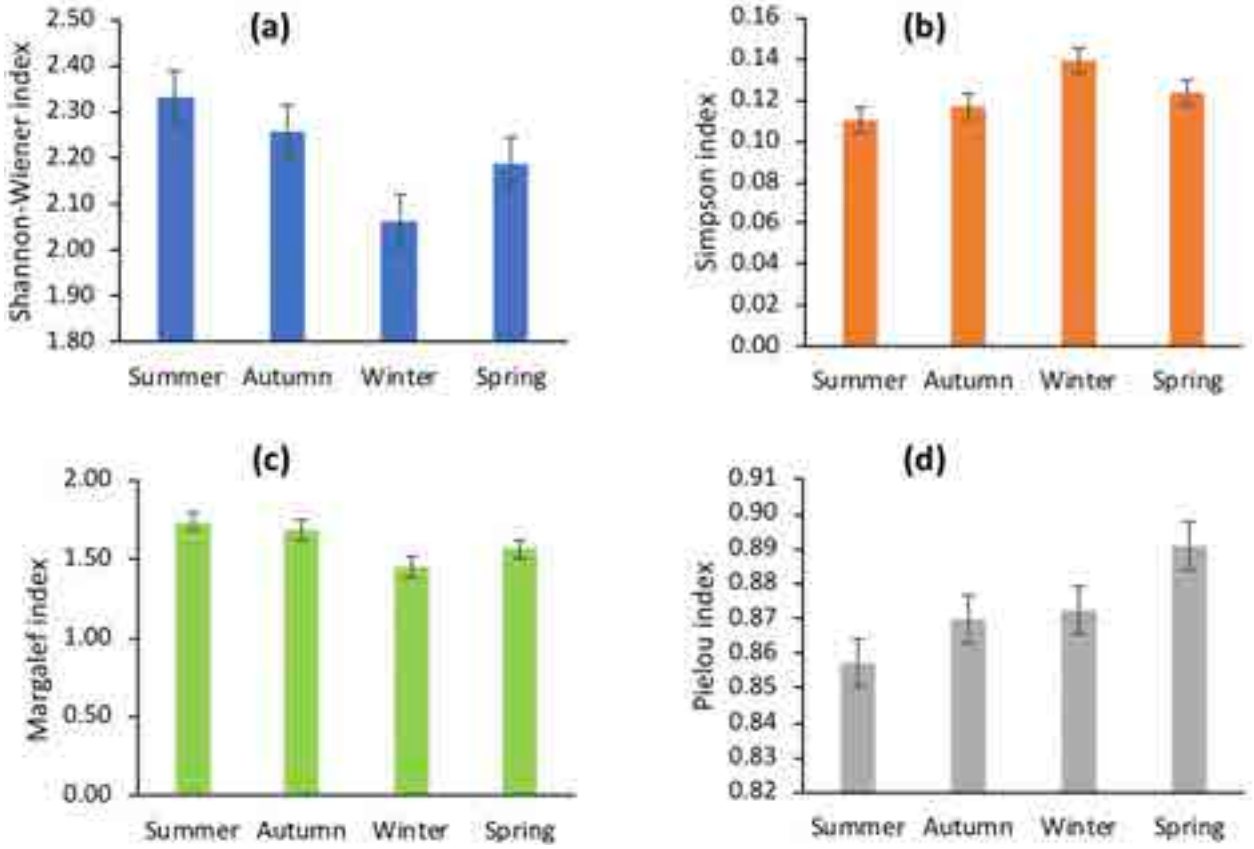


Figure 6. Temporal variation in the diversity of malacofauna from Aripal stream.

correlation with physico-chemical parameters. Many workers have reported a positive correlation between these parameters and mollusca (Malhotra et al. 1996). The dissolved oxygen showed spatially and temporally non-significant variation in the stream and also revealed a non-significant correlation with molluscan species. A similar trend was observed in earlier studies (Sharma 1986). In the temporal variation of mollusca, the species diversity and richness were observed maximum in the summer season while minimum in the winter season. This may be related to the two important parameters, viz., temperature and organic matter. The increase in the temperature during the summer season may activate the decomposition of organic matter suspended in the bottom substrate and may accelerate its conversion into inorganic nutrients. This process may promote the growth and structure of periphyton and macrophytes which form the suitable substrate for malacofauna. The statement is related to the findings of various other authors as well (Dutta & Malhotra 1986; Malhotra et al. 1996; Bath et al. 1999). The present study presents the spatial and temporal diversity patterns of malacofauna in the Aripal stream of Kashmir Himalaya. Mollusca as one of the components of macrobenthic invertebrates play role in the regulation of suspended organic matter within the bottom substrate of streams. The study emphasizes the need for the conservation of streams and their role in shaping the occurrence, distribution, abundance, and richness of malacofauna. Streams as freshwater ecosystems provide habitat for diverse flora and fauna and thus form an important model for ecological studies.

REFERENCES

Alhassan, A., A. Abidemi, I. Gadzama, R. Shaaba & Y. Wada (2020). Distribution and Diversity of Freshwater Snails of Public Health Importance in Kubanni Reservoir and Weir/Sediment Trap, Zaria, Nigeria. *Journal of Environmental and Occupational Health* 10(1): 1–9.

Allaie, I.M., R.A. Shahardar, A. Prasad, S.R. Tramboo, Z.A. Wani & S.S. Kubra (2019). Prevalence of snails in central Kashmir, India 7(3): 1018–1020.

American Public Health Association APHA (1998). Standard methods for the examination of water and wastewater. Washington, DC, 20 pp.

Aravind, N.A., K.P. Rajashekhar & N.A. Madhyastha (2010). A review of ecological studies on patterns and processes of distribution of land snails of the Western Ghats, India. *Proceeding of World*

Congress of Malacology 222 pp.

Barbour, M.T., J. Gerritsen, B.D. Snyder & J.B. Stribling (1999). Rapid Bioassessment Protocols for Use in Streams and Wadable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. 2nd Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency. Office of Water. Washington, District of Columbia, U.S.A. 339 pp.

Bath, K.S., H. Kaur & S.S. Dhillon (1999). Correlation of Molluscs with Physico-chemical factors at Harike Reservoir (Punjab). *Indian Journal of Environmental Sciences* 3: 159–163.

Bhat, S. & A.K. Pandit (2010). Ecological study of Benthic communities in Three Limnocrene freshwater springs in Kashmir Himalaya. *Journal of Natural Sciences and Mathematics* 3(2): 89–96.

Biggs, B.J., I.G. Jowett, J.M. Quinn, C.W. Hickey, R.J. Davies-Colley & M. Close (1990). Ecological characterization, classification, and modeling of New Zealand rivers: An introduction and synthesis. *New Zealand Journal of Marine and Freshwater Research* 24: 277–304.

Bilby, R.E. & J.W. Ward (1991). Characteristics and function of large woody debris in streams draining old growth, clear cut, and second-growth forests in southwestern Washington. *Canadian Journal of Fisheries and Aquatic Sciences* 48: 2499–2508.

Blanford, W.T. & H.H. Godin-Austen (1908). The Fauna of British India, including Ceylon and Burma, Mollusca I: Testacellidae and Zonitidae. *Taylor & Francis*, London 311 pp.

Boulton, A.J. & P.S. Lake (1992). The ecology of two intermittent streams in Victoria, Australia III. Temporal changes in faunal composition. *Freshwater Biology* 27: 123–138.

Bournard, M., H. Tachet, A.L. Roux & Y. Auda (1987). The effects of seasonal and hydrological influences on the macroinvertebrates of the Rhone River, France 1. Methodological aspects. *Archives of Hydrobiology* 109: 287–304.

Carter, J.L & Resh V.H (2001). After site selection and before data analysis: sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies. *Journal of North American Benthological Society* 20: 658–682.

Dhar, D.N., G.C. Bansal & R.L. Sharma (1985). Studies on the aquatic snails of Kashmir Valley with particular reference to *Lymnaea auricularia sensu stricto*. *Indian Journal of Parasitology* 9: 241–44.

Dutta, S.P.S. & Y.R. Malhotra (1986). Seasonal variations in the macro-benthic fauna of Gadigarh stream (Miran Sahib), Jammu. *Indian Journal of Ecology* 13: 138–145.

Edmondson, W.T. (1959). *Freshwater Biology*. John Wiley and Sons Inc., New York, London.

Ghani, A., N. Afsar & S. Rahman (2017). Quantitative analysis of macrobenthic molluscan populations inhabiting Bandri area of Jiwani, South West Pakistan Coast. *Jordan Journal of Biological Sciences* 10: 281–287.

Habib, S. & A.R. Yousuf (2012). Benthic macroinvertebrate community of Yousmarg streams (Doodganga stream and Khanshah Manshah canal) in Kashmir Himalaya. *Indian Journal of Ecology and the Natural Environment* 4(11): 280–289.

Habib, S. & A.R. Yousuf (2014). Benthic macroinvertebrate community of a fourth order stream in Kashmir Himalaya, India. *African Journal of Environmental Sciences and Technology* 8(4): 234–238.

Hayslip & Gretchen (2007). Methods for the collection and analysis of benthic macroinvertebrate assemblages in wadeable streams of the Pacific Northwest. Pacific Northwest Aquatic Monitoring Partnership, Cook, Washington.

Hora, S.L., G.M. Mulik & H. Khajuria (1955). Some interesting features of the aquatic fauna of the Kashmir Valley. *Journal of the Bombay Natural History Society* 53(1): 140–143.

Hynes, H.B.N. (1970). The Ecology of Running Waters. Liverpool University Press, England 555 pp.

Linke, S., R.C. Bailey & T.J. Schwind (1999). Temporal variability of stream bioassessments using benthic macroinvertebrates. *Freshwater Biology* 42: 575–584.

Lydeard, C., R.H. Cowie, W. Ponder, A.E. Bogan, P. Bouchet, S.A. Clark, K.S. Cummings, T.J. Frest, O. Gar- Gominy, D.G. Herbert, R. Hershler, K.E. Perez, B. Roth, M. Seddon, E.E. Strong & F.G. Thompson (2004). The global decline of nonmarine mollusks. *BioScience* 54: 321–330.

Malhotra, Y.R., K.K. Sharma & M.R. Thakial (1996). Ecology of macro invertebrates from a fish pond. *Proceedings of the National Academy of Sciences India* 66: 55–59.

Margalef, R. (1958). Temporal succession and spatial heterogeneity in phytoplankton, pp. 323–347. In: Buzzati-Traverso (ed.). *Perspectives in Marine Biology*. University of California Press, Berkeley.

Martin, A. (1991). Molluscs as agricultural pests. *Outlooks on World Agriculture* 20: 167–174.

Mir, K.A. & M. Saleem (2016). District survey report of Pulwama district. Department of Geology and Mining, J&K Srinagar, 26 pp.

Mostafa, O.M.S. (2009). Effect of salinity and drought on the survival of *Biomphalaria arabica*, the intermediate host of *Schistosoma mansoni* in Saudi Arabia. *Egyptian Academic Journal of Biological Science* 1(1): 1–6.

Moulton, S.R., J.L. Carter, S.A. Grotheer, T.F. Cuffney & T.M. Short (2000). Methods of analysis by the US Geological Survey National Water Quality Laboratory: processing, taxonomy, and quality control of benthic macroinvertebrate samples. US Geological Survey Open-File Report, 212 pp.

Nelson, J.W., J.A. Kadlec & H.R. Murkin (1990). Responses by macroinvertebrates to cattail litter quality and timing of litter submergence in a northern prairie marsh. *Wetlands* 10(1): 47–60.

Pandit, A.K., S.A. Rather, S.A. Bhat & A.Q Shah (2002). *Physico-chemical features of freshwaters of Kashmir Himalaya*, pp. 112 –138. In: Unni, K.S. (ed.). Conservation and Management of Aquatic Ecosystems. Daya Publishing House, Delhi.

Peck, D.V., J.M. Lazorchak & D.J. Klemm (2002). Environmental Monitoring and Assessment Program--Surface Waters: Western Pilot Study Field Operations Manual for Wadable Streams. National Health and Environmental Effects Research Laboratory [and] National Exposure Research Laboratory, Office of Research and Development, US Environmental Protection Agency.

Peeters, E.T. & J.J.P. Gardeniers (1998). Logistic regression as a tool for defining habitat requirements of two common gammarids. *Freshwater Biology* 39: 605–615.

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

Poff, N.L. & J.V. Ward (1989). Implications of streamflow variability and predictability for lotic community structure: A regional analysis of streamflow patterns. *Canadian Journal of Fisheries and Aquatic Sciences* 46: 1805–1817.

Primack, R.B. (2002). *Essentials of Conservation Biology*, 3rd Ed. Sinauer Associates, Sunderland, Massachusetts, 698 pp.

Qadri, M.Y., S.A. Naqash, G.M. Shah, & A.R. Yousuf (1981). Limnology of two trout streams of Kashmir. *Journal of Indian Institute of Sciences* 63: 137–141.

Ramakrishna & A. Dey (2007). *Handbook on Indian freshwater molluscs*. AICOPTAX--Mollusca, Zoological Survey of India, 399 pp.

Rao, N.V.S. (1989). *Handbook of Freshwater Molluscs of India*, Zoological Survey of India, Calcutta, 290 pp.

Rao, N.V.S. (1993). Fresh water molluscs of India. In: Roa K.S. (ed.). *Recent Advances in Fresh Water Biology*. Anmol Publications Pvt. Ltd., New Delhi, India, 380 pp.

Reddy, V.M. (1995). *Soil organisms and litter decomposition in the tropics*. Oxford and IBH CO. Pvt. Ltd., 272 pp.

Rosenberg, D.M. & V.H. Resh (1993). Introduction to fresh water biomonitoring and benthic macroinvertebrates, pp. 1–9. In: Rosenberg, D.M. & V.H. Resh (eds.). *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman and Hall, New York.

Rosillon, D. (1987). Seasonal variation in the benthos of a chalk trout stream, the River Samson, Belgium. *Hydrobiologia* 126: 253–262.

Shannon, C. E. & W. Wiener (1949). *The Mathematical Theory of Communication*. Urbana, University of Illinois Press, 177 pp.

Sharma, K.K., S. Chowdhary & A. Sharma (2010). Malacofuana diversity of river Chenab fed stream (Gho-Manhasan). *The Bioscan* 6(2): 267–269.

Sharma, R.C. (1986). Effect of physico-chemical factors on benthic

fauna of Bhagirathi river, Garhwal Himalayas. *Indian Journal of Ecology* 13: 133–137.

Silva, E.L., A.J. Rocha, M.F. Leal, O. Dos Santos, J.H. Sousa, A.R.V. Silva, K.K.S. Dantas, E.M.M. Rulim, E.S. Castro, A.C.L. Pacheco & T.G. Pinheiro (2020). Freshwater mollusks from three reservoirs of Piaui, northeastern Brazil. *Biota Neotropica* 20(1): 1–8.

Simpson, E.H. (1949). Measurement of diversity. *Nature* 163: 688pp.

Strzelec, M. & A. Krolczyk (2004). Factors affecting snail (Gastropoda) community structure in the upper course of the Warta river (Poland). *Biologia Bratislava* 59(2): 159–163.

Wagh, G.A., H.A. Qurashi & S. Patil (2019). A Brief Note on Molluscan Diversity From Water Bodies of Amravati MS India. *Bioscience Biotechnology Research Communications* 12(3): 814–819.

Wosu, L.O. (2003). *Commercial Snail Farming in West-Africa - A Guide*. AP Express Publishers Ltd., Nsukka.

Yousuf, A.R., F.A. Bhat & M.D. Mahdi (2006). Limnological features of River Jhelum and its important tributaries in Kashmir Himalaya with a note on fish fauna. *Journal of Himalayan Ecology and Sustainable Development* 1: 37–50.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20758–20772

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

https://doi.org/10.11609/jott.6754.14.3.20758-20772

#6754 | Received 30 September 2020 | Final received 09 December 2021 | Finally accepted 02 March 2022

OPEN ACCESS

COMMUNICATION

A checklist of blue-green algae (Cyanobacteria) from Punjab, India

Yadvinder Singh [1*], Gurdarshan Singh [2], D.P. Singh [3] & J.I.S. Khattar [4*]

[1,2] Department of Botany and Environmental Science, Sri Guru Granth Sahib World University, Fatehgarh Sahib, Punjab 140406, India.
[3,4] Department of Botany, Punjabi University, Patiala, Punjab 147002, India.
[1] yadbotany@gmail.com, [2] gurdarshanrangra@gmail.com, [3] dp.khokhar@rediffmail.com, [4] jisk_pbi@rediffmail.com
* (corresponding authors)

Abstract: A checklist of Cyanobacteria (Blue-green algae) has been made by reviewing available literature in order to contribute to the knowledge of biodiversity of algae in the Punjab state of India. The list records 317 taxa of the phylum Cyanobacteria distributed among 74 genera, 32 families, and six orders. The order Oscillatoriales has 115 taxa, followed by Nostocales (84), Synechococcales (60), Chroococcales (49), Spirulinales (8), and Pleurocapsales (1). The family Nostocaceae has the maximum number of genera followed by Microcoleaceae, Chroococcaceae, Oscillatoriaceae and other reported families. The genera with the highest number of species were *Phormidium* (39 species), *Lyngbya* (15 species), *Oscillatoria* (14 species), and *Leptolyngbya* & *Scytonema* (13 species each). The checklist revealed a high degree of species richness within phylum Cyanobacteria found in Punjab. This checklist can provide a baseline for future floristic studies with taxonomically updated/accepted name of genera/species of cyanobacteria.

Keywords: Algae, biogeography, cyanophyceae, diversity, documentation, inventory, taxonomy.

Punjabi: ਭਾਰਤ ਦੇ ਪੰਜਾਬ ਰਾਜ ਵਿੱਚ ਕਾਈ ਦੀ ਜੈਵ-ਵਿਭਿੰਨਤਾ ਦੇ ਗਿਆਨ ਵਿੱਚ ਯੋਗਦਾਨ ਪਾਉਣ ਲਈ ਉਪਲਬੱਧ ਲਿਟਰੇਚਰ ਦੀ ਸਮੀਖਿਆ ਕਰਕੇ ਸਾਇਨੋਬੈਕਟੀਰੀਆ (ਨੀਲੀ-ਹਰੀ ਕਾਈ) ਦੀ ਇੱਕ ਸੂਚੀ ਬਣਾਈ ਗਈ ਹੈ। ਸੂਚੀ ਵਿੱਚ ਸਾਇਨੋਬੈਕਟੀਰੀਆ ਦੇ 06 ਕੁਲਾਂ ਦੇ 32 ਪ੍ਰੀਵਾਰਾਂ ਦੀਆਂ 74 ਪ੍ਰਜਾਤੀਆਂ ਦੀਆਂ 317 ਕਿਸਮਾਂ (ਟੈਕਸਾ) ਨੂੰ ਸੂਚੀ ਬੰਦ ਕੀਤਾ ਗਿਆ ਹੈ। ਸੂਚੀ ਅਨੁਸਾਰ ਪੰਜਾਬ ਰਾਜ ਵਿੱਚ ਓਸੀਲੇਟੋਰੀਏਲਸ ਕੁਲ ਦੀਆਂ ਸਭ ਤੋਂ ਵੱਧ 115 ਕਿਸਮਾਂ ਹਨ, ਇਸ ਤੋਂ ਬਾਅਦ ਨੋਸਟੋਕੇਲਸ (84), ਸਿਨੇਕੋਕੋਕੇਲਸ (60), ਕਰੂਕੋਕੇਲਸ (49), ਸਪੀਰੂਲਿਨੇਲਜ਼ (8), ਅਤੇ ਪਲੀਰੋਕੈਪਸੇਲਸ (1) ਕੁਲ ਆਉਂਦੇ ਹਨ। ਨੋਸਟੋਕੇਸੀ ਪਰਿਵਾਰ ਦੀਆਂ ਸਭ ਤੋਂ ਵੱਧ ਪ੍ਰਜਾਤੀਆਂ ਸੂਚੀ ਵਿੱਚ ਸ਼ਾਮਿਲ ਹਨ। ਇਸ ਤੋਂ ਬਾਅਦ ਮਾਈਕ੍ਰੋਕੋਲੀਏਸੀ, ਕਰੂਕੋਕੇਸੀ, ਓਸੀਲੇਟੋਰੀਏਸੀ ਅਤੇ ਬਾਕੀ ਰਿਪੋਰਟ ਕੀਤੇ ਗਏ ਪਰਿਵਾਰਾਂ ਦੀ ਵਾਰੀ ਆਉਂਦੀ ਹੈ। ਸਭ ਤੋਂ ਵੱਧ ਜਾਤੀ ਵਾਲੀਆਂ ਪ੍ਰਜਾਤੀਆਂ ਫੋਰਮਿਡੀਅਮ (39 ਜਾਤੀਆਂ), ਲਿੰਗਬਿਆ (15 ਜਾਤੀਆਂ), ਓਸੀਲੇਟੋਰੀਆ (14 ਜਾਤੀਆਂ), ਅਤੇ ਲੈਪਟੋਲਿੰਗਬਿਆ ਅਤੇ ਸਾਇਟੋਨੇਮਾ (ਹਰੇਕ 13 ਜਾਤੀਆਂ) ਹਨ। ਇਸ ਸੂਚੀ ਅਨੁਸਾਰ ਪੰਜਾਬ ਵਿੱਚ ਪਾਏ ਜਾਣ ਵਾਲੇ ਸਾਇਨੋਬੈਕਟੀਰੀਆ ਦੀਆਂ ਜਾਤੀਆਂ ਵਿਚ ਉੱਚ ਪੱਧਰੀ ਵਿਭਿੰਨਤਾ ਹੈ। ਇਹ ਸੂਚੀ ਸਾਇਨੋਬੈਕਟੀਰੀਆ ਦੀਆਂ ਪ੍ਰਜਾਤੀਆਂ / ਜਾਤੀਆਂ ਦੇ ਟੈਕਸੋਨੋਮਿਕ ਤੌਰ 'ਤੇ ਅੱਪਡੇਟ ਕੀਤੇ/ਸਵੀਕਾਰ ਕੀਤੇ ਗਏ ਨਾਮਾਂ ਦੇ ਨਾਲ-ਨਾਲ ਭਵਿੱਖੀ ਫਲੋਰਿਸਟਿਕ ਅਧਿਐਨਾਂ ਲਈ ਅਧਾਰ ਪ੍ਰਦਾਨ ਕਰਦੀ ਹੈ।

Editor: K. Priyadarshani, Y.C. Institute of Science, Satara, India. **Date of publication:** 26 March 2022 (online & print)

Citation: Singh, Y., G. Singh, D.P. Singh & J.I.S. Khattar (2022). A checklist of blue-green algae (Cyanobacteria) from Punjab, India. *Journal of Threatened Taxa* 14(3): 20758–20772. https://doi.org/10.11609/jott.6754.14.3.20758-20772

Funding: Early career research grant (No. ECR/2017/001103) from SERB-DST, New Delhi to Yadvinder Singh (YS).

Competing interests: The authors declare no competing interests.

Author details: Dr. Yadvinder Singh is working as Assistant Professor (Botany) in Department of Botany and Environmental Science of Sri Guru Granth Sahib World University. He has published extensively on various aspects of extremophilic cyanobacteria, fresh water limnology and ecology, bioremediation potential of cyanobacteria, cyanobacterial systematics and phylogenetics. Mr. Gurdarshan Singh currently doing his PhD at Department of Botany and Environmental Science, Sri Guru Granth Sahib World University. He is doing his research work on the water quality and diversity of blue green algae (cyanobacteria) from the wetlands of Punjab, India. Prof. D.P. Singh is working as Professor (Botany) and Head in Department of Botany, Punjabi University, Patiala. He is the member of various professional bodies and organizations. He has published a number of research papers in journals of international repute and several book chapters, having more than 674 citations with 15 h-index and 22 i10-index. Prof. J.I.S. Khattar is working as Professor (Botany), Department of Botany, Punjabi University. He has published 65 research papers in reputed International Journals on various aspects of algae including the physiology & biochemistry of cyanobacteria, environmental microbiology, and cyanobacterial biotechnology. He was completed 07 research projects sponsored by various funding agencies. He has guided 27 Ph.D. and M.Phil. students in their research projects.

Author contributions: Conceptualization (YS, JISK & DPS), investigation (GS & YS), writing (GS), original draft (YS & GS), writing - review & editing (GS, YS, JISK & DPS).

Acknowledgements: The authors are thankful to the vice-chancellor, Sri Guru Granth Sahib World University, Fatehgarh Sahib, Punjab, India for providing laboratory facilities and SERB-DST, New Delhi for financial assistance in the form research project (ECR/2017/001103).

INTRODUCTION

Cyanobacteria, also known as Blue-green algae, are oxygenic photosynthetic prokaryotes belonging to the class Cyanophyceae. It has been estimated that these organisms originated nearly 3.5–3.8 billion years ago at the beginning of Archean era (Schopf 2002; Blank & Sanchez-Baracaldo 2010; Sleep 2010). Cyanobacteria occur in diverse range of aquatic and terrestrial habitats including extreme environments (Whitton & Potts 2000; Singh et al. 2014, 2018; Kimambo et al. 2019). They show high degree of phenotypic variation when compared to other prokaryotic organisms (Dvořák et al. 2017). Traditionally these organisms have been identified and categorized mainly using morphological features such as dimension, shape of vegetative and perennation stage, colour & characteristics of sheath, branching pattern, and cell contents (Komárek & Anagnostidis 1998, 2005; Komárek 2013). Presently, the advancement and use of modern taxonomic tools including ultrastructural studies, 16S rRNA gene, 16S-23S rRNA ITS region and cpcB-cpcA IGS region of phycocyanin locus has lead to the changes in taxonomic position of various cyanobacterial genera/ species (Komárek 2014). The ability of cyanobacteria to release exopolysaccharides and fix atmospheric nitrogen is pertinent in maintaining a healthy condition of the soil; addidtionally, this ability can further assist with the reclamation of barren land (Singh et al. 2016). In recent years, cyanobacterial research has gained greater academic interest as many species in this phylum have been identified to be a potential source of various value-added products such as biofertilizers, biofuels, and bioactive compounds. Cyanobacteria is also an attractive laboratory model that is used for genetic studies to understand their adaptation to extreme conditions and climatic changes. (Abed et al. 2008; Al-Haj 2016; Singh et al. 2017; Kumar et al. 2019).

Cyanobacteria have been reported from various habitats in Punjab including wetlands, paddy fields and polluted water etc. (Vasishta 1960a, 1961, 1962a,b, 1963; Pandhol 1974; Grover & Pandhol 1975; Mehta 1975; Sarma et al. 1979; Dhingra 2006; Singh et al. 2009; Khattar et al. 2015). Despite an increase in research effort, knowledge regarding the diversity and distribution of cyanobacteria in Punjab is still inconsistent. Thus there is need for an updated species checklist in order to contribute to the current knowledge of cyanobacterial diversity of the state. Although, in Gupta (2012) published a checklist of cyanobacteria from India in which 218 cyanobacterial taxa were reported from Punjab, the present study adds 99 taxa to this list, hence increasing the total to 317 taxa. Since cyanobacteria are an important component of the aquatic ecosystem, cyanobacterial wealth of the state should be known so that these can be collected and cultured for future studies.

The objective of this work was to revise and organize all available existing taxonomic data for cyanobacteria of recent taxonomic revisions in the state of Punjab. The checklist could serve as a baseline for future diversity, limnological, environmental impact assessment, bio-geographic distribution and speciation studies. Creation of a checklist is the most basic taxonomic work on a group of organisms arranged in systematic or alphabetical order. The checklist prepared during present work is done in a systematic order by reviewing the available literature up to September 2020. This is the first complete checklist of cyanobacteria from Punjab covering all currently accepted species names and their synonyms.

MATERIALS AND METHODS

This checklist has been prepared by consulting available literature including research papers and dissertations (PhD/ M.Phil/ MSc.). Data were compiled by reviewing diversity, taxonomy and ecological studies containing lists of cyanobacteria identified up to species level. Geographically, Punjab is situated in the north of the country between 29.30–32.32 °N and 73.55–76.50 °E (Figure 1). The climate of Punjab is continental, semiarid to sub-humid, it experiences both extreme summer and winter with annual rainfall of 58–96 cm (Gosal 2004; Krishan et al. 2015). The texture of soil in Punjab varies from coarse to fine sand, silt, and loam (Dhingra 2006). Cyanobacterial species recorded in this checklist were identified by various workers from the year 1936 to 2020. In this checklist species were arranged taxonomically by following the classification system recommended by Komárek (2014). Additionally, the taxonomic position, authorities and the currently accepted name was verified from AlgaeBase website (Guiry & Guiry 2020).

RESULTS AND DISCUSSION

This compiled checklist revealed that cyanobacterial diversity within Punjab is represented by 317 taxa (297 species, 13 varieties, and 7 forms) belonging to 74 genera and five orders (i.e., Chroococcales,

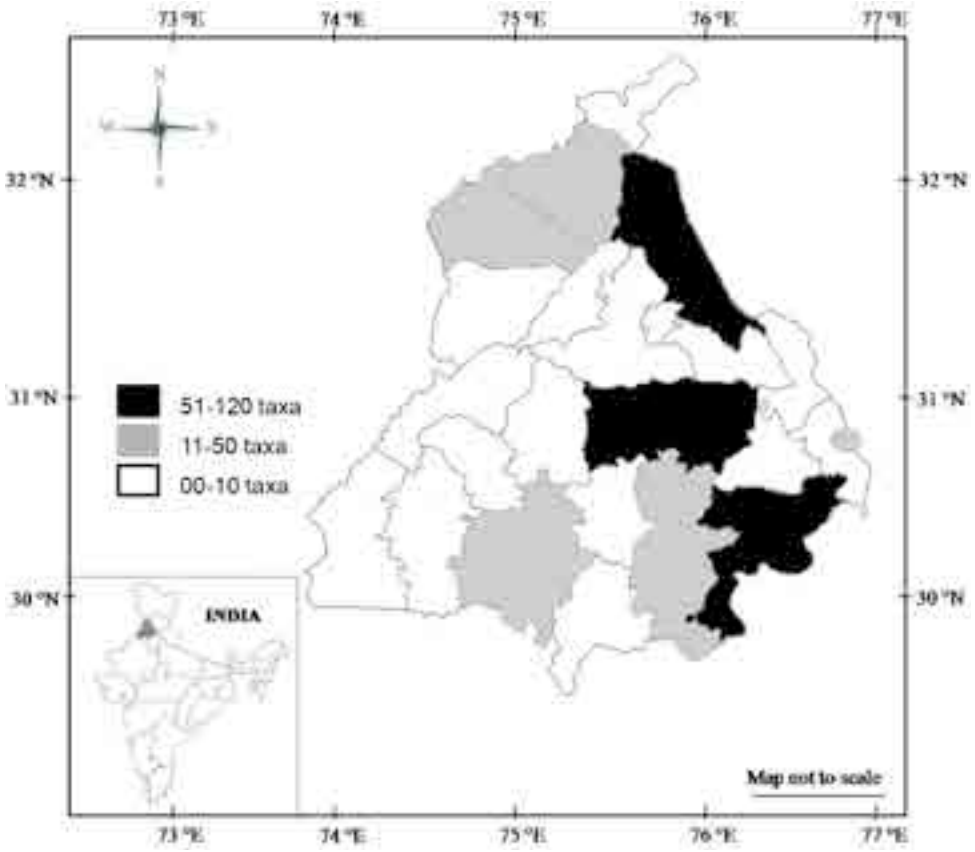


Figure 1. Distribution of cyanobacterial taxa in different regions of Punjab state of India (Source: www.google.com)

Synechococcales, Spirulinales, Oscillatoriales, and Nostocales) of Class Cyanophyceae (Table 1). On the basis of number of species, order Oscillatoriales (36%) is found to be the most diverse followed by Nostocales (27%), Synechococcales (19%), Chroococcales (15%), and Spirulinales (3%) (Figure 2). Among the genera, genus *Phormidium* had the maximum number of species, i.e., 39 followed by *Lyngbya* with 15 species, *Oscillatoria* with 14 species, *Leptolyngbya* and *Scytonema* with 13 species each. The families with the highest number of taxa were Oscillatoriaceae (72), Nostocaceae (51), Microcoleaceae (30), Microcystaceae (22) and Merismopediaceae (16). Vasishta (1960d, 1961, 1963b) reported 117 cyanobacterial taxa from Hoshiarpur district of Punjab. Grover and Pandhol (1974) reported 62 cyanobacterial species from paddy fields of Punjab. Sarma et al. (1979) identified 67 cyanobacterial species from varied localities in Patiala district of Punjab. Extensive floristic work performed by Dhingra (2006) on blue-green algae reported 158 species from moist soils, wetlands, ponds, roadside puddles, bricked and cemented surfaces from various localities of Punjab. Singh et al. (2009) studied cyanobacterial diversity from the rice fields of Patiala district and reported 25 cyanobacterial species from the study area.

The taxonomic identity of 87 cyanobacterial taxa previously reported from Punjab on their morphology has been revised with the help of modern taxonomic tools (marked with '*' in Table 1). Current accepted names of such taxa were updated following Algaebase. Taxonomic revision is continuous leading to the revision of taxonomic status as well as the nomenclature of the organism. Application of modern ecological, ultra-structural and molecular methods, aided by the cultivation of numerous cyanobacterial morphotypes, has substantially changed our knowledge of these organisms (Komárek 2006). Modern taxonomic tools have also enabled major advances in cyanobacterial taxonomy and aided with the criteria used for their phylogenetic classification (Komárek 2006, 2014).

Cyanobacteria recorded from Punjab inhabit varied habitats from planktonic to terrestrial and epilithic to epiphytic. Observations made from the present checklist note that the number of cyanobacterial species growing on terrestrial habitats (110) were greater than planktonic (84), epilithic (26), and epiphytic (15) (Table 1). However,

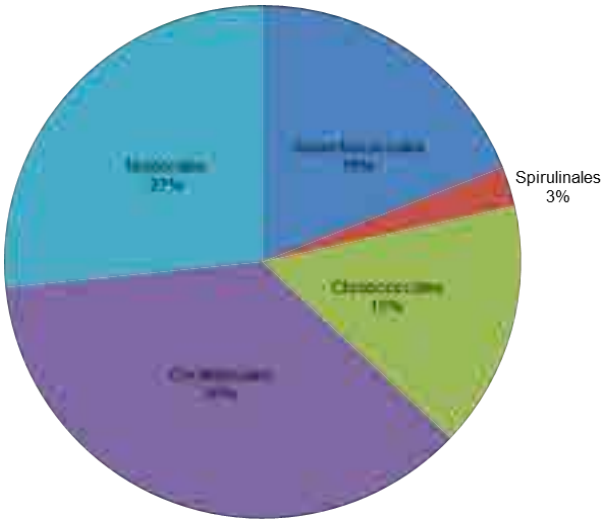


Figure 2. Prevalence of taxa belonging to different cyanobacterial orders in Punjab.

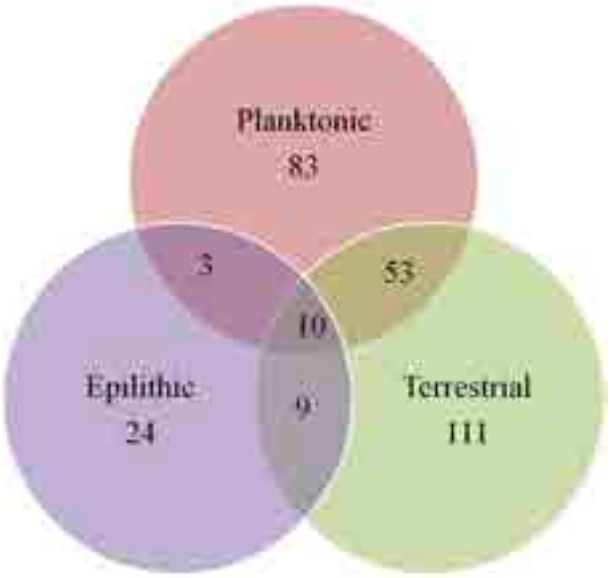


Figure 3. Habitat-wise distribution of cyanobacteria in Punjab.

78 cyanobacterial species were reported from more than one habitat (Table 1, Figure 3). They colonize large portions of the available terrestrial habitats due to its ability of 'anhydrobiosis' (Billi & Potts 2002; Alpert 2005). Moreover, they have a wide distribution range due to their unimaginable adaptive capacities (Gaysina 2019).

In conclusion, as a first complete and updated checklist of cyanobacteria from Punjab this will provide a baseline data for future floristic study. The explored and poorly explored regions of Punjab in terms of number of cyanobacterial taxa are highlighted in Figure 1. We can also assume that future studies of cyanobacterial diversity from poorly explored regions will increase the number of species by exploring more unexplored habitats of Punjab.

REFERENCES

Abed, R.M.M., S. Dobretsov & S. Kumar (2008). Applications of cyanobacteria in biotechnology. *Journal of Applied Microbiology* 106: 1–12.

Al-Haj, L., Y.T. Lui, R. M. M. Abed, M. A. Gomaa & S. Purton (2016). Cyanobacteria as chassis for industrial biotechnology: Progress and Prospects. *Life* 6: 1–17.

Alpert, P. (2005). The limits and frontiers of desiccation-tolerant life. *Integrative and Comparative Biology*. 45: 685–695.

Billi, D. & M. Potts (2002). Life and death of dry prokaryotes. *Research in Microbiology* 153(1): 7–12.

Blank, C.E. & P. Sanchez-Baracaldo (2010). Timing of morphological and ecological innovations in the cyanobacteria -a key to understanding the rise in atmospheric oxygen. *Geobiology* 8 (1): 1–23.

Dhingra, R. (2006). Biodiversity assessment and conservation of blue green algae from Punjab. PhD thesis. Department of Botany, Panjab University, Chandigarh, 241 pp.

Dvořák, P., D.A. Casamatta, P. Hašler, E. Jahodářová, A.R. Norwich & A. Poulíčková (2017) Diversity of the Cyanobacteria. pp. 3–46. In: P.C. Hallenbeck (eds.) *Modern topics in the Phototrophic Prokaryotes*. Springer. International Publshing Switzerland, 480pp.

Gaysina, L. A., A. Saraf & P. Singh (2019). Cyanobacteria in Diverse Habitats, pp. 1-28. In: Rai, A.N., D.N. Tewari and A.K. Mishra (eds.) *Cyanobacteria: From Basic Science to Applications*. Elsevier: Amsterdam, The Netherlands, 541 pp.

Gosal, G. (2004). Physical geography of the Punjab. *Journal of Punjab Studies*. 11: 19–37.

Grover, I.S. & R.K. Pandhol (1975) Algal flora of paddy fields of Ludhiana and its adjacent areas. *Phykos* 14(1–2): 89–97.

Guiry, M.D. & G.M. Guiry (2020). AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. https://www.algaebase.org. Searched on 26 February 2020.

Gupta, R.K. (2012). *Algae of India* Vol-1: *A checklist of Cyanoprokaryota (Cyanophyceae)*. Botanical Survey of India, Ministry of Environment & Forests, Kolkata, 160 pp.

Jindal, N., D.P. Singh & J.I.S. Khattar (2013). Optimization, characterization, and flow properties of exopolysaccharides produced by the cyanobacterium *Lyngbya stagnina*. *Journal of Basic Microbiology* 53(11): 902–912.

Kaur, S., A.S. Ahluwalia & S. Kumar (2017). Seasonal variation of phytoplankton assemblages and relation to environmental variables in a freshwater lake situated in the zoological park, Chattbir, Punjab, India. *Panjab University Research Journal (Science)* 67: 35–48.

Kimambo, O.N., R.G. Jabulani & C. Hector (2019). The occurrence of cyanobacteria blooms in freshwater ecosystems and their link with hydro-meteorological and environmental variations in Tanzania. *Heliyon* 5(3): 1–23.

Khattar, J.I.S. & N. Jindal (2008). Isolation and characterization of exopolysaccharides produced by the cyanobacterium *Phormidium valderianum*. *Journal of Biotechnology* 136: 423–424.

Khattar, J.I.S. & Shailza (2009). Optimization of Cd^{2+} removal by the cyanobacterium *Synechocystis pevalekii* using the response surface methodology. *Process Biochemistry* 44(1): 118–121.

Khattar, J.I.S., S. Kaur, S. Kaushal, Y. Singh, D.P. Singh, S. Rana & A. Gulati (2015). Hyperproduction of phycobiliproteins by the cyanobacterium *Anabaena fertilissima* PUPCCC 410.5 under

Table 1. Checklist of cyanobacteria recorded for the state of Punjab, India.

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
	Class: Cyanophyceae					
	Subclass: Synechococcophycidae					
	Order: Synechococcales					
	Family: Synechococcaceae					
1	*Anathece clathrata* (West & G.S.West) Komárek, Kastovsky & Jezberová **Aphanothece clathrata* West & G.S.West	+	-	-	-	16
2	*Rhabdogloea minuta* B. Hickel	+	-	-	-	16
3	*Synechococcus elongatus* (Nägeli) Nägeli	+	+	-	-	16, 20
	Family Merismopediaceae					
4	*Aphanocapsa biformis* A.Braun	+	-	-	-	7
5	*Aphanocapsa delicatissima* West & G.S.West	-	+	-	-	12
6	*Aphanocapsa elachista* West & G.S.West	-	+	-	-	12
7	*Aphanocapsa grevillei* (Berkeley) Rabenhorst	+	-	-	-	16
8	*Aphanocapsa koordersi* K.M.Strøm	+	-	-	-	16
9	*Aphanocapsa muscicola* (Meneghini) Wille **Aphanocapsa montana* Cramer	+	+	+	-	1, 7, 12
10	*Aphanocapsa roseana* De Bary	-	+	-	-	12
11	*Aphanocapsa stagnalis* (Lemmermann) R.N.Beljakova **Microcystis stagnalis* (Lemmermann) Lemmermann	+	-	-	-	12, 16
12	*Limnococcus limneticus* (Lemmermann) Komárková, Jezberová, O.Komárek & Zapomelová **Chroococcus limneticus* Lemmermann	+	-	-	-	10
13	*Merismopedia elegans* A. Braun ex Kützing	+	-	-	-	16, 25
14	*Merismopedia glauca* (Ehrenberg) Kützing **Merismopedia aeruginea* Brébisson	+	+	-	-	7, 10, 16
15	*Merismopedia sparsa* Komárek & G.Cronberg	+	-	-	-	30
16	*Merismopedia tranquilla* (Ehrenberg) Trevisan **Merismopedia punctata* Meyen	+	+	-	-	2, 12, 16
17	*Merismopedia warmingiana* (Lagerheim) Forti	+	+	+	-	16
18	*Synechocystis aquatilis* Sauvageau	+	+	-	-	10, 11, 16
19	*Synechocystis pevalekii* Ercegovic	+	+	+	-	11, 19, 21
	Family Coelosphaeriaceae					
20	*Coelosphaerium aerugineum* Lemmermann	+	-	-	-	16
21	*Coelosphaerium dubium* Grunow	+	-	-	-	16
22	*Snowella lacustris* (Chodat) Komárek & Hindák	+	-	-	-	16
	Family Pseudanabaenaceae					
23	*Limnothrix redekei* (Goor) Meffert	-	+	-	-	21
24	*Pseudanabaena amphigranulata* (Goor) Anagnostidis **Oscillatoria amphigranulata* Goor	+	-	-	-	10
25	*Pseudanabaena catenata* Lauterborn	+	+	-	-	16
26	*Pseudanabaena galeata* Böcher	+	-	-	-	16
27	*Pseudanabaena limnetica* (Lemmermann) Komárek	+	-	-	-	16
28	*Pseudanabaena minima* (G.S.An) Anagnostidis	+	+	-	-	16
29	*Pseudanabaena mucicola* (Naumann & Huber-Pestalozzi) Schwabe **Phormidium mucicola* Nauman & Huber-Pestalozzi	-	+	+	-	16, 20
	Family Leptolyngbyaceae					
30	*Leibleinia gracilis* (Rabenhorst ex Gomont) Anagnostidis & Komárek **Lyngbya gracilis* (Menegh) Rabenhorst ex Gomont	+	+	-	-	11
31	*Leptolyngbya africana* (Lemmermann) Anagnostidis & Komárek **Phormidium africanum* Lemmermann	-	+	-	-	12, 20

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
32	*Leptolyngbya amplivaginata* (Goor) Anagnostidis & Komárek	+	-	-	-	16
33	*Leptolyngbya boryana* (Gomont) Anagnostidis & Komárek **Plectonema boryanum* Gomont	-	+	-	-	31
34	*Leptolyngbya foveolarum* (Gomont) Anagnostidis & Komárek **Phormidium foveolarum* Gomont	-	+	-	-	12, 20, 27
35	*Leptolyngbya fragilis* (Gomont) Anagnostidis & Komárek **Phormidium fragile* Gomont	-	+	+	-	10, 12
36	*Leptolyngbya mucosa* (N.L.Gardner) Anagnostidis & Komárek **Phormidium mucosum* N.L.Gardner	-	+	+	-	10, 20
37	*Leptolyngbya nostocorum* (Bornet ex Gomont) Anagnostidis & Komárek **Plectonema nostocorum* Bornet ex Gomont	-	+	-	-	20
38	*Leptolyngbya perelegans* (Lemmermann) Anagnostidis & Komárek **Lyngbya perelegans* Lemmermann	+	+	-	-	6
39	*Leptolyngbya polysiphoniae* (Frémy) Anagnostidis **Lyngbya polysiphoniae* Frémy	-	-	+	-	2
40	*Leptolyngbya purpurascens* (Gomont ex Gomont) Anagnostidis & Komárek **Phormidium purpurascens* Gomont ex Gomont	-	-	+	-	7
41	*Leptolyngbya scottii* (F.E.Fritsch) Anagnostidis & Komárek **Lyngbya scottii* Fritsch	-	+	-	-	20
42	*Leptolyngbya truncata* (Lemmermann) Anagnostidis & Komarek	+	-	-	-	16
43	*Leptolyngbya valderiana* (Gomont) Anagnostidis & Komárek **Phormidium valderianum* Gomont	-	+	-	-	7, 18, 20
44	*Phormidesmis molle* (Gomont) Turicchia, Ventura, Komárková & Komárek **Phormidium molle* Gomont	+	+	-	-	12, 20, 22
	Family Trichocoleusaceae					
45	*Trichocoleus delicatulus* (West & G.S.West) Anagnostidis	+	+	-	-	16
46	*Trichocoleus hospitus* Hansgirg	-	-	+	-	16
47	*Trichocoleus sociatus* (West & G.S.West) Anagnostidis **Microcoleus sociatus* West & G.S.West	+	+	-	-	10, 11
	Family *Oculatellaceae*					
48	*Drouetiella lurida* (Gomont) Mai, J.R.Johansen & Pietrasiak **Phormidium luridum* Gomont	-	-	+	-	7
	Family Synechococcales familia incertae sedis					
49	*Dasygloea amorpha* Berkeley ex Gomont	+	-	-	-	16
50	*Heteroleibleinia gardneri* (Geitler) Anagnostidis & Komárek **Lyngbya gardneri* Geitler	+	+	-	-	6
51	*Heteroleibleinia kuetzingii* (Schmidle) Compère **Lyngbya kuetzingii* Schmidle	+	-	-	-	10
52	*Heteroleibleinia lachneri* (W.Zimmermann) Anagnostidis & Komárek **Lyngbya lachneri* (W.Zimmermann) Geitler	-	-	+	+	10, 12
53	*Heteroleibleinia mesotricha* (Skuja) Anagnostidis & Komárek **Lyngbya mesotricha* Skuja	-	+	-	-	20
54	*Jaaginema angustissimum* (West & G.S.West) Anagnostidis & Komárek	-	+	-	-	16
55	*Jaaginema borodinii* (Woronichin) Anagnostidis & Komárek	-	+	-	-	16
56	*Jaaginema subtilissimum* (Kützing ex Forti) Anagnostidis & Komárek **Oscillatoria subtilissima* Kützing ex Forti	+	+	-	-	11, 16
57	*Schizothrix arenaria* Gomont	-	+	-	-	16
58	*Schizothrix heufleri* Grunow ex Gomont	-	+	-	-	16
59	*Schizothrix lateritia* Gomont	-	-	+	-	7
60	*Schizothrix mexicana* Gomont	+	-	-	-	1
	Subclass Oscillatoriophycidae					
	Order Spirulinales					
	Family Spirulinaceae					
61	*Spirulina labyrinthiformis* Gomont	-	+	-	-	12, 16
62	*Spirulina major* Kützing ex Gomont	+	-	-	-	16

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
63	*Spirulina meneghiniana* Zanardini ex Gomont	+	-	-	-	16
64	*Spirulina platensis* var. *tenuis* C.B.Rao **Arthrospira platensis tenuis* (C.B.Rao) Desikachary	+	-	-	-	11
65	*Spirulina princeps* West & G.S.West	+	+	-	-	7, 12, 20
66	*Spirulina subsalsa* Oersted ex Gomont	+	+	-	-	11, 16
67	*Spirulina subtilissima* Kützing ex Gomont	-	+	-	-	11
68	*Spirulina tenerrima* Kützing ex Gomont	-	+	-	-	16
	Order Chroococcales					
	Family Microcystaceae					
69	*Gloeocapsa aeruginosa* Kützing	-	+	+	-	7, 12
70	*Gloeocapsa calcarea* Tilden	-	-	+	-	16
71	*Gloeocapsa cordae Guiry* **Gloeocapsa violacea* (Corda) Rabenhorst	-	-	+	-	11
72	*Gloeocapsa decorticans* (A.Braun) P.Richter	-	+	-	-	16
73	*Gloeocapsa kuetzingiana* Nägeli ex Kützing	-	-	+	-	10
74	*Gloeocapsa livida* (Carmichael) Kützing	+	+	-	-	16
75	*Gloeocapsa nigrescens* Nägeli	+	-	-	-	11
76	*Gloeocapsa pleurocapsoides* Novácek	-	-	+	-	7
77	*Gloeocapsa punctata* Nägeli	-	+	-	-	16
78	*Gloeocapsa quaternata* Kützing	-	-	-	+	10
79	*Gloeocapsa sanguinea* (C.Agardh) Kützing	-	-	-	+	10
80	*Microcystis aeruginosa* (Kützing) Kützing	+	+	-	-	6, 11, 12, 16, 30
81	*Microcystis elongata* Desikachary	+	-	-	-	12
82	*Microcystis flosaquae* (Wittrock) Kirchner	+	-	-	-	7, 11, 16
83	*Microcystis marginata* (Meneghini) Kützing	+	-	-	-	12
84	*Microcystis protocystis* W.B. Crow	+	-	-	-	12
85	*Microcystis pulvera* (H.C.Wood) Forti	+	-	-	-	12, 16
86	*Microcystis pulverea* f. *irregularis* (J.B.Petersen) Elenkin **Aphanocapsa lachista* var. *irregularis* J.B.Petersen	+	-	-	-	16
87	*Microcystis scripta* (P.Richter) Lemmermann	+	-	-	-	16
88	*Microcystis smithii* Komárek & Anagnostidis **Aphanocapsa pulchra* (Kützing) Rabenhorst	+	+	-	-	11, 12
89	*Microcystis viridis* (A.Braun) Lemmermann	+	-	-	-	16
90	*Microcystis wesenbergii* (Komárek) Komárek ex Komárek	+	-	-	-	16
	Family Aphanothecaceae					
91	*Aphanothece microscopica* Nägeli	+	+	-	-	6, 12, 16
92	*Aphanothece naegelii* Wartmann	-	+	-	-	11, 16
93	*Aphanothece nidulans* P.Richter	+	-	-	-	16
94	*Aphanothece pallida* (Kützing) Rabenhorst	+	+	-	-	11
95	*Aphanothece saxicola* Nägeli	+	+	-	-	16
96	*Aphanothece stagnina* (Sprengel) A.Braun	-	+	-	+	7, 11
97	*Gloeothece membranacea* (Rabenhorst) Bornet	-	+	-	-	12
98	*Gloeothece rupestris* (Lyngbye) Bornet	-	+	-	-	6, 12
99	*Gloeothece samoensis* Wille	-	+	-	-	7
	Family Cyanobacteriaceae					
100	*Cyanobacterium cedrorum* (Sauvageau) Komárek, J. Kopecký & Cepák **Synechococcus cedrorum* Sauvageau	+	+	-	-	10, 12

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
	Family Cyanothrichaceae					
101	*Johannesbaptistia pellucida* (Dickie) W.R.Taylor & Drouet	+	-	-	-	16
	Family Gomphosphaeriaceae					
102	*Gomphosphaeria natans* Komárek & Hindák	+	-	-	-	16
	Family Chroococcaceae					
103	*Asterocapsa nidulans* (N.L.Gardner) Komárek & Komárková-Legnerová **Anacystis nidulans* N.L.Gardner	+	-	-	-	15
104	*Chroococcus indicus* Zeller	-	+	-	-	20
105	*Chroococcus minimus* (Keissler) Lemmermann	+	-	-	-	7
106	*Chroococcus minor* (Kützing) Nägeli	+	+	+	-	10, 11, 12, 16
107	*Chroococcus minutus* (Kützing) Nägeli	+	+	+	-	7, 11, 16
108	*Chroococcus pallidus* Nägeli	-	+	-	-	11
109	*Chroococcus subnudus* (Hansgirg) G.Cronberg & J.Komárek	+	-	-	-	16
110	*Chroococcus turgidus* (Kützing) Nägeli	-	+	-	-	12
111	*Chroococcus varius* A.Braun	+	-	-	-	16
112	*Cyanosarcina burmensis* (Skuja) Kovácik	-	-	+	-	16
113	*Cyanosarcina spectabilis* (Geitler) Kovácik **Myxosarcina spectabilis* Geitler	-	-	-	+	10
114	*Gloeocapsopsis cyanea* (Krieger) Komárek & Anagnostidis	-	+	-	-	16
115	*Pseudocapsa dubia* Ercegovic	+	+	-	-	16
116	*Dactylococcopsis rhaphidioides* Hansgirg	+	-	-	-	7
	Family Entophysalidaceae					
117	*Chlorogloea microcystoides* Geitler	-	-	+	-	16
	Order *Pleurocapsales*					
	Family *Dermocarpellaceae*					
118	*Stanieria sphaerica* (Setchell & N.L.Gardner) Anagnostidis & Pantazidou **Dermocarpa sphaerica* Setchell & N.L.Gardner	+	-	-	-	7
	Order Oscillatoriales					
	Family Coleofasciculaceae					
119	*Anagnostidinema acutissimum* (Kufferath) Strunecký, Bohunická, J.R.Johansen & J.Komárek **Geitlerinema acutissimum* (Kufferath) Anagnostidis	-	+	-	-	31
120	*Anagnostidinema exile* (Skuja) Strunecky **Geitlerinema exile* (Skuja) Anagnostidis	-	+	-	-	16
121	*Anagnostidinema ionicum* (Skuja) Strunecky **Geitlerinema ionicum* (Skuja) Anagnostidis	+	-	-	-	16
122	*Anagnostidinema lemmermannii* (Woloszynska) Strunecky **Geitlerinema lemmermanni* (Woloszynska) Anagnostidis	+	-	-	-	16
123	*Coleofasciculus chthonoplastes* (Thuret ex Gomont) M.Siegesmund, J.R.Johansen & T.Friedl in Siegesmund **Microcoleus chthonoplastes* Thuret ex Gomont	-	+	-	-	2, 7, 16
124	*Geitlerinema bigranulatum* (C.B.Rao) Anagnostidis **Oscillatoria claricentrosa* f. *bigranulata* C.B.Rao	-	-	+	-	6
125	*Geitlerinema crassum* (Woronichin) Anagnostidis **Oscillatoria deflexa crassa* (Woronichin) Elenkin & Poljansky	+	+	-	-	2, 11
	Family Microcoleaceae					
126	*Arthrospira gigantea* (Schmidle) Anagnostidis **Spirulina gigantean* Schmidle	+	+	-	-	10, 11
127	*Arthrospira jenneri* Stizenberger ex Gomont	+	+	-	-	11
128	*Arthrospira khannae* Drouet & Strickland	+	-	-	-	7
129	*Arthrospira massartii* var. *indica* Desikachary	+	-	-	-	16
130	*Arthrospira platensis* Gomont	+	-	-	-	12

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
131	*Arthrospira platensis non-constricta* (Banerji) Desikachary	+	-	-	-	12, 16
132	*Kamptonema animale* (C.Agardh ex Gomont) Strunecký, Komárek & J.Smarda **Oscillatoria animalis* C.Agardh ex Gomont **Phormidium animale* (C.Agardh ex Gomont) Anagnostidis & Komárek	+	+	+	-	10, 16
133	*Kamptonema chlorinum* (Kützing ex Gomont) Strunecký, Komárek & J.Smarda **Oscillatoria chlorina* Kützing ex Gomont **Phormidium chlorinum* (Kützing ex Gomont)	+	+	-	-	6, 11, 12, 16, 22
134	*Kamptonema cortianum* (Meneghini ex Gomont) Strunecký, Komárek & J.Smarda **Phormidium cortianum* (Meneghini ex Gomont) Anagnostidis & Komárek	-	+	-	-	16
135	*Kamptonema formosum* (Bory ex Gomont) Strunecký, Komárek & J.Smarda **Phormidium formosum* (Bory ex Gomont) Anagnostidis & Komárek **Oscillatoria formosa* Bory ex Gomont	+	+	+	-	10, 16, 20
136	*Kamptonema gebhardtianum* (Claus) Strunecký, Komárek & J.Smarda **Phormidium gebhardtianum* (Claus) Anagnostidis & Komárek	-	+	-	-	16
137	*Kamptonema jasorvense* (Vouk) Strunecký, Komárek & J.Smarda **Oscillatoria jasorvensis* Vouk	-	+	-	-	11
138	*Kamptonema laetevirens* (H.M.Crouan & P.L.Crouan ex Gomont) Strunecký, Komárek & J. Smarda **Phormidium laetevirens* (P.Crouan & H.Crouan ex Gomont) Anagnostidis & Komárek **Oscillatoria latevirens* P.Crouan & H.Crouan ex Gomont	-	+	-	-	16, 20
139	*Kamptonema okenii* (C.Agardh ex Gomont) Strunecký, Komárek & J.Smarda **Oscillatoria okenii* C.Agardh ex Gomont **Phormidium okenii* (C.Agardh ex Gomont) Anagnostidis & Komárek	+	+	+	-	11, 12, 16
140	*Kamptonema proteus* (Skuja) Strunecký, Komárek & J.Smarda **Oscillatoria proteus* Skuja	+	+	-	-	7, 12
141	*Microcoleus amoenus* (Gomont) Strunecky, Komárek & J.R.Johansen Strunecky **Phormidium amoenum* Kützing ex Anagnostidis & Komárek	-	+	-	-	16
142	*Microcoleus autumnalis* (Gomont) Strunecky, Komárek & J.R. Johansen **Phormidium autumnale* Gomont	-	+	+	-	16
143	*Microcoleus lacustris* Desikachary	-	+	-	-	16
144	*Microcoleus lacustris* f. *intermedius* Vasishta	-	+	-	-	7
145	*Microcoleus paludosus* Gomont	+	+	-	-	7, 11, 16
146	*Microcoleus subtorulosus* Gomont ex Gomont	+	-	-	-	11
147	*Microcoleus vaginatus* Gomont ex Gomont	-	+	-	-	11
148	*Oxynema acuminatum* (Gomont) Chatchawan, Komárek, Strunecky, Smarda & Peerapornpisal **Oscillatoria acuminata* Gomont	-	+	-	-	20
149	*Planktothrix agardhii* (Gomont) Anagnostidis & Komárek **Oscillatoria agardhii* Gomont	+	+	-	-	2, 7, 17
150	*Planktothrix compressa* (Utermöhl) Anagnostidis & Komárek	+	-	-	-	16
151	*Planktothrix isothrix* (Skuja) Komárek & Komárková	+	-	-	-	16
152	*Planktothrix rubescens* (De Candolle ex Gomont) Anagnostidis & Komárek **Oscillatoria mougeotii* Kützing ex Forti	+	-	-	-	10, 16
153	*Porphyrosiphon kashyapii* (Ghose) Anagnostidis & Komárek **Lyngbya kashaypii* Ghose	-	+	-	-	11
154	*Porphyrosiphon notarisii* Kützing ex Gomont	-	-	+	-	16
155	*Porphyrosiphon shackletonii* (West & G.S.West) Anagnostidis & Komárek **Lyngbya shackletoni* W.& G.S. West	-	+	-	-	12
	Family *Homoeotrichaceae*					
156	*Homoeothrix desikacharyensis* Vasishta	-	+	-	-	9
157	*Homoeothrix juliana* (Bornet & Flahault ex Gomont) Kirchner	-	-	+	-	7
158	*Homoeothrix moniliformis* Vasishta	-	+	-	-	9

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
	Family Oscillatoriaceae					
159	*Limnoraphis birgei* (G.M.Smith) J.Komárek, E. Zapomelová, J.Smarda, J.Kopecký, E.Rejmánková, J.Woodhouse, B.A.Neilan & J.Komárková **Lyngbya birgei* G.M.Smith	-	+	-	-	11
160	*Limnoraphis cryptovaginata* (Schkorbatov) J.Komárek, E.Zapomelová, J.Smarda, J.Kopecký, E.Rejmámková, J.Woodhouse, B.A.Neilan & J.Komárková **Lyngbya cryptovaginata* Schkorbatov	+	+	-	-	10, 11, 12, 20
161	*Limnoraphis hieronymusii* (Lemmermann) J.Komárek, E.Zapomelová, J.Smarda, J.Kopecký, E.Rejmánková, J.Woodhouse, B.A.Neilan & J.Komárková **Lyngbya hieronymusii* Lemmermann	+	+	-	-	7, 11, 12
162	*Limnospira fusiformis* (Voronichin) Nowicka-Krawczyk, Mühlsteinová & Hauer **Arthrospira fusiformis* (Voronichin) Komárek & J.W.G.Lund	+	-	-	-	16
163	*Lyngbya aerugineocoerulea* Gomont	-	+	-	-	11, 12
164	*Lyngbya aestuarii* Liebman ex Gomont	+	-	-	-	7
165	*Lyngbya aestuarii* var. *arbustiva* Brühl & Biswas	-	+	-	-	7
166	*Lyngbya anomala* (C.B.Rao) Umezaki & Watanabe **Phormidium anomalum* C.B.Rao	-	+	-	+	12, 16
167	*Lyngbya laxespiralis* Skuja	-	+	-	-	12
168	*Lyngbya laxespiralis* var. *major* Vasishta	-	+	-	-	10
169	*Lyngbya martensiana* Meneghini ex Gomont	+	+	+	-	2, 6, 12, 16
170	*Lyngbya major* Meneghini ex Gomont	+	-	-	-	7
171	*Lyngbya palmarum* Brühl & Biswas	-	-	-	+	6
172	*Lyngbya putalis* Montagne ex Gomont	+	-	-	-	7
173	*Lyngbya semiplena* J.Agardh ex Gomont	-	-	+	-	16
174	*Lyngbya spiralis* Geitler	+	+	-	-	6, 20, 22
175	*Lyngbya spirulioides* Gomont	-	+	-	-	12
176	*Lyngbya spirulinoides* var. *minor* Vasishta	+	-	-	-	10
177	*Lyngbya trunicola* Ghose	-	-	-	+	16
178	*Oscillatoria anguina* Bory ex Gomont	+	+	-	-	16
179	*Oscillatoria annae* Goor	+	+	-	-	12, 16
180	*Oscillatoria curviceps* C.Agardh ex Gomont	+	+	-	-	11, 12, 16
181	*Oscillatoria indica* P.C.Silva **Oscillatoria salina* Biswas	+	-	-	-	7
182	*Oscillatoria limosa* C.Agardh ex Gomont	+	+	-	-	7, 12, 16
183	*Oscillatoria mehrai* Vasishta	-	+	-	-	9
184	*Oscillatoria obscura* Brühl & Biswas	-	+	-	-	11
185	*Oscillatoria perornata* Skuja	+	-	-	-	16
186	*Oscillatoria princeps* Vaucher ex Gomont	+	+	-	-	1, 11
187	*Oscillatoria sancta* Kützing ex Gomont	+	+	+	-	7, 11, 12, 16
188	*Oscillatoria simplicissima* Gomont	+	+	-	-	12
189	*Oscillatoria subbrevis* Schmidle	+	+	+	-	2, 6, 11, 12, 25
190	*Oscillatoria tenuis* C.Agardh ex Gomont	+	-	-	-	16
191	*Oscillatoria variabilis* C.B.Rao **Oscillatoria raoi* G. De Toni	+	-	-	-	11, 12
192	*Phormidium abronema* Skuja	-	+	-	-	12
193	*Phormidium allorgei* (Frémy) Anagnostidis & Komárek	-	+	-	-	6
194	*Phormidium ambiguum* Gomont	-	+	-	-	10, 16
195	*Phormidium articulatum* (N.L.Gardner) Anagnostidis & Komárek	+	-	-	-	16

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
196	*Phormidium boryanum* (Bory ex Gomont) Anagnostidis & Komárek **Oscillatoria boryana* Bory de Saint-Vincent ex Gomont	+	+	-	-	11, 12
197	*Phormidium breve* (Kützing ex Gomont) Anagnostidis & Komárek	-	+	-	-	16
198	*Phormidium bulgaricum* (Komárek) Anagnostidis & Komárek	+	-	-	-	16
199	*Phormidium calcareum* Kützing ex Gomont	-	-	+	-	16
200	*Phormidium corbierei* (Frémy) Anagnostidis	-	-	+	-	16
201	*Phormidium corium* Gomont ex Gomont	-	-	+	-	10
202	*Phormidium dimorphum* Lemmermann	-	+	-	-	12
203	*Phormidium favosum* Gomont	+	-	+	-	16
204	*Phormidium foreaui* (Frémy) Umezaki & Watanabe **Oscillatoria foreaui* Frémy	+	+	-	-	10, 11, 12
205	*Phormidium granulatum* (N.L.Gardner) Anagnostidis	-	+	-	-	16
206	*Phormidium hieronymusii Lemmermann*	-	+	-	-	10
207	*Phormidium interruptum* Kützing ex Forti	-	-	+	-	16
208	*Phormidium inundatum* Kützing ex Gomont	-	+	-	-	20
209	*Phormidium jadinianum* Gomont	-	+	-	-	12
210	*Phormidium janthiphorum* (Gomont) Elenkin	-	+	-	-	16
211	*Phormidium jenkelianum* G.Schmid	+	+	-	-	12, 16, 20
212	*Phormidium karakalpakense* (Muzafarov) Anagnostidis & Komárek	-	+	-	-	16
213	*Phormidium kuetzingianum* (Kirchner ex Hansgirg) Anagnostidis & Komárek	-	+	-	-	16
214	*Phormidium molle* var. *tenuior* West & G.S.West ex Geitler **Phormidium molle* f. *tenuior* West & G.S.West	-	-	+	-	10
215	*Phormidium nigrum* (Vaucher ex Gomont) Anagnostidis & Komárek	+	-	-	-	16
216	*Phormidium papyraceum* Gomont ex Gomont	-	+	-	-	12
217	*Phormidium rubriterricola* N.L.Gardner	-	+	-	-	10
218	*Phormidium schultzii* (Lemmermann) Anagnostidis & Komárek **Oscillatoria schultzii* Lemmermann	-	+	-	-	11
219	*Phormidium stagninum* Anagnostidis **Lyngbya stagnina* Kützing	+	-	+	-	16, 24
220	*Phormidium stagninum* var. *minus* Vasishta	-	-	+	-	10
221	*Phormidium subfuscum* Kützing ex Gomont	-	+	-	-	16
222	*Phormidium subincrustatum* Fritsch & M.F.Rich	-	+	-	-	12
223	*Phormidium takyricum* (Novichkova) O.N.Vinogradova **Phormidium paulsenianum* f. *takyricum* Novickova	-	+	-	-	16
224	*Phormidium terebriforme* (C.Agardh ex Gomont) Anagnostidis & Komárek **Oscillatoria terebriformis* C.Agardh ex Gomont	+	+	-	-	2, 11
225	*Phormidium tergestinum* (Rabenhorst ex Gomont) Anagnostidis & Komárek	-	+	-	-	16
226	*Phormidium thwaitesii* I.Umezaki & M.Watanabe **Oscillatoria subuliformis* Kützing ex Gomont	-	-	-	+	10
227	*Phormidium tortuosum* (N.L.Gardner) Anagnostidis & Komárek	-	+	-	-	16
228	*Phormidium uncinatum* Gomont ex Gomont	-	-	+	-	16
229	*Phormidium usteri* Schmidle	-	+	-	-	12
230	*Phormidium willei* (N.L.Gardner) Anagnostidis & Komárek **Oscillatoria willei* N.L.Gardner	-	+	-	-	11
	Family Phormidiaceae					
	Sub Family Phormidioideae					
231	*Potamolinea aerugineocaerulea* (Gomont) M.D.Martins & L.H.Z.Branco **Lyngbya aerugineocaerulea* Gomont **Phormidium aerugineo-caeruleum* (Gomont) Anagnostidis & Komárek	+	+	+	-	7, 16

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
	Family Gomontiellaceae					
232	*Komvophoron breve* (N.Carter) Anagnostidis	-	+	-	-	16
233	*Komvophoron groenlandicum* Anagnostidis et Komarek	+	-	-	-	16
	Subclass Nostocophycidae					
	Order Nostocales					
	Family Scytonemataceae					
234	*Scytonema burmanicum* Skuja	-	-	+	-	16
235	*Scytonema hofmanii* C.Agardh ex Bornet & Flahault	-	+	-	-	10, 16
236	*Scytonema iyengarii* Bharadwaja	-	-	+	-	2
237	*Scytonema julianum* Meneghini ex B.A.Whitton	-	-	+	-	16
238	*Scytonema leptobasis* S.L.Ghose	-	-	+	-	16
239	*Scytonema millei Bornet ex Bornet & Flahault*	-	+	-	-	10
240	*Scytonema ocellatum* Lyngbye ex Bornet & Flahaul	-	+	+	-	10, 16
241	*Scytonema pseudohofmanni* Bharadwaja	-	+	+	-	16
242	*Scytonema saleyeriense* Weber-van Bosse	+	-	+	-	16
243	*Scytonema simplex* Bharadwaja	+	-	-	-	16
244	*Scytonema simplex* f. *majus* Vasishta	+	-	-	-	7
245	*Scytonema tolypothrichoides* Kützing ex Bornet & Flahault	-	+	-	-	16
246	*Scytonema varium* Kützing ex Bornet & Flahault	-	+	-	-	17
	Family Rivulariaceae					
247	*Microchaete tenera* var. *major* Möbius	-	-	-	+	10
248	*Rivularia joshii* Vasishta	+	-	-	-	8, 11
249	Rivularia mehrai Vasishta	-	+	-	-	5
	Family Tolypothrichaceae					
250	*Tolypothrix crassa* West & G.S.West	-	-	-	+	7
251	*Tolypothrix campylonemoides S.L.Ghose*	-	-	-	+	7
	Family Chlorogloeopsidaceae					
252	*Chlorogleopsis fritschii* (A.K.Mitra) A.K.Mitra & D.C.Pandey	-	+	-	-	16
	Family Hapalosiphonaceae					
253	*Hapalosiphon welwitschii* West & G.S.West	-	+	-	-	16
254	*Mastigocladus laminosus* Cohn ex Kirchner	-	+	-	-	7, 16
255	*Westiellopsis prolifica* Janet	-	+	-	-	17
	Family Gloeotrichiaceae					
256	*Gloeotrichia ghosei* R.N.Singh	-	+	-	-	11
257	*Gloeotrichia natans* Rabenhorst ex Bornet & Flahault **Rivularia natans* (Hedwig) S.F.Gray	+	-	-	-	1
258	*Gloeotrichia raciborskii* var. *kashiensis* C.B.Rao	-	-	-	+	7
	Family Calothricaceae					
259	*Calothrix braunii* Bornet & Flahault	-	+	-	-	7, 11
260	*Calothrix castellii* var. *somastipurense* C.S.Rao	+	-	-	-	16
261	*Calothrix clavata* G.S.West	-	+	-	-	16
262	*Calothrix desikacharyensis* Vasishta	-	-	-	+	9
263	*Calothrix fusca* Bornet & Flahault	-	+	-	-	2
264	*Calothrix parietina* Thuret ex Bornet & Flahault	-	-	+	-	7
	Family Aphanizomenonaceae					
265	*Anabaenopsis arnoldii* Aptekar	+	-	-	-	16

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
266	*Anabaenopsis circularis* (G.S.West) Woloszynska & V.V.Miller	+	-	-	-	16
267	*Dolichospermum nathii* (Vasishta) Wacklin, L.Hoffmann & Komárek **Anabaena nathii Vasishta*	+	-	-	-	3
268	*Nodularia spumigena* Mertens ex Bornet & Flahault	+	-	-	-	1, 6, 7
	Family Nostocaceae					
269	*Anabaena ambigua* C.B.Rao	-	+	-	-	11
270	*Anabaena anomala* F.E.Fritsch	-	+	-	-	11
271	*Anabaena iyengarii* Bharadwaja	+	+	-	-	10, 14, 16
272	*Anabaena iyengarii* var. *tenuis* C.B.Rao	+	+	-	-	6, 16
273	*Anabaena mehrai* Vasishta	+	-	-	-	6
274	*Anabaena oryzae* F.E.Fritsch	-	+	-	-	11
275	*Anabaena oscillarioides* Bory ex Bornet & Flahault	+	-	-	-	7
276	*Anabaena oscillarioides* var. *crassa* Vasishta	+	-	-	-	6
277	*Anabaena sphaerica* Bornet & Flahault	+	+	-	-	11, 14
278	*Anabaena sphaerica* var. *attenuata* Bharadwaja	+	-	-	-	16
279	*Anabaena sphaerica* f. *major* Kiselev	+	-	-	-	7
280	*Anabaena torulosa* Lagerheim ex Bornet & Flahault	+	+	-	-	11, 12, 20, 22, 23
281	*Aulosira aenigmatica* Frémy	-	+	-	-	12
282	*Aulosira fertilissima* S.L.Ghose	+	+	-	-	1, 7, 11
283	*Aulosira fertilissima* var. *tenuis* C.B.Rao	+	-	-	-	16
284	*Aulosira laxa* O. Kirchner ex Bornet & Flahault	-	+	-	-	12
285	*Aulosira prolifica* Bharadwaja	+	+	-	-	6, 11, 12
286	*Aulosira pseudoramosa* Bharadwaja	-	+	-	-	16
287	*Camptylonemopsis iyengarii* Desikachary	-	-	-	+	16
288	*Cylindrospermum alatosporum* F.E.Fritsch	-	+	-	-	6
289	*Cylindrospermum doryphorum* Brühl & Biswas	-	+	-	-	16
290	*Cylindrospermum licheniforme* Kützing ex Bornet & Flahault	+	-	-	-	10
291	*Cylindrospermum majus* Kützing ex Bornet & Flahault	-	+	-	-	11, 16
292	*Cylindrospermum michailovskoense* Elenkin	-	+	-	-	16
293	*Cylindrospermum muscicola* Kützing ex Bornet & Flahault	+	+	-	-	2, 6
294	*Cylindrospermum muscicola* var. *kashmiriensis* Bharadwaja	-	+	-	-	16
295	*Cylindrospermum muscicola* f. *hoshiarpurense* Vasishta	-	+	-	-	7
296	*Cylindrospermum stagnale* Bornet & Flahault	+	+	-	-	1, 16
297	*Desmonostoc muscorum* (C.Agardh ex Bornet & Flahault) Hrouzek & Ventura in Hrouzek **Nostoc muscorum* C.Agardh ex Bornet & Flahault	-	+	-	-	7, 13, 16, 29
298	*Nostoc carneum* C.Agardh ex Bornet & Flahault **Nostoc spongiaeformae* C.Agardh ex Bornet & Flahault	+	+	-	-	10, 12, 16, 20
299	*Nostoc commune* C.Agardh ex Bornet & Flahault	-	+	-	-	16
300	*Nostoc corneum* Vaucher ex Bornet & Flahault	-	+	-	-	12
301	*Nostoc ellipsosporum* Rabenhorst ex Bornet & Flahault	+	+	-	-	6, 17
302	*Nostoc hatei* S.C.Dixit	+	-	-	-	16
303	*Nostoc linckia* Bornet ex Bornet & Flahault, **Nostoc piscinale* Kützing ex Bornet & Flahault	-	+	-	-	6, 12, 16, 20
304	*Nostoc maculiforme* Bornet & Flahault	+	+	-	-	7, 11
305	*Nostoc paludosum* Kützing ex Bornet & Flahault **Nostoc entophytum* Bornet & Flahault	-	+	-	-	12, 16
306	*Nostoc parmeliodes* Kutz. ex Born.e/ Flah.	-	+	-	-	16

	Taxonomic Assignment	Planktonic	Terrestrial	Epilithic	Epiphytic/ Endophytic	References
307	*Nostoc punctiforme* Hariot	-	+	-	-	6, 12, 16
308	*Nostoc spongiiforme* var. *tenue* C.B.Rao	-	+	-	-	10
309	*Nostoc verrucosum* Vaucher ex Bornet & Flahault	-	-	+	-	2, 6
310	*Trichormus azollae* (Strasburger) Komárek & Anagnostidis	-	-	-	+	16
311	*Trichormus fertilissimus* (C.B.Rao) Komárek & Anagnostidis **Anabaena fertilissima* C.B.Rao	-	+	-	-	28
312	*Trichormus hoshiarpurensis* (Vasishta) Komárek & Anagnostidis **Anabaena hoshiarpurensis* Vasishta	+	-	-	-	4
313	*Trichormus indicus Komárek* **Anabaena vaginicola* f. *fertilissima* Prasad	+	-	-	-	10
314	*Trichormus naviculoides* (F.E.Fritsch) J.Komárek & K.Anagnostidis **Anabaena naviculoides* F.E.Fritsch	-	+	-	-	20, 26
315	*Trichormus variabilis* (Kützing ex Bornet & Flahault) Komárek & Anagnostidis **Anabaena variabilis* Kützing ex Bornet & Flahault	+	+	-	-	16, 20
316	*Wollea bharadwajae* R.N.Singh	-	-	-	+	7
317	*Wollea vaginicola* (F.E.Fritsch & Rich) R.N.Singh	-	-	-	+	6

Previously accepted name/synonym of taxa are marked with star '*'
1—Randhawa (1936) | 2—Singh (1941) | 3—Vasishta (1960a) | 4—Vasishta (1960b) | 5—Vasishta (1960c) | 6—Vasishta (1960d) | 7—Vasishta (1961) | 8—Vasishta (1962) | 9—Vasishta (1963a) | 10—Vasishta (1963b) | 11—Grover & Pandhol (1975) | 12—Sarma (1979) | 13—Surekha (1989) | 14—Reena (1992) | 15—Khattar et al. (1999) | 16—Dhingra (2006) | 17—Singh et al. (2007) | 18—Khattar & Jindal (2008) | 19—Khattar & Shailza (2009) | 20—Singh et al. (2009) | 21—Khattar et al. (2010) | 22—Shailza (2010) | 23—Singh et al. (2012) | 24—Jindal et al. (2013) | 25—Sharma et al. (2013) | 26—Singh et al. (2013) | 27—Singh et al. (2014) | 28—Khattar et al. (2015) | 29—Singh et al. (2015) | 30—Kaur et al. (2017) | 31—Manpreet (2017).

optimized culture conditions. *Algal Research* 12: 463–469.

Khattar, J.I.S., T.A. Sarma & D.P. Singh (1999). Removal of chromium ions by agar immobilized cells of the cyanobacterium *Anacystis nidulans* in a continuous flow bioreactor. *Enzyme and Microbial Technology* 25(7): 564–568.

Khattar, J.I.S., D.P. Singh, N. Jindal, N. Kaur, Y. Singh, P. Rahi & A. Gulati (2010). Isolation and characterization of exopolysaccharides produced by the cyanobacterium *Limnothrix redekei* PUPCCC 116. *Applied Biochemistry and Biotechnology* 162(5): 1327–1338.

Komárek, J. & K. Anagnostidis (1998). Cyanoprokaryota 1. Chroococcales. – In: Ettl H., Gärtner G., Heynig H. & Mollenhauer D. (eds), Süsswasserflora von Mitteleuropa 19/1. Gustav Fischer, Jena-StuttgartLübeck-Ulm, 548 pp.

Komárek, J. & K. Anagnostidis (2005). Cyanoprokaryota. 2. Oscillatoriales. – In: Büdel B., Krienitz L., Gärtner G. & Schagerl M. (eds), Süsswasserflora von Mitteleuropa 19/2. Elsevier/Spektrum, Heidelberg, 759 pp.

Komárek, J. (2006). Cyanobacterial taxonomy: current problems and prospects for the integration of traditional and molecular approaches. *Algae* 21: 349–375.

Komárek, J. (2013). Cyanoprokaryota. 3. Heterocytous genera. In: Büdel B., G. Gärtner, L. Krienitz & M. Schagerl (eds.). Süswasserflora von Mitteleuropa/Freshwater flora of Central Europe. Springer Spektrum Berlin, Heidelberg, 1130 pp.

Komárek, J., J. Kaštovský, J. Mareš & J.R. Johansen (2014). Taxonomic classification of cyanoprokaryotes (cyanobacterial genera) 2014, using a polyphasic approach. *Preslia* 86: 295–335.

Krishan, G., S.K. Chandniha & A.K. Lohani (2015). Rainfall Trend Analysis of Punjab, India Using Statistical Non-Parametric Test. *Current World Environment* 10(3): 792–800.

Kumar, J., D. Singh, M.B. Tyagi & A. Kumar (2019). Cyanobacteria: Applications in Biotechnology, pp. 327–346. In: Rai, A.N., D.N. Tewari and A.K. Mishra (eds.) *Cyanobacteria: From Basic Science to Applications*. Elsevier, Amsterdam, The Netherlands, 541 pp.

Manpreet (2017). Temperature tolerance and level of antioxidants in selected cyanobacteria in the presence of sodium sulphide. PhD Thesis. Department of Botany, Punjabi University, Patiala, 141 pp.

Randhawa, M.S. (1936) Marked periodicity in reproduction of the Panjab freshwater algae. *Proceedings of the Indian Academy of Sciences - Section* B3: 401–406.

Mehta, S.K. (1975). Blue-green algae of Patiala city and adjacent areas. M.Sc. thesis. Department of Botany, Punjabi University, Patiala, 32 pp.

Pandhol, R.K. (1974). Survey of Algal Flora of Ludhiana & its Adjoining areas with particular reference to the Paddy Fields. M.Sc. thesis. PAU, Ludhiana, 146 pp.

Reena (1992). Studies on heterocyst and akinetes differentiation in some anabaena species. PhD Thesis. Department of Botany, Panjab University, Chandigarh, 223 pp.

Sarma, T.A., S. Kanta & Sunita (1979) Algal flora of Patiala and its environs- Cyanophyceae II. *Phykos* 18: 13–14.

Schopf, J.W., A.B. Kudryavtsev, D.G. Agresti, T.J. Wdowiak & A.D. Czaja (2002). Laser–Raman imagery of Earth's earliest fossils. *Nature* 416 (6876): 73–76.

Shailza (2010). Evaluation of heavy metal bioremediation potential of algae growing in polluted water. PhD Thesis. Department of Botany, Punjabi University, Patiala, 134 pp.

Sharma, C., R. Jindal, U.B. Singh, A.S. Ahluwalia & R.K. Thakur (2013). Population dynamics and species diversity of plankton in relation to hydrobiological characteristics of river Sutlej, Punjab, India. *Ecology, Environment and Conservation* 19(3): 717–724.

Singh, D.P., J.I.S. Khattar, G. Ahuja & Y. Singh (2007). Cyanobacterial diversity in rice fields of Malwa region of Punjab and their tolerance to Chlorpyrifos. *Journal, Punjab Academy of Sciences* 4(1&2): 106–113.

Singh, V.P. (1941) On a collection of algae from the Chamba state (Punjab) I. *Procedings of the Indian Academy of Sciences B* 14(3): 250–255.

Singh, Y., A. Gulati, D.P. Singh & J.I.S. Khattar (2018). Cyanobacterial community structure in hot water springs of Indian north-western Himalayas: a morphological, molecular and ecological approach. *Algal Research* 29: 179–192.

Singh, Y., J.I.S. Khattar, D.P. Singh, P. Rahi & A. Gulati (2014). Limnology and cyanobacterial diversity of high altitude lakes of Lahaul-Spiti in

Himachal Pradesh, India. *Journal of Biosciences* 39: 643–657.

Singh, D.P., J.I.S. Khattar, M. Gupta & G. Kaur (2014). Evaluation of toxicological impact of cartap hydrochloride on some physiological activities of a non-heterocystous cyanobacterium *Leptolyngbya foveolarum*. *Pesticide Biochemistry and Physiology* 110: 63–70.

Singh, D.P., J.I.S. Khattar, G. Kaur, M. Gupta, Y. Singh & A. Gulati (2015). Effect of pretilachlor on nitrogen uptake and assimilation by the cyanobacterium *Desmonostoc muscorum* PUPCCC 405.10. *Acta Physiologiae Plantarum* 37(9): 1–14.

Singh, D.P., J.I.S. Khattar, K. Kaur, B.S. Sandhu & Y. Singh (2012). Toxicological impact of anilofos on some physiological processes of a rice field cyanobacterium *Anabaena torulosa*. *Toxicological & Environmental Chemistry* 94(7): 1304–1318.

Singh, D.P., J.I.S. Khattar & Y. Singh (2009). Effect of pesticides on the distribution pattern of cyanobacteria in a rice field ecosystem. *The Journal of the Indian Botanical Society* 88(1&2): 163–169.

Singh, H., A.S. Ahluwalia & J.I.S. Khattar (2013). Induction of sporulation by different nitrogen sources in *Anabaena naviculoides*, a diazotrophic strain capable of colonizing paddy field soil of Punjab (India). *Vegetos* 26(1): 283–292.

Singh, J.S., A. Kumar, A.N. Rai & D.P. Singh (2016). Cyanobacteria: a precious bio-resource in agriculture, ecosystem, and environmental sustainability. *Frontiers in Microbiology* 7(529): 1–19.

Singh, R., P. Parihar, M. Singh, A. Bajguz, J. Kumar, S. Singh & V.P. Singh & S.M. Prasad (2017). Uncovering potential applications of cyanobacteria and algal metabolites in biology, agriculture and medicine: current status and future prospects. *Frontiers in Microbiology* 8(515): 1–37.

Sleep, N.H. (2010). The Hadean-Archaean Environment. *Cold Spring Harbor Perspectives in Biology* 2(6): 1–14.

Surekha (1989). Studies on the effect of some pesticides on growth and differentiation in two blue-green algal species. PhD Thesis. Department of Botany, Panjab University, Chandigarh, 258 pp.

Vasishta P.C. (1960a). *Anabaena nathi* sp. nov. from Hoshiarpur. *Research bulletin of the Panjab University* 2(1–2): 63-67.

Vasishta P.C. (1960b). *Anabaena hoshiarpurensis* sp. nov. from Hoshiarpur. *Research bulletin of the Panjab University* 2(1–2): 93–97.

Vasishta P.C. (1960c). On the structure and life history of *Rivularia mehrai* sp. nov. *Research bulletin of the Panjab University* 2(3–4): 237–244.

Vasishta P.C. (1960d). A systematic and ecological account of the cyanophyceae of Hoshiarpur. *Journal of the Bombay Natural History Society* 57(3): 579–589.

Vasishta P.C. (1961). More cyanophyceae of Hoshiarpur. *Journal of the Bombay Natural History Society* 58(1): 135–146.

Vasishta P.C. (1962a). Some observations on the life history of *Rivularia joshii* sp. nov. from Hoshiarpur (Punjab, India). *Journal of the Indian Botanical Society* 41(4): 516–523.

Vasishta P.C. (1962b). Three colourless Cyanophyceae from Hoshiaipur. *Journal of the Indian Botanical Society* 41(2): 99–103.

Vasishta P.C. (1963a). Five new cyanophyceae from Hoshiarpur. *Journal of the Bombay Natural History Society* 41(1–2): 574–582.

Vasishta P.C. (1963b). More cyanophyceae of Hoshiarpur II. *Journal of the Bombay Natural History Society* 60(3): 671–678.

Whitton, B.A. & M. Potts (2000). Introduction to the Cyanobacteria, pp 1–11. In: Whitton, B.A. & M. Potts (eds.). Ecology of Cyanobacteria: Their Diversity in Space and Time, 632 pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20773–20779

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

https://doi.org/10.11609/jott.6985.14.3.20773-20779

#6985 | Received 13 December 2020 | Final received 15 March 2022 | Finally accepted 18 March 2022

OPEN ACCESS

SHORT COMMUNICATION

Breeding biology of Sri Lanka White-eye *Zosterops ceylonensis* (Aves: Passeriformes: Zosteropidae) in tropical montane cloud forests, Sri Lanka

W.D.S.C. Dharmarathne [1], P.H.S.P.Chandrasiri [2] & W.A.D. Mahaulpatha [3]

[1–3] Department of Zoology, University of Sri Jayewardenepura, Sri Lanka.

[1] chathurangadharma@gmail.com, [2] spchandrasiri@gmail.com, [3] mahaulpatha@sjp.ac.lk (corresponding author)

Abstract: Breeding biology of the endemic Sri Lanka White-eye *Zosterops ceylonensis* was studied from January 2017 to January 2018 in the montane cloud forests of Horton Plains National Park, in Nuwara Eliya District of Sri Lanka. A total of 46 active nests were studied. Breeding occurred March–May. The peak egg-laying was in March and April. Mean nest construction period 11±2.87 days (n= 17), nest height was 3.16±1.22 m from the ground. Majority of nests were built on *Sarcococca brevifolia, Berberis ceylanica*, and *Cinnamomum ovalifolium* trees of 4–12 m tall. Most number of pen cup nests were constructed by the fine grass stalks and mosses woven with cobwebs and internal cup lined with grass roots. Eggs were pale blue. Mean clutch size 2.15±0.37 eggs (n= 11). The incubation period was 10.92±0.9 days (n= 11). Nestling period was 28.33±1.55 days (n= 11). Both sexes participate in nest construction, incubation and brood rearing. About 25.53% of nests were depredated (N= 12). The overall nest success was 74.46%. The study reveals that undisturbed cloud forests are critical to conservation of Sri Lanka White-eye.

Keywords: Brood rearing, eggs, endemic, Horton Plains, incubation period, nest construction.

Information on breeding ecology is essential for planning conservation strategies. However, the inadequacy of scientific data on avifauna is the major problem to conserve the birds of Sri Lanka. White-eyes (Passeriformes: Zosteropidae) are a widely distributed family of Old World birds. They are found on the mainland of tropical Africa, southern and eastern Asia, Australia, and on the islands of these continents, including Indian Ocean, Indonesia, Melanesia, and parts of Micronesia (Lack 1971). The largest of the genera is Zosterops, with over 85 species (Clements et al. 2016). There are two species of white-eye occurring in Sri Lanka, the Sri Lanka White-eye *Zosterops ceylonensis* (Holdsworth, 1872) and Oriental White-eye *Zosterops palpebrosus* (Temminck, 1824).

Z. ceylonensis is a small passerine highland endemic (Figure 1). It is a resident breeder in montane forests and usually found in pairs during the breeding season. Outside the breeding season, it may be found in large, scattered flocks (Ali & Ripley 2001). This species can be distinguished by duller green mantle and more extensive yellow on the breast. It has a darker patch between the eye and the bill (Wait 1922). Though mainly insectivorous, also eat nectar and fruits. It is sociable, forming large flocks. The global population size has not been quantified, climate change, habitat alteration are current threats to the species (Birdlife international 2016).

It appears to be more sociable than the Oriental White-eye (Henry 1971; Ali & Ripley 2001). Furthermore, it appears to be equally at home in bushes and undergrowth as well as in the foliage of large trees. Its food consists of nectar, berries, insects, and caterpillars.

Editor: R. Jayapal, Sálim Ali Centre for Ornithology and Natural History, Coimbatore, India. **Date of publication:** 26 March 2022 (online & print)

Citation: Dharmarathne, W.D.S.C., P.H.S.P. Chandrasiri & W.A.D. Mahaulpatha (2022). Breeding biology of Sri Lanka White-eye *Zosterops ceylonensis* (Aves: Passeriformes: Zosteropidae) in tropical montane cloud forests, Sri Lanka. *Journal of Threatened Taxa* 14(3): 20773–20779. https://doi.org/10.11609/jott.6985.14.3.20773–20779

Funding: University of Sri Jayewardenepura, Sri Lanka.

Competing interests: The authors declare no competing interests.

Acknowledgements: We would like to thank the University of Sri Jayewardenepura for financial support through the university grant (ASP/01/RE/SCI/2016/20). We extend our gratitude to the Department of Wildlife Conservation for granting permission to carry out this study (permit no-WL/3/2/14/15).

The breeding season is bimodal. The first extends from February to July with a peak in April. The second season is in August and September. Investigation of breeding biology was the main objective of this study.

The nesting behavior of many forest bird species are still completely unknown, and detailed information concerning the breeding biology and reproductive success of most species is lacking. Collecting information on breeding biology and ecology is an important part of many studies of the population ecology of birds. This is often essential in identifying effective conservation measures for threatened and declining species (Sutherland et al. 2004). Although it is an endemic species with a very restricted distribution, making it more susceptible to becoming endangered, the basic natural history of *Z. ceylonensis* is still poorly known and, to date, no detailed study of its breeding biology exists.

Figure 1. Study site of the Horton Plains National park, Sri Lanka.

Materials and Methods

Study site

The study was conducted in Horton Plains National Park (HPNP) from January 2017 to January 2018. HPNP is located at an elevation range of 2,100–2,300 m and encompasses montane grassland and cloud forest (Gunatilleke & Gunatilleke 1986). It is rich in biodiversity and many species found here are endemic to the region. The mean annual rainfall is greater than 2,000 mm. Frequent cloud cover limits the amount of sunlight that is available to plants. The mean annual temperature is 13 °C but the temperature varies considerably during a day, reaching as high as 27 °C during the daytime, and dipping as low as 5 °C at night. Dry season occurs from January to March. The ground frost is common in February. Mist can persist in the day during the wet season (De Silva 2007).

The vegetation of the park is classified into wet patana and cloud forests (International Water Management Institute 2010). HPNP is considered as one of the Important Bird Areas (IBAs) in Sri Lanka (BirdLife International 2009).

Methods

Nest sites were searched on three consecutive days in each month from March to May from 0600h to 1800h.

Nests were searched in the interior of the forest patches. Five 25 x 25 m quadrats were marked in each habitat using a global positioning system device (GPS). Proportioned time was spent between habitats for nest searching (Kozma & Mathews 1997).

Approachable nests were observed directly. Unapproachable nests were observed through a 10 x 50 binocular. Pole and mirror method was used to check the nest contents. Nests were monitored until they were no longer in use. The time interval between nest checks was optimized by fieldwork logistics. Near the dates of egg-laying and hatching, nests were checked more frequently, when possible, to estimate the nesting phenology precisely. Focal animal sampling method was used to study the breeding behavior of the species (Altman 1974).

Nesting materials were identified by observing adult birds carrying nest materials from the resources during the nest construction period. Nesting habitat variables were recorded in each nest site. Nest parameters such as nest length and nest width were recorded. Canopy cover recorded using a spherical densitometer. Standard methods were used to estimate fruit cover and flower cover (Struhsaker 1975), shrub cover (Zollner & Crane 2003) and habitat insect availability on trunks/twigs and leaves were recorded. Environmental variables near nesting habitats were recorded using pocket weather meter (Krestel ™ 4000, USA). Nest site characteristics, such as nest height from the ground, height of the nesting tree and distance for the nearest nest of same species were recorded.

Available habitats were classified as cloud forests (CF), cloud forest die-back (CFD), and grasslands (GL) in the HPNP. The observer stayed at a hidden position and behaviour of the breeding couples were studied using a binocular (Nikon™ - Monarch, 10 × 42).

Surface temperatures of eggs were measured using

EXTECH Infrared thermometer initially after incubation adults left the nest. Incubation patterns such as on-bout and off-bout duration, nest trips rate and nest attentiveness were studied. Moreover, after the eggs hatching on-bout and off-bout duration, feeding trips rate and nest attentiveness of *Z. ceylonensis* were observed in the nestling period separately. The diurnal period was divided as, dawn (0600–0900 h), morning (0901–1200 h), mid-day (1201–1500 h), and evening (1501–1800 h). A nest was considered successful if at least one young fledged. Nesting observations were made with no disturbance to the birds and nests.

Data analysis

Differences were considered at $p<0.05$ significant level, mean and standard deviation (M±SD) values were reported throughout. Microsoft Excel™ was used to store data. Principal component analysis (PCA) was performed to analyze nesting habitat variables of *Z. ceylonensis* and graphical illustrations were performed in Minitab 17™.

Results and Discussion

A total of 47 active nests were recorded during the study period breeding occurred mainly from March to May comparatively low nesting observations were recorded during the second season from August to September. The peak egg-laying was in March and April (Figure 2).

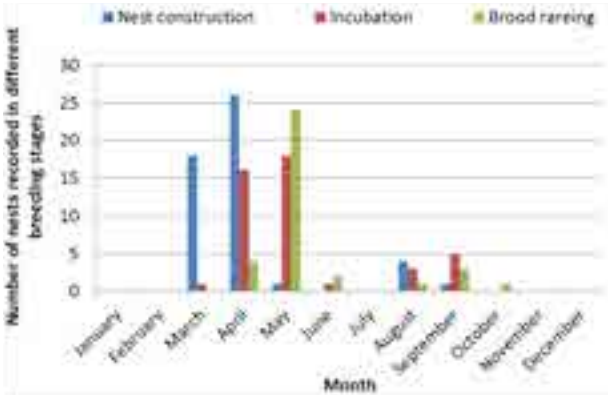


Figure 2. The number of total *Z. ceylonensis* nests recorded during the study in different breeding stages at HPNP, 2017.

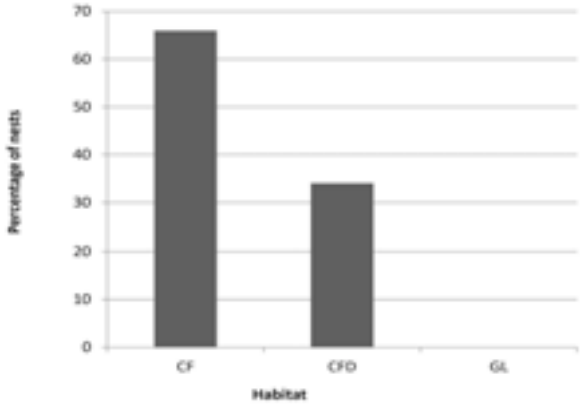


Figure 3. Percentage of *Z. ceylonensis* nests recorded during the study in different habitats at HPNP, 2017.

Most of the nests were recorded in the CF (65.95%) habitat compared to the CFD (34.05%) habitat. There were no nests recorded in the GL habitats (Figure 3). The study revealed that CF habitats occupied by the *Z. ceylonensis* for their breeding. First two axes of the PCA analysis of habitat variables which were significantly different from available habitat characteristics account for 85.5% of the total variance according to the Eigen analysis of the correlation matrix.

In the first principal component (PC1), wind speed (PC1, 0.466) contributed mostly to where the highest contributed factors for PC1 that variable correlated positively. It correlated negatively with temperature and (PC1, -0.528) and shrub cover (PC1, -0.504). Hence an increase in shrub cover will lead to a decrease in wind speed. Therefore, this habitat attributes influence on nesting habitat selection of *Z. ceylonensis.*

The second component (PC2) gave high scores to sites with high values of canopy cover (PC2, 0.562) and flower cover (PC2, 0.572). The overall PCA result indicated that determining factors of breeding habitat utilization in natural habitats of *Z. ceylonensis* in HPNP were availability of high shrub cover, canopy cover and flower cover (Figure 4).

Mean nest construction period 11 ±2.87 days (n= 17). Both male and females built the nest, during nest construction activity. We did not observe any cases of *Z. ceylonensis* reusing material from an abandoned or predated nest.

Majority of nests were built on *Sarcococca brevifolia, Berberis ceylanica Cinnamomum ovalifolium* trees of 4–12 m tall. Nest height was 3.16±1.22 m from the ground. Approximate distance for the active nests of same species was 4–6 m. There were few records that two nests in the same tree within 4m distance.

Most of the nests (89.36%) were built on the mosses hanging from the tree branches. *Z. ceylonensis* using this *Usnea barbarta* mosses as a substrate to their nests (72.4%). It will help them to conceal their nest and avoid predation via mossy camouflage in these montane habitats. Hammock like open cup nests constructed by mostly the fine grass stalks and mosses woven with

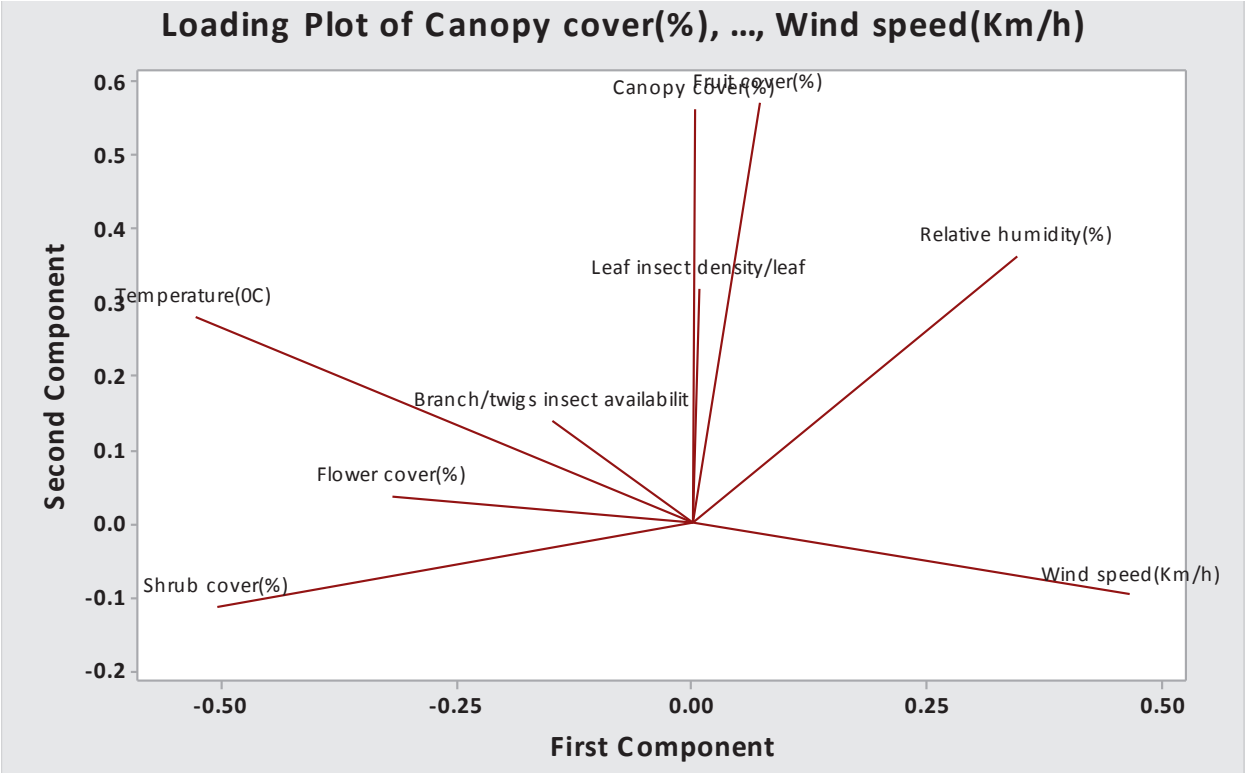


Figure 4. Factors affecting the breeding habitat utilization of *Z. ceylonensis* at HPNP.

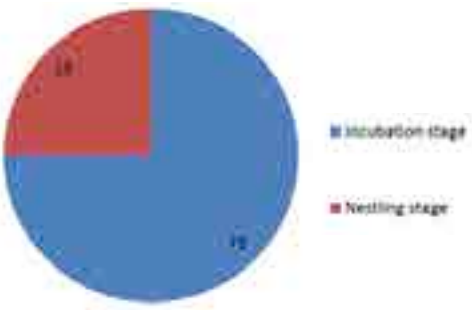


Figure 5. Percentage of *Z. ceylonensis* nests failure according to the habitats at HPNP, 2017.

Table 1. Nesting tress of Zosterops ceylonensis at HPNP.

Tree Species	Number of nests (n= 47)
Sarcococca brevifolia	7
Berberis ceylanica	6
Cinnamomum ovalifolium	6
Neolitsea fuscata	4
Syzygium rotundifolium	4
Elaeocarpus sp.	3
Rhododendron arboreum	3
Rubus ellipticus	3
Symplocos bractealis	2
Sinarundinaria debilis	2
Actinoaphne speciosa	2
Strobilanthes sp.	2
Eugenia mabaeoides	1
Rhodomyrtus tomentosa	1
Vaccinium leschenaultii	1

cobwebs and internal cup lined with grass stalks and plant fibre. Nests were always covered by surrounding leaves. Average nest width was 6.42±0.42 cm (n= 17), and average nest length was 3.91±0.22 cm (n= 17). Eggs were unspotted and pale blue. Mean clutch size 2.15±0.39 eggs (n= 16). One nest was destroyed by the predators before we observe the clutch.

Nest observations revealed that both male and female were involved in incubation, brooding and feeding of the young at both the nestling and fledgeling stage. The average incubation period was 10.92±0.9 days (M±SD) (n= 11) and the average nestling period was 28.33±1.55 days (n= 11).

During the incubation period, on-bout duration (35.41±3.28 min (M±SD)) and nest attentiveness (92.21±5.43% (M±SD)) was higher in the evening

period. Off-bout duration (22.32 ±5.21 min (M±SD)) was higher in the morning period. Nest trips rate (4.02± 0.54 $^{h-1}$ (M±SD)) was higher in the mid-day. The mean egg temperature under the parental incubation (25.92 ±3.41 C^0 (M±SD)) is significantly different from that of the absence of parental incubation (13.17±0.54 C^0 (M±SD)) (One way ANOVA, $p<0.01$). Both percentages of attendance and length of sitting bouts increase in bad weather. Pair sometimes meets on a branch near the nest to allopreening.

During the nestling period, on-bout duration (3.14 ± 1.26 min (M±SD)) and nest attentiveness (68.96 ± 10.34% (M±SD)) was higher in the evening period. Off-bout duration (2.49 ± 1.04 min (M±SD)) and feeding trips rate (10.31 ± 1.54 h^{-1} (M±SD)) was higher during the morning.

Z. ceylonensis single-brooded although some pairs made re-nesting attempts after first nests failed. About 23.40% of nests were depredated (N= 11), with evidence suggesting predation by Jungle Crow *Corvus levaillantii* and Greater Coucal *Centropus sinensis*. Furthermore, 2.13% of nests were broken by rainy winds (N= 1). About 75% of nests were failed during the incubation period while 25% nests failed during nestling stage. The overall nest success was 74.46%.

Comparatively higher nest failure was recorded in the CFD habitat (56.25%) compared to CF habitat (6.45%) (Figure 5). Therefore, study reveals that undisturbed cloud forests are essential to ensuring the breeding of this endemic species.

Incubating birds face ecological costs associated with reproductive effort during the breeding season (Conway & Martin 2000). Studies have shown that the first step of success of individual breeding attempts involves the location of nests being used by birds (Krebs & Davies 2009). Generally, factors that help decide the location of nesting site, and probably the choice of mate as well, including local food availability, presence of suitable nest materials and shelter from the physical environment and protection from predators (Collias & Collias 2014).

Z. ceylonensis occupied different tree species to build their nest all the nests shows that nests well protected from the heavy rains by a dense cluster of broad leave over the nest. It is generally placed on a small branch or twig directly under a canopy of foliage. The nest is built largely of fibres with outer surface often covered by the mosses. the open cup nest is typical of most passerine birds, the size of the inner cup is automatically moulded to the body size of the species because of the typical movements used in building, pushing in the nest with breast while rotating and pushing back with the feet (Collias & Collias 2014).

The close fit of the nest to bird helps make something of a seal, holding in warmth when the incubating bird is sitting closely. Our findings indicate that *Z. ceylonensis* maintained about 12 ^{0}C warmer than the surrounding air during the incubation. One reason for the prevalence of open nests among small birds of cool climates may be the need of the bird on the nest and its nestlings for the warming rays of the morning sun (Collias & Collias 2014).

Birds have evolved a variety of anti-predator adaptations in their nest-building behavior (Skutch 1976). When considering the *Z. ceylonensis* nests they are hidden in the vegetation, to deceive predators they camouflage their nests covered with *Usnea barbarta* mosses by resembling a mass of natural vegetation. It seems that the importance of nest concealment varies with ecological circumstances and with the type of predators at a given time and habitat. Since there is less abundance of snakes in the Horton plains most of the predator attacks occurred by avian predators. Therefore, nest concealment is a very important factor for nesting success.

The Horton Plains is one of the remaining pristine montane cloud forest habitats in Sri Lanka. Due to tourist activities invaded the population of Jungle Crow increased at human-induced habitat in the HPNP (Chandrasiri et al. 2017). When considering the nest failures of *Z. ceylonensis* most of the nest predation occurred due to predation by Jungle Crow. Unfortunately, nesting colony of Jungle Crow was observed in 2018 in the CF habitat. Many crows are a major threat to endemic animals. Increased number of crows is an indicator of pollution because they are scavengers in the food chain. To establish the protection of *Z. ceylonensis* in this important Montane Cloud Forest, admissible methods to control the number of Jungle Crow are needed.

Good nest sites are often traditional, serving as 'ecological magnets' over many years and regularly continue to attract individuals of the same species (Burnham 2007). Forest on Sri Lanka has suffered rapid degradation and fragmentation in the past decades through the excessive gathering of fuel-wood, clearance for permanent agriculture, shifting cultivation, fire, urbanization and logging. It is feared that habitat loss will continue in the hills and the status of this species therefore requires monitoring. There is no known targeted conservation action for this species. Therefore, conservation of breeding habitats is recommended to protect this species.

Image 1. *Zosterops ceylonensis* at HPNP, Sri Lanka.

Image 2. Mist-netted *Zosterops ceylonensis* individuals at HPNP, Sri Lanka.

Image 3. *Zosterops ceylonensis* nest covered with mosses at HPNP, Sri Lanka.

Image 4. *Zosterops ceylonensis* eggs at HPNP, Sri Lanka.

Image 5. Adult incubating on the nest at HPNP, Sri Lanka.

Image 6. *Zosterops ceylonensis* nestlings (4days) in a nest at HPNP, Sri Lanka.

Image 7. *Zosterops ceylonensis* fledgeling (25 days old) on a branch near the nest site at HPNP.

Image 8. Sri Lanka White-eye broken predated nest attached to twigs at HPNP, Sri Lanka.

References

Ali, S.L. & S.D. Ripley (eds.) (2001). *Handbook of the Birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan, and Sri Lanka.* Oxford University Press, Delhi, India.

Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behaviour* 49: 227–267.

BirdLife International (2016). *Zosterops ceylonensis*. In: IUCN 2012. IUCN Red List of Threatened Species. 2012. Date of download 2019/01/28. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22714023A94397877.en

Burnham, K.K. (2007). Inter-and intraspecific variation of breeding biology, movements, and genotype in Peregrine Falcon *Falco peregrinus* and Gyrfalcon *F. rusticolus* populations in Greenland. PhD Thesis. University of Oxford.

Chandrasiri, P.H.S.P., W.D.S.C.Dharmarathne, S. Lakmal & W.A.D. Mahaulpatha (2017). Distribution of the jungle crow (*Corvus levaillantii* lesson, 1831) and their potential threats to biodiversity in Horton Plains National Park, Sri Lanka. *Wildlanka* 5(2): 073–077.

Clements, J.F., T.S. Schulenberg, M.J. Iliff, D. Roberson, T.A. Fredericks, B.L. Sullivan & C.L. Wood (2016). *The Clements checklist of birds of the world.* http://www.birds.cornell.edu/clementschecklist/download/Google Scholar.

Collias, N.E. & E.C. Collias (2014). *Nest Building and Bird Behavior*. Princeton University Press.

Conway, C.J. & T.E. Martin (2000). Evolution of passerine incubation behavior: influence of food, temperature, and nest predation. *Evolution* 54(2): 670–685.

de Silva, A. (2007). *The Diversity of Horton Plains National Park (with special reference to its herpetofauna)*. Vijitha Yapa Publishers. Sri Lanka.

Gunatilleke, C.V.S. & I.A.U.N. Gunatilleke (1986). Horton Plains: some aspects of its vegetation and ecology. *Sri Lanka Wildlife* 3(4): 9–11.

Henry, G.M. (1971). *A Guide to the Birds of Ceylon (Second Edition)*. Oxford University Press, London, UK.

Horton Plains National Park (2010). International Water Management Institute. https://web.archive.org/web/20100805010613/http://dw.iwmi.org/wetland_profile/Horton.asp

BirdLife International **(2009).** IBAs in Sri Lanka. http://www.birdlife.org/datazone/country/sri-lanka.

Kozma, J.M & N.E. Mathews (1997). Breeding bird communities and nest plant selection in Chihuahuan Desert habitats in south-central New Mexico. *The Wilson Bulletin* 109(03): 424–436.

Krebs, J.R & N.B. Davies (2009). *Behavioural Ecology: An Evolutionary Approach*. John Wiley & Sons.UK.

Lack, D.L. (1971). *Ecological Isolation in Birds*. Harvard University Press, Cambridge, Massachusetts, USA.

Skutch, A.F. (1976). *Parent Birds and Their Young*. Austin and London: University of Texas Press.

Struhsaker, T.T. (1975). *The Red Colobus Monkey*. University of Chicago Press, Chicago, 311pp.

Sutherland, W.J., I. Newton & R. Green (2004). *Bird Ecology and Conservation*: *A Handbook of Techniques* (No. 1). Oxford University Press.

Wait, W.E. (1922). *The Passerine Birds of Ceylon. Spolia Zeylanica* 12: 182.

Zollner, P.A. & K.J. Crane (2003). Influence of canopy closure and shrub coverage on travel along coarse woody debris by eastern chipmunks (*Tamias striatus*). *The American Midland Naturalist* 150(1): 151–157.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20780–20785

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

https://doi.org/10.11609/jott.6962.14.3.20780-20785

#6962 | Received 03 December 2020 | Final received 09 October 2021 | Finally accepted 15 March 2022

OPEN ACCESS

SHORT COMMUNICATION

Two new species of army ants of the *Aenictus ceylonicus* group (Hymenoptera: Formicidae) from Kerala, India

Anupa K. Antony [1] & **G. Prasad** [2]

[1,2] Department of Zoology, University of Kerala, Kariavattom, Thiruvananthapuram, Kerala 695581, India.
[1] shininglantern90@gmail.com (corresponding author), [2] probios1@gmail.com

Abstract: The genus *Aenictus* Shuckard is a diverse group of army ants in the Old World tropics and subtropics. Herein, two new species from India (*Aenictus kodungallurensis* and *Aenictus malakkaparensis*) belonging to *Aenictus ceylonicus* group were discovered from Kerala, India. An updated key to the *Aenictus ceylonicus* species group from southern Asia is presented.

Keywords: Coastal area, Dorylinae, elevation, hand picking, Kodungallur, Malakkapara, taxonomic analysis, Thrissur.

Aenictus Shuckard 1840, belonging to the subfamily *Dorylinae* of the family *Formicidae,* is one of the true army ant genera occurring throughout Africa and in tropical and subtropical areas from India, Middle-east, southern China, Taiwan, Japan, Afghanistan, Armenia, southern Asia to New Guinea and Australia (Gotwald 1995; Shattuck 1999, 2008; Jaitrong & Yamane 2013). The genus *Aenictus* Shuckard, is the most diverse among all 18 genera of the monophyletic army ant subfamily Dorylinae (Brady et al. 2014) with 187 valid species and 30 valid subspecies (Bolton 2020). In the present paper we deal with the largest species group, the *Aenictus ceylonicus* Mayr group that has been revised in detail by Jaitrong & Yamane (2013). The group contains 23 species distributed in southern Asia. Two new species based on the worker caste are described here. Morphological and bionomic information is presented for each species. A key to the species is given. Most of the species of this species group have more or less limited distribution ranges. This may be due to the poor dispersal ability generally seen among the *Aenictus* species, in which the propagule (reproductive unit) is an apterous queen plus accompanying workers (Jaitrong & Yamane 2013).

Materials and Methods

The specimens were collected using hand picking method. The taxonomic analysis was done using a Labomed stereo zoom microscope. Optika Litevision stereozoom microscope was used to take images and measurements. Images taken were subsequently cleaned as per the requirement for Adobe Photoshop CC 2017. Images of whole ants and micro sculpture of parts were obtained using ZESS scanning electron microscope. Measurements and indices follow Jaitrong & Yamane (2013). Taxonomy follow Bolton (1994), Jaitrong & Yamane (2011, 2013) and Bharti et al. (2012). Holotype is deposited at the Zoological Survey of India Western Ghats Regional Centre (ZSIWGRC), Kozhikode, Kerala, India.

Morphological terminology for measurements (given in millimeters) and indices include: HL—Maximum length of head in dorsal view, measured in straight line from

ZooBank: urn:lsid:zoobank.org:pub:B71660E3-65E0-4F47-A2B1-38E823B1AB38

Editor: Anonymity requested. **Date of publication:** 26 March 2022 (online & print)

Citation: Antony, A.K. & G. Prasad (2022). Two new species of army ants of the *Aenictus ceylonicus* group (Hymenoptera: Formicidae) from Kerala, India. *Journal of Threatened Taxa* 14(3): 20780–20785. https://doi.org/10.11609/jott.6962.14.3.20780-20785

Funding: CSIR-UGC.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are grateful to Manoj vembhayam, member, TNHS for his support and guidance.

the anterior most point of the median clypeal margin to the midpoint of a line drawn across the posterior margin of head; HW—Maximum width of head in dorsal view; SL—Maximum length of the scape excluding the basal neck and condyle; ML—Mesosoma length. In side view, maximum longitudinal distance from posteroventral corner of mesosoma to the farthest point on the anterior face of pronotum, excluding the neck; PTL—Maximum length of the petiole in dorsal view; PTH—Petiole Height. Maximum height of petiole in profile; PPTL—Maximum length of the postpetiole in dorsal view.

TL—Total Length. HL + ML + PTL + PPTL + GL.

CI—Cephalic Index. (HW/HL) × 100.

SI—Scape Index. (SL/HW) × 100.

Results

Diagnosis: Jaitrong & Yamane (2011) defined this species group as follows:

Antenna 10-segmented; scape reaching or extending beyond half of head length, but not reaching the occipital corner of head in full-face view. Mandible linear; it's basal and lateral margins almost parallel; masticatory margin with large apical tooth followed by medium-sized subapical tooth; between subapical tooth and basal tooth 0–6 small denticles present. With mandibles closed, a gap is present between mandibles and anterior margin of clypeus. Anterior clypeal margin weakly concave or almost straight, lacking denticles. Frontal carina short and thin, reaching or slightly extending beyond the level of posterior margin of torulus; anterior curved extension of frontal carina reaching or extending beyond the level of anterior clypeal margin in full-face view; parafrontal ridge absent. Promesonotum usually convex dorsally and sloping gradually to propodeum. Subpetiolar process developed. Head and first gastral tergite smooth and shiny. Body yellowish, reddish or dark brown; typhlatta spot absent.

Aenictus malakkaparensis sp. nov.
(Images 1–8)

urn:lsid:zoobank.org:act:7344C361-9591-470B-B359-479C1A68D2DC

Type material: Holotype: ZSI/WGRC/IR-INV.13903, 04.xii.2018, Female, worker, Malakkapara, Thrissur, India, Kerala, 10.280N, 76.861E, 1,016m, hand collection from ground, coll. A. Antony.

Holotype worker measurements: TL 2.57mm; HL 0.57mm; HW 0.49mm; SL 0.38mm; ML 0.90mm, PTL 0.21mm, PTH 0.19mm, PPTL 0.20mm, CI 84; SI 77.

Worker description

Head: Head in full-face view sub rectangular, slightly longer than broad, sides convex, posterior margin almost straight; anterior part of head is broader than posterior part. Antennae with 10 segments, with ill-defined three segmented club and scape is short reaching almost 1/2 of head length. Anterior clypeal margin almost straight or feebly concave. Mandibles with basal margin edentate, masticatory margin of mandible with large acute apical tooth followed by a medium-sized subapical tooth, three denticles, and a medium-sized basal tooth.

Mesosome: Promesonotum convex dorsally and sloping gradually to metanotal groove; mesopleuron relatively long, clearly demarcated from metapleuron by a groove. Propodeum in profile with almost straight dorsal outline; propodeal junction angulate; declivity of propodeum flat, with blunt lateral carinae but not demarcated basally by a transverse carina.

Petiole, Post Petiole. Petiole longer than high, node short, elevated posteriorly and dorsal outline convex; sub petiolar process low and short, with anterior and posterior corners bluntly angulated and its ventral outline convex. Postpetiole clearly smaller than petiole, its dorsal outline convex.

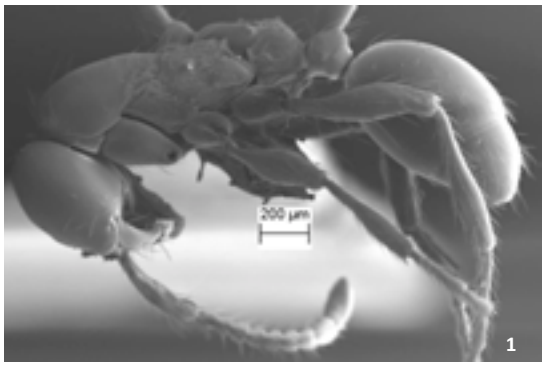
Head, antenna and gaster entirely smooth and shiny; mandible finely striate with long decumbent hairs. Promesonotum smooth and shiny except for anteriormost portion punctate; mesopleuron with slightly irregular rugae; metapleuron, and propodeum wrinkled and reticulate. Petiole and postpetiole entirely reticulate except small area on dorsa smooth and shiny. Head and mesosoma dorsally with relatively sparse standing hairs. Legs with dense long decumbent hairs.

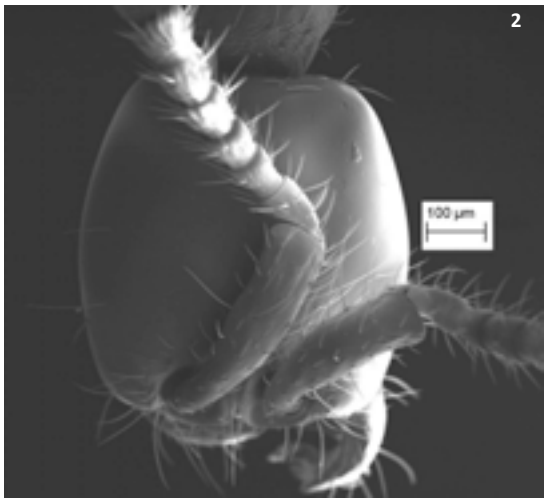
Mesosoma, petiole and postpetiole reddish-brown; head, antennal scape, gaster and legs yellowish-brown.

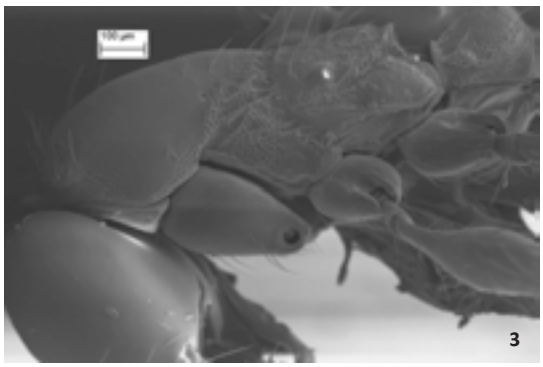
Etymology: The species name is after the type locality, Malakkapara.

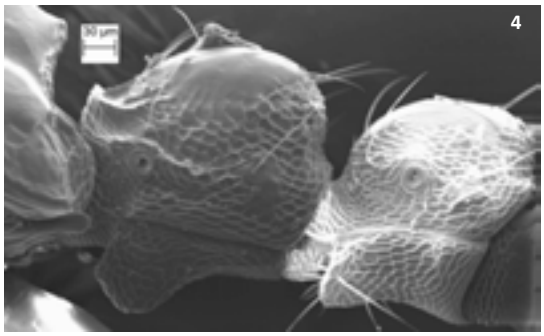
Distribution: Known only from the type locality in Kerala.

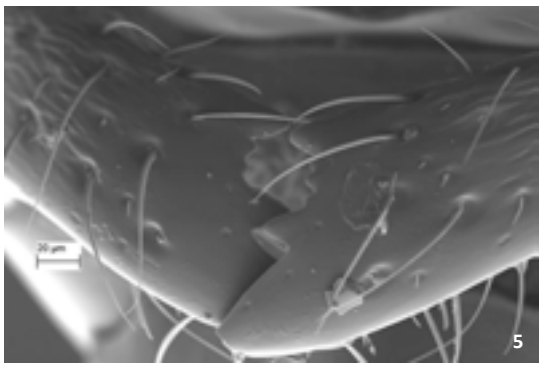
Remarks: *Aenictus malakkaparensis* sp. nov. is similar to *Aenictus appressipilosus* from which it can be fairly separated by a combination of characters. *Aenictus appressipilosus* have two long standing hairs mixed with few short appressed hairs on the vertex and has a few appressed hairs mixed with few decumbent hairs on promesonotum whereas in *Aenictus malakkaparensis* sp. nov. two long standing hairs are absent and its sub petiolar process is low and short, with anterior and posterior corners bluntly angulated and the ventral outline convex.











Images 1–8. *Aenictus malakkaparensis* sp. nov. worker (SEM images): 1—lateral view of body | 2—front of head | 3—Mesonotum | 4—Subpetiolar process | 5—Mandible. Stereozoom Images | 6—dorsal view of body | 7—lateral view of body | 8—front of head.

Aenictus kodungallurensis sp. nov. (Images 9–16)

urn:lsid:zoobank.org:act:353B7C3C-1BFD-42D6-8601-216C111509B3

Type material: Holotype: ZSI/WGRC/IR-INV.13902, 11.vi.2016, Female, worker, Kodungallur, Thrissur, Kerala, India, 10.238N, 76.161E, 9 m, hand collection on ground, coll. A. Antony.

Holotype worker measurements: TL 2.40mm; HL 0.54mm; HW 0.50mm; SL 0.40mm; ML 0.89mm, PTL 0.20mm, PTH 0.17mm, PPTL 0.17mm, CI 89; SI 76.

Worker description

Head: Head in full-face view sub rectangular, slightly longer than broad, sides convex, posterior margin almost straight; anterior part of head is broader than posterior part. Antennae with 10 segments, with ill-defined three segmented club and scape reaching almost 2/3 of head length. Anterior clypeal margin almost straight or feebly concave. Mandibles with basal margin edentate, masticatory margin of mandible with a large acute apical tooth followed by a medium-sized subapical tooth, two denticles, and a medium-sized basal tooth.

Mesosome: Promesonotum convex dorsally and sloping gradually to metanotal groove; mesopleuron relatively long, clearly demarcated from metapleuron by a groove. Propodeum in profile with almost straight dorsal outline; propodeal junction angulate; declivity of propodeum flat, with blunt lateral carinae but not demarcated basally by a transverse carina.

Petiole longer than high, node short, elevated posteriorly and dorsal outline convex; subpetiolar process low and subrectangular with anteroventral and posteroventral corners bluntly angulated and margin between the corners straight to feebly concave. Postpetiole clearly smaller than petiole, its dorsal outline convex.

Head, antenna and gaster entirely smooth and shiny; mandible finely striate. Promesonotum smooth and shiny except for anterior most portion punctate; mesopleuron with slightly irregular rugae; metapleuron, and propodeum wrinkled and reticulate. Petiole and postpetiole entirely reticulate except small area on dorsa smooth and shiny. Head and mesosoma dorsally with relatively dense standing hairs mixed with relatively dense decumbent hairs. Legs with dense long decumbent hairs. Mesosoma, petiole and postpetiole reddish-brown; head, antennal scape, gaster and legs yellowish-brown.

Etymology: The species name is after the type locality, Kodungallur.

Distribution: Known only from the type locality in Kerala.

Bionomics: So far, this species has been known only from Kodungallur.

Remarks: *Aenictus kodungallurensis* sp. nov. is collected from coastal area with loose coastal alluvium soil by handpicking method. *Aeniictus kodungallurensis* sp. nov. is smaller in size than *Aenictus malakkaparensis* sp nov. The antennal scape of *Aenictus malakkaparensis* sp nov. is shorter compared to *Aenictus kodungallurensis* sp. nov. The shape of subpetiolar process is also different, the ventral margine between corners is straight or feebly concave in *Aenictus kodungallurensis* sp. nov. but it is convex in *Aenictus malakkaparensis* sp. nov. Head and mesosome of *Aenictus kodungallurensis* sp. nov. is covered with dense hairs but in case of *Aenictus malakkaparensis* sp. nov. head and mesosome is only covered by sparse hairs.

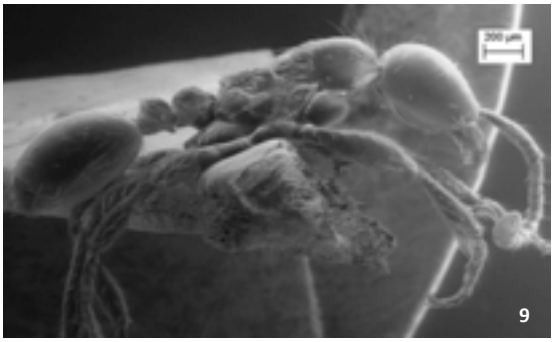
Discussion

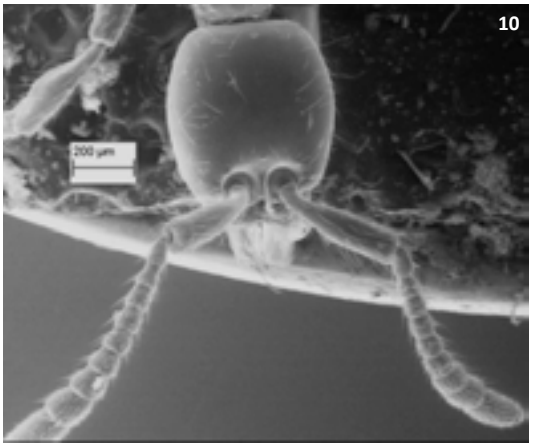
Aenictus kodungallurensis sp. nov. and *Aenictus malakkaparensis* sp. nov. are members of *A. ceylonicus* group, which is a unique group easily separated from the other groups by the following characteristics: mandible linear; a gap is present between mandibles and anterior margin of clypeus when mandibles are closed; anterior clypeal margin almost straight or feebly concave, lacking denticles. The *A. ceylonicus* group occurs in the Oriental, Indo-Australian and Australasian regions (Wilson 1964; Shattuck 2008; Jaitrong & Yamane 2011). *A. kodungallurensis* sp. nov. and *A. malakkaparensis* sp. nov. are the only members of *Aenictus ceylonicus* group reported from Kerala. Both the species are collected from ground by hand picking method. Major difference between both the species is in the structure of sub petiolar process and the promesonotum of *A. kodungallurensis* is covered with dense decumbent hairs. *A. kodungallurensis* sp. nov. is collected from a mixed vegetation area in coastal region with coastal alluvium soil whereas *Aenictus malakkaparensis* sp. nov. is collected from a hilly area with silty loam at an elevation of 1,016 m.

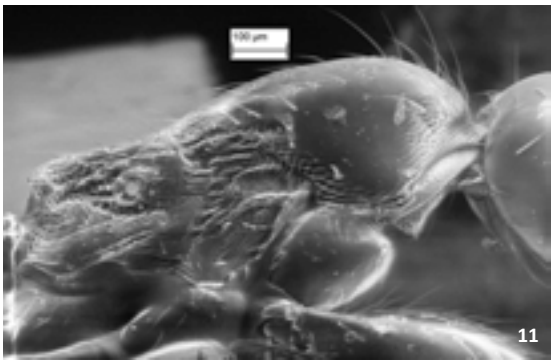
References

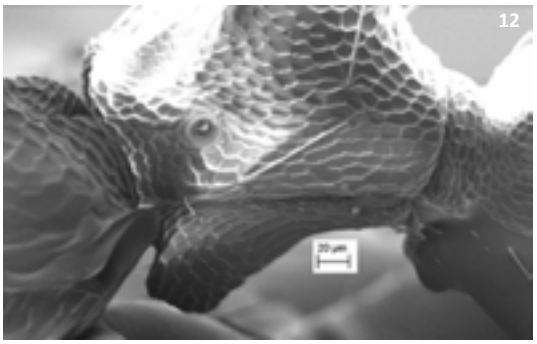
Bharti, H., A.A. Wachoo & R. Kumar (2012). Two remarkable new species of Aenictus (Hymenoptera: Formicidae) from India. *Journal of Asia-Pacific Entomology* 15: 291–294. https://doi.org/10.1016/j.aspen.2012.02.002

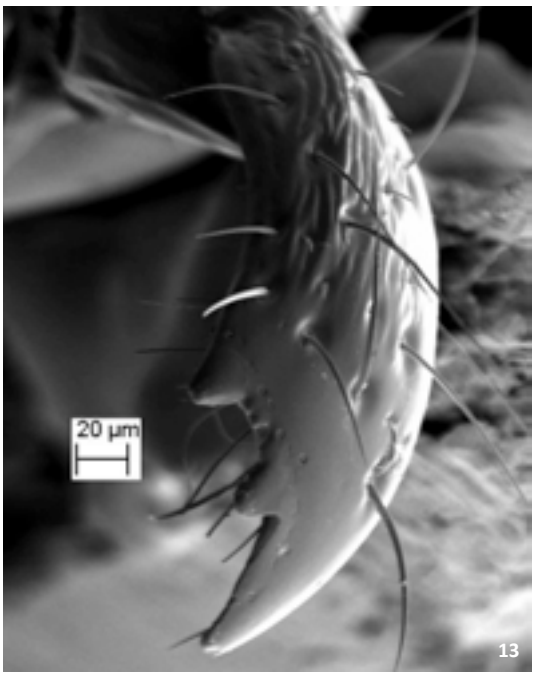
Brady, S.G., B.L. Fisher, T.R. Schultz & P.S. Ward (2014). The rise of army ants and their relatives: diversification of specialized predatory doryline ants. *BMC Evolutionary Biology* 14: 93. http://www.biomedcentral.com/1471-2148/14/93

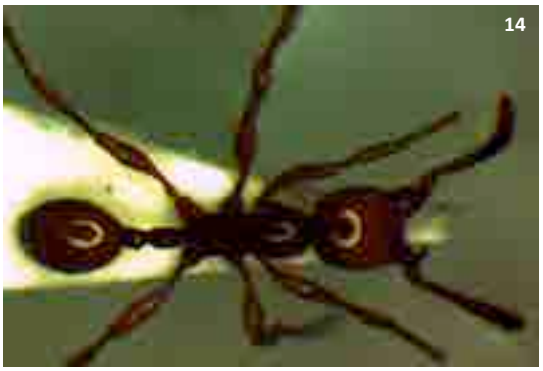












Images 9–16. ***Aenictus kodungallurensis*** **sp. nov. worker (SEM images): 9—lateral view of body | 10—front of head | 11—Mesonotum | 12—Subpetiolar process | 13—Mandible. Stereozoom Images | 14—dorsal view of body | 15—lateral view of body | 16—front of head.**

Key to *A. ceylonicus* group species based on the worker caste, modified and updated after the key of Jaitrong & Yamane (2013).

1. Mandible with 2–6 teeth/denticles between subapical and basal teeth (mandible with more than 4 teeth/denticles) 2
- Mandible with 0–1 tooth/denticle between subapical and basal teeth (mandible with 3–4 teeth/denticles) ..... Extralimitial

2. Vertex with sparse standing hairs and with a few short appressed hairs; promesonotum with few appressed hairs and a few decumbent hairs 3
- Vertex and promesonotum with dense standing or decumbent hairs 4

3. Vertex with two long standing hairs mixed with a few short appressed hairs (Sabah) .... ***A. appressipilosus* Jaitrong & Yamane, 2013**
- Vertex without two long standing hairs but with a few short appressed hairs (India) ..... ***A. malakkaparensis* sp. nov.**

4. Subpetiolar process subtriangular, its apex directed downward, anteroventrally not angulate; postpetiole elevated posteriorly; its posterior face much steeper than anterior face (Sumatra) ..... ***A. itoi* Jaitrong & Yamane, 2013**
- Subpetiolar process subrectangular or low, convex, straight or feebly concave in its ventral outline, anteroventrally always angulate; postpetiole with roundly convex dorsal outline 5

5. Dorsal outline of propodeum weakly convex; metapleural gland bulla weakly sculptured and shiny (Vietnam) .... ***A. eguchii* Jaitrong & Yamane, 2013**
- Dorsal outline of propodeum straight; metapleural gland bulla strongly sculptured (puncto-reticulate) and opaque 6

6. Posteroventral corner of subpetiolar process bluntly angulate (not spiniform) (India) ..... ***A. kodungallurensis* sp. nov.**

- Posteroventral corner of subpetiolar process acutely produced below (spiniform) ..... ***A. jawadwipa* Jaitrong & Yamane, 2013**

Bolton, B. (1994). *Identification Guide to Ant Genera of The World*. Mass.: Harvard University Press, Cambridge, 222 pp.

Bolton, B. (2020). An online catalogue of the ants of the world. http://www.antweb.org. Accessed on 3 July 2020.

Gotwald, W.H. (1995). *Army Ants: The Biology of Social Predation*. Cornell University Press, Ithaca and London, 320 pp.

Jaitrong, W. & S. Yamane (2011). Synopsis of Aenictus species groups and revision of the *A. currax* and *A. laeviceps* groups in the eastern Oriental, Indo-Australian, and Australasian regions (Hymenoptera: Formicidae: Aenictinae). *Zootaxa* 3128: 1–46. https://doi.org/10.11646/zootaxa.3128.1.1

Jaitrong, W. & S. Yamane (2013). The *Aenictus ceylonicus* species group (Hymenoptera, Formicidae, Aenictinae) from Southeast. *Journal of Hymenoptera Research* 31: 165–233. https://doi.org/10.3897/JHR.31.4274

Shattuck, S.O. (1999). Australian ants: their biology and identification. *Monographs in Invertebrate Taxonomy* 3: 1–226.

Shattuck, S.O. (2008). Review of the ant genus *Aenictus* (Hymenoptera: Formicidae) in Australia with notes on A. ceylonicus (Mayr). *Zootaxa* 1926: 1–19. https://doi.org/10.11646/zootaxa.1926.1.1

Wilson, E.O. (1964). The true army ants of the Indo-Australian area (Hymenoptera: Formicidae: Dorylinae). *Pacific Insects* 6(3): 427–483.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20786–20791

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

https://doi.org/10.11609/jott.7790.14.3.20786-20791

#7790 | Received 15 December 2021 | Final received 20 March 2022 | Finally accepted 22 March 2022

OPEN ACCESS

SHORT COMMUNICATION

Addition of three new angiospermic taxa to the flora of Bangladesh

M. Ashrafuzzaman [1], M. Khairul Alam [2] & A.K.M. Golam Sarwar [3]

[1,3] Laboratory of Plant Systematics, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
[2] Bangladesh Forest Research Institute, GPO Box No 273, Chattogram 4000, Bangladesh.
[1] ashrafcbot@bau.edu.bd, [2] khairulalam1952@gmail.com, [3] drsarwar@bau.edu.bd (corresponding author)

Abstract: During updating the plant holding database of the botanical garden, Bangladesh Agricultural University, the authors identified three species of the family Commelinaceae namely, *Callisia fragrans* (Lindl.) Woodson, *Murdannia gigantea* (Vahl) G.Brückn., and *Tradescantia sillamontana* Matuda as new records to the flora of Bangladesh. This paper provides a comprehensive description and colour photographs of these species from Bangladesh.

Keywords: *Callisia fragrans*, Commelinaceae, dayflower, *Murdannia gigantea*, new records, *Tradescantia sillamontana*.

The dayflower or spiderwort family Commelinaceae is widely distributed throughout tropical and subtropical regions comprising 41 genera and 731 species (Christenhusz & Byng 2016) and is characterized by several features including a distinct closed leaf sheath, a succulent leaf blade, deliquescent three-merous flowers with distinct petals and sepals and a lack of nectaries (Cronquist 1981). The members of this family are important for their valuable ornamentals such as dayflower, spiderwort, moses-in-the-bulrushes, and wandering Jew; young shoots and leaves as vegetables, as well as for their medicinal uses as a laxative, to treat inflammation of the eyes, fractured bones, burns, arthritis, skin & oncological diseases, tuberculosis & asthma, among others (Alam 2007; Tan et al. 2014). Khan & Alam (1977) reported 28 species under 13 genera of the Commelinaceae from Bangladesh. After some nomenclatural changes, later the family was exemplified from the country by 10 genera and 27 species (Alam 2007). Recently, Alam & Uddin (2018) recorded 23 species under 10 genera of Commelinaceae from the greater Chittagong and the Chittagong Hill Tracts. All these reports include taxa both from wild and cultivated states.

The Botanical Garden of Bangladesh Agricultural University (BAUBG) is located on the western bank of the old Brahmaputra River between 24.433°N and 90.263°E. Since its inception in 1963, the BAUBG has been involved in the collection and conservation of plant genetic resources from both local and international sources. With a land area of about 10 ha, approximately 1,150 plant species under 327 genera and 215 families are being conserved here over a period of time for the study by students, academicians, and researchers (Sarwar 2019). The garden's collections were primarily acquired through field / forest exploration; however, some species were acquired through exchange programmes and/or from commercial nurseries. Although BAUBG collection is enriched day by day and the database is well-managed, some of the plant collections have been

Editor: Anonymity requested.

Date of publication: 26 March 2022 (online & print)

Citation: Ashrafuzzaman, M., M.K. Alam & A.K.M.G. Sarwar (2022). Addition of three new angiospermic taxa to the flora of Bangladesh. *Journal of Threatened Taxa* 14(3): 20786–20791. https://doi.org/10.11609/jott.7790.14.3.20786-20791

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The present and previous Curators, who have enriched the collection and curated the plant genetic resources of this Botanical Garden, are thankfully acknowledged.

lost due to different natural calamities, diseases, insect predation, and theft. These necessitate initiating a new programme to update the plant holding database of the BAUBG (Sarwar 2019; Ashrafuzzaman & Sarwar 2021; Ashrafuzzaman et al. 2021).

This article includes taxonomic descriptions of the species, including the most recent nomenclature and the most frequently used synonyms, as well as information on flowering and fruiting time, ecology, mode of propagation, uses, global distribution, and conservation status.

Methods

A detailed survey on the plant genetic resources growing and conserved throughout BAUBG has been carried out through frequent visits. During these visits, fresh flowering samples were collected; herbarium specimens were prepared as vouchers by drying the fresh samples following standard procedure (Anonymous 1996). The dried specimens were mounted on the herbarium sheet and preserved in Prof. Arshad Ali Herbarium at the botanical garden, Department of Crop Botany, Bangladesh Agricultural University (AAHBAU). The collected fresh (or dried) specimens were identified in the field or by comparing with herbarium specimens or pertinent published literature. While updating the list of the family Commelinaceae, the authors came across a few interesting specimens which, after critical examination and with help of web resources and type specimens, were identified as *Callisia fragrans* (Lindl.) Woodson, *Murdannia gigantea* (Vahl) G.Brückn., and *Tradescantia sillamontana* Matuda. A comprehensive description and colour photographs are provided for easy identification of the species. The botanical names were updated following WFO–The World flora online <http://www.worldfloraonline.org> (older http://www.theplantlist.org) and Plants of the world online <https://powo.science.kew.org/>.

Results and Discussion

While updating the list of Commelinaceae species conserved at BAUBG, we identified three new species to the flora of Bangladesh: *Callisia fragrans* (Lindl.) Woodson, *Murdannia gigantea* (Vahl) G.Brückn. and *Tradescantia sillamontana* Matuda.

These species and even the genus *Callisia* were not included in any previous reports of the country (Khan & Alam 1977; Alam 2007). There is no mention of the species in the recent floristic accounts that covered the major floristic areas of the country (Hossain & Hossain 2014; Rahman 2017; Rahman et al. 2015, 2017; Alam & Uddin 2018; Haque et al. 2018; Harun-Ur-Rashid et al. 2018; Khan et al. 2021; Uddin et al. 2021).

Three species of Commelinaceae recorded as new to the flora of Bangladesh are described below.

Callisia fragrans (Lindl.) Woodson, Annals of the Missouri Botanical Garden. 29: 154 (1942).

Spironema fragrans Lindley, Edwards's Bot. Reg. 26: t. 47 (TYPE), misc. 26 (1840). *Rectanthera fragrans* (Lindl.) O.Deg., Fl. Hawaiiensis [Degener] Fam. 62 (1932); *Spironema orthandrum* Lindb., Acta Soc. Sci. Fenn. 10: 127. t. 4. (1871) (Image 1).

Common names: Basket plant, false bromeliad, octopus plant, inch plant, purple succulent, sweet-scented spiral thread.

A perennial, robust, stoloniferous, herb, ascending, to 1 m. Leaves in clusters from long stems, spirally arranged, oblong to lanceolate-oblong, 15–30 x 2.5–5 cm, glabrous, glossy green, tend to become reddish-purple in strong light, distal leaf blades much narrower than sheaths when sheaths opened, flattened, apex acuminate, glabrous. Inflorescences terminal panicles to 30 cm or longer, flowers emerging on slender peduncles. Flowers fragrant, subsessile; bract papery, 10–15 mm long; sepals 3, whitish-transparent, membranous, lanceolate, 5–6 mm; petals three, white, short-lived, lanceolate, 6 mm; stamens six, long-exserted, connectives white, broad, flag-like; filaments glabrous; ovary 3-locular, stigma penicillate. Fruit a capsule, 3-locular; seeds two per locule, exarillate, uniseriate, hilum punctiform to linear, embryotega dorsal to lateral.

Flowering & fruiting: February to June.

Chromosome number: 2n= 18 (Nandikar et al. 2010).

Ecology: Common cultivated ornamental. Often becomes open perennial drought-resistant colonies on the ground.

Mode of propagation: Can be easily propagated through stem cuttings.

Uses: A common ornamental indoor plant. It is traditionally used to treat burns, arthritis, skin and oncological diseases, tuberculosis, and asthma (Chernenko et al. 2007). It has a rich folkloric reputation as an antiviral and antimicrobial plant. Especially in eastern Europe, its leaves are used for the treatment of various skin diseases, burns, and joint disorders (Yarmolinsky et al. 2010).

Distribution: Endemic to Mexico, and is a popular pot plant cultivated throughout Europe, Asia, and the Americas. Introduced into Dominican Republic, Florida, Hawaii, Jamaica, Leeward Is., Louisiana, Morocco, Netherlands Antilles, Norfolk Is., Puerto Rico, Taiwan,

Image 1. ***Callisia fragrans*****: A–B—Habit | C—Terminal inflorescence. © M. Ashrafuzzaman & A.K.M. Golam Sarwar.**

Venezuelan Antilles, and Windward Is. In Bangladesh, it is so far recorded in cultivation only.

Conservation status: *Callisia fragrans* is currently known only in cultivation state, hence no threat has been assessed and is considered as Least Concern.

The species can be easily identified by spirally arranged clustered leaves, terminal panicle with white fragrance flowers.

Representing specimens examined: Mymensingh, Botanical Garden, Bangladesh Agricultural University, cultivated, 19.vi.21. Ashrafuzzaman & Sarwar (AAHBAU)

Murdannia gigantea (Vahl) G.Brückn., Nat. Pflanzenfam., ed. 2 15a: 173 (1930). Faden, Revis. Handb. Fl. Ceylon 14: 147 (2000); Nandikar & Gurav, Phytodiversity 2(1): 72 (2015). *Commelina gigantea* Vahl, Enum. Pl. 2: 177 (1805–06). Type: India, Röttler (lectotype Herb. Vahl C) cited by Faden (2000).

Aneilema giganteum (Vahl) R.Br., Prodr. Fl. Nov. Holland. 271 (1810); Hook.f., Fl. Brit. Ind. 6: 379 (1892). *Aneilema ensifolium* Wight, *Icon. Pl. Ind. Orient. 6: 30, t. 2074 (1853).* TYPE: India, Courtallum, Herb. Wight s.n. (SYNTYPES: K). (Image 2).

A tufted, erect, perennial herb; roots thickened but not tuberous. Stem 25–60 cm high, glabrous, or puberulous, with long internodes. Rosette leaves linear, 25–60 × 0.5–1 cm, apex acuminate to finely acuminate, base narrowed, sheath 1–7 (–8) cm long; flowering shoots terminal in the rosette, erect, 1 m tall, leafy with long internodes, leaves on flowering shoot gradually reduced. Inflorescences terminal with many-flowered cincinni; bracteoles. 5 mm long. Flowers many, pedicellate; pedicel erect, 6 mm long, glabrous; sepals elliptic, 5–8 mm long; petals ovate to obovate, pale lavender to blue; stamens 2, filaments bearded, anthers ellipsoid; staminodes 4, filaments sparsely bearded, antherodes trilobed, yellow; ovary green, ovoid. Fruit a capsule, ellipsoid ovoid, 0.6–10 × 5–6 mm, brown, glabrous; seeds 2 per locule, uniseriate, ovoid ellipsoid in outline, 2.5–4 × 2–2.5 mm, rugose with warts and ridges in lines radiating from embryotega, the whole surface finely granular.

Flowering & fruiting: May to August.

Chromosome number: 2n= 22 (Rao et al. 1960); 44 (Kammathy & Rao 1961)

Ecology: Seepage areas on rock outcrops and secondary forest, full sun to part shade; 0–200 m (Faden 2000).

Mode of propagation: Vegetative propagation through plant division.

Uses: Planted as an ornamental in many parts of the world.

Distribution: Native range is Madagascar, tropical Asia to northern Australia, cultivated in India, Sri Lanka, Singapore, Cambodia, Viet Nam, Thailand, Lao People's Democratic Republic, Myanmar, Sri Lanka, Indonesia, Papua New Guinea, Philippines, China, Australia and Madagascar. In Bangladesh, it is so far recorded in cultivation only.

Conservation status: *Murdannia gigantea* is currently known only in cultivation state; hence no threat has been assessed and is considered as Least Concern.

The species can easily differentiate with tall flowering shoot terminal in the rosette with leafy internodes; broad leaves.

Representing specimens examined: Mymensingh,

Image 2. *Murdannia gigantea*: A—Habit | B—Flower on flowering twig and immature fruit. © M. Ashrafuzzaman & A.K.M. Golam Sarwar.

Botanical Garden, Bangladesh Agricultural University, cultivated, 19.vi.21. Ashrafuzzaman & Sarwar s.n. (AAHBAU)

Note: One herbarium (specimen) collection is recorded by Silva, F.W.de & W. Gomez (G-DC-357361/1) from Sylhet - Mont. Sillet/Sylhet Division stored in Geneva Herbarium – De Candolle's Prodromus (G-DC) <https://www.gbif.org/occurrence/1144569612>.

C.B. Clarke's note of 25 August 1896 on "Wallich Catalogue: Sylhet, Pundua and Khasia Hills" indicate that Wallich distinguished between 'Sillet', i.e., the old (and present) Zilla, and the 'Mont. Sillet' or 'Mont. Sillet vicinae', by which he indicated Khasia https://stories.rbge.org.uk/archives/5029 seen on 01 July 2021.

Tradescantia sillamontana Matuda, Bol. Soc. Bot. México 18: 1 Fig. 1 (1955). TYPE: Mexico, Nuevo Leon (White & Chatters 30 [MICH, GH, MEXU]) (Hunt 2020).

Tradescantia pexata H.E.Moore Jr., Baileya 8: 100 (1960). TYPE: H.E. Moore Jr. 7750, July 1959 (in flower); 7750 bis, 23 February 1960 (vegetative) (BH) (Moore, Jr. 1960) (Image 3).

Common name: White Velvet, White Gossamer lant, Hairy Wandering Jaw, Cobweb Spiderwort

A tuberous, xerophytic, evergreen perennial herb, 30–40 cm tall. Stem erect to trailing, rooting on the soil surface. Leaves spirally alternate, distichous, fleshy, elliptic-ovate to broadly ovate-lanceolate, 3–7 x 2.0–2.5 cm, upper surface silvery green, turning bright purplish-red under high light conditions, covered with a dense layer of silvery hairs, undersurface reddish-purple. Inflorescence terminal and usually solitary, often cluster of flowers enclosed by leaf-like bracts. Flowers c. 2 cm across, bright magenta to pink deep rosy-pink, sepals three, more or less transparent forming calyx tube, elliptic to broadly elliptic, petals three, sessile or clawed, equal, free to connate, stamens six, arranged in two series, equal, filaments epipetalous, hairless, ovary glabrous or pubescent, locules 2-ovulate, style straight at anthesis and post-anthesis. Fruit a capsule, subglobose to globose, loculicidal, 3-valved, seeds exarillate, 1–2 per locule.

Flowering & fruiting: June–August.

Chromosome number: Tetraploids, 2n= 24 (Chinnappa 1976).

Ecology: Almost succulent and nearly xerophytic in nature.

Mode of propagation: Can be easily propagated through stem cuttings.

Uses: Grown as indoor pot plants. It can also be grown as a ground cover.

Distribution: Native to Mexico, Italy, USA, Brazil, Spain, Argentina, South Korea, Norway, Chinese Taipei, South Africa, Belgium, Greece, Nicaragua, El Salvador, India. In Bangladesh, it is so far recorded in cultivation only.

Conservation status: *Tradescantia sillamontana* is currently known only in cultivation state; hence no threat has been assessed and is considered as Least Concern.

Easy to recognize by its distinctive feature being the

Image 3. ***Tradescantia sillamontana*****: A—Habit | B—Leaves surface covered with a dense layer of silvery hairs | C—Flower.**

leaf surface covered with dense layer of silvery hairs.

Representing specimens examined: Mymensingh, Botanical Garden, Bangladesh Agricultural University, cultivated, 19.vi.21. Ashrafuzzaman & Sarwar (AAHBAU)

References

Alam, M.K. (2007). Commelinaceae R. Brown, pp. 142–162. In: Siddiqui, K.U., M.A. Islam, Z.U. Ahmed, Z.N.T. Begum, M.A. Hassan, M. Khondker, M. M. Rahman, S.M.H. Kabir, M. Ahmad, A.T.A. Ahmed, A.K.A. Rahman & E.U. Haque (eds). *Encyclopedia of Flora and Fauna of Bangladesh, Vol. 11. Angiosperms: Monocotyledons (Agavaceae–Najadaceae)*. Asiatic Society of Bangladesh, Dhaka.

Alam, M.K. & S.N. Uddin (2018). Commelinaceae, pp. 352–370. In: Uddin, S.N. & M.A. Hassan (eds.). *Vascular Flora of Chittagong and the Chittagong Hill Tracts Vol. 1*. Bangladesh National Herbarium, Ministry of Environment, Forest & Climate Change, Government of the People's Republic of Bangladesh, Dhaka.

Anonymous (1996). *Techniques and Procedures for Collecting, Preserving, Processing, and Storing Botanical Specimens.* Research Branch, British Columbia Ministry of Forest, Victoria, B.C. Work Paper 18/1996.

Ashrafuzzaman, M. & A.K.M.G. Sarwar (2021). Species diversity of Sterculiaceae at Bangladesh Agricultural University Botanical Garden and their ethnobotanical uses. *Asian Journal of Research in Botany* 5: 1–8.

Ashrafuzzaman, M., M.M. Khatun, N.A. Tunazzina & A.K.M.G. Sarwar (2021). Conservation of minor fruit genetic resources at the Botanical Garden, Bangladesh Agricultural University. *International Journal of Minor Fruits Medicinal & Aromatic Plants* 7: 1–18. https://doi.org/10.53552/ijmfmap.2021.v07i01.001

Chernenko, T.V., N.T. Ul'chenko, A.I. Glushenkova & D. Redzhepov (2007). Chemical investigation of *Callisia fragrans*. *Chemistry of Natural Compounds* 43: 253–255. https://doi.org/10.1007/s10600-007-0098-x

Chinnappa, C.C. (1976). Cytology of *Tradescantia sillamonta*. *Caryologia* 29: 363–367. https://doi.org/10.1080/00087114.1976.10796511

Christenhusz, M.J.M. & J.W. Byng (2016). The number of known plants species in the world and its annual increase. *Phytotaxa* 261(3): 201–217. https://doi.org/10.11646/phytotaxa.261.3.1

Cronquist, A. (1981). *An Integrated System of Classification of Flowering Plants*. New York: Columbia University Press.

Faden, R.B. (2000). Commelinaceae, pp. 116–196. In: Dassanayake, M.D. & W.D. Clayton (eds). *Revised Handbook to the Flora of Ceylon Vol. 14*. Oxford and IBH Publishing, New Delhi.

Haque, A.K.M.K., S.A. Khan, S.N. Uddin & S.S. Shetu (2018). An annotated checklist of the angiospermic flora of Rajkandi Reserve Forest of Moulvibazar, Bangladesh. *Bangladesh Journal of Plant Taxonomy* 25(2): 187–207. https://doi.org/10.3329/bjpt.v25i2.39525

Harun-Ur-Rashid, M., S. Islam & S.B. Kashem (2018). Floristic diversity (Magnoliids and Eudicots) of Baraiyadhala National Park, Chittagong, Bangladesh. *Bangladesh Journal of Plant Taxonomy* 25(2): 273–288. https://doi.org/10.3329/bjpt.v25i2.39532

Hossain, M.K. & M.A. Hosain (2014). *Biodiversity of Chunati Wildlife Sanctuary: Flora*. Arannayk Foundation & Bangladesh Forest Department, Dhaka, Bangladesh, v +175pp.

Hunt, D.R. (2020). *Tradescantia* Commelinaceae, pp. 1183–1187. In: Eggli, U. & R. Nyffeler (eds.). *Illustrated Handbook of Succulent Plants. Monocotyledons*. 2nd ed., Springer-Verlag GmbH, Germany.

Kammathy, R.V. & R.S. Rao (1961). Notes on Indian Commelinaceae. 3: Cytological observations. *Bulletin of the Botanical Servey of India* 3: 393–394.

Khan, M.S. & M.K. Alam (1977). Commelinaceae, pp. 13–41. In: Khan, M.S. (ed.). *Flora of Bangladesh. Fasc. No. 4*. Bangladesh National Herbarium, Dhaka.

Khan, S.A., S. Sultana, G.M. Hossain, S.S. Shetu & M.A. Rahim (2021). Floristic composition of Jahangirnagar University campus - A semi-natural area of Bangladesh. *Bangladesh Journal of Plant Taxonomy* 28(1): 27–60. https://doi.org/10.3329/bjpt.v28i1.54207

Moore, H.E. Jr. (1960). *Tradescantia pexata* (Commelinaceae), a New Species. *Baileya* 8: 98–101.

Nandikar, M.D., M. Lekhak & R.V. Gurav (2010). Karyotype analysis of a new cytotype of *Callisia fragrans* (Lindl.) Woodson (Commelinaceae). *Nucleus* 53(3): 95–97. https://doi.org/10.1007/s13237-011-0019-z

Rahman, M.A. (2017). Plant diversity in Hazarikhil Wildlife Sanctuary of Chittagong and its conservation management. *Journal of Biodiversity Conservation & Bioresources Management* 3(2): 43–56.

Rahman, M.R., M.K. Hossain, M.A. Hossain & M.S. Haque (2017). Floristic composition of Madhupur National Park (MNP), Tangail, Bangladesh. *Bangladesh Agriculture* 7(10): 27–45.

Rahman, M.S., G.M. Hossain, S.A. Khan & S.N. Uddin (2015). An annotated checklist of the vascular plants of Sundarban Mangrove

Forest of Bangladesh. *Bangladesh Journal of Plant Taxonomy* 22(1): 17–41. https://doi.org/10.3329/bjpt.v22i1.23862

Rao, R.S., G. Panigrahi & R.V. Kammathy (1960). Cytotaxonomic studies on Indian Commelinaceae. *Proceedings of Indian Science Congress 1960*, 366 pp. (Abst.).

Sarwar, A.K.M. Golam (2019). Plant Biodiversity and Conservation of Higher Plants in Bangladesh: Present Status and Future Prospects, pp. 259–288. In: Sangeetha, J., D. Thangadurai, H.C. Goh & S. Islam (eds.). *Biodiversity and Conservation: Characterization and Utilization of Plants, Microbes and Natural Resources for Sustainable Development and Ecosystem Management*. AAP/CRC, Florida, USA.

Tan, J.B.L., W.J. Yap, S.Y. Tan, Y.Y. Lim & S.M. Lee (2014). Antioxidant content, antioxidant activity, and antibacterial activity of five plants from the Commelinaceae family. *Antioxidants* 3: 758–769. https://doi.org/10.3390/antiox3040758

Uddin, M.Z., A. Shomrat, M.S. Hasan, M.R. Khan, A.R. Fahad & M. Al-Amin (2021). Evaluation of plant species diversity in the road dividers of Dhaka city. *Bangladesh Journal of Plant Taxonomy* 28(1): 141–154**.** https://doi.org/10.3329/bjpt.v28i1.54214

Yarmolinsky, L., M. Zaccai, S. Ben-Shabat & M. Huleihel (2010). Anti-Herpetic activity of *Callissia fragrans* and *Simmondsia chinensis* leaf extracts in vitro. *The Open Virology Journal* 4(1): 57–62. https://doi.org/10.2174/1874357901004010057

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20792–20797

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

https://doi.org/10.11609/jott.6536.14.3.20792-20797

#6536 | Received 07 August 2020 | Final received 18 November 2021 | Finally accepted 14 March 2022

OPEN ACCESS

SHORT COMMUNICATION

A new distribution record of *Memecylon clarkeanum* Cogn. (Melastomataceae) to Karnataka from Sharavathi river basin, central Western Ghats, India

Malve Sathisha Savinaya [1], Jogattappa Narayana [2], Venkatarangaiah Krishna [3] & Kalamanji Govindaiah Girish [4]

[1,2] Department of P.G. Studies & Research in Environmental Science, [3] Department of P.G. Studies & Research in Biotechnology, Jnana Sahyadri, Kuvempu University, Shankarghatta, Shivamogga, Karnataka 577451, India.
[1,4] Panchavati Research Academy for Nature, Kalamanji, Sagar, Shivamogga, Karnataka 577421, India.
[4] Indira Gandhi Government First Grade College for Women, Sagar, Shivamogga, Karnataka 577401, India.
[1] savimalve@gmail.com (corresponding author), [2] janaes@rediffmail.com, [3] krishnabiotech2003@gmail.com, [4] girishjanney@gmail.com

Abstract: *Memecylon clarkeanum* Cogn., a vulnerable species, is reported as a new record for Karnataka from primeval sacred forest, Rameshwara Devarakadu of Hulkodu village in the region of Sharavathi river basin, Sagar taluk, Shivamogga district, central Western Ghats. The present discovery highlights the importance of sacred groves in conserving rare, endangered and endemic flora. Prior to this, the species was reported as a new record for India from Kerala in 2012. The present paper illustrates the range extension of the species further towards northern latitudes up to central Western Ghats, Karnataka. The study assessed distributional range, habitat, ecology, status of threat, and vulnerability for planning conservation measures.

Keywords: Conservation, endemic flora, Karnataka, new report, range extension.

Memecylon L., is one of the largest genera in the family Melastomataceae. In 1753, Linnaeus introduced the genus *Memecylon* with a description of *Memecylon capitellatum* from Sri Lanka (Linnaeus, 1753). The genus, today comprising ca. 352 accepted species distributed in Old World tropics ("Memecylon L. | Plants of the World Online | Kew Science," 2018). The members of *Memecylon* are small trees or shrubs and found in habitats ranging from tropical wet evergreen to semi-evergreen forests and most of them are understory species (Bremer 1981; Das 2017; Melastomataceae.Net, 2020). Clarke (1879) reported 40 species and 27 varieties of *Memecylon* for the flora of British India, whereas, Cooke (1901) recorded five species from the Bombay presidency and Gamble (1919) reported 18 species from

Editor: A.G. Pandurangan, Jawaharlal Nehru Tropical Botanic Garden And Research Institute, Palode, India. **Date of publication:** 26 March 2022 (online & print)

Citation: Savinaya, S.M., J. Narayana, V. Krishna & K.G. Girish (2022). A new distribution record of *Memecylon clarkeanum* Cogn. (Melastomataceae) to Karnataka from Sharavathi river basin, central Western Ghats, India. *Journal of Threatened Taxa* 14(3): 20792–20797. https://doi.org/10.11609/jott.6536.14.3.20792-20797

Funding: Department of Biotechnology, New Delhi under Boost to University Interdisciplinary Life Science Departments for Education and Research Programme (DBT-BUILDER) project entitled "Bio-prospecting of medicinal plants of Western Ghats, Karnataka".

Competing interests: The authors declare no competing interests.

Acknowledgements: This research was financially supported by the Department of Biotechnology, Government of India through DBT-BUILDER Project (Order No. BT/PR9128/INF/22/190/2013, Dated: 30/06/2015). We hereby extend our thankfulness to DBT, New Delhi. We thank Kuvempu University for offering facility to carry out research. We would also like to show our gratitude to Panchavati Research Academy for Nature (PRANA), an organisation which extended their assistance of helping hands in the field studies.

the presidency of Madras (Clarke 1879; Cooke 1901; Gamble 1919). The digital Flora of Karnataka included 11 species of *Memecylon* from the state (Herbarium JCB 2020).The recent study on this genus for India have delimited 53 species of which 26 are endemics to the region (Das 2017).

In 2018, while documenting angiosperm diversity of Rameshwara Devarakadu, a sacred (Kaanu) forest at Hulkodu village, Sagara taluk, Shivamogga district in the region of Sharavathi river basin, central Western Ghats, the authors have collected a specimen of a *Memecylon* species. The specimen was critically examined by referring relevant literature and digital images of type specimen (Thwaites C.P2468), it was identified as *Memecylon clarkeanum* Cogn. (Saldanha & Ramesh 1984; Ramaswami et al. 2001; Bhat 2003; "HerbWeb", 2020). The species was earlier thought to be an endemic to Sri Lanka until it was reported as a new record for India from the evergreen forests of Wayanad, Malappuram and Kozhikode districts of Kerala by Sivu et al. (2012). Later, Udayavani & Ramachandran (2013) reported the occurrence of *M. clarkeanum* from Nilgiris, Tamil Nadu. The present collection of this species from a sacred grove (14.134N and 74.959E, altitude of 640 m) in Sharavathi river basin constitutes the first authentic record from Karnataka and therefore reported here as an addition to the flora of Karnataka with full bibliographic citations, morphological description, ecology, association, phenology, distribution, and specimens examined with colour photographs of plant to facilitate further collection, correct identification and conservation. The specimen (KUBPHS150) is deposited in Biodiversity Laboratory of BUILDER Project, Bio Sciences Complex, Kuvempu University, Shankarghatta, Shivamogga, Karnataka. The species has been globally assessed its threat status and treated it under 'Vulnerable' category (World Conservation Monitoring Centre 1998).

Image 1. *Memecylon clarkeanum* Cogn.: A—Habit | B–Phyllotaxy and dorsal view of leaves | C—Immature/Unripe fruit with hypantho-calyx rind | D—Fruit insertion (Fruit bud) | E—Acuminate leaf apex | F—Cuneate leaf base | G—Stout petiole (Channelled upper side) | H—Fruiting twig | I—Pale lower leaf surface and shape of lamina | J—Shiny upper leaf surface. © Savinaya M.S.

Image 2. Leaf phenological stages of *Memecylon clarkeanum* Cogn.: A—Leaf insertion | B—Leaf bud (Purple colour leaf bud) | C—Immature leaf (Turning green) | D—Expanding leaf | E—Matured leaf | F—View of matured leaves in the terminal position of branch | G—Dry leaf. © Savinaya M.S.

Taxonomic Treatment

***Memecylon clarkeanum* Cogn.**

in DC. Mon. Phan. 7: 1141. 1891; Trimen, Handb. Fl. Ceylon 2: 217. 1894; Bremer, Opera. Bot. 50: 24.1979; Dassanayake & Fosberg, Rev, Handb. Fl. Ceylon 6: 213. f. 3B.1987. M. Heyneanum Benth. in Wall. ex Wight & Arn. var. latifolia Clarke in Hook.f., Fl. Brit. Ind. 2: 560. 1879. Sivu et al., Taiwania 57(3): 327–330. 2012. Das, Taxonomic Account of Memecylaceae (Ph.D. Thesis), University of Calcutta. 2017. Type: Sri Lanka: Thwaites C.P. *2468.*

Shrubs, 2–2.5m high. Stems up to 4 cm in girth; branchlets subterete; internodes 4–5 cm long; bark shallowly fissured, greyish-brown. Leaves widely elliptic to lanceolate, 15–20 × 3–6 cm, apex acuminate, base cuneate, margins entire, pale beneath, glaucous above, coriaceous; midrib raised below, with fairly prominent intramarginal veins and secondary veins, foliar sclereids filiform; petioles 7–10 mm long, channelled on upper side. Inflorescence a fascicle, 2 or 3-flowered, strictly on leafless nodes, sessile; pedicels absent or shorter than receptacle. Bracts ovate-lanceolate, ca. 1.5 mm long, visible to naked eyes. Flower buds acute in shape; flowers 4–6 mm across, pale blue. Hypantho-calyx campanulate, ca. 2.5 mm across, truncate; disk rays prominent, raised, yellowish or white. Petals 4, broadly ovate, ca. 4 × 4.5 mm, pale blue, acute at apex. Stamens 8, equal; filaments folded in buds, slender, ca. 5mm long, whitish-blue; anthers ca. 2 mm long, horse-shoe–shaped, curved; connectives with a central brown gland. Ovary unilocular with 10–12 ovules; free-central placentation; style subulate, filiform, ca. 5 mm long, pale bluish-white; stigma pointed. Fruits globose, 8–10mm with persistent calyx rind, yellow, bluish-black at maturity, 1-seeded.

Distribution

Global distribution: Sri Lanka and India.

India: Kerala (Kozhikode, Malappuram, and Wayanad

Image 3. *Memecylon clarkeanum* Cogn.: A—Fruiting branch | B—Inflorescence | C—Immature fruit | D—Leafless node | E—Shallowly fissured bark | F—Herbarium sheet. © Savinaya M.S.

Image 4. Distribution map of *Memecylon clarkeanum* Cogn. in India. A—Previous distribution map | B—Present distribution map. Map source—Google Earth.

districts), Tamil Nadu (Nilgiri district), Karnataka (Shivamogga district).

Habitat ecology

Memecylon clarkeanum Cogn. is recorded at an altitude range of 640 m in Rameshwara sacred grove in a semi-evergreen forest in the Sharavathi river basin, Shivamogga district, Karnataka. The area receives an annual rainfall of 2,800–3,200 mm and the average temperature ranges 23–25 °C. The particular habitat is a slope of an undulated mountain terrain covered with thick canopy of gigantic trees.

Image 5. A—View of Rameshwara temple | B—Stand view of sacred forest (Rameshwara devarakadu, Hulkodu, Sagar, Shivamogga, Karnataka). © Savinaya M.S.

Associated species

The associated plant species commonly found in the habitat are *Aporosa lindleyana* (Wight) Baill., *Artocarpus hirsutus* Lam., *Canarium strictum* Roxb., *Chukrasia tabularis* A.Juss., *Diospyros buxifolia* (Blume) Hiern, *Holigarna grahamii* (Wight) Kurz, *Hopea ponga* (Dennst.) Mabb., *Ixora brachiata* Roxb., *Ixora nigricans* R. Br. ex Wight & Arn., *Knema attenuata* (Hook.f. & Thomson) Warburg, *Olea dioica* Roxb., *Psychotria flavida* Talbot, and *Syzygium laetum* (Ham.) Gandhi.

Phenology: Flowering starts in the month of September and continues till November. Fruits can be seen throughout the month of December and January.

Conservation status: *Memecylon clarkeanum* Cogn. is listed as 'Vulnerable' based on the threat factor (A1c) (World Conservation Monitoring Centre 1998).

Notes

The present record confirmed the range extension of the species from south to north and distributed up to central Western Ghats in Karnataka which deserves phytogeographical significance. Further its occurrence in sacred groves is a testimony that signifies the importance of age old practice of conserving representatives of past vegetation in the name of sacred forests which have immense biodiversity values for humanity.

The Rameshwara Devarakadu is a community forest of Hulkodu village where indigenous communities make use of forest green leaves for various agricultural purposes. Though, a season based green leaves collection by pruning tree branches was followed, the understory shrubs often get affected due to falling of woody branches during the course of collection knowingly or unknowingly. The authors identified only two individuals, of which only one plant is in reproductive stage. Since they occur near areca plantations, there is severe threat of anthropogenic pressure. Therefore, strict conservation of sacred groves should be followed under the guidance of the state forest department and regular monitoring must be done with the support of the local indigenous communities.

Specimen examined: KUBPHS150, 01.iv.2018, India, Karnataka, Shivamogga district, Sagar taluk, Hulkodu village, Rameshwara devarakadu (Sacred grove), Sharavathi river basin, central Western Ghats, Savinaya M.S.

References

Bremer, K. (1979). Taxonomy of *Memecylon* (Melastomataceae) in Ceylon. *Opera Botanica* 50: 1–32.

Bremer, K. (1981). "Seeds and embryos in Sri Lanka (Ceylonese) species of Memecylon, with notes on Spathandra (Melastomataceae)". *Nordic Journal of Botany* 1(1): 62–65. https://doi.org/10.1111/j.1756-1051.1981.tb01036

Clarke, C.B. (1879). Melastomaceae, pp. 512–565. In: Hooker, J.D. (ed.), *The Flora of British India*, Vol. 2. L. Reeve and Co., London.

Cooke, T. (1901). *The Flora of the Presidency of Bombay* - Volume I. Taylor & Francis, London.

Das, M. (2017). Taxonomic revision of the family memecylaceae dc. in India, Department of Botany, Calcutta University (unpublished).

Dassanayake, M.D. & F.R. Fosberrg (1987). *Memecylon* clarkeanum Cogn. In: *A Revised Handbook to the Flora of Ceylon.* Vol. VI. Oxford & IBH Publishing C. Pvt. Ltd., New Delhi.

Gamble, J.S. (1994). *Memecylon*, pp. 500–505. In: *Flora of the presidency of Madras*. London, part. 111.

Gopalakrishna, K.B. (2003). *Memecylon*. In: *Flora of Udupi.* Manipal Press Limited, Manipal, 219 pp.

Herbarium JCB (2012). Retrieved 23 March 2020 from http://flora-peninsula-indica.ces.iisc.ac.in/herbsheet.php?id=5727&cat=7

Herbarium JCB (2020). Retrieved 23 March 2020 from http://florakarnataka.ces.iisc.ac.in/hjcb2/search.php

HerbWeb (2020). Retrieved 17 October 2020, from http://apps.kew.org/herbcat/detailsQuery.do?barcode=K000357752

Linnaeus, C. (1753). *Species Plantarum*. Laurentius Salvius, Stockholm, 1,200 pp.

Melastomataceae.Net (2020). Retrieved 16 October 2020 from http://

www.melastomataceae.net/

Memecylon, L. (2018). Retrieved 17 October 2020 from Plants of the World Online http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:26452-1

Ramaswami, S.N., R.M. Radhakrishna & D.A. Govindappa (2001). *Memecylon,* pp. 239–240. In: *Flora of Shimoga District, Karnataka.* Prasaranga.

Saldanha, C.J. & S.R. Ramesh (1984). *Memecylon* In: *Flora of Karnataka.* Oxford & IBH, New Delhi.

Sivu, A.R., M.K.R. Narayanan, E.S.S. Kumar, K.A. Sujana, N.S. Pradeep, N.A. Kumar & A.G. Pandurangan (2012). *Memecylon clarkeanum* Cogn. (Melastomataceae) - a threatened species, new record for India. *Taiwania* 57(3): 327–330. https://doi.org/10.6165/tai.2012.57(3).327

Trimen, H. (1894). *A Handbook to the flora of Ceylon,* Part-II. London.

Udhayavani, C. & V.S. Ramachandran (2013). On the occurrence of *Memecylon clarkeanum* Cogn. (Melastomataceae) - a vulnerable species from Nilgiris, Tamil Nadu, India. *Journal of Threatened Taxa* 5(3): 4811–4814. https://doi.org/10.11609/JoTT.o3638.4811-3

World Conservation Monitoring Centre (1998). *Memecylon clarkeanum*. The IUCN Red List of Threatened Species 1998: e.T33517A9789376. Accessed on 19 March 2022. https://doi.org/10.2305/IUCN.UK.1998.RLTS.T33517A9789376.en

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20798–20800

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

https://doi.org/10.11609/jott.7802.14.3.20798-20800

#7802 | Received 24 December 2021 | Final received 07 March 2022 | Finally accepted 14 March 2022

OPEN ACCESS

NOTE

First record of Doherty's Dull Oakblue *Arhopala khamti* Doherty, 1891 from upper Assam, India

Arun Pratap Singh

Entomology Branch, Forest Protection Division, Forest Research Institute, Dehradun, Uttarakhand 248006, India.
ranoteaps@gmail.com

Doherty's Dull Oakblue *Arhopala khamti* Doherty, 1891 is distributed from Sikkim through Assam, Myanmar, Thailand, Laos, Vietnam, and Hainan (China) and is considered a 'rare species' (Evans 1932; Inayoshi 1996–2022). It is identified and differentiated from its congener Hewitson's Dull Oakblue *A. oenea* (Hewitson, [1869]) in having black tornal lobe with prominent green scales on under hindwing, absent in the latter (Evans 1957) (Image 1a&b). Additionally, *A. khamti* is dark blue purple with a 0.5 mm border from upper side, while *A. oenea* being violet blue with 1.5 mm border (Image 1c). Otherwise, both the species superficially look alike and have an overlapping distribution range in northeastern India, and sometimes considered ecological subspecies, being seen together in northeastern India (Evans 1957; Inayoshi 1996–2022). However, *A. oenea* also occurs further west in the Himalaya up to Uttarakhand through Nepal (Evans 1932; Wynter-Blyth 1957; Smith 2006; Gasse 2013; Kehimkar 2016) and is protected under Schedule II, Wildlife Protection Act 1972 (Anonymous 2006). Specimens of *A. khamti* have been collected from Sikkim and Assam (India) and Chittagong (Bangladesh) (Gasse 2013). There are recent records of *A. khamti* from Pakke Tiger Reserve (13 October 2013 & 28 September 2018) and Namdapha National Park (04 March 2014) in Arunachal Pradesh (Anonymous 2021). Besides, it has also been reported from Barail Wildlife Sanctuary in Cachar hills in southern Assam (Gogoi et al. 2016).

During random sampling surveys carried out on 01 October 2021 in Shibari (26.7926N & 94.6737E; ~180m; Image 2), near Nazira, Shivasagar district, Assam, India the author recorded at least six individuals of the species. The habitat was the middle and understory of semi-evergreen forest in remnant forest patches in between tea gardens and paddy fields along the homesteads of upper Assam. The habitat was shared with Centuar Oakblue, *Arhopala centaurus pirithous* (Moore, [1884]) which was quite common in the area. This the first authentic record of this species from upper Assam as there are no previous records from this area in published literature or museum specimens (Doherty 1889; Bettes 1950; Gogoi 2013, 2015; Singh et al. 2015; Neog 2015; Bourah & Das 2017; Konwar & Bortamuly 2021). The location of the current record bridges the gap along the Patkai hills in its distribution range, as the present record lies in between Cachar hills in southern Assam and Namdapha in Arunachal Pradesh. The affinity of this species with the Indo-Burma hotspot highlights the importance of these remnant forest patches of upper Assam which still harbor these rare species of

Editor: Monsoon J. Gogoi, Bombay Natural History Society, Mumbai, India. **Date of publication:** 26 March 2022 (online & print)

Citation: Singh, A.P. (2022). First record of Doherty's Dull Oakblue *Arhopala khamti* Doherty, 1891 from upper Assam, India. *Journal of Threatened Taxa* 14(3): 20798–20800. https://doi.org/10.11609/jott.7802.14.3.20798-20800

Funding: Indian Council of Forestry Research & Education.

Competing interests: The author declares no competing interests.

Image 1. Comparison of *Arhopala khamti* Doherty, 1891 with *Aehopala oenea* (Hewitson, [1869]).
a—*Arhopala khamti* Doherty, 1891 (01.x.2021, Shibari, Shivsagar district, Assam, India) | b & c—*Arhopala oenea* (Hewitson, [1869]) female from Khasi Hills, Meghalaya, India (20106-NFIC, Forest Research Institute, Dehradun, India).

conservation priority.

References

Anonymous (2006). *The Wildlife (Protection) Act 1972*. Natraj Publishers, Dehradun, 235 pp.

Anonymous (2021). *Arhopala khamti* Doherty, 1891 - Luster Oakblue. Kunte, K., S. Sondhi, & P. Roy (Chief Editors). *Butterflies of India, v. 3.24*. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/2763/Arhopala-khamti

Bettes, F.N. (1950). On the collection of Butterfies from the Balipara Frontier Tract and the Subansiri Area (North Assam). *Journal of the Bombay Natural History Society* 49: 487–501.

Boruah, A. & G.N. Das (2017). Butterflies (Lepidoptera) of Dangori Reserve Forest, Upper Assam, India. *BugsRAllNews letter of the ICINSA* 32(11): 12–23.

Doherty, W. (1889). Notes on Assam Butterflies. *Journal of the Asiatic Society of Bengal* 58: 118–134.

Evans, W.H. (1932). *The Identification of Indian Butterflies - 2nd Edition*. Bombay Natural History Society, Mumbai, 454 pp.

Evans, W.H. (1957). A revision of the Arhopala group of oriental Lycaenidae (Lepidoptera: Rhopalocera). *Bulletin of British Museum (Natural History) Entomology* 5(1): 85–141.

Inayoshi, Y. (1996–2022). *A Check list of Butterflies in Indo-China, chiefly from Thailand, Laos & Vietnam.* http://yutaka.it-n.jp/lyc4f/81870001.html

Konwar, A. & M. Bortamuly (2021). Observations on butterflies of non-protected areas of Titabar, Assam, India. *Journal of Threatened Taxa* 13(5): 18364–18377. https://doi.org/10.11609/jott.4126.13.5.18364-18377

Gogoi, M.J. (2013). A preliminary checklist of butterflies recorded from Jeypore-Dehing forest, eastern Assam, India. *Journal of Threatened Taxa* 5(2): 3684–3696. https://doi.org/JoTT.o3022.3684-96

Gogoi, M.J. (2015). Observations on lycaenid butterflies from Panbari Reserve Forest and adjoining areas, Kaziranga, Assam, northeastern India. *Journal of Threatened Taxa* 7(15): 8259–8271. https://doi.org/10.11609/jott.2467.7.15.8259-8171

Neog, S. (2015). *Butterflies of Gibbon Wildlife Sanctuary*. Bhabani Books, Guwahati, 112 pp.

Singh, A.P., L. Gogoi & J. Sebastain (2015). The seasonality of butterflies in a semi-evergreen forest: Gibbon Wildlife Sanctuary, Assam, northeastern India. *Journal of Threatened Taxa* 7(1): 6774–6787. https://doi.org/10.11609/JoTT.o3742.6774-87

Singh, A.P. (2017). Butterflies of eastern Assam, India. *Journal of Threatened Taxa* 9(7): 10396–10420. https://doi.org/10.11609/jott.3177.9.7.10396-10420

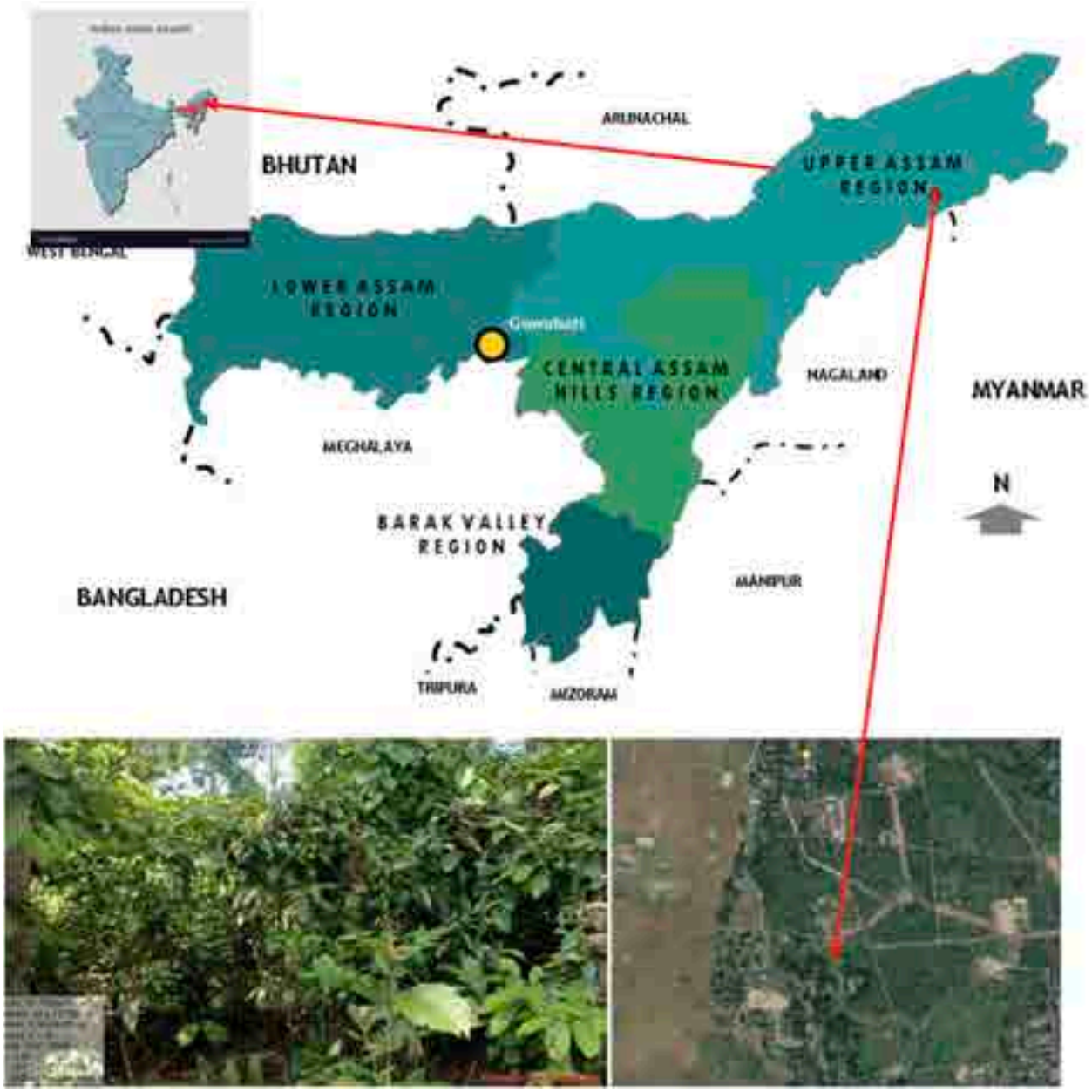


Image 2. Location of Shibari (near Nazira), Shivasagar district, Assam, India from where *Arhopala khamti* Doherty, 1891 was recorded on 01 October 2021.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20801–20804

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

https://doi.org/10.11609/jott.7700.14.3.20801-20804

#7700 | Received 12 October 2021 | Finally accepted 03 March 2022

OPEN ACCESS

NOTE

A new species of *Pancratium* Dill. ex L. (Amaryllidaceae) from Eastern Ghats of India

R. Prameela [1], J. Prakasa Rao [2], S.B. Padal [3] & M. Sankara Rao [4]

[1] Department of Botany, M.R. College for Women, Vizianagaram, Andhra Pradesh 535002, India.
[2,3] Department of Botany, Andhra University, Visakhapatnam, Andhra Pradesh 530003, India.
[4] Botanical Survey of India, Deccan Regional Centre, Hyderabad, Telangana 500095, India.
[1] prameelachris@yahoo.com (corresponding author), [2] jprakasarao@gmail.com, [3] sbpadal08@gmail.com, [4] mudadlas@gmail.com

The family Amaryllidaceae has large beautiful flowers and is widely distributed in tropical to sub-tropical regions. The genus *Pancratium* belongs to Amaryllidaceae and the word Pancratium was derived from Greek, which means "all strength" alluding to the medicinal properties of the bulbs of these plants. It was first described by Linnaeus (1753) and it is represented by 21 species from the World (WFO 2021). While India has 11 species—*P. bhramarambae* Sadas., *P. biflorum* Roxb., *P. donaldii* Blatt., *P. longiflorum* Roxb. ex Ker Gawl., *P. nairii* Sasikala & Reema Kumari., *P. parvum* Dalzell., *P. st-mariae* Blatt. & Hallb., *P. telanganense* Sadas., *P. triflorum* Roxb., *P. verecundum* Aiton, and *P. zeylanicum* L. (Sadasivaiah & Karuppasamy 2018). Only two species, *P. longiflorum* and *P. triflorum*, are reported from Eastern Ghats of Andhra Pradesh (Pullaiah 2018).

The genus *Pancratium* having unique characteristics like perennial herbaceous bulbous, linear lanceolate leaves, umbellate Inflorescence, large flowers with funnel shaped perianth, six stamens attached on the throat of the perianth with filiform filaments united below by a coronal membrane into a toothed or lobed cup, oblong or linear dorsifixed anthers, tricarpellary, syncarpous and trilocular, inferior ovary with 2-seriatein numerous ovules and filiform style.

During our botanical explorations in the Eastern Ghats of Andhra Pradesh, first author was collected an interesting species of *Pancratium* from hills of Vizianagaram District (Figure 1). It is resembles *P. st-mariae*. After critical taxonomic assessment it was identified as a new species and herbarium specimen was deposited in Herbarium, Department of Botany, Andhra University (Image 2). Some of the bulbs were introduced into the College Campus Garden. A detailed description, comparison table (Table 1), and photographs were provided in this article (Image 1).

***Pancratium venkaiahii* R.Prameela, J.Prak.Rao, S.B.Padal & M.Sankara Rao sp. nov. (Image 1,2)**

Holotype: AUV 23367, 30.xi.2020, India, Andhra Pradesh, Vizianagaram District, Ginjeru Village, Elevation 75 m, 18.170N, 83.265E, coll. R. Prameela (Image 2)

Diagnosis: Globose bulbs having 5 cm neck; up to 25 cm long leaves; 2-flowered scape having up to 5 cm

Editor: Anonymity requested.

Date of publication: 26 March 2022 (online & print)

Citation: Prameela, R., J.P. Rao, S.B. Padal & M.S. Rao (2022). A new species of *Pancratium* Dill. ex L. (Amaryllidaceae) from Eastern Ghats of India. *Journal of Threatened Taxa* 14(3): 20801–20804. https://doi.org/10.11609/jott.7700.14.3.20801-20804

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

भारतीय वनस्पति सर्वेक्षण
BOTANICAL SURVEY OF INDIA

Acknowledgements: Authors are thankful to the local people and forest department for their help in the studies. Authors are thankful the Director, Botanical Survey of India and Head, Department of Botany, Andhra University for providing facilities. The Authors are especially thankful to E. Ramanjaneyulu for his great support for the plant collection.

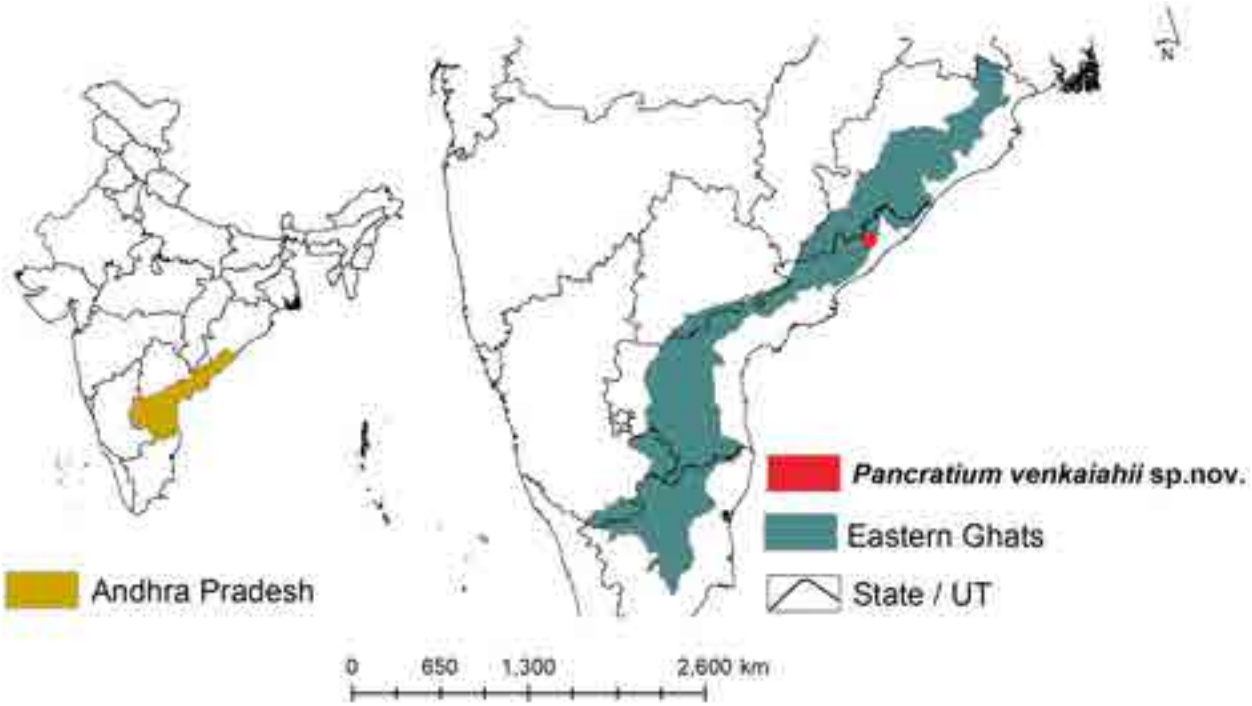


Figure 1. Location map of *Pancratium venkaiahii* sp. nov.

membranous spathe, apex acuminate; flowers without fragrance, with very short perianth tube (1.3cm long), perianth lobes long, filament, greenish white anthers pollen oval shape and long style.

Description: A small perennial bulbous herbs grows up to 30–32 cm height; bulbs globose, 3.2 x 4.1 cm, tunica membranous, dark brown, white when remove the tunica, neck 5–5.5 x 0.4 cm, dark brown; leaves 5–6, radical, narrowly elliptic, semi succulent, 24–25 x 2–2.4 cm, dorsiventral, adaxis dark green, abaxis light green, glabrous, acute; scape 2-flowered, 9 x 0.3 cm, compressed and veined, succulent, green; flowers white, not fragrant, 5.1 x 6.5 cm, bloom at morning; spathe 5 cm long, acute, membranous covered the pedicel and ovary, opening at one side, 2-veined, veins green; pedicel 0.5 cm long, green; perianth tube 1–1.2 cm long, light green, slightly grooved; perianth lobes glabrous, recurved 4–4.5 x 0.25 cm, linear, entire, mucronate white; stamens 6, filaments white, slightly curved at base, shorter than the perianth lobes, 2.2 cm, anthers 0.2 cm long, pale green or tea green, longitudinal dehiscence, versatile, opposite to the filament, pollen oval shape; staminal corona white, 1.1 x 2.2 cm, 12-toothed, tooth 0.2 cm, tip attenuate, glabrous, the two teeth where the filaments arise are close, whereas between the filaments teeth are distant; ovary 3-celled, green, 0.8–1 x 0.4–0.5 cm, glabrous, numerous ovules on axile placentation, style longer than the filaments, slender, 6.5 cm, stigma simple. Fruits and seeds not found.

Table 1. Comparison table of *P. venkaiahii* sp. nov. with *P. st-mariae*.

	Description	*P. venkaiahii* sp.nov.	*P. st-mariae*
1.	Bulb	Globose, 3.2 x 4.1 cm, tunica dark brown membranous	Globose, 3.5–6 cm, tunica pale brown, many veined
2	Neck	5–5.5 cm	10 cm
3	Leaves	5–6, narrowly elliptic, acute, 24–25 x 2–2.4 cm	2–5, lanceolate, obtuse, 10–15 x 1–1.5 cm
4	Scape	8–9 cm, long, 2-flowered	10–15 cm long, 2–5 flowered
5	Spathe	5 cm	2 cm
6	Pedicel	0.5 cm	0.5 cm
7	Perianth tube	1.2 cm, light green	3 cm, green
8	Perianth lobes	Oblong or linear oblong, 4–4.5	Lanceolate, 2–2.5 x 0.2–0.3
9	Staminal cup	1.1 cm, teeth 0.2 cm	7–10 mm, teeth 2 mm
10	Anthers	Pale green or pea green	Yellow
11	Style	6.5 cm	3.5–4.5 cm

Flowering: November–December.

Etymology: The specific epithet of species was given in honour of Prof. Malleboena Venkaiah (Retired), Department of Botany, Andhra University for his great

Image 1. *Pancratium venkaiahii* sp. nov.: a—Habit | b—flower | c—close-up of flower showing perianth tube and staminal corona. © R. Prameela.

contribution in taxonomy and ethno botany.

Habitat and species association: Rarely found in the open canopy dry deciduous vegetation with an association of ground flora: *Andrographis paniculata* (Burm.f.) Nees, *Aristida adscensionis* L., *Cleome aspera* J.Koenig ex DC., *Cynodon dactylon* (L.) Pers., *Imperata cylindrica (L.)* Raeusch., *Ledebouria revoluta* (L.f.) Jessop, *Sacciolepis interrupta* (Willd.) Stapf; Shrubs: *Canthium coromandelicum* (Burm.f.) Alston, *Opuntia stricta* (Haw.) Haw., *Pavetta zeylanica* (Hook.f.) Gamble, *Senna auriculata* (L.) Roxb.; Climbers: *Cajanus scarabaeoides*(L.) Thouars, *Canavalia gladiata* (Jacq.) DC., *Cissus quadrangularis* L., *Paracalyx scariosus*(Roxb.) Ali, *Smilax zeylanica* L., *Tinospora cordifolia* (Willd.) Miers; Trees: *Ailanthus excelsa* Roxb., *Anogeissus acuminata* (Roxb. ex DC.) Wall. ex Guillem. & Perr., *Bombax ceiba* L., *Butea monosperma* (Lam.) Taub., *Gmelina asiatica* L., *Streblus asper* Lour., *Strychnos nux-vomica* L., and *Tamarindus indica* L.

Conservation status: Rare in the study area, quantification of the natural populations of this species is not known but this species is facing threats from grazing and anthropogenic activities. First author introduced this species into the College Campus Garden and observed that all individuals were acclimatized and flowered but there was no fruit set . It was observed that the leaves of this plant was fed by caterpillars in the campus and this species is host for some lily moths.

Ethnomedicine: Generally, bulbs are used as medicine for veterinary diseases and is called 'adavivulli'. Ethno medicinal information for human beings is still not known.

India has more than 50% native *Pancratium* species including current report, and detailed studies need to

Image 2. Herbarium specimen of *Pancratium venkaiahii* sp. nov. holotype (AUV 23367). © J. Prakasa Rao.

be conducted in the aspects of taxonomy, distribution, economic importance, and conservation status.

References

Linnaeus, C. (1753). *Pancratium* L. Species Plantarum, Vol. 1. Stockholm, 289–291.

Pullaiah, T. (2018). *Flora of Andhra Pradesh, India. Vol. 3*. Scientific Publisher, Jodhpur.

Sadasivaiah B, S. Karuppusamy (2018). Two new species of *Pancratium* (Amaryllidaceae) from India. *Species* 19: 132–139.

WFO (2021). *Pancratium* L. http://www.worldfloraonline.org/-taxon/wfo-4000027860. Accessed on 01 October 2021.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20805–20807
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.7591.14.3.20805-20807
#7591 | Received 27 July 2021 | Final received 10 January 2022 | Finally accepted 24 February 2022
OPEN ACCESS

NOTE

Tribulus ochroleucus (Maire) Ozenda & Quezel (Zygophyllaceae) - a new addition to the flora of India

K. Ravikumar [1], Umeshkumar Tiwari [2], Balachandran Natesan [3] & N. Arun Kumar [4]

[1,4] Centre for Conservation of Natural Resources, The University of Trans-disciplinary Health Sciences and Technology (TDU), Foundation for Revitalisation of Local Health Traditions (FRLHT), No. 74/2, Jarakabande Kaval, Attur Post, Yelahanka Via, Bengaluru, Karnataka 560064, India.
[2] Technical Section, Director office, Botanical Survey of India, DF block 5th floor, CGO Complex Salt Lake, Kolkata, West Bengal 700064, India.
[3] Ecology Department, French Institute of Pondicherry, 11, St Louis Street, White Town, Puducherry 605001, India.
[1] ravikumarfrlht@gmail.com (corresponding author), [2] tigerumesh11@gmail.com, [3] nbala_plant@yahoo.co.in, [4] narun@tdu.edu.in

The Foundation for Revitalisation of Local Health Tradition (FRLHT) is an NGO that is recognized as Centre of Excellence (CoE) for Medicinal plants and Traditional Knowledge used in Indian Systems of Medicine by the Ministry of Environment and Forest (MoEF), Government of India, New Delhi. As part of this project, National Herbarium of Medicinal Plants used in Indian System of Medicine (ISM) was established. To accomplish the mission of the national herbarium, in-house botanical team undertakes field survey in various bio-geographic zones of the country to collect medicinal plants and house them in FRLHT herbarium (FRLH). As part of this program, surveys were undertaken in Sirohi, Chittorgarh, Ajmer, Jaisalmer, Bikaner, and Pokhran Districts of Rajasthan to collect semi-arid region specific species. One *Tribulus* species collected during the survey was not matching to any of the State floras published by Sharma & Tiagi (1979), Singh (1983), Shetty & Pandey (1983), Bhandari (1990), Shetty & Singh (1987, 1991, 1993), Singh & Singh (2006), and Tiagi & Aery (2007). Later, after a thorough scrutiny with Ghafoor (1974), Maire (1933); Ahmad & Mohamed (2005), and referring the herbarium specimens of Dr. R.C.J.E. Maire in central Sahara, 1939 (catalogue no. MPU367347) it was identified and confirmed as *Tribulus ochroleucus* (Maire) Ozenda & Quezel. There are 42 collections of *Tribulus ochroleucus* (Maire) Ozenda & Quézel on GBIF , collected from Niger, Libya, Algeria, Iran, and Saudi Arabia from the year 1928 to 2006. Therefore, it forms a new record to India, collected for the first time from Rajasthan. Hence it is provided here with the correct name, description, specimens examined, phenology, distribution, notes, and ecology.

The voucher specimens are deposited at the Foundation for Revitalisation of Local Health Traditions Herbarium (FRLH), Bengaluru. As far as genus *Tribulus* is concerned, Thomas (2006) mentions that there are six species and one variety occurring in India whereas Singh & Singh (1997) reported five species and two varieties for India.

Editor: Mandar Nilkanth Datar, MACS-Agharkar Research Institute, Pune, India. **Date of publication:** 26 March 2022 (online & print)

Citation: Ravikumar, K., U. Tiwari, B. Natesan & N.A. Kumar (2022). *Tribulus ochroleucus* (Maire) Ozenda & Quezel (Zygophyllaceae) - a new addition to the flora of India. *Journal of Threatened Taxa* 14(3): 20805–20807. https://doi.org/10.11609/jott.7591.14.3.20805-20807

Funding: The Ministry of Environment, Forest and Climate Change (MoEFCC), New Delhi Centre for Excellence Scheme.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to Shri. Darshan Shankar, vice-chancellor of TDU-FRLHT for the facilities and late Shri. D.K. Ved, IFS (Retd.) for constant support and encouragements; Ministry of Environment & Forests and Climate Change, Government of India, New Delhi for the financial support under CoE project.

***Tribulus ochroleucus* (Maire) Ozenda & Quezel**

in Ozenda, Quézel. In: Trav. L'Inst. Recherehes Sahariennes 14: 74. 1956. (Zygophyllaceae).

Type: Sahara centralis, Mouydir Oued Arak, Maire 284.

Tribulus macropterus var. *ochroleucus* Maire in Ozenda, Quézel. Trav. L'Inst. Recherehes Sahariennes 14: 74. 1956.

T. ochroleucus var. *perplexans* (Maire) Ozenda & Quézel in Ozenda, Quézel. Trav. L'Inst. Recherehes Sahariennes 14: 75. 1956.

T. macropterus subsp. *serolei* Maire in Diagn. Pl. Orient. 1: 161 1843.

Herbs decumbent, semi-erect or erect. Stems many, terete, pilose, arising from the rootstock. Leaves 2.5–4 cm long, opposite, unequal, the larger one with seven pairs of leaflets, the smaller one with 5 pairs of leaflets. Leaflets 4–8 x 1.5–3 mm, sessile or subsessile, oblique, oblong-ovate, acute, densely villous beneath, sparingly pubescent or glabrous when mature on upper surface. Stipules 3–4 x 0.5–1 mm, ovate to linear, densely pilose. Buds ovoid, densely silky villous. Flowers axillary to solitary; pedicels 5–15 mm long, sparsely to densely villous. Sepals 5, ovate-lanceolate, subequal, 4–6 x 1–2 mm, acute, villous outside, pubescent inside. Petals 5, broadly obovate to ovate, truncate at apex, glabrous, yellow; stamens 8–10; filaments ca. 2.5 mm long; anthers ca. 1 mm long, ovate-oblong, yellow. Ovaries ca. 1 mm long. Styles sessile or subsessile, ca. 1 mm long, cylindrical; stigma pyramidal. Schizocarps breaking into 4–5 mericarps, 4–5 subequally lobed, up to 7 mm across, densely hispid, with many long white hairs and many scattered short white hairs, devoid of spines or wings, pyramidal-ovoid. (Image 1).

Specimen examined: 117458 (FRLH), 19/8/2014, Near Harchand Kidani on SH-65, Jaisalmer District, Rajasthan, 26.388 N, 71.803 E, alt. 236 m, coll. K. Ravikumar, N. Balachandran & Umeshkumar Tiwari.

Flowering: August; Fruiting: September–October.

Image 1. A—*Tribulus ochroleucus* (Maire) Ozenda & Quezel – Habitat | B—Habit | C—Flower | D–F—Different views of mericarps | G—Voucher specimen. © K. Ravikumar.

Global Distribution: Afghanistan, Algeria, Chad, Djibouti, Ethiopia, India (northwestern Rajasthan), Iran, Libya, Mali, Mauritania, Niger, northern Africa, Oman, Pakistan, Palestine, Sinai, Somalia, Sudan, and Yemen.

Ecological notes: This plant is found associated with herbs such as *Aristida hystricula* Edgew., *Bergia capensis* L., *Boerhavia erecta* L., *Cenchrus* sp. *Cistanche tubulosa* (Schenk) Wight ex Hook.f., *Cleome brachycarpa* Vahl ex DC., *Cleome pallida* Kotschy, *Cleome gynandra* L., *Cyperus arenarius* Retz., *Dactyloctenium scindicum* Boiss., *Digera muricata* (L.) Mart., *Dipcadi erythraeum* Webb & Berthel., *Enneapogon elegans* (Nees ex Steud.) Stapf, *Euploca rariflora* (Stocks) Diane & Hilger., *Fagonia schweinfurthii* (Hadidi) Hadidi, *Farsetia hamiltonii* Royle, *Glinus lotoides* L., *Heliotropium strigosum* var. *brevifolium* (Wall.) C.B.Clarke, *Indigofera linnaei* Ali, *Kohautia aspera* (B.Heyne ex Roth) Bremek., *Mollugo cerviana* (L.) Ser., *Phyllanthus* species, *Polygala abyssinica* R.Br. ex Fresen., *Portulaca oleracea* L., *Pulicaria crispa* (Forssk.) Oliv., *Solanum albicaule* Kotschy ex Dunal, *Tribulus alatus* Drège ex C.Presl, *Tribulus terrestris* L., and *Zygophyllum simplex* L.

Other associated trees and shrubs include *Calotropis procera* (Aiton) W.T. Aiton, *Capparis decidua* (Forssk.) Edgew., *Leptadenia pyrotechnica* (Forssk.) Decne., *Prosopis cineraria* (L.) Druce, *Salvadora oleoides* Decne. and *Ziziphus* sp.

Tribulus ochroleucus (Maire) Ozenda & Quezel is comparatively less common than *T. terrestris* L. It can be easily recognized in the field by its semi-erect habit and 4–5 subequally lobedschizocarps without any wings or spines. It can be found growing in grey brown desert soil that is mixed with red and yellow soil. *T. ochroleucus* (Maire) Ozenda & Quezel is closely allied to *T. mollis* Ehrenb. ex Schweinf. but differs in entire plant and the fruit does not have prominently silky hair.

References

Ghafoor, A. (1974) Flora of Pakistan No. 76. January. Zygophyllaceae, University Karachi; First Edition, 76: 1–35.

Maire, R. (1933). Mission du Hoggar II. *Études sur la Flore et la Végétation du Sahara central*. *Mémoires de la Société d'histoire naturelle de l'Afrique du nord* 3: 36 pl., 2 cartes: 272.

Ahmad, A. & A.H. Mohamed (2005). A Taxonomic Study of the Genus Tribulus L. in Egypt. *Arab Universities Journal of Agricultural Sciences* 13(2): 197–206.

Bhandari, M.M. (1990). *Flora of Indian Desert*. MPS. Repros, Jodhpur, 435 pp.

Shetty, B.V. & R.P. Pandey (1983). *Flora of Tonk District*. Botanical Survey of India, Calcutta, i+312 pp.

Shetty, B.V. & V. Singh (1987). *Flora of Rajasthan*. Botanical Survey of India, Calcutta, i+452 pp.

Shetty, B.V. & V. Singh (1991). *Flora of Rajasthan*. Botanical Survey of India, Calcutta, ii+453–860 pp.

Shetty, B.V. & V. Singh (1993). *Flora of Rajasthan*. Botanical Survey of India, Calcutta, iii+861–1246 pp.

Singh, V. (1983). *Flora of Banswara, Rajasthan*. Botanical Survey of India, Calcutta, 312 pp.

Singh, V. & M. Singh (2006). *Biodiversity of Desert National Park, Rajasthan*. Botanical Survey of India, Kolkata, 343 pp.

Tiagi, Y.D. & N.C. Aery (2007). *Flora of Rajasthan (South & South East Region)*. Himanshu Publications, New Delhi, 725 pp.

Sharma, S. & B. Tiagi (1979). *Flora of North-East Rajasthan*. Kalyani Publishers, New Delhi, 540 pp.

Singh, P. & V. Singh, Editors Hajra, P.K & V.J. Nair (1997). Zygophyllaceae. Flora of India Volume 4. Botanical Survey of India, Calcutta: 51–57.

Thomas, J. (2006). Taxonomic Status of Some of the *Tribulus* species in the Indian Subcontinent. *Saudi Journal of Biological Sciences* 13(1): 7–12.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20808–20810

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

https://doi.org/10.11609/jott.7615.14.3.20808-20810

#7615 | Received 11 August 2021 | Final received 06 February 2022 | Finally accepted 01 March 2022

OPEN ACCESS

NOTE

Abnormalities in the female spikelets of *Coix lacryma-jobi* L. (Poaceae) India

Nilesh Appaso Madhav [1] & **Kumar Vinod Chhotupuri Gosavi** [2]

[1,2] Department of Botany, HPT Arts & RYK Science College, Nashik, Maharashtra 422003, India.
[1] nileshmadhav@gmail.com, [2] kumarvinodgosavi@gmail.com (corresponding author)

Coix lacryma-jobi L. consists of three varieties, *Coix lacryma-jobi* var. *stenocarpa* Oliv., *Coix lacryma-jobi* var. *ma-yuen* (Rom. Caill.) Stapf, and *Coix lacryma-jobi* var. *puellarum* (Balansa) E.G. Camus & A. Camus. *C. lacryma-jobi* var. *stenocarpa* can be easily distinguished by very much longer than broad and having cylindrical or roughly bottle shaped utricle and this variety distributed in South East Asia (Bor 1960). *Coix lacryma-jobi* var. *ma-yuen* can be distinguished by having soft utricle than other taxa of *Coix* and cultivated in China, Myanmar, and northeastern India for its medicinal and food value (Arora 1977; Li 2006; Xi et al. 2016). *Coix lacryma-jobi* var. *puellarum* can be distinguished by its perennial habit and white to bluish globose utricle (ca. 4 mm in diam.), distributed in Myanmar, Malaysia, and Indo-China (Bor 1960). *Coix lacryma-jobi* is widely distributed throughout pantropic in different habitat like seasonal streams, stagnant water, along seashore, saline water, muddy region, slopes of hills; thus, the species shows a range of morphological variations. During taxonomical study of the genus *Coix,* authors collected *C. lacryma-jobi* var. *lacryma-jobi* from different habitat in different regions of the Western Ghats and the western coast, India (Figure 1). Some populations show same type of abnormalities but these are rare.

Usually, all the taxa of *Coix* shows single basal sessile pistillate flower, however, rarely two to three pistillate flowers are reported in *C. lacryma-jobi* var. *lacryma-jobi* for the first time in present communication. In three pistillate flowers, top most flower becomes rudimentary. These abnormalities located from hilly slopes of Harishchandra gad, cultivated fields of Rajur, Aluva, and Kalmanja from state of Maharashtra, Kerala, and Karnataka, respectively (Table 1, Figure 1, Image 1). That means the genus shows more advance nature as reducing pistillate flowers and showing affinities towards related genera like *Polytoca* R.Br., *Tripsacum* L., and *Trilobachne* M. Schenck ex Henrard as these genera consists of more than one pistillate flowers. Another interesting rare abnormality is appearances of leaf blade on utricle with range of variation in length. During our investigations populations bearing extended leaf blades of utricles from 0.5 mm to 10 cm these populations were in different habitats like on hilly forest slopes of Harishchandra gad, cultivated marshy water-logged soil of Rajur, and estuary of Arabian sea of Devgad (Table 1, Figure 1, Image 1). Such abnormality is relict of leaf sheath, which is modified as protective covering around the seed and shows affinities with *C. gasteenii* B.K.Simon.

Editor: Mandar Nilkanth Datar, MACS-Agharkar Research Institute, Pune, India. **Date of publication:** 26 March 2022 (online & print)

Citation: Madhav, N.A. & K.V.C. Gosavi (2022). Abnormalities in the female spikelets of *Coix lacryma-jobi* L. (Poaceae) India. *Journal of Threatened Taxa* 14(3): 20808–20810. https://doi.org/10.11609/jott.7615.14.3.20808-20810

Funding: Core Research grant scheme of Science and Engineering research Board (SERB), File no. CRG/2018/001381.

Competing interests: The authors declare no competing interests.

Acknowledgements: Authors are thankful to SERB-DST Government of India (project under the scheme of core research grant; File No. CRG/20l8/00l381) for financial assistance; principal, HPT Arts and RYK Science College, Nashik for laboratory facilities.

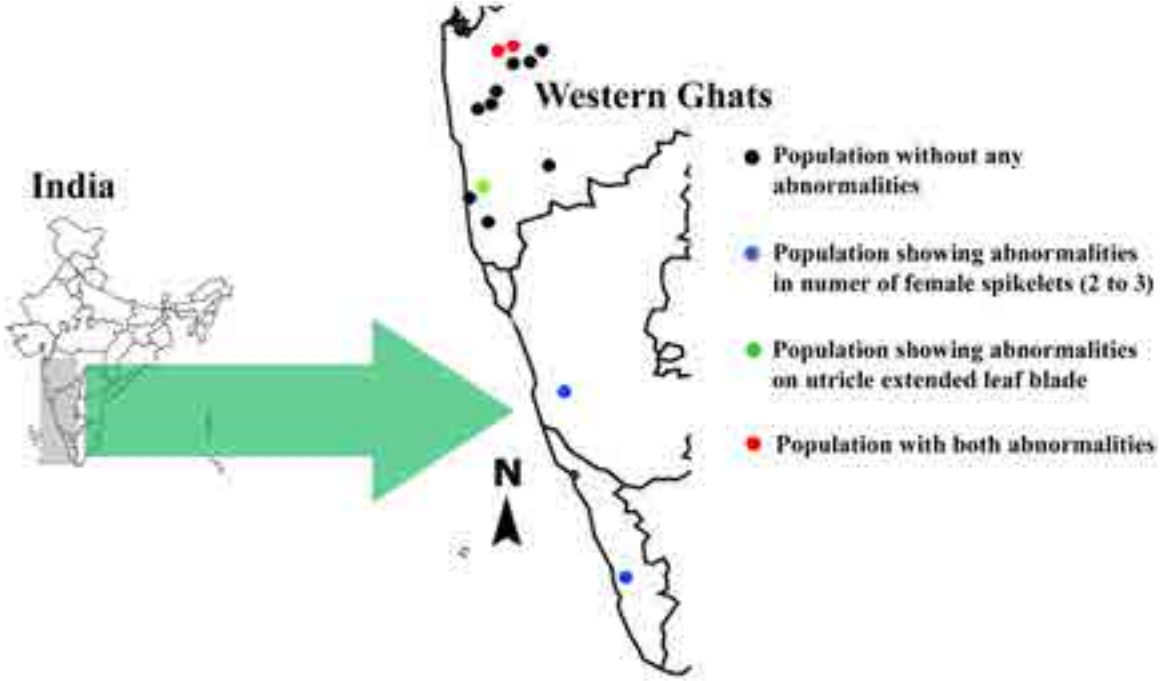


Figure 1. Map of Western Ghats and western coast showing observation localities of *Coix lacryma-jobi* L.

Image 1. Abnormalities in female spikelets of *Coix lacryma-jobi* L.: A—Inflorescence with single female spikelet | B—Inflorescence with two female spikelets | C—female spikelets without leaf blade on utricle | D–F—female spikelets with different lengths of leaf blade on utricle.

Table 1. Observed localities in Western Ghats and western coast of *Coix lacryma-jobi* L. populations.

	Localities	Abnormalities observed	
		No. of female spikelets more than one	Extended leaf blade
1	Shivaji University Kolhapur (Dist: Kolhapur; MH)	-	-
2	Harishchandragad (Dist: Ahmednagar; MH)	+	+
3	Kudal (Dist: Sindhudurg; MH)	-	-
4	Napane (Dist: Sindhudurg; MH)	-	-
5	Titvala (Dist: Thane; MH)	-	-
6	Devgad (Dist: Sindhudurg; MH)	-	-
7	Igatpuri (Dist: Nashik; MH)	-	+
8	Gavalwadi (Dist: Nashik; MH)	-	-
9	Tryambakeshwar (Dist: Nashik; MH)	-	-
10	Mokhada (Dist: Palghar; MH)	-	-
11	Plot pada (Dist: Thane; MH)	-	-
12	Rajur (Dist: Ahmednagar; MH)	+	+
13	Aluva (Dist: Ernakulam; KL)	+	-
14	Kalmanja, (Dist: Dakshina Kannada; KA)	+	-

Dist—District | MH—Maharashtra | KL—Kerala | KA—Karnataka.

References

Arora, R.K. (1977). Job's-tears (*Coix lacryma-jobi*) A minor food and fodder crop of northeastern India. *Economic Botany* 31: 358–366.

Bor, N.L. (1960). *The grasses of Burma, Ceylon, India, and Pakistan, excluding Bambuseae.* Pergamon, New York.

Li, D.P. (2006). Research advance on ethnopharmacology, pharmacodynamics, pharmacokinetics and clinical therapeutics of *Coix* seed and its preparation, Kanglaite injection. *Asian Journal of Pharmacodynamics and Pharmacokinetics* 6(2): 83–102.

Simon, B.K. (1989). A new species of *Coix* L. (Poaceae) from Australia. *Austrobaileya* 3(1): 1–5.

Xi, X.J., Y.G. Zhu, Y.P. Tong, X.L. Yang, N.N. Tang, S.M. Ma, S. Li & Z. Cheng (2016). Assessment of the genetic diversity of different job's tears (*Coix lacryma-jobi* L.) accessions and the active composition and anticancer effect of its seed oil. *PLoS ONE* 11(4): e0153269. https://doi.org/10.1371/journal.pone.0153269

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,
No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road,
Saravanampatti, Coimbatore, Tamil Nadu 641035, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa

www.threatenedtaxa.org

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

March 2022 | Vol. 14 | No. 3 | Pages: 20703–20810
Date of Publication: 26 March 2022 (Online & Print)
DOI: 10.11609/jott.2022.14.3.20703-20810

Publisher & Host

WILD ZOOREACH
Threatened Taxa