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Cover: Mugger Crocodile basking on the banks of Savitri River at Mahad in Maharashtra, India. © Utkarsha M. Chavan.

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COMMUNICATION

New records of pteridophytes in Mount Matutum Protected Landscape, South Central Mindanao, Philippines with notes on its economic value and conservation status

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Abstract: New records on distribution of pteridophytes in Mount Matutum Protected Landscape were documented. The species list was accounted with reference to specimen collections from various herbaria posted in digital databases and reliable literature on pteridophyte flora. Results further showed 105 new records for MMPL and its vicinity-South Cotabato, Sarangani province and General Santos City. From these, seven were new records for South Central Mindanao Region (Region 12). About 19 families, 56 genera were represented – 41 were epiphytes, 10 lithophytes, and 45 soil inhabitants, the rest with dual habits – two (ground and lithophytic); seven (epiphytic and lithophytic). Moreover, 11 species were found to be threatened based on national list while local conservation assessment based on relative frequency noted 91 threatened species. A conservation plan for these valuable species in the protected landscape is also proposed to ensure sound intervention and sustainable environment for this plant group.

Keywords: Ferns, General Santos, lycophytes, Matutum, protected area, Sarangani, South Cotabato.

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Author contributions: Christine Dawn Obemio lead author. Assisted in the study conception and design, collected, analyzed data, interpreted the results and drafted the manuscript. Inocencio E. Buot, Jr. led the study conception and design. Assisted in the analysis of data and interpretation of results. Reviewed the draft manuscript and added critically important intellectual content. Maria Celeste Banaticla-Hilario assisted in study conception and design, analysis of data and interpretation of results and drafting the manuscript. Reviewed the draft manuscript and organized the flow of the discussion.

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LOS BAÑOS USAID FROM THE AMERICAN PEOPLE

INTRODUCTION

A significant understory flora growing in the forest reserves are the pteridophytes or the ferns and lycophytes. These plants are widely distributed both in the tropical and temperate regions especially at higher elevations, and they flourish in moist, shaded habitats (Delos Angeles & Buot 2012). They are known to have high economic value as ornaments, food, and medicine, and are noted for its high ecological importance as indicators of environmental quality (Pouteau et al. 2016; Silva et al. 2018; Khine et al. 2019). Pteridophytes are also host to diverse faunal species (Ellwood & Foster 2004; Beaulieu et al. 2010; Scheffers et al. 2014). However, its richness and diversity are continuously challenged by geogenic and anthropogenic factors that lead to fragmentation and decrease in species over the years (Rodriguez et al. 2011; Silva et al. 2018). It is then very important to know the floristics of pteridophytes in the landscape to have a better understanding on appropriate conservation interventions.

The majestic Mount Matutum Protected Landscape (MMLP) in the South Cotabato, Sarangani and General Santos (SOCSARGEN) region of southern Mindanao, is an important source of pteridophyte diversity. In fact, the entire island of Mindanao has been explored for pteridophyte diversity and about 186 species were identified (Hassler 2004-2022). Meanwhile, 11 species were described and named bearing the epithets of *mindanaoensis, mindanensis* or *mindanaense* – *Adiantum mindanaense, Alsophila mindanensis, Cyclosorus mindanaensis, Thelypteris mindanaensis, Microsorum mindanense, Polypodium mindanense, Polypodium punctatum* ssp. *mindanense, Polypodium punctatum* var. *mindanense, Selaginella mindanaoensis, Tectaria mindanaensis,* and *Aenigmopteris mindanaensis* (Hassler 2004-2022). Though all of these except *A. mindanaense* were already considered synonyms, it still highlights the significant flora in this southern part of the country.

Mount Matutum was declared as protected area in 1995 through the Presidential Proclamation 552, and included in the rooster of Key Biodiversity Areas (KBAs) (Conservation International - Philippines, Haribon Foundation and the Department of Environment and Natural Resources) and Important Bird Areas (IBAs) (Birdlife International 2018) making it a priority site for conservation. It holds forest wealth of significant flora, largely unexplored that could potentially be lost together with the ecosystem services they provide, with influx of population in the surrounding communities.

Scientific studies on Mt. Matutum's biodiversity have been scarce with only a handful published accounts on trees (Obemio et al. 2016), and bryophytes (Azuelo et al. 2016). Similarly, assessments on its faunal resource were limited to anurans (Nuñeza et al. 2017a), reptiles (Nuñeza et al. 2017b), avians (Nuñeza et al. 2019), and bats (Nuñeza et al. 2015). Until this time, these remained the only published accounts for Mt. Matutum.

Interestingly, the earliest pteridophyte exploration in the protected area dates back to more than a hundred years ago (1917) by Copeland where he observed about 99 species. Among these, *Gleichenia peltophora* and *Diplazium calliphyllum* are known in the Philippines from this site only. Also, three species, though currently treated as synonyms, were named after the landscape, namely, *Ctenopteris matutumensis, Dryopteris matutumensis*, and *Selliguea matutumensis*. However, a concerted effort on documenting the Pteridophyte flora of the area remains unfinished.

The present attempt is thus the first of its kind in collating the details from various sources, including data from various herbaria and on recent field studies. It also seeks to present the economic uses associated with the pteridophytes and develop a local conservation status for each as many were not yet assessed with reference to the threatened list by the International Union for the Conservation of Nature (IUCN). As this study is the first attempt to document a more comprehensive account of the pteridophytes in the protected area, a lot of species then are new records for Mount Matutum and its vicinity – south central Mindanao region. The feature of these species is a remarkable milestone for MMPL and a significant step towards strengthening conservation interventions in the protected area. The authors seek to address the gap of an updated floristics and new records of pteridophytes in MMPL that would be crucial in their integration to conservation management as they are inevitably part of the ecosystem and function to enhance stability, resiliency, and sustainability of the landscape. This in turn cascade to the communities in form of ecosystem services, highlighting its conservation value.

MATERIALS AND METHODS

Study Area

Mount Matutum Protected Landscape (MMPL) is an important landmark and ecological watershed of South Cotabato and Sarangani Provinces in Southern Mindanao. It is surrounded by four municipalities (three in South Cotabato; one Sarangani Province) and 14 barangays (12 South Cotabato, two Sarangani Province). A stratovolcano, this landscape stands to about 2,286 m, covering an approximate area of 14,000 ha of forestland, with 3,000 ha of a primary forest. A community of vascular (trees, pines, ferns) and non-vascular (mosses, liverworts, hornworts) plants thrive in this this primary forest.

The climate in the northwestern and southwestern parts of this protected area is tropical with significant rainfall throughout the year even in the driest months. It is classified as Type IV with reference to Philippine-climate types and tropical wet (Af category) based on the worldwide Köppen-Geiger. Monthly temperature variations are no greater than three degrees Celsius characterized by intense surface heating and high humidity resulting to daily formation of cumulus and cumulonimbus. These conditions favor the growth of different kinds of ferns and fern allies, which greatly prefer shaded and damp habitats. Moreover, the presence of rocky environments, slopes, and host trees make this landscape a host to diverse species of pteridophytes.

Field Methods

Assessment was done following the method of Banaticla & Buot (2004) and Delos Angeles & Buot (2015). A line transect of 10–20 m, depending on the heterogeneity of pteridophyte patches, was established. At least one transect was assessed for every 100 m elevation range. All fern and lycophytes along the transect were documented including epiphytes observed below 2.5 m.

Two sites in MMPL were considered as study areas to represent its northwestern slope (Image 1). Site 1 was in the municipality of Tupi, South Cotabato, accessible through the Glandang Trail (6.3505^{0}N, 125.0570^{0}E) while site 2 was in the municipality of Polomolok, South Cotabato, around the Keumang-Alnamang trail (6.3300^{0}N, 125.0605^{0}E).

A total 92 transects were subjected for sampling, Site 1 with 52 and Site 2 with 40 transects. Composition of ferns and fern allies were listed in every transect. Voucher specimens were collected in duplicate to triplicate whenever possible. Geographic location and elevation were determined using a geographic positioning system (GPS) device.

Laboratory Methods

Voucher preparation and identification

Collected specimens from MMPL were pressed and mounted in herbarium sheets. The herbarium specimens were stored, labeled, and prepared for distribution in Mindanao State University-General Santos City and Plant Biology Division, Institute of Biological Sciences, UPLB herbaria. Taxonomic identification and determination of distribution records were done using relevant taxonomic literature - Copeland (1958) and online databases (Pteridoportal: https://www.pteridoportal.org/portal/index.php, Co's Digital Flora: https://www.philippineplants.org/, Ferns of the World: https://www.fernsoftheworld.com/). Experts in the field – Barbara Parris (Fern Research Foundation), Fulgent Coritico (Central Mindanao University, Bukidnon, Northern Mindanao), Cherie Cano (University of Southern Mindanao, Kabacan, North Cotabato), were also consulted to validate the specimen identification. Based on these the new records, new distribution and rediscovered pteridophyte species in Mount Matutum and its vicinity - surrounding provinces of South Cotabato, Sarangani Province and city of General Santos were identified.

New records were evaluated and described with reference to relevant literature and database information. Key literature were the Fern Flora of the Philippines (Copeland 1958), and others such as Ebihara et al. (2006), Lehtonen et al. (2013), Parris & Sundue (2020). Database searches were also made through Cos Digital Flora of the Philippines (Pelser et al. 2011 in www.philippineplants.org), Catalogue of Life (Species 2020) (www.catalogueoflife.org), Flora of China (www.efloras.org) and Pteridoportal (Pteridophyte Collections Consortium) (www.pteridoportal.org) World Ferns (Hassler 2004–2022) and Flora Malesiana – www.floramalesiana.org (accessed 27 April 2018).

The conservation status of new records was determined from International Union for the Conservation of Nature (IUCN) Threatened List version 2021 from www.iucn.org, and the Department of Environment and Natural Resources (DENR) Administrative Orders (DAO) 2017–11 which features the Updated List of Threatened Philippine Plants and their Categories.

Local Conservation Assessment

Local assessment of conservation was done using the relative frequency of species distribution in MMPL with reference to the work of Villanueva and Buot (2020). Relative frequency (RF) was determined by the ratio of the number of transects where the species were observed and the total number of transects. Frequency below < 0.1% was considered critically endangered (CR), > 0.1 – 0.4% endangered (EN), > 0.4 – 0.7 vulnerable (VU),

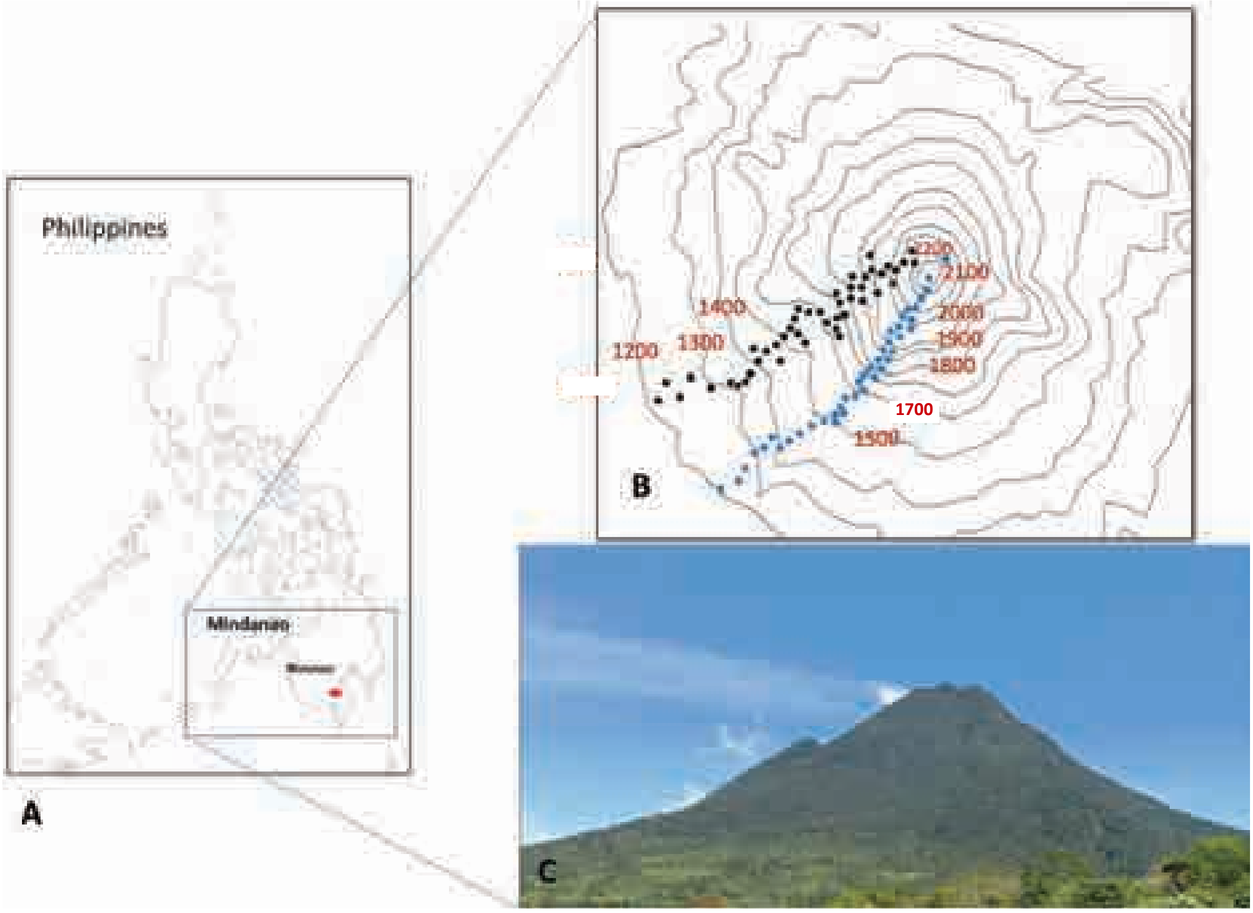

Figure 1. Study Site: A—Location of Mount Matutum in Mindanao | B—Sampling sites in the North-West aspect of Mount Matutum | C—A view of Mount Matutum Protected Landscape.

0.7 -1 nearly threatened (NT), and > 1 least concerned (LC). This local assessment highlighted the conservation status of those species found in MMPL that were not yet assessed in IUCN nor identified in DAO (2017–11).

RESULTS AND DISCUSSION

New Records in Mount Matutum Protected Landscape (MMPL)

Earlier studies recorded about 160 pteridophytes in Mount Matutum (Copeland 1917; Gaerlan et al. 1992; Gonzales 2001; Mindanao State University-General Santos City 2013), while this present undertaking adds another 105 taxa, totaling to 265 species in the Matutum area. Of these, 12 were lycophytes while 93 were monilophytes (ferns). As to habit, 45 were terrestrial, 41 epiphytes, 10 lithophytes and the rest showed dual habits such as terrestrial & lithophytic (two species) and epiphytic & lithophytic (seven species) (Table 1).

Copeland (1917) observed 57 ferns which were highlighted in his work on Fern Flora of the Philippines. Seventy-five years later, Gaerlan et al. (1992) collected 24 species as part of the biodiversity inventory of Philippine National Musuem. The next assessment was done in 2001 by Dr. Gonzales which showed 188 species and so far, the largest collection prior to this study. Meanwhile, MSU-GSC did an assessment in the lowland forest in 2013 and enlisted about 42 species. The works of Dr. Gonzales and MSU-GSC were unpublished records.

On the opposite side of MMPL, in Mount Busa, Kiamba, Sarangani Province, about 114 pteridophytes were observed from the exploration by Barcelona & Busemeyer (1993) based on digitized herbarium specimen collections from Miami University, Willard Sherman Turrell Herbarium (MU) and National Museum of Natural History-US Botany published in Pteridophyte Collections Consortium (www.pteridoportal.org). Meanwhile, in the Allah Valley Protected Landscape, northern part of MMPL, no records of pteridophytes have been known yet.

Interesting new records are the *Athyrium nakanoi,*

Table 1. Composition of new records in MMPL (with exsiccatae) and description of their spot characters and habit.

Families and species composition (Common Name)	Description	Habit	Exsiccata
I. Lycopodiopsida (Fern Allies)			
1. Lycopodiaceae			
Huperzia javanica (Sw.) Fraser-Jenk. (Fir clubmosses)	Stem ascending, dichotomously branched, leaves whorled, narrowly elliptic, margin serrate, apex caudate, spores trilete	Epiphyte.	OBEMIO453MSU
Lycopodium clavatum L. (Common clubmoss)	Stem creeping with erect tips, dichotomously branched of unequal length, leaves small, moss-like, spirally arranged, dimorphic strobili, adventitious roots present	Ground.	OBEMIO587MSU
Phlegmariurus delbrueckii A.R. Field & Bostock (Tassel fern)	Pinnate, leaves alternate, compact, ovate-obtuse, 3 mm wide x 5 mm long, apex rounded-cuspidate, base cuneate, strobili dichotomous 20–35 mm, straight	Epiphyte	OBEMIO451MSU
Phlegmariurus verticullatus (L.f) A.R. Field (Tassel fern)	Stems dichotomously branching, leaves bristle-like, strobili terminal	Epiphyte	OBEMIO419MSU
Pseudodiphasium volubile (G. Forst.) Holub	Scrambling, horizontal stems, spreading, numerous dichotomous branching, dimorphic, fertile stems with short linear leaves, pendulous strobili at tip, sterile leaves widely spaced, linear-peltate.	Ground.	OBEMIO555MSU
2. Selaginellaceae			
Selaginella boninensis Baker (Spikemoss)	Stems long, creeping, large leaves oblong, alternate small leaves ovate, spiral, apex acute, base rounded, rhizophore filiform	Lithophyte	OBEMIO485MSU
Selaginella biformis A. Br. ex Kuhn (Spikemoss)	Stems long, creeping, branched on upper part, stramineous, primary leafy branches flattened, ovate, leaves on stem ovate-lanceolate, apex acute, base rounded, rhizophore on rhizomes	Lithophyte	OBEMIO549MSU
Selaginella engleri Hieron (Spikemoss)	Stems erect, fronds bipinnate, alternate, pinna ovate, sporangia at tips of fertile pinna, branched microphylls contiguous	Ground	OBEMIO7396PBDH
Selaginella gastrophylla Warb. (Spikemoss)	Stems erect, fronds bipinnate, alternate, pinna ovate, leaves on stems unappressed, widely spaced, microphylls not contiguous, sporangia at tips of fertile pinna, cylindrical	Ground	OBEMIO488MSU
Selaginella involvens (Sw.) Spring (Spikemoss)	Stems erect, leaves on stems scale-like, pale yellow, median stems branched, fronds pinnate, ovate-triangular, ventral leaves contiguous, sporangia terminal	Lithophyte	OBEMIO486MSU
Selaginella remotifolia Spring (Spikemoss)	Stems branched from base; secondary branches forked. Fronds pinnate, axillary leaves ovate, acute, leaves on branches elliptic-lanceolate, not overlapping	Ground	OBEMIO489MSU
II. Polypodiopsida (Ferns)			
1. Aspleniaceae			
Asplenium affine Sw.	Pinnatifid-bipinnatifid.alternate, opposite at base, petiolulate, lobed, acuminate apex, pinnules aternate, rounded apex, cuneate base, stalked, acroscopic pinnules smaller, lower pinnules more lobed. Sori linear forming V shape over lamina veins	Lithophyte	OBEMIO052MSU
Asplenium cuneatum Lam.	Lamina ovate. Pinna triangular, apex aristate, base convex, pinnules fan-shape, basal pinnules larger, lobed, apex toothed, base convex-truncate, actinodromous. Sori linear 3–4 interspersed over veins	Epiphyte	OBEMIO053MSU
Asplenium elmeri Christ	Stipe clumped or solitary, Lamina bipinnate, ovate, alternate, pinnules alternate, basal pinnule larger, fan-shaped. Sori laminar, linear, single or paired at segments.	Lithophyte	OBEMIO056MSU
Asplenium horridum Kaulf. (Lacy spleenwort)	Stipe scaly, lamina pinnate, alternate, lobes cut down halfway the costa, margin with deep sinuses, pinna linear-lanceolate, apex attenuate, base convex. Sori linear parallel and very near the costa	Ground	OBEMIO074MSU
Asplenium laserpitiifolium Lam.	Lamina tripinnate, alternate, pinnae ovate, pinnules obovate, rachis dark brown, apex acute, base cuneate. Sori linear incline over veinlets.	Epiphyte	OBEMIO7283PBDH
Asplenium lobulatum Mett.	Stipe clumped (2 or more), Lamina pinnate, triangular, acuminate apex, truncate base, basiscopic pinna opposite, acroscopic subopposite, reduced, pinnules lanceolate, acuminate, truncate-cuneate-convex base, margin serrate. Some basal pinnules forming prominent lobes on one side of the blade. Sori linear, inclined close to midrib	Epiphyte	OBEMIO169MSU

Families and species composition (Common Name)	Description	Habit	Exsiccata
Asplenium longissimum Blume (Spleenwort)	Pinnate, ovate, attenuate apex, base, truncate, pinna alternate, stalked or sessile, apex attenuate, base truncate-convex. Sori linear dark-brown inclined close to costa	Ground	OBEMIO7395PBDH
Asplenium pellucidum Lam.	Stipe clumped, Lamina elliptic, pinna lanceolate-triangular, leaf base covering rachis on the ventral side, margin lobed, apex acute, base truncate. Sori linear inclined with ends touching the costa	Epiphyte	OBEMIO303MSU
Hymenasplenium excisum (C. Presl) S. Linds.	Pinnate, thin, papyraceous, wedge-shape, rounded apex, truncate base, toothed, unlobed, sori linear over veinlets, 2 venation cladodromous, decurrent attachment, stele haplostele, x-shape xylem.	Epiphyte	OBEMIO049MSU
Hymenasplenium subnormale Copel.	Pinnate, lamina ovate-triangular, cordate base, attenuate apex, pinna ovate reduced at apex, opposite-subopposite, rounded apex, truncate base., sori linear, inclined halfway from costa	Lithophyte	OBEMIO7379PBDH
2. Athyriaceae			
Athyrium puncticaule (Blume) T. Moore (Lady fern)	Evergreen pinnatifid, Lamina triangular-lanceolate, pinna stalked, margins serrate, apex acute, base cuneate, basiscopic pinna strongly auriculate. Sori medial on the veins, round	Ground	OBEMIO7252PBDH
Athyrium nakanoi Makino (Lady fern)	Evergreen, rhizome creeping-ascending, erect, frond solitary or caespitose, bipinnate, lamina papyraceous, pinnae linear-lanceolate,pinnules, pinnatifid, deltoid, apex acuminate, base truncate, basal pinnules ovate-lanceolate.margin shallowly lobed. Sori continuous, U-shape, over tertiary veins	Ground	OBEMIO7251PBDH
Cornopteris banaohensis (C. Chr.) K. Iwats. & M.G.Price	Stipe clumped, frond coriaceous, short, Lamina short, papyraceous, lower pinna bipinnatisect, opposite, larger than acroscopic pinna. Pinna apex acuminate, pinnules cuneate, base truncate, dissection almost to the midrib. Sori parallels the midrib, bright orange	Ground	OBEMIO7253PBDH
Diplazium dilatatum Blume (Twinsorus ferns)	Fronds pinnate-bipinnatifid, lamina dark green adaxially, pinna opposite-sub-opposite, sessile-subsessile, acroscopic pinna smaller, less lobed, base of pinnule wider, apex acuminate, base truncate. Sori linear inclined along costa forming v-shape	Ground	OBEMIO235MSU
Diplazium geophilum Alderw. (Twinsorus ferns)	Evergreen. pinnate, lamina ovate, pinnae short-stalked, wide ovate, rounded-acute apex, base of the pinna asymmetric, deeply-lobed. Sori linear grooved over craspedodromous veinlets.	Ground	OBEMIO225MSU
Diplazium sorzogonense (C. Presl.) C. Presl. (Twinsorus ferns)	Stipe clumped, fronds pinnatifid, pinnae oblong-triangular, apex acuminate, base cuneate, basal and apical segments reduced. Sori linear, on veinlets half-way to margin	Ground	OBEMIO602MSU
3. Cyatheaceae			
Alsophila apoensis (Copel) R.M. Tryon (Tree fern)	Tree fern. Tripinnatifid, Frond glabrescent, coriaceous, pinnules sessile, oblong, short acuminate, segments serrulate toward apex. Sori costal, globose	Ground	OBEMIO7255PBDH
Alsophila hermannii R.M. Tryon (Tree fern)	Tree fern. Tripinnatifid, Frond glabrescent, coriaceous, pinnules sessile, triangular, caudate, truncate, serrulate toward apex. Sori costal, globose	Ground	OBEMIO7256PBDH
Alsophila heterochlamydea (Copel.) R.M. Tryon (Tree fern)	Tree fern. Tripinnatifid, Pinnules sessile, pinnate at base, segments oblong, serrulate at apex. Sori costal, obsolete.	Ground	OBEMIO016MSU
Sphaeropteris elmeri (Copel) R.M. Tryon (Tree fern)	Tree fern. Tripinnate. Pinnules triangular, apex caudate, base truncate, segments, oblong, apex rounded, thin, papyraceous. Sori costal, small, circular on sides of secondary veins	Ground	OBEMIO177MSU
Sphaeropteris glauca (Blume) R.M. Tryon (Tree fern)	Tree fern. Tripinnate. Pinnules triangular, acuminate apex, truncate base, untoothed, segments oblong, papyraceous, rounded apex, sessile, up to 14 veins on a side. Sori costal, globose about 7 pairs	Ground	OBEMIO029MSU
Sphaeropteris lepifera (J.Sm. ex Hook.) Copel. (Tree fern)	Tree ferns. Tripinnate, Pinnules short-stalked, oblong, truncate base, segments pinnate, linear, acute apex. Sori costal, globose	Ground	OBEMIO7257PBDH
4. Dennstaedtiaceae			
Histiopteris incisa (Thunb.) J.Sm. (Bat's wing fern)	Rhizome robust, creeping, fronds widely spaced, widely ovate slightly dimorphic with fertile lobes slightly narrower, pinnae pale green, opposite, wide-angle with deep lobation on margins, sori marginal continuous, linear and exindusiate surrounded by reflexed leaf margin.	Ground	OBEMIO7258PBDH

Families and species composition (Common Name)	Description	Habit	Exsiccata
Miicrolepia strigosa (Thunb.) C. Presl (Lace Fern)	Fronds wide-ovate, bipinnatifid, pinnae alternate, attenuate apex, convex base, pinnules subsessile,	Ground	OBEMIO7259PBDH
Monachosorum henryi Christ	Rhizome erect. Lamina ovate-triangular, pinna oblong, pinnules ovate-lanceolate, base truncate-round, thin, basal pinnules more lobed, apical pinnules more lanceolate, sori circular at vein ends, petiole round, solenostele stele, 2-linear vascular bundles	Ground.	OBEMIO176MSU
5. Dicksoniaceae			
Dicksonia amorosoana Lehnert & Coritico (Amoroso's wooly tree fern)	Ground tree fern. tripinnatifid, lamina dark green adaxially, light green abaxially, pinna subsessile, lanceolate, base truncate, attentuate apex, basal segmentshorter, sori circular, spores globose	Ground.	OBEMIO7260PBDH
6. Dryopteridaceae			
Arachniodes amabilis (Blume) Tindale	Rhizome creeping, Fronds oblong-ovate, bipinnate, coriaceous, acroscopic pinnules reduced, apex caudate, base cuneate. Sori terminal on veinlets	Ground, Lithophyte	OBEMIO7325PBDH
Bolbitis heteroclita (C. Presl) Ching	Rhizome horizontal. Frond odd-pinnate, opposite, apical lamina larger, elliptic, caudate apex, cuneate base, margin crenose, dimorphic, secondary veins brochidodromous, tertiary veins reticulate, opposite-subopposite, tertiary veins. Sori naked covering fertile blades	Epiphyte	OBEMIO7261PBDH
Dryopteris hendersonii (Bedd.) C. Chr. (Wood fern).	Tripinnatifid. Fronds wide ovate, pinnae alternate, base pinnae larger, pinnules triangular-oblong, acuminate apex, truncate-oblique base, lobe, apex toothed. Sori round, indusiate	Ground	OBEMIO484MSU
Dryopteris purpurascens (Blume) Christ (Wood fern).	Frond pinnatisect-bipinnatisect, alternate, pinnae triangular, apex acuminate with alternate tooth along margins, pinnules triangular, acuminate apex, rounded base, base pinnules of larger pinna pinnate, toothed, acroscopic pinnules toothed. Sori costal, round, side by side the midvein.	Ground	OBEMIO502MSU
Dryopteris permagna M. Price (Wood fern).	Ground, bipinnatifid on acroscopoc pinna tripinnatifid on lower pinna, alternate, triangular, acuminate apex, base truncate, acroscopic segments pinnatisect, lower to middle segments serrate. Sori round, parallel along midrib and secondary veins	Ground	OBEMIO7262PBDH
Polystichum moluccense T. Moore	Tripinnate, alternate, dark green adaxial, pinnae oblong, acuminate apex, rounded base, pinnules thick, rough, ovate-triangular, base lobed, truncate-oblique, apex acute, toothed. Sori round, laminar over veinlet tips	Epiphyte	OBEMIO393MSU
Polystichum elmeri Copel.	Bipinnate, alternate, light green on adaxial, pinnae oblong, acuminate apex, convex base, pinnules thick, rough, ovate, base truncate-oblique.	Epiphyte	OBEMIO5833MSU
Teratophyllum aculeatum (Blume) Mett. ex Kuhn	Bathyphylls pinnate-bipinnate, alternate, dichotomously branched, rhizome creeping. Lamina pinnate, lanceolate. Fertile pinnae alternate, linear. Sori continuous covering entire blade of fertile leaf.	Epiphyte/ Climber	OBEMIO7263PBDH
7. Hymenophyllaceae			
Abrodictyum pluma (Hook.) Ebihara & K. Iwats.	Rhizome creeping. Fronds tufted, alternate, oblong, opposite at base, pinna reduced, needle-like middle pinna larger, segments clumped, dichotomous tips. Sori cup-shape at vein ends of basal segments.	Epiphyte	OBEMIO468MSU
Abdrodictyum obscurum (Blume) Ebihara & K. Iwats.	Rhizome creeping, stipe dark or light brown, lamina tripinnate-quadripinnate, herbaceous, triangular-ovate, pinnae oblong-ovate, apex obtuse-acute, widely-tooth, base cuneate. Sori apical on some segments, involucres cylindrical.	Lithophyte	OBEMIO469MSU
Crepidomanes minutum (Blume) K. Iwats.	Rhizome branching, stipe dark brown, lamina ovate, base cuneate, thin filmy, entire, segments linear, apex obtuse, base rounded-cordate. Involucres funnelform	Lithophyte	OBEMIO7264PBDH
Crepidomanes grande (Copel.) Ebihara & K. Iwats.	Rhizome short, erect, tufted fronds, lamina quadipinnate, ovate-oblong, Sori tubular on distal part of fronds	Ground, Lithophyte	OBEMIO735MSU
Hymenophyllum ramosii Copel. (Filmy fern)	Rhizomes long, creeping, lamina pinnate-tripinnatifid, elliptic-triangular, alternate, pinna ovate, Sori bud-shape on apical portion of lamina	Epiphyte	OBEMIO616MSU
Hymenophyllum denticulatum Sw. (Filmy fern)	Rhizomes long, creeping, rachis narrowly-winged, toothed, lamina bipinnatifid, pinnae alternate, wide-ovate, margins wide-serrate, veins prominent at abaxial portion. Sori cup-shape at tips of acroscopic segments	Epiphyte, Lithophyte	OBEMIO546MSU

Families and species composition (Common Name)	Description	Habit	Exsiccata
Hymenophyllum fimbriatum J. Sm (Filmy fern)	Rhizomes long, creeping, rachis narrowly-winged entire nearly toward the base, alternate, elliptic, pinna ovate pinnatisect, Sori at tip of acroscopic segments with slightly extruded involucres	Epiphyte, Lithophyte	OBEMIO545MSU
Hymenophyllum holochilum (Bosch) C. Chr. (Filmy fern)	Rhizome long, creeping, rachis narrowly-winged almost inconspicuous, pinnatifid, alternate, margins toothed, elliptic, pinnae deltoid, sparsely toothed, unequally cuneate-oblique. Sori on acroscopic segments, involucres elongate-elliptic, receptacles exserted.	Epiphyte, Lithophyte	OBEMIO7266PBDH
Hymenophyllum imbricatum Blume (Filmy fern)	Rhizomes, long, creeping, bipinnatifid, stipe and rachis winged, lamina bipinnatifid, alternate, wide space between pinnae, pinnae wide-ovate, terminal segments filiform margin entire, sori involucre wide, round.	Epiphyte	OBEMIO544MSU
Hymenophyllum nitidulum (Bosch) Ebihara & K. Iwats. (Filmy fern)	Rhizomes long, creeping, filiform, stipes almost wingless, lamina obovate, dichotomously lobed, dissected at base, lobes linear or forked. Sori terminal on lobes, involucres deltoid-like, sunken	Epiphyte	OBEMIO736MSU
Hymenophyllum pallidum (Blume) Ebihara & K. Iwats. (Filmy fern)	Rhizomes long, creeping, stipes hairy at base, lamina bipinnatifid, oblong, obtuse apex, cuneate base, pinnae alternate, sessile, ovate. Sori terminal on acroscopic pinnae, enclosed	Epiphyte, Lithophyte	OBEMIO547MSU
Hymenophyllum serrulatum (C. Presl) C. Chr. (Filmy fern)	Rhizome, long, creeping, stipe hairy, wingless, lamina translucent, ovate, bipinnatifid-tripinnatifid, pinna alternate, oblong-ovate,stalked, apex round, lobed. Sori axillary on acroscopic portion	Epiphyte	OBEMIO601MSU
Hymenophyllum thiudium Harrington (Filmy fern)	Rhizome, long, creeping, stipe narrowly winged, lamina bipinnatifid-tripinnatifid, pinna alternate, ovate, sori at terminal tips of ultimate segments, involucres capitate.	Epiphyte	OBEMIO7268PBDH
Vandenboschia auriculata (Blume) Copel.	Frond creeping, alternate, oblong, petiolulate, basal pinnules wider, wide ovate. Sori apical on acroscopic segments.	Epiphyte	OBEMIO7269PBDH
8. Hypodematiaceae			
Leucostegia truncata (D. Don) Fraser-Jenk.	Fronds tripinnate, ovate, coriaceous, pinna alternate, triangular, size increasing toward base, pinnules ovate-triangular, apex acuminate, base convex, basal segments in basal pinnae deeply lobed, widely ovate, rounded base, obtuse apex. Sori kidney-shaped on veinlet ends.	Ground	OBEMIO347MSU
9. Lindsaceae			
Odontosoria retusa (Cav.) J. Sm.	Fronds tripinnate-pinnate, pinnae alternate, ovate, stalked decurrent to rachis, acuminate apex, base convex, pinnules fan-shape, stalked, truncate apex, cuneate base.Sori linear on apex of pinnules in false indusium	Ground	OBEMIO737MSU
Tapeinidium pinnatum (Cav.) C. Chr.	Rhizome short, creeping, fronds pinnate, elliptic-oblong, papyraceous, pinna linear, apex acuminate, subsessile, rachis stramineous, margin shallowly crenate, apex acuminate, base cuneate. Sori submarginal on vein ends, cup-shape indusia	Ground	OBEMIO7274PBDH
Tapeinidium gracile (Blume) Alderw.	Rhizome short, creeping, fronds ovate, alternate, pinna elliptic-linear, acuminate apex, rounded base, upper pinna pinnatifid, lower pinnules pinnatifid, linear. Sori round, marginal	Ground	OBEMIO738MSU
Lindsaea pulchella (J. Sm.) Mett. ex Kuhn	Rhizome long, creeping, fronds linear, acuminate apex, papyraceous, lower pinnae opposite, upper sub-opposite, triangular, truncate apex, cuneate base. Sori submarginal on vein ends.	Epiphyte, Climber	OBEMIO7270PBDH
Osmolindsaea odorata (Roxb.) Lehtonen & Lehtonen	Rhizome short, creeping, fronds pinnate, lamina wide, lanceolate, pinnae alternate, truncate apex, slightly lobed convex base. Sori marginal, elongated, interrupted	Lithophyte	OBEMIO739MSU
10. Marratiaceae			
Angiopteris evecta Sw. (Giant fern)	Fronds tripinnate, alternate, pinna elliptic-oblong, fleshy, pinnules stalked, apex acuminate, serrate, rounded base, margin crenose, Sori submarginal, oval shape.	Ground	OBEMIO7275PBDH
Ptisana pellucida (C. Presl) Murdock	Fronds bipinnate, alternate, fleshy, pinna ovate, pinnules lanceolate, apex acuminate, base rounded, margins serrate. Sori oval, submarginal.	Ground	OBEMIO428MSU

Families and species composition (Common Name)	Description	Habit	Exsiccata
11. Oleandraceae			
Oleandra sibbaldi Grev.	Rhizome long-creeping, fronds elliptic, base cuneate, apex acuminate, membranous, with sparse catenate hairs, costa, hairy, darker on lower surface. Sori inframedial, reniform.	Epiphyte	OBEMIO091MSU
12. Ophioglossaceae			
Botrychium daucifolium Wall. ex Hook. & Grev. (Moonwort)	Rhizome erect, lamina bipinnate, pinnate to bipinnate, herbaceous, pinnae alternate-subopposite, short stalked or subsessile, triangular, pinnules ovate, apex acute-acuminate, base rounded, serrate, basal pinnules lobed. Sori round on separate fertile stalks	Ground	OBEMIO7276PBDH
13. Plagiogyriaceae			
Plagiogyria glauca (Blume) Mett.	Pinnate, Fronds ovate, pinna linear, acuminate, base truncate, subsessile, glaucous ventral surface, adaxial surface green, margin serrate. Sori tetrahedral	Ground, Lithophyte	OBEMIO473MSU
14. Polypodiaceae			
Calymmodon gracillimus (Copel.) Nakai ex H. Itô	Small, caespitose, linear, segments alternate, triangular, up to 2mm. Sori round numerous enclosed by folds of margin.	Epiphyte	OBEMIO7277 PBDH
Chrysogrammitis glandulosa (J.Sm.) Parris	Pinnatisect. Lamina lanceolate, apex acute, base cuneate. Segments triangular, larger at middle, decreasing toward apex. Sori round, 1 in acroscopic segments, 2-3 along middle segments.	Epiphyte	OBEMIO033MSU
Drynaria aglaomoprha Christenh (Oak leaf fern)	Pinnatisect, dimorphic, coriaceaous, margin crenose. Sori continuous, oval-square-shaped almost filling the segment	Epiphyte, Lithophyte	OBEMIO7279 PBDH
Drynaria descensa Copel. (Oak leaf fern)	Pinnatisect, dimorphic, coriaceous, margin crenose. Sori circular scattered on abaxial surface	Epiphyte, Lithophyte	OBEMIO7280PBDH
Dasygrammitis malaccana (Baker) Parris (Shaggy fern)	Stipe clumped, fronds pinnate, lanceolate-oblong, aristate, base cuneate, pinna alternate-sub-opposite, sessile, linear, apex rounded. Sori continuous on apical portion of pinna	Epiphyte	OBEMIO740MSU
Goniophlebium subauriculatum (Blume) C. Presl (Lacy Pine Fern)	Pinnate, alternate, pinna linear, light green, apex acuminate, base auriculate, short-stalked, margin mildly serrate. Sori globose, parallel with midrib, within reticulate veinlets	Epiphyte	OBEMIO467MSU
Goniophlebium persicifolium (Desv.) Bedd.	Pinnate, alternate, stalked, pinna lanceolate, apex narrowly acuminate, base oblique, margins crenose to mildly serrate. Sori orbicular on both sides of midrib within reticulate veinlets	Epiphyte	OBEMIO539MSU
Goniophlebium pseudoconnatum Copel.	Pinnate, alternate, pinna linear, dark green, apex acuminate, base auriculate, short-stalked, margin mildly serrate. Sori globose, parallel with midrib, within reticulate veinlets.	Epiphyte	OBEMIO540MSU
Leptochilus insignis (Blume) Fraser-Jenk.	Pinnatisect. Pinna broadly ovate, rounded base, acute apex, sinus increasing to the base, segments elliptic, aristate. Sori oval randomly interspersed	Epiphyte.	OBEMIO115MSU
Loxogramme avenia (Blume) C. Presl	Simple, lamina linear-obovate, acute apex, base attenuate, midrib raised on abaxial side, symmetrical. Sori tubular, parallel the midrib on acroscopic side.	Epiphyte.	OBEMIO741MSU
Loxogramme paralella Copel.	Simple lamina, obovate. dark green abaxial, light green adaxial, Sori linear lining the veins spaced increasingly to the middle of the blade.	Epiphyte.	OBEMIO742MSU
Loxogramme scolopendriodes (Gaudich.) C.V.Morton	Simple lamina, lanceolate, Sori linear inclined on the midrib at acroscopic side	Epiphyte, Lithophyte	OBEMIO035MSU
Oreogrammitis jagoriana (Mett ex Kuhn) Parris & Sundue	Simple, leaf linear, hirsute,apex obtuse, base attenuate, margin entire, Sori circular, exindusiate, one on each side of costa.	Epiphyte	OBEMIO057MSU
Oreogrammitis reindwarti (Blume) Parris	Simple, small-leaf, apex acuminate, base attenuate, margin crenate or non-crenate, hirsute. Sori circular, exindusiate, one on each side of midrib.	Epiphyte	OBEMIO596MSU
Prosaptia celebica (Blume) Tagawa & K. Iwats.	Stipe clumped, lamina elliptic, pinnatisect, coriaceous, pinnae linear. Sori oval, submarginal	Epiphyte	OBEMIO743MSU
Prosaptia multicaudata (Copel) Parris	Stipe clumped, lamina widely elliptic, pinnatisect, coriaceous, pinna linear, apex attenuate. Sori oval at an angle toward the midrib, halfway from apex never reaching the base	Epiphyte.	OBEMIO370MSU
Selliguea albidosquamata (Blume) Parris	Odd-pinnate. Alternate, Long-stalked. Pinna lanceolate, stalked, apex acumate, base cuneate, symmetrical, margin entire, lined with bright white scales. Sori small, dot shape between the midrib and margin	Epiphyte	OBEMIO7287PBDH

Families and species composition (Common Name)	Description	Habit	Exsiccata
Thylacopteris papillosa (Blume) Kunze ex J.Sm.	Pinnate-pinnatisect. Lanceolate. Thin, papery. Pinna linear, round apex, lowest pinna pinnate, sessile.Sori at tip of veinlets, appearing to be embedded on the adaxial side. Tertiary veins cladodromous	Epiphyte	OBEMIO7288PBDH
Tomophyllum macrum (Copel.) Parris	Stipe clumped, pinnatisect, subopposite, segments linear-elliptic, round apex, rachis and midrib prominent, black, Sori round exindusiate, sub-marginal	Epiphyte	OBEMIO7289PBDH
Tomophyllum millefolium (Blume) Parris	Rhizome erect. Stipes in whorls. Bipinnate-pinnatisect, Pinnules alternate, narrowly linear.	Epiphyte.	OBEMIO7290PBDH
15. Pteridaceae			
Adiantum hosei Baker (Maidenhair fern)	Pinnate, trifoliate, papyraceous, linear-lanceolate, pinnules alternate, sessile, oblong, stipe thin, black, sori marginal, false indusium	Ground. Lithophyte	OBEMIO7291PBDH
Antrophyum parvulum Blume	Simple, thick, entire, obovate, base attenuate, apex cuspidate-round. Sori linear over reticulate veins	Ground	OBEMIO577MSU
Pteris oppositipinnata Fee (Brake fern)	Ground. Broadleaved. pinnate, Lamina thick, ovate, pinna opposite, pinnatisect, basal pinnae divergent, ovate-oblong, acuminate apex, convex base, pinnules with rounded apex, sori elongate, marginal, tertiary veins cladodromous	Ground	OBEMIO247MSU
Vaginularia junghuhnii Mett.	Rhizome short creeping, Stipe clumped, pinna linear, coriaceous, apex acute, base cuneate. Sori continuous at the abaxial side	Epiphyte	OBEMIO181MSU
16. Tectariaceae			
Tectaria dissecta (G.Forst.) Lellinger (Halberd fern)	Rhizome ascending, Stipe solitary, fronds pinnatifid-bipinnatifid, pinna subopposite, margin deeply-lobed, apex acuminate, base obtuse, base segments pinnate, apex rounded. Sori circular, marginal at acroscopic pinnae.	Ground	OBEMIO7298PBDH
Tectaria melanocaulos (Blume) Copel. (Halberd fern)	Stipe and rachis black, innatifid-bipinnatifid large-leaf, wide-ovate, basal pinnae pinnate, margins serrate and lobed, apex acuminate, base rounded. Sori interspersed over the abaxial portion of the lamina	Ground	OBEMIO7297PBDH
17. Thelypteridaceae			
Chingia ferox (Blume) Holttum	Fronds pinnate, stipes to rachis bristle-like, pinna alternate, short-stalked, acuminate, round base, basal pinna oriented downwards, margin mildly lobed, Sori circular in two adjacent rows within each lobe segment	Ground	OBEMIO7292PBDH
Christella acuminata (Houtt.) Holttum	Pinnatifid, lamina wide-ovate, pinna opposite at base, sub-opposite towards acroscopic pinna, acuminate, base sagittate with basal pinna oriented downwards, pinnae triangular, acuminate, truncate. Sori circular submarginal terminating at ends of lobes	Ground	OBEMIO179MSU
Christella dentata (Forssk.) Brownsey & Jermy	Pinnatifid, Lamina widely elliptic, apical and basal pinna reduced, oblong, acuminate, basal pinna oriented downwards, margins moderately lobed. Sori circular, submarginal	Ground	OBEMIO745MSU
Pneumatopteris laevis (Mett.) Holttum	Stipes clumped, frond pinnate, widely-ovate, alternate, acuminate, pinnae lanceolate,	Ground	OBEMIO541MSU
Pneumatopteris nitidula (C. Presl) Holttum	acuminate, obtuse. Sori circular submarginal Stipes whorled, frond pinnate, wide ovate, pinna linear-triangular, opposite-sub-opposite, lobed halfway to costa. Sori circular at mid-portion of veinlets	Ground	OBEMIO7294PBDH
Pronephrium nitidum Holttum	Pinnatifid. Lamina wide ovate, pinna opposite, deeply-lobed, 190 mm long x 130 mm wide, basal pinna pinnate sessile, rachis black. Sori interspersed within tertiary veins forming areoles.	Lithophyte	OBEMIO744MSU
Sphaerostephanos ellipticus (Rosenst.) Holttum	Stipes clumped, rachis pilose, frond pinnate, wide-elliptic, pinna liner-triangular, acuminate, truncate, margin moderately-lobed. Sori circular over lamina in lobe margins	Ground	OBEMIO7296PBDH

Athyrium puncticaule, *Calymmodon gracillimus, Dicksonia amorosoana*, *Diplazium geophilum*, *Dryopteris purpurascens*, *Oreogrammitis jagoriana*, *Oreogrammitis reinwardtii*, *Prosaptia multicaudatum*, *Prosaptia celebica*, *Sphaerostephanos ellipticus,* as they are the first or second occurrence report in the region or Mindanao. Mt. Matutum holds the second record so far in the country for *A. nakanoi* and *D. amorosoana. A. nakanoi* used to be documented in India, Nepal, Bhutan, China, Taiwan, Japan, Indonesia, and Malaysia and was first seen in the country in Mount Dulang-dulang Kitanglad Range, northern Mindanao (Coritico et al. 2019). The tree fern *D. amorosoana* on the other hand, is a recently described narrow endemic species of *Dicksonia* from the Philippines, first observed in Mount Apo, Kidapawan, North Cotabato, Mindanao (Lehnert & Coritico 2018). Its second distribution record is in MMPL and to date, occurrence is confined to South Central Mindanao (Region 12). Abundance in MMPL of these species is marked as rare with < 5 species and frequency data of < 10%.

The species *C. gracillimus*, *O. reinwardtii*, and *O. jagoriana* are noteworthy records of grammitid ferns as they are not only new observations in MMPL and surrounding provinces, but also new for Region 12. They were last observed in 1904 & 1909 and 1904 & 1924, respectively, in Mount Apo and Davao Region (www.pteridoportal.org, www.worldplants.de/worldferns). Similarly, *S. ellipticus* an endemic fern, is a new record for the region with type specimens found in Mindanao – Agusan & Zamboanga, from 1911–1912 collections (www.pteridoportal.org).

Also forming the new records for South Central Mindanao are *Asplenium laserpitiifolium, D. geophilum, P. multicaudatum* and *P. celebica* which were all observed in the montane forest of MMPL. There were also ferns discovered by E. Copeland in 1917 which at that time were second occurrence records in the entire Philippines — *Sphaerostephanos urdanetensis, Cornopteris opaca, Cornopteris philippinensis*. Meanwhile, based on worldwide database for herbarium collections, two species in Mount Matutum recorded by Copeland in 1917 remained to be the only record so far in the country namely *G. peltophora* and *Diplazium calliphyllum*.

These new records in MMPL provide significant contribution to the biodiversity heritage of Mindanao island. Prior to this study, published accounts on pteridophyte diversity has largely been from two regions — 10 (Mt. Malindang & Mt. Kitanglad Range in Bukidnon) and 11 (Mt. Hamiguitan Range). The highest richness reported here was in Mt. Kitanglad Range which totalled to 439 with a total account of 632 species for the entire Mindanao island (Amoroso et al. 2011). It is expected then that the account on species richness will change with the results from this study.

Several species were also highlighted as useful either as medicine, food, or ornamental (Table 2). Tree ferns (*Alsophila, Sphaeropteris*) have been used as source

Table 2. Economic uses from several new records of ferns and lycophytes in MMPL.

Species	Uses	Reference
Adiantum spp.	Ornamental	Oloyede 2012
Angiopteris evecta Sw.	Medicinal. Leaf extract used to treat dysentery, blood diseases and ulcers. Spores used to treat leprosy and other skin diseases. Antiviral, antihyperglycemic and analgesic	Benjamin 2011
Asplenium cuneatum Lam.	Medicinal. Vermifuges (anthelmintic)	Burkill 1985
Asplenium spp.	Ornamental	Simpson 2019
Christella dentata (Forssk.) Brownsey & Jermy	Medicinal. Anti-bacterial. Antihyperglycemic and analgesic activity of leaves	Srivastava 2007; Manhas et al. 2018
Drynaria spp.	Ornamental	Simpson 2019
Dryopteris spp.	Medicinal. Abortifacient, anthelmintic. Food. Rhizomes source of fats (90% monoethenoid acids)	May 1978; Srivastava 2007; Mannan et al. 2008;
Lycopodium clavatum L.	Medicinal. Emetic for stomach disorders, cure for kidney and lung diseases, analgesic, antioxidant, anti-cancerm anti-inflammatory, neuroprotective, immunomodulatory and hepatoprotectivel nosebleeding and heal wounds , treatment for learning and memory impairment ,diuretic and anti-spasmatic , cure headaches . Household Material (mats)	May 1978; Srivastara 2007; Benjamin 2011; Oloyede 2012;; Hanif et al. 2015; Bhardwaj & Misra 2018
Pseudodiphasium volubile (G. Forst.) Holub	Ornamental. Table decoration	Benjamin 2011
Odontosoria chinensis (L.) J. Sm.	Medicinal. Cure for chronic enteritis. Ornamental. landscape plant	Ho et al. 2010; Oloyede 2012
Tree ferns *(Alsophila, Sphaeropteris)*	Food. Rhizomes as source of starch	Ripperton 1924; Leach 2003

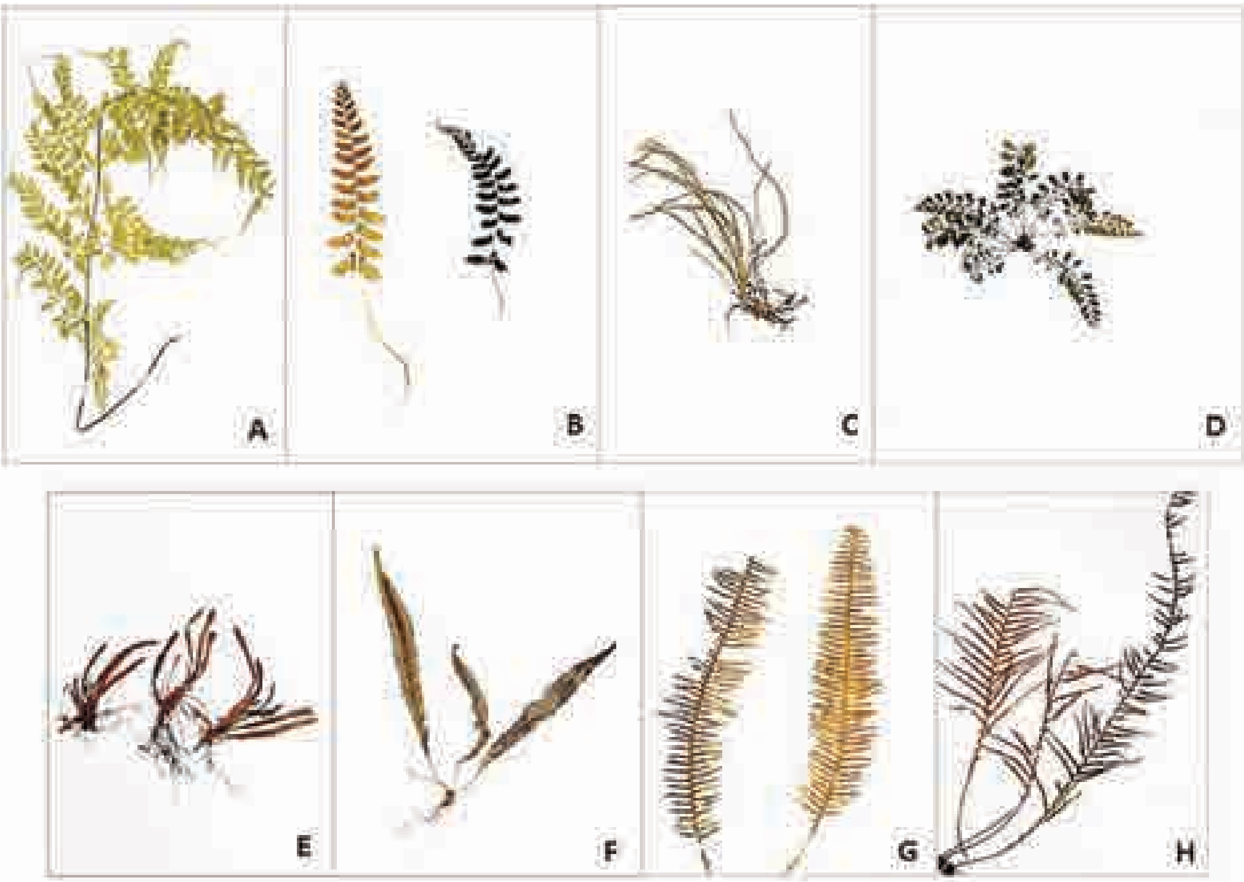

Image 2. Noteworthy Ferns in MMPL: First distribution record in South Central Mindanao Region A—*Asplenium laserpitifolum* (Habit: Epiphyte/ Lithophyte, Elevation: 1,300 m) | B—*Athyrium nakanoi* (Habit: Ground, Elevation: 2,100 m) | C—*Calymmodon gracilis* (Habit: Epiphyte, Elevation: 2,100 m) D—*Diplazium geophilum* (Habit: Ground, Elevation: 2,000 m) | E—*Oreogrammitis jagoriana* (Habit: Epiphyte, Elevation: 2,100 m) | F—*Oreogrammitis reindwartii* (Habit: Epiphyte, Elevation: 2,000 m) | G—*Prosaptia celebica* (Habit: Epiphyte, Elevation: 2,100 m) | H—*Prosaptia multicaudatum* (Habit: Epiphyte, Elevation: 2,100 m).

of starch in Hawaii (Ripperton 1924; May 1978; Leach 2003) while in India it is sought from stems of giant ferns *Angiopteris* (Liu et al. 2012). Starch is an important product worldwide used for different purposes – preservative, thickening agent, food enhancer and stabilizer and key ingredients in pastas, soups, sauces (Mason 2009; Egharevba 2019). Fern starch has been used as additive along with rice, potato and corn flour in the production of liquor and soft drinks (Liu et al. 2012). Meanwhile, fats from rhizomes have been extracted from *Dryopteris* which contains 90% monoethenoid (unsaturated) acids (May 1978).

Medicinal ferns have been used since ancient times for common diseases — gastric, inflammatory, infections, because of the ethnobotanical knowledge on their potential as antibacterial, anti-inflammatory, diuretics and pain killers passed on to generations (Ho et al. 2010). Medicinal value was identified in *Lycopodium clavatum, Selaginella involvens, Angiopteris evecta, Christella dentata, Asplenium cuneatum,* and *Dryopteris* species while ornamental uses were featured in several *Asplenium*, *Adiantum* and, *Drynaria* species, and in *Odontosoria chinensis* and *Pseudodiphasium volubile* (Table 2). On the other hand, ornamental ferns have been sought to provide aesthetic value for the enjoyment of the public and potentially for environmental protection and management (Oloyede 2012) and interestingly, more money is spent for this than for all other uses (May 1978).

Notable from the list of new records is *L. clavatum* having been widely documented for medicinal purposes. It has been known as emetic for stomach disorders (Srivastava 2007), cure for kidney and lung diseases, analgesic, antioxidant, anti-cancer, anti-inflammatory, neuroprotective, immunomodulatory, and hepatoprotective (Bhardwaj & Misra 2018). It was also explored as potent treatment for learning and memory impairment (Hanif et al. 2015). It is diuretic

Image 3. Noteworthy Ferns in MMPL: A —Herbarium collection from Pteridophyte Collections Consortium of *Diplazium calliphyllum* by Copeland (1917), the only record in the country | B—Field picture of *Gleichenia peltophora*, also the only record in the country recorded by Copeland (1917) | C—Field picture of *Dicksonia amorosoana*, the second distribution record for Mindanao and the country; first discovered in Mount Apo, North Cotabato.

and anti-spasmatic and also smoked with *Selaginella rupestris* to cure headaches (Watt & Brandwijk 1962). In Sweden, *L. clavatum* is also woven into mats (May 1978).

The checklist of new records for MMPL highlights the significance of the landscape as biodiversity area in South Central Mindanao. It confirms the favorable microenvironment brought about by stable ecosystem processes in the landscape (MMPL), thereby able to house unique plants, enhancing the natural heritage. The discovery of these new records after more than 100 years, is a significant achievement, realizing that there had been few explorations in between then and now. Moreover, knowledge of species occurrence is crucial to biodiversity conservation as this provides basis for scientific-based efforts to restore diversity at its different levels (Pavlik 1995; Mehltreter 2010; Cutko 2009; Green et al. 2009; Weigelt et al. 2019). It is perceived that this study would jumpstart the continuous and regular monitoring and inventory of pteridophytes in order to aid planning, management, and policy development for the protected area. This would further lead to the inclusion of MMPL pteridophyte flora in national and worldwide botanical data and provide extensive compilation of geographic species at regional, national, and global levels.

The discovery of many economic uses of ferns and lycophytes is very instrumental to raising awareness and appreciation on the utilitarian values of this plant group. Studies to elucidate the bioactive products found in its various plant parts have led to its integration in drug discovery and potential use for various chronic and infectious diseases (Ho et al. 2010; Baskaran et al. 2018). Likewise, its ornamental values serve a pivotal role in environmental protection and management interventions and can be harnessed to improve environmental landscapes (Oloyede 2012). As the country is among the richest in pteridophyte diversity in Asia, avenues for expanding current knowledge on their utilitarian as well as ecological values are numerous, waiting to be explored.

Conservation status of the new records

With reference to IUCN Threatened List 2021, it can be grasped that all new records in MMPL belong to the Not Assessed (NA) category. The DAO-2017-11 of DENR is another reference which also integrated the national red list of threatened species (in reference to IUCN) developed in 2008 by Fernando et al. (2008). From this, a total of 11 species from new records were in the threatened category. The rest belong to other wildlife species (OWS) which refers to the native species in the landscape that were not classified to any of the threatened category. Meanwhile, seven of these new records were found to be endemic, confined only in the country.

Local assessment tool based on the relative frequency values showed a different picture as many of the OWS in DAO were placed in threatened category (Table 3). From the NA of IUCN, the OWS of DAO and native species which is roughly the least-concerned at national, and global levels, 20 were classified under CR, 44 under EN, sixVU and nine NT. Only nine species were noted to be relatively the same with least concerned status. Meanwhile, from the not threatened but endemic species (NA in IUCN, OWS in DAO and Endemic), two were found to be CR, three EN and one VU.

Under the threatened and native species category (NA in IUCN, threatened in DAO, native), one was found as CR, three were endangered, two vulnerable, one NT and four were LC. Further, the threatened and endemic category enlisted one VU and three LC species.

The local conservation status developed in this study is a simple categorical classification intended to have an immediate reference for conservation priority of pteridophyte species in MMPL. It is a vital alternative in the absence of data from IUCN which generally considers global distribution of high-valued plant species (Langenberger 2006; Villanueva & Buot 2020). As can be drawn from this study, the new records in MMPL were not yet assessed in IUCN except for one species, *Sphaeropteris glauca,* which was classified as least concerned. Some were also highlighted in the national list DAO 2017–11. The use of relative frequency scores could serve as reliable representation of the species' adaptation, higher RF as widely-adapted while low RF values depict restricted-range species. It is significant as in the case of MMPL which needs immediate reference as scientific information is scarce. Moreover, it can be modified in the future to include other factors that may influence their diversity and distribution such as harvest use, economic uses, threats, and other ecological factors similar to those highlighted in several works (Bacchetta et al. 2012; Rana et al. 2020; Villanueva & Buot 2020).

High priority species based on local assessment along with their endemicity and threatened status at the national level (DAO 2017–11) would serve as basis for inclusion in management plans and advocacy interventions for MMPL. Based on frequency records, these species are not widely-adapted and their elevation range is limited. Alongside that is the gradual increase of human-led activities that can potentially threaten the health of the landscape. The rise of tourist sites, plantation areas, and human settlements around MMPL, collection of wildlife species in prohibited zones, and unauthorized trekking activities in MMPL would in the long run cause degradation of the landscape. Moreover, majority of these locally threatened flora are found along montane to upper montane forest (1,600–2,000 m). As such, this study proposed for the recognition of this altitudinal range as fern biodiversity hotspot. As such, conservation programs can be focused towards the species in this zone as they could be the most sensitive to environmental changes and may in the future vanish in the landscape.

CONCLUSION

The discovery of more than one hundred new records for South Central Mindanao region and MMPL highlights its rich natural heritage and confirms its significance as key biodiversity area for pteridophytes. It is a significant addition to current botanical information as it addressed gaps in knowledge of ferns and lycophytes. The determination of conservation priority species and hotspot fern area (1,600–2,000 m) is hoped to serve as vital reference for the integration of pteridophytes in local conservation plans for MMPL.

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Table 3. New records in MMPL highlighting their category as to geographic distribution, international (IUCN), national (DAO) and local assessment based on relative frequency (RF).

Families and Species Composition	Species category as regards geographic distribution	IUCN 2021	DAO 2017-11	Relative Frequency (RF)	Local Assessment based on RF
1. Lycopodiaceae					
Huperzia javanica (Sw.) Fraser-Jenk.	Indigenous	NA	OWS	0.403	VU
Lycopodium clavatum L.	Indigenous	NA	OWS	0.109	EN
Phlegmariurus delbrueckii A.R. Field & Bostock	Indigenous	NA	OWS	0	CR
Phlegmariurus verticullatus (L.f) A.R. Field	Indigenous	NA	OWS	0.019	CR
Pseudodiphasium volubile (G. Forst.) Holub	Indigenous	NA	OWS	0	CR
2. Selaginellaceae					
Selaginella boninensis Baker	Indigenous	NA	OWS	0.33	EN
Selaginella biformis A. Br. ex Kuhn	Indigenous	NA	OWS	0.11	EN
Selaginella cupressina (Willd.) Spring	Indigenous	NA	OWS	0.11	EN
Selaginella engleri Hieron.	Indigenous	NA	OWS	0.22	EN
Selaginella gastrophylla Warb.	Indigenous	NA	OWS	0.7	NT
Selaginella involvens (Sw.) Spring	Indigenous	NA	OWS	0.44	VU
Selaginella remotifolia Spring	Indigenous	NA	OWS	0.28	EN
1. Aspleniaceae					
Asplenium affine Sw.	Indigenous	NA	OWS	0	CR
Asplenium cuneatum Lam.	Indigenous	NA	OWS	0.14	EN
Asplenium elmeri Christ	Indigenous	NA	OWS	0.31	EN
Asplenium horridum Kaulf. *Asplenium laserpitiifolium* Lam.	Indigenous Indigenous	NA NA	OWS OWS	0.31 0.21	EN EN
Asplenium lobulatum Mett.	Indigenous	NA	OWS	1.56	LC
Asplenium longgisimum Blume	Indigenous	NA	OWS	0.7	NT
Asplenium pellucidum Lam.	Indigenous	NA	OWS	0.44	VU
Hymenasplenium excisum (C. Presl) S. Linds.	Indigenous	NA	OWS	2.19	LC
Hymenasplenium subnormale (Copel.) Nakaike	Indigenous	NA	OWS	0.22	EN
2. Athyriaceae					
Athyrium nakanoi Makino	Indigenous	NA	EN	0.33	EN
Athyrium puncticaule (Blume) T. Moore	Indigenous	NA	OWS	0.22	EN
Cornopteris banaohensis (C. Chr.) K. Iwats. & M.G. Price	Indigenous	NA	OWS	0	CR
Diplazium dilatatum Blume	Indigenous	NA	OWS	1.44	LC
Diplazium geophilum Alderw.	Indigenous	NA	OWS	0.38	EN
Diplazium pseudocyatheifolium Rosenst.	Indigenous	NA	EN	0.22	EN
3. Cyatheaceae					
Alsophila apoensis (Copel.) R.M. Tryon	Endemic	NA	EN	0.42	VU
Alsophila hermannii R.M. Tryon *Sphaeropteris elmeri* (Copel.) R.M. Tryon	Endemic Endemic	NA NA	EN VU	1.56 0.28	LC EN
Sphaeropteris glauca (Blume) R.M. Tryon	Indigenous	LC	EN	1.69	LC
Alsophila heterochlamydea (Copel.) R.M. Tryon	Endemic	NA	VU	1.56	LC
Sphaeropteris lepifera (J.Sm. ex Hook.) R.M. Tryon	Indigenous	NA	EN	0.28	EN
4. Dennstaedtiaceae					
Histiopteris incisa (Thunb.) J.Sm.	Indigenous	NA	OWS	0.88	NT
Microlepia enulose (Thunb.) C. Presl	Indigenous	NA	OWS	0.22	EN

Families and Species Composition	Species category as regards geographic distribution	IUCN 2021	DAO 2017-11	Relative Frequency (RF)	Local Assessment based on RF
Monachosorum henryi Christ	Indigenous	NA	OWS	2	LC
5. Dicksoniaceae					
Dicksonia amorosoana Lehnert & Coritico	Endemic	NA	OWS	0.42	VU
6. Dryopteridaceae					
Bolbitis enulosete (C. Presl) Ching	Indigenous	NA	OWS	0.42	VU
Dryopteris hendersonii (Bedd.) C. Chr.	Indigenous	NA	OWS	0.22	EN
Dryopteris purpurascens (Blume) Christ	Indigenous	NA	OWS	0	CR
Dryopteris permagna M. Price	Indigenous	NA	EN	0	CR
Polystichum moluccense T. Moore	Indigenous	NA	EN	0.82	NT
Polystichum elmeri Copel.	Endemic	NA	OWS	0.18	EN
Teratophyllum aculeatum (Blume) Mett. ex Kuhn	Indigenous	NA	OWS	0	CR
7. Hymenophyllaceae					
Abrodictyum pluma (Hook.) Ebihara & K.Iwats.	Indigenous	NA	OWS	0.56	VU
Abdrodictyum obscurum (Blume) Ebihara & K. Iwats.	Indigenous	NA	OWS	0.31	EN
Crepidomanes minutum (Blume) K. Iwats.	Indigenous	NA	OWS	0	CR
Crepidomanes grande (Copel.) Ebihara & K. Iwats.	Indigenous	NA	OWS	0.14	EN
Hymenophyllum ramosii Copel.	Indigenous	NA	OWS	0	CR
Hymenophyllum denticulatum Sw.	Indigenous	NA	OWS	0.11	EN
Hymenophyllum fimbriatum J. Sm.	Indigenous	NA	OWS	0.94	NT
Hymenophyllum holochilum (Bosch) C. Chr.	Indigenous	NA	OWS	0	CR
Hymenophyllum imbricatum Blume	Indigenous	NA	OWS	0.88	NT
Hymenophyllum nitidulum (Bosch) Ebihara & K. Iwats.	Indigenous	NA	OWS	0.14	EN
Hymenophyllum pallidum (Blume) Ebihara & K. Iwats.	Indigenous	NA	OWS	0.94	NT
Hymenophyllum serrulatum (C. Presl) C. Chr.	Indigenous	NA	OWS	0.19	EN
Hymenophyllum thiudium Harrington	Indigenous	NA	OWS	0.12	EN
Vandenboschia auriculata (Blume) Copel.	Indigenous	NA	OWS	0.11	EN
8. Hypodematiaceae					
Leucostegia truncata (D. Don) Fraser-Jenk.	Indigenous	NA	OWS	0.88	NT
9. Lindsaceae					
Lindsaea pulchella (J. Sm.) Mett. ex Kuhn	Indigenous	NA	OWS	0.14	EN
Odontosoria retusa (Cav.) J. Sm.	Indigenous	NA	OWS	0.14	EN
Osmolindsaee odorata (Roxb.) Lehtonen & Lehtonen	Indigenous	NA	OWS	0.14	EN
Tapeinidium gracile (Blume) Alderw.	Indigenous	NA	OWS	0.14	EN
Tapeinidium pinnatum (Cav.) C. Chr.	Indigenous	NA	OWS	0.28	EN
10. Mariatiaceae					
Angiopteris evecta Sw.	Indigenous	NA	OTS	1.56	LC
Ptisana pellucida (C. Presl) Murdock	Indigenous	NA	OWS	1.31	LC
11. Oleandraceae					
Oleandra sibbaldi Grev.	Indigenous	NA	OWS	0.14	EN
12. Ophioglossaceae					
Botrychium daucifolium Wall. ex Hook. & Grev.	Indigenous	NA	OWS	0.75	NT

Families and Species Composition	Species category as regards geographic distribution	IUCN 2021	DAO 2017-11	Relative Frequency (RF)	Local Assessment based on RF
13. Plagiogyriaceae					
Plagiogyria glauca (Blume) Mett.	Indigenous	NA	OWS	1.38	LC
14. Polypodiaceae					
Calymmodon gracillimus (Copel.) Nakai ex H. Itô	Indigenous	NA	OWS	0.13	EN
Chrysogrammitis glandulosa (J.Sm.) Parris	Indigenous	NA	OWS	0.14	EN
Dasygrammitis malaccana (Baker) Parris	Indigenous	NA	OWS	0.44	VU
Drynaria aglaomorpha Christenh.	Indigenous	NA	VU	0.22	EN
Drynaria descensa Copel.	Endemic	NA	OWS	0.11	EN
Goniophlebium persicifolium (Desv.) Bedd.	Indigenous	NA	OWS	1	NT
Goniophlebium pseudoconnatum (Copel.) Copel.	Indigenous	NA	OWS	1.44	LC
Goniophlebium subauriculatum (Blume) C. Presl	Indigenous	NA	OWS	0	CR
Leptochilus insignis (Blume) Fraser-Jenk.	Indigenous	NA	OWS	0	CR
Loxogramme avenia (Blume) C. Presl	Indigenous	NA	OWS	0.06	CR
Loxogramme paralella Copel.	Indigenous	NA	OWS	0.06	CR
Loxogramme scolopendriodes (Gaudich.) C.V.Morton	Indigenous Indigenous	NA NA	OWS OWS	0 0.15	CR CR
Oregrammitis beddomeana (Alderw) T.C. Hsu *Oreogrammitis jagoriana* (Mett. ex Kuhn) Parris & Sundue	Indigenous Indigenous	NA NA	OWS OWS	0.19 0.15	EN CR
Oreogrammitis reinwardtii (Blume) Parris	Indigenous	NA	OWS	0.14	EN
Oreogrammitis torricelliana (Brause) Parris	Indigenous	NA	OWS	0.11	EN
Prosaptia contigua (G. Forst.) C. Presl *Prosaptia celebica* (Blume) Tagawa & K. Iwats.	Indigenous Indigenous	NA NA	OWS OWS	0.14 0.15	EN CR
Prosaptia multicaudatum (Blume) Tagawa & K. Iwats.	Indigenous	NA	OWS	0	CR
Prosaptia venulosa (Blume) M.G. Price	Indigenous	NA	OWS	0.14	EN
Selliguea albidosquamata (Blume) Parris	Indigenous	NA	OWS	0.14	EN
Thylacopteris papillosa (Blume) Kunze ex J.Sm.	Indigenous	NA	OWS	0.33	EN
Tomophyllum macrum (Copel.) Parris	Endemic	NA	OWS	0.14	EN
Tomophyllum millefolium (Blume) Parris	Indigenous	NA	OWS	0.14	EN
15. Pteridaceae					
Adiantum hosei Baker	Indigenous	NA	OWS	0.75	NT
Antrophyum parvulum Blume	Indigenous	NA	OWS	0.14	EN
Pteris oppositipinnata Fee	Indigenous	NA	OWS	1.25	LC
Vaginularia junghunii Fee	Indigenous	NA	OWS	0.22	EN
16. Thelypteridaceae					
Chingia ferox (Blume) Holttum	Indigenous	NA	OWS	0	CR
Christella acuminata (Houtt.) Holttum	Indigenous	NA	OWS	0.89	NT
Christella dentata (Forssk.) Brownsey & Jermy	Indigenous	NA	OWS	0.11	EN
Pneumatopteris laevis (Mett.) Holttum	Indigenous	NA	OWS	0.75	NT
Pneumatopteris nitidula (C. Presl) Holttum	Endemic	NA	OWS	0	CR
Pronephrium nitidum Holttum	Indigenous	NA	OWS	0	CR
Sphaerostephanos ellipticus (Rosenst.) Holttum	Endemic	NA	OWS	0	CR
17. Tectariaceae					
Tectaria melanocaulos (Blume) Copel.	Indigenous	NA	OWS	0	CR
Tectaria dissecta (G. Forst.) Lellinger	Indigenous	NA	OWS	0	CR

Legend: NA (Not Assessed), OWS (Other Wildlife Species), CR (Critically endangered), EN (Endangered), NT (Near threatened), LC (Least Concern)

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COMMUNICATION

Some threatened woody plant species recorded from forests over limestone of the Philippines

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Abstract: This study was conducted to determine threatened woody plants in forests over limestone in Samar Natural Park (SINP), Guiuan Marine Resource Protected Landscapes and Seascapes (GMRPLS), and other areas in the Philippines, in order to design a strategic framework for sustainable conservation of threatened species. Combined fieldwork using standard vegetation techniques and comparative literature review were done. Results revealed a total of 196 woody plant species belonging to 48 families, with 60 (DAO 2017-11) and 182 (IUCN) threatened woody plant species in the forests over limestone. The top 10 important species noted include three Critically Endangered: *Diospyros longiciliata* Merr., *Cynometra cebuensis* Seidenschwarz, F., and *Shorea astylosa* Foxw; three Endangered: *Cinnamomum cebuense* Kosterm., *Tectona philippinensis* Benth. & Hook.f. and *Vitex parviflora* Juss.; and four Vulnerable species: *Agathis philippinensis* Warb., *Aquilaria cumingiana* (Decne) Ridley, *Dipterocarpus gracilis* Blume, and *Shorea polysperma* (Blanco) Merr. A framework for sustainable conservation has been designed to prevent the loss of these threatened botanical treasures.

Keywords: Karst forest, native plants, Philippine teak, Samar Island, Verde Island Passage.

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INTRODUCTION

Forests over limestone (karst forests) have unique geomorphological features that result from the dissolution of soluble bedrock, usually carbonates (Day & Urich 2000). Tropical forests over limestone occur in southern Mexico, central America, the Caribbean, and southeastern Asia including the Philippines, which have roughly 35,000 km^2 of karst forests (Piccini & Rossi 1994). Generally, plants experience more stress in this type of forest due to shallow soil substrates, high temperature, and other limiting factors. Hence, unique plants abound and are expected to possess secondary metabolites with high potential against stressors. Plants in forests over limestone are valuable sources of wood and non-wood products for nearby village communities. They also serve as food, medicine, shade plants and perching materials for local fauna and forest pollinators, sustaining life cycles, and ecosystem dynamics. Anthropogenic pressures can result in overharvesting, deforestation, and biodiversity loss.

Karst forests in the Philippines harbor rich biodiversity, but some are also threatened due to human pressures. These include Mount Lantoy in Cebu Island, one of the 117 terrestrial areas designated as Key Biodiversity Areas (KBA) based on vulnerability and irreplaceability criteria (Lillo et al. 2019, 2020, 2021). The area has two Critically Endangered, two Endangered, four Vulnerable, and 16 restricted-range species (CI/DENR-PAWB/Haribon 2006). In another site Cadiz & Buot (2009, 2010) assessed the native trees and woody plants in Cantipla and Tabunan forests in Cebu City. The Cantipla forest clusters were once a continuous forest cover that was part of the Central Cebu National Park (CCNP) and the Kotkot-Lusaran Watershed. On the other hand, the Tabunan forest covers at least 40 ha and is the only large patch of natural virgin forest left in Metro Cebu Watershed and the home to the endemic but threatened *Cinnamomum cebuense* (Quimio 2006). Another unique forest over limestone is found along Verde Island Passage, Batangas, Luzon Island where the endemic Philippine teak, *Tectona philippinensis* Benth. & Hook.f., is a dominant component (Caringal et al. 2019, 2021).

One of the most extensive forests over limestone in the Philippines is in Samar Island Natural Park (SINP) and Guiuan Marine Resource Protected Landscapes and Seascapes (GMRPLS). A number of studies have shown that these areas are rich in biodiversity (Fernandez et al. 2020; Tolentino et al. 2020; Madera et al. 2021; Obeña et al. 2021; Villanueva et al. 2021a,b; Delos Angeles et al. 2022; Tandang et al. 2022). In a series of biodiversity assessments conducted in various municipalities of Samar Island, it was revealed that the municipality of Paranas has been recorded to have 99 plant species from 63 genera and 44 families (Villanueva et al. 2021a). Furthermore, the municipality of Basey has a total of 67 plant species representing 54 genera and 38 families (Villanueva et al. 2021b), and 30 floral species representing 22 genera and 18 families were recorded in Taft, Eastern Samar (Obeña et al. 2021). Fernandez et al. (2020) recorded 41 floral species belonging to 17 families and 24 genera from Calicoan Island in Guiuan, eastern Samar.

Samar Island, specifically the SINP and the GMRPLS, have been severely degraded despite enforced protective policies such as the National Integrated Protected Areas System (NIPAS) Act of 1992. In the last 70 years, there has been significant logging and forest clearing for agricultural purposes in the area (UNDP-GEF 2014). Other threats (SEARCA 2004), include coal and chromite mining, unregulated limestone quarrying, charcoal production, over-harvesting of non-timber forest products (including rattans), pollution from industries, alien species invasion, and the proliferation of small-scale illegal logging. These activities contribute to forest destruction and pose a significant threat to the biodiversity of the island's forests over limestone ecosystem. If current trends continue, these activities could have serious consequences for both plant populations and the livelihoods of the people who rely on forest resources. Unfortunately, species decline from various locations throughout the country has not yet been documented for inclusion in the Philippine red list or the IUCN. Hence, the need to investigate the threatened woody plants in forests over limestone and their conservation status and catalyze additional actions and potentially save a species from extinction (Zahler & Rosen 2013), particularly in areas where future plant species endangerment is expected to be high (Giam et al. 2010). The study specifically aims to: 1) determine the threatened woody plants species in forests over limestone in Samar Island and in other parts of the Philippines and 2) design a strategic framework for sustainable conservation of forests over limestone threatened species.

Information on threatened woody species in limestone forests in the Philippines is critical because it can have a direct impact on human well-being and will help decision makers and stakeholders in better understanding the significance of this study in achieving the United Nations Sustainable Development Goals, specifically, SDG 1 (no poverty), SDG 6 (clean water and sanitation), SDG 8 (decent work and economic growth), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), SDG 13 (climate action), and SDG 17 (partnership to achieve the goal).

MATERIALS AND METHODS

The study sites

The primary study area inventoried. Samar Island is the third-largest island in the Philippines archipelago, covering an area of 13,107 km^2 and extending between 10.75-12.75 °N & 124.25-124.75 °E (PhilGIS 2016). The island is considered a botanical diversity hotspot in both the country and the Malesian region (Madulid 2000).

SINP (Figure 1) contains 333,300 ha of the protected area and 125,400 ha of buffer zone, making it the Philippines' largest terrestrial protected area (UNDP-GEF 2014). The park was designated as a forest reserve in 1996, but it was elevated to the status of a natural park in 2003 by Presidential Proclamation No. 442 in accordance with Republic Act No. 7586 (NIPAS Act of 1992). The SINP is situated in Samar island's low rugged central mountain range, which is shared by all three provinces on the island. SINP is made up of 13 municipalities and one city in the province of Samar, 19 municipalities in the province of Eastern Samar, and five municipalities in northern Samar. The interior natural habitats of Samar Island are dominated by lowland evergreen rainforests and limestone forests (UNDP 2007; Taylor et al. 2015). It also has an interior highland with distinct accordant peaks and a surrounding limestone or karst terrain. The landscape in the southern part is made up of jungle-covered limestone ridges. Its geology is predominantly Miocene and Holocene, with a sedimentary formation composed of basement rocks and overlying clastic rocks or limestone (Patindol 2016). It has high biodiversity and is a center of plant and animal diversity and endemism in the Philippines, home to several threatened species from the Eastern Visayas and Mindanao biogeographic regions (Madulid 2000).

GMRPLS (Figure 1), is a protected area located off the coast of the municipality of Guiuan situated in the Province of Eastern Samar, Philippines. It was designated as a protected area by virtue of Presidential Proclamation No. 469 in 1994 and consists of the following islands: Calicoan, Manicani, Suluaan, Tubabao, Victory, Homonhon, and other smaller islands and their surrounding reefs. It also includes the coastal area of mainland Guiuan, which totals 60,448 ha. The land that is now part of the conservation area was previously designated as a Marine Reserve and Tourist Zone in 1978, and it was placed under the administration and control of the Philippine Tourism Authority. It was re-proclaimed and re-classified as a protected landscape/seascape in 1994 under the National Integrated Protected Areas System Act of 1992.

Based on Modified Corona's Climate Classification, Samar Island is divided into two regions. The northeastern part manifests the Type II climate which has no dry season and has a pronounced rain period, particularly during December and January. The southeastern region has a Type IV climate, with rainfall distributed fairly evenly throughout the year. Throughout the year, the island has a humid climate (Kintanar 1984).

Other forests over limestone cited. Other forests over limestone were cited in available literature and included in the analysis (Figure 2). These are Cantipla forest (Cadiz & Buot 2009) and Mount Tabunan (Cadiz & Buot 2010) of Cebu City, Mount Lantoy of southern Cebu (Lillo et al. 2019, 2020, 2021), and the coastal landscapes and seascapes of the Verde Island Passage, Batangas, southern Luzon (Caringal et al. 2019, 2021).

Like the SINP and the GMRPLS, these other forests over limestone were threatened. Mount Lantoy forests declined significantly during the Spanish colonial period to provide lumber for the construction of Spanish galleons (Asia Magazine 1984). Recently, Bensel (2008) reported that agricultural expansion and fuelwood gathering are still increasing – putting pressure on this Cebu's last remaining forests. Respondents also reported illegal logging, hunting, and widespread conversion of forests to agriculture. Despite these, Mount Lantoy KBA is rated moderately disturbed according to the Beynen & Townsend (2005) scoring system. This means that the recorded disturbances and threats in the area do not have critical effects yet on species diversity for the time being. It could not, however, deny the deterioration of native trees that affects the biodiversity, the ecosystem, and the community surrounding Mount Lantoy KBA.

Similarly, even though Cantipla forest was part of the CCNP and Tabunan forest is in the strict protection zone, their forest resources are still being exploited by the local residents. On its first botanical survey in May 1970, most of the dipterocarp forests in Cantipla had already been destroyed (Colina & Jumalon 1974), and the destruction was accelerated due to the widespread practice of swidden agriculture. Similarly, there is occasional tree cutting and rattan harvesting within the Tabunan forest, and its forest exterior is dominated by

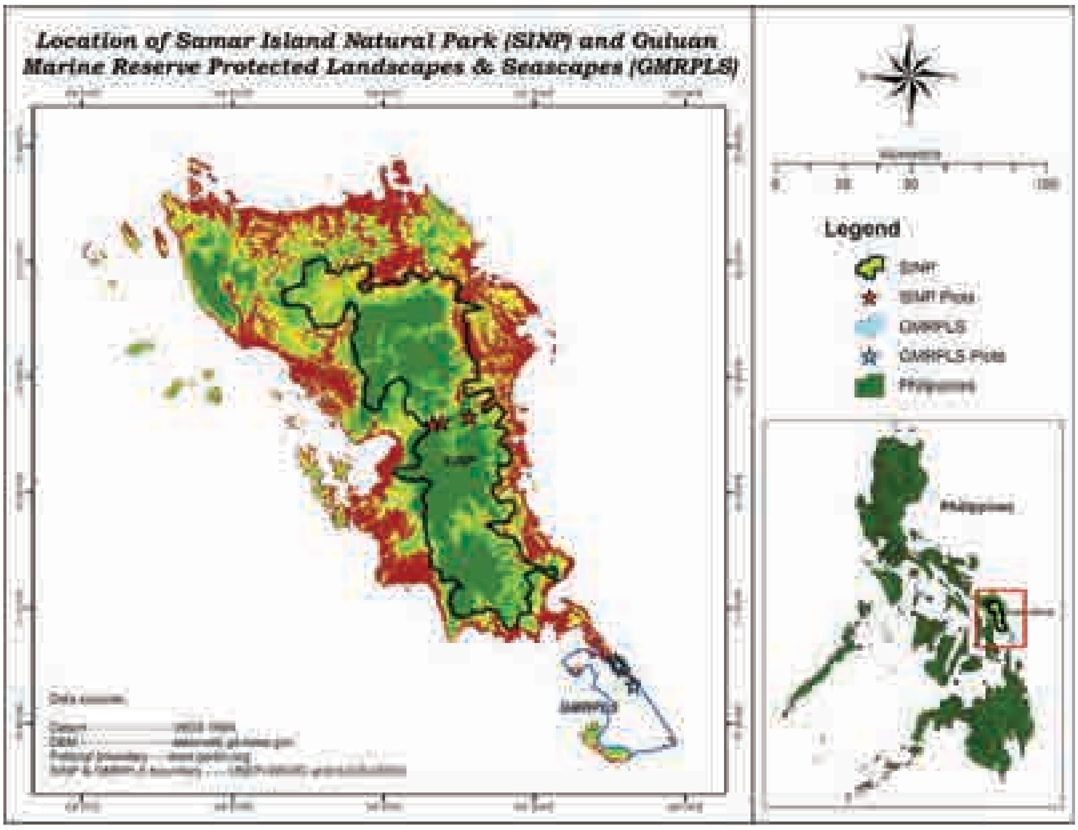

Figure 1. Location of the research area where the authors did the actual fieldwork.

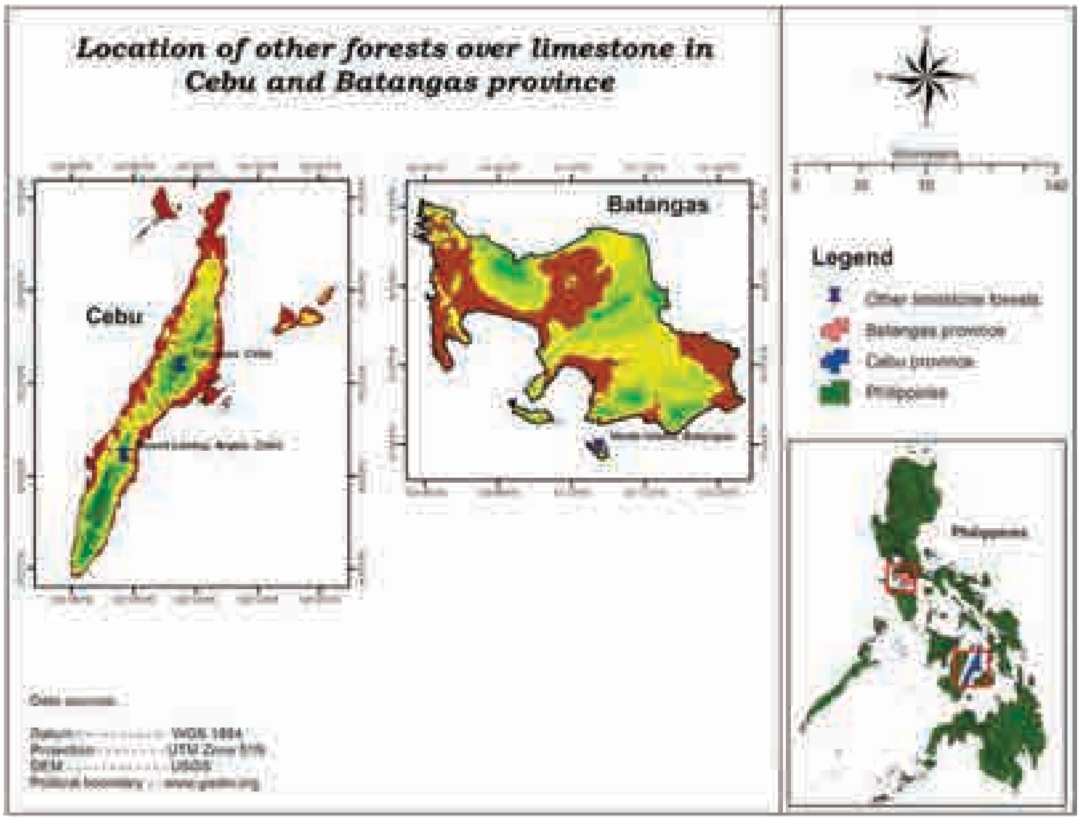

Figure 2. Locations of some forests over limestone included in the study.

agricultural activities of the local residents. In fact, these activities contributed significantly to the reduction of the forested area by approximately 0.3% of its original forest cover (SSC 1988), which is mostly confined to rocky limestone cliffs.

Tectona philippinensis in the forests over limestone along Verde Island Passage, Batangas is an endangered species that has long been regarded as one of the most important floristic elements of this coastal forests over limestone (Madulid & Agoo 1990; DENR-UNEP 1997; Cordon et al. 2004). The tree is also an iconic species, a living witness to the Filipino people's economic and political history, as its wood was once used to repair galleon ships that plied the Manila-Acapulco route during the Spanish colonial era (ERDB 1998). Meanwhile, the number of remaining Philippine teak populations is decreasing due to rapid and continuous destructive human disturbances in the area. Land conversion (from forest to sugar apple plantation and coastal area to resorts), habitat destruction, ecotourism projects, quarry operation, development of road networks and lateral expansion of urban settlements, kaingin (slash and burn farming), accidental fire during summer months, and natural threats such as prolonged droughts caused by the El Nino phenomenon and pests and diseases are threats documented by Caringal (2004) and RDC-CALABARZON (2006).

Inventory of the woody species composition

The study was carried out through a combination of fieldwork using standard vegetation techniques in Samar Island, and extensive literature review of papers in forests over limestone in the Philippines. Two sets of field sampling methods were used to determine the plant composition. The quadrat or plot method (Mueller-Dombois & Ellenberg 1974) was used to assess trees (≤1 m) while the line intercept technique was used for understory species. The plots were purposely selected based on the heterogeneity of the plants and the presence and absence of human-related disturbances in the area. To assess the woody plant species, 27 20 x 20 m plots were established in SINP and GMRPLS last October 2019. Generally, 20 m is the longest distance that can be accurately surveyed in a dense forest (Dallmeier 1992). Two line transects, 5 m in length and subdivided with 1 m intervals, were established inside each sampling plot. Altitude and geographic location of each plot and plant species were determined using a geographic positioning system (GPS) device.

Besides fieldwork using standard vegetation techniques in Samar Island, extensive literature review was conducted, on papers related to forests over limestone in the Philippines. These include papers about the Cantipla forest, Cebu (Cadiz & Buot 2009), Mount Tabunan, Cebu (Cadiz & Buot 2010), Mount Lantoy, Cebu (Lillo et al. 2019, 2020, 2021), Verde Island Passage, Batangas (Caringal et al. 2021) and Basey, Samar (Villanueva et al. 2021b).

Experts were consulted to ascertain tree species identification. Nomenclature follows that of Dictionary of Philippine plant names (Madulid 2001, 2001a), Co's Digital Flora (Pelser et al. 2011 onwards), IPNI (2020), and POWO (2022).

Determining threatened taxa

The conservation status of woody plant species was determined using the list of threatened species identified by the Philippines' DENR Administrative Order No. 11 series of 2017 (DAO 2017) and the International Union for Conservation of Nature (IUCN) (IUCN 2022). DAO No. 2017-11 (DAO 2017) is the national reference for threatened species of the Philippines. This is being used by researchers and planners as basis in decision-making related to forest management and conservation. IUCN (IUCN 2022), on the other hand, is the global reference for threatened species of various countries. So, in this study, we made use of these two relevant documents as bases in determining the threatened status of the woody species in forests over limestone.

Designing a framework for conservation

The study proposes a framework for sustainable conservation of threatened species to put a stop to the current and continuing loss of woody plant species in the country. The framework was developed in response to conservation gaps identified in scientific publications, existing policies, reports, and measures that must be taken seriously towards protection and conservation of floral species in forests over limestone. It highlights the practicality and locally doable in situ and ex situ strategies and the extent and dedicated engagement of the government and the community as well as the stakeholders towards the conservation of the threatened woody taxa.

RESULTS AND DISCUSSION

Threatened woody plant species in forests over limestone

The study found 196 woody plant species belonging to 48 families in the forest over limestone in the

Philippines (Table 1). About half (40%) of the recorded species are endemic to the Philippines (DAO 2017-11; Pelser et al. 2011 onwards). Additionally, Moraceae family is the most represented family, having 16 documented species, followed by Fabaceae (16 species), Euphorbiaceae and Dipterocarpaceae, having 15 species each, and Rubiaceae and Sapindaceae, with 10 species each.

Meanwhile, for SINP and GMRPLS alone, a total of 85 (out of 196) woody plant species, including 37 families, were recorded, including the flora checklist in the municipality of Basey, Samar.

As shown in Table 1, 60 woody plant species in Philippine forests over limestone have conservation status recorded in DAO 2017-11, Philippines as follows: 11 Critically Endangered (CR), nine Endangered (EN), 30 Vulnerable (VU), and 10 other threatened species (OTS). The 37 (out of 60) species are endemic to the Philippines. On the other hand, IUCN classified 182 woody plant species in the Philippine forests over limestone with seven Critically Endangered (CR), 23 Endangered (EN), 26 Vulnerable (VU), 15 Near Threatened (NT), 110 Least Concern (LC), and one Data Deficient (DD) (Table 1). The 75 of the 182 woody species determined by IUCN are Philippine endemics. In addition, it was noticed that among the woody plant species in the Philippines, there are only five Endangered species, and seven Vulnerable species have the same conservation status in DAO 2017-11 and the IUCN.

Figures 3 and 4 show a comparison of the conservation status of threatened species found on Samar Island, Cebu, and Batangas based on DAO 2017-11 and IUCN. In contrast to the DAO 2017-11 assessment, many of the species found in limestone forests were classified in the IUCN conservation status assessment, as shown in Figure 3. Samar Island has 43 species classified by DAO 2017-11, with seven CR, five EN, 22 VU, and nine OTS, and 80 species classified by IUCN, with six CR, 13 EN, 17 VU, nine NT, and 35 LC. Mt. Tabunan has four species classified by DAO 2017-11 (one CR and three VU), and 41 species classified by IUCN (one CR, two EN, one VU, three NT, 33 LC, and one DD). *Mangifera altissima* Blanco is the only DD species found on Mt. Tabunan. This species was, however, classified as vulnerable in DAO 2017-11. Additionally, Mt. Cantipla has three species classified by DAO 2017-11 (two CR and one EN), while 23 species classified by IUCN (seven EN, three VU, two NT, and 11 LC). Mt. Lantoy has 17 species classified by DAO 2017-11 (two CR, three EN, nine VU, and three OTS), and 12 species classified by IUCN (two EN, three VU, one NT and six LC). Verde Island Passage has three species classified by DAO 2017-11, with two EN and one VU, and 50 species classified by IUCN, with two EN, three VU, and 45 LC, respectively (see Table 1; Figure 3, 4). Based on DAO 2017-11 and IUCN assessments, Samar Island has the highest number of CR, EN, VU, OTS, and NT species, while Verde Island Passage in Batangas has the highest number of Least Concern (LC) species (see Figure 2,3). The low number of species classified by DAO 2017-11 could be attributed to the fact that the Philippine red list was out of date, as the listing was made in 2017. This figure may change if the assessment and listing of threatened species in the Philippines are completely

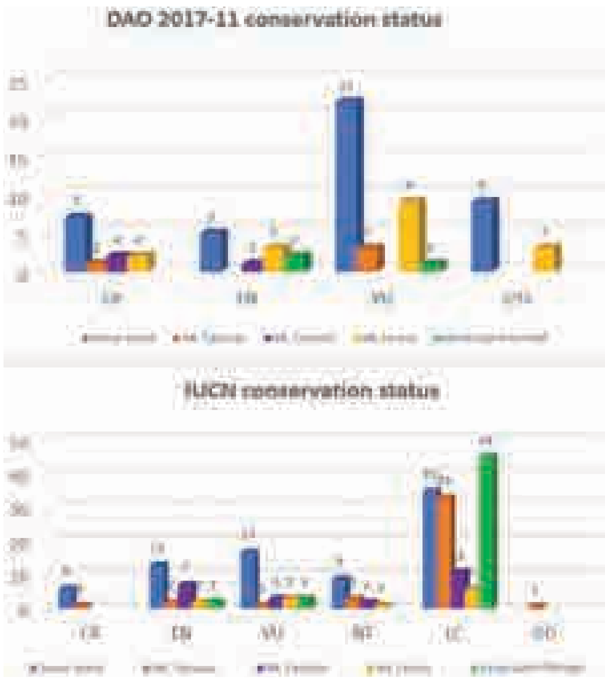

Figure 3. Conservation status of the threatened taxa in Samar Island, Mt. Tabunan, Mt. Cantipla, & Mt. Lantoy, Cebu, and Verde Island Passage, Batangas.

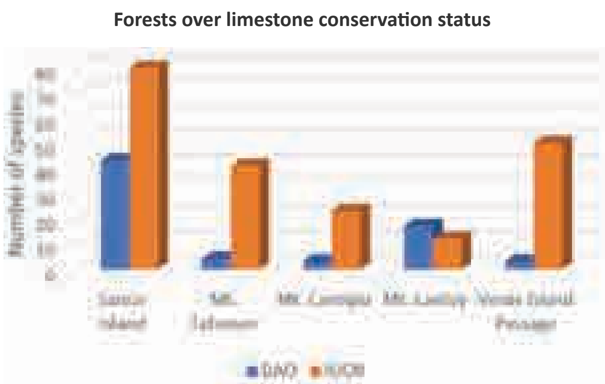

Figure 4. Comparison of assessments by IUCN & DAO of threatened woody species in forests over limestone.

Table 1. List of threatened woody plant species in forests over limestone in the Philippines.

	Family & scientific name	Common name	Location	Endemicity	Conservation status		References
					DAO 2017-11	IUCN	
1	**Achariaceae**						
	Hydnocarpus subfalcatus Merr.	Damol, Ngeret	Basey, Samar	Native	-	LC	Quimio (2016); Villanueva et al. (2021b)
2	**Anacardiaceae**						
	Dracontomelon dao (Blanco) Merr. & Rolfe	Dao	Basey, Samar	Native	VU	LC	Quimio (2016); Villanueva et al. (2021b)
	Mangifera altissima Blanco	Paho	Mount Tabunan, Cebu	Endemic	VU	DD	Cadiz & Buot (2010)
	Mangifera monandra Merr.	Malapaho, Malipajo	Paranas, Samar	Endemic	VU	NT	Villanueva et al. (2021a)
3	**Annonaceae**						
	Annona squamosa L.	Sugar Apple, Atis	Verde Island Passage, Batangas	-	-	LC	Caringal et al. (2021)
	Goniothalamus elmeri Merr.	Lanutan	Mount Tabunan, Cebu	Endemic	-	LC	Cadiz & Buot (2010)
	Goniothalamus lancifolius Merr.	Monat	Paranas, Samar	Endemic	EN	EN	Villanueva et al. (2021a)
	Orophea cumingiana S. Vidal	Amúnat, Karasákat, Lobanti	Paranas, Samar	Endemic	OTS	NT	Villanueva et al. (2021a)
4	**Apocynaceae**						
	Alstonia macrophylla Wall. Ex DC.	Batino, Devil Tree	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Alstonia scholaris (L.) R. Br.	Dita	Mount Tabunan, Cebu; Calicoan, Guiuan	Native	-	LC	Cadiz & Buot (2010); Fernandez et al. (2020)
	Kibatalia merrilliana Woodson	Merrill Pasnit	Paranas, Samar	Endemic	VU	EN	Villanueva et al. (2021a)
	Kibatalia puberula Merr.	Pasnit-mabolo	Paranas, Samar	Endemic	EN	EN	Villanueva et al. (2021a)
	Tabernaemontana pandacaqui Poir.	Banana Bush, Pandakaki	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Voacanga globosa (Blanco) Merr.	Bayag-usa, Testicle Tree, Alibutbut	Verde Island Passage, Batangas	Endemic	-	LC	Caringal et al. (2021)
	Wrightia pubescens R. Brown subsp. *Laniti* (Vidal) Ngan	Lanete	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
5	**Araliaceae**						
	Osmoxylon serratifolium (Elmer) Philipson	-	Mount Tabunan, Cebu	Endemic	-	EN	Cadiz & Buot (2009, 2010)
	Polyscias nodosa (Blume) Seem.	Malapapaya	Paranas, Samar	Native	-	LC	Villanueva et al. (2021a)
6	**Araucariaceae**						
	Agathis philippinensis Warb.	Almaciga	Basey, Samar	Native	VU	-	Quimio (2016); Villanueva et al. (2021b)
7	**Arecaceae**						
	Caryota rumphiana Mart.	Pugahan	Calicoan, Guiuan; Paranas, Samar	Native	-	LC	Fernandez et al. (2020); Villanueva et al. (2021a)
	Heterospathe intermedia (Becc.) Fernando	Banga, Marighoi	Calicoan, Guiuan; Taft, Eastern Samar; Paranas, Samar	Endemic	-	VU	Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021a)
	Oncosperma tigillarium (Jack) Ridl. Syn. *Filamentosum* Blume.	Anibong	Paranas, Samar	Native	VU	-	Villanueva et al. (2021a)
	Saribus rotundifolius (Lam.) Blume	Anahaw	Calicoan, Guiuan; Taft, Eastern Samar	Native	OTS	-	Fernandez et al. (2020); Obeña et al. (2021)
8	**Bignoniaceae**						
	Radermachera pinnata (Blanco) Seem. Syn. *R. Quadripinnata*	Banaybanay	Basey, Samar	Native	-	LC	Quimio (2016); Villanueva et al. (2021b)
9	**Boraginaceae**						
	Cordia dichotoma Forst.f.	Anonang, Soap Berry	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
10	**Burseraceae**						
	Canarium hirsutum Willd.	Milipili, Dulit	Cantipla, Cebu; Paranas, Samar; Basey, Samar	Native	-	LC	Cadiz & Buot (2009); Quimio (2016); Villanueva et al. (2021a, b)

	Family & scientific name	Common name	Location	Endemicity	Conservation status		References
					DAO 2017-11	IUCN	
	Canarium ovatum Engl.	Pili	Basey, Samar	Native	OTS	LC	Quimio (2016); Villanueva et al. (2021b)
	Garuga floribunda Decne *var. Floribunda*	Bogo, Kedondong	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
11	**Calophyllaceae**						
	Calophyllum soulattri Burm. F.	Pamintaogon	Mount Tabunan, Cebu; Calicoan, Guiuan; Taft, Eastern Samar; Paranas, Samar	Native	-	LC	Cadiz & Buot (2010); Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021a)
12	**Cannabaceae**						
	Celtis philippensis Blanco	Malaiino; Celtis, Malaikmo, Magabuyo	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Trema orientalis (L.) Blume	Andrarezina	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
13	**Capparidaceae**						
	Crateva religiosa Forst. F.	Balay-lamok	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
14	**Casuarinaceae**						
	Gymnostoma rumphianum (Miq.) L. Johnson	Agoho del Monte, Mountain Agoho	Mount Lantoy, Cebu; Paranas, Samar	Native	OTS	-	Lillo et al. (2019), Villanueva et al. (2021a)
15	**Clusiaceae**						
	Garcinia rubra Merr.	Kamandiis	Paranas, Samar	Endemic	-	NT	Villanueva et al. (2021a)
16	**Combretaceae**						
	Terminalia calamansanai (Blanco) Rolfe	Malakalumpit	Cantipla, Cebu	Native	-	LC	Cadiz & Buot (2009)
	Terminalia catappa Linn.	Talisay	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
17	**Cycadaceae**						
	Cycas riuminiana Regel	Pitogo, Bayit	Taft, Eastern Samar	Endemic	VU	EN	Obeña et al. (2021)
18	**Dilleniaceae**						
	Dillenia philippinensis Rolfe	Katmon	Basey, Samar	Endemic	-	NT	Quimio (2016); Villanueva et al. (2021b)
19	**Dipterocarpaceae**						
	Dipterocarpus gracilis Blume	Panau	Basey, Samar	Native	VU	VU	Quimio (2016); Villanueva et al. (2021b)
	Hopea foxworthyi Elmer	Dalingdingan	Basey, Samar	Endemic	CR	EN	Quimio (2016); Villanueva et al. (2021b)
	Hopea malibato Foxw.	Yakal-kaliot	Basey, Samar	Endemic	CR	VU	Quimio (2016); Villanueva et al. (2021b)
	Hopea philippinensis Dyer	Gisok-gisok, Gisok	Mount Tabunan, Cebu; Taft, Eastern Samar, Paranas, Samar	Endemic	CR	EN	Cadiz & Buot (2010); Obeña et al. (2021); Villanueva et al. (2021a)
	Hopea quisumbingiana Gutierrez	Quisumbing Gisok	Paranas, Samar	Endemic	CR	EN	Villanueva et al. (2021a)
	Hopea samarensis Gutierrez	Samar Gisok	Paranas, Samar	Endemic	CR	EN	Villanueva et al. (2021a)
	Parashorea malaanonan (Blanco) Merr.	Bagtikan	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Shorea almon Foxw.	Almon	Basey, Samar	Native	VU	NT	Quimio (2016); Villanueva et al. (2021b)
	Shorea astylosa Foxw.	Yakal	Calicoan, Guiuan; Taft, Eastern Samar; Paranas, Samar; Basey, Samar	Endemic	CR	EN	Quimio (2016); Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021a, b)
	Shorea contorta Vidal	White Lauan, Lawaan na Puti	Mount Tabunan, Cebu; Parana, Samar	Endemic	VU	LC	Cadiz & Buot (2010); Villanueva et al. (2021a)
	Shorea falciferoides Foxw. [= *Shorea gisok* Foxw.]	Yakal-yamban	Paranas, Samar	Native	VU	CR	Villanueva et al. (2021a)
	Shorea malibato Foxw.	Yakal-malibato	Cantipla, Cebu	Endemic	CR	VU	Cadiz & Buot (2009)

	Family & scientific name	Common name	Location	Endemicity	Conservation status		References
					DAO 2017-11	IUCN	
	Shorea negrosensis Foxw.	Red Lauan, Takuban	Calicoan, Guiuan; Taft, Eastern Samar; Paranas, Samar	Endemic	VU	LC	Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021a)
	Shorea polysperma (Blanco) Merr.	Tanguile	Mount Lantoy, Cebu; Basey, Samar	Endemic	VU	LC	Quimio (2016); Lillo et al. (2019); Villanueva et al. (2021b)
	Shorea squamata (Turcz.) Dyer ex S. Vidal	Mayapis	Basey, Samar	Endemic	-	LC	Quimio (2016); Villanueva et al. (2021b)
20	**Ebenaceae**						
	Diospyros bulusanensis Elmer syn. *D. Philippinensis*	Baganito, Oi-oi	Basey, Samar	Native	VU	NT	Quimio (2016); Villanueva et al. (2021b)
	Diospyros discolor Willd. [= *D.blancoi* A.DC]	Kamagong	Mount Tabunan, Cebu; Taft, Eastern Samar, Paranas, Samar	Native	VU	-	Cadiz & Buot (2010); Obeña et al. (2021); Villanueva et al. (2021a)
	Diospyros ferrea (Willd.) Bakh.	Batulinaw	Verde Island Passage, Batangas	Native	VU	-	Caringal et al. (2021)
	Diospyros longiciliata Merr.	Itom-itom	Mount Lantoy, Cebu	Endemic	CR	EN	Lillo et al. (2019)
	Diospyros pilosanthera Blanco	Bolong-eta	Mount Lantoy, Cebu	Native	VU	-	Lillo et al. (2019)
	Diospyros pyrrhocarpa Miq.	Anang	Mount Lantoy, Cebu	Native	VU	LC	Lillo et al. (2019)
21	**Elaeocarpaceae**						
	Elaeocarpus fulvus Elmer	Lanauting-dilau	Cantipla, Cebu	Endemic	-	EN	Cadiz & Buot (2009)
22	**Euphorbiaceae**						
	Blumeodendron kurzii (Hook.f.) J.J.Sm. Ex Koord. & Valeton [= *Blumeodendron philippinense* Merr. & Rolfe.]	Salngan	Mount Tabunan, Cebu; Basey, Samar	Native	-	LC	Cadiz & Buot (2010); Quimio (2016); Villanueva et al. (2021b)
	Drypetes globosa (Merr.) Pax & K. Hoffm.	Kalugkugan, Bato-bato	Cantipla, Cebu	Endemic	-	VU	Cadiz & Buot (2009)
	Glochidion philippicum (Cav.) C.B. Rob.	Iba-ibaan	Cantipla, Cebu	Native	-	LC	Cadiz & Buot (2009)
	Hancea cordatifolia (Slik) S.E.C.Sierra, Kulju & Welzen [=*Mallotus cordatifolius* Slik]	-	Basey, Samar	Endemic	-	CR	Slik (1988); Slik and van Welzen (2001); Villanueva et al. (2021b)
	Hancea wenzeliana (Slik) S.E.C.Sierra, Kulju & Welzen	Apanang	Calicoan, Guiuan; Paranas, Samar; Taft, Eastern Samar	Endemic	-	CR	Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021a);
	Macaranga bicolor Müll.Arg.	Pailig, Amilik, Baranti, Bagambang	Mount Tabunan, Cebu; Calicoan, Guiuan	Endemic	-	LC	Cadiz & Buot (2010); Villanueva et al. (2021a)
	Macaranga grandifolia (Blanco) Merr.	Takip-asin	Mount Tabunan, Cebu	Native	-	VU	Cadiz & Buot (2010)
	Macaranga hispida (Blume) Müll. Arg.	Lagapak	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Macaranga tanarius (L.) Müll.Arg.	Minunga, Binunga	Mount Tabunan, Cebu; Calicoan, Guiuan	Native	-	LC	Cadiz & Buot (2010); Fernandez et al. (2020)
	Mallotus cumingii Muell. –Arg	Apanang	Mount Tabunan, Cebu; Basey, Samar	Native	-	LC	Cadiz & Buot (2010); Quimio (2016); Villanueva et al. (2021)
	Mallotus philippensis (Lam.) Muell-Ang	Kamala Tree, Banato	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Melanolepis multiglandulosa (Reinw. Ex. Blume) Rchb. F. & Zoll.	Alim	Mount Tabunan, Cebu; Verde Island Passage, Batangas	Native	-	LC	Cadiz & Buot (2010); Caringal et al. (2021)
	Neoscortechinia arborea (Elmer) Pax & K.Hoffm. Syn. *N. Nicobarica* (Hook.f.) Pax & Hoffm	Magong	Cantipla, Cebu	Native	-	LC	Cadiz & Buot (2009)
	Neoscortechinia parvifolia (Merr.) Merr. Syn. *N. Philippinensis* (Merr.)	Magon-liitan	Cantipla, Cebu	Native	-	LC	Cadiz & Buot (2009)
	Tritaxis ixoroides (C.B.Rob.) R.Y.Yu & Welzen	Agindulong	Paranas, Samar	Endemic	-	VU	Villanueva et al. (2021a)

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					DAO 2017-11	IUCN	
23	**Fabaceae**						
	Acacia farnesiana (L.) Willd. Syn. *Vachellia farnesiana*	Aroma	Verde Island Passage, Batangas	-	-	LC	Caringal et al. (2021)
	Acacia mangium Willd.	Mangium	Cantipla, Cebu	-	-	LC	Cadiz & Buot (2009)
	Adenanthera intermedia Merr.	Tanglin	Mount Lantoy, Cebu	Endemic	OTS	VU	Lillo et al. (2019)
	Afzelia rhomboidea (Blanco) Vidal	Tindalo	Mount Lantoy, Cebu	Native	EN	-	Lillo et al. (2019)
	Albizia philippinensis Nielsen	Unik	Verde Island Passage, Batangas	Endemic	-	VU	Caringal et al. (2021)
	Albizia procera (Roxb.) Benth.	White Siris	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Albizia saponaria (Lour.) Miq.	Salingkugi	Basey, Samar	Native	-	LC	Quimio (2016); Villanueva et al. (2021b)
	Archidendron clypearia (Jack) I. C. Nielsen	Alobahay, Inep	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Bauhinia malabarica Roxb.	Alibangbang	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Cassia spectabilis L.	Antsoan-dilau	Cantipla, Cebu	-	-	LC	Cadiz & Buot (2009)
	Cynometra cebuensis F.Seid.	Nipot-nipot	Mount Lantoy, Cebu	Endemic	CR	-	Lillo et al. (2019)
	Cynometra copelandii (Elmer) Elmer	Matolog	Mount Taburan, Cebu	Endemic	-	CR	Cadiz and Buot (2010)
	Gliricidia sepium (Jacq.) Kunth ex Walp.	Madre de Cacao	Verde Island Passage, Batangas	-	-	LC	Caringal et al. (2021)
	Intsia bijuga (Colebr.) Kuntze	Ipil	Mount Lantoy, Cebu	Native	VU	NT	Lillo et al. (2019)
	Tamarindus indica Linn.	Tamarind, Sampalok	Verde Island Passage, Batangas	-	-	LC	Caringal et al. (2021)
	Wallaceodendron celebicum Koord.	Banuyo, Salonggigi	Mount Lantoy, Cebu; Calicoan, Guiuan, Taft, Eastern Samar; Paranas, Samar	Native	VU	-	Lillo et al. (2019); Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021a)
24	**Fagaceae**						
	Lithocarpus celebicus (Miq.) Rehder [= *Lithocarpus llanosii* (A.DC.) Rehder]	Ulaian	Basey, Samar	Native	-	LC	Quimio (2016); Villanueva et al. (2021b)
25	**Gesneriaceae**						
	Teijsmanniodendron pteropodum (Miq.) Bakh.	Tikoko	Basey, Samar	Native	-	LC	Quimio (2016); Villanueva et al. (2021b)
26	**Gnetaceae**						
	Gnetum gnemon L.	Bago	Mount Tabunan, Cebu; Calicoan, Guiuan; Taft, Eastern Samar; Basey, Samar	Native	-	LC	Cadiz & Buot (2010); Quimio (2016); Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021b)
27	**Hypericaceae**						
	Cratoxylum sumatranum (Jack) Blume subsp. *Sumatranum*	Kansilay, Guyong-guyong	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
28	**Icacinaceae**						
	Stemonurus gitingensis (Elmer) Sleumer	Tugbak	Cantipla, Cebu	Endemic	-	EN	Cadiz & Buot (2009)
29	**Lamiaceae**						
	Callicarpa erioclona Schauer	Tambalabasi	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Gmelina arborea Roxb.	Gmelina	Verde Island Passage, Batangas	-	-	LC	Caringal et al. (2021)
	Premna congesta Merr. Syn. *P.serratifolia* L.	Alakaag	Cantipla, Cebu	Native	-	LC	Cadiz & Buot (2009)
	Stachytarpheta jamaicensis (L.) Vahl	Jamaica Vervain	Verde Island Passage, Batangas	-	-	LC	Caringal et al. (2021)

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					DAO 2017-11	IUCN	
	Tectona philippinensis Benth. & Hook.f.	Philippine Teak	Verde Island Passage, Batangas	Endemic	EN	EN	Caringal et al. (2021)
	Vitex parviflora Juss.	Molave	Mount Lantoy, Cebu; Verde Island, Batangas	Native	EN	LC	Lillo et al. (2019); Caringal et al. (2021)
	Vitex quinata (Lour.) F.N. Williams	Kalipapa Sau, kulipapa, Hamulawen	Basey, Samar	Native	-	LC	Quimio (2016); Villanueva et al. (2021b)
	Vitex turczaninowii Merr. Syn. *Viticipremna philippinensis* (Turcz.) H.J. Lam.	Lingo-lingo	Mount Tabunan, Cebu; Parana, Samar	Native	-	LC	Cadiz & Buot (2010); Villanueva et al. (2021a)
30	**Lauraceae**						
	Alseodaphne malabonga (Blanco) Kosterm. Syn. *Nothaphoebe umbelliflora* (Blume)	Malabunga, Yaban	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Cinnamomum cebuense Kosterm.	Kaningag, Cebu Kalingag	Cantipla, Cebu; Mount Lantoy, Cebu	Endemic	EN	EN	Cadiz & Buot (2009); Lillo et al. (2019)
	Cinnamomum mercadoi S.Vidal	Mercadoi, Kalingag	Mount Lantoy, Cebu; Basey, Samar	Endemic	OTS	LC	Quimio (2016); Lillo et al. (2019); Villanueva et al. (2021b)
	Cryptocarya ampla Merr.	Bagarilau	Mount Lantoy, Cebu	Endemic	VU	LC	Lillo et al. (2019)
	Dehaasia triandra Merr. Syn. *D. Incrassata* (Jack) Nees	Makuhay	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Litsea tomentosa Blume	Bakan-mabolo	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
31	**Malvaceae**						
	Bombax ceiba DC.	Malabulak, Red Silk Cottontree	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	*Camptostemon philippinensis (*S. Vidal) Becc.	Gapas-gapas, Dandulit	Basey, Samar	Native	EN	EN	Quimio (2016); Villanueva et al. (2021b)
	Colona serratifolia Cav.	Anilao	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Kleinhovia hospita Linn.	Tan-ag	Paranas, Samar	Native	-	LC	Villanueva et al. (2021a)
	Pterocymbium tinctorium (Blanco) Merr.	Taluto	Mount Tabunan, Cebu	Endemic	-	LC	Cadiz & Buot (2010); Caringal et al. (2021)
	Pterospermum diversifolium Blume	Bayo, Bayok	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Thespesia populnea (Linn.) Soland. Ex Correa	Banalo, Portia Tree	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Urena lobata L.	Dalupang, Kulotan, Caesar Weed	Verde Island Passage, Batangas	-	-	LC	Caringal et al. (2021)
32	**Marantaceae**						
	Phrynium minutiflorum Suksathan & Borchs.	Hagikhik (Bicol-Catanduanes)	Paranas, Samar	Endemic	VU	-	Villanueva et al. (2021a)
33	**Meliaceae**						
	Aglaia lawii (Wight) Saldanha & Ramamoorty	Talisayan, Aglaia	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Aglaia rimosa (Blanco) Merr.	Balubar, Bayanti	Paranas, Samar	Native	OTS	NT	Villanueva et al. (2021a)
	Chisocheton cumingianus Harms	Balukang, Balukanag	Basey, Samar	Native	-	LC	Quimio (2016); Villanueva et al. (2021b)
	Melia azedarach Linn.	Bagalunga, Chinaberry	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Sandoricum vidalii Merr.	Malasantol	Basey, Samar	Endemic	-	VU	Quimio (2016); Villanueva et al. (2021b)
34	**Moraceae**						
	Artocarpus blancoi (Elm.) Merr.	Antipolo	Mount Tabunan, Cebu; Calicoan, Guiuan	Endemic	-	LC	Cadiz & Buot (2010); Fernandez et al. (2020)
	Artocarpus odoratissimus Blanco	Marang	Mount Tabunan, Cebu	-	-	NT	Cadiz & Buot (2010)
	Artocarpus rubrovenius Warb.	Tugop, Kalulot	Calicoan, Guiuan; Taft, Eastern Samar; Paranas, Samar	Endemic	OTS	-	Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021a)

	Family & scientific name	Common name	Location	Endemicity	Conservation status		References
					DAO 2017-11	IUCN	
	Ficus ampelas Burm.f.	Upling-gubat	Mount Tabunan, Cebu; Calicoan, Guiuan; Paranas, Samar	Native	-	LC	Cadiz & Buot (2010); Fernandez et al. (2020); Villanueva et al. (2021a)
	Ficus congesta Roxb.	Malatibig	Cantipla, Cebu	Native	-	LC	Cadiz & Buot (2009)
	Ficus drupacea Thunb. *Var. Drupacea*	Payapa, Nonok, Brown Woolly Fig	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Ficus linearifolia Elmer	Tabog	Mount Tabunan, Cebu	Endemic	-	LC	Cadiz & Buot (2010)
	Ficus minahassae (De Vriese & Teijsm.) Miq.	Hagimit	Mount Tabunan, Cebu; Calicoan, Guiuan	Endemic	-	LC	Cadiz and Buot (2010); Fernandez et al. (2020)
	Ficus nota (Blanco) Merr.	Tibig	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Ficus odorata (Blanco) Merr.	Pakiling	Mount Tabunan, Cebu	Endemic	-	LC	Cadiz & Buot (2010)
	Ficus septica Burm. F.	Hawili, Labnog	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Ficus stipulosa Miq. Syn. *F. Caulocarpa* (Miq.)	Dalakit	Calicoan, Guiuan	Native	-	LC	Fernandez et al. (2020)
	Ficus sumatrana Mig. Var. *Microsyce* Corner	Baleteng-ibon, Baleteng-liitan	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Ficus ulmifolia Lam	Is-is	Verde Island Passage, Batangas	Endemic	-	VU	Caringal et al. (2021)
	Ficus variegata Blume	Tangisang Bayawak	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010); Caringal et al. (2021)
	Streblus asper Lour.	Kalios	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Streblus ilicifolius (Vid.) Corner syn. *Taxotrophis ilicifolia*	Kuyos-kuyos	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
35	**Myricaceae**						
	Morella javanica (Blume) I.M.Turner [=*Myrica javanica* Blume]	Hindang	Basey, Samar	Native	-	LC	Quimio (2016); Villanueva et al. (2021b)
36	**Myristicaceae**						
	Horsfieldia ardisiifolia (A.DC.) Warb.	Dagoan, Tigan-tigan	Paranas, Samar	Endemic	-	VU	Villanueva et al. (2021a)
	Horsfieldia samarensis W.J.de Wilde	Samar Yabnob	Paranas, Samar	Endemic	VU	CR	Villanueva et al. (2021a)
	Knema stellata ssp. Stellata	Durogo, Panigan	Paranas, Samar	Native	-	VU	Villanueva et al. (2021a)
	Myristica agusanensis Elmer	Agusan Duguan	Mount Tabunan, Cebu	Endemic	-	NT	Cadiz & Buot (2010)
	Myristica laevis subsp. *Laevis* de Wilde	-	Basey, Samar	Endemic	-	VU	de Wilde (1997); Villanueva et al. (2021b)
	Myristica philippinensis Gand.	Duguan	Basey, Samar	Endemic	OTS	-	Quimio (2016); Villanueva et al. (2021b)
	Myristica pilosigemma W.J.de Wilde	-	Paranas, Samar	Endemic	OTS	CR	Villanueva et al. (2021a)
37	**Myrsinaceae**						
	Discocalyx euphlebia Merr.	Dikai-dikaian	Cantipla, Cebu	Endemic	-	EN	Cadiz & Buot (2009)
38	**Myrtaceae**						
	Eugenia tulanan Merr. [= *Jossinia tulanan* (Merr.) Merr.]	Tulanan	Basey, Samar	Endemic	-	EN	Quimio (2016); Villanueva et al. (2021b)
	Psidium guajava L.	Guava	Verde Island Passage, Batangas	-	-	LC	Caringal et al. (2021)
	Syzygium mindorense (C.B.Rob.) Merr	Butor	Verde Island Passage, Batangas	Endemic	-	VU	Caringal et al. (2021)
	Syzygium hutchinsonii (C.B. Robinson) Merr.	Malatambis	Basey, Samar	Endemic	-	CR	Quimio (2016); Villanueva et al. (2021b)
	Syzygium striatulum (C.B. Rob.) Merr.	Malaruhat Sapa	Basey, Samar	Endemic	-	VU	Quimio (2016); Villanueva et al. (2021b)
	Syzygium trianthum (Merr.) Merr.	Tubal	Cantipla, Cebu	Endemic	-	EN	Cadiz & Buot (2009)
	Tristania micrantha Merr.	Tiga	Basey, Samar	Endemic	-	EN	Quimio (2016); Villanueva et al. (2021b)

	Family & scientific name	Common name	Location	Endemicity	Conservation status		References
					DAO 2017-11	IUCN	
	Tristaniopsis decorticata (Merr.) Wilson & Waterhouse	Malabayabas	Mount Lantoy, Cebu	Endemic	VU	LC	Lillo et al. (2019)
39	**Opiliaceae**						
	Champereia manillana Blume	Garimo, Liyong-liyong	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
40	**Phyllanthaceae**						
	Antidesma ghaesembilla Gaertn. Var. *Ghaesembilla*	Binayuyo	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Antidesma pentandrum (Blanco) Merr. Syn. *A. Montanum* Blume	Bignai-pogo	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Breynia cernua (Poir.) Muell.-Arg.	Matang-ulang	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Breynia vitis-idaea (Burm. F.)	Matang-hipon	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Bridelia glauca Blume	Anislag	Calicoan, Samar; Paranas, Samar	Native	-	LC	Fernandez et al. (2020); Villanueva et al. (2021a)
41	**Rubiaceae**						
	Antherostele grandistipula	Kurudan	Basey, Samar	Endemic	EN	VU	Obico & Alejandro (2013); Villanueva et al. (2021b)
	Antherostele samarensis Obico & Alejandro		Basey, Samar	Endemic	CR	-	Obico & Alejandro (2013); Villanueva et al. (2021b)
	Antirhea livida Elmer	Lumangog	Basey, Samar	Endemic	VU	VU	Quimio (2016); Villanueva et al. (2021b)
	Atractocarpus obscurinervius (Merr.) Puttock	Kalanigi	Cantipla, Cebu	Endemic	CR	VU	Cadiz & Buot (2009)
	Dolicholobium philippinense Trenteuse	-	Cantipla, Cebu	Endemic	-	NT	Cadiz & Buot (2009)
	Guettarda speciosa Linn.	Banaro	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Mussaenda philippica A. Rich	Kahoy-dalaga	Verde Island Passage, Batangas	Endemic	-	LC	Caringal et al. (2021)
	Neonauclea formicaria Elm.	Hambabalud, Ambabalod	Calicoan, Guiuan; Paranas, Samar; Taft, Eastern Samar; Basey, Samar	Endemic	-	LC	Quimio (2016); Fernandez et al. (2020); Obeña et al. (2021); Villanueva et al. (2021a, b)
	Tarenna littoralis Merr. Syn. *Coptosperma littorale*	Bosiling-dagat	Verde Island Passage, Batangas	Endemic	-	LC	Caringal et al. (2021)
	Timonius appendiculatus Merr.	Upong-upong, Pututan	Basey, Samar	Endemic	-	VU	Quimio (2016); Villanueva et al. (2021b)
42	**Rutaceae**						
	Lunasia amara Blanco	Lunas	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
43	**Sapindaceae**						
	Dimocarpus foveolatus (Radlk.) Leenh	Mahugis,Pamirigin	Verde Island Passage, Batangas	Endemic	-	EN	Caringal et al. (2021)
	Dimocarpus longan Lour. *Ssp. Longan var. Malesianus*	Alupag Lalaki, Longan Tree	Mount Tabunan, Cebu	-	-	NT	Cadiz & Buot (2010)
	Dodonaea viscosa (Linn.) Jacquin	Kalapinay	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Elattostachys verrucosa (Blume) Radlk.	Baniwi	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
	Gloeocarpus patentivalvis (Radlk.) Radlk.	Tamaho, Igiw	Paranas, Samar	Endemic	EN	NT	Villanueva et al. (2021a)
	Guioa discolor Radlk.	Alahan-puti	Paranas, Samar	Endemic	VU	VU	Villanueva et al. (2021a)
	Harpullia arborea (Blanco) Radlk.	Puwas, Uwas	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
	Litchi chinensis Sonn. Subsp. *Philippinensis* (Radlk.) Leenh	Alupag	Mount Lantoy, Cebu	Native	VU	VU	Lillo et al. (2019)
	Lepisanthes fruticosa (Roxb.) Leenh.	Linawnaw	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)

	Family & scientific name	Common name	Location	Endemicity	Conservation status		References
					DAO 2017-11	IUCN	
	Pometia pinnata Forst.	Malugay-liitan	Mount Tabunan, Cebu	Native	-	LC	Cadiz & Buot (2010)
44	**Sapotaceae**						
	Manilkara fasciculata (Warb.) H.J.Lam & Maas Geest.	Patsaragon	Taft, Eastern Samar; Paranas, Eastern Samar	Native	-	VU	Obeña et al. (2021); Villanueva et al. (2021a)
	Mimusops parvifolia R. Br. Syn. *M. Elengi* L.	Bansalagin	Cantipla, Cebu	-	-	LC	Cadiz & Buot (2009)
	Palaquium elliptilimbum Merr.	Alakaak-tilos	Cantipla, Cebu	Endemic	-	EN	Cadiz & Buot (2009)
	Palaquium elongatum Merr.	Long-leaved Nato	Paranas, Samar	Endemic	-	EN	Villanueva et al. (2021a)
	Palaquium gigantifolium Merr.	Alakaak, Alaka	Cantipla, Cebu	Endemic	-	NT	Cadiz & Buot (2009)
	Palaquium luzoniense (Fern.-Villar) S. Vidal	Nato	Mount Lantoy, Cebu; Calicoan, Guiuan; Basey, Samar	Native	VU	VU	Quimo (2016); Lillo et al. (2019); Fernandez et al. (2020); Villanueva et al. (2021b)
	Planchonella velutina (Elmer) H.J.Lam [= *Pouteria velutina* (Elmer) Baehni]	Amahit, Wakatan	Basey, Samar	Endemic	-	NT	Quimio (2016); Villanueva et al. (2021b)
45	**Simaroubaceae**						
	Harrisonia perforata (Blco.) Merr.	Mamikil, Laiya	Verde Island Passage, Batangas	Native	-	LC	Caringal et al. (2021)
46	**Stemonuraceae**						
	Gomphandra fernandoi Schori & Utteridge	Fernando Mabunot	Paranas, Samar	Endemic	VU	VU	Villanueva et al. (2021a)
	Gomphandra mappioides Valeton	-	Paranas, Samar	Native	-	LC	Villanueva et al. (2021a)
47	**Thymelaeaceae**						
	Aquilaria cumingiana (Decne.) Ridl.	Butlo, Lapnisan, Agar	Calicoan, Samar; Paranas, Samar	Native	VU	VU	Fernandez et al. (2020); Villanueva et al. (2021a)
48	**Urticaceae**						
	Oreocnide rubescens (Blume) Miq.	Lingatong, Kalulit	Paranas, Samar	Native	-	LC	Villanueva et al. (2021a)

Conservation status: CD—Conservation Dependent | DD—Data Deficient | OT—Other Threatened Species | LC—Least Concern | VU—Vulnerable | EN—Endangered | CR—Critically Endangered | NT—Near Threatened).

updated based on recent activities since the previous assessment.

The island of Samar, where SINP and GMRPLS are located, has been subjected to anthropogenic pressures such as timber cutting due to extensive logging, rattan extraction, and kaingin extraction (clearing of land through slash-and-burn agriculture) (Fernandez et al. 2020; Obeña et al. 2021; Villanueva et al. 2021a). Mount Cantipla (Cadiz & Buot 2009), Mount Tabunan (Cadiz & Buot 2010), Mount Lantoy (Lillo et al. 2019, 2021) forest in Cebu and Verde Island Passage in Batangas (Caringal et al. 2021) have been harmed by illegal logging and land use change activities. This is indeed true as also reported in several studies (Dirzo & Raven 2003; Rodrigues et al. 2006; Wright 2010; Croteau & Mott 2011). A variety of human activities, including habitat destruction, logging operations, shifting cultivation, fragmentation and degradation, pollution, the introduction of non-native species, and over-exploitation resulting from the conversion of natural vegetation such as forests into other uses amidst aggravating climate change issues, contribute to species endangerment and eventual local plant extinctions in the tropics. Many dipterocarp species, for instance, are particularly vulnerable in Southeast Asia because they play a unique role in forest ecology and are highly valued for their timber (Ashton & Kettle 2012; Maycock et al. 2012), and hence, are prone to exploitation through overharvesting (Sodhi et al. 2004; Fernando et al. 2015; McKinney 1997). If these anthropogenic threats are not mitigated and prevented, the number of woody plant species will decline and likely become extinct in the future. In fact, Koh et al. (2004) predicted that 6,300 species would become endangered if their host species become extinct. This is critical in the context of our forests over limestone not only those in Samar Island and the entire Philippines, but throughout the tropics. The ecosystem is already in severe stress due to microhabitat agroclimatic challenges, thus, if other

Image 1. Critically Endangered (CR) species: a—*Hopea philippinensis* Dyer | b—*Shorea astylosa* Foxw. | c—*Hancea wenzeliana* (Slik) S.E.C. Sierra, Kulju & Welzen. © CONserve-KAIGANGAN.

Image 2. Endangered (EN) species: a—*Tectona philippinensis* Benth. & Hook.f. | b—*Cinnamomum cebuense* Kosterm | c—*Camptostemon philippinense* (S. Vidal) Becc. © a—Caringal, A.; b—Cebu Cinnamon Tree FB page; c—Buot et al. 2022.

Image 3. Vulnerable (VU) species: a—*Aquilaria cumingiana* (Decne.) Ridl. | b—*Wallaceodendron celebicum* Koord. | c—*Shorea negrosensis* Foxw. © CONserve-KAIGANGAN.

anthropogenic disturbances occur, growth and survival of indigenous and endemic flora as well as fauna will be negatively affected. Also, these activities could have serious consequences on the livelihood of the local people who rely on them.

Unfortunately, the decline in number of some threatened woody plant species from various locations throughout the country has not yet been documented for inclusion in the Philippine red list or the IUCN. With 95% of plant species yet to be assessed on a global scale, new approaches to conservation assessment are urgently needed (Lughadha et al. 2005; Krupnick et al. 2009; Schatz 2009; Miller et al. 2012).

Notes on some threatened species in forests over limestone with economic importance

***Agathis philippinensis* Warb.**

Agathis philippinensis, commonly known as almaciga, can be found in the Philippines, Moluccas and Sulawesi. It is tapped and produces high quality of resin commercially known as Manila copal, which is used as raw material for varnish, lacquer, paper paint driers, linoleum, and ink, among others (Brown 1921; Samiano & Ella 2014). Due to the current high market demand for resin, sustained pressure from logging and resin collection, as well as unsustainable tapping methods, has contributed to declining populations of *A. philippinensis* in the Philippines (Jose 2018).

Conservation status: Vulnerable (DAO 2017-11).

***Antirhea livida* Elmer**

Antirhea livida is an endemic found in Luzon and Mindanao. Based on the IUCN (2022) assessment, this species will continue to decline due to the habitat-threatening effects of commodity-driven deforestation, shifting agriculture, urbanization, and losses from forest plantations and natural forest harvesting. Despite having a relatively large distribution, the species is still classified as Vulnerable due to its limited number of locations, small area of occupancy (AOO) value, and current threats to population and habitat quality. As such, immediate and active conservation measures must be considered to prevent the species from being pushed into a more threatened category in the future (IUCN 2022).

Conservation status: Vulnerable (DAO 2017-11 & IUCN).

***Aquilaria cumingiana* (Decne.) Ridl.**

Aquilaria cumingiana is a shrub or small tree which is found in the Philippines and Indonesia. *A. cumingiana* most famous product is agarwood, a resin containing heartwood produced from old and diseased trees (Tawan 2003) that is used for ornamentation, perfume and aromatic purposes (Swee 2008). Anthropogenic pressure on lowland primary forest within the range is reducing the amount of available habitat across its range (Lemmens & Bunyapraphatsara 2003).

Conservation status: Vulnerable (DAO 2017-11 & IUCN).

Camptostemon philippinensis

According to the IUCN (2022) assessment, this species is extremely rare and has a limited and patchy distribution in Indonesia and the Philippines. Throughout its range, it is severely threatened by the removal of mangrove areas for fish and shrimp aquaculture, as well as coastal development. It is estimated that there are less than 2,500 mature individuals left and there has been a least 30% decline in mangrove area within this species range since 1980 (one generation length).

Conservation status: Endangered (DAO 2017-11 & IUCN).

***Cinnamomum cebuense* Kosterm.**

Cinnamomum cebuense is an endemic tree species in the Philippines. Based on the assessment of IUCN (2022), the population of this species is expected to continuing declining due to the habitat threatening effects of commodity-driven deforestation, urbanization, unsustainable farming practices, and large-scale forestry operations. The species occurs naturally in Cebu Protected Landscape, providing some passive conservation. However, more proactive measures (e.g., artificial propagation, reintroduction to various arboreta in the country) should be implemented to prevent the species from becoming more threatened in the future.

Conservation status: Endangered (DAO 2017-11 & IUCN).

***Dipterocarpus gracilis* Blume**

Dipterocarpus gracilisis is native to the Philippines. The wood of this species is used for general building construction, particularly for house posts and frames, planking in lighters and ships, flooring, piling, bridge construction, wharves, and railroad ties (NRMC 1986). Due to continued deforestation and overexploitation, the DAO 2017-11 and IUCN (2022) classified this species as Vulnerable. The IUCN (2022) recommended that species harvest and trade be monitored, that remaining habitat be protected, and that research into the genetic diversity of the species be conducted.

Conservation status: Vulnerable (DAO 2017-11 & IUCN).

Dracontomelon dao **(Blanco) Merr. & Rolfe**

Dracontomelon dao species according to NRMC (1986), is used for sliced and rotary veneers, furniture making, cabinet work, tables, panels, boxes, and matches. Because of logging, kaingin making, and conversion of low elevation forest to agricultural lands, its ecological status has depleted.

Conservation status: Vulnerable (DAO 2017-11) / Least Concern (IUCN).

Goniothalamus lancifolius **Merr.**

Goniothalamus lancifolius is an endemic tree. The species is assessed as endangered in IUCN due to population declines caused by illegal logging, shifting cultivation and land conversion. It is expected to decline as a result of these threats (IUCN 2022).

Conservation status: Endangered (DAO 2017-11 & IUCN).

Guioa discolor **Radlk.**

Guioa discolor is an endemic tree. Based on the assessment of IUCN (2022), this species will continue to decline due to the habitat-threatening effects of commodity-driven deforestation, shifting agriculture, urbanization, and losses from forest plantation and natural forest harvesting. Immediate and active conservation measures are needed to keep the species from becoming more threatened in the future.

Conservation status: Vulnerable (DAO 2017-11 & IUCN).

Hopea foxworthyi **Elmer**

Hopea foxworthyi is endemic. Its wood is used for general house construction, posts, bridge timber, and other wood applications that require strength and durability (NRMC 1986).

Conservation status: Critically Endangered (DAO 2017-11) / Endangered (IUCN).

Hopea philippinensis **Dyer**

Hopea philippinensis is endemic to the Philippines. Based on NRMC (1986), this species is used locally for house posts and temporary railroad ties, but it is not widely used in construction due to its small size. However, *H. philippinensis* is depleted as a result of logging and kaingin making.

Conservation status: Critically Endangered (DAO 2017-11) / Endangered (IUCN).

Kibatalia puberula **Merr.**

Kibatalia puberula is endemic to the Philippines. Based on IUCN (2022) information, *K. puberla* is restricted only in Samar and Leyte where it is known from dipterocarp forests or riverbanks, at elevation ranging from 100 to 250 meters asl. The species has a small area of occupancy and extent of occurrence, and it is declining due to threats to its habitat such as unlawful logging, poaching, charcoal making and firewood collection in Mt. Nacolod. These factors contribute to population decline of this species.

Conservation status: Endangered (DAO 2017-11 & IUCN).

Litchi chinensis **Sonn.**

Litchi chinensis is native to the Philippines and New Guinea. According to Pareek (2016), this species is cultivated commercially in more than 20 countries. It is a high-value tropical fruit on the international fruit market (Miranda-Castro 2016). Because it is the best source of gutta-percha in the Philippines, destructive harvesting of the trees for gutta-percha in the past has severely eroded population levels (Brown 1920).

Conservation status: Vulnerable (DAO 2017-11 & IUCN).

Palaquium luzoniense **(Fern.-Villar) S. Vidal**

Palaquium luzoniense is a native species in the Philippines and Sulawesi. The timber constitutes the majority of red nato in the Philippines. It is used to make furniture and cabinets, cigar boxes, and ship planking, as well as veneer and plywood. The latex of this species is used to make gutta-percha (Lemmens 1993).

Conservation status: Vulnerable (DAO 2017-11 & IUCN).

Shorea almon **Foxw.**

Shorea almon is native to the Philippines and Borneo. The wood of *S. almon* is used for furniture and interior work of all kinds, boat planking and decking patterns, and for uses requiring a moderately hard and comparatively light wood with a beautiful ribbon figure. This species is in great demand for plywood both of rotary and sliced veneer. However, *S. almon* is now depleted due to logging and kaingin making (NRMC 1986).

Conservation status: Vulnerable (DAO 2017-11) / Near Threatened (IUCN).

***Shorea astylosa* Foxw.**

Shorea astylosa is a Philippine endemic. It is used for high-grade construction, bridges and wharves, mine timber and other installations requiring high strength and durability. However, due to logging and kaingin making, *S. astylosa* is now threatened (NRMC 1986).

Conservation status: Critically Endangered (DAO 2017-11) / Endangered (IUCN).

***Shorea contorta* Vidal**

Shorea contorta is a Philippine endemic. According to NRMC (1986), the wood of this species is used for general construction, veneer, hardboard and plywood making, and cabinet and furniture making. *S. contorta* is now depleted due to logging and kaingin making.

Conservation status: Vulnerable (DAO 2017-11) / Least Concern (IUCN).

***Shorea malibato* Foxw.**

Shorea malibato is endemic to the Philippines. This species as stated in NRMC (1986), this species is primarily used in permanent and general construction, ship framing, wharves, railroad ties, and other applications requiring strength and durability. *S. malibato* is now under threat due to logging and kaingin making.

Conservation status: Critically Endangered (DAO 2017-11) / Vulnerable (IUCN).

***Shorea negrosensis* Foxw.**

Shorea negrosensis is an endemic tree. It is commonly used for furniture and cabinet work of all kinds, veneer, hardboard and plywood, sash and millwork, boat planking and decking, and general building construction. However, the ecological status of this species is depleted due to logging and kaingin making (NRMC 1986).

Conservation status: Vulnerable (DAO 2017-11) / Least Concern (IUCN).

***Tectona philippinensis* Benth. & Hook.f.**

Tectona philippinensis is endemic to the Philippines. It is restricted only in coastal forests, littoral cliffs, and inland limestone ridges. This species is highly threatened due to its habitat preference, which is vulnerable to land conversion and development. It is also harvested for its timber and used to make fuelwood and charcoal (IUCN 2022).

Conservation status: Endangered (DAO 2017-11 & IUCN).

***Vitex parviflora* Juss.**

Vitex parviflora can be found throughout the Philippines. This wood of this species is used for construction work that requires strength and durability, such as railroad ties, bridge posts, etc. Its ecological status is depleted due to logging and kaingin making (NRMC 1986).

Conservation status: Endangered (DAO 2017-11) / Least Concern (IUCN).

Framework for sustainable conservation of threatened taxa

We developed and are proposing a framework for sustainable conservation of forests over limestone threatened species (Figure 5) to arrest their continuous decline. The framework illustrates an integrated practice of in situ and ex situ conservation strategies supportive of enhanced onsite protection and plant reintroduction (Buot 2008a,b,c; Kawelo et al. 2012; Miller et al. 2016; Tobias et al. 2021). If implemented with the aid of community participation, localized and national policy implementation, this could help save the species from extinction.

The framework emphasizes the enhancement of the ecosystem structure, function, and processes through practical and locally doable in situ and ex situ strategies. The integrity of the ecosystems rests in having a rich species composition and diversity (structure) and stable and dynamic ecosystem function and processes (Sulistiyowati & Buot 2013, 2016, 2020; Sulistiyowati et al. 2017). In situ strategy via the protected area systems, remain the country's best hope for preserving plant biodiversity and genetic resources onsite (Fernando et al. 2015), such as those found in some areas in Samar Island forests over limestone and many other types of forests in the country (e.g., Cebu's Mounts Tabunan, Cantipla, Lantoy) and in other parts of the world. There are still large tracts of forests over limestone which are not yet covered by national or even local protection (e.g., in GMRPLS).

Ex situ strategy, on the other hand, can be used to preserve groups of species that have experienced rapid declines as a result of anthropogenic activities, especially land use conversion. This conservation strategy can take the form of cultivation in botanic gardens and gene banks, nursery propagation, backyard gardening (Tobias et al. 2021), and establishment of forest groves and patches, to name a few. These forms of ex situ strategy will ensure the preservation of the species gene pool and can be used in reforestation and reintroduction in the natural habitat.

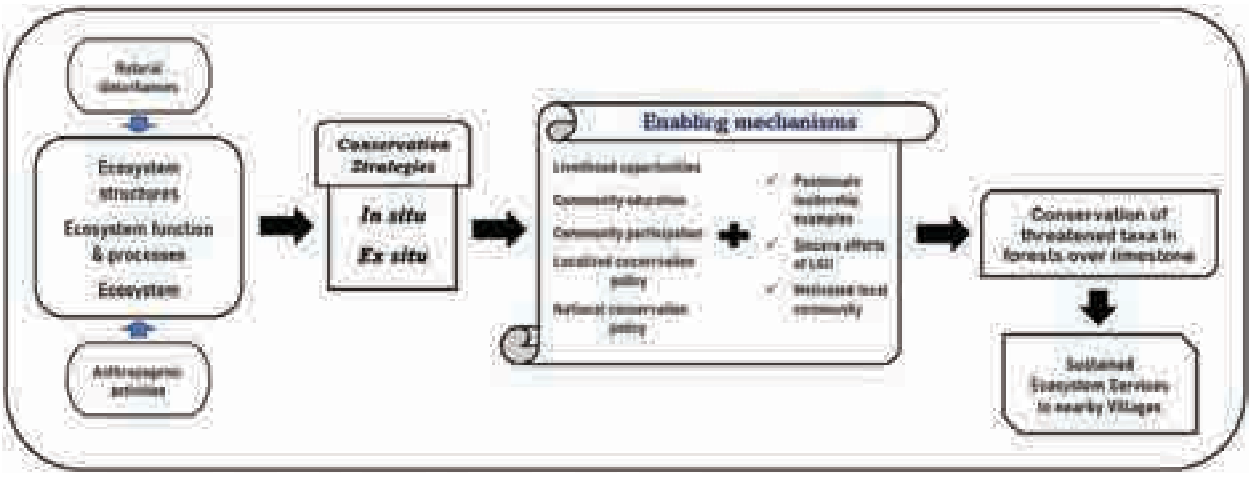

Figure 5. Framework for conservation of threatened taxa in forests over limestone.

Some enabling mechanisms are critical for the framework to be a success. In Figure 8, enabling mechanisms are divided into two columns. The left side enumerates the usual enabling strategies which have failed in many instances in the past. In this proposed framework, we included a PLUS (+) sign to illustrate the importance of the second column. As usual, there should be livelihood opportunities for the community (DENR-PAWB et al. 2003). The economic currency is of utmost importance for the community to understand the ecological contexts of conservation of the forests over limestone. Then, local community motivation is essential to participate in conservation strategies because success and failure of any task, is largely dependent on local people (Toit 2002), the empowered local people (Mathur 1997). Alongside this, there should be sustained forest conservation advocacy and the availability of appropriate community education and public awareness (CEPA) materials (Tolentino et al. 2019; Buot 2020; Buot & Buhay 2022). Additionally, coupled with localized conservation policies (Villanueva & Buot 2020) and national executive orders (Chanthavong & Buot 2019; Betts et al. 2020; Buot & Buhay 2022), we are positive to have a good enabling mechanism for conservation of threatened taxa.

The aforementioned had been done in the past and yet, we still are struggling to stop escalating depletion of plant resources leading to extinction. Hence, we thought of adding the second column of the Enabling Mechanism in Figure 5. We emphasize the PLUS sign (+). We envision the need for passionate leadership examples, sincere efforts of the local government units and a highly motivated local community to attain success in our conservation efforts. The success of these conservation strategies and initiatives is dependent on the extent and dedicated engagement of the innovator with the local government unit and the community members, themselves. The change agent/innovator should have the passion and sincere intentions to earn community's trust and attention.

CONCLUSION AND RECOMMENDATION

The findings of the study revealed that 40.81% of the threatened species found in forests over limestone in SINP, GMRPLS, Mt. Lantoy, Tabunan, Cantipla forest, and Verde Island Passage are indigenous and endemic to the Philippines. These species are primarily threatened by natural (typhoons, landslides, climate change) and anthropogenic activities such as unlawful logging and land conversion. There is an urgent need to address the steady increase in the number of these endangered species in recognition of their critical role in ecosystem structure and processes that would keep the integrity of the forests over limestone ecosystems in the country and in the world. A framework has been suggested in this paper to stop the continued species loss by integrating in situ and ex situ conservation strategies along with enabling mechanisms like enhancing livelihood, community awareness and participation to name a few, in order to stabilize species richness and diversity and hence, ecosystem function, processes, and dynamics. These will lead to the overall conservation of forests over limestone ecosystems, and hence, sustaining the life of the community in the vicinities through the sustained provision of ecosystem services.

The findings of this study will help achieve the

Sustainable Development Goals (SDGs) by protecting and conserving biodiversity, promoting, and sustainably managing resources, and preventing human pressures in forests over limestone in the Philippines.

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Status of mangrove forest in Timaco Mangrove Swamp, Cotabato City, Philippines

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Abstract: Mangrove forests are important coastal ecosystem considering its various ecosystem services. This study was conducted to generate an updated list and the current abundance of mangrove species in Timaco Mangrove Swamp located in Cotabato City, Bangsamoro Autonomous Region for Muslim Mindanao (BARMM). Three sampling plots measuring 5 x 40 m were established in three identified sampling sites. Based on the result of the study, 15 species of mangroves were identified in Timaco Mangrove swamp. This number of species is higher compared to the previous study wherein 12 species were identified. With this number of species, seven species were considered new in the area, and five species were not recorded which were identified in the previous study. A total of 115 individuals were recorded in the present study which indicates a decrease of 79% compared to the previous study. Furthermore, the present study recorded two threatened species, namely, *Aegiceras floridum* (Near Threatened) and *Avicennia rumphiana* (Vulnerable). Continuous anthropogenic activities were observed in the sampling sites which can be attributed to population decrease. Thus, the need for immediate local conservation is recommended.

Keywords: Anthropogenic activities, Bangsamoro Autonomous Region, biodiversity, conservation, Mindanao Island, restoration.

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INTRODUCTION

Mangrove forest, similar to other forest ecosystems, provides an array of ecosystem services that directly and indirectly benefit humans. Among these, provisioning services is the most common. It is a good source of timber for construction materials, fuel wood, marine food, and medicine. On the other hand, regulating services can also be provided which include prevention of floods and erosion, and protection against severe impacts of storms and even tsunamis. Recently, mangrove forests are also utilized for their aesthetic values which include tourism, and educational activities, among others (Camacho et al. 2020). Mangrove forests are identified as the main ecosystem that supports life in coastal and marine areas (Suharno & Saraswati 2020). In 1920, Philippine mangrove is about 400,000–500,000 ha, however, a tremendous decline to 120,000 ha in 1994 was recorded (Primavera 2000) which becomes alarming.

Several studies showed (e.g., Long et al. 2014; Fortes & Salmo III 2017) that a decreasing trend of mangrove forest areas in the Philippines is evident and this is due to environmental and anthropogenic activities (Van Lavieren et al. 2012). Major factors identified that leads to the destruction of our mangrove ecosystem include the conversion of mangrove areas to fishponds and charcoal production (Eusebio et al. 1986; Primavera 1995; Melana et al. 2005). Aside from this, the constant increase in population put pressure on our coastal areas which directly and indirectly affect mangrove forests (WIlkie & Fortuna 2003). Accordingly, the lack of awareness of the community have resulted to exploitation and disturbances on mangrove areas. Dangan-Galon et al. (2016) revealed that increased human population, mangrove deforestation, and improper waste disposal are among of the human-related disturbances which have affected mangrove forests particularly in Puerto Princesa Bay, Palawan, Philippines. These activities, as indicated by Camacho et al. (2020), will place mangrove ecosystems on the verge of complete collapse.

Timaco mangrove swamp is situated in Cotabato City, Philippines which covers three barangays. Dimalen & Rojo (2018) conducted a floral assessment in Timaco mangrove swamp wherein they reported low diversity of mangroves in the area. This result was attributed to anthropogenic activities such as crab hunting, shell picking, timber cutting for charcoal production and conversion to fishpond. From the year of the first assessment, no studies have been conducted on the remaining species in the area. Thus, the study was conducted to have an updated checklist of mangrove species including the species' conservation status in Timaco mangrove swamp and to determine its abundance. Results of this study can be a useful tool in the effective implementation of policy for the restoration, protection, and conservation of this mangrove forests.

MATERIALS AND METHODS

The study was conducted in June–July 2021 in Timaco Magrove Swamps in Cotabato City, Philippines. This thin strip of mangrove forest lies within the coordinates of 7.2031 °N, 124.19 °E, 2.1 km (Image 1) within the elevation of 5 m. The mangrove swamp extends south-west traversing Timaco Hill, one of the highest elevated portions of Cotabato City, Philippines (Dimalen & Rojo 2018).

The sampling sites considered in the study were mangrove areas of (1) Kalanganan I, (2) Kalanganan II and (3) Kalanganan Mother. These areas were also the sites of the previous study conducted by Dimalen & Rojo (2018). Sampling plots were purposively established in the 'bakawan'-dominated part. A total of three (3) 5 x 40 m sampling plots were established in each site. All mangrove species found within each sample plot were identified and counted. Relative abundance was computed using the formula: Relative abundance = Total # of spp./ total # of spp. population x 100. Field notes were taken, and preliminary identifications of mangrove species were done on-site. Morphological characteristics of leaves, flowers, and propagules were noted and used in the confirmation of the identification of species. Key guides such as the Field guide to Philippine Mangrove by Primavera et al. (2004) and other published work were used to identify samples up to species level if possible. Samples were photographed for further identification of species. Anthropogenic activities observed in the sampling site were also noted.

RESULTS AND DISCUSSION

A total of 15 species of mangrove belonging to 10 genera and nine families are identified in Timaco Mangrove swamp. This number of species is higher compared to the study of Dimalen & Rojo (2018). Among the 12 species identified in the previous study, eight were still present in the area namely *Ceriops tagal, Aegiceras corniculatum, A. floridum, Lumnitzera littorea, Sonneratia alba, S. caseolaris, Rhizophora mucronata*, and *Xylocarpus granatum*. Moreover, 7 species were

Image 1. Satellite aerial view of Timaco Mangrove Swamp with 1-km radius showing the surrounding landscape.

newly recorded: *Acrostichum aureum, A. speciosum, A. rumphiana, Acanthus ebracteatus, Brugiuera cylindrica, Nypa fruticans, L. littorea*, and *Rhizophora stylosa* (Table 1).

The difference in the number of species identified in this paper compared to that of Dimalen & Rojo (2018) can be contributed to the sampling effort done in this study. A comprehensive accounting of species was done and did not limit only in the species found within the established sampling plots. In the identification of species, we used the guides and reference books authored by Primavera et al. (2004), in which *A. aureum, A. speciosum, A. ebracteatus*, and *N. fruticans* were listed as mangrove species. Moreover, the present mangrove species thriving in Timaco mangrove swamp is higher compared with the species identified from various coastal areas in Mindanao including Alabel and Maasim, Saranggani Bay Protected Seascape (Natividad et al. 2014), Butuan Bay, Agusan del Norte (Goloran et al. 2020). Despite being greatly affected by disturbances observed in the area, Timaco mangrove swamp still harbors a considerable number of species. This is an indicator that there is a high possibility of restoring the mangrove swamps as a considerable number of saplings have also been observed.

Among the 15 species identified, two (2) have conservation issues, 1 Vulnerable (VU) and 1 Near Threatened (NT). The Near Threatened species is *A. floridum* (Image 2A), while the vulnerable is the *A rumphiana* (Image 2B). However, three species listed – *A. rumphiana, L. littorea*, and *X. granatum* have been categorized as species with decreasing population as recognized by IUCN Red List. There is a conservation policy towards the area, however, conservation measures for these threatened species are not evident.

A total of 115 mangrove individuals were recorded in the three sampling sites (Table 1). *A. corniculatum* had the highest relative abundance of 19.1, followed by *N. fruticans* with 10.4 and *X. granatum* has the least with 0.9. Three species were commonly observed in all three sites—*N. fruticans, A. floridum*, and *B. cylindrica*.

There was a decrease of 79% in the total number of individuals in Timaco Mangrove swamps based on the previous study. Dimalen & Rojo (2018) mentioned that the lower species richness of mangroves in the study site, specifically in Kalanganan I, was due to the aforementioned anthropogenic activities despite the presence of local ordinance. Moreover, it was observed that there were structures such as houses for human settlement. These anthropogenic activities along with land conversion to fishponds contribute significantly to the decline of mangrove forests in the Philippines (Dangan-Galon et al. 2016; Buitre et al. 2019). This decrease will not affect only the biodiversity and ecosystem function

Table 1. An updated list of mangrove species in Timaco Mangrove Swamp.

Family	Species name	Common name	Relative abundance	Conservation status
Lower vascular plant				
Pteridaceae	*Acrostichum aureum* L.	Palaypay	8.7	Least Concern
	Acrostichum speciosum Willd.	Palaypay	6.1	Least Concern
Flowering plant				
Acanthaceae	*Acanthus ebracteatus* Vahl	Lagiwliw	7.8	Least Concern
Arecaceae	*Nypa fruticans* Wurmb	Nipa	10.4	Least Concern
Avicenniaceae	*Avicennia rumphiana* (Hallier f.) Bakh.	Bungalon	7.8	Vulnerable
Combretaceae	*Lumnitzera littorea* (Jack) Voigt.	Tabao, Culasi	4.3	Least Concern
Meliaceae	*Xylocarpus granatum* J. Koenig	Tabigi	0.9	Least Concern
Myrsinaceae	*Aegiceras corniculatum* (L.) Blanco	Saging-saging, Tinduk-tindukan	19.1	Least Concern
	Aegiceras floridum Roem. & Schult.	Saging-saging, Tinduk-tindukan	6.1	Near Threatened
Sonneratiaceae	*Sonneratia alba* Sm.	Pagatpat	4.3	Least Concern
	Sonneratia caseolaris (L.) Engl.	Pedada	3.5	Least Concern
Rhizophoraceae	*Bruguiera cylindrica* (L.) Bl.	Pottan, Busain	9.6	Least Concern
	Ceriops tagal (Perr.) C.B. Rob.	Tungog, Tangal	1.7	Least Concern
	Rhizophora mucronata Lamk	Bakhaw babae	3.5	Least Concern
	Rhizophora stylosa Griff.	Bakhaw bata	6.1	Least Concern

of the mangrove forest but also ecosystem services that generally benefited human population (Cardinale et al. 2012) especially those villagers who are dependent on coastal resources (Primavera 2000). Furthermore, it was observed that mangrove individuals commonly noted as tall with big trunk species have shorter and lesser trunk diameter particularly *A. rumphiana*. According to Patindol & Casas (2019), such a condition has resulted from the long history of cutting mangroves. Individuals of species under the families Avicenniaceae and Sonneratiaceae found in the area were almost multi-stem which must have been restored after heavy cutting in the early years (Image 3). Efforts have been done to rehabilitate the area using propagules of the *Rhizophora* species; however, various factors affect the unsuccessful growth towards maturity of the seedlings planted. During hightide, seedlings were being covered by water hyacinth (abundance of water hyacinth is a perennial problem of the area) which eventually cause the seedlings to die during low tide. In addition, domesticated animals of the community nearby were observed to feed on the growing plant which inhibits the growth of the propagules. Though mangrove forest conservation and rehabilitation have captured the interests of various stakeholders, most efforts were unsuccessful due to the lack of science-based approach guidelines (López-Portillo et al. 2017). Moreover, if rehabilitation strategies employed by other mangrove areas in the southern Philippines will be done in Timaco mangrove swamp such as community involvement and science-based strategy, the rehabilitation endeavor will be successful. In the case of Katunggan Eco Park situated in Lebak Sultan Kudarat, Philippines policy strengthening in mangrove forest conservation and protection is accompanied by community involvement (Mangaoang & Flores 2019). Locals were made part in the management of the said mangrove forest such as involvement in the tree-growing activities and delegated as forest guards.

CONCLUSION AND RECOMMENDATION

The significant decrease of mangroves in Timaco Mangrove Swamp calls for immediate action to conserve this important coastal mangrove forest not only on the presence of two species with conservation concerns but the whole mangrove ecosystem which is facing the effects of the unregulated harvest of timber, the establishment of structures and as well as attempts to secure ownership of the part of the area is on its way. Cotabato City was once hit by an earthquake in the year 1976 and produced tsunami which destroy properties and even lives. If this mangrove forest will be rehabilitated, this will prevent the greater impact of the aforementioned natural calamity. Utilization of the

Image 2. Noteworthy species in Timaco Mangrove Swamp: A—*Aegiceras floridum* | B—*Avicennia rumphiana*. © Authors.

Image 3. Short and multi-stemmed individuals of *Sonneratia alba* and *Avicennia rumphiana*: A—*Sonneratia alba* | B—*Avicennia rumphiana* | C—Sampling area showing short individuals of mangroves. © Authors.

remaining individuals of mangrove species in the area can be utilized as a source of propagules in rehabilitating it. Restoration effort of an almost denuded mangrove forest like of the Timaco Mangrove swamp requires a concerted effort of the government, community, and stakeholders; a sense of ownership must be felt by the community to lessen if not totally eradicated the activities leading to mangrove forest destruction. Furthermore, a more comprehensive study on the mangrove biodiversity of this area must be conducted to strengthen policy decisions for Timaco mangrove swamp restoration, protection, and preservation.

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COMMUNICATION

A comparative analysis of the past and present occurrences of some species of *Paphiopedilum* (Orchidaceae) in northeastern India using MaxEnt and GeoCAT

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Abstract: Members of the genus *Paphiopedilum* are well known for their long-lasting unique flowers. They are becoming rare due to over-collection and habitat loss because of human disturbances and deforestation. The present study aimed to compare the past and present occurrences of the genus *Paphiopedilum* in northeastern India using MaxEnt and GeoCAT. A historical occurrence model (HOM) was prepared using secondary data, and an actual occurrence model (AOM) was constructed with primary field data. The HOM and AOM revealed that bioclimatic factors, topography and precipitation play a significant role in the survival of *Paphiopedilum* populations in northeastern India in both the current and historical distributions. The other vital environmental variables were elevation (h_dem), mean diurnal range (bio_2), annual mean temperature (bio_1), temperature annual range (bio_5) and annual precipitation (bio_12). The results showed a sharp decline in the extent of occurrence and the area of occupancy of *Paphiopedilum* in the study area. The extent of occurrence and area of occupancy for HOM were 170,972 km^2 and 18 km^2. For the AOM, they were 125,315 km^2 and 12 km^2, respectively. The HOM model indicated that *Paphiopedilum* was earlier growing sporadically. On the other hand, the AOM result indicates that it is presently growing sparsely in isolated pockets that are more prone to extinction. *Paphiopedilum* can be conserved successfully using an integrative conservation approach, comprising ecological modeling techniques to search for additional locations, ex situ propagation techniques, and possible reintroduction in selected areas.

Keywords: Ecological niche modeling, environmental variables, lady slipper orchids, orchid conservation.

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Author details: Debonina Dutta is currently pursuing her PhD. Her research interest includes the study of few selected species of *Paphiopedilum* genus in northeastern India and their conservation using biotechnological tools. Aparajita De is a professor. She has specialized in forest ecology, RS, and GIS applications in forest ecology and ethnobiology.

Author contributions: DD carried out the fieldwork and drafted the manuscript. AD provided guidance to conduct the field surveys and has reviewed and corrected the manuscript.

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INTRODUCTION

Predictive habitat distribution models are being used extensively in ecology as they can statistically relate the geographic distribution of species or communities to their environment (Guisan & Zimmermann 2000). These models correlate known species occurrence with climatic data available for relevant areas to determine the boundaries of the multidimensional range of the species. By projecting such conditions onto geographical space, one can predict the potential distribution of the target species. These techniques are applied in a wide variety of studies to: 1. predict the distribution of rare, threatened, or invasive species (Serra et al. 2012; Silva et al. 2013, 2014; Deka et al. 2018), 2. optimize future faunal/floristic surveys (De Siqueira et al. 2009), and 3. inform the establishment of future protected areas (Nóbrega & De Marco Jr 2011).

Studies related to species distribution models have been conducted for the family Orchidaceae by many workers (Kolanowaska & Konowalik 2014; Kolanowska & Busse 2020). Orchids are one of the most threatened group of plants as their complex life history makes them particularly vulnerable to global environmental change. There are more than 1,200 genera of orchids reported in India (Misra 2019; Singh et al. 2019; Schuiteman 2022). The present study tries to model the current distribution of the genus *Paphiopedilum*, family Orchidaceae in northeastern India, and compare it with the historical occurrence data depicting its distribution in the past. The genus *Paphiopedilum* is highly preferred in the horticultural market for its exotic, large flowers on small plants (Cribb 1998). A few species are regarded as threatened or even extinct in the wild due to over-collection from natural areas and large-scale illegal trade (Long et al. 2010). The genus *Paphiopedilum* is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2022). All the species under the genus *Paphiopedilum* found in India come under the category of Vulnerable to Critically Endangered according to the IUCN Red List of Threatened Species (IUCNredlist.org/2021-3) (Table 1). Due to its high horticultural importance (Zhen et al. 2006), the genus faces extensive collection pressure from the wild. This, along with the rapid degradation of its habitat has led to the drastic reduction in the population of the genus (Cribb 1998).

Nine species of *Paphiopedilums* have been reported from India: *Paphiopedilum druryi* (Bedd.) Stein, growing at an altitudinal range 1,400–1,550 m, *Paphiopedilum fairrieanum* (Lindl.) Stein growing at 200–1,200 m, *Paphiopedilum venustum* (Wall. ex Sims) Pfitzer at 500–1,500 m, *Paphiopedilum wardii* (Summerh.) at 1,200–2,500 m, *Paphiopedilum villosum* (Lindl.) Stein at 1,300–2,200 m, *Paphiopedilum insigne* (Wall. ex Lindl.) Pfitzer at 1,000–1,500 m, *Paphiopedilum charlesworthii* (Rolfe) Pfitzer at 1,200–1,600 m, *Paphiopedilum spicerianum* (Rchb.f.) Pfitzer at 300–1,400 m and *Paphiopedilum hirsutissimum* (Lindl. ex Hook.) Stein at 200–1,800 m. Eight species are found in the eastern Himalaya and northeastern India, and one in southern India (Hajra & De 2009; Chowdhery 2015). All the species of this genus found in northeastern India have been reported to grow at altitudes of 200–2,200 m. Several species of *Paphiopedilum* are found growing in shady vertical/ limestone cliffs at varying altitudes (Averyanov 2007; Averyanov et al. 2014; Gurung et al. 2019).

The present work deals with the following objectives: estimation of the past and the present distribution status of some *Paphiopedilum* orchids in northeastern India, estimation of changes in the area and the extent of occurrence of *Paphiopedilum* spp. (if any), and determination of the environmental variables that are vital to the distribution of the genus.

Study area

Northeastern India comprises the eastern part of the Himalayan range, intercepted by plains, valleys, and hilly terrains (Yadava 1990). Our study was carried out in Meghalaya, Mizoram, Arunachal Pradesh, Sikkim, Nagaland, and Assam (Figure 1). The following species of *Paphiopedilum* were recorded in the present study, viz, *P. spicerianum, P. venustum, P. insigne, P. fairreanum*, and *P. hirsutissimum*.

MATERIALS AND METHODS

Study design

Ecological niche models (ENM) were prepared using maximum entropy modelling (MaxEnt) of species geographic distributions (Phillips et al. 2006). The version 3.3 of MaxEnt was used for the current study. We executed two models for our study. Past and present data were divided into historical occurrence points and actual occurrence points. Model 1 was executed using the Historical occurrence points. Historical occurrence data of *Paphiopedilum* were obtained from the recorded historical data such as herbarium records (Kew Herbarium catalogue 2022; Museum National D histoire Naturelle 2022; GBIF 2022; Natural History Museum 2022) and published literature (Table 2). We have named

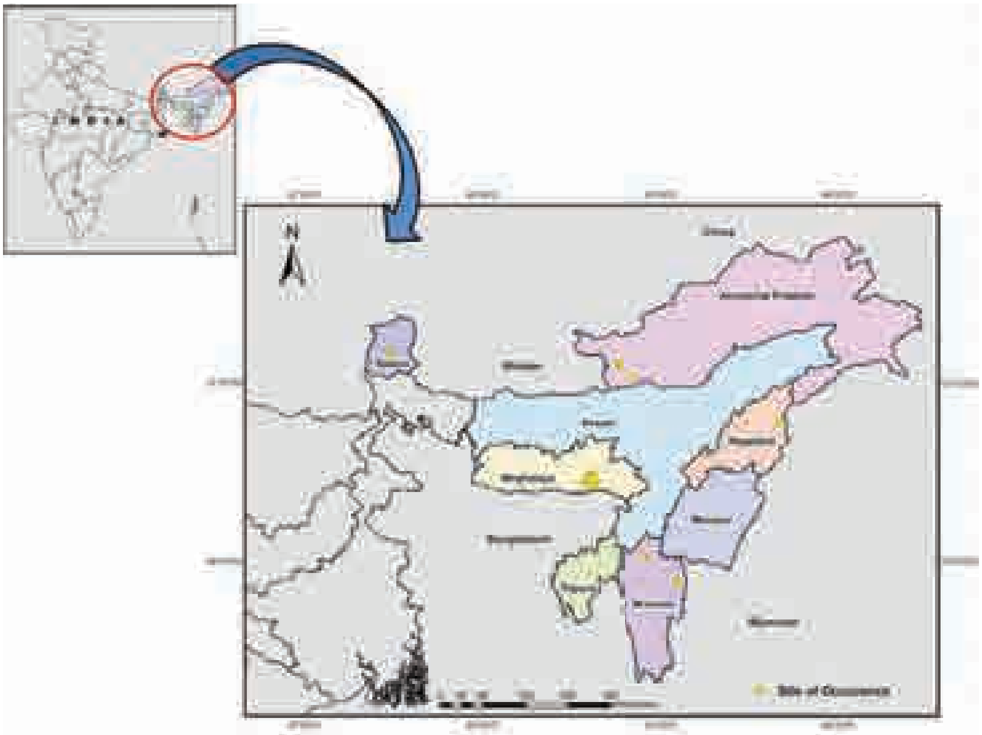

Figure 1. The study area.

it as historical occurrence model (HOM) in this paper. Model 2 was executed using the actual occurrence data (Table 3). Therefore, model 2 is referred to as the actual occurrence model (AOM).

The results obtained from the ecological niche model were verified in the study area during the period of 2015–2021. The details of the historical presence sites and actual presence sites are given in the Table 2 & 3. Based on the ENM observations, the area of occupancy (AOO) & extent of occurrence (EOO) of historical and actual occurrence data of *Paphiopedilum* were estimated. The estimation of AOO & EOO were performed using Geospatial Conservation Assessment Tool (GeoCAT), calculated at a 1 km^2 area cell size. Figure 2 gives the details of the study design.

Table 1. The threat category of genus Paphiopedilum (IUCN: Ver.2021–3)

Name	Threat category	Population trend
P. druryi	Critically endangered	Decreasing
P. fairrieanum	Critically endangered	Decreasing
P. venustum	Endangered	Decreasing
P. wardii	Endangered	Decreasing
P. villosum	Vulnerable	Decreasing
P. insigne	Endangered	Decreasing
P. charlesworthii	Endangered	Decreasing
P. spicerianum	Endangered	Decreasing
P. hirsutissimum	Vulnerable	Decreasing

Data collection

Historical data were collected from various herbaria (both offline and online) and literature sources. Occurrence data of *Paphiopedilum* was obtained from herbaria of the Botanical Survey of India, ERC, Shillong (Assam), Global Biodiversity Information Facility (GBIF), Central National Herbarium (CAL), Forest Research Institute, Dehradun (DD), Botanical Survey of India, Arunachal Pradesh Regional Centre (ARUN), Natural History Museum (NHM), Museum National d'Histoire Naturelle (MNHN) and Kew herbarium (KEW) (Table 2). The previous occurrence reports were also noted from the literature survey (Pradhan 1971; Pradhan 1975; Pradhan 1976, 1979; Kataki et al. 1984; Bose et al. 1999; Lucksom 2007; Misra 2007; Russel 2008a,b; Mao 2010; Bhattacharjee et al. 2018). The records obtained from literature reviews were used for cross-referencing with the reported locations of herbarium collections. Further the herbaria collections having location information (nearby village name or landmark) were tagged and digitized with the help of Google Earth following Milagros & Funk (2010).

AOM was prepared from the primary data. The primary data were collected from field visits to respective localities of different states (Table 3). The field surveys were conducted by snowball sampling method (Spreen 1992; Johnson 2014). The flowers of each species growing on the cliff were identified using a binocular. Geo -coordinates of the location were recorded using GPS (Garmin etrex 20) and the habitat features were recorded. The accessible sites were thoroughly surveyed for a closer view of the habitat.

Environmental variables

The dataset for ENM include NDVI (Normalized differential vegetation index), bioclimatic variables, and hydrological variables (i.e., slope, aspect, topography, and elevation). A total of 12 environmental variables were selected for the study. Table 4 shows the list of the final selected variables for the present study.

The environmental variables were applied with principal component analysis (PCA) to avoid multi-co linearity (correlation among the variables that could create redundancy in models) (Chaudhary et al. 2021). The bioclimatic layers in ASCII format were used with a resolution of 30 ARC seconds for this study. The variables for the area of interest were obtained by masking the bioclimatic rosters with the boundary of northeastern India using ArcView. Highly correlated variables were excluded by performing a Pearson correlation test of variables exhibiting a value of r <0.9 (i.e., 90%). A total of 12 environmental variables were used post correlation (Table 4).

RESULTS

A total of 40 specimens were obtained from various herbaria in India and other countries (Table 2). During the present study, we located five species of *Paphiopedilum* in different sites of the study area (Table 3). They were *P. spicerianum*, *P. insigne, P. fairreanum, P. venustum*, and *P. hirsutissimum.* A total of 16 actual occurrence sites were recorded for the five species. Image 1 shows the habitat of a few *Paphiopedilum* species. The two ecological niche models were executed based on this data and the results obtained are given as follows.

Historical occurrence model and actual occurrence model

Two models were obtained using the historical occurrence data and actual occurrence data. The ENM models are represented in Figure 3. Model 1 or HOM represents the historical occurrence distribution of *Paphiopedilum*, and model 2 or AOM represents the actual occurrence distribution of *Paphiopedilum* in northeastern India.

AUC and jackknife interpretation

The model calibration test for *Paphiopedilum* yielded satisfactory results for both models. The red line shows the 'fit' of the model to the training data, and the blue line indicates the 'fit' of the model to the testing data (Figure 4). The area under the curve (AUC) value of each model aids in the assessment of the model quality. In the jackknife of AUC, the blue line depicts the real test of the predictive power of the MaxEnt model. An AUC value above 0.9 (closer to 1.0) indicates a good model performance. The AUC values for HOM (AUCtest = 0.972 ± 0.015) and AOM (AUCtest = 0.942 ± 0.015) therefore indicated that the model performance was good in both cases.

The significance of environmental variables on each model was assessed by interpretation of the jackknife of AUC (Figure 5). The contribution of the environmental variables on the model build was assessed from the percent contribution of variables and permutation importance (Table 5). Among all the variables, bio_2 (mean diurnal range) and bio_1 (annual mean temperature) were the most influential variables in the build of HOM as evident from the percent contribution of the variables in model build. The variable bio_2 contributed 46.6% and bio_1 contributed 19.3% respectively on HOM (Table 5). According to the internal jackknife of AUC for HOM, bio_1 (annual mean temperature) has the highest contribution to the model, followed by h_dem (elevation) (Figure 5). Jackknife of AUC shows the contribution of environmental variables in both models. The variables collectively contributed 100% to the HOM. Aspect (h_aspect) and topographic index (h_topoind) contributed 19.1% and 0.7% (Table 5). Considering the permutation importance, bio_5 contributed the highest (55.3%) to the model, followed by h_dem (27. 5%) and bio_2 (8. 9%) (Table 5). The variable bio_2 was the most influential environmental variable in the model build of HOM.

The percent contribution of variables in the model build of AOM revealed that bio_12 (annual precipitation) and bio_2 (mean diurnal range) were most influential in the model build. Bio_12 contributed 41.9% and bio_2 contributed 29.1% to the model build. The variable bio_2 was followed by bio_5 (max temperature of the warmest month) that contributed 24.4%, and h_topoind contributed 3.9% to the AOM. Considering the permutation importance, bio_5 contributed 53.1%. Jackknife of AOM infers the highest contribution of h_topoind and bio_14 (precipitation of driest month),

Table 2. Historical occurrence records of *Paphiopedilum* spp.

	Species	Year	Location	Herbarium source
1	*P. fairreanum*	1857	NA	Royal Botanic garden, Kew
2	*P. insigne*	1859	Mount Khasia, Meghalaya	Museum National d'Histoire Naturelle
3	*P. venustum*	1893	Sonai, Assam	Natural History Museum
4	*P. venustum*	1893	Sikkim Himalaya	Natural History Museum
5	*P. insigne*	1894	Cherrapunjee, Meghalaya	Central National Herbarium, Kolkata
6	*P. insigne*	1899	Shella, Meghalaya	Central National Herbarium, Kolkata
7	*P. insigne*	1899	Jaintia hills, Meghalaya	Central National Herbarium, Kolkata
8	*P. insigne*	1899	Jaintia hills, Meghalaya	Bavarian Natural History Collections (SNSB-GBIF)
9	*P. venustum*	1899	Lingzah Tolung,North Sikkim	Naturalis Biodiversity Center (GBIF)
10	*P. venustum*	1899	Sikkim	Harvard University Herbaria (GBIF)
11	*P. fairreanum*	1941	Rohlu, Sikkim	Central National Herbarium, Kolkata
12	*P. insigne*	1944	Smit, Meghalaya	Natural History Museum
13	*P. venustum*	1952	Cherrapunjee, Mount Khasia, Meghalaya	Naturalis Biodiversity Center (GBIF)
14	*P. venustum*	1952	Khasia hills, Meghalaya	Museum National d'Histoire Naturelle, ,
15	*P. fairreanum*	1957	Dirang dzong, Arunachal Pradesh	Central National Herbarium, Kolkata
16	*P. hirsutissimum*	1962	Khasi hills, Meghalaya	Central National Herbarium, Kolkata
17	*P. villosum*	1963	Cultivated plant	Central National Herbarium, Kolkata
18	*P. spicerianum*	1972	National orchidarium	BSI-ERC, Shillong
19	*P. fairreanum*	1974	Tenga Valley, Arunachal Pradesh	BSI-ERC, Shillong
20	*P. insigne*	1974	Mount Khasia, Meghalaya	Natural History Museum
21	*P. insigne*	1974	Mount Khasia, Meghalaya	Museum National d'Histoire Naturelle
22	*P. insigne*	1975	Khasia Mountains	Royal Botanic Garden, Kew
23	*P. villosum*	1976	Lunglei, Mizoram	Forest research Institute, Dehradun
24	*P. fairreanum*	1978	Jameri, Arunachal Pradesh	Forest research Institute, Dehradun
25	*P. venustum*	1984	Khasya hills, Meghalaya	Royal Botanic Garden, Kew
26	*P. venustum*	1984	Sikkim Himalaya	Royal Botanic Garden, Kew
27	*P. venustum*	1993	Khasia hills, Meghalaya	Museum National d'Histoire Naturelle
28	*P. hirsutissimum*	2006	Maram, Manipur	BSI-ERC, Shillong
29	*P. insigne*	2016	Sohra, Meghalaya	iNaturalist (GBIF)
30	*P. fairreanum*	2017	Arunachal Pradesh	Wildlife Institute of India (GBIF)
31	*P. venustum*	2019	East Khasi Hills, Meghalaya	University of Michigan Herbarium (GBIF)
32	*P. hirsutissimum*	2019	Senapati, Manipur	University of Michigan Herbarium (GBIF)
33	*P. hirsutissimum*	NA	NA	Royal Botanic Garden, Kew
34	*P. fairreanum*	NA	Rupa bridge, Arunachal Pradesh	Central National Herbarium, Kolkata
35	*P. fairreanum*	NA	Gochum, Rupa	BSI-ERC, Shillong
36	*P. insigne*	NA	Khasiya mountains	Royal Botanic Garden, Kew
37	*P. villosum*	NA	Sairep, Mizoram	BSI-ERC, Shillong
38	*P. insigne*	NA	Khasi hills, Meghalaya	Central National Herbarium, Kolkata
39	*P. spicerianum*	NA	Cachar, Assam	Central National Herbarium, Kolkata
40	*P. hirsutissimum*	NA	Naga hills. Nagaland	Central National Herbarium, Kolkata

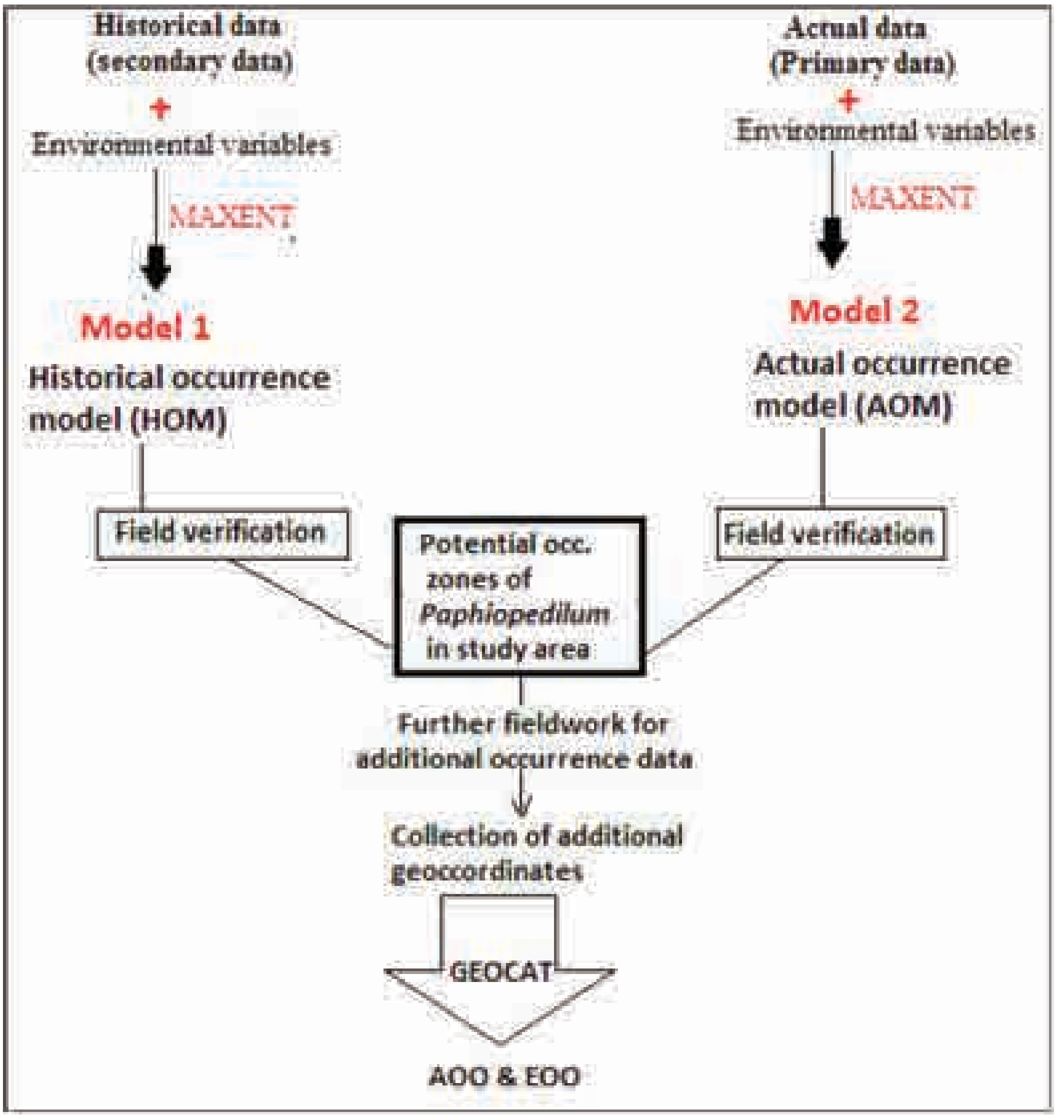

Figure 2. Flowchart of the study design.

Image 1. i—Cliff habitat site of *Paphiopedilum insigne* | ii—Habitat of *Paphiopedilum insigne* | iii— Habitat of *Paphiopedilum fairrieanum* | iv—Habitat of *Paphiopedilum spicerianum*. © Debonina Dutta.

Table 3. Actual occurrence records of *Paphiopedilum* spp.

	Species	State	Locality	District
1.	*P. spicerianum*	Mizoram	Lengpui	Mammit
2.	*P. insigne*	Meghalaya	Laimotsiang	East Khasi Hills
3.	*P. insigne*	Meghalaya	Latara	East Khasi Hills
4.	*P. insigne*	Meghalaya	Mawlyndiar	East Khasi Hills
5.	*P. insigne*	Meghalaya	Mawlyndiar (Liewla)	East Khasi Hills
6.	*P. insigne*	Meghalaya	Sohra (Nohkalikai)	East Khasi Hills
7.	*P. venustum*	Arunachal Pradesh	Dirang	West Kameng
8.	*P. venustum*	Meghalaya	Sohra	East Khasi Hills
9.	*P. fairreanum*	Arunachal Pradesh	Dirang	West Kameng
10.	*P. fairreanum*	Arunachal Pradesh	Dirang	West Kameng
11.	*P. fairreanum*	Arunachal Pradesh	Tenga	West Kameng
12.	*P. fairreanum*	Arunachal Pradesh	Rupa	West Kameng
13.	*P. venustum*	Sikkim	Upper Dzongu	North Sikkim
14.	*P.hirsutissimum*	Nagaland	Tobu	Mon
15.	*P.hirsutissimum*	Nagaland	Meluri	Phek
16.	*P. venustum*	Sikkim	Mangan	North Sikkim

followed by bio_2 (mean diurnal range) and bio_12 (annual precipitation). Amongst the bioclimatic factors, bio_12 showed the highest contribution to the build of AOM (Table 5).

Potential habitat areas and actual habitat areas of *Paphiopedilum* spp.

Figure 3 shows the Ecological niche model for HOM and AOM. The figure depicts the probable habitats in different colours. Areas in red are the highest potential areas for the distribution of *Paphiopedilum*. Yellow represents areas with medium potential whereas the low potential areas are represented by green; 40 secondary occurrence records (historical occurrence records) were recorded from literature and herbarium sources (Table 2). However, the field survey results revealed 16 actual occurrence records of the *Paphiopedilum* spp. in the study area (Table 3).

EOO & AOO of the genus *Paphiopedilum*

HOM shows the distribution regions of *Paphiopedilum* in Assam, Mizoram, Meghalaya, Sikkim, Arunachal Pradesh, Nagaland, and Manipur. However, according to AOM, the distribution of *Paphiopedilum* is

Table 4. List of environmental variables.

	Variable	Description
1.	Bio_1	Annual mean temperature
2.	Bio_2	Mean Diurnal Range (mean of monthly (max temp – min temp))
3.	Bio_3	Isothermality (P2/P7)*(100)
4.	Bio_4	Temperature Seasonality (standard deviation *100)
5.	Bio_5	Max temperature of the warmest month
6.	Bio_12	Annual precipitation
7.	Bio_14	Precipitation of Driest Month
8.	Bio_15	Precipitation of Seasonality (coefficient of variation)
9.	h_dem	Digital elevation model
10.	h_ topoind	Topographic index
11.	h_aspect	Aspect
12.	h_slope	Slope

found in all the states of northeastern India, found in HOM except Assam (Table 6). The EOO and the AOO for HOM of *Paphiopedilum* were 170,972 km^2 and 18 km^2. EOO and AOO for the AOM were 125,315 km^2 and 12 km^2.

DISCUSSION

Ecological niche modeling has efficiently predicted the potential population areas of the genus in this study. The high AUC values for training and testing (> 0.90) infer the high efficiency of the niche model to differentiate between presence and absence areas for the species.

In the Table 6, a comparison between the historical presence sites and actual presence sites obtained through ENM survey is presented. This comparison revealed the high predictive value of the model. It, therefore, provides a check on the accuracy and reliability of the ENM model in the present study.

Significant environmental variables determining the distribution of *Paphiopedilum*

According to the jackknife model and the percent contribution of variables in model build, the parameter bio_2 (mean diurnal range) shows the highest contribution to the build of HOM (Table 5). The variable bio_2 infers to the mean of monthly temperatures (max temperature-min temperature). It contributes 46.6% to the model build of HOM, indicating the high importance of the mean temperature in the growth of the orchids of this genus.

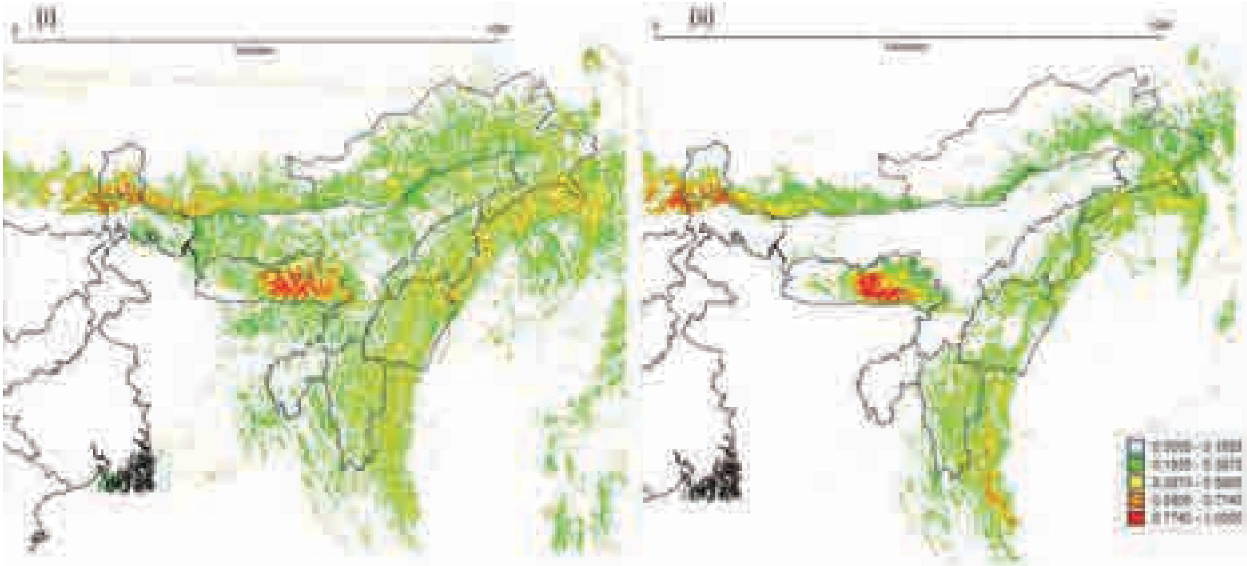

Figure 3. ENM Models representing: i—Historical distribution of *Paphiopedilum* (Model 1) | ii—Actual distribution of *Paphiopedilum* (Model 2) in study area.

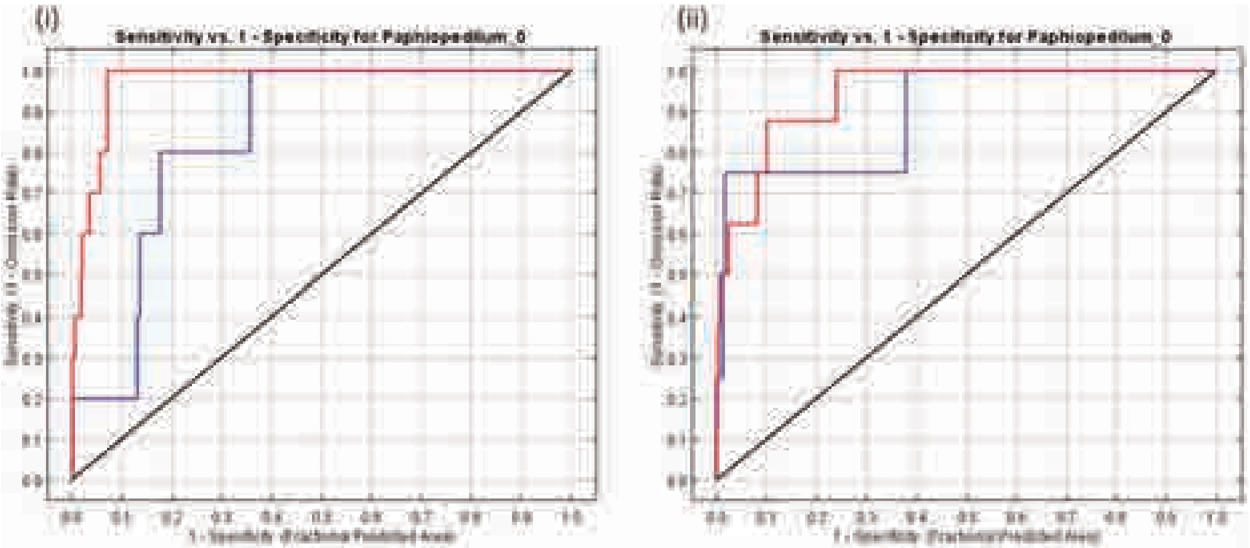

Figure 4. AUC: i—Historical occurrence model | ii—Actual occurrence model.

In the AOM, bio_12 is the most significant variable in the jackknife interpretation of the model (Figure 5). The variable bio_12 indicates the annual precipitation in the model build. The bio_12 variable is followed by bio_2 (mean diurnal range) and bio_5 (max temperature of the warmest month). These results indicate that temperature and rainfall are two important contributors that determine the availability of the members of genus *Paphiopedilum*. The field observations also correlate the importance of precipitation and temperature requirements of *Paphiopedilum*.

All the species of this genus found in northeastern India are found between an altitude of 200–2,200 m, which shows importance of h_dem (digital elevation model) being one of the highest contributing variables of the internal jackknife of HOM (Figure 5, Table 5). Similarly, mean temperature, mean diurnal range, max temperature of the warmest month and annual precipitation play a significant role in the model execution of *Paphiopedilum* in both HOM and AOM.

Other workers have also studied the dependence of the survival, reproduction, and germination of different plant species on temperature and precipitation. For instance, Wilkie et al. (2008) reported the influence of

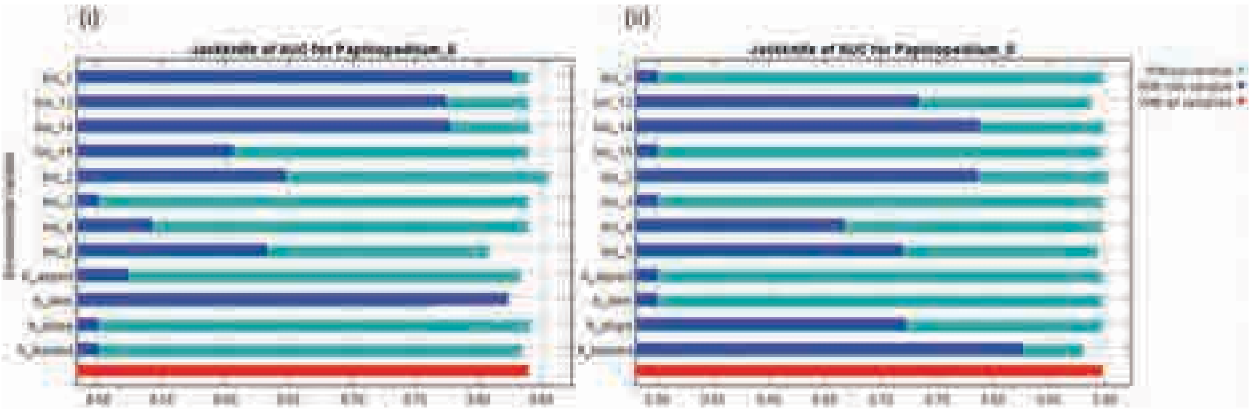

Figure 5. Jackknife of environmental variables: i—Historical occurrence model | ii—Actual occurrence model.

Table 5. Percent contribution of variables in model build.

Percent contribution of variable in Historical occurrence model			Percent contribution of variables in Actual occurrence model		
Variable	Percent contribution	Permutation importance	Variable	Percent contribution	Permutation importance
bio_2	46.6	8.9	bio_12	41.9	0
bio_1	19.3	0	bio_2	29.1	43.1
h_aspect	19.1	6.6	bio_5	24.4	53.1
h_dem	6	27.5	h_topoind	3.9	3.8
bio_14	4.3	0.2	bio_14	0.7	6.7
bio_5	3.7	55.3	bio_15	0	0
h_topoind	0.7	1.3	h_slope	0	0
bio_12	0.3	0	h_dem	0	0
h_slope	0	0	h_aspect	0	0

low temperatures (vernalization), seasonal variations in temperature, photoperiod, and water stress on the flowering of plants (Wilkie et al. 2008). In another study, inadequate temperature conditions during endodormancy compromised flowering or led to erratic and longer flowering duration with morphological disorders and flower necrosis (Rodrigo & Herrero 2002).

AOO, EOO concerning the past and present distribution of *Paphiopedilum*

Comparison of both models shows that the species distribution of *Paphiopedilum* has undergone a sharp decline over the past two decades. Field observations also indicate highly fragmented populations. All the species of this genus have very few individuals in the study area. A reduction in the extent of occurrence (EOO) and area of occupancy (AOO) was observed in the AOM compared to the HOM. During the field survey no species was located in the earlier reported sites of Assam (Table 6).

The reduction in AOO could be due to factors like over-collection, climate change, urbanisation, unplanned development, and habitat fragmentation. An increased frequency of large-scale disturbances caused by extreme weather events is known to cause increasing gaps and an overall contraction of the distribution range, particularly in areas with relatively low levels of spatial cohesion (Paul & Wascher 2004).

Effects of habitat fragmentation on the persistence of populations and species play a major role in conservation biology (Reed & Frankham 2003). Limitations of plant species dispersal also affect plant colonization (Olivier et al. 2002). Small population sizes, lead to decreased population fitness and eventually make the small population sizes more vulnerable to extinction (Reed & Frankham 2003; Reed 2005, 2008). The field studies revealed that the populations of *Paphiopedilum* had very few individuals. The habitat was also highly fragmented. These factors are further exacerbating the risk of extinction of the genus.

It was observed that *Paphiopedilum* grew in the rock crevices of east-facing slopes of the habitats situated

Table 6. Comparison between historical occurrence data and actual presence data.

Species	State	Locality	Source	Nearby Positive sites as per field findings
P. spicerianum	Mizoram	Mammit district	Literature review	Present
	Assam	Cachar, Sonai river Bank, Barak river bank, Narpuh WS.	Literature review Herbarium data ENM depiction	Not found
P. fairrieanum	Sikkim	Tinkitam	Literature review	Previously presence reported. Habitat Destruction due to ongoing agricultural practices (Jhum cultivation)
P. insigne	Meghalaya	Cherrapunjee, Mawsynram, East Khasi hills	Literature review, Herbarium data, ENM depiction	Present
P. venustum	Sikkim	Beh, Tong, Sanklang (Sikkim)	Literature Review, Herbarium data	Present
	Meghalaya	Jaintia Hills	Literature Review, Herbarium data	Not found
P. fairreanum	Arunachal Pradesh	Gacham village, Rupa, Tenga valley	Herbarium data	Present
P. fairreanum	Arunachal Pradesh	Jameri village	Herbarium data	Absent
P. villosum	Mizoram	Sairep, Theiriat, Lunglei	Herbarium data, ENM depiction	Present
P. hirsutissimum	Manipur	Maram	Herbarium data	Not found

in the hilly terrains (Image 1). They also grew in the space between tree roots and rock layers of the habitat substratum. The prolonged filling of the conjoining rock fissures between the rock crevices and tree roots by the dry leaves and soil organic matter of the forests provide an excellent growth medium for these orchids in the otherwise soil-deprived cliff sides (Phillips 2017).

CONCLUSION

In this study, the present status of *Paphiopedilum* in northeastern India has been determined using ENM-based surveys combined with historical data. The herbarium data provided location history from 1857 onwards (Table 2), while the field data helped in the present assessment of the genus. There was a significant reduction in the EOO and AOO in the actual model as compared with the historical model. The results of the model reveal that temperature and precipitation are the highest contributing factors determining its availability. We were unable to locate the plants in many locations that were earlier mentioned by previous workers. Therefore, it can be inferred that change in the temperature and precipitation patterns in many locations have led to its scarcity. However, this inference needs to be further corroborated with detailed records of the climate parameter.

These orchids are becoming increasingly rare mainly due to over collection from the wild, rising urbanization causing habitat destruction and also global warming (Swarts & Dixon 2009; Seaton et al. 2010; Barman & Devadas 2013; Ye et al. 2021). Favorable climatic conditions, access to wild habitat sites, and a conducive environment are important for the survival of plants (Hulme 2005; Ballantyne & Pickering 2015; Wraith & Pickering 2018; Li et al. 2020; Ye et al. 2021). The comparison of environmental requirements of the distribution of *Paphiopedilum* over the years imparts an understanding of the adaptability of these orchids with changing environmental conditions. The dwindling population size of the various species under the genus is increasing the risk of extinction of the already sparse populations in the study area. The over-collection of the *Paphiopedilum* flowers from the wild for its high market demand results in further habitat loss. Forest road constructions and urbanization also cause further degradation of the *Paphiopedilum* habitats in different areas of Northeast India. Such reasons have caused the *Paphiopedilum* orchids to become increasingly rare with time.

Ex situ conservation techniques for mass production of the species with higher market demand could reduce collection pressure on already dwindling wild populations in northeastern India. *Paphiopedilum* orchids are being propagated elsewhere in the world using various techniques (Huang 1988; Hong et al. 2008; Ng & Saleh 2011). Various individuals have been reintroduced into other suitable habitats by various workers in China (Yang et al. 2020; Gao et al. 2020). Since, in situ conservation is not a viable approach in many locations due to their habitat degradation and other developmental pressures, reintroduction into potential habitats will aid in conservation of the species. We recommend that reintroduction of *Paphiopedilum* orchids should be conducted on a large scale by both government and non-governmental agencies in northeastern India. We recommend the conservation of *Paphiopedilum* orchids using an integrative conservation approach of ecological niche modeling to search for additional locations, ex situ propagation techniques, and possible reintroduction in selected areas. Such schemes can be helpful to meet the market demands of *Paphiopedilum* orchids and boost the conservation of wild populations in northeastern India.

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COMMUNICATION

Foraging activity and breeding system of *Avicennia officinalis* L. (Avicenniaceae) in Kerala, India

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Abstract: Field studies were carried out to assess the foraging activity and the breeding system of *Avicennia officinalis* L. in Chettuwa, Thrissur, India during the two flowering seasons of 2018–2019. *A. officinalis*, also known as the Indian mangrove is a common mangrove occupying the river banks of the Kerala coast of southern India. The plant blooms massively during the onset of the first summer showers. The flowering to fruiting period lasted from April to July. Bagging experiments revealed that *A. officinalis* preferred a mixed breeding system though they had a low fruit set recorded in self-pollination experiments. A total of 15 species of foraging insects belonging to three orders, Hymenoptera, Diptera, and Lepidoptera, were observed. The three most abundant insect foragers were *Apis florea* Fabr., *Campsomeriella collaris* Fabr., and *Chrysomya megacephala* Fabr. Among these, *A. florea* showed a significantly high visitation rate followed by *C. collaris* and then *C. megacephala*. *C. collaris*, however, had the highest and most significant handling time for *Avicennia officinalis than A. florea*. The peak foraging activity was recorded from 1000h to 1100h and from 1500h to 1700h. These findings emphasize the importance of insect flower visitors in the breeding of *A. officinalis*, highlighting the need to maintain the plant-pollinator relationships for the protection of mangrove ecosystems.

Keywords: *Apis florea*, foraging behaviour, handling time, mangroves, pollinators, visitation rate.

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Author contributions: VK—conceptualization, work design, data collection, data analysis, writing original draft, reviewing & editing. CFB—work design, critical reviewing of the article, editing , final approval of the article and supervision.

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INTRODUCTION

Mangroves are shrubs seen in the coastal area of the tropics and the subtropics. They are well known for their irreplaceable role in protecting the coasts and for their large carbon pool. These salt-tolerant plants exhibit varied physiological and morphological adaptations that enable them to thrive in the extreme conditions of hypersalinity and tidal inundations. It is one of the important coastal ecosystems that provide numerous ecosystem services and carry out several ecological functions (UNEP 2014). This architecturally different and unique ecosystem is home to a variety of plant and animal species. Due to anthropogenic activities, however, there is a drastic decline in the mangroves around us. Nearly one-third of the mangrove forests have been lost over the past fifty years (Alongi 2002). According to the India state forest report by FSI (2019), the total area of mangroves in Kerala is about 9 km^2 which accounts for 0.18% of the total mangrove cover of India. *Avicennia officinalis*, belonging to the Avicenniaceae family is one of the major mangrove species occupying the coasts of Kerala. *Avicennia* species, in particular, are capable of surviving in the normal tidal range to hyper-saline conditions, thus they occupy diverse habitats (Raju et al. 2012). Hence, maintaining a highly productive ecosystem is essential to maintain the balance of nature.

Insects play a major role in many ecological processes especially pollination of mangroves. Pollination refers to the actual mechanism of transferring pollen from one flower to another (Tomlinson 1986). It is considered as one of the vital processes in plant–animal interaction. Pollinators play a crucial role in the breeding mechanisms of some mangrove plants (Pandit & Choudhury 2001). It is one of the important phenomenon in angiosperm reproduction to an extent and it is said to be coevolved and mutualistic (Huang & Giray 2012). Pollinators and their activity on mangroves of Kerala are less documented, however, in the eastern coasts, pollination biology of *Avicennia* species in the Coringa forest was documented by Raju et al. (2012). Studies on the reproductive strategies in *Aegiceras corniculatum* (L.) Blanco in the Gujarat coast was done by Pandey & Pandey (2014). The pollinators of mangroves from Sundarbans were carried out by Mitra et al. (2015). On the southern coast, Remadevi et al. (2019) documented the insect visitors of three mangrove species.

Understanding the breeding system of the plant is essential for any pollination-related studies. Mangroves exhibit both self-pollination and cross-pollination (Kathiresan & Bingham 2001; Tomlinson 2016). Though *A. officinalis* exhibit both pollination mechanisms, self-pollination is unlikely due to protandry (Tomlinson 1986). Protandrous flowers have the male and female functions temporarily separated and the pollen is presented before the stigma becomes receptive (Imbert & Richards 1993). This study aims to determine the foragers and their foraging activity and the breeding system of *Avicennia officinalis* on the Kerala coast which might be helpful in protecting this species in this fragile ecosystem.

MATERIALS AND METHODS

Frequency of visits by foragers

The study was carried out in Chettuva (Peringad village 10.5463^{0}N 76.0641^{0}E) (Figure 1), Thrissur District, Kerala the southern coast of India during 2018–2019. Flowering seasons were ascertained through regular field visits. Insect visitors were recorded during the daytime. For this, an area of a 3 sq. m. area was marked and 50 flowers were tagged and insects visiting them were observed from 0700 to 1700 h to understand their frequency of visits and peak foraging time. Anthesis were determined in prior, thus the time was selected. Insects were recorded visually, photographed, and collected for analysis and identification. Transparent bottles were used to collect the insects. Collected insects were preserved in 70% ethanol and identified using standard literature and with the help of experts. A bar chart was plotted to better interpret the frequency of insect visits.

Breeding experiment

To understand the breeding pattern, mature floral buds of the same age from selected inflorescences on different individual plants were tagged and enclosed in paper bags. About 50 flowers were selected to study each mode of the breeding system. The flowers were bagged with fine mesh to observe the fruit set in spontaneous autogamy. To understand the manipulated autogamy, the stigmas of the flowers were hand-pollinated and then bagged. For geitonogamy, the emasculated flowers were hand-pollinated with pollen from another flower of the same plant and for xenogamy, the emasculated flowers were pollinated with pollen from the flower of a different plant of the same species and bagged and then observed till the fruit set. One set was left for open pollination, where flowers on a different plant were tagged and the fruit set was noted as given in Raju et al. (2012).

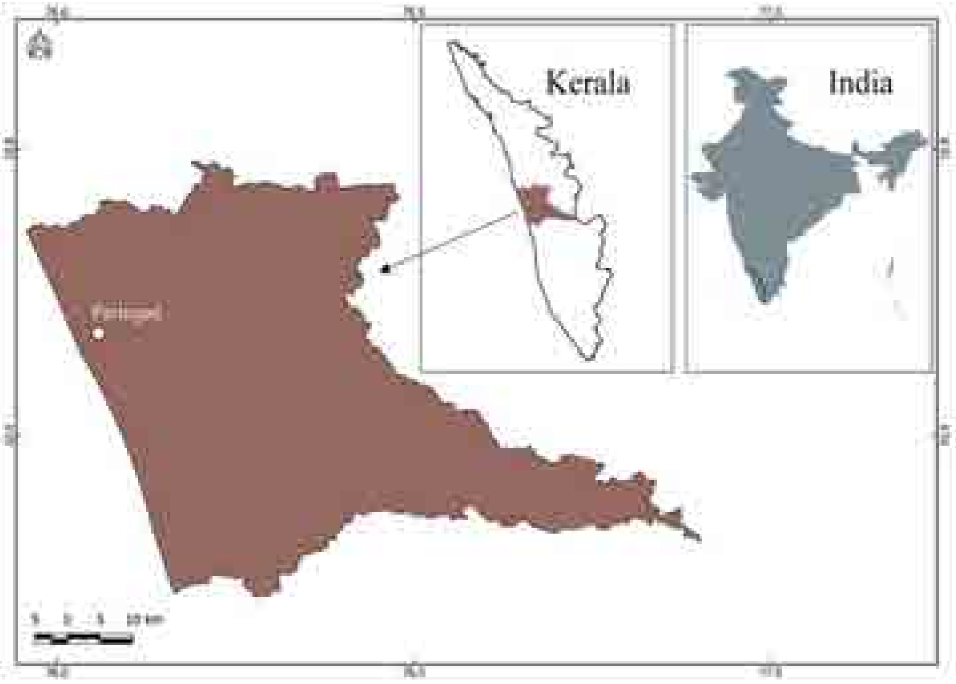

Figure 1. The study area (Peringad, Thrissur, Kerala).

Insect visitors and the number of flowers bloomed

The total number of insects visiting the bloomed flowers on a single branch of the plant in a minute was recorded to understand the relation between the insect visitors and the number of bloomed flowers. A total of 30 observations were recorded among the plants selected randomly.

Foraging behavior of insects using visitation rate and handling time

The foraging activity of insects was measured as the visitation rate and handling time, where the visitation rate can be defined as 'the average number of flowers visited per unit time' and handling time can be defined as 'the average time spent on each visited flower' (Herrera 1989). Individual insects were monitored continuously for a maximum of 2 min while they are actively foraging on the flowers of *A. officinalis*. Observations were made for 10 days during the massive flowering period each year. For, each time sequence of 2 min, the total time spent on flowers (TF—from landing to take off) and total observation time (TT—time in flowers plus time in flight between two consecutive flowers) were noted using separate stopwatches. The total number of flowers visited (NF) over the entire observation period was also recorded for each time sequence. From these observations, visitation rate (the average number of flowers visited per unit time (NF/TT)), handling time (average time spent on each flower by an insect (TF/NF)), and flight time (average time spent in flight between two consecutive flower visits (TT-TF)/NF) were computed as given in Herrera (1989).

Statistical analysis

Statistical analyses were carried out using PAST 4.03 software. To analyse the relationship between the number of bloomed flowers and the number of insect visitors, correlation analysis was performed. Visitation rate (VR) and handling time (HT) were analysed using one-way ANOVA. This was carried out by taking the average value in each and was tested at a 5% significance level ($P < 0.05$). Box plot was used for easy interpretation of the results.

RESULTS AND DISCUSSION

Field observations were carried out to understand the breeding biology of *Avicennia officinalis*, and to identify major insect foragers, their visitation rate, and foraging activity on the Kerala coast. It was observed that flowering commenced in late March and extended up to July. Mature buds were seen during mid-April, and a peak in flowering was observed between late April and early May followed by June. There was a decline in the flowering with the arrival of the monsoon and the flowering ceased by September, however, in previous studies, the flowering of *A. officinalis* on the Godavari Mangrove Forest, Andhra Pradesh, and on the Karnataka coast, both representing the East coast of India, were recorded in late summer to the end of August (Raju et al. 2012) and in July (Remadevi et al. 2019), respectively.

The flowers were fragrant, small, and sessile, 1–1.5 cm in length, yellow-orange, actinomorphic, and bisexual. Nearly 10–14 flowers were found in one unit of inflorescence and a bloomed flower lasted for six days. Stamens are four, epipetalous, filaments 2.5 mm long that are fused with corolla. Anthers are 1 mm long, basifixed alternating to petals. The ovary is superior and unilocular with four imperfect locules having one ovule each. The glabrous style has a tapering stigma that is bilobed.

Results from the bagging experiments revealed that cross-pollination resulted in better fruit set in *A. officinalis*, where the fruit formation was 70% for xenogamy, 64% for geitonogamy, 58% for open pollination, and 40% for manipulated autogamy (Table 1). In the current study, the rate of success of unmanipulated autogamy was 10%. These results were similar to the observation of Raju et al (2012). Manipulated autogamy indicated that the flowers were self-compatible, but the reduced reproductive success suggests that the pollination was vector-dependent. Raju et al. (2012) observed the role of insects like bees and flies in the pollination of *A. officinalis*. The successful formation of fruits in different modes of reproduction suggests that a flexible (or mixed) breeding system was entertained by the plant to promote outcrossing and genetic diversity through both self-pollination and cross-pollination (Primack et al. 1981; Reddi et al. 1995).

Fifteen insect species belonging to nine families and three orders (Hymenoptera, Diptera, and Lepidoptera) were identified as foragers (Table 2). Bees and flies visited the flowers in groups, whereas butterflies were found individually. Insects were observed probing in the upright position for collecting the pollen and nectar which allows the ventral part of the insects to touch the stamens and anthers. Thirteen insect species were reported as foragers in the Coringa forest in Andhra Pradesh (Raju et al. 2012). *Apis dorsata* Fabricius recorded in previous studies as one of the foragers on *A. officinalis* was not observed in the current study. On the other hand, *C. megacephala* was reported in Sunderbans and Karnataka (Raju et al. 2012; Remadevi et al. 2019; Chakraborti et al. 2019). Among the three orders, hymenopterans were found to be the most dominant forager group followed by dipterans and lepidopterans. In hymenopterans, Apidae were the major foragers and the most dominant pollinator species were *Apis florea* and *Campsomeriella collaris*. The greater preference for bees by *Avicennia* species was reported by Chakrabarty (1987) and Akter et al. (2020). This contrasts with the observation of Mitra et al. (2015) where the flowers of Avicenniaceae were found to be predominantly visited by dipterans with calliphorids as major visitors followed by sarcophagids, tabanids, tephritis, and drosophilids. Further, seven families of dipterans as predominant foragers of *A. officinalis* were recorded from the coast of Karnataka (Chatterjee et al. 2010).

Since hymenopterans have visited flowers more frequently than lepidopterans and dipterans, the foraging activities of two major hymenopteran species such as *C. collaris* and *A. florea* were considered for the detailed study. The foraging activity of both species showed a peak between 1000 and 1100 h in the forenoon

Table 1. Results of the breeding experiments in *Avicennia officinalis*.

Breeding system	No. of flowers pollinated	No. of Fruit set	Fruit set (%)
Autogamy	50	5	10%
Autogamy (manipulated)	50	20	40%
Geitonogamy	50	32	64%
Xenogamy	50	35	70%
Open-pollination	50	29	58%

Table 2. Insect visitors of *Avicennia officinalis*.

	Order	Family	Species
1.	Hymenoptera	Scolidae	*Campsomeriella collaris* Fabr.
2.		Apidae	*Apis florea* Fabricius
3.		Apidae	*Apis cerana indica* Fabr.
4.		Apidae	*Xylocopa* sp.
5.		Apidae	*Ceratina* sp.
6.		Vespidae	*Polistes* sp.
7.		Formicidae	*Oecophylla smaragdina* Fabr.
8.	Diptera	Calliphoridae	*Chysomya megacephala* Fabr.
9.		Calliphoridae	*Lucilia* sp.
10.		Sarcophagidae	*Parasarcophaga* sp.
11.		Syrphidae	*Eristalinus* sp.
12.		Dolicophodidae	*Dolichopus* sp.
13.	Lepidoptera	Nymphalidae	*Junonia atlites* L.
14.		Nymphalidae	*Danaus genutia* Cramer
15.		Nymphalidae	*Tirumala limniace* Cramer

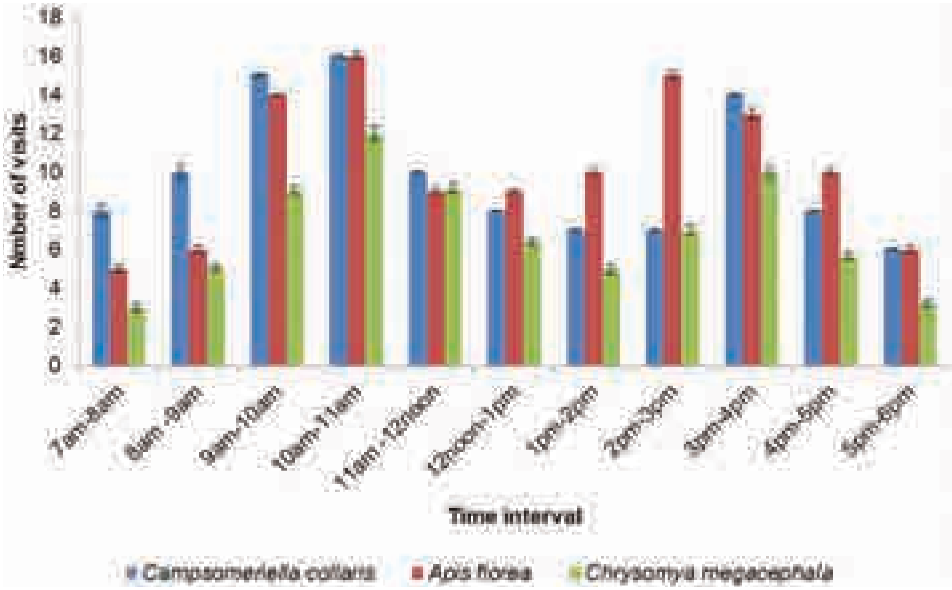

Figure 2. Hourly foraging activity of the three selected insects on *Avicennia officinalis*.

and between 1500 and 1630 h. The foraging activities were greatly dependent on resource availability and environmental parameters, especially temperature which majorly affects the activity (Mani 1982). In the study, both species favored high temperatures by increasing foraging activity to specific times of the day during the mid and late afternoon (Pandit & Choudhary 2001). On the Karnataka coast, nearly 23 insect species (Remadevi et al. 2019) and on the eastern coast, 14 insect species (Raju et al. 2012), and in Sundarbans, 23 insect species (Chakraborti et al. 2019) were reported foraging on *A. officinalis*. The foraging activities of other insects such as odonates were also noted though their role as foragers or pollinators has yet to be established (Panda et al. 2019). Moreover, the role of these insect visitors in maintaining a healthy mangrove ecosystem on the Kerala coast needs to be further elucidated. As the abundance of pollinators symbolizes a healthy environment, their periodic monitoring and assessment will be an effective tool in the environmental impact studies and management of any vulnerable ecosystem.

Relation between flowers blooming and insect visitors

Analyzing the relation between the number of flowers that bloomed and the number of insect visitors helps to understand pollinator behavior. The correlation study between the number of flowers that bloomed against the number of insect visitors showed a positive linear correlation ($r = 0.88$, $n = 20$, $P < 0.05$; Figure 3) between the flower abundance and the number of insects visited. Similarly, a positive linear correlation

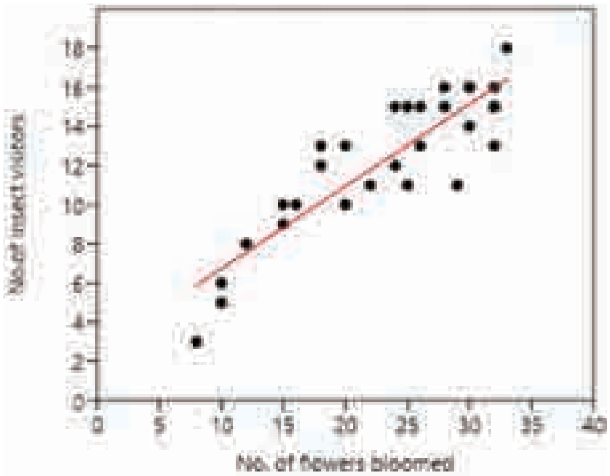

Figure 3. Correlation analysis (r) between the number of flowers bloomed versus number of insect visitors (n = 30). Values closer to 1 shows strong correlation and values closer to 0 indicate weak correlation.

was also observed between insect visitors and bloomed flowers in Sunderbans mangrove forests (Chakraborti et al. 2019).

Visitation rate and handling time

Among the three major pollinators, *A. florea* has the highest visitation rate (5 ± 0.20 flowers/min) followed by *C. collaris* (4.95 ± 0.25 flowers/min) and *C. megacephala* (3.07 ± 0.15 flowers/min) (Figure 4). *C. collaris* has the highest handling time (9.59 ± 0.42) followed by *A. florea* (6.05 ± 0.4) and *C. megacephala* (5.85 ± 0.23) (Figure 5). A significant difference was noted in the visitation rate

Table 3. One-way ANOVA of insect visitors on *Avicennia officinalis* for their visitation rate (VR) and handling time (HT).

Test for equal means					
Visitation rate					
	Sum of squares	df	Mean square	F	P <0.05
Between groups	48.1583	2	24.0792	30.11	0.0001*
Within groups	45.5875	57	0.799781		
Total	93.7458	59	24.0792		
Handling time					
Between groups	175.396	2	87.6982	32.73	0.00003*
Within groups	152.741	57	2.67966		
Total	328.137	59			

*Significant at P <0.05.

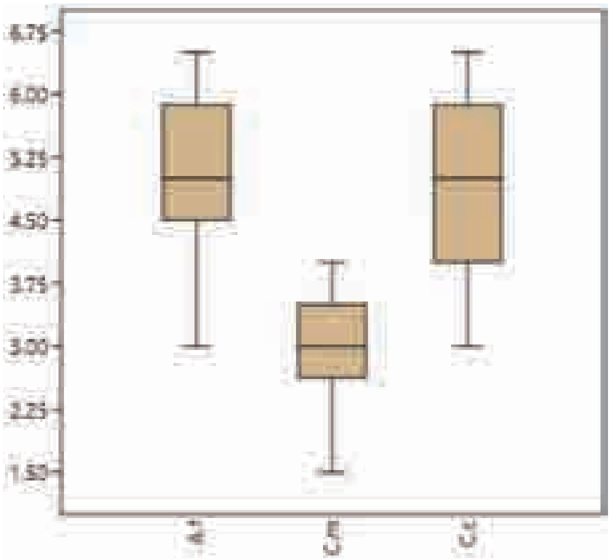

Figure 4. Box-plot analysis for visitation rate (VR) of three species of insects on *A. officinalis*, *Apis florea* (A.f), *Chrysomya megacephala* (C.m), *Campsomeriella collaris* (C.c).

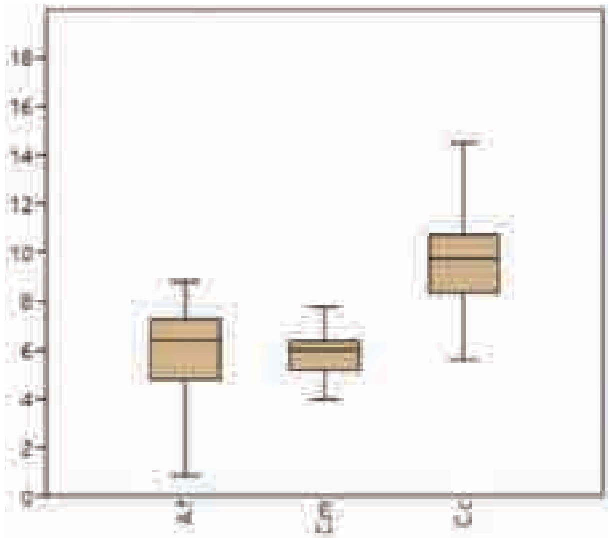

Figure 5. Box plot analysis for handling time (HT) of three species of insects on *A. officinalis*, *Apis florea* (A.f), *Chrysomya megacephala* (C.m), and *Campsomeriella collaris* (C.c).

and handling time between these three insect visitors on *A. officinalis* (Table 3). The significant difference is seen in the visitation rate of *A. florea* & *C. megacephala* (P-value 0.0002) and that between *C. collaris* and *C. megacephala* (P-value 0.0003) (Figure 4). It was also found that the handling time for hymenopterans was greater than that of the dipteran giving us an inference that hymenopterans could be a potential pollinator for *A. officinalis*. Visitation rates may depend upon floral characters and have insect-specific variations. Different insects respond differently to the same plant due to these reasons (Primack & Inouye 1993; Pandit & Choudhury 2001).

Mangroves are one of the most threatened ecosystems all over the world (Alongi 2002). From the conservation point of view, this study gives us insights into the importance of insect visitors and pollinators in the fragile ecosystem of the Kerala coasts of India. More studies, however, are to be carried out to understand the different ecological requirements of various species in this ecosystem and to implement better conservation measures.

CONCLUSION

The common mangrove *Avicennia officinalis* bloomed during mid-summer from April to July on the Kerala coast of southern India. The three most abundant insect foragers on *Avicennia officinalis* found in this study were *Campsomeriella collaris* (Fabr.), *Apis florea* (Fabr.), and *Chrysomya megacephala* (Fabr.). Bagging experiments showed that an effective fruit set was more prominent in cross-pollinated flowers than self-pollination. *Apis florea* was an efficient forager as they showed a higher visitation rate and low handling time than *Campsomeriella collaris*. Understanding the foraging behavior help in implementing necessary measures at the habitat level for the protection of the pollinators which in turn helps in ecosystem conservation. Therefore, it is essential to protect these insect species for the long-term conservation of the mangrove ecosystem.

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COMMUNICATION

Diversity patterns and seasonality of hawkmoths (Lepidoptera: Sphingidae) from northern Western Ghats of Maharashtra, India

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Abstract: As most of the biodiversity studies report the abundance and enlist the species, there is severe data deficiency in understanding the diversity patterns. The present study was designed to carry out periodic diversity assessments to understand the trends in diversity patterns of hawk moths. The study was carried out in the northern Western Ghats in Nashik district. Seven sampling stations were identified and periodic visits to these places were carried out over the span of five years (2011–2015). A total of 463 moths were recorded belonging to 18 species, represented by 10 genera. A new record from Western Ghat, *Theretra sumatrensis* (Joicey & Kaye 1917) is reported for the first time along with its DNA barcode. Six diversity indices (four alpha diversity indices and two beta diversity indices) were employed to understand the diversity dynamics. Whittaker's plot was generated using the rank abundance suggesting high species evenness for all sampling stations. Maximum diversity was observed during Monsoon. Wani was the most diverse sampling station throughout the study period (Shannon's Index = 2.7132±0.060; Simpson's Index = 0.9273±0.006; Brillouin's Index = 2.252±0.089; Fisher's alpha = 10.9472±1.685). Beta diversity was assessed with the help of Dice's coefficient and Jaccard's similarity index. Hence, we recommend rigorous periodic diversity assessments to generate adequate information about diversity that expedites conservational strategies' pace.

Keywords: DNA barcode, moth diversity, new report, range extension, species abundance, Sphingidae.

Abbreviations: CH—Chandwad; IG—Igatpuri; KL—Kalwan; NC—Nashik City; PT—Peint; TM—Triambakeshwar; WN—Wani.

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Author contributions: ASK and SM were involved in project design. Data collection and analysis were performed by ASK, GDK and SM. ASK and SSG were involved in manuscript preparation.

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INTRODUCTION

Insecta, being the most diverse class of Kingdom Animalia, rules the planet with their existence in all habitats. The adaptive features of this group of organisms allowed their natural selection in due course of evolution. Insects have existed since the Silurian period, approximately 420 mya (Misof et al. 2014). Currently, insects account for almost half of the known species on the earth (Chapman 2009). The tropical climate of India provides a conducive environment for a variety of insects. According to Murugan, 80% of insects from India are endemic (Murugan 2006).

Lepidoptera is one of the four super radiations of the class Insecta and includes butterflies and moths. Moths account for 85% of the lepidopteran population, and the remaining 15 % are butterflies and skippers. Moths serve as food for a variety of animals such as birds, bats, and praying mantis (Macgregor et al. 2015). The moth caterpillars are plant feeding, while the adult forms of the moths may be nectar feeding or fruit piercing (Reddy et al. 2005). Thus, forming a major pest clade (Cho et al. 2008). Moreover, their association with the plants makes them an integral part of the ecosystem. As a result, their numbers and availability are a good indicator of ecosystem's health (Thomas 2005).

Diversity studies of sphingid moths from India have been done and reported by many taxonomists (Bell & Scott 1937; Roonwal & Thapa 1963; Subalakmi 2008; Smetacek & Kitching 2012; Chandra et al. 2013, 2014; Kitching et al. 2014; Pathania et al. 2014; Sondhi et al. 2017; Melichar et al. 2018; Iyer & Kitching 2019; Singh et al. 2021). E.C. Cotes and C. Swinhoe conducted preliminary pioneering studies on Sphingid moths (Cotes & Swinhoe 1889). Further substantial work was done by Hampson (Hampson 1892). He reported 121 species of sphingid moths across India. Later, Bell & Scott (1937) documented sphingid from the Indian sub-continent. Almost three decades later, Roonwal & Thapa (1963) enlisted sphingids from peninsular India. Sambath (2011) described documented sphingid fauna from Dalma Wildlife Sanctuary, Jharkhand. Shubhalaxmi et al. (2011) described 45 hawk moths from northern Western Ghats near Mumbai. Sphingid moths from peninsular India were listed by Patil et al. (2013). Chandra et al. (2013) reported sphingid diversity from Veerangana Durgavati Wildlife Sanctuary, Damoh, Madhya Pradesh. The sphingid fauna from Ladakh, Jammu & Kashmir was reported by Smetacek & Kitching (Kitching et al. 2014). Sondhi et al. (2017) described a new species of *Theretra* Hubner from southern Western Ghats. Even though there are many studies of moth diversity, there has been a meagre number of inventories undertaken to focus primarily on the family Sphingidae. Further, there has been one report of sphingid diversity from the northern Western Ghats (Gurule & Nikam 2013). However, this study did not focus entirely on the diversity and dynamics of sphingid moths.

The novelty of the present study lay in the exclusivity and thoroughness attained to understand and analyze the hawkmoth moth diversity. Hawkmoths account for a very low number (~1,400 global species) than other giant moth families such as Erebidae and Geometridae (van Nieukerken et al. 2011); thus, get insufficient attention to the inventories. However, sphingids are known to be major pests but also good pollinators (Madden 1944; Eisikowitch & Galil 1971; Nilsson et al. 1985; Danaher et al. 2019). Hence, their presence creates a unique balance in the ecological niche. Also, these are some of the best flyers amongst the moth community.

MATERIAL & METHODS

Study Area

The present study aimed to analyze the diversity of sphingid moths from the northern Western Ghats (Nashik district), Maharashtra, India. Nashik district is located between 18.33–20.53 °N & 73.16–75.16 °E (Image 1). It covers approximately 15,582 km^2 and lies on the western edge of the Deccan plateau. The Sahyadri Mountains lie in the western part of the district, while Wani and Chandwad hill ranges cover the central part of the district. There are no ranges in the eastern part of the district. Forest coverage is approximately 3,400 km^2. The forests are of mixed type, with Teak and Sissoo being the significant trees. The forests are tropical moist deciduous, tropical dry deciduous and tropical hill forest types. As per Koppen's climate classification, the study area is a tropical wet and tropical dry climate with peak rains in July (McKnight 2017). The Western Ghats divides the district into two parts: The western part lies in the rainfed region, while the eastern part lies in the rain shadow region.

Collection & Identification

From 2011 to 2015, extensive observation and collection were carried out. The study area was thoroughly studied to finalize the sampling stations (Table 1). After the initial survey, seven sampling stations were finalized. Table 2 describes the details of the sampling stations and the collection events. Light traps

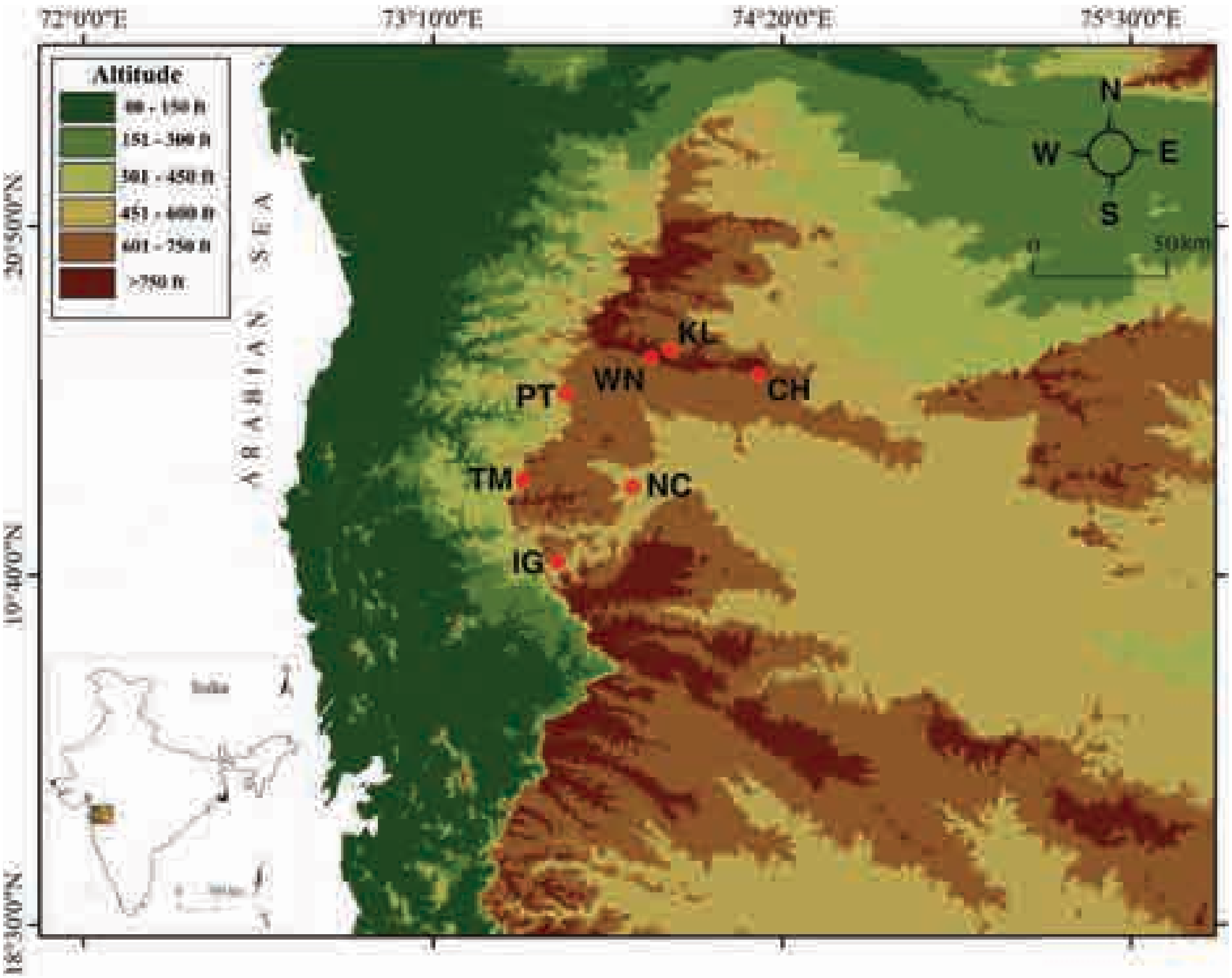

Image 1. Geographical location of the sampling sites.

Table 1. Sampling stations with their co-ordinates.

Name of sampling station	Abbreviation	Latitude	Longitude
Chandwad	CH	20°20'26.42"N	74°15'10.18"E
Igatpuri	IG	19°42'37.21"N	73°34'42.56"E
Kalwan	KL	20°25'12.49"N	73°57'8.99"E
Nashik City	NC	19°57'31.44"N	73°49'47.01"E
Peint	PT	20°15'33.42"N	73°36'40.43"E
Triambakeshwar	TM	19°59'6.19"N	73°28'1.21"E
Wani	WN	20°23'26.49"N	73°54'25.79"E

or a simple spreadsheet operated by fluorescent light (Compton 35 W; Philips tornado 27 W 130–320 V) were used. Collection set up was run from around 1900 h to 0500 h. Inverter batteries were used for operating the lights.

According to Brehm & Axmacher (2006), adaptability and flexibility in collection methods result in better collection and observations. Therefore, the collection assembly type varied initially, and the best-suited method was followed based on the collection conditions. However, hawkmoths vibrate their wings, causing loss of wing scales in the light trap. Moreover, all the observed specimens were not collected, and documentation of moths was easier by spreadsheet setup. Hence, the spreadsheet method was preferred over light traps. The sampling sites with large capture rates are challenging to handle, which is a common experience shared by many lepidopterists. In such situations, collecting, relaxing, and spreading of specimens is arduous (Abang & Ak Karim 2002; Gurule & Nikam 2013). Therefore, moths were observed, and the species abundance was calculated during the collection visits. Unique moth specimens which could not be identified were collected and brought back to the laboratory to investigate further. A small sample size of moths was collected from each sampling station. Collected moth specimens were spread on spreading boards and were oven-dried for 3–5 days depending upon the size of the moth. The digital documentation was carried out using Nikon 3200 DSLR. Photographs were edited with the help of the software GIMP.

All the specimens were identified with the help of reference manuscripts (Barlow 1982; Holloway 1987; Haruta 1992, 1994, 1995; Inoue et al. 1997; Kendrick 2002; Srivastava 2002; Gurule & Nikam 2013; Sondhi et al. 2017). Unique samples were processed for molecular identification.

Along with the observation and collection of moths, other metadata was also collected, such as time of collection, altitude, the topography of the collection site, overall vegetation, season, and overall rainfall. These metadata are known to affect the moth availability and helps in understanding the ecological dynamics and intricate patterns of moth abundance (Hardwick 1972; McGeachie 1989; Yela & Holyoak 1997; Mittelbach et al. 2007; Chen et al. 2009).

Molecular Identification

Total genomic DNA was isolated using the modified phenol chloroform extraction method (Sperling et al. 1994). The isolated DNA was amplified using readily available markers LCO 1490–HCO 2198. A total reaction mixture of 25 µl was prepared, comprising of 12.5 µl trehalose, 2.5 µl 10X reaction buffer, 1 µl of $MgCl_2$, 2 µl of dNTP, 1 µl each of forward and reverse primer, 1.88 µl of water and 3 µl of DNA template. The thermal cycle included initial heating for DNA denaturation at 94°C for 2 minutes. The next five cycles were at 94 °C for 30 seconds followed by 45 °C for 1 minute and 30 seconds and final extension at 72 °C for 1 minute. The next 35 cycles were for 94 °C for 1 minute 30 seconds, 51 °C for 1 minute and 30 seconds, and extension at 72 °C for 1 minute. PCR product was cycle sequenced and sequencing was carried out in ABI 3130 sequencer. The sequencer files were aligned and edited using Bioedit and were converted to FASTA format. The FASTA files were uploaded on BOLD (Barcode of life Data systems, https://boldsystems.org) (Ratnasingham & Hebert 2007).

Figure 1. Recorded geographical expanse of *Theretra sumatrensis*. (© https://mol.org/species/Theretra_sumatrensis)

Diversity analysis

Four alpha diversity indices were employed: Shannon's, Simpson's, Brillouin's, and Fisher's alpha. Beta diversity was assessed with the help of two indices: Dice's Coefficient and Jaccard's similarity index. These diversity indices were calculated using cumulative abundance data, and all the calculations were performed using the software PAST ver. 4.03.

RESULTS

A total of 463 hawkmoths were recorded over five years (2011–2015). These moths were identified into 18 species represented by three subfamilies and ten genera (Image 2). The most diverse subfamily was Macroglossinae, represented by 12 species, and *Theretra* Hübner, 1819, was the most diverse genus comprising of seven species. Table 3 depicts the systematic position, distribution, and status of all the moths recorded.

T. sumatrensis (Joicey & Kaye 1917), the Southern Spotted Hunter Hawkmoth, was a unique record from this region and has not been previously reported. As described by Joicey & Kaye, 1917, *Theretra sumatrensis* has dull greyish-brown forewing. Black marks are present at the base. The post medial line is faint and marked on veins as dashes. Diffused darker clouds are present across the middle of the forewing. The hindwing is black with paler margins. There is the presence of a distally pointed yellowish patch at the anal angle. Sondhi et al. 2017 have compared the habitus of other species of the genus *Theretra* and have confirmed the similarity between *T. boisduvalii* and *T. sumatrensis*. However, the two can be differentiated by the pattern of colouration where *T. boisduvalii* is more greenish in colour with uniform suffusion while the latter is paler and brownish in colour.

The species identification was confirmed by DNA barcoding, and there is no published article describing its presence in the entire Western Ghats. This species has been reported only from the Himalayan region (Sondhi et al. 2017). Ballesteros-Mejia et al. (2017) have created global distribution maps for sphingid moths. Figure 1 shows the distribution of *T. sumatrensis* according to Ballesteros-Mejia et al. 2017 (https://mol.org/species/Theretra_sumatrensis). Thus, we further extend the range of *T. sumatrensis* to the Western Ghats, the specimens recorded at Wani and Kalwan from Nashik District, Maharashtra, India. Table 4 describes the details of sequences mined from BOLD and GenBank to generate the neighbour-joining tree based on the K_2P model using mitochondrial COI gene. The NJ tree based on K_2P model indicated approximate species relationship within genus *Theretra* (Figure 2).

Table 2. Overview of inventory visits and moth recorded.

Sampling station	Symbol	Inventory visits made between 2011–2015			Number of moths secorded
		Summer	Monsoon	Winter	
Chandwad	CH	5	14	5	59
Igatpuri	IG	5	11	5	60
Kalwan	KL	5	11	5	43
Nashik City	NC	5	6	5	21
Peint	PT	5	6	5	15
Triambakeshwar	TM	5	9	5	24
Wani	WN	5	14	5	241
Grand Total					463

Although the geographical expanse of the present study was small, it exhibited great diversity (Image 1). The seven sampling stations showed varied diversity patterns. The most diverse sampling community was WN, where all the 18 species of moths were recorded, followed by IG and CH, having seven species. Figure 3 describes the relative species abundance at all sampling stations over five years (2011–2015). Figure 4 represents Whittaker's plot for abundance. It is clear from Figure 4A that the species richness and evenness for sampling stations vary drastically. KL, TM, and PT show precisely the same richness, while TM and PT have the same evenness. KL has the least evenness amongst all the sampling stations. On the other hand, WN has maximum richness and evenness in the entire study. Further, Whittaker's plot is originally used to describe species richness and evenness. In contrast, we have also utilized it to compare our observations annually (Figure 4B). This figure helps clarify that collection over five years showed nearly the same trend confirming that there was no bias or error and the collection events were carried out randomly. We want to support this further because the rigorous collection and increased number of samples helped eliminate the errors. Figure 5 illustrates variations in the four alpha diversity indices (Shannon's, Simpson's, Brillouin's, and Fisher's alpha) at all the sampling stations over five years (2011–2015). Figures 6 & 7 are heatmaps elucidating the beta diversity amongst the seven sampling stations.

Table 3. Taxonomic position, distribution, and status of hawkmoths from northern Western Ghats.

Family	Sub-family	Species	Distribution	Status
Sphingidae	Macroglossinae	*Daphnis nerii* (Linnaeus, 1758)	CH, WN	U
		Hippotion celerio (Linnaeus, 1758)	CH, IG, KL, WN	C
		Hippotion rosetta (Swinhoe, 1892)	CH, IG, KL, NC, PT, TM, WN	C
		Hyles livornica (Esper, 1780)	IG, KL, WN	C
		Nephele hespera (Fabricius, 1775)	IG, KL, NC, WN	C
		Theretra alecto (Linnaeus, 1758)	CH, IG, PT, TM, WN	C
		Theretra castanea (Moore, 1872)	WN	R
		Theretra clotho (Drury, 1773)	WN	R
		Theretra gnoma (Fabricius, 1775)	WN	U
		Theretra nessus (Drury, 1773)	WN	U
		Theretra oldenlandiae (Fabricius, 1775)	WN	R
		Theretra sumatrensis (Joicey & Kaye, 1917)	KL, WN	U
	Smerinthinae	*Marumba dyras* (Walker, 1856)	WN	U
		Polyptychus dentatus (Cramer, 1777)	WN	U
	Sphinginae	*Acherontia lachesis* (Fabricius, 1775)	WN	U
		Acherontia styx (Westwood, 1847)	IG, WN	U
		Agrius convolvuli (Linnaeus, 1758)	CH, IG, KL, NC, PT, TM, WN	C
		Psiligramma vates (Butler, 1875)	CH, WN	C

DISCUSSION

India shares 8.1% of global diversity on only 2.4% of the global land area resulting in diversity richness (Balasubramanian 2017). There are 12 mega biodiverse countries in the entire world, and India is one of them. The present study area lies in the Western Ghats, which have been declared World Heritage Site as it harbours humungous diversity. Continuous inventories have proved to generate valuable information and increased taxonomic knowledge (Janzen et al. 2009). Hence, we strongly support and recommend continuous periodical assessments to understand the diversity and its dynamics. The incorporation of molecular tools has also encouraged young taxonomists to indulge more. Moreover, diversity studies are necessary to understand the species distribution and unfold the ecological dynamics. It is frequently observed that diversity studies are reported with the species diversities, which may or may not be combined with the diversity analysis. However, there exist complex dynamics between the species and its environmental and ecological surroundings. Understanding this can help to predict diversity for unassessed areas and develop better conservation strategies. Thus, understanding diversity becomes indispensable.

When diversity indices are applied, interpreting species distribution becomes easier. The present study calculated alpha and beta diversity indices for each sampling station to understand the species distribution. Four indices were used to assess alpha diversity (Shannon's, Simpson's, Brillouin's, and Fisher's alpha) and two to study beta diversity (Dice's Coefficient and Jaccard's similarity index). According to Barrantes & Sandoval (2009), using multiple indices helps eliminate drawbacks of the individual index. Further, the indices chosen in the present study focus on varied aspects of diversity. Shannon's Index describes species diversity. Maximum species diversity was observed for WN (2.7132±0.060) and minimum diversity for TM (0.9683±0.185) Figure 5A. When Shannon's index is calculated, a weighted geometric mean of the proportional abundances is employed. Thus, it reflects the logarithm of actual diversity observed and is used frequently.

Simpson's index uses the weighted arithmetic mean or proportional abundances and describes species richness and evenness. Thus, a high Simpson's index

Table 4. Sequences used to generate Neighbour Joining Tree based on K2P model for species from genus *Theretra*.

Species	Sequence ID	BIN	Genbank Accession	Source
Theretra sumatrensis	MOTH011-12	BOLD:ADG0374	MG783973	Present Study
	MOTH044-14	BOLD:ADG0374	MG783956	Present Study
	MOTH061-14	BOLD:ADG0374	MG783950	Present Study
	MOTH063-14	BOLD:ADG0374	MG783977	Present Study
	SPTVA370-07	BOLD:ABX5127	JN678600	Wilson et al. 2011
Theretra clotho	SPHAP046-06	BOLD:AAB2442	-	https://boldsystems.org
Theretra gnoma	SPTMA241-07	BOLD:AAE7656	JN678605	Wilson et al. 2011
Theretra alecto	SPRBA164-08	BOLD:AAC6760	-	https://boldsystems.org
	SOWC887-06	BOLD:AAC6760	-	https://boldsystems.org
	SOWC888-06	BOLD:AAC6760	-	https://boldsystems.org
Theretra castanea	SPHAP054-06	BOLD:AAW6578	JN678603	Wilson et al. 2011
Theretra oldenlandiae	SPHAP068-06	BOLD:AAA4630	KJ168195	Rougerie et al. 2014
Theretra nessus	SPTMB038-09	BOLD:AAB3024	GU704539	https://www.ncbi.nlm.nih.gov/nuccore/GU704539
	SPHAP055-06	BOLD:AAB3024	KJ168203	Rougerie et al. 2014
Agrius convolvuli (out group)	MOTH177-14	BOLD:AAA2393	MG783948	Shere 2018

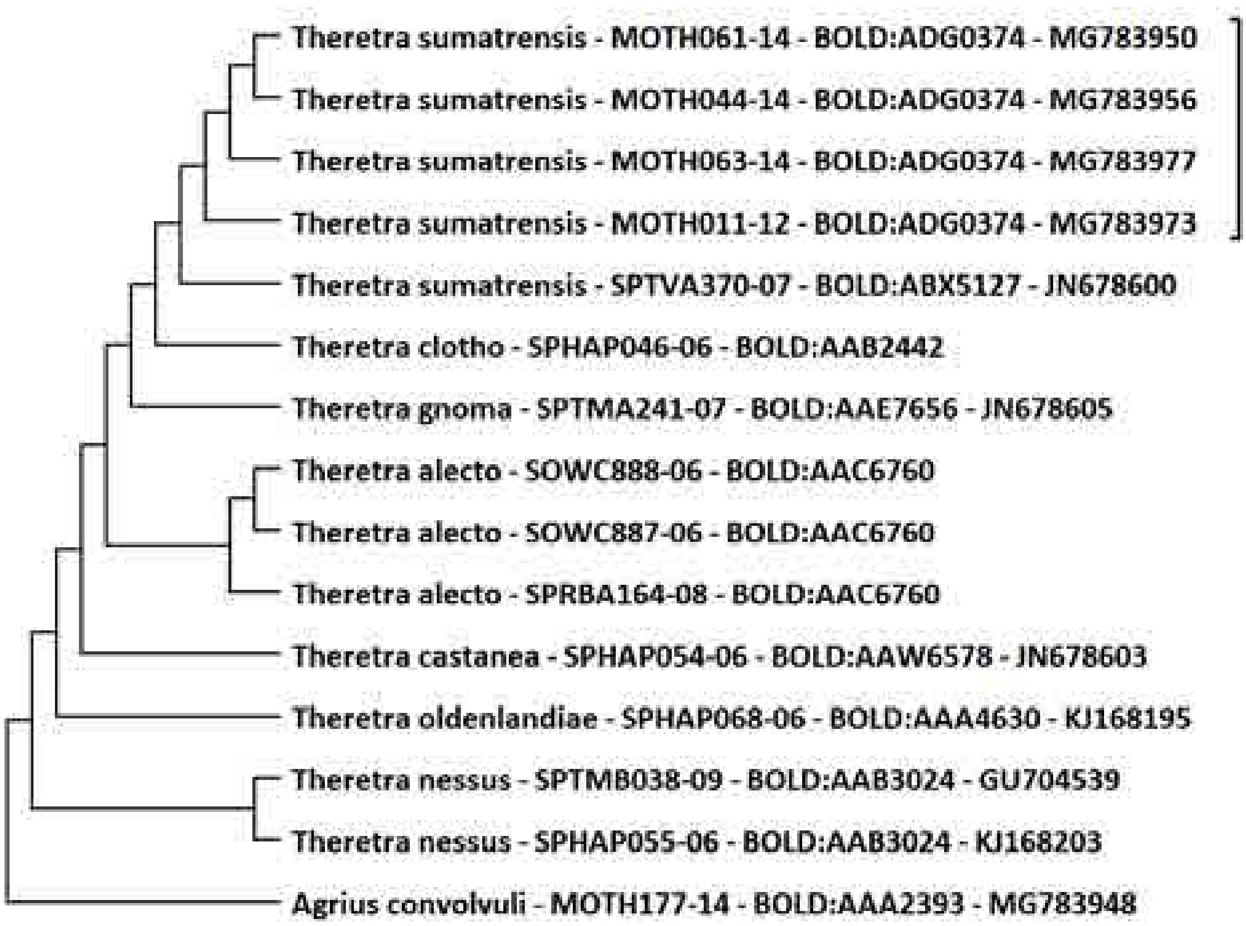

Figure 2. NJ tree based on K2P model of genus *Theretra* using mitochondrial COI gene sequence.

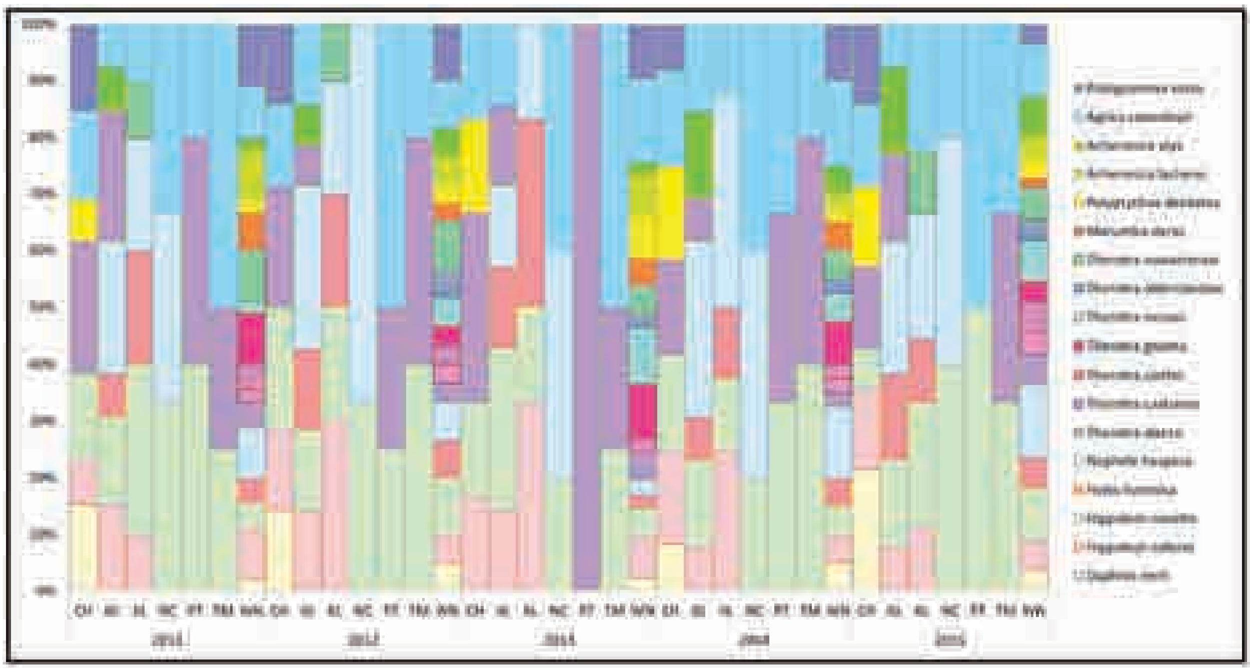

Figure 3. Relative species abundance at all sampling station over five years (2011–2015).

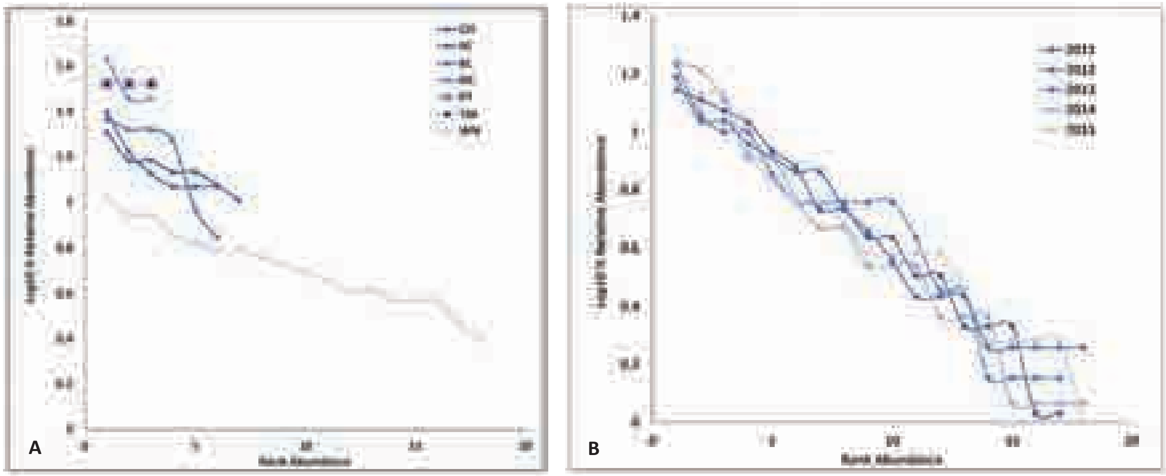

Figure 4. Whittaker's plot: A—Sampling station-wise | B—Sampling year-wise.

suggests higher species richness and evenness. The maximum value for Simpson's index was calculated for WN (0.9273±0.006) and minimum for TM (0.5978±0.086) (Figure 5B). this suggests that the species richness at WN is definitely high and there is an evenness to the species distribution too.

The following index calculated was Brillouin's index. According to Magurran, this diversity index serves better when there is no surety for the randomness of the sample (Magurran 1988). Thus, to eliminate any biases raised unknowingly, we employed this index. The maximum value for this index was calculated again for WN (2.252±0.089) and minimum for again Triambakeshwar TM (0.6056±0.136) (Figure 5C).

Lastly, Fisher's alpha was the fourth alpha diversity index employed. Fisher's alpha has a good discriminating capability in cases where sample sizes vary a lot. As the sample size for all the sampling stations varied (Table 2), this index was used. Maximum value for this index was calculated for WN (10.9472±1.685) and minimum for TM (3.5152±1.108) (Figure 5D). Thus, all the four alpha diversity indices confirm that maximum alpha diversity

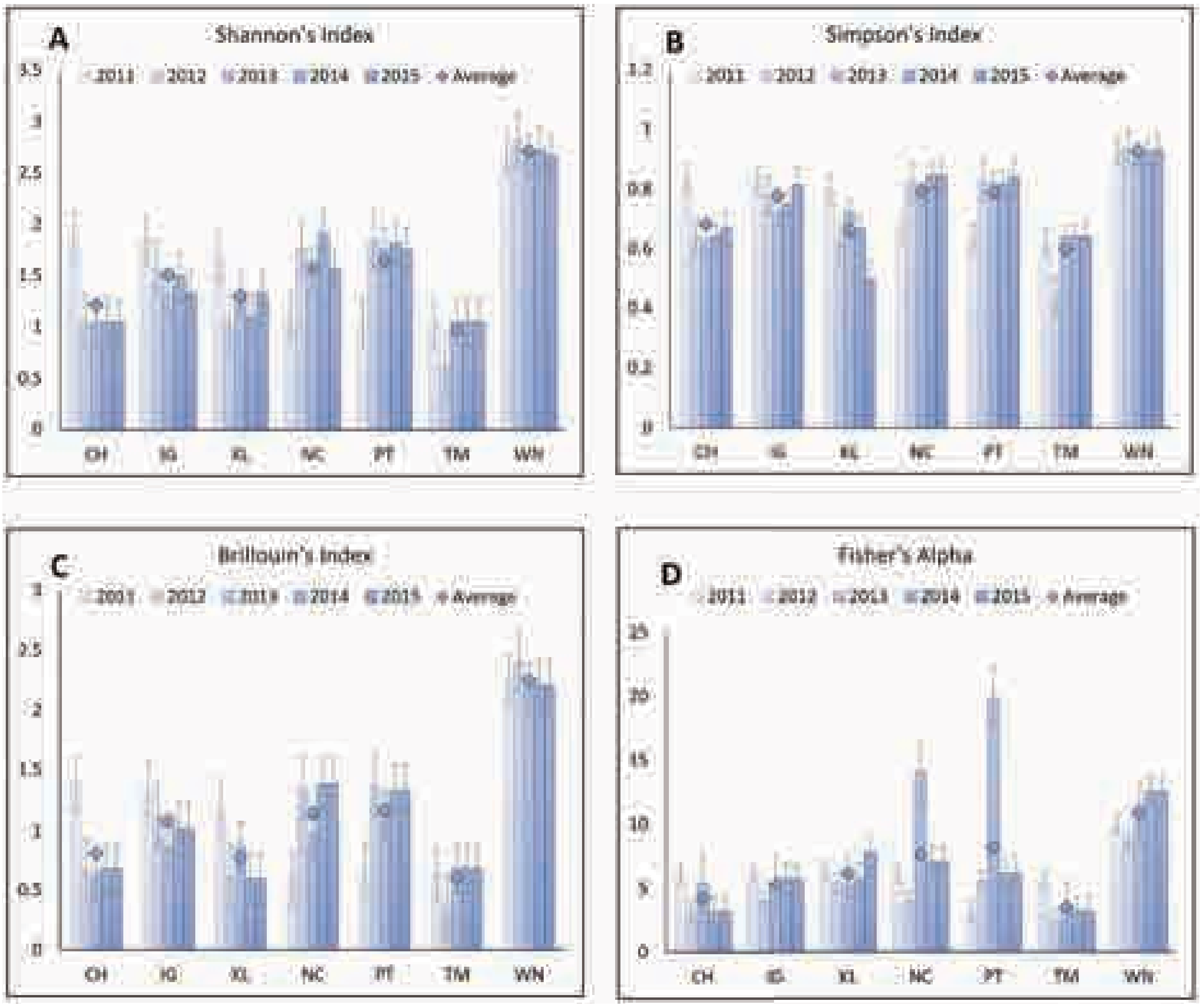

Figure 5. Alpha diversity indices calculated for seven sampling stations over five years (2011–2015).

was observed at WN and minimum at TM.

Dice's coefficient and Jaccard's Similarity index were used to assess beta diversity indices. Beta diversity is used to compare the similarity between two sampling points. The value for beta diversity always lies between 0 and 1, and the level of similarity increases with an increase in value. The sampling points where the value is 0 indicate no common species between those sampling points. On the other hand, when the value is 1, all the species were shared by both sampling points. The maximum value was calculated for TM and PT (1) as both the sampling stations shared all the species. Further, minimum values for Dice's coefficient and Jaccard's similarity index were between WN & TM, PT & NC (Dice's coefficient = 0.2857; Jaccard's Similarity Index = 1.666) (Figure 6, 7). It is also clear from the figure that there was no difference in the pattern; only the values of the indices varied slightly.

In the present study, the seasonality of moths was also observed. It is quite conspicuous from Figure 8 that moth abundance is maximum during monsoon. During summers, almost the majority of species are not found except *Nephele hespera* (Fabricius, 1775), *Agrius convolvuli* (Linnaeus, 1758), and *Psilogramma vates* (Butler, 1875). However, all these individuals were observed at almost the summer's end and the monsoon's beginning. In winters, moth abundance was observed but not as much as during the monsoon. The probable reason for high moth abundance during monsoon could be the conducive environment created at the time. The temperatures decrease with an increase in relative humidity, which favours moths.

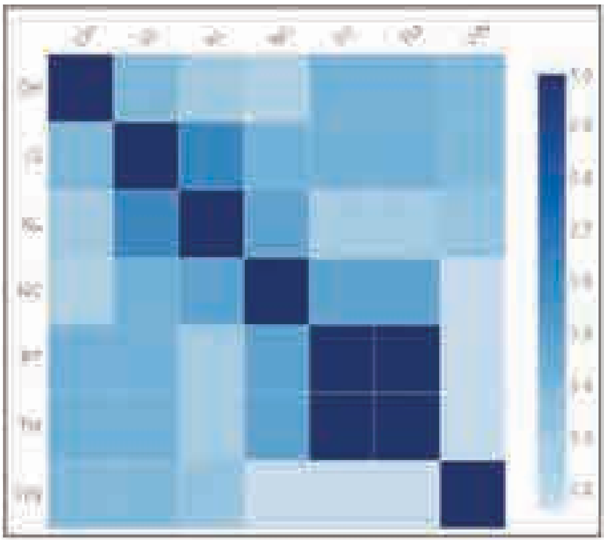

Figure 6. Heatmap for Jaccard's similarity index.

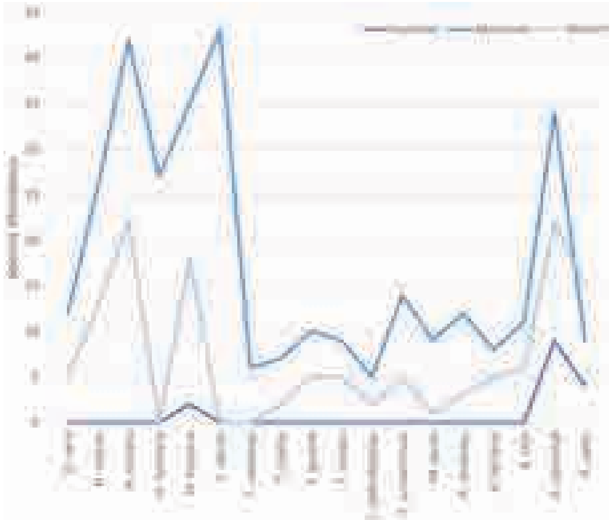

Figure 8. Seasonality in moth distribution.

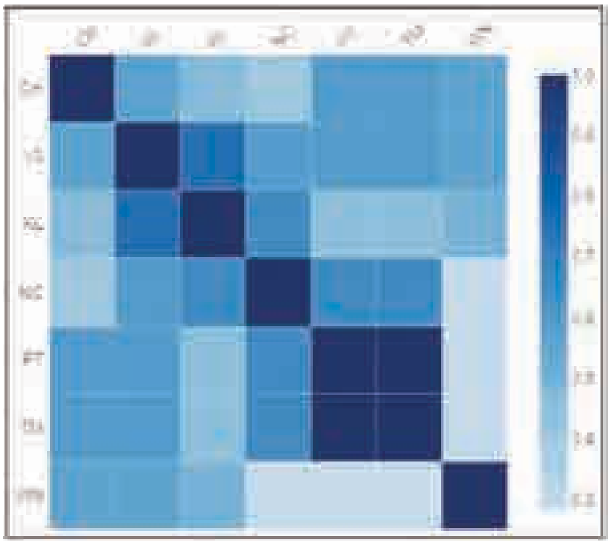

Figure 7. Heatmap for Dice's coefficient.

CONCLUSION

Alpha diversity indices strongly support that high hawkmoth diversity is observed in the northern Western Ghats. However, there is variation in the moth availability at different sampling stations, reinforcing the knowledge that these organisms are sensitive to changes and can be used as flagships. It was conspicuous that the moth availability showed seasonal variations, and maximum diversity was observed during monsoon.

We strongly recommend monitoring the moth diversity throughout the year for a prolonged duration. These data inputs would elaborate the knowledge of natural history information of the moths and reinforce the need for further research on ecological and taxonomic consequences of differences in the seasonal activity. Complete knowledge of the distribution patterns of the individual species helps expound the reasons for species' availability in a peculiar area. When such results are combined with other ecological parameters, a comprehensive database is created. Such complex knowledge further helps in devising conservational strategies. Comprehensive knowledge and stepwise incorporations of the natural history information would lead to a deeper understanding of the complex dynamics of any ecological niche. Moreover, we cannot conserve what we do not know. Thus, we suggest extensive taxonomic studies involving periodic assessments and statistical analysis to monitor the diversity patterns, which would help devise customized conservational strategies for different localities.

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Image 2. 1—*Daphnis* nerii | 2—*Hippotion celerio* | 3—*Hippotion rosseta* | 4—*Hyles livornica* | 5—*Nephele hespera* | 6—*Theretra alecto* | 7—*Theretra castanea* | 8—*Theretra clotho* | 9—*Therertra gnoma* | 10—*Theretra nessus* | 11—*Theretra oldenlandiae* | 12—*Theretra sumatrensis* | 13—*Marumba dyras* | 14—*Polyptychus dentatus* | 15—*Acherontia Lachesis* | 16—*Acherontia styx* | 17—*Agrius convolvuli* | 18—*Psilogramma vates.*

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COMMUNICATION

Population trends of Mugger Crocodile and human-crocodile interactions along the Savitri River at Mahad, Maharashtra, India

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Abstract: In this paper, we report monitoring of a resident population of Mugger Crocodile *Crocodylus palustris* (Lesson, 1831) along a stretch of 3.5 km of the river Savitri on the outskirts of Mahad town of Raigad District in Maharashtra, on monthly basis from 2014 to 2021. This river is increasingly becoming a sink of anthropogenic wastes emerging from adjacent settlements impacting its habitat value, and puts the reptile side by side with humans and human-wastes that could be a cause of rising incidents of crocodile mortality in the recent times here, as also reported from elsewhere. Savitri River has been a fishing ground for local indigenous communities, who also use the river bank for washing clothes and utensils, and for swimming. Such proximity between people and crocodiles creates a potential for negative interaction. This long term study monitored the Mugger population trends for the last eight years at four transect stretches along the river. Counts are suggestive of a healthy viable population of Mugger in this river currently, but a future conflict situation cannot be ruled out. Being generalist feeders, Muggers can sustain themselves on fish, and scavenge on dumped carrion and other anthropogenic organic wastes. With the exception of a few sporadic incidents of aggression by the Muggers at this location, no human casualties have been reported thus far, however, this does not rule out fatal reciprocal interactions in future and hence a few practical mitigation measures have been suggested.

Keywords: Encounter frequency, indigenous community, negative human-mugger interaction, relative density, size-classes, spill over.

Marathi abstract: या शोधनिबंधात, आम्ही महाराष्ट्रातील रायगड जिल्ह्यातील महाड शहराच्या सीमेवरील सावित्री नदीच्या ३.५ किमी. च्या पट्ट्यात अधिवास असलेल्या क्रोकोडायलस पॅलुस्ट्रिस (लेसन, १८३१) मगरींच्या संख्या निरीक्षणाचा २०१४ ते २०२१ ह्या कालावधीसाठीचा मासिक अहवाल सादर करीत आहोत. ही नदी, काठावरील मानवीय वसाहतींमधून सतत बाहेर पडणाऱ्या मानववंशीय घन-कचरा व सांडपाण्याने प्रदूषित होत आहे आणि तिच्या परिस्थितिकीच्या मूल्यांवर प्रतिकुल परिणाम झाला आहे, त्या मुळे इथल्या मगरी मनुष्याच्या सान्निध्यात तसेच मानव निर्मित प्रदूषक घटकांच्या संपर्कात येतात, आणि हेच येथील मगरींच्या मृत्यूच्या वाढत्या घटनांचे कारण असू शकते. सावित्री नदी व तिचा काठ हे इथे वास्तव्यास असलेल्या उपेक्षित काठोडी समुदायांसाठी मासेमारीचे ठिकाण आहे, जे नदीचा वापर कपडे -भांडी धुण्यासाठी आणि पोहण्यासाठी करतात. अलीकडील काळात लोक आणि मगरी यांच्यातील अशा समीपतेमुळे मानव-वन्यप्राणी संघर्ष होण्याची शक्यता निर्माण होते आहे. या दीर्घकालीन संशोधनांतर्गत मागील आठ वर्षांत नदीच्या पात्रात तसेच काठावरील चार निरीक्षण पट्ट्यात मगरींची सांख्यिक गणना केली गेली. सध्या या नदीत मगरींची संख्या व्यवहार्य आणि शाश्वत आहे असे सूचित होते, परंतु भविष्यात संघर्षाची परिस्थिती नाकारता येत नाही. अमूकच वैशिष्ट्यपूर्ण आहाराची गरज नसल्या मुळे मगरी नदीच्या पत्रातील मासे, तसेच इथे टाकलेल्या मानवनिर्मित सेंद्रिय पोषक घटकांचे भक्षण करून आपली पोषणपूर्ती करतात. इथल्या अवघ्या काही आक्रमक मगरींच्या तुरळक घटनांचा अपवाद वगळता, मानवी जीवहानीच्या घटनांची इथे अजून तरी नोंद झाली नाही. तथापि, भविष्य काळात मगर व माणूस ह्या दोन प्रजातीं मधील परस्पर घातक संबंध नाकारता येणार नाही, आणि म्हणून त्यावर काही व्यावहारिक संघर्ष -शमन उपाय सुचवले गेले आहेत.

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Author contributions: UMC has planned and conducted field studies, photo-documentation, and data collation, assisted in analysis and literature survey. MRB has conceptualized the study, supervised field work, analyzed and interpreted the collated data, and written and revised the manuscript.

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INTRODUCTION

From the global count of 27 crocodilian species (Hekkala et al. 2011; Shirley et al. 2013, 2018; Murray et al. 2019; Stevenson 2019), India is a home to three. Among the three Indian crocodilian species, Mugger or Marsh Crocodile *Crocodylus palustris* Lesson, 1831 is the one with a wide distribution across the Indian peninsula, either as isolated populations or communal aggregations in estuarine and riverine ecosystems (Deraniyagala 1939; Whitaker & Whitaker 1989; Da Silva & Lenin 2010). It is distinguished by its morphology, morphometry, and ethology from the other two species, viz., Salt Water Crocodile *Crocodylus porosus* Schneider, 1801 residing along the shoreline of eastern India and the Gharial *Gavialis gangeticus* Gmelin, 1789 restricted to northern part of the Indian subcontinent. Once common in its range from eastern Iran to Bangladesh and down south to Sri Lanka; the Mugger populations declined drastically due to hunting for meat and hide trade, besides nest predation and poaching. Additionally, changes in land-use and other incompatible encroachments led to shrinking and loss of crocodile habitats in the country. From 1975 to 1982, the species recovery efforts through in situ and ex situ interventions by Government of India under UNDP/FAO direction and thereafter conservation action by NGOs and private individuals have helped the Mugger to recover across its Indian range (De Vos 1984). Interestingly, many former habitats having been repopulated, spillovers have begun leading to conflict situations (Distefano 2008; Pooley 2016). Also, the international (CITES-I listed, IUCN Vulnerable category) and country legislation (IWPA Schedule-I) having accorded a protected status to the reptile, have paid rich dividends to crocodile conservation in India. The expanding demography of a populous country like India has been a major driver of crocodilian habitat degradation, and also brings people in dangerously close proximity to these opportunist predators residing in rivers, tanks, dams and irrigation ponds (Wolch 1996; Kochery 2018).

Though temperamentally *Crocodylus palustris* is believed to be more tolerant of people than its salt water counterpart, and that it is supposedly not a frequent man-eater (Daniel 2002; Sidaleau & Britton 2012), is no guarantee of safety to people who share the habitat with this reptile. CrocBITE reports that between 2008 and 2013, 110 people were attacked by Muggers, out of which approximately one-third of those attacks were fatal for the victims (CrocBITE: Worldwide Crocodilian Attack Database). These numbers though not very large, provide evidence of the potential hazard and conflict. In shared habitats potential negative Human Crocodile interactions emerge inevitably. Literature on Human-Crocodile Conflict reveals conflict situations across the Mugger habitats in Indian states of Goa, Maharashtra, Madhya Pradesh and Gujarat (Borkar et al. 1993; Whitaker 2008; Rao & Gurjwar 2013; Upadhyay & Sahu 2013; Vasava et al. 2015). Identifying such conflict locations and mitigating a potential conflict is a key to sustained in situ conservation of this species in India (Distefano 2008; Das & Jana 2017).

Despite the perceived threat from crocodiles, until recently it was held that these reptiles are top predators and keystone species, and perform an important role in maintaining the structural and functional integrity of freshwater ecosystems (Thorbjarnarson 1992; Ross 1998; Leslie & Spotila 2001; Glen et al. 2007). In absence of evidence-based justification, these attributions have been questioned recently (Somaveera et al. 2020). Data presented in this paper is a part of long term monitoring of Muggers of Savitri River, which flows through Mahad in Raigad District of Maharashtra in India. Since the objective of this study was to measure Mugger abundance over time, their encounter frequency has been considered.

Besides analyzing the population trends; potential human-crocodile interaction interface at four fixed stretches along the riparian habitat were examined and mitigation measures suggested with a view to change the potential negative interactions into coexistence.

METHODOLOGY AND FIELD PROTOCOLS:

Environmental setting of the river Savitri

Savitri River originates on the crest of Western Ghats in Mahabaleshwar hills and flows towards the west through Raigad District and eventually meets Arabian Sea at Harihareshwar in Maharashtra State, India. Where the river takes a sudden turn towards Mahad is a tidal zone. Out of the total 2,899 km^2 of water catchment area of Savitri basin, about 2,513 km^2 area is in Raigad District. The Savitri River basin lithologically belongs to Deccan Trap formation of upper Cretaceous to lower Eocene. The climate of the basin is typical of west coast and characterized with plentiful and regular seasonal rainfall, oppressive weather in summer and high humidity throughout the year. The Savitri basin bears deciduous and evergreen type natural vegetation.

Initial survey

Before the commencement of the long term survey, a pilot survey was conducted at day time during low tide to determine river conditions such as access to a boat ramp, location of barriers, water depth; all with a view to streamline the nocturnal spotlight survey without compromising on safety. Given that crocodile densities vary within river stretches (Fukuda et al. 2007, 2011), four separate survey stretches with different start and finish points were fixed. During a given survey the adjacent sample stretches were surveyed on consecutive nights, to reduce the possibility of crocodiles moving between sections.

Survey planning

The start and end points of each of the four survey sections have been fixed between the months and over the years, because crocodile abundance and distribution along a river varies over time and space (Fukuda et al. 2007). To minimize the influence of seasonal changes in temperature and water level that affect crocodile behaviour (Webb 1991), repeated surveys over years were conducted every month, ideally within the same week period, however the exact date and time of a survey was decided on the basis of the tide. All crocodile population enumeration surveys were carried out during ebbing at night.

Due consideration was given to the fact that during winter, crocodiles choose to stay in relatively warm waters and can be easily spotted; while in summer they preferred to bask on banks or rest in the bank vegetation and hence making sighting difficult. Surveys always proceeded from down-streams to up-streams and the average speed of boat cruising in the river was 8–10 km per hour. Fixed tasks were assigned to boat driver, spotter and data recorder during every survey.

Crocodile Spotting

The spotter scanned water surface, water edges, banks and vegetation by shining a torch held near eye level standing at the advancing end of the boat. The light was shone in a zigzag manner from one bank of the river to the other to catch the eye-shine of a crocodile.

The study area is a stretch of the river flowing on the outskirts of Mahad city limits. The observation area starts from Kemburli to Smashaan, a distance of 3581m which is divided into four sampling transects totaling 3.248 km; namely Kemburli, Mohalla, Dadli, and Smashaan (Image 1). Each of these transects differed in their habitat attributes and topography as tabulated (See Table 1 & Image 3)

The data presented here has accrued from monthly reconnaissance visits from 2014 to 2021, along a 3.5 km stretch of river Savitri at four fixed transects, viz., Kemburli along Mumbai–Goa Highway (18.0661^{0}N; 73.4138^{0}E), Mohalla near Gandhari River bridge (18.0725^{0}N; 73.4188^{0}E), Dadli on both sides of Dadli Bridge (18.0697^{0}N; 73.4311^{0}E), and Smashaan including Vaikuntha Bhumi near Prabhat colony (18.0669^{0}N; 73.4411^{0}E) (Image 1). Population estimates were based on nocturnal flash count or spot light survey (Fukuda et al. 2012) carried out on monthly basis in identified fixed sampling transects along the river. Since the objective of this study was to monitor the population of Muggers over time, Index of Relative Abundance was calculated based on frequency of sightings. Foot surveys were conducted for studying crocodile behavior and habitat attributes.

At all times observations were made from optimal distances for safety of field crew as well as to avoid breaching the Mugger's basking territory on the river banks, as also in water. Observations were recorded from 0700 to 2100 h. The sizes of Muggers were approximated visually by the same team of observers, based on the reported constant ratio of head length to total length (1:7), and that it changes little across size classes in many crocodilians species including the Mugger (Verdade 2000; Wu et al. 2006; Whitaker & Whitaker 2008; Mobaraki et al. 2021). This value in inches was converted into feet with one inch equaling one foot and was found to be matching with total body length. Only in the months of April 2020 and 2021 the count included hatchlings (up to 0.3 m) at Smashaan; rest at all times the number is of juveniles (<1 m), sub-adults (1–2 m), and adults (>2 m). Species-specific indirect evidences included documentation of fecal pellets, tunnels, tracks or trails and shell fragments of hatched eggs. Regular interactions with locals were held and their narratives recorded. Photo-documentation was accomplished with Digital and DSLR cameras (Nikon P 900 – Digital and Canon 1200 D– DSLR).

OBSERVATIONS AND DISCUSSION

A. Mugger population dynamics in Savitri River, Mahad

The Crocodilian species inhabiting the Savitri River was confirmed to be the Mugger based on presence of the quintessential row of four post-occipital scutes preceding the nuchal scutes (see Image 2B); and also its biometry was found commensurate with the species recorded data. The Mugger population of this habitat was observed and monitored over a linear distance of about 3,581 m of river Savitri meandering along the

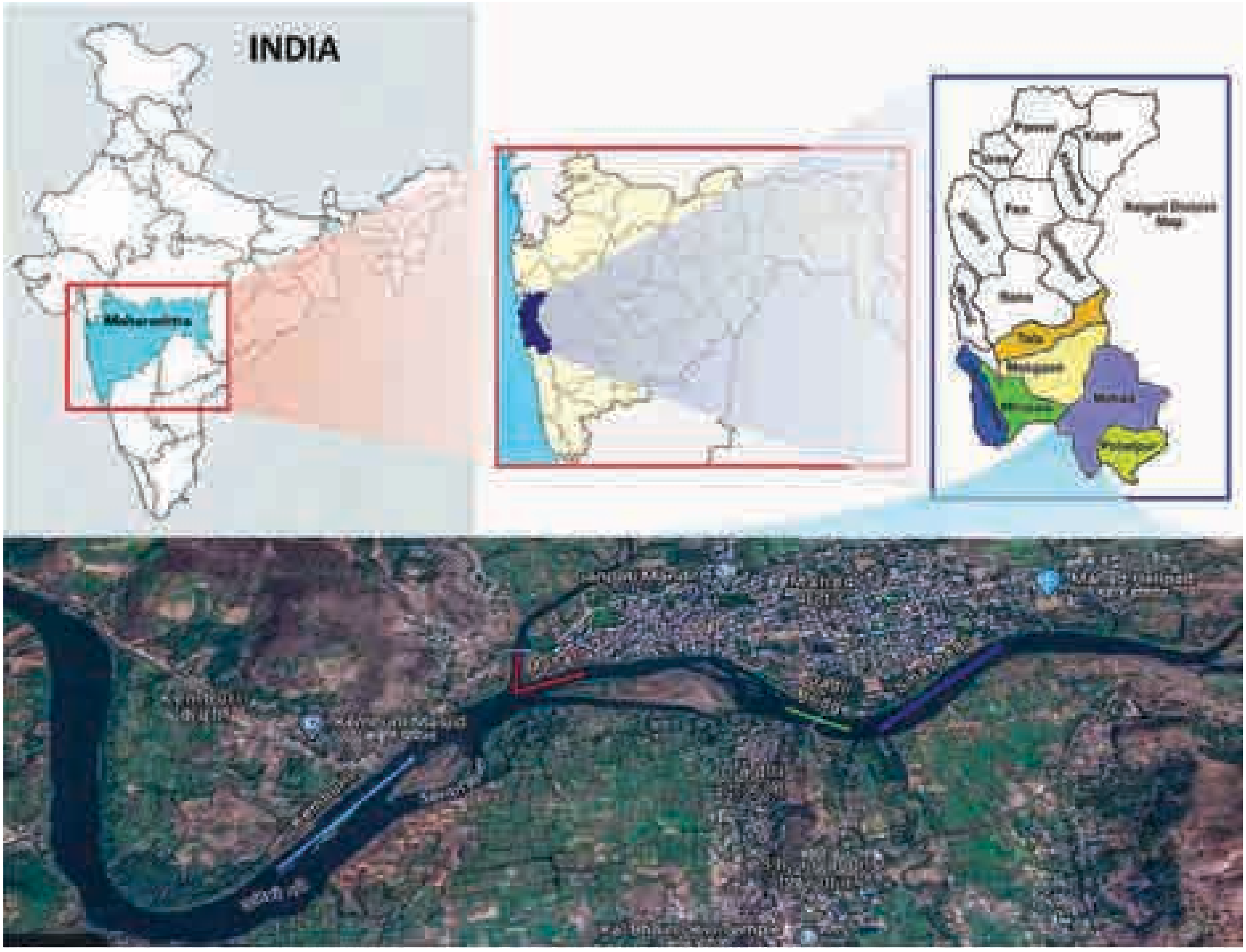

Image 1. Geographic locations of the four transect stretches along the river Savitri of Mahad in Raigad District of Maharashtra, India. Kemburli, Mohalla, Dadli, Smashaan

outskirts of Mahad town; the four transect stretches being Kemburli, Mohalla, Dadli and Smashaan. The first observation site is close to Goa–Mumbai Highway, whereas the last observation station is a Hindu crematorium ground of adjacent residential area. The Mugger encounter frequency dominance across the four sample transects was Smashaan >Kemburli >Dadli >Mohalla (Figure 2A,B), with maximum counts recorded at Smashaan. Such preponderance at Smashaan may be attributed to this site meeting requirements of basking grounds as also with the right slope for easy movements in and out of waters.

The general age class hierarchy of Muggers in this river at all four sites was adults >sub-adults >juveniles. The average annual percentage of different size-classes representing different age groups in the Muggers encountered at the four transects during the entire study period has been tabulated (Figure 1).

The counts have been based on sightings, numbers generally peaking during the summer months; except at Mohalla where more sightings were recorded towards the end of monsoons. The lesser counts were obtained during high water levels and monsoons; and in the latter case could be because of clouded skies when these reptiles withdraw from regular basking sites to backwaters with abundant fish resources, a view that has been corroborated by Smith (1979). The enumeration shows a progressive trend between 2014 till the end of 2021, with highest count of 155 individuals inclusive of hatchlings recorded at Smashaan in April 2020 (Figure 2A).

The preferential residence and basking in Smashaan area leading to higher counts could be attributed to greater fish stocks in the productive waters as can be seen from the basket catch of the fisher folks here, more foraging opportunities on these banks due to anthropogenic organic wastes, and optimal basking sites here. Such a possibility has been corroborated previously by Singh (1993). Despite being a severely disturbed site, that Smashaan is preferentially occupied

Table 1. Sample transects and their habitat attributes.

Sampling transect of the river	Linear distance (in m)	Latitude & Longitude	Depth of water in dry season in feet	Slope of the bank (land to river)	Bank zone character	Predominant flora in riparian bench
Kemburli	1134.81	18.066°N; 73.4138°E	05-25 feet	−35° to −80°	Muddy shoreline interspersed with gravel	*Typha angustifolia, Ficus benghalensis, Ficus glomerata, Ficus religiosa, Abelmoschus manihot, Celosia argentea*, *Alternanthera sessilis, Amaranthus spinosus*
Mohalla	771.48	18.0725°N; 73.4188°E	15-25 feet for Savitri and 10-15 feet for Gandhari	−13° to −15°	City side Muddy and opposite side Gravelly	*Cassia fistula, Ricinus communis, Amaranthus spinosus, Aternanthera sessalis*
Dadli	446.07	18.0697°N; 73.4311°E	35-45 feet	−17° to −22°	Muddy	*Cleome viscosa, Clitoria annua, Clitoria ternatea, Colocasia sp., Cyathocline purpurea, Datura sp., Ipomoea campanulata, Ipomoea hederifolia, Malachra capitata, Parthenium hysterophorus, Urena lobata*
Smashaan	896.45	18.0669°N; 73.4411°E	5-20 feet	−37° to −42°	Muddy with boulders along shore line	*Ficus benghalensis, Ficus glomerata, Ficus religiosa, Morinda pubescens, Morinda tomentosa, Mucuna pruriens Fioria vitifolia*

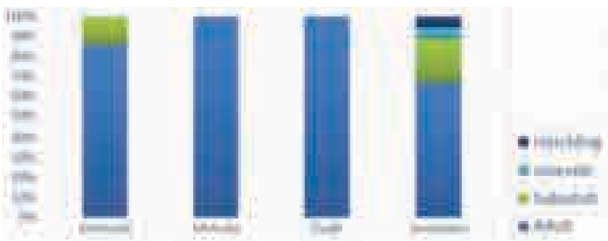

Figure 1. Average annual percentage of various size-classes in Mugger population at each of the four transects (Kemburli, Mohalla, Dadli and Smashaan) in river Savitri from 2014 to 2021. The measurements are in meters which include hatchlings (up to 0.3 m), juveniles (<1 m), sub-adults (1–2 m), and adults (>2 m).

by Mugger is not unusual, given that it is a 'disturbance adapted' species and can thrive very well despite all adverse influences on its habitat (Choudhary et al. 2018).

Discussions with locals suggest that Muggers have been thriving in this river since 1998, when a breeding pair from a private custody of a hobbyist was released at Smashaan area of the river Savitri (Salunkhe Yashwant pers. comm. 2014).

Population size of a species in a defined area provides the information needed to measure ecological change (Thompson 2002) and offers insights about the conservation status of the species (Lettink & Armstrong 2003). A time-series data as accrued here provides insight into the conservation future of this species. Based on the long term data (2014–2021) the population trajectory inferred from encounter frequency and relative density recorded at the four sample transects in this investigation indicate no risk to this viable Mugger population here at present; though a few stochastic oscillations are evident towards April 2020, attributable to a wide range of natural and anthropogenic factors operating here. Nonetheless, these overall trends in relative abundance have a conservation context, since they have been based on four data sets over a period of eight years infusing precision and eliminating potential biases (Holmes 2001; Holmes et al. 2007; Connors et al. 2014). From the view point of conservation future of this Mugger population it is crucial to take into account the age group structure of this population. The average annual percentage of various size-classes in the population over a period of eight years indicate that the number of adults is more as compared to that of sub-adults and juveniles. Such a trend implies a likely 'recruitment deficit' and a probable decline of this population in near future.

Given the deteriorating habitat conditions, there is a possibility that individuals of this population could spill-over into adjacent settlement areas in near future. Crocodilian populations are not randomly distributed

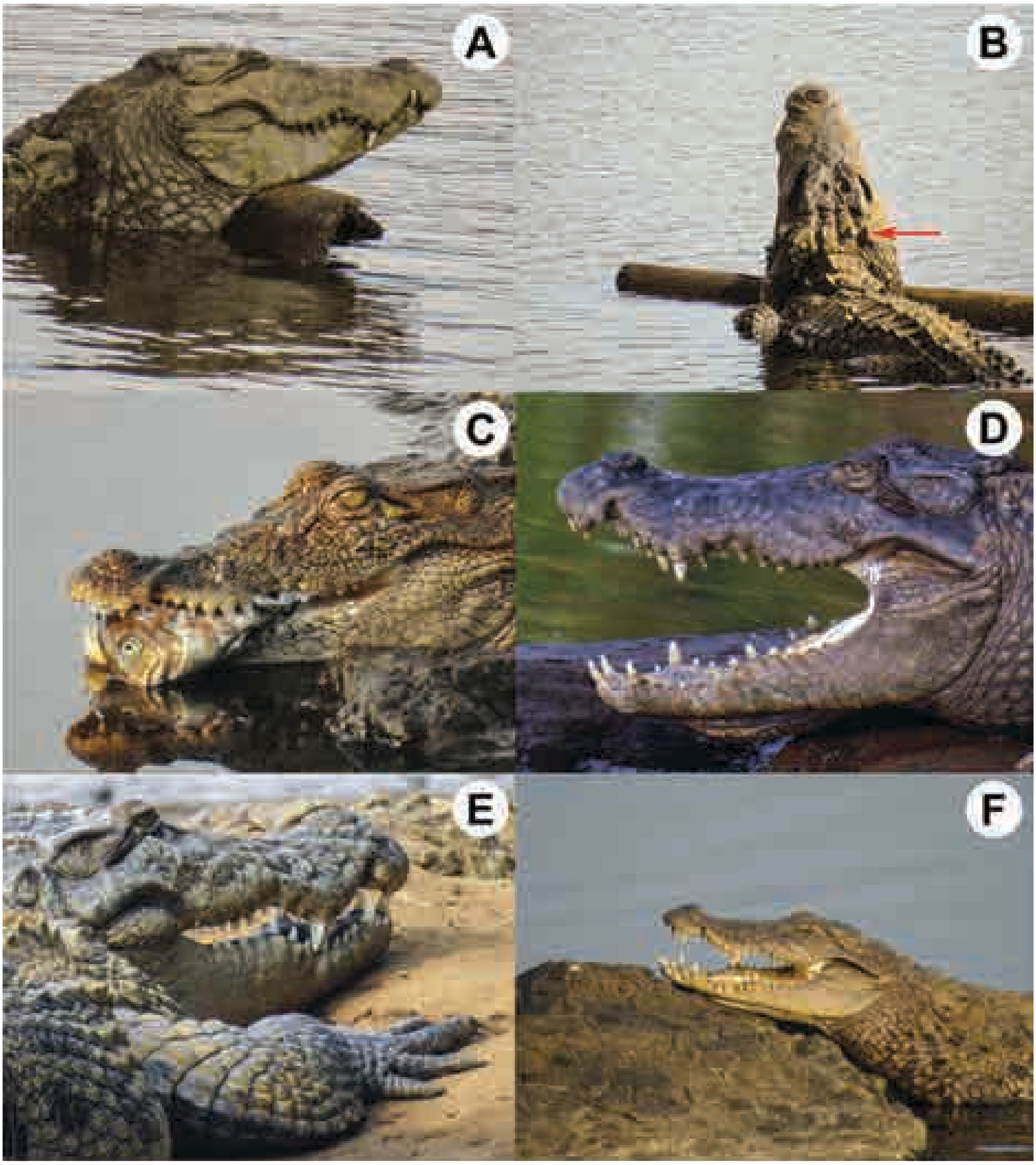

Image 2 (A–F). Mugger Crocodiles *Crocodylus palustris* Lesson, 1831 in the river Savitri at Mahad. Note the snout character (A–C), dentition (D–F) and post-occipital scutes (B) of diagnostic value in specific taxonomy. © Utkarsha M. Chavan.

because they have a tendency to cluster together over smaller areas as observed in this study. Therefore, striving for theoretical distributions in crocodile populations as a means of describing dispersion may not be appropriate (Balaguera-Reina et al. 2018).

Also, a bias in the population size estimation is that the mean number of animals seen in a survey series will always be below the actual number of individuals present if there is no way to identify each individual (Southwood & Henderson 2003).

B. Muggers and indigenous communities of Mahad:

Modern approach of wildlife management consider people as integral in the habitat of wild animals, and further that such communities which share territory with wildlife influence their spatial use of the habitat, as well as overall eco-dynamics. Further, it is accepted that the attitudes of such communities determine the present status as well as conservation future of this wildlife (Patel et al. 2014; Mir et al. 2015; Hariohay et al. 2018).

The river resources like water and fish are shared by the crocodiles, people and their livestock that makes this riverine ecosystem vulnerable to anthropogenic stressors, and also point to Human-wildlife competition (Image 4). The river Savitri at Mahad is not only a crocodilian habitat but also offers subsistence fishing to the indigenous 'Katkari' or 'Kathodi' communities, who go into the waters for fishing and clam collection regardless of Muggers floating around them (Image 4A–C).

The Katkari community regularly fish in Mugger-infested waters of Savitri (Image 4A–C) raising chances of human-crocodile interaction. Major anthropogenic activities here are water extraction, bathing and washing (Image 4D), livestock grazing on the river bank (Image 4E), sewage water discharged in river (Image 4F), open air defecation along the banks (Image 4G), and cremation wastes' run-off (Image 4H), dumping of animal carcasses (Image 4I), burning of urban wastes dumps along the river bank (Image 4J). Carcass of a juvenile Mugger (Image 4K) and Mugger basking near gunny bag full of waste were also observed during our surveys (Image 4L).

The Mugger population here seems to have been conditioned to human presence, as long as their private space is not violated; and there is admirable level of tolerance between people and the crocodiles. The native community here seems to be at ease with the crocodiles floating dangerously close to them in their precarious fishing grounds in the river, perhaps due to a keen understanding of the reptile's behaviour and know how not to elicit their aggression. As 'river people' elsewhere in southeastern Asia, they associate the crocodilian habitats with good fish stocks and their relationship with the reptile is a mix of vigilance and veneration (Gonzales et al. 2013; Bucol et al. 2014). Such unusual closeness of humans to the potentially dangerous reptile has also been reported of the indigenous people of Philippines, for whom the crocodile is a totemic species (Mangansakan 2008). The fishing communities of Mahad, do not have any pagan rituals unlike the 'Mannge Thapnee' or crocodile worship practiced by the *Gawdas* of Goa who live along the Cumbarjua canal, a Mugger habitat of Goa (Borkar & Mallya 1992), or the Mogri tribals of Gujarat (Fisher & Shah 1971).

C. Ecological Integrity and impact on Mugger habitat in Savitri at Mahad

To ensure conservation future of crocodiles, their habitat integrity is a prerequisite (Vyas & Vasava 2019). Present investigation also has laid emphasis on identifying the drivers of crocodilian habitat deterioration and loss. The river front is regularly subject to erosion and accretion due to seasonal changes in hydrodynamics. In some stretches the Muggers excavate tunnels as heat shelters, rest and nest (De Silva 2016).

Regrettably, the civic authorities have been using this stretch of the river as a sink of urban wastes, dumping huge quantity of unsorted wastes posing threat to the health of this riverine ecosystem. Often during the night-counts, Muggers were seen navigating their way through heaps of litter. Already the river banks at multiple destinations are smothered with mounds of wastes which deprive the Muggers of their basking sites. Though the Mugger is a 'disturbance-adapted' species and can thrive very well despite all adverse influences on their habitat (Choudhary et al. 2018); loss of basking sites can result in abandoning the territory by the reptile (Venugopal & Prasad 2003) further heightening the possibility of a mutually negative interaction between humans and the reptile. Also, these litter dumps are often burnt in the open causing air pollution and the residue ends up in the water, contaminating it (Image 4J).

Sewage from adjacent settlement is also being released in the river (Image 4F) presumably impacting the water quality and altering its hydrochemistry that could be detrimental both to this apex predator as also its aquatic prey-base. In fact on a few occasions dead Mugger juveniles and adults have been found floating in the waters or stranded on the banks (Image 4K & 5C). In absence of any wildlife forensic facility in Mahad, however, the cause of mortality cannot be conclusively established. At Smashaan particularly during the monsoons; the human cremation wastes including ash often drain into the waters (Image 4H). Also, the locals dump the carcasses of livestock (Image 4I) into the river adding to the load of oxygen demanding organic wastes. Regular use of river banks for open air defecation by the impoverished local communities in absence of sanitary facilities adds human wastes to this water body where people also fish (Image 4G).

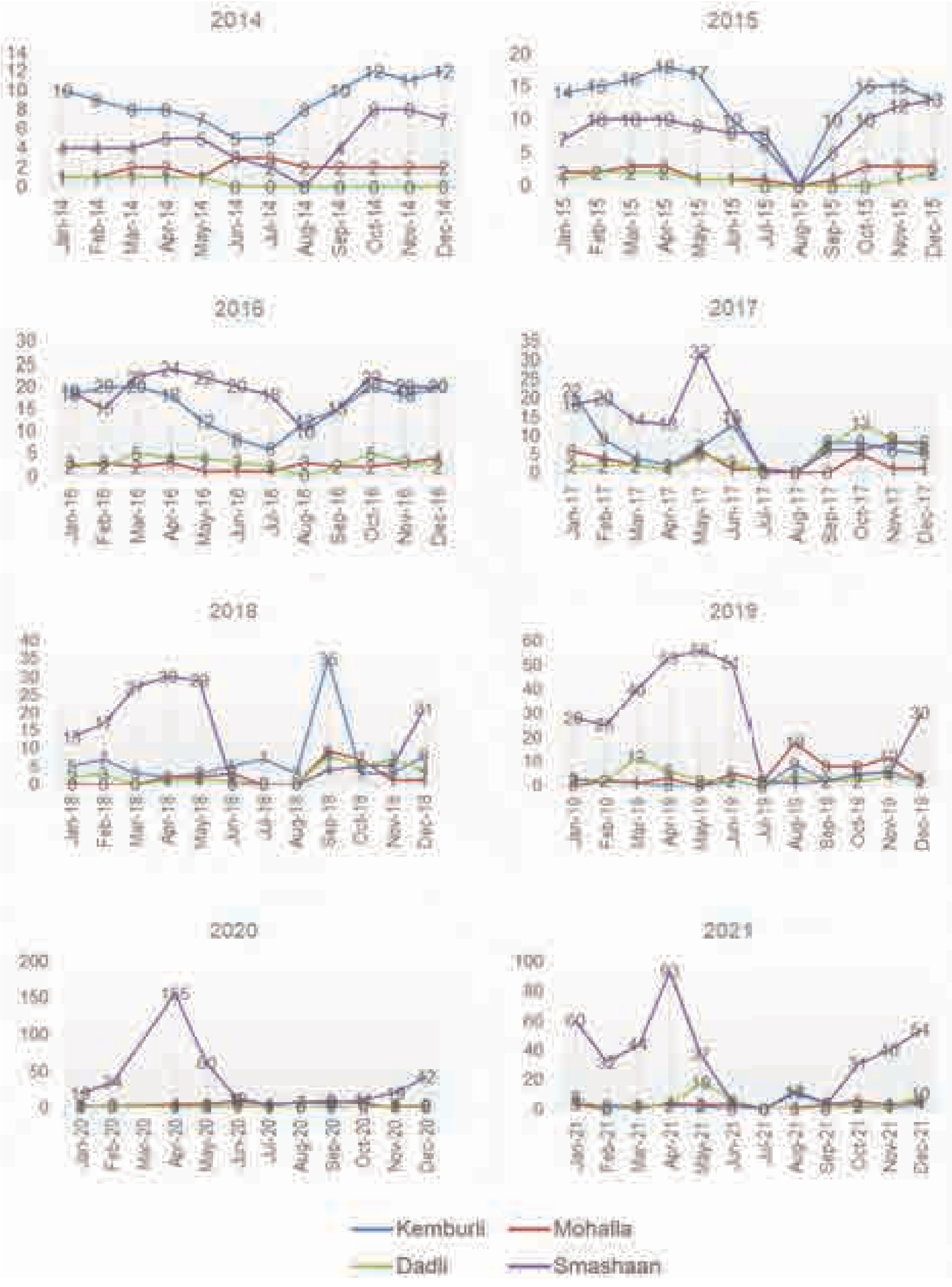

Figure 2A. Encounter frequency of Muggers at four sample transects of river Savitri, Mahad from 2014 to 2021.

Table 2. Quantification of impacts on Savitri River banks at four locations [- Nil, + Low, ++ Moderate, +++High].

Station		Anthropogenic Impact				
		Garbage Dumping	Boating/ Movement of People	Fishing	Washing, Bathing etc.	Carcass Dumping
1	Kemburli	++	+++	+++	-	+
2	Mohalla	++	+++	+++	+	++
3	Dadli	-	+++	+++	++	++
4	Smashaan	+++	+++	+++	+++	+++

From the foregoing observations it is clear that the quality of crocodilian habitat along the Savitri River is precarious. Quantification of impacts at the four locations along the river front has been tabulated (Table 2). It is an established tenet in Conservation Biology that habitat protection is a prerequisite for conservation of biological diversity and protecting the habitat is a pre-emptive approach to species conservation that can negate the drivers of extinction (National Research Council (US) 1995). The view that loss of habitat is a major factor in species extinctions is also corroborated by Groombridge (1992).

The pragmatic approach shall be to find potential ways to reduce or prevent negative interaction for the better well-being of both people and crocodiles. Such a view has been corroborated by Linnell et al. (2011). Recent works on human wildlife conflict includes a paradigm of coexistence (König et al. 2020), where humans and wildlife co-adapt to live in shared landscapes, and their interactions are sought to be governed by systems that guarantee long-term wildlife population persistence, social legitimacy, and tolerable levels of risk (Carter & Linnell 2016).

In the recent past there has been some debate and discomfort among wildlife biologists on the use of the term "Conflict" and it is suggested that the term is provocative, human-centric and places the burden of blame on the wildlife (Davidar 2018). Hill (2021) opines that rise or exacerbation of 'human-wildlife conflicts' is only a reflection of changing dimensions of human-wildlife interaction that are complex and nuanced. Implicit in this opinion is the understanding that human wildlife interactions need not strictly fall into discrete categories as conflict or coexistence, and that such dichotomous perception though easy to understand is oversimplified and even inaccurate. Further, Frank (2016) argues that 'conflict-coexistence continuum' has no fixed points but socio-cultural and geographical variables that change with time and circumstances. In this paper we consciously and rationally choose to use the term 'negative Human Wildlife interaction' to denote all such interactions that may have implications of damage and loss of life to both the sides.

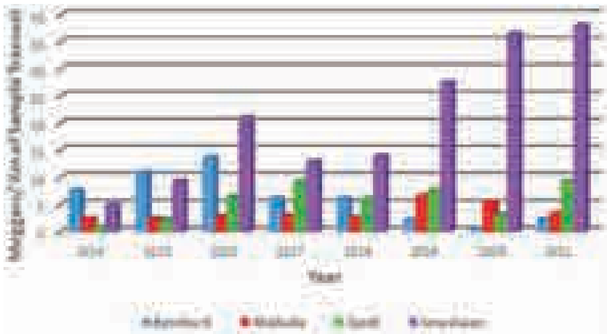

Figure 2B. Mean annual relative density of Mugger at the four linear transects of Savitri River, Mahad, Maharashtra between 2014 and 2021.

D. Human-Mugger interface at Mahad:

When people and wildlife share habitat and compete for resources therein, their encounters may become reciprocally negative due to spatial overlaps, at worst leading to loss of livelihoods and life. Human-wildlife interaction, is not just a humanitarian issue but also a conservation concern that must be addressed rationally. Incremental episodes of Negative Human Wildlife Interactions (NHWI) have been variously attributed to expanding human settlements and increasing human activities in and near wildlife habitats, recovery of depleted populations of wildlife, and spill-over of a few wild species populations besides large scale environmental changes (Treves 2009).

Perusal of available records and discussions with the locals here revealed that until 2016, no attacks on humans were recorded, barring a few stray incidents when a Mugger caught the leg of a fisherman but immediately released it, perhaps due to lack of predatory drive at the time of incident. Though this caused only superficial injuries to the fisherman, this episode unleashed fear

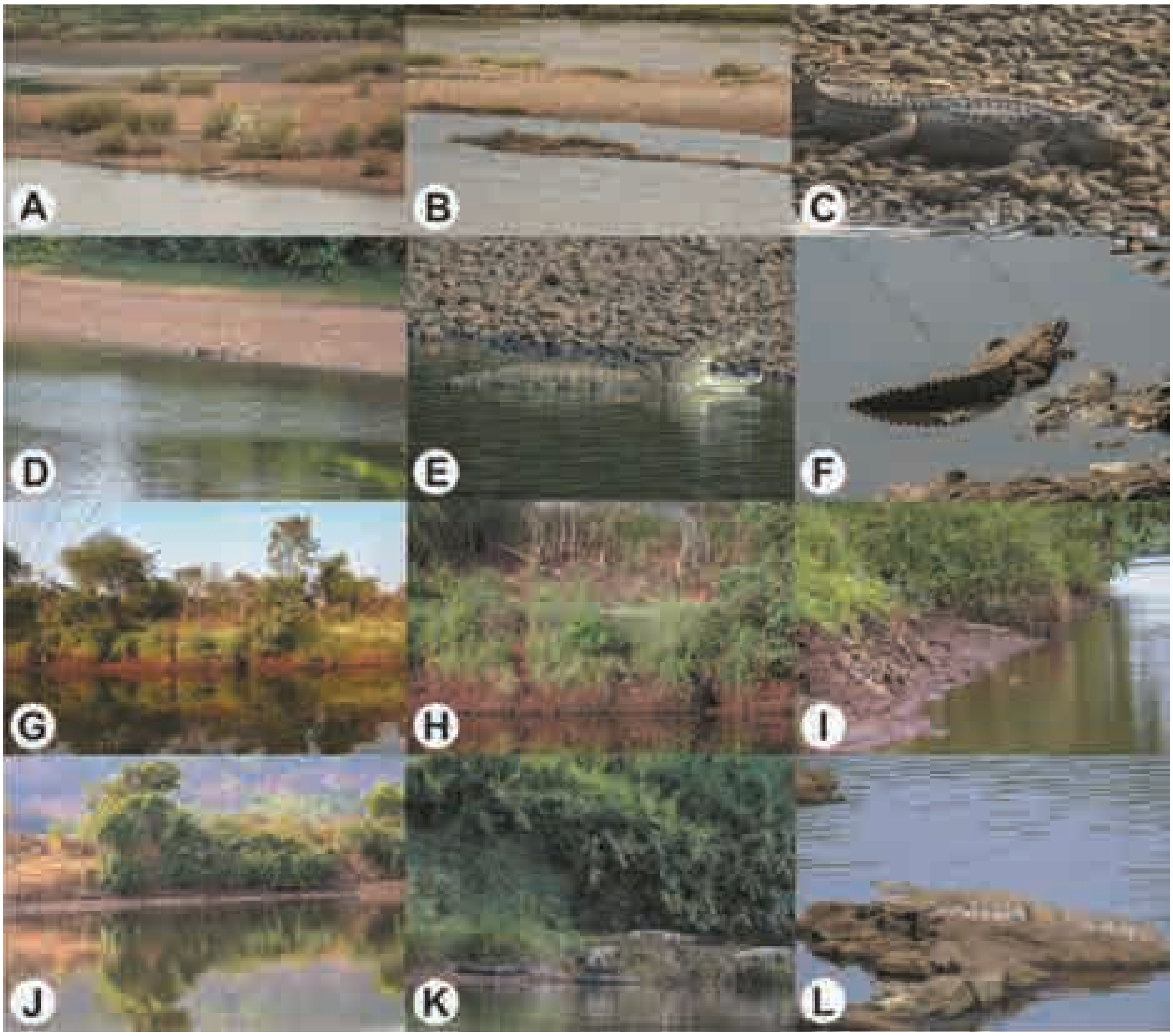

Image 3. Mugger habitats at 1—Kemburli (A–C) | 2—Mohalla (D–F) | 3—Dadli (G–I) and | 4—Smashaan (J–L) in the riparian stretches of River Savitri at Mahad, Maharashtra. Note the differences in vegetation, bank slope and surface character at the four locations. © Utkarsha M. Chavan.

among the people whose livelihoods were linked with waters of Savitri, though the indigenous people continue to fish in those waters in company of Muggers (Image 4A,B,C). Perhaps, the rich aquatic resources in river are excellent food source for both humans and crocodiles (Image 2C). Negative Human-Crocodile interactions (NHCI) have been reported from different parts of the country (Deutsch & Coleman 2000; Whitaker 2007, 2008; Rao & Gurjwar 2013; Upadhyay & Sahu 2013; Vasava et al. 2015; Vyas & Stevenson 2017).

Mugger attacks on humans have been recorded and attributed to several reasons. The known triggers include provocation and fishing (Whitaker & Srinivasan 2020), however, Muggers have also been living in harmony with people as in three districts of Gujarat; namely Kheda, Anand & Charotar (Vyas 2013) implying conditioning through long term exposure to humans.

It must be emphasized, however, that Mugger Crocodile is responsible for the third highest number of fatal attacks on humans after *C. niloticus* and *C. porosus* (CrocBITE: Worldwide Crocodilian Attack Database), though it never eats its human victim, implying that the basis of such extreme aggression is either defending the territory or protecting the nest or hatchlings; rather than predatory (Sidaleau & Britton 2012).

That dead remains of humans and other animals disposed in river water can also invite crocodile attacks has been suggested (Stevenson et al. 2014). A stray incident has been reported from Dasgaon, a place 7 km away from Mahad, where a person was attacked by

Image 4. Spectrum of anthropogenic stressors on Mugger habitat along the river Savitri at Mahad, Maharashtra, India. © Utkarsha M. Chavan

Mugger during rainy season apparently in defense of its hatchlings. Similar aggression by Muggers has been recorded by Whitaker (2007) from the banks of Krishna River in Maharashtra. Incidentally in the present study, it has been recorded that passersby and onlookers often throw stones for sheer fun and to see basking crocodiles in motion.

E. Negative Human-Mugger Interactions (NHMI) along the river Savitri, Mahad, Maharashtra India.

The rich aquatic resources in mangrove areas, estuaries, and rivers are excellent food source for both humans and crocodiles, making this livelihood option of local communities a reason for potential conflict. An important objective of this research was to identify a hostile human-Mugger interface if any and mitigate it. Though such episodes entail reciprocal damage both to the wildlife and people, the former is usually branded culpable. This antagonism between humans and wildlife is globally recognized and merits attention from the perspectives of conservation, management and livelihood of local communities (Messmer 2000; Dickman 2010; Bowen-Jones 2012). Across the world unresolved NHWI have been the cause of declining community support for conservation (Hill et al. 2002). Also, retaliatory killing of wildlife is fallout of this threat perception by local community (Inskip & Zimmermann 2009; Mateo-Tomas et al. 2012). Studies have also

Image 5. Negative human-crocodile interaction interface: A—Mugger stranded on roof top of a house during floods | B—Strayed Mugger vulnerable to road kill an adult | C—Mugger killed by entanglement in fishing net. © Mubin Khalfe

shown that there is a correlation between degree of conflict and decline of wildlife (Woodroffe et al. 2005; Michalski et al. 2006). NHWI also has an economic angle in that it takes a toll on life and livelihoods (Rao et al. 2002; Gillingham & Lee 2003; Sahoo & Mohnot 2004). Crop raiding by herbivores and livestock depredation by carnivores inflict significant monetary losses (Mackenzie & Ahabyona 2012; Brara 2013; Schon 2013). Lamarque et al. (2009) have also shown the diminishing financial and human resources implications of NHWI in countries affected by it.

In this study of crocodiles of Savitri River at Mahad; as of now the conflict interface is very subtle, and more than the people the reptile is at the receiving end. Until now there have been no reports of loss of human lives and livestock, despite a close proximity with the crocodiles (Image 4A–C,E). There is an imminent threat to the quality of this Mugger habitat due to incremental anthropogenic pressure. The greatest threat to the integrity of their habitat is from the land-based garbage, sewage, dumping of carcasses, and loss of basking sites due to human presence and activities (Image 4). The human-Mugger negative interaction interface gets further expanded due to straying of Muggers in human settlements during monsoons. Also during floods that occur intermittently following heavy rainfall here, residential areas get inundated and Muggers have been seen stranded on roof tops of houses (Image 5A) as also stray on roads (Image 5B). Occasionally the adults get entangled in fishing nets and die (Image 5C).

F. NHMI Mitigation and conservation management.

Notwithstanding this hostile interaction potential of the Mugger, these reptiles play a critical role in aquatic ecosystems as indicators of ecological health, ecosystem engineers, apex predators, keystone species, and as facilitators of nutrient and energy transfer across ecosystems (Somaweera et al. 2020). While conventional tourism has reached a saturation point, crocodiles can offer alternative resources for ecotourism promoting sustainable livelihood options for local communities. Borkar et al. (1993) have shown the ecotourism potential of Mugger in the backwaters of Cumbarjua canal in the adjacent state of Goa, and in Maharashtra State as well there are a few success stories of crocodile safaris at Maldoli creek, Chiplun. Incidentally a similar venture is also in the offing at Powai Lake in suburban Mumbai, for which Maharashtra Tourism Development Corporation (MTDC) has begun the process.

From the view point of disallowing escalation in the negative interactions here, it is important to raise awareness and build capacity of the local community and other stakeholders. Based on several years of field studies here, it is confirmed that the Smashaan area is a potential NHMI interface, though human fatalities haven't been recorded here as yet.

Currently, there is a single signage put up by the Mahad Forest Range Office declaring this area as 'crocodile infested', which also is now rusted and defaced. The forest department must establish a surveillance post here as a deterrence to anti-conservation activity. The facility could have basic rescue equipment as also staff trained in conducting rescue and autopsy. A suitable site here could also serve as an interpretation facility for visitor education.

As for the use of the river waters and banks by local indigenous communities, micro-mapping of such vulnerable areas for NHMI along river Savitri could be a valuable mitigation approach. After identifying such spots, 'Crocodile Excluding Enclosures' could be constructed using indigenous material for safety of people who share the habitat with the reptile. Such approach has been effectively tried in Sri Lanka (Uluwaduge et al. 2018). Poverty alleviation and community development initiatives could help lessen the dependence of locals on this river and consequently move them away from conflict.

Much of the conflict stems from spatial overlap and competition for resources, besides ignorance and fear, and impact of human activity on the habitat.

Areas with significant presence and activity of crocodiles must be mapped and notified by the local civic administration with sign boards in local language along the river banks. Local NGOs like SEESCAP and Srishtiutkarsha that regularly organize awareness programs at Mahad must be engaged by the forest division to sensitize locals towards avoiding risky behaviour and unwarranted machismo towards the reptile. The indigenous communities must be taken into confidence and their livelihood dependence on the river should be compensated with safer and viable alternatives. Sanitation and basic amenities like clean water must be guaranteed under the existing schemes of the government for socioeconomically disadvantaged population that share the crocodile habitat. Mahad municipality must strictly ban dumping of garbage in the riparian zone in stretches of the river like Smashaan where the reptile has a territory, as also regulate the discharge of raw sewage. The forest department must invoke provisions of the Indian Wildlife Protection Act, 1972 to initiate punitive action. In event of a situation of conflict, a quick response team must be available with the necessary paraphernalia for rescue.

CONCLUSION

The data presented here is accrued from a long-term monitoring programme and has documented presence of a viable Mugger population in river Savitri at Mahad. The Mugger habitat here in some locations is under discrete anthropogenic pressures and there are visible signs of habitat deterioration that could cause a likely spillover in years to come accentuating the negative human-Mugger interaction potential. Currently the reptilian population trends suggest stability, but the present age group distribution raises questions on the optimal recruitment and a likely decline in the population in the coming years. Timely interventions shall be a win-win situation for both, Mugger and people. The state and the community must synergize their efforts to secure conservation future of the crocodile here while encouraging and incentivizing the community involvement.

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COMMUNICATION

Paresis as a limiting factor in the reproductive efficiency of a nesting colony of *Lepidochelys olivacea* (Eschscholtz, 1829) in La Escobilla beach, Oaxaca, Mexico

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Abstract: Rear flippers are crucial in the nesting process of Olive Ridley Turtles *Lepidochelys olivacea*, so any impact on them could constitute a limiting factor in reproductive efficiency. Muscle weakness of the rear legs has been observed in some nesting females on La Escobilla beach in Oaxaca state, Mexico; however, this disorder has not been sufficiently researched. The aim of this study was to identify and describe this problem in a nesting colony of *L. olivacea* in La Escobilla. We obtained the biochemical profiles of eight females with clinical signs of muscle weakness of the rear legs, that could not build the incubation chamber for their nest. In order to compare their blood characteristics, we selected eight seemingly healthy turtles that successfully built their nests, laid eggs through oviposition and covered the nest. We found no significant differences in most of the blood parameters, except for Creatinine-Kinase (CK). Female turtles with muscle weakness presented significantly higher concentrations of CK (t = 2.1448, d.f. = 2, P <0.0001) when compared to the healthy turtles. CK is an appropriate enzyme for identifying the integrity of the muscle cell and is a muscle damage indicator. Our hypothesis is that the paresis observed in the rear legs of the female turtles in La Escobilla could be a chronic debilitation caused by a gradual exposure to biotoxins such as saxitoxins.

Keywords: Health, muscle, Olive Ridley Turtles, oviposition, rear-flippers.

Resumen: Las aletas traseras son cruciales en el proceso de anidación de la tortuga golfina *Lepidochelys olivacea*, así que cualquier impacto en ellas podría constituir un factor limitante en la eficiencia reproductiva. La debilidad muscular de las aletas traseras ha sido observada en algunas hembras anidantes de la playa La Escobilla en el estado de Oaxaca, México; sin embargo, este desorden no ha sido suficientemente investigado. El objetivo de este estudio fue identificar y describir este problema en una colonia anidante de *L. olivacea* en La Escobilla. Obtuvimos los perfiles bioquímicos de ocho hembras anidantes con signos clínicos de debilidad muscular de las aletas traseras, que impidió la construcción de la cámara de incubación para su nido. Con el fin de comparar sus características sanguíneas, seleccionamos además ocho hembras aparentemente sana que construyeron exitosamente su nido, pusieron sus huevos mediante oviposición y los cubrieron. No encontramos diferencias significativas en la mayoría de los parámetros sanguíneos, excepto por la Creatinina-Kinasa (CK). Las hembras con la debilidad muscular presentaron altas concentraciones significativas de CK (t = 2.1448, g.l.= 2, P<0.0001) cuando fueron comparadas las tortugas aparentemente sanas. CK es una enzima apropiada para identificar la integridad de la célula muscular y es un indicador de daño muscular. Nuestra hipótesis es que la paresis observada en las patas traseras de las hembras anidantes en La Escobilla podría ser una debilitación crónica causada por una exposición gradual a biotoxinas tales como las saxitocinas.

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INTRODUCTION

The Olive Ridley Turtle *Lepidochelys olivacea* (Eschscholtz, 1829) is one of the most abundant sea turtle species and classified as Vulnerable by IUCN Red List of Threatened Species (Abreu-Grobois & Plotkin 2008). In Mexico, all sea turtles are also classified as endangered species through the regulation NOM-ECOL-059-2010, and additionally, they are considered a priority species for conservation.

The Olive Ridley Turtle has a circumtropical distribution and inhabits the Atlantic, Pacific, and Indian Oceans, living mainly in the northern hemisphere (Bjorndal 1997). On the American continent, their most notable nesting beaches are located in Costa Rica (Cornelius et al. 1991; Fonseca et al. 2009), Panama (Cornelius et al. 2007; Honarvar et al. 2016), Nicaragua (Stewart 2001; Hope 2002), and Mexico (Peñaflores et al. 2000; Campbell 2007).

In Mexico, one of the world's major nesting sites for this species is La Escobilla beach in Oaxaca state; where impressively large mass synchronous nesting aggregations – called arribadas – occur (Márquez & Van Dissell 1982). Despite their importance, relatively little is known about the health status or the presence of clinical signs of a disease in the nesting colony (Mashkour et al. 2020). In addition to human activity and predation, diseases are another important factor that have contributed to the decrease in the population of sea turtles (Wallace et al. 2010).

In Olive Ridley Turtle nesting activity, rear flippers play a key role in building the nest cavity (egg chamber); hence, the depth of a nest chamber is dependent on the size of a female's rear flippers (Rusli 2019). Therefore, rear flippers are crucial in the nesting process, and any impact on them could constitute a limiting factor in reproductive efficiency.

On La Escobilla beach, various nesting turtles with muscle weakness of the rear legs have frequently been observed during the arribadas, a situation that is widely known empirically; however, the disorder has not been sufficiently researched. Until now, no studies on this subject have been performed on any nesting colony of *L. olivacea*; thus, the aim of this study was to identify and describe this problem in a nesting colony of *L. olivacea* in La Escobilla, Oaxaca, Mexico. This information will contribute to the protection of the species and allow for long-term health assessments and monitoring.

MATERIALS AND METHODS

This study was conducted on La Escobilla beach, located in the municipality of Santa Maria Tonameca on the southwestern Mexican Pacific coast (235,9041^{0}N, 1451,2041^{0}W). The beach is approximately 25 km long, and the Olive Ridley Turtles mainly nest along an 8 km strip at its western end.

During the development of a research project focused on assessing blood parameters in nesting Olive Ridley Turtles on La Escobilla beach, we encountered several females that displayed difficulties in making the egg chamber during the arribada events (September, October, and November) of the 2021 nesting season.

We obtained the biochemical profiles of eight females with clinical signs of muscle weakness of the rear legs that could not build the incubation chamber; as a result, after many attempts they ended up laying their eggs on the surface level of the sand (Image 1). Additionally, in order to compare their blood characteristics, we selected eight seemingly healthy turtles that successfully built their nests, laid eggs through oviposition and covered the nest. Previously, we conducted an external inspection of all the turtles evaluated to determine the existence of traumatic injuries.

Biometric data of all the turtles were taken according to the methodology described by Bolten (2000), including curved carapace length (CCL) and curved carapace width (CCW), which were measured using a flexible fiberglass tape (measurement error ± 0.5 cm, Limpus et al. 1983). The weight of each turtle was measured by suspending the turtle attached to a digital scale (MH-C 100 model, Mini Crane Scale).

Afterward, we collected blood samples from the dorsal cervical sinus, using a 1.5'-gauge needle and a 5 ml syringe and transferred the samples into vacutainers® containing lithium heparin as an anticoagulant (Owens & Ruiz 1980). Prior to sampling, the puncture area was cleaned. Samples were stored in refrigeration at 4 °C until laboratory processing at the Universidad del Mar (not more than eight hours after sampling).

A whole blood sample was centrifuged in an Eppendorf model 5430 centrifuge at 3,000 rpm for 10 min. We used plasma in preference to serum because in reptiles clot formation is unpredictable, changing biochemical values and occasionally producing hemolysis in the blood samples (Bolten & Bjorndal 1992). Plasma was placed posteriorly into 1.6-ml cryogenic vials. Sixteen plasma parameters were recorded using the automated blood chemistry analyzer Celercare V5 (Kabla Veterinary DX) to establish the sea turtles' health

Image 1. *Lepidochelys olivacea* with evident muscle weakness (paresis) of the rear legs laid eggs on the surface of the sand in La Escobilla beach, Oaxaca, Mexico. © Jesús García-Grajales.

profiles (Anderson et al. 2011; Espinoza-Romo et al. 2018). Additionally, we repeated the sampling process in the healthy turtles.

Analyzed parameters were divided into three groups: 1) nutrients and metabolites: Albumin (ALB; g dL^{-1}), total protein (TP), globulin (GLO), Albumin/Globulin (A/G) ratio, glucose (GLU), blood urea nitrogen (BUN), cholesterol (CHOL), creatinine (CRE), blood urea nitrogen/creatinine (BUN/CRE) ratio, total bilirubin (TBIL); 2) enzymes: amylase (AMY), Alanine aminotransferase (ALT), creatinine kinase (CK), alkaline phosphatase (ALP); and 3) electrolytes: calcium (Ca) and phosphorus (P).

Results are presented as mean, range and standard deviation (SD). Data normality and homoscedasticity were assessed using Kolmogorov-Smirnov and Levene tests, respectively. Differences in blood parameters between groups (with and with clinical signs) were assessed employing a *t*-student test. We performed all analyses using Past 4.08 statistical software (Hammer et al. 2001).

Turtle samples were collected under the SGPA/DGVS/03919/21 permit granted by SEMARNAT, Mexico.

RESULTS

Descriptive statistics of SCL, WCL, CCL, CCW, weight and blood parameters of the Olive Ridley Turtles are presented in Table 1. We found no significant differences in most of the blood parameters, except for CK.

Female turtles with muscle weakness presented significantly higher concentrations of CK ($t = 2.1448$, d.f. $= 2$, $p < 0.0001$) when compared with healthy turtles. During the external examination of the turtles, there was no evidence of recent traumatic injuries. However, one of the turtles with evident muscle weakness (paresis) of the rear legs laid eggs on the surface of the sand, after several failed attempts to perform the incubation chamber (Image 1).

DISCUSSION

Although Olive Ridley Turtles are the most abundant sea turtle species globally, knowledge regarding their health on mass nesting beaches remains limited. We found similar values in most blood parameters between turtles with clinical signs of paresis and seemingly healthy turtles; however, CK was highlighted as the muscle damage indicator.

Table 1. Biometric data and blood chemistry of the Olive Ridley Turtles with clinical signs of muscle weakness of the rear legs (paresis) and seemingly healthy turtles in La Escobilla beach, Oaxaca, Mexico.

	Turtles with paresis		Seemingly healthy	
	Mean (SD)	Range	Mean (SD)	Range
Biometric data				
Weight	36.2 ± 6.71	27.55 – 45.45	36.29 ± 3.56	31– 42
CCL	65.97 ± 4.18	61.5 – 72.1	65.77 ± 2.59	63 – 69.5
CCW	69.3 ± 4.91	62.6 – 78.7	69.6 ± 2.78	65.9 – 73
Blood chemistry				
ALB	1.01 ± 0.16	0.8 – 1.3	1.15 ± 0.23	1 – 1.7
TP	3.41 ± 0.49	2.8 – 4.2	3.6 ± 0.4	3.2 – 4.5
GLO	2.4 ± 0.45	1.9 – 3.3	2.4 ± 0.2	2.2 – 2.8
A/G	0.44 ± 0.09	0.3 – 0.6	0.46 ± 0.07	0.4 – 0.6
GLU	76.6 ± 25.56	42 – 107	106.6 ± 9.4	94 – 120
BUN	17.4 ± 13.94	7.68 – 50.2	9.68 ± 1.8	7.39 – 12.6
CHOL	234.1 ± 48.06	176 – 339	244 ± 69.48	178 – 396
CRE	0.74 ± 0.23	0.46 – 0.99	0.65 ± 0.21	0.31 – 0.99
BUN/CRE	29.75 ± 33.98	11 – 109	16.5 ± 5.83	9 – 26
TBIL	0.21 ± 0.07	0.12 – 0.34	0.23 ± 0.07	0.16 – 0.39
AMY	338.5 ± 129.16	143 – 552	305.4 ± 84.9	239 – 487
ALT	2.5 ± 0.92	1 – 3	24.1 ± 9.64	11 – 45
CK *	**1921.5 ± 771.79**	**1133 – 3143**	**250 ± 108.89**	**87 – 393**
ALP	21.6 ± 5.52	13 – 31	2.875 ± 0.35	2 – 3
P	8.6 ± 1.4	6.98 – 10.55	8.2 ± 1.19	6.84 – 9.78
Ca	6.8 ± 1.74	4.9 – 10.1	5.6 ± 1.9	2 – 7.9

* Denote significant differences. CCL—Curved Carapace Length | CCW—Curved Carapace Width | ALB—Albumin | TP—Total Protein | GLO—Globulin | A/G Albumin/Globulin ratio | GLU—Glucose | BUN—Blood Urea nNitrogen | CHOL—Cholesterol | CRE—Creatinine | BUN/CRE—Blood Urea Nitrogen/Creatinine Ratio | TBIL—Total Bilirubin | AMY—Amylase | ALT—Alanine Aminotransferase | CK—Creatinine Kinase | ALP—Alkaline Phosphatase | Ca—calcium | P—Phosphorus.

CK is an appropriate enzyme for identifying the integrity of the muscle cell; and is considered a specific muscle enzyme; that is, it increases in the bloodstream when a muscle disease is present (Perrault et al. 2012; Anderson et al. 2013). With this in mind, paresis is characterized as an inability of muscles to perform their usual functions. Its physiopathology is related to the motor function of the voluntary tracks consisting of the upper and lower motor neurons, peripheral nerves, neuromuscular plate and muscle fibers, so damage to any of these structures causes a paresis that depends on the degree of the injury.

Except for Espinoza-Romo et al. (2018), there are no previous reports on CK values in *L. olivacea*. Those authors showed a CK mean of 245.3 ± 386 for *L. olivacea* in northern Sinaloa, Mexico. On the contrary, we found high CK values in turtles with obvious muscle problems of the rear legs; however, the apparently healthy females showed values close to those reported by Espinoza-Romo et al. (2018). Because there are no papers published about muscle weakness (paresis) in *L. olivacea*, we compared our results to *Caretta caretta*, since this species has some similarities in their eating habits, sharing an analogous position in the food chain.

Previous studies on several species have reported different degrees of paresis. Jacobson et al. (2006) describes clinical signs of a neurological disorder in subadult loggerhead sea turtles (*C. caretta*) in south Florida, USA. In this study, there was no evidence of heavy metal toxicosis and organophosphate toxicosis as possible causes; instead, the clinical changes observed resulted from combined spirorchiid parasitism and possible chronic exposure to a novel toxin present in the diet of *C. caretta*.

Herrera-Galindo et al. (2015) reported several dead sea turtles (*Chelonia mydas*, *Eretmochelys imbricata*, *L. olivacea*) on the coast of Oaxaca, Mexico. This study described the presence of salps and cells of *Pyrodinium* *bahamense* in the turtles' stomach contents. Later, Ley-Quiñónez et al. (2020) presented evidence of paralytic shellfish poisoning (PSP) causing mass mortality of sea turtles in Puerto Vallarta, Jalisco, Mexico.

PSP has been identified as the most toxic and dangerous syndrome along the Pacific coast (Sierra-Beltrán et al. 1998). Two dinoflagellate species (*Gymnodinium catenatum* and *P. bahamense*) produce saxitoxin that is associated with these PSP events (Ochoa et al. 1997; Cusik & Sayler 2013). These phenomena affect the entire trophic web, principally primary consumers, but organisms such as fish, marine mammals and sea turtles that feed on planktivorous species may also be affected (Sellner et al. 2003; Garate-Lizarraga et al. 2004).

In animals and humans, clinical signs of saxitoxin intoxication include muscular paralysis and pronounced dyspnea, which, if not promptly treated, can result in death from respiratory paralysis (Hallegraeff 1993). Although lethal doses of saxitoxins have not been defined for sea turtles or other reptiles (González-Barrientos et al. 2019), constant ingestion of this dinoflagellate species could probably provide enough toxin to produce muscle weakness of the rear legs in sea turtles.

Later, González Barrientos et al. (2019) presented evidence of abnormal clinical signs in stranded Green Sea Turtles *Chelonia mydas* that were exposed to saxitoxins and tetrodotoxins on the southern Caribbean coast of Costa Rica. Among the stranded turtles, two live green turtles exhibited extreme paresis. Saxitoxicosis in green turtles appears to have resulted from opportunistic foraging on the Caribbean Sharp-nosed Puffer *Canthigaster rostrata*.

Although specific causes of muscle weakness (paresis) in Olive Ridley Turtles remain unknown, we hypothesize that the paresis observed in the rear legs of the female turtles in La Escobilla could be a chronic debilitation due to a gradual exposure to biotoxins such as saxitoxins. It is important to mention that this debilitation could be a limiting factor in the reproductive efficiency of a nesting colony of *L. olivacea* in La Escobilla, Oaxaca; therefore, we recommended initiating a continuous monitoring program to follow the occurrence of paresis in subsequent years in order to better document its prevalence and to follow the progression of this muscle weakness among sea turtles.

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COMMUNICATION

Notes on the nesting and foraging behaviours of the Common Coot *Fulica atra* in the wetlands of Viluppuram District, Tamil Nadu, India

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Abstract: The nesting and foraging behaviours of the Common Coot *Fulica atra* were studied in the wetlands of Viluppuram District, Tamil Nadu during the breeding season. A total of 4,054 individuals of Common Coot including 467 juveniles and 1,327 nests were enumerated. Of the 1,327 nests, 1,191 were built on *Ipomoea carnea* vegetation and 136 on open water. The birds used twigs of *Ipomoea carnea* and various parts of eight other plant species as nest material. The nests were elliptical in shape, with flattened upper surfaces containing nest cup and a ramp-like structure each. 49.96 % of nests were found within 50 m distance from the edge of wetlands. A total of 16 plant species were identified as food sources including five algal species, such as *Aphanothece stagnina*, *Spirogyra irregularis*, *Chara flaccida*, *C. vulgaris*, and *C. zeylanica*. The Common Coots maintained strict territory during the breeding season and no other water birds were observed in the vicinity of their nesting and foraging sites. Even after completion of the breeding season, sporadic nesting was observed by a few pairs till June 2022.

Keywords: Chick behaviour, foraging plants, nest cup, nest materials, open nests, reproduction.

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INTRODUCTION

The Eurasian Coot or Common Coot *Fulica atra* (Linnaeus, 1758) (Aves: Gruiformes: Rallidae) is a sexually monomorphic, monogamous, gregarious, aggressive, and territorial bird. The Common Coot occurs as an extant species (resident) in India, Sri Lanka, Nepal, Bangladesh, Pakistan, Afghanistan, Bhutan, China, France, Germany, Egypt, Saudi Arabia, and the United Kingdom (BirdLife International 2019). The Common Coot has four subspecies, namely *Fulica atra atra* of India, southeastern Asia, Philippines, Europe, and northern Africa to Japan; *Fulica atra lugubris* of Java, Bali, northeastern New Guinea; *Fulica atra novaeguineae* of Central New Guinea and, *Fulica atra australis* of Australia and New Zealand (Gill et al. 2020). The IUCN Red List of Threatened Species has classified the species as 'Least Concern' (BirdLife International 2019).

The reproductive biology of the Common Coot was studied in North-east Algeria (Samraoui & Samraoui 2007) and in Heilonjiang Province of China (Zhang et al. 2018). Common Coots have been reported breeding in Gujarat (Himmatsinhji et al. 1991; Patel et al. 1998), Maharashtra (Khacher 1978), Andhra Pradesh (Nadarajan et al. 1993), and Tamil Nadu (Balachandran 1994; Santharam 1996). No other literature is available on the nesting and foraging behaviours of the Common Coot in Tamil Nadu. In order, to fill the gap, the present study was carried out.

In this study, I documented the number of birds and nests, and the roosting and foraging habits of the Common Coot in the wetlands of Viluppuram District in Tamil Nadu. This study aimed to investigate the number of individuals of the Common Coot inhabiting the wetlands during the breeding season, the source of their nesting materials and food, and the total number of nests. Additionally, roosting and foraging behaviours and interactions with other bird species were addressed.

MATERIALS AND METHODS

Study area

The present study was carried out at 30 sites in the wetland areas covering 29 villages in the Viluppuram District (12.0579°N & 79.5603°E), of Tamil Nadu (Table 1). Except for the Veedur reservoir other wetlands are seasonal and found dry during the summer months of June–August. These wetlands get filled in the Northeast monsoon during October–December every year. The vegetation at the study sites mainly consisted of herbs like *Ipomoea carnea*, reeds/grass *Typha angustifolia*, and *Chrysopogon zizanoides*, and trees such as *Vachellia niliotica* and *Prosopis juliflora*. Agriculture is the primary occupation in the district. The major crops of the area are Paddy *Oryza sativa*, Jowar *Sorghum bicolor*, Pearl Millet *Pennisetum glaucum*, Finger Millet *Eleusine coracana*, Foxtail Millet *Setaria italica*, Sugarcane *Saccharum officinarum*, and Pulses, such as Black gram *Vigna mungo*, Green gram *Vigna radiata*, and Pigeon pea *Cajanus cajan*. Temperature ranges 36–20 °C. The average annual rainfall is 1,060 mm (Viluppuram 2021).

Methods

With the help of two field assistants, the survey was conducted in the wetlands of Veedur Reservoir and wetlands of other areas in the district between 0545 and 1800 h, during the breeding season from the third week of December 2021 to the fourth week of March 2022. The number of birds was counted by following the total count method (Bibby et al. 2000) when the birds were foraging. Bird census was carried out over three monthly sessions during the second week of every month for three months and the bird population size was arrived at as the average of each session's total count. Chicks at various developmental stages were counted during March 2022. Variables such as nesting sites, sources of nest materials, and food sources, such as algae and angiosperm plants foraged by the birds were identified. The distance between the nests and the edges of water bodies was measured using measurement tape after the breeding season. The distance between the nests and edges of the water body was grouped into intervals 0–50, 51–100, 101–150, and 151–200 m. The exterior length and width of the nests as well as the length, width, depth of nest cups, and the height of nests above the water level were measured using a measuring tape after the nests (20) were abandoned by the birds. The count of adult, and juvenile birds, their roosting and foraging activities, and interactions with other water bird species within the wetland were observed using binoculars from a safe distance (ca. 30 m). All the guidelines and protocols of nesting studies, as prescribed by Barve et al. (2020) were followed scrupulously. No eggs, chicks, and adult birds were handled during the study. The locations of nesting sites were determined using Garmin Etrex 20x GPS device. Photographs and videos were taken using Nikon P1000 digital camera. The collected data were tabulated, analyzed and shown as a graphical representation.

RESULTS

A total of 3,587 adult individuals, 467 chicks, and 1,327 active nests of the Common Coot were enumerated in 30 water bodies. Out of 1,327 nests, 89.75% of nests (n = 1,191) were found constructed in the thick vegetation of *Ipomoea carnea* (Figure 2d,e) and 10.25% of nests (n = 136) were found constructed in open water (Figure 2a–c). At the end of the breeding season, a total of 467 chicks were enumerated (Table 1).

Nest construction

Nine plant species belonging to seven genera and seven families were utilized by the Common Coot as nesting materials. Of the nine plant species, eight were dicotyledons and one monocotyledon. The birds utilized various plant parts such as twigs, petioles, leaves, inflorescence, and even entire plants as nesting material. During nest construction, Common coots used live and dead twigs of *I. carnea*, formed base-like structures for nests and added dry twigs brought from nearby places. The nests are elliptical with a flattened upper surface containing the nest cup. The major part of the nest consisted of twigs of *I. carnea*. Open nests were built on leaves of *Nymphaea* spp. or *Aponogeton natans* using the twigs of *I. carnea* along with various parts of other plant species (Table 2). Moreover, they added leaves and inflorescence of grass *C. zizanoides* in the inner surface of the nest cup as egg lining. Even during incubation, many nests contained partly eaten fruits of species of genera *Nelumbo* and *Nymphaea* (Image 1,3b).

Abandoned nests (n = 20) after the breeding season revealed that the nests were found 12–18 cm height above the water level. The entire length of the nests including nest cups was in the range of 64.7±21.79 cm and the width was in the range of 46.95±17.56 cm. The length of the elliptical-shaped nest cup was in the range of 21.3±3.29 cm and the width of the nest cup was 9.85±2.52 cm. The depth of the nest cup was in the range of 7.45±2.63 cm.

Distance between the edges of water bodies and the locations of nests (both open nests and nests on vegetation) revealed that a maximum of 49.96 % of nests (n = 663) occurred within 50 m distance from the edges and 1.88% of nests (n = 25) between 151 and 200 m distance from edges of water bodies. The percentage of nests that occurred at various distance interval ranges is given in Figure 2. The clutch size ranged 3–8 eggs.

The study revealed that the adult birds continued to expand their nests even after the chicks had grown by adding plant materials and used the nests as roosting sites. It was observed that chicks also brought plant materials and added them to the nests. The size of the nest cup was relatively small when compared to the overall upper surface area of the nest. Apart from the nest cup, each nest contained a peculiar ramp-like structure on the margin. Whenever residents entered the water to harvest lotus/lilies or for fishing, young chicks jumped into the water, swam, temporarily hid in the nearby *I. carnea* vegetation and later returned to the nests by climbing through the ramps (Image 2j,k). Even partly grown-up chicks used the ramps to climb into their nests. The present study revealed that the breeding of the Common Coot concluded during the fourth week of March 2022. Sporadic nesting (11 nests in May and eight nests in June), however, was observed till the second week of June 2022.

Foraging

In the present study, 16 plant species belonging to nine families foraged by the Common Coot were observed. Out of the 16 species, five were algae (thallophytes), a solitary grass species *C. dactylon* (monocotyledon) and the remaining 10 species were dicotyledons. The Common Coots swallowed entire colonies of blue-green alga *Aphanothece stagnina* and thalli of macro green algae *Spirogyra irregularis* and *Chara* spp. The birds usually dive into the water and cut off fruits of *Nelumbo nucifera* and *Nymphaea* spp. along with peduncles submerged in water, take them and placed them in the nests, pluck seeds using beaks, and feed their chicks. Adults were also observed consuming such seeds. Apart from hydrophytes, adult birds were found foraging on terrestrial plants, such as *C. dactylon* and *Phyla nodiflora* on the banks of water bodies. A list of plant species and their parts consumed by the birds is given in Table 3. In three instances, the adults collected small insects on the leaves of *Nymphaea* spp. and placed them in front of young chicks in the nests and the chicks swallowed the prey. Eight abandoned nests contained empty shells of snails.

Chicks

A total of 467 chicks at various developmental stages were enumerated at the end of the breeding period. Eighty-nine adults were found moving with a single chick each, 81 adults had two chicks each, 41 adults had three chicks each, eight adults had four chicks each, and the remaining 61 chicks were found wandering independently without any adult/parent birds probably because the parents had abandoned them or the parent birds might have been killed by predators (Image 2f,g).

Table 1. Details of nesting sites, number of birds, nests, distance from water body edges, and chicks of Common Coot counted in the study area.

	Name of the village/ study sites	GPS coordinates	Lake/ pond	Number of adult birds counted	Number of active nests counted	Open nests	Nests found in bushes	Number of nests located from edges of water bodies				Total number of chicks counted
								0–50 m	51–100 m	101–150 m	151–200 m	
1	Veedur	12.073201°N–79.620535°E	Reservoir	45	16	10	6	0	2	3	11	12
2	Veedur	12.072787°N–79.621395°E	Lake	320	62	28	34	14	27	7	14	72
3	Vallam	12.253836°N–79.512884°E	Lake	130	41	3	38	35	6	0	0	11
4	Alagramam	12.174401°N–79.577836°E	Lake	600	230	20	210	30	110	90	0	60
5	Keezhedayalam	12.170917°N–79.628823°E	Lake	170	78	4	74	32	12	34	0	22
6	Thenkalavai	12.178328°N–79.642219°E	Lake	18	6	0	6	2	2	2	0	8
7	Annamputhur	12.173768°N–79.674404°E	Lake	169	56	0	56	27	9	20	0	12
8	Omandur	12.170285°N–79.684428°E	Lake	8	2	0	2	0	1	1	0	0
9	Urani	12.154740°N–79.907088°E	Lake	260	110	10	100	70	40	0	0	43
10	Munoor	12.188669°N–79.813499°E	Lake	68	17	0	17	13	4	0	0	7
11	Thenkolapakam	12.122414°N–79.633937°E	Lake	10	4	0	4	3	1	0	0	6
12	Ponnampoondi	12.050018°N–79.622626°E	Lake	320	130	20	110	70	60	0	0	23
13	Eraiyur	12.064028°N–79.649245°E	Lake	210	65	0	65	35	20	10	0	17
14	Ambuzhukai	12.053135°N–79.652319°E	Lake	215	110	25	85	60	50	0	0	34
15	Pomboor	12.039517°N–79.601541°E	Lake	2	1	0	1	0	1	0	0	0
16	Siruvai	12.085022°N–79.605374°E	Lake	12	3	0	3	2	1	0	0	6
17	Kooteripet	12.152769°N–79.602806°E	Lake	12	4	0	4	2	1	1	0	0
18	Kodima	12.168730°N–79.596345°E	Lake	22	9	0	9	6	3	0	0	0
19	Kenipet	12.172076°N–79.606865°E	Lake	27	11	0	11	8	3	0	0	9
20	Thenpasiyar	12.188961°N–79.613161°E	Lake	70	29	4	25	23	6	0	0	0
21	Jakkampettai	12.188895°N–79.610063°E	Lake	32	13	0	13	9	4	0	0	8
22	Karnavoor	12.195530°N–79.651071°E	Lake	278	112	12	100	59	53	0	0	34
23	Deevanur	12.259598°N–79.557778°E	Lake	73	29	0	29	21	8	0	0	12
24	Mannampoondi	12.292093°N–79.557769°E	Lake	43	16	0	16	12	4	0	0	5
25	P.S. Palayam	11.962182°N–79.634326°E	Lake	10	4	0	4	3	1	0	0	0
26	Sorathur	12.206139°N–79.458818°E	Lake	36	16	0	16	9	7	0	0	0
27	Kanniyam	12.087708°N–79.635536°E	Lake	14	6	0	6	4	2	0	0	0
28	Kallakulathur	12.128919°N–79.649977°E	Lake	212	76	0	76	55	17	4	0	45
29	Vengai	12.164787°N–79.659901°E	Lake	22	7	0	7	4	3	0	0	0
30	Kazhuveli	12.150835°N–79.905336°E	Lake	179	64	0	64	55	9	0	0	21
	Total			3587	1327	136	1191	663	467	172	25	467

Image 1. Nest types of Common Coot in the study area. a—An individual Common Coot searching nest site | b & c—Open type nests, and | d—Nest built on Ipomoea carnea vegetation. © M. Pandian.

Interactions with other birds and threats

Common Coots maintained strict nesting territory during the breeding season and no other water birds were observed in the vicinity of their nesting and foraging sites. Other water bird species, such as Little Egret *Egretta garzetta*, Lesser Duck *Aythya affinis*, Indian Spot-billed Duck *Anas poecilorhyncha*, Pheasant-tailed jacana *Hydrophasianus chirurgus*, Little Grebe *Tachybaptus ruficollis* and Lesser Whistling Duck *Dendrocygna javanica* were found foraging in the water bodies where nests of the Common Coot occurred. Individual Common Coots used to chase/attack when other bird species come in the vicinity of their nesting and foraging sites. Other bird species stop their activities like swimming, foraging, preening, or perching on aquatic plants, and become alert and ready to escape whenever a Common Coot moves nearby. In four instances, individuals of Pheasant-tailed Jacana used abandoned nests of Common Coot as a day roost. Fishing by locals caused disturbance to the foraging of adults and chicks. No killing of adult birds/ nest predation, however, was observed (Image 4).

DISCUSSION

Nest construction

In southern Algeria, 63.2% of nests of Common Coot were associated with *Phragmites australis* probably to reduce predation risk from the air (Samraoui & Samraoui 2007). Emergent vegetation is important for habitat selection by Coots, presumably because it provides nesting habitats and protection against aerial predators (Nieoczym & Kloskowski 2018). In the present study, 89.75% of nests were built in emergent vegetation *I. carnea* probably to avoid aerial predators as stated by Samraoui & Samraoui (2007) and Nieoczym & Kloskowski (2018). Most of the nests of Common Coot were associated with *T. angustifolia* in Algerian Sahara (El-Yamine et al. 2018). Though *T. angustifolia* reeds occurred abundantly in the present study area, the birds did not build nests on these reeds, whereas they preferred *I. carnea* vegetation. The study also revealed that 50% of the nests occurred within 0–50 m and another 35.19% of nests occurred within 51–100 m

Table 2. List of plant species used as nest materials by the Common Coot in the study area.d—Nest built on Ipomoea carnea vegetation.

	Name of the plant	Family	Plant parts used as nest materials
1	*Ipomoea carnea* Jacq.	Convolvulaceae	Twigs
2	*Nymphaea pubescens* Willd.	Nymphaeaceae	Leaves and petiole
3	*Nymphaea nouchali* Burm.f.		Leaves and petiole
4	*Aponogeton natans* (L.) Engl. & K. Krasuse	Aponogetonaceae	Entire plant
5	*Polygonum hydropier* (L.) Delabre	Polygonaceae	Twigs
6	*Polygonum barbatum* L.		Twigs
7	*Pentapetes phoenicea* L.	Malvaceae	Twigs
8.	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae	Twigs
9	*Chrysopogon ziznoides* (L.) Roberty	Poaceae	Leaf blades and inflorescence.

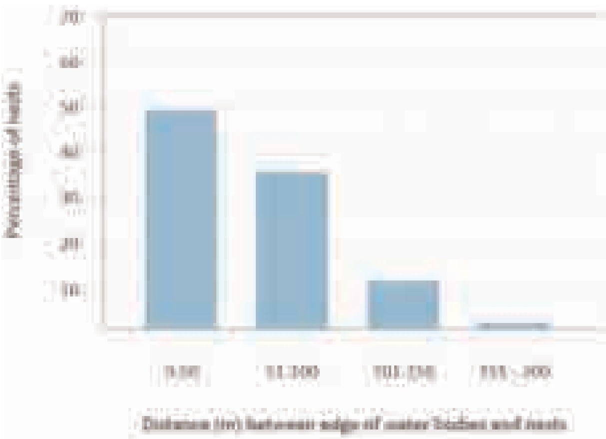

Figure 1. Details of the percentage of nests found from the edges of water bodies.

distance from edges of water bodies. The construction of the highest number of nests near the banks is probably due to the shallow water containing emergent *I. carnea* vegetation, the availability of abundant nest material and food sources like algae and other hydrophytes. Studies over larger geographical areas, however, may throw light on the causes for the construction of more nests near the edges of water bodies.

Common Coots rarely raise two broods per season (Taylor 1998). The present study reveals that despite the conclusion of breeding during the fourth week of March 2022, sporadic nesting by a few pairs continued till the second week of June 2022. It was not possible to ascertain whether these were cases of late breeding or it was a second breeding in the year. Nests often

Table 3. List of plant species and their parts fed by the Common Coot in the study area.

	Name of the plant	Family	Plant parts used
1	*Aphanothece stagnina* (Spreng.) A. Braun	Cyanophyceae	Entire algal colony.
2	*Spirogyra irregularis* Ngeli ex Kutzing	Zygnemataceae	Entire algal colony.
3	*Chara flaccida A. Braun*	Charophyceae	Entire algal thallus.
4	*Chara vulgaris* (L.)		Entire algal thallus.
5	*Chara zeylanica* Klein ex Willd.		Entire algal thallus.
6	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae	Entire plant.
7	*Ottelia alismoides* (L.) Pers.		Stem, young buds, leaves, and flowers.
8	*Nechamandra alternifolia* (Roxb. *ex* Wight) Thwaites		Stem, Leaves, and flowers.
9	*Najas minor* All.		Entire plant
10	*Ceratophyllum demersum* (L.)	Ceratophyllaceae	Entire plant
11	*Lemna gibba (L.)*	Lemnaceae	Entire plant
12	*Cynodon dactylon* (L.) Pers.	Poaceae	Leaves
13	*Nelumbo nucifera* Gaertn.	Nymphaeaceae	Stamen, pistil, and seeds
14	*Nymphaea pubescens* Willd.		Stamen, pistil, and seeds.
15	*Nymphaea nouchali* Burm.f.		Stamen, pistil, and seeds
16	*Phyla nodiflora* (L.) Greene	Verbenaceae	Leaves, tender stems, and inflorescence.

remain used by the family for roosting (Taylor 1998). In the study sites, adult Common Coots with their juveniles not only used their nests for roosting but also expanded the existing nests further by adding fresh nest materials. These observations corroborate the findings of Taylor (1998).

Foraging

The Common Coot is omnivorous, feeding on small prey, eggs of other birds, algae, vegetation, seeds and fruits (Martin et al. 1997). Sago pondweed *Stuckenia pectinata* in France and Germany (Allouche & Tamisier 1984; Hilt 2006) and Watermilfoil *Myriophyllum verticillatum* and horn-wort *Ceratophyllum demersum* in China are their main sources of food (Wang et al. 1990; Zhang & Ma 2011). Submerged vegetation is an important food source for Common Coot and it is positively related to its breeding success (Nieoczym & Kloskowski 2018). The Common Coots exhibit considerable plasticity in their foraging behaviours by foraging on a wide range of plants and animal materials,

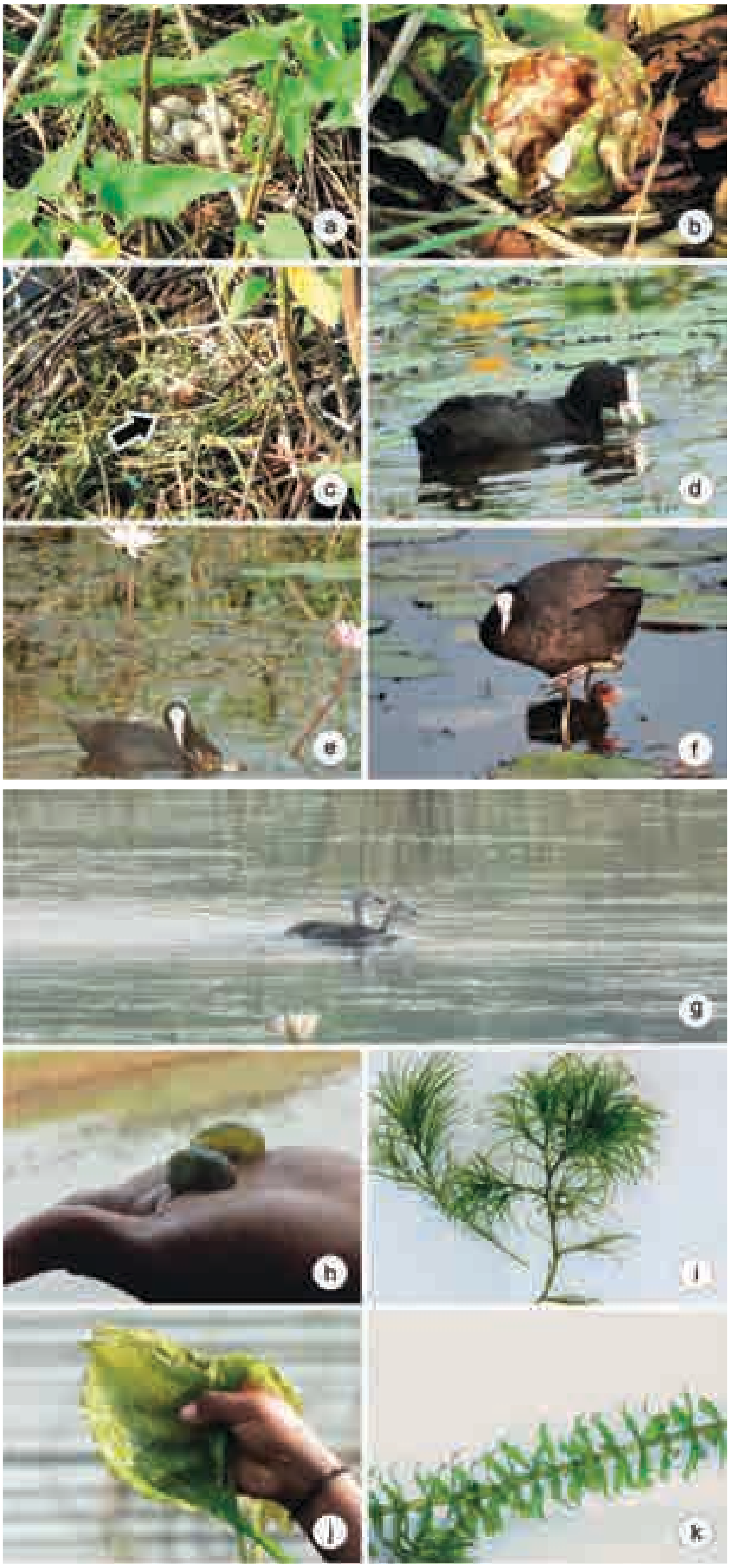

Image 2. Nest and foraging habits of Common Coot in the study area. a—Nest found hidden in *Ipomoea carnea* vegetation | b—Nest containing a partly eaten fruit of *Nymphaea* spp. | c—An empty shell of snail in nest cup | d—Common Coot consuming *Hydrilla verticillata* plant | e—Common Coot swallows thalli of blue-green alga *Aphanothece stagnina* | f—Foraging adult bird with a solitary chick | g—Two chicks foraging without a parent | h—Colonies of blue-green alga *Aphanothece stagnina* | i—*Chara zeylanica* thallus | j—Leaves of *Otellia alsinoides* | k—*Hydrilla verticillata* plant. © M. Pandian.

Image 3. Threats and interactions with other bird species. a—Residents fishing in the study site | b—A chick jumped out of its nest and swims on seeing a fisherman, and | c—Lesser-whistling duck escapes on seeing Common Coot. © M. Pandian.

such as algae, macrophytes, seeds, insects, and benthic invertebrates (Draulans & Vanherck 1987; Howes & Perrow 1994). In the present study area, diverse animal/plant species, such as snails, insects, five algal species, and eleven macrophytes including submerged, floating and terrestrial plants played an important role as a food source of Common Coots. Hence, the present study corroborates the findings of Martin et al. (1997), Draulans & Vanherck (1987), Howes & Perrow (1994), and Nieoczym & Kloskowski (2018).

CONCLUSION

The present study area harbours 4054 individuals of Common Coot including 467 juveniles and 1327 nests. Birds collected nest material mainly from *I. carnea* and eight other plant species for the construction of nests. The wetland habitats contained a wide range of food materials and nesting sites. Despite rapid urbanization, industrialization, population increase, habitat destruction, and decreasing areas of wetlands, considerable populations of the Common Coot exist in the study area. A special management plan could be devised for the area, considering the anthropogenic pressures on the habitats like fishing, and harvesting of flowers and reeds by residents.

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COMMUNICATION

Population abundance and threats to Black-headed Ibis *Threskiornis melanocephalus* and Red-naped Ibis *Pseudibis papillosa* at study sites in Jhajjar district, Haryana, India

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Abstract: The Black-headed Ibis and Red-naped Ibis are large wading birds of the order Pelecaniformes. This study documents abundance and threats affecting both species at Dighal, Gochhi, and Chhochhi villages located in Jhajjar district, Haryana, India. Field visits were made twice a month at each site from October 2020 to September 2021. Dighal had proportionately the largest populations of both species. Black-headed Ibis were most abundant in wetlands and Red-naped Ibis in agricultural areas. Populations of both species did not vary among seasons. Major threats observed included dumping of solid waste, fishing, growth of weeds, release of untreated sewage, collisions with transmission lines, grazers (e.g., cattle and goats), and stray dogs. The findings of this study suggest that despite having sizable populations near Dighal, both species face major threats and conservation efforts will require monitoring and management of ibis habitat.

Keywords: Dighal wetland, habitat, solid waste, wading birds.

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INTRODUCTION

Abundance of a species in an area is largely dependent upon a suitable habitat having all the resources required for its survival and reproduction (Whittaker et al. 1973; Krausman 1999). Ibises were included under the order Pelecaniformes and the family Threskiornithidae of class Aves (IUCN 2016) which includes the average-sized waders having a probing type downwardly curved beak (Hancock et al. 2001; IUCN 2016). Black-headed Ibis *Threskiornis melanocephalus* and Red-naped Ibis *Pseudibis papillosa* are the most widely distributed species of northern and western India (Hancock et al. 2001; Ali & Ripley 2007; BirdLife International 2012).

Black-headed Ibis and Red-naped Ibis were known to utilize the area in and around the shallow water habitat (Hancock et al. 2001), but the most preferred habitat for Black-headed Ibis include wetlands, lagoons, freshwater ponds, riverine lakes, paddies, swamps, marshlands, and salty marshes (Hancock et al. 2001; Chaudhury & Koli 2018); whereas Red-naped Ibis preferred dry zones and agricultural area found near the shallow water land (Thapa & Saund 2012; Chaudhury & Koli 2018). They use these habitats for foraging, nesting, and roosting (Senma & Acharya 2009; Chaudhary 2018). Black-headed Ibis always shows nesting and roosting in colonies of egretries or heronries (Balakrishnan & Thomas 2004; Laughlin et al. 2014; Chaudhury & Koli 2016; Chaudhary 2018). But Red-naped Ibis never shows nesting and roosting in colonies and always tends to form one nest per tree (Senma & Acharya 2009).

Black-headed Ibis usually prefers to feed in seasonal wetlands, as the availability of food is higher than in perennial wetlands (Sundar 2006; Chaudhury & Koli 2018), however, Red-naped Ibis feeds on the insects and crustaceans found in agricultural land and nearby wetland habitat (Hancock et al. 2001). But their habitat were encountering various threats like the discharge of chemicals from industries, deposition of solid waste, washing clothes in nearby wetland areas, spray of pesticides in the agricultural land area, and agricultural land conversion which leads to their population decline (Choudhury 2012). Therefore, some conservation measures should be required to conserve both species.

A very few studies are available regarding the ecology and behavior of both the ibis species in India (Balakrishnan & Thomas 2004; Senma & Acharya 2009; Thapa & Saund 2012; Chaudhury & Koli 2018) and none of them have been conducted in Haryana. So, this present study was conducted at the selected study sites of district Jhajjar, Haryana; based on the following objectives: (1) to census the population of both Black-headed Ibis and Red-naped Ibis in the selected study sites and (2) to evaluate the various threat factors faced by both the Ibis species in their respective study sites. This study will be helpful in the conservation of both the ibises and ultimately provide conservation measures that will prevent the conversion of wetlands or the ponds used by the wading bird species into any sort of urbanization.

MATERIALS AND METHODS

Study area

This present study was conducted at the selected study sites namely Dighal, Gochhi, and Chhochhi villages of district Jhajjar, Haryana. The climatic conditions of the district are subtropical having four different seasons; summer season from May to July; autumn commence in August and ends in late October; winter season approaches from November and last to January and spring season occurs from February to April. District Jhajjar remains arid in summers with an intense hot environment and cold in winters. Approximately, 577 mm of annual rainfall occurs in this region out of which near about 75% occurs in the monsoon period (from late June to August) (Bhatia 2013).

Dighal is located at 28.7694°N & 76.6326°E of Jhajjar district covering 30.57 km^2 geographical areas (Gulati 2001). It constitutes the maximum number of freshwater as well as marshy wetland areas among the three selected study sites, that endows an appropriate habitat for several large number migrant bird species for their environmental needs; ultimately making this area a potential IBA site with a code IN-HR-06 stated by ENVIS (Rahmani et al. 2016). Village Chhochhi is located at 28.7264 °N & 76.6756 °E of district Jhajjar covering only 5.44 km^2 geographical areas (Gulati 2001). The maximum area covered by this village is included under agricultural land with wetland areas acting as homes for a variety of flora and fauna. Village Gochhi lies at 28.7330 °N & 76.5965 °E in Jhajjar district (Figure 1, Image 1). It constitutes a number of wetland areas surrounded by agricultural land areas providing habitat to many species.

Methods

The selected study sites were surveyed twice a month from October 2020 to September 2021. Data regarding the population abundance and threats was collected from sunrise to sunset avoiding the rainy and

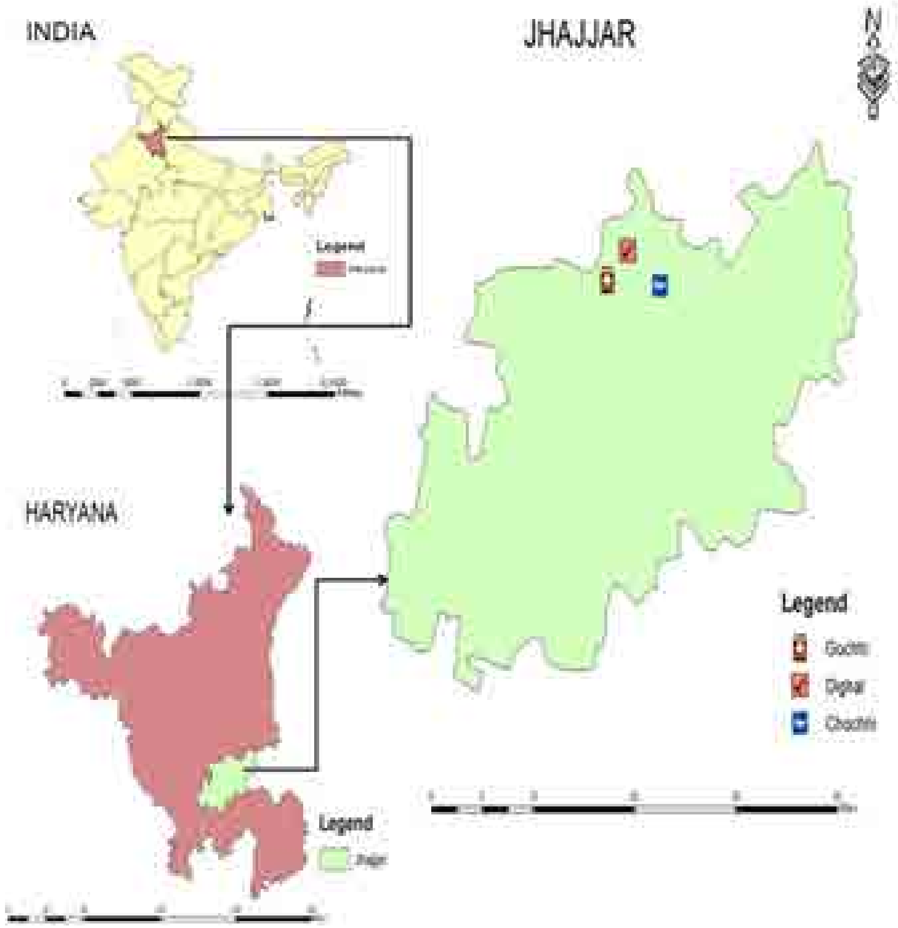

Figure 1. Design of the artificial substrate used for coral transplantation in Palk Bay | a—Top View | b—Front view of the structure | c— Front view of the design.

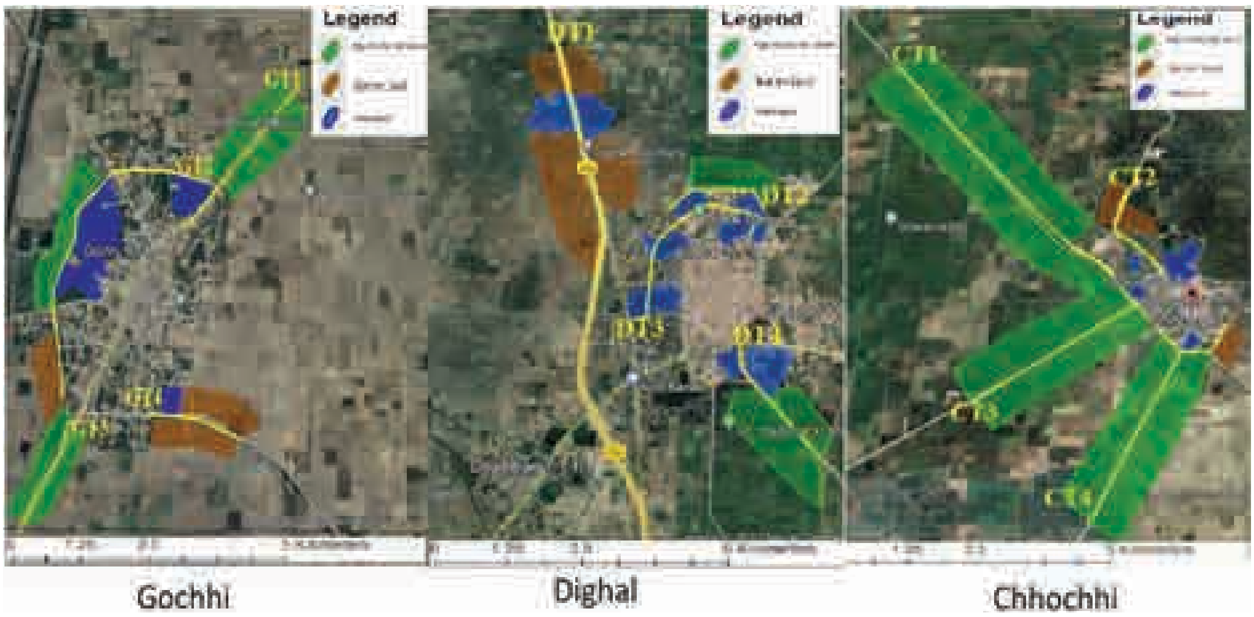

Image 1. Map showing the different study sites surveyed to collect the data for population abundance and threats of Black-headed Ibis and Red-naped Ibis. (Yellow line shows the different transects chosen at selected sites DT1, DT2, DT3 and DT4 transects at village Dighal, GT1, GT2, GT3 and GT4 transects at village Gochhi; whereas CT1, CT2, CT3 and CT4 at village Chhochhi).

foggy days. Line transect method (Gaston 1975) was used to collect the data for the population census. At each study site, four transects of 500 m to 1.5 km were laid to observe the Ibises. On each transect Ibises were observed upto a distance of 250 m on both sides. Nikon 10x50 binoculars were used to scan the Ibises from specific vantage points and Nikon Coolpix P900 point-&-shoot camera were used to capture the photographs. The data regarding the population of both the ibises were represented as mean ± standard error (SE) (Table 1). While the population of both Black-headed Ibis and Red-naped Ibis was compared at different study sites using the One-way analysis of variance (ANOVA). All statistical analysis was done using IBM SPSS 23.

RESULTS

Population

During the entire study period 60 flocks, consisting of 248 individuals (adults and juveniles) of Black-headed Ibis and 83 flocks comprises of 794 individuals (adults and juveniles) of Red-naped Ibis were observed from all three different study sites. Among the three selected study sites, village Dighal holds the major population of both Black-headed Ibis (10.41 ± 1.60) and Red-naped Ibis (28.58 ± 5.57). However, the lowest population of Black-headed Ibis was reported from village Chhochhi (3.50 ± 2.13) and Red-naped Ibis from village Gochhi (10.08 ± 1.78) (Table1). In between different age groups; juvenile Red-naped Ibis does not vary significantly ($P > 0.05$, $F_{2,33} = 2.28$) at distinct study sites. While the number of Black-headed Ibis (adult and juvenile) and Red-naped Ibis (adult) varied significantly among different study sites ($P < 0.05$; $F_{2,33} = 3.96$, $F_{2,33} = 5.53$ and $F_{2,33} = 5.65$; Table 1). Throughout the study period, number of adults was always found to be maximum as compared to juveniles in all study sites.

During this present study population abundance of Black-headed Ibis and Red-naped Ibis does not vary significantly among the seasons ($P > 0.05$, $F_{3,8} = 1.96$, $F_{3,8} = 2.44$) (Table 2). However; the habitat-wise population abundance of both Black-headed Ibis and Red-naped Ibis varies significantly ($P < 0.05$) (Table 3).

Table 1. Population of Black-headed Ibis and Red-naped Ibis censuses from October 2020 to September 2021.

Study site	Black-headed Ibis					95% CI (Min– Max)	Red-naped Ibis					95% CI (Min- Max)
	N	%	Mean ±Standard error				N	%	Mean ±Standard error			
			Adult	Juvenile	Total				Adult	Juvenile	Total	
Dighal	125	50.40%	7.75 ±1.15^B	2.66 ±0.66^B	10.41 ±1.60^B	6.87–13.95	343	43.19%	26.66 ± 5.45^B	1.91 ±0.48	28.58 ±5.57^B	16.30–40.86
Chhochhi	52	20.96%	3.83 ±0.84^A	0.50 ±0.28^A	4.33 ±1.07^A	1.96–6.70	330	41.56%	26.25 ± 4.32^B	1.25 ±0.49	27.50 ±4.44^B	17.70–37.29
Gochhi	71	28.68%	5.00 ±1.00^{AB}	0.91 ±0.43^A	5.91 ± 1.11^A	3.45–8.37	121	15.23%	9.41 ±5.68^A	0.66 ±0.22	10.08 ± 1.78^A	6.15–14.01
P- value			0.029	0.008	0.001				0.008	0.125	0.006	
F- value (F)			3.96	5.53	5.97				5.65	2.21	5.97	

*N—Total number of observations | CI—Confidence interval. All values are presented in mean ± standard error by one-way ANOVA, significant level at ($P < 0.05$). Different capital letters in superscript among column indicates a significant difference between groups ($P < 0.05$).

Table 2. Seasonal population abundance of Black-headed Ibis and Red-naped Ibis from October 2020 to September 2021.

Seasons	Black-headed Ibis				Red-naped Ibis			
	N	%	Mean ±Standard error	95% CI (Min– Max)	N	%	Mean ±Standard error	95% CI (Min–Max)
Summer	33	13.30%	11.00± 3.21^A	-2.83–24.83	116	14.60%	38.66± 12.25^A	-14.04–91.38
Autumn	67	27.01%	22.33± 6.33^A	-4.91–49.58	163	20.52%	54.33± 14.24^A	-6.93–115.60
Winter	92	37.09%	30.66± 7.21^A	-0.39–61.72	350	44.08%	116.66± 39.07^A	-51.45–284.78
Spring	56	22.58%	18.66± 5.78^A	-6.21–43.54	165	20.78 %	55.00± 8.08^A	20.22–89.77
P- value	0.198				0.138			
F- value (F)	1.96				2.44			

*N—Total number of observations | CI—Confidence interval. All values are presented in mean ± standard error by one-way ANOVA, significant level at ($P < 0.05$). Different capital letters in superscript among column indicates a significant difference between groups ($P < 0.05$)

Image 2. Solid waste deposition and cattles grazing near Black-headed Ibis. © Anjali

Image 3. Invasion of *Ipomoea aquatica* and stray dogs. © Anjali

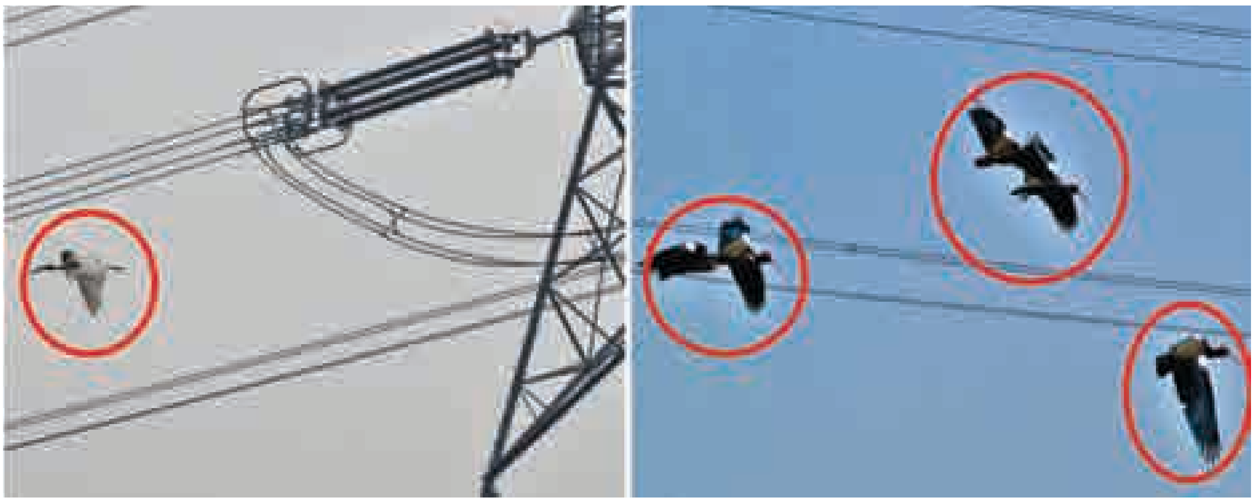

Image 4. Risk of collision with transmission lines at village Dighal. © Anjali

Table 3. Habitat wise population abundance of Black-headed Ibis and Red-naped Ibis from October 2020 to September 2021.

Habitat	Black-headed Ibis				Red-naped Ibis			
	N	%	Mean ±Standard error	95 % CI (Min–Max)	N	%	Mean ±Standard error	95 % CI (Min–Max)
Wetland	170	68.54%	56.66± 14.81[B]	-7.07–120.40	67	8.43%	22.33± 7.53[A]	-10.08–54.75
Agricultural land	65	26.20%	21.66 ± 5.69[AB]	-2.84–46.17	545	68.63%	181.66± 30.88[B]	48.76–314.57
Barren Land	13	5.24%	4.33± 0.88[A]	0.53–8.12	182	22.92%	60.66± 9.76[A]	18.63–102.70
P- value	0.018				0.03			
F- value (F)	8.43				18.75			

*N—Total number of observations | CI—Confidence interval. All values are presented in mean ± standard error by one-way ANOVA, significant level at (P <0.05). Different capital letters in superscript among column indicates a significant difference between groups (P <0.05)

Table 4. Types and severity of threats to both Black-headed Ibis and Red-naped Ibis.

	Type of threat	Resulting stress on Black-headed Ibis and Red-naped Ibis	Level of threat
1.	Solid waste deposition	Habitat unsuitable for nesting, feeding and roosting	1
2.	Cattle grazing	Disturbance to Ibis species	3
3.	Feral dogs	Leads to population decline	2
4.	Invasive species	Loss of important habitat for foraging, roosting and nesting	2
5.	Untreated sewage waste	Impacts on habitat quality that leads to reduced food sources	3
6.	Collision with high tension transmission lines	Mortality	2

Scoring for the severity of threats to Black-headed Ibis and Red-naped Ibis (Harris & Mirande 2013). 3—Lesser threat (has been, or has the potential to be, a detrimental factor in some localities or for some populations, but not with a critical impact on the species as a whole) | 2—Significant threat (has been, or has the potential to be, an important though not leading factor in the decline in the population size and/ or restricted to the species range) | 1—Critical threat (has been, or has the potential to be, a major factor in the decline of the population size and/ or restriction of the species range).

Population abundance of Black-headed Ibis was found to be significantly greater in wetland habitat (P <0.05, $F_{2,6}$ = 8.43) as compared to agricultural land and barren land; similarly the population of Red-naped Ibis was also found to be significantly greater in agricultural land area (P <0.05, $F_{2,6}$ = 18.75) as compared to other habitats as shown in Table 3.

Threats

Several threat factors were observed throughout the study period from every study sites; out of which the deposition of solid waste and grazing activities by cattle grazers were the major anthropogenic activities among the study areas (Image 2). These dumping sites are found to be very common at all the study sites majorly found near the wetland habitat. A total number of seven dumping sites were observed from all the study sites out of which four were observed from village Dighal. All along with these anthropogenic activities; some natural threats like stray dogs (3–5 dogs per site) and excessive growth of weeds like *Eichhornia* sp. (Water Hyacinth) and *Ipomoea aquatica* (Water Morning Glory) which reduces their feeding stations seem to be universal at all the respective study sites as shown in Image 3. In context to specific sites, both the Ibises in village Dighal were facing threats like deposition of unprocessed sewage waste and network of high tension transmission lines which lies in approximate 50 m distance from the Ibis habitat can lead to the collision of ibis species (Image 4). Feral dogs were observed to be attacking the Black-headed Ibis in village Dighal. Various threats were classified as lesser, significant and critical in Table 4.

DISCUSSION

In our present study, a total of 248 individuals of Black-headed Ibis and 794 individuals of Red-naped Ibis were reported from all the selected study sites. Out of which maximum number was observed from village Dighal, while the lowest number of Black-headed Ibis from village Chhochhi and Red-naped Ibis from village Gochhi. As abundance depends upon habitat preference (Krausman 1999); this variation in population size among different sites might be because of the difference in the number of wetlands and the agricultural land area surrounding this wetland which act as a most favorable habitat for the Black-headed Ibis as stated by Chaudhury

& Koli (2018) and Red-naped Ibis (Thapa & Saund 2012). Maximum number of Black-headed Ibis and Red-naped Ibis was found in and near-by the shallow water area as they provide feeding, roosting and nesting grounds to waders (Ali 2004; Sundar 2006; Chaudhury & Koli 2018). Similar findings were also observed in this present study among three different habitats, i.e., wetland, agricultural land and barren land respectively; where the population of Black-headed Ibis was found to be highest in wetland habitats (68.54%); while Red-naped Ibis from agricultural land (68.63%). The highest sightings of Black-headed Ibis in village Dighal were observed on either side of the transect (D1) despite of having lots of disturbances due to ongoing traffic on this road. This is probably because of the presence of a very rich supply of food and the surrounding environment providing their roosting habitat. Red-naped Ibis was sighted in higher numbers on either side of the D4 transect having agricultural land and it was observed to be roosting, nesting as well as feeding on some insects.

Chaudhary & Koli (2018) observed that the population of Black-headed Ibis shows a significant increase after the monsoon period when the number of seasonal wetlands increases which increases their feeding guilds (Sundar & Kittur 2013). But in our study, no significant variation in the population size was observed throughout the year among different seasons as well as after the monsoon period. This might be because of the increased water level of the existing wetlands, which is not suitable feeding ground for these shallow water wading birds (Senma & Acharya 2009; Chaudhury & Koli 2018).

Anthropogenic threats in the study areas include the dumping of solid waste, cattle grazing, fishing activities- observed at all sites, however the release of untreated sewage waste observed in village Dighal- which can leads to the destruction of their habitat due to anthropogenic pressure (Prasad et al. 2002) and ultimately can lead to the extinction of the native species found in that area (Godefriod 2001). Dumping of solid waste and growth of weeds like water hyacinth and water morning glory were also observed during the study period, which seems to be a potential threat that eventually leads to the transition of wetlands into a solid land area. The transition of these wetland can diminish the feeding stations of a number wading birds- which could be the ultimate factor for their declining population (Chaudhary 2018). Till now no death records of the Ibises due to collision with transmission lines have been reported, but mortality was observed in many bird species like Sarus Crane and Flamingos due to their collision with transmission lines, so can be considered a major threat (Sundar & Choudhury 2005; Tere & Parasharya 2011; Rameshchandra 2014; Gosai et al. 2016; Kumar & Rana 2021). Koli et al. (2013) noticed predation of eggs and chicks of Black-headed Ibis by House crow and Eagle in Rajasthan, but during this present study, no such observations were made. Although feral dogs were observed to be staring on both the Ibis species at every site, but the killed Black-headed Ibis by the dog was only observed at village Dighal, thus considered as a potential major threat which can lead to population decline. So, to conclude, though village Dighal serves as major habitat for both the Ibises, threats exists for the species. Hence this area requires long-term planning and conservation efforts to conserve the flora and fauna.

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COMMUNICATION

Crop raiding and livestock predation by wildlife in Khaptad National Park, Nepal

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Abstract: Crop raiding and livestock predation are major conservation problems throughout most protected areas in Nepal, including the Khaptad National Park (KNP). However, no information exists on the extent of crop raiding, livestock predation, and animal attacks among villages surrounding KNP. We conducted a survey of 304 households in 30 villages in four districts (Bajhang, Bajura, Doti, and Achham) in the buffer zone of KNP between 24 May and 20 June 2019, using the snowball sampling technique. All households experienced numerous major incidents of crop raiding between April 2017 and May 2019. Major wildlife involved were Wild Boar *Sus scrofa*, Himalayan Black Bear *Ursus thibetanus*, Rhesus Macaque *Macaca mulatta*, Barking Deer *Muntiacus vaginalis*, Common Leopard *Panthera pardus*, Golden Jackal *Canis aureus*, and Porcupine *Hystrix* spp. Of the 304 households, all had their crops raided over the past two years, 55.5% (n = 169) faced livestock predation, and 2% (n = 6) attacks resulting in death or injury. Over 40% of households reported taking mitigation measures to minimize crop raiding. Common measures such as night guarding, noise making, use of scarecrows, watch dogs, and fencing were practiced. More than half of respondents had negative opinions towards wildlife but they still believed that wildlife should be conserved. There was no or negligible correlation between general opinion of respondents towards wildlife and wildlife conservation with their education, sex, or involvement in natural resources management group. We established baseline information on crop raiding and livestock predation in villages surrounding KNP. Gathered information will be transmitted to relevant authorities to design and implement measures to mitigate such conflicts.

Keywords: Buffer zone, Common Leopard, protected area, Wild Boar.

Abbreviations: BNP—Bardiya National Park | CNP—Chitwan National Park | GCA—Gaurishankar Conservation Area | KCA—Kanchenjunga Conservation Area | KNP—Khaptad National Park | SNNP—Shivapuri Nagarjun National Park.

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INTRODUCTION

Nepal has designated 23% of its total land mass as protected areas, and approximately 29% of the country's forestland outside protected areas are designated as community forests, managed sustainability by local communities (Acharya et al. 2016). Success of community forestry programs nationwide and the initiation of buffer zone programs surrounding protected areas from 1990s in Nepal created an additional habitat beyond protected areas (Gurung et al. 2008; Acharya et al. 2016). This resulted in an increase in both movement of wildlife in newly developed habitats and consequently the frequency of crop raiding, livestock predation as well as animal and human attacks (Gurung et al. 2008). Conflict between humans and wildlife has become a significant problem on a global scale (Wang & Macdonald 2006) and one of the most complex conservation challenges faced by conservationists and local communities around protected areas (Banikoi et al. 2017). Such conflicts bring many social, economic and ecological consequences and if the damages severely affect the livelihood of local communities, getting their active support for conservation will be challenging (Mishra 1997). Thus, careful planning and management is required if the dual goal of wildlife conservation and support of communities is to be achieved (Madden 2004; Acharya et al. 2016).

The mid-hill mountain zone is under-represented in Nepal's protected system (Acharya et al. 2016). One such protected area that encompasses the mid-hill to lower Himalayan region of Nepal is the Khaptad National Park (KNP). Crop raiding and livestock predation are major conservation problems in most protected areas in Nepal (Banikoi et al. 2017). Various dimensions of human-wildlife negative interactions have been assessed in different protected areas of Nepal, including Gaurishankar Conservation Area (GCA; Awasthi & Singh 2015), Kanchenjunga Conservation Area (KCA; Sherchan & Bhandari 2017), Shivapuri Nagarjun National Park (SNNP; Pandey et al. 2016; Pandey & Bajracharya 2016), Bardiya National Park (BNP; Thapa 2010), and Chitwan National Park (CNP; Banikoi et al. 2017; Lamichhane et al. 2018). However, no information exists on the extent of crop raiding, livestock predation and animal attacks across the buffer zone of KNP.

MATERIALS AND METHODS

Study area

Khaptad National Park (29.37°N, 81.15°E; Image 1) is situated in Province 7 of Nepal that covers an area of 225 km^2 with an elevation range 1,000–3,276 m (GoN/MoFSC 2014). It is the only national park in mid-hill to lower Himalayan region in western Nepal and represents a unique and important ecosystem (DNPWC 2019). KNP harbors dense forest of genus *Shorea, Pinus*, and *Alnus* in subtropical zone; *Quercus*, *Aesculus, Daphniphyllum, Abies,* & *Peceea*, in temperate zone and *Quercus, Taxus,* & *Betula* in subalpine zone (DNPWC 2019). It is home to 266 species of migratory and residential birds, 20 species of mammals, 15 species of butterfly, 192 species of flowering plants (Mishra 2000) and 224 species of medicinal plants (Kunwar & Duwadee 2006). The buffer zone in KNP was established in 2006 spreading over four districts (Doti, Achham, Bajhang, and Bajura) and covering an area of 216 km^2 (DNPWC 2019).

Data collection and analysis

We employed open-ended questionnaires to households in various villages in the buffer zone of KNP using the snowball sampling technique between 24 May 2019 and 20 June 2019 (Image 1). We collected data on five major topics including general socio-economic information of respondents, crop-raiding incidents, livestock predation, animal attacks, and attitude towards wildlife. We took prior informed consent of respondents (generally head of the family) before administering questionnaire. We gathered information on conflict incidences that occurred from April 2017 to May 2019. We performed data analysis using Deducer package (Fellows 2012) in R (R Core Team 2018) and presented mean values with standard deviation. We tested for association between variables by performing Spearman's rank correlation test.

RESULTS

Socio-economic status of respondents

We covered 120 km on foot and surveyed a total of 304 households from various villages across the buffer zone of KNP (Image 1). The highest representation surveyed was from villages in the Bajhang district (32.2%; n = 98), and the lowest representation was from Doti (17.1%; n = 52; Table 1). Majority of the respondents were male (71.7%, n = 218) and average age of the respondent was 44.98 ± 15.35 years (17–82

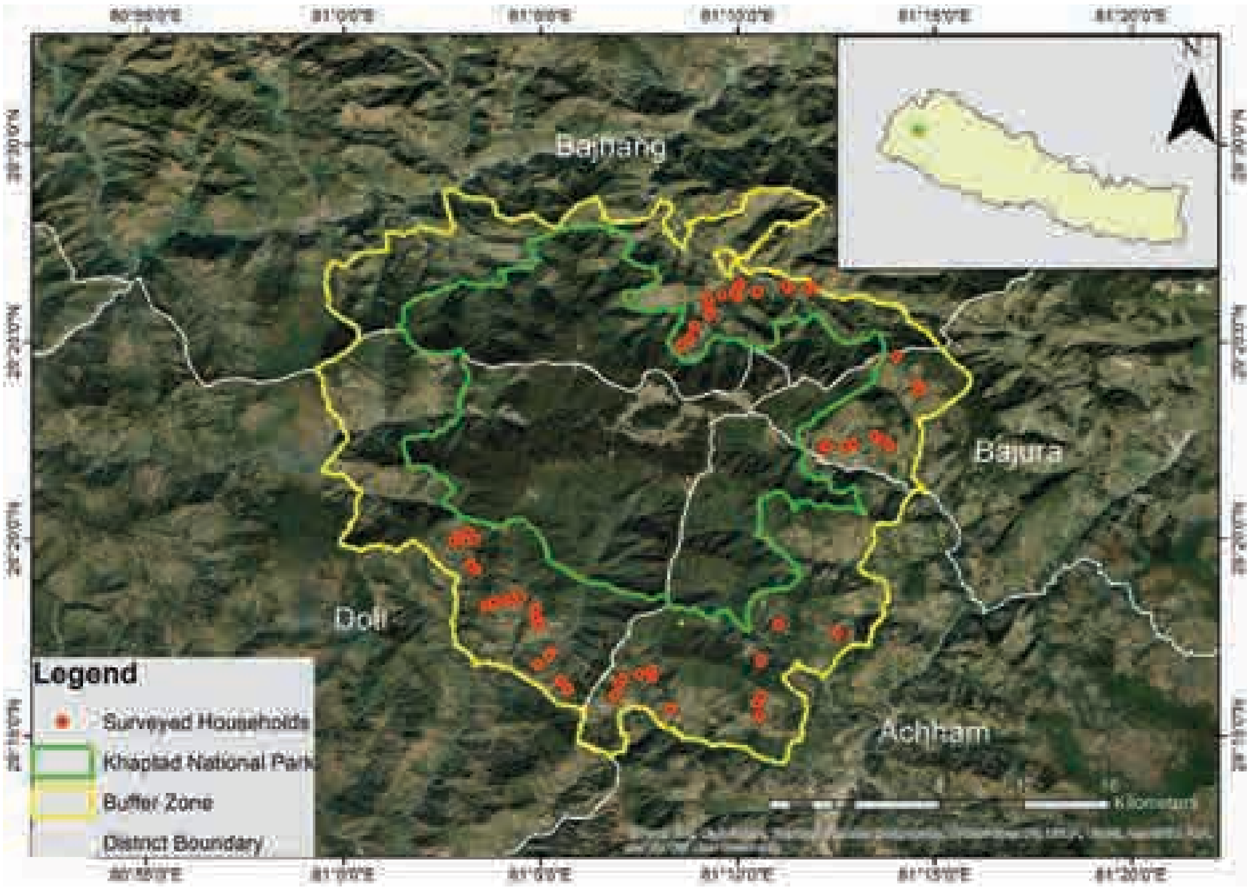

Image 1. Map of Khaptad National Park (also indicated by green shaded area on inset map of Nepal) showing the locations (red circles) where questionnaire surveys were conducted in villages in the buffer zone (indicated by yellow solid line) across four districts – Doti, Achham, Bajura, and Bajhang.

years; Table 1). An average family size was 7.59 ± 2.99 (range = 2–28; n = 304). Although we highly encouraged females to participate in our surveys, female individuals were either shy and nominate males in their house to participate or were occupied with household chores. Around half of respondents (58.6%; n = 178) did not have any formal schooling (Table 1). Agriculture was the dominant occupation (91.1%; n = 277) and average land holding was 1.20 ± 2.43 acres (range = 0.04–36.82 acres; n = 304). Although majority of population were engaged in farming, 34.2% (n = 104) were dependent on remittance as a major source of income (Table 1).

Almost all households were dependent on nearby forest for fodder (99.3%; n = 302) and firewood collection (99.7%; n = 303). A small fraction of respondents (14.15%; n = 43) were involved in natural resources management groups (KNP buffer zone management committee, and community forest users group etc.) with an average involvement of 0.87 ± 2.81 years (range = 0–28 years). Major livestock raised were cows (91.7%; n = 279 households), bulls (66.2%; n = 201 households), goats (62%; n = 189 households) and buffalos (27.2%; n = 83) with an average holding size of 1.85 ± 1.31 (range = 0–30) for cows, 0.49 ± 0.97 (range = 0–5) for buffalos, 3.52 ± 5.47 (range = 0–60) for goats and 1.18 ± 1.06 (range =0–6) for bulls.

Crop raiding

All of the surveyed households (n = 304) had experienced numerous incidents of crop raiding between April 2017 and May 2019. Most of the households had experienced crop raiding so frequently during the harvest season that they couldn't recall the exact number of incidents during that time frame. Major crops included rice, corn, wheat, barley, millet, and potatoes. Major wildlife responsible for crop raiding were Wild Boars *Sus scrofa*, Himalayan Black Bears *Ursus thibetanus*, Rhesus Macaque *Macaca mulatta*, Barking Deer *Muntiacus vaginalis*, and porcupines *Hystrix* sp. (Table 2). Rhesus Macaques, Porcupines, Himalayan Black Bears, and Wild Boars were frequent crop raiders and responsible for more than 80% of the raids claimed by households

Table 1. Detailed information on socio-economic attributes of respondents (n = 304) across villages in the buffer zone of the Khaptad National Park, Nepal.

Variable	Variable categories	n	Percentage
Education Level	Illiterate	178	58.6
	Primary	43	14.1
	Lower-secondary	10	3.3
	Secondary	43	14.1
	Higher secondary	22	7.2
	Bachelors	8	2.6
District	Achham	93	30.6
	Bajhang	98	32.2
	Bajura	61	20.1
	Doti	52	17.1
Major occupation	Agriculture	277	91.1
	Service	14	4.6
	Business	7	2.3
	Student	6	2
Main source of income	Agriculture	170	55.9
	Remittance	104	34.2
	Others	30	9.9

Table 2. Major wildlife involved in and total cases of crop raiding across villages in the buffer zone of the Khaptad National Park, Nepal.

Wildlife	Cases involved	Percentage
Wild Boar	301	99
Rhesus Macaque	296	97.4
Porcupine	255	83.9
Himalayan Black Bear	252	82.9
Barking Deer	100	32.9
Golden Jackal	60	19.7
Himalayan Goral	26	8.6
Himalayan Thar	20	6.6
Others	7	2.3

(Table 2). Respondents ranked Rhesus Macaques as first, Wild Boars as second, Himalayan Black Bears and porcupines as joint third based on burden to households considering crop-raiding frequency, severity of damage and economic loss incurred (Table 3). Majority of respondents suggested that population of crop-raiding wildlife (98.4%; n = 299) and trend of crop-raiding frequency (97.7%; n = 297) were both increasing.

Livestock depredation

A large number of respondents (55.5%; n = 169) reported their livestock being killed/injured between 2017 and 2019 (Table 4). Common Leopard *Panthera pardus* and Golden Jackal *Canis aureus* were the two species most frequently involved in livestock predation, and some by Himalayan Black Bears (Table 4). Almost all respondents suggested that population of wildlife involved in livestock predation (98.4%; n = 299) and frequency of livestock depredation (98.4%; n = 299) were both increasing. Majority of respondents (78.3%; n = 238) employed herders to graze their livestock in nearby grasslands to discourage wildlife, whereas a small number (1.3%; n = 7) let their livestock graze without a herder. However, we did not find any correlation (ρ= 0.23; P <0.05) between grazing system (presence/absence of herder) and incidents of livestock predation.

Animal attacks

Only 2% (n = 6) households had cases of animal attacks. Out of the six, four cases were of injury and all involved Himalayan Black Bears and two cases involved loss of human life that resulted from attacks by Common Leopards. Although attacks on human are low, respondents mentioned that they had to live under constant fear of being attacked by wildlife while performing their daily chores such as collecting fodder and firewood, and taking livestock for grazing.

Mitigation measures

From the 304 respondents, almost half of the households (41.4%; n = 126) reported to have used some form of mitigation measures to minimize crop raiding. Guarding crops during night by kudo (Nepali: Burning fire) was the most common measure (65.8%; n = 83) and considered most effective. This practice was used to prevent crop raiding by Himalayan Black Bears and Wild Boars, but proved tiresome and put villagers at risk from potential wildlife attacks. Noise making using metal utensils was the second most used practice (46.03%; n = 58). Approximately 18.25% (n = 23) of households used scarecrows which worked only for the initial few days. Some household used watch dogs (11.9%, n = 15) to chase wildlife (*Rhesus macaques*) during the daytime. Dogs were ineffective, as they were often outnumbered by the macaques. Similarly, some households (7%; n =10) fenced their farm, but proven ineffective against macaques and Wild Boars. Stone fence was found to be comparatively more effective than wood and bamboo fencing, but was time consuming and expensive to set up. Interestingly, one (0.79%) respondent worshipped 'Hanuman' (Nepali: Hindu Monkey god) during harvest season and believed it helped to prevent crop raiding by monkeys.

Table 3. Crop raiding wildlife ranked by respondents (n = 304) based on burden to them across villages in the buffer zone of the Khaptad National Park, Nepal.

Wildlife	Respondent (n)	Percentage	Rank
Rhesus Macaque	140	46.1	1
Wild Boar	127	41.8	2
Himalayan Black Bear	18	5.9	3
Porcupine	18	5.9	4
Golden Jackal	1	0.3	5

Table 4. Major wildlife involved in and total cases of livestock predation across villages in the buffer zone of the Khaptad National Park, Nepal.

Wildlife	Cases involved	Percentage
Common Leopard	121	39.8
Golden Jackal	39	12.8
Himalayan Black Bear	5	1.6
Others	4	1.3

Attitude toward wildlife

Around half of respondents (53%; n = 198) had a negative opinion towards wildlife (Table 5). Nonetheless, a good proportion of respondents (52.7%; n = 160) still believed that wildlife should be conserved. Majority of respondents (85.2%; n = 259) agreed that if appropriate compensation was provided for their loss, it would encourage them towards wildlife conservation (Table 5). These respondents generally cited "wildlife also has right to live despite the trouble they are causing us by raiding our crops and depredating on our livestock" as a reason for their support for wildlife conservation. Similarly, 84.2% (n = 254) of respondents agreed that if provided with effective measures to alleviate crop-raiding and livestock predation and if the intervention worked effectively, it would encourage them in wildlife conservation. Half of the respondents (51.6%; n = 157) positively believed that their community could benefit from eco-tourism based on wildlife and landscape (forest, alpine meadows) in this region. Whereas 45.7% (n = 139) were neutral in their opinion and mentioned that they had no idea about how eco-tourism could benefit their community and therefore chose to remain neutral.

There was no or negligible correlation between general opinion of respondents towards wildlife and their education (ρ =-0.30; P <0.05), sex (ρ =-0.20; P <0.05) or involvement in any sort of natural resources management group (ρ =-0.05; P >0.05). Similarly, there was no or negligible correlation between opinions of respondents on wildlife conservation and their education (ρ =-0.30; P <0.05), sex (ρ =-0.28; P <0.05) or involvement in any sort of natural resources management group (ρ =-0.09; P <0.05). These findings indicate that negative attitude of respondents towards wildlife and their conservation is most likely due to negative impacts from crop-raiding and livestock predation over other factors.

Table 5. Attitude of respondents (n = 304) towards wildlife involved in crop raiding, livestock predation and animal attacks across villages in the buffer zone of the Khaptad National Park, Nepal.

Factor	Value	Respondent (n)	Percentage
What is your general opinion on wildlife involved in conflicts?	Strongly positive	4	1.3
	Positive	108	35.5
	Neutral	31	10.2
	Negative	161	40.8
	Strongly negative	37	12.2
In your opinion, should wildlife be conserved?	Strongly positive	2	0.7
	Positive	158	52
	Neutral	81	26.6
	Negative	48	15.8
	Strongly negative	15	4.9
Would appropriate compensation encourage you in wildlife conservation?	Strongly positive	26	8.6
	Positive	233	76.6
	Neutral	26	8.6
	Negative	17	5.6
	Strongly negative	2	0.7
Would implementation of conflict mitigation measures encourage you in wildlife conservation?	Strongly positive	14	4.6
	Positive	242	79.6
	Neutral	40	13.2
	Negative	8	2.6
	Strongly negative	0	0
Would wildlife based eco-tourism be beneficial to your community?	Strongly positive	12	3.9
	Positive	145	47.7
	Neutral	139	45.7
	Negative	7	2.3
	Strongly negative	1	0.3

DISCUSSION

Our findings revealed that crop-raiding is widespread and frequent in villages in the buffer zone of the KNP. Our findings corroborate with other studies and identify Wild boars, Rhesus macaques, porcupines and Himalayan black bears as main crop raiding wildlife among various protected areas in Nepal (Thapa 2010; Awasthi & Singh 2015; Pandey & Bajracharya 2016; Pandey et al. 2016; Banikoi et al. 2017; Sherchan & Bhandari 2017; Lamichhane et al. 2018). Almost all respondents in our study area mentioned that frequency of both crop raiding and livestock predation have increased over time. Although almost all respondents believed that the wildlife populations involved in crop raiding and livestock predation are also increasing over time, respondent's idea on increasing population of crop-raiding wildlife could very well be based on the increasing frequency of crop-raiding incidents, and as such should be treated cautiously.

Crop raiding with varying levels of magnitude have been reported from various protected and human dominated landscapes in Nepal. Awasthi & Singh (2015) assessed crop-raiding incidents by wildlife in GCA and reported that 84% of households surveyed (n = 170), had their crops raided by monkeys, porcupines and Himalayan Gorals. Himalayan Black Bears were also involved in crop-raiding to a smaller extent, but there were no cases on conflicts involving Wild boars in GCA (Awasthi & Singh 2015). In KCA, Civet, Barking Deer, porcupines, squirrel and monkeys have been reported to be frequent crop raiders (Sherchan & Bhandari 2017). The same study also reported recent involvement of Himalayan Black Bears since 2010, but no involvement by Wild Boars. Gurung (2002) identified Wild Boar, Himalayan Black Bear, monkey and porcupine as the major crop raiders in SNNP. Similarly, Ulak (1992), Kattel (1993), and Poudyal (1995) all reported Wild Boar as the frequent crop raider. Maize was the most raided crop by wildlife in SNNP. Although the crops raided varied among regions, the major crops raided included rice, wheat, corn, millet, barley, and potato (Ulak 1992; Kattel 1993; Poudyal 1995; Gurung 2002; Awasthi & Singh 2015; Sherchan & Bhandari 2017). In protected areas of low-land Nepal, such as BNP, CNP and Parsa National Park, Elephants are the main crop raiders (Thapa 2010; Pandey & Bajracharya 2016; Banikoi et al. 2017; Lamichhane et al. 2018).

Protected areas in central and western mid-hill regions of Nepal (SNNP and KNP) appeared to have very high extent and frequency of crop raiding involving Wild Boars and Himalayan Black Bears. Respondents in villages surrounding KNP revealed that crop damage caused by wildlife, like the Wild Boar, was historically low. Traditionally, hunting kept the Wild Boar population in check, but the establishment of the KNP increased the forest area and made it illegal to own a gun and hunt wild animals, thus increasing crop raiding frequency. The increase in forest area would reduce the forest proximity to farms, which has been determined as one of the factor associated with wildlife damage to crops (Genov et al. 1996; Geisser 2000; Saj et al. 2001; Naughton-Treves et al. 2003; Linkie et al. 2007).

Common Leopards and Golden Jackals were mostly involved in livestock predation in villages surrounding KNP. Adhikari et al. (2018) also reported Common Leopards as the major livestock depredator in Panchase protected forest in the mid-hill region of western Nepal. In Chitwan National Park, Tigers and Common Leopards were involved in >90% of reported livestock depredation (n = 2213) between 1998 and 2016 (Lamichhane et al. 2018). The same study also reported that livestock predation by Common Leopards was higher than tigers between 2014 and 2016. Leopards are generalist predators, consuming wide variety of prey, including ungulates, carnivores, rodents, bird and fish. Lack of natural prey and poor husbandry makes domestic animals more vulnerable to attacks by wildlife (Shehzad et al. 2015). A nation-wide survey between 2010 and 2014 showed that the Common Leopard and Himalayan Black Bear along with the Tiger, Elephant, and Rhinoceros as major drivers of attacks on human (death and injury) in Nepal (Acharya et al. 2016).

Due to success of community forestry in Nepal, the spatial distribution of both Common Leopards and Himalayan Black Bears has increased (Acharya et al. 2016). Since these two species have wider distribution in mid-hill region of Nepal, including the buffer zone of the KNP, they are found to be responsible for majority of crop raiding, livestock predation and animal attacks outside protected areas (Acharya et al. 2016). Common Leopards are known to adapt well in human-modified landscapes as well (Acharya et al. 2016). Although more than half of respondents had their livestock predated, they had more negative feelings towards crop-raiding wildlife than those involved in livestock depredation. Livestock predation was only occasional, but crop-raiding occurred frequently all year round.

As the crop yields were severely impacted by the wild animals such as Wild Boars and Rhesus Macaque, we found locals using combinations of measures to minimize crop raiding. Farmers often produced loud noise or fire to deter crop raiding wildlife. Pandey & Bajracharya (2016) reported similar techniques used by the locals during their study in Shivapuri National park. However, they reported that producing loud noises and flames were only effective for shorter period. Saraswat et al. (2015) reported the use of loud noise from firecrackers, tin cans and dogs to chase away macaques in India. However, such measures were not effective in preventing/minimizing crop raiding (Saraswat et al. 2015). Sterilization of macaques were also tested in Himachal Pradesh of India, but they were not effective either (Saraswat et al. 2015; Anand & Radhakrishna 2020). Sekhar (1998) reported watch tower was the most effective and safer measure in Rajasthan, India but according to our respondents it was not financially feasible in KNP. Farmers worshipping "Hanuman" the monkey god during the harvest season were also reported across India. Sekhar (1998) and Saraswat et al. (2015). In other regions of Nepal techniques like mesh wire fencing, electric fencing, beehive fencing and chilly fencing, trenches are being used (Banikoi 2012; Lamichhane et al. 2018). Habitat enrichment program- which addresses the food shortage faced by the Rhesus Macaque by planting of fruit plantations in forests might help them to reduce dependence on human crops (Anand & Radhakrishna 2020).

In general, respondents had negative attitudes towards KNP and blamed the national park for their losses and believed that the national park prioritized wildlife over residents and their crops. Respondents also complained that process of receiving compensation from the national park was lengthy and financially burdensome. For instance, respondents from some villages had to travel 2–3 days to reach the KNP office just to file a case for compensation. So, respondents had to spent good amount of money to pay for their food and accommodation. In many cases, respondents also mentioned that the compensation received for dead livestock, especially horses was less than the actual price of the lost animal. We did not, however, verify these claims with the KNP authority.

CONSERVATION RECOMMENDATIONS

During the survey, we observed that most of the respondents were not fully aware of process and paperwork required to claim compensations from KNP office for the economic loss they had incurred due to crop raiding, livestock predation and animal attacks. We distributed brochures (in Nepali) explaining process for claiming compensations to villagers during our survey and was received positively. We recommend that KNP office and the KNP buffer zone management committee take steps to raise awareness among villagers regarding the process in claiming compensation. Similarly, to the possible extent, the KNP office should consider simplifying and shortening the compensation process since some of the villagers had to travel 2–3 days to claim compensation. Site and species-specific mitigation measures could be put in place. Exchange of best practice and success stories between farmers from different villages mediated by the KNP office and buffer zone management committee could be helpful in promoting human-wildlife coexistence and fostering healthy park-people relation.

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REVIEW

An annotated checklist of odonates of Amboli-Chaukul-Parpoli region showing new records for the Maharashtra State, India with updated state checklist

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Abstract: Amboli region, consisting Amboli, Chaukul, Nene, and Parpoli villages is one of the biodiversity rich areas in northern Western Ghats. We opportunistically surveyed odonates from the region and prepared an annotated checklist of 93 species belonging to 12 families. We report 15 Western Ghats endemic species and six new records for the State of Maharashtra. We further present an updated checklist of Odonata of Maharashtra state with a total of 144 species.

Keywords: Anisoptera, biodiversity, range extension, Sindhudurg, Western Ghats, taxonomy, zygoptera.

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Author contributions: All the three authors equally contributed in field surveys, odonata identification, data compilation, specimen collection and manuscript preparation.

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INTRODUCTION

The Western Ghats mountain range runs parallel to the west coast of peninsular India. The high human population density, changing use of landscape, pollution, natural disasters like landslides, increased anthropogenic interference and climate change have a negative impact in conserving biodiversity of this region. The Western Ghats has been thoroughly surveyed for odonates. Fraser (1933, 1934, 1936) and many others did comprehensive documentation in this region. Subramanian & Babu (2020) made a checklist of 196 odonates species of Western Ghats with Kerala having the most number of species. Regarding Maharashtra state, Tiple & Koparde (2015) recorded 134 species (see discussion). After that many species have been added to the list of Maharashtra with no formal efforts to compile them.

Amboli region is considered as one of the most biodiverse regions in Maharashtra with semi-evergreen forest and heavy rainfall (Satose et al. 2018). Amboli region consists of Amboli, Chaukul, Nene, and Parpoli villages, out of which Parpoli is located at the foothills of Western Ghats and remaining are located at the high altitude (100–1,100 m). The landscape around Amboli is heterogenous with patches of evergreen forest, riparian habitats, open lateritic plateaus with grasslands, and moist deciduous forests at mid and low elevations. Due to the unique location at the junction of northern and central Western Ghats with drastic variation in habitats, Amboli region harbors many spectacular odonate species. However, no attempt was made to document the Odonata fauna of this region. We surveyed Amboli region for two years and here we present an annotated checklist of 93 odonates with six new records for Maharashtra state. We also update the checklist of Maharashtra, which now contains 144 species.

MATERIAL AND METHODS

We opportunistically surveyed Amboli-Chaukul-Parpoli region of Sawantwadi Taluka, Sindhudurg District from August 2019 to August 2021 for odonates. Details of survey locations are given in Table 1 with photographs in Image 1. We photographed odonates and collected a few individuals from non-protected areas for the purpose of identification. All collected specimens are deposited in Research Collections, National Centre for Biological Sciences (NCBS), Bangalore, India (details of all specimens are given in Table 2). Field photographs were taken with DSLR cameras and macro lenses (Canon Inc. and Nikon Inc., Japan). We identified odonates based on the Fraser (1933, 1934, 1936); Subramanian et al. (2018). Systematic arrangement of the species follows Kalkman et al. (2020). As the subspecies status of some species remains unresolved, the present checklist is up to the species level. Abbreviations in the text: S1–S10 = abdominal segments 1–10. Maps are created with QGIS v3.10.2 and Google Maps © 2021. Distribution maps are based on the data given by Subramanian et al. (2018) and Anonymous (2021a, 2021b, 2021c).

RESULTS AND DISCUSSION

We recorded a total of 93 odonates belonging to 12 families, with family Libellulidae having the highest number of species (38 species), followed by family Coenagrionidae (20 species) (see Table 6; Images 2–6). Detailed checklist of odonates with their International Union for Conservation of Nature (IUCN) Red List of Threatened Species status is given in Table 3. According to IUCN Red List Version 2021–2, one species is Vulnerable (VU), one is Near Threatened (NT), and six are Data Deficient (DD). Out of 93 species, 15 species are endemic to the Western Ghats (Subramanian et al. 2018; Kalkman et al. 2020; Bhakare et al. 2021). We also report six species for the first time in Maharashtra State which are the northernmost range extensions for the respective species (see Table 4; Image 7). Taxonomical and distributional notes on these six species are as follows:

1. *Protosticta sanguinostigma* Fraser, 1922. Hemant Ogale photographed this Western Ghats endemic damselfly in a hill stream of Nene village on 6.vi.2021 (Image 2c). Three males were observed resting in bushes out of which one male was collected. It was identified by a robust, pointed spine of cerci (Image 2d); brown synthorax with bluish stripes, and blue mark on S8 with narrow black line on dorsum. Earlier, the species was known from Goa, Karnataka, Kerala, and Tamil Nadu (Subramanian et al. 2018). Thus, *P. sanguinostigma* is reported from Maharashtra state for the first time with distribution range extension in northern Western Ghats (Image 7b).

2. *Cyclogomphus flavoannulatus* Rangnekar et al., 2019. Hemant Ogale photographed a small sized female Gomphid in Amboli on 02.x.2011. The species was identified as *C. flavoannulatus* female based on absence of yellow 'Y'-shaped mark on synthorax and basal yellow annular rings on abdominal segments

Image 1. Locations: a—Riverine habitat with wetland, Amboli | b—Seasonal ponds, Amboli | c—Hill stream, Amboli | d—Hill river, Amboli | e—Riverine habitat, Nene | f—Hill stream, Chaukul | g—Plateau lake, Chaukul | h—Rocky hill stream, Chaukul | i—Forested stream, Parpoli. © a, h—i—Hemant Ogale; b—g—Dattaprasad Sawant.

Table 1. Survey locations (all locations fall in Sawantwadi Taluka, Sindhudurg District, Maharashtra).

	Location	Latitude	Longitude	Altitude (in meter)	Habitat
01	Amboli	15.9647 °N	74.0036 °E	690	High altitude streams, wetlands and seasonal ponds
02	Chaukul	15.9283 °N	74.0388 °E	800	High altitude streams, wetlands and plateau lake
03	Dabhil	15.8969 °N	73.9330 °E	190	Low altitude forested stream
04	Nene	15.926 0°N	74.0223 °E	800	High altitude riverine habitat
05	Parpoli	15.9542 °N	73.9771 °E	100	Low altitude forested stream

Table 2. Details of collected specimens.

	Specimen deposited at	Voucher code	Species	Sex	Preservation method
01	NCBS	BN825	*Protosticta sanguinostigma*	Male	Dry only
02	NCBS	BN806	*Euphaea thosegharensis*	Male	Dry only
03	NCBS	BN805	*Bradinopyga konkanensis*	Male	Dry only
04	NCBS	BN807	*Idionyx saffronata*	Male	Dry only
05	NCBS	BN808	*Idionyx saffronata*	Female	Dry only
06	NCBS	BN827	*Macromidia donaldi*	Male	Dry only
07	NCBS	BN828	*Macromidia donaldi*	Female	Dry only

Table 3. Checklist of odonates of Amboli-Chaukul-Parpoli region, Sindhudurg District.

	Scientific name	Authority	IUCN Red List status	Image
	Suborder: Zygoptera Selys, 1854			
	Family: Lestidae Calvert, 1901			
01	*Lestes concinnus*	Hagen in Selys, 1862	LC	-
02	*Lestes elatus*	Hagen in Selys, 1862	LC	2a
03	*Lestes viridulus*	Rambur, 1842	LC	2b
	Family: Platystictidae Kennedy, 1920			
04	*Protosticta sanguinostigma**#	Fraser, 1922	VU	2c-d
	Family: Calopterygidae Selys, 1850			
05	*Neurobasis chinensis*	(Linnaeus, 1758)	LC	2e
06	*Vestalis apicalis*	Selys, 1873	LC	2f
07	*Vestalis gracilis*	(Rambur, 1842)	LC	2g
	Family: Chlorocyphidae Cowley, 1937			
08	*Heliocypha bisignata*	(Hagen in Selys, 1853)	LC	2h
09	*Libellago indica*	(Fraser, 1928)	NE	2i
	Family: Euphaeidae Yakobson & Bainchi, 1905			
10	*Euphaea fraseri*#	(Laidlaw, 1920)	LC	2j
11	*Euphaea pseudodispar*#	Sadasivan & Bhakare, 2021	NE	2k
12	*Euphaea thosegharensis*#	Sadasivan & Bhakare, 2021	NE	2l
	Family: Platycnemididae Yakobson & Bainchi, 1905			
13	*Caconeura ramburi*	(Fraser, 1922)	DD	2m
14	*Copera marginipes*	(Rambur, 1842)	LC	2n
15	*Copera vittata*	Selys, 1863	LC	2o
16	*Disparoneura quadrimaculata*	(Rambur, 1842)	LC	2p
17	*Elattoneura tetrica*#	(Laidlaw, 1917)	LC	2q
18	*Prodasineura verticalis*	(Selys, 1860)	LC	2r
	Family: Coenagrionidae Kirby, 1890			
19	*Aciagrion approximans*	Fraser, 1921	LC	3a
20	*Aciagrion occidentale*	Laidlaw, 1919	LC	3b
21	*Aciagrion pallidum*	Selys, 1891	LC	3c
22	*Agriocnemis pieris*	Laidlaw, 1919	LC	3d
23	*Agriocnemis pygmaea*	(Rambur, 1842)	LC	3e
24	*Agriocnemis splendidissima*	Laidlaw, 1919	LC	3f
25	*Amphiallagma parvum*	Selys, 1876	LC	3g
26	*Ceriagrion cerinorubellum*	(Brauer, 1865)	LC	3h
27	*Ceriagrion chromothorax*#	Joshi & Sawant 2019	NE	3i
28	*Ceriagrion coromandelianum*	(Fabricius, 1798)	LC	3j
29	*Ceriagrion olivaceum*	Laidlaw, 1914	LC	3k
30	*Ceriagrion rubiae*	Laidlaw, 1916	NE	3l
31	*Ischnura rubilio*	Selys, 1876	LC	3m
32	*Ischnura senegalensis*	Rambur, 1842	LC	3n
33	*Mortonagrion varralli*	Fraser, 1920	LC	3o
34	*Pseudagrion decorum*	Rambur, 1842	LC	3p
35	*Pseudagrion indicum*#	Fraser, 1924	LC	3q

	Scientific name	Authority	IUCN Red List status	Image
36	*Pseudagrion malabaricum*	Fraser, 1924	LC	3r
37	*Pseudagrion microcephalum*	(Rambur, 1842)	LC	4a
38	*Pseudagrion rubriceps*	Selys, 1876	LC	4b
	Suborder Anisoptera Selys, 1854			
	Family: Aeshnidae Leach, 1815			
39	*Anaciaeschna jaspidea*	(Burmeister, 1839)	LC	-
40	*Anax ephippiger*	(Burmeister, 1839)	LC	4c
41	*Anax guttatus*	(Burmeister, 1839)	LC	4d
42	*Anax immaculifrons*	Rambur, 1842	LC	4e
43	*Gynacantha dravida*	Lieftinck, 1960	LC	4f
44	*Gynacantha millardi*	Fraser, 1920	LC	4g
	Family: Gomphidae Rambur, 184			
45	*Cyclogomphus flavoannulatus**#	Rangnekar et al 2019	NE	4h
46	*Gomphidia kodaguensis*#	Fraser, 1923	DD	4i
47	*Ictinogomphus rapax*	(Rambur, 1842)	LC	4j
48	*Macrogomphus wynaadicus*#	Fraser, 1924	DD	4k
49	*Megalogomphus hannyngtoni**#	(Fraser, 1923)	NT	4l
50	*Melligomphus acinaces**#	(Laidlaw, 1922)	DD	4m
51	*Paragomphus lineatus*	(Selys, 1850)	LC	4n
	Family: Macromiidae Needham, 1903			
52	*Epophthalmia vittata*	Burmeister, 1839	LC	4o
53	*Macromia cingulata*	Rambur, 1842	LC	4p
	Family: Libellulidae Leach, 1815			
54	*Acisoma panorpoides*	Rambur, 1842	LC	4q
55	*Brachydiplax sobrina*	Rambur, 1842	LC	-
56	*Brachythemis contaminata*	(Fabricius, 1793)	LC	4r
57	*Bradinopyga geminata*	(Rambur, 1842)	LC	5a
58	*Bradinopyga konkanensis*	Joshi & Sawant, 2020	NE	5b
59	*Cratilla lineata*	(Brauer, 1878)	LC	5c
60	*Crocothemis servilia*	(Drury, 1770)	LC	5d
61	*Diplacodes lefebvrii*	(Rambur, 1842)	LC	5e
62	*Diplacodes trivialis*	(Rambur, 1842)	LC	5f
63	*Epithemis mariae**#	(Laidlaw, 1915)	LC	5g
64	*Hylaeothemis apicalis*	Fraser, 1926	DD	5h
65	*Indothemis carnatica*	Fabricius, 1798	LC	-
66	*Lathrecista asiatica*	(Fabricius, 1798)	LC	5i
67	*Neurothemis fulvia*	(Drury, 1773)	LC	5j
68	*Neurothemis intermedia*	(Rambur, 1842)	LC	5k
69	*Neurothemis tullia*	(Drury, 1773)	LC	5l
70	*Onychothemis testacea*	Laidlaw, 1902	LC	5m
71	*Orthetrum chrysis*	(Selys, 1891)	LC	5n
72	*Orthetrum glaucum*	(Brauer, 1865)	LC	5o
73	*Orthetrum luzonicum*	(Brauer, 1868)	LC	5p
74	*Orthetrum pruinosum*	(Burmeister, 1839)	LC	5q

	Scientific name	Authority	IUCN Red List status	Image
75	*Orthetrum sabina*	(Drury, 1770)	LC	5r
76	*Orthetrum taeniolatum*	(Schneider, 1845)	LC	6a
77	*Orthetrum triangulare*	(Selys, 1878)	LC	6b
78	*Palpopleura sexmaculata*	(Fabricius, 1787)	LC	6c
79	*Pantala flavescens*	(Fabricius, 1798)	LC	6d
80	*Potamarcha congener*	(Rambur, 1842)	LC	6e
81	*Rhodothemis rufa*	(Rambur, 1842)	LC	-
82	*Tetrathemis platyptera*	Selys, 1878	LC	6f
83	*Tholymis tillarga*	(Fabricius, 1798)	LC	6g
84	*Tramea basilaris*	(Palisot de Beauvois, 1805)	LC	6h
85	*Tramea limbata*	(Desjardins, 1832)	LC	6i
86	*Trithemis aurora*	(Burmeister, 1839)	LC	6j
87	*Trithemis festiva*	(Rambur, 1842)	LC	6k
88	*Trithemis kirbyi*	Selys, 1891	LC	6l
89	*Trithemis pallidinervis*	(Kirby, 1889)	LC	6m
90	*Zygonix iris*	Selys, 1869	LC	6n
91	*Zyxomma petiolatum*	Rambur, 1842	LC	6o
	Genera incertae sedis			
92	*Idionyx saffronata**#	Fraser, 1924	DD	6p-q
93	*Macromidia donaldi*#	(Fraser, 1924)	LC	6r

DD—Data Deficient | LC—Least Concern | NE—Not Evaluated | NT—Near Threatened | VU—Vulnerable | *—New records for the Maharashtra State | #—Species endemic to Western Ghats.

(Image 4h). The species was known from Kerala and Goa (Rangnekar et al. 2019). This observation is the first record from Maharashtra state with distributional range extension for the species (Image 7c).

3. *Megalogomphus hannyngtoni* (Fraser, 1923). Hemant Ogale photographed a large sized male Gomphid in Amboli on 9.vi.2021. It was identified by its large size; long and sharp pointed caudal appendages with 'sabre'-like appearance; apple green markings on black synthorax, and prominent yellow markings on S8–10 (Image 4l). This 'Near Threatened' Western Ghats endemic dragonfly was earlier known from Goa, Karnataka, Kerala, and Odisha (Subramanian 2011; Subramanian et al. 2018). Present record is the first from Maharashtra state and also extends the distribution range of *M. hannyngtoni* (Image 7d).

4. *Melligomphus acinaces* (Laidlaw, 1922). Hemant Ogale photographed a male of medium sized Gomphid, resting on rocks in Parpoli stream on 30.xi.2019. It was easily identified by its 'claw'-like caudal appendages with paraprocts longer than cerci (Image 4m). Koparde et al. (2014) recorded similar individuals from Parpoli and Verle villages. They wrongly identified the species as *Lamelligomphus nilgiriensis* (= *Onychogomphus nilgiriensis*). Tiple & Koparde (2015) retained the same record in the checklist of Maharashtra. After close examination of photographs provided by Koparde et al. (2014), we identified the male as *M. acinaces*. Dattaprasad Sawant photographed a male in Shahapur Taluka, Thane District in 2018 which is another record of this species in Maharashtra state. Earlier the species was known from Gujrat, Karnataka, and Kerala (Rathod et al. 2016; Subramanian et al. 2018) (Image 7e). Our records fill the distribution gap for *M. acinaces*.

5. *Epithemis mariae* (Laidlaw, 1915). Hemant Ogale and Dattaprasad Sawant observed many individuals of *E. mariae* in Amboli, Chakul and Nene villages (Image 5g). This medium sized Libellulid can be easily identified by its bright red coloured proximal abdominal segments. This Western Ghats endemic dragonfly was reported by Sathe & Bhusnar (2010) from Kolhapur, but omitted by Tiple & Koparde (2015) due to absence of taxonomic identity or spatial distribution. Here we confirmed its presence in Maharashtra state with photographic evidence (Image 7f). The species can be easily seen in riverine habitats from mid-August to

Table 4. List of Odonata species added in the checklist of Maharashtra since 2015.

	Species	Family	Reference
01	*Lestes concinnus* Hagen in Selys, 1862	Lestidae	Dow (2017); Anonymous (2021d)
02	*Lestes patricia* Fraser, 1924	Lestidae	Bhakare et al. (2020)
03	*Lestes praemorsus* Hagen in Selys, 1862	Lestidae	Mujumdar et al. (2020); Koli et al. (2021)
04	*Platylestes platystylus* Rambur, 1842	Lestidae	Mujumdar et al. (2020)
05	*Protosticta sanguinostigma* Fraser, 1922	Platystictidae	Present Study
06	*Libellago indica* (Fraser, 1928)	Chlorocyphidae	Subramanian et al. (2018); Present Study
07	*Euphaea pseudodispar* Sadasivan & Bhakare, 2021	Euphaeidae	Bhakare et al. (2021); Present Study
08	*Euphaea thosegharensis* Sadasivan & Bhakare, 2021	Euphaeidae	Bhakare et al. (2021); Present Study
09	*Dysphaea ethela* Fraser, 1924	Euphaeidae	Personal observations by Dattaprasad Sawant at Hadpid, Devgad Taluka, Maharashtra.
10	*Melanoneura bilineata* Fraser, 1922	Platycnemididae	Koli and Dalvi (2021)
11	*Aciagrion approximans* (Selys, 1876)	Coenagrionidae	Subramanian et al. (2018); Present Study
12	*Agriocnemis keralensis* Peters, 1981	Coenagrionidae	Koli et al. (2021)
13	*Ceriagrion chromothorax* Joshi & Sawant 2019	Coenagrionidae	Joshi and Sawant (2019)
14	*Ischnura rubilio* Selys, 1876	Coenagrionidae	Subramanian et al. (2018); Present Study
15	*Gynacantha khasiaca* MacLachlan, 1896	Aeshnidae	Mujumdar et al. (2020); Koli et al. (2021)
16	*Cyclogomphus flavoannulatus* Rangnekar et al 2019	Gomphidae	Present Study
17	*Merogomphus longistigma* Fraser, 1922	Gomphidae	Payra et al. (2022)
18	*Megalogomphus hannyngtoni* (Fraser, 1923)	Gomphidae	Present Study
19	*Melligomphus acinaces* (Laidlaw, 1922)	Gomphidae	Present Study
20	*Bradinopyga konkanensis* Joshi & Sawant, 2020	Libellulidae	Joshi and Sawant (2019); Present Study
21	*Epithemis mariae* (Laidlaw, 1915)	Libellulidae	Present Study
22	*Hylaeothemis apicalis* Fraser, 1926	Libellulidae	Subramanian et al. (2018); Present Study
23	*Macrodiplax cora* (Brauer, 1867)	Libellulidae	Anonymous (2021e)
24	*Idionyx saffronata* Fraser, 1924	Genera incertae sedis	Present Study
25	*Macromidia donaldi* (Fraser, 1924)	Genera incertae sedis	Payra et al. (2022); Present Study. Payra et al. (2022) enlisted this species in family Synthemistidae. However Kalkman et al. (2020) consider this species to be belonged to Genera incertae sedis.

October.

6. *Idionyx saffronata* Fraser, 1924. Hemant Ogale collected a pair of *Idionyx* sp. from Amboli on 10.vi.2021 (Image 6p). Later it was confirmed as *I. saffronata* based on the shape of caudal appendages of male. Paraprocts are trifid with a broad apical portion (Image 6q). Genus *Idionyx* is distributed till Goa state in the Western Ghats but not reported from Maharashtra state (Subramanian et al. 2018). We confirm the presence of *I. saffronata* in Maharashtra with distributional range extension for the species (Image 7g).

Despite being one of the most biodiverse regions in the northern Western Ghats, no efforts were taken for documentation of Odonata fauna of Amboli-Chaukul-Parpoli region. Due to the unique location of Amboli, it was speculated to have many endemic odonates. Out of total number of species we reported, ~16% are endemic to the Western Ghats, highlighting the rich biodiversity of the region with need of conservation of natural habitat. Western Ghats and adjacent areas in Sindhudurg district are facing tremendous anthropogenic pressure in the form of habitat loss. Change in existing landscape may lead to the disappearance of species which are extremely seasonal and localized in a small geographic area.

Maharashtra state has varied biogeography due to which it harbors several species of flora and fauna. The state has been thoroughly studied in terms of odonates. Tipale & Koparde (2015) combined various checklists and made a comprehensive database of odonates. They recorded a total of 134 species from 11 families. Since then, many species have been reported and discovered from Maharashtra. Table 4 gives detailed information of species added to Odonata fauna of Maharashtra. Citizen Science platforms such as Indian Odonata have

Table 5. List of Odonata species omitted from the checklist of Maharashtra due to various reasons.

	Species	Family	Reason
01	*Lestes thoracicus* (Laidlaw, 1920)	Lestidae	Dumont et al. (2017) synonymized *L. thoracicus* with *L. concinnus*.
02	*Lestes umbrinus* (Selys, 1891)	Lestidae	Dumont et al. (2017) synonymized *L. umbrinus* with *L. concinnus*.
03	*Aciagrion hisopa* (Selys, 1876)	Coenagrionidae	Joshi et al. (2016) showed that taxon *krishna* belongs to *A. approximans* and not to *A. hisopa*. Hence we include *A. approximans* in updated checklist
04	*Cercion dyeri* (Fraser, 1920)	Coenagrionidae	Weeker & Dumont (2004) synonymized *C. dyeri* with *Paracercion calamorum*.
05	*Ischnura aurora* (Brauer, 1865)	Coenagrionidae	Papazian et al. (2007) showed *I. a. aurora* is found in Australia and *I. a. rubilio* is found in the Indian Subcontinent and Iran. Kalkman et al. (2020) consider *I. rubilio* as a complete species.
06	*Anax imperator* (Leach, 1815)	Aeshnidae	Tiple & Koparde (2015) listed *A. imperator* from Nashik without any photographic or specimen evidence. However, it is distributed in Africa, Europe and North India. This record needs to be confirmed with either photo or specimen.
07	*Anormogomphus heteropterus* (Selys, 1854)	Gomphidae	Babu et al. (2009) recorded a female Gomphid from Aurangabad, Maharashtra and identified it as *A. heteropterus*. However, no male individual has been reported from the state since then. This species occurs in North India with no records from Western Ghats and nearby regions. Hence until the record of male individuals, we omit this species from the checklist of Maharashtra.
08	*Asiagomphus nilgiricus* (Laidlaw, 1922)	Gomphidae	Sathe & Bhusnar (2010) mentioned *A. nilgiricus* without any specimen or photographic evidence from Amba Reserve Forest. However, Subramanian et al. (2018) mentioned the distribution in Karnataka and Tamilnadu.
09	*Davidioides martini* (Fraser, 1924)	Gomphidae	Sathe & Bhusnar (2010) mentioned *D. martini* without any specimen or photographic evidence from Amba Reserve Forest. However, Subramanian et al. (2018) mentioned the distribution in Kerala only.
10	*Cyclogomphus vesiculosus* (Selys, 1873)	Gomphidae	Kalkman et al. (2020) synonymized *C.vesiculosus* with *C. ypsilon*.
11	*Onychogomphus nilgiriensis* (Fraser, 1922)	Gomphidae	Koparde et al. (2014) recorded *O. nilgiriensis* from Parpoli, which is a case of misidentification. The individual shown by Koparde et al. (2014) is actually *Melligomphus acinaces*.
12	*Hylaeothemis indica* (Fraser, 1946)	Libellulidae	Kalkman et al. (2020) synonymized *H. indica* with *H. apicalis*.
13	*Orthetrum anceps* (Schneider, 1845)	Libellulidae	Prasad (1996) reported this European species from Maharashtra. This species is very similar to *O. glaucum*, *O. luzonicum* and *O. taeniolatum*, and it cannot be identified without genital examination. Considering the known geographical range of *O. anceps* given by Boudot et al. (2013), we omit this record from the checklist of Maharashtra.
14	*Orthetrum testaceaum* (Burmeister, 1839)	Libellulidae	Babu et al. (2009) reported this species from Pune. However, Subramanian et al. (2018) omitted this species from the checklist of Western Ghats. No other records are available from the state.
15	*Sympetrum hypomelas* (Selys, 1884)	Libellulidae	Kulkarni et al. (2012) mentioned *S. hypomelas* in the checklist of Maharashtra from Bhimashankar WS. However, Subramanian et al. (2018) mentioned this as a doubtful record. Considering the geographical range given by Subramanian & Dow (2010), we omit this species until any strong evidence is found.

Table 6. Family-wise distribution of Odonata species.

	Family	Amboli-Chaukul-Parpoli Region	Maharashtra State (updated)
01	Lestidae	02	06
02	Platystictidae	01	02
03	Calopterygidae	03	03
04	Chlorocyphidae	02	03
05	Euphaeidae	03	04
06	Platycnemididae	06	10
07	Coenagrionidae	20	28
08	Aeshnidae	06	10
09	Gomphidae	07	21
10	Macromiidae	02	06
11	Corduliidae	00	01
12	Libellulidae	38	48
13	Genera incertae sedis	02	02
	Total	**93**	**144**

contributed for understanding the distribution range of many odonates (Joshi et al. 2021). However, due to some taxonomic changes, a few species are omitted from the Odonata checklist. Details about such species and the reason for omission is given in Table 5. Hence the updated Odonata checklist of Maharashtra has 144 species from 13 families. Table 6 shows the taxonomic breakup with families arranged as per Kalkman et al. (2020).

Odonates are freshwater insects and need stable microhabitat for reproduction. The Western Ghats including Amboli region is now under constant threat of habitat loss resulting from anthropogenic activities. Systematic surveys are needed to document the overall biodiversity of this unique landscape which will ultimately help to make appropriate habitat conservation plans.

Image 2. Field images of: a—*Lestes elatus* | b—*Lestes viridulus* | c—*Protosticta sanguinostigma*| d—Caudal appendages of *Protosticta sanguinostigma*| e—*Neurobasis chinensis*| f—*Vestalis apicalis*| g—*Vestalis gracilis*| h—*Heliocypha bisignata*| i—*Libellago indica*| j—*Euphaea fraseri*| k—*Euphaea pseudodispar*| l—*Euphaea thosegharensis*| m—*Caconeura ramburi*| n—*Copera marginipes*| o—*Copera vittata*| p—*Disparoneura quadrimaculata*| q—*Elattoneura tetrica*| r—*Prodasineura verticalis*. © a—r—Hemant Ogale.

Image 3. Field images of: a—*Aciagrion approximans* | b—*Aciagrion occidentale* | c—*Aciagrion pallidum* | d—*Agriocnemis pieris* | e—*Agriocnemis pygmaea* | f—*Agriocnemis splendidissima* | g—*Amphiallagma parvum* | h—*Ceriagrion cerinorubellum* | i—*Ceriagrion chromothorax* | j—*Ceriagrion coromandelianum* | k—*Ceriagrion olivaceum* | l—*Ceriagrion rubiae* | m—*Ischnura rubilio* | n—*Ischnura senegalensis* | o—*Mortonagrion varralli* | p—*Pseudagrion decorum* | q—*Pseudagrion indicum* | r—*Pseudagrion malabaricum*. © a—r—Hemant Ogale.

Image 4. Field images of: a—*Pseudagrion microcephalum* | b—*Pseudagrion rubriceps* | c—*Anax ephippiger* | d—*Anax guttatus* | e—*Anax immaculifrons* | f—*Gynacantha dravida* | g—*Gynacantha millardi* | h—*Cyclogomphus flavoannulatus* | i—*Gomphidia kodaguensis* | j—*Ictinogomphus rapax* | k—*Macrogomphus wynaadicus* | l—*Megalogomphus hannyngtoni* | m—*Melligomphus acinaces* | n—*Paragomphus lineatus* | o—*Epophthalmia vittata*| p—*Macromia cingulate* | q—*Acisoma panorpoides* | r—*Brachythemis contaminata*. © a—r—Hemant Ogale.

Image 5. Field images of: a—*Bradinopyga geminata* | b—*Bradinopyga konkanensis* | c—*Cratilla lineata* | d—*Crocothemis servilia* | e—*Diplacodes lefebvrii* | f—*Diplacodes trivialis* | g—*Epithemis mariae* | h—*Hylaeothemis apicalis* | i—*Lathrecista asiatica* | j—*Neurothemis fulvia* | k—*Neurothemis intermedia* | l—*Neurothemis tullia*| m—*Onychothemis testacea* | n—*Orthetrum chrysis* | o—*Orthetrum glaucum* | p—*Orthetrum luzonicum* | q—*Orthetrum pruinosum* | r—*Orthetrum sabina*. © a—r—Hemant Ogale.

Image 6. Field images of: a—*Orthetrum taeniolatum* | b—*Orthetrum triangulare* | c—*Palpopleura sexmaculata* | d—*Pantala flavescens* | e—*Potamarcha congener* | f—*Tetrathemis platyptera* | g—*Tholymis tillarga*| h—*Tramea basilaris* | i—*Tramea limbata* | j—*Trithemis aurora* | k—*Trithemis festiva* | l—*Trithemis kirbyi*| m—*Trithemis pallidinervis* | n—*Zygonix iris* | o—*Zyxomma petiolatum* | p—*Idionyx saffronata* | q—Caudal appendages of *Idionyx saffronata* | r—*Macromidia donaldi*. © a—r—Hemant Ogale.

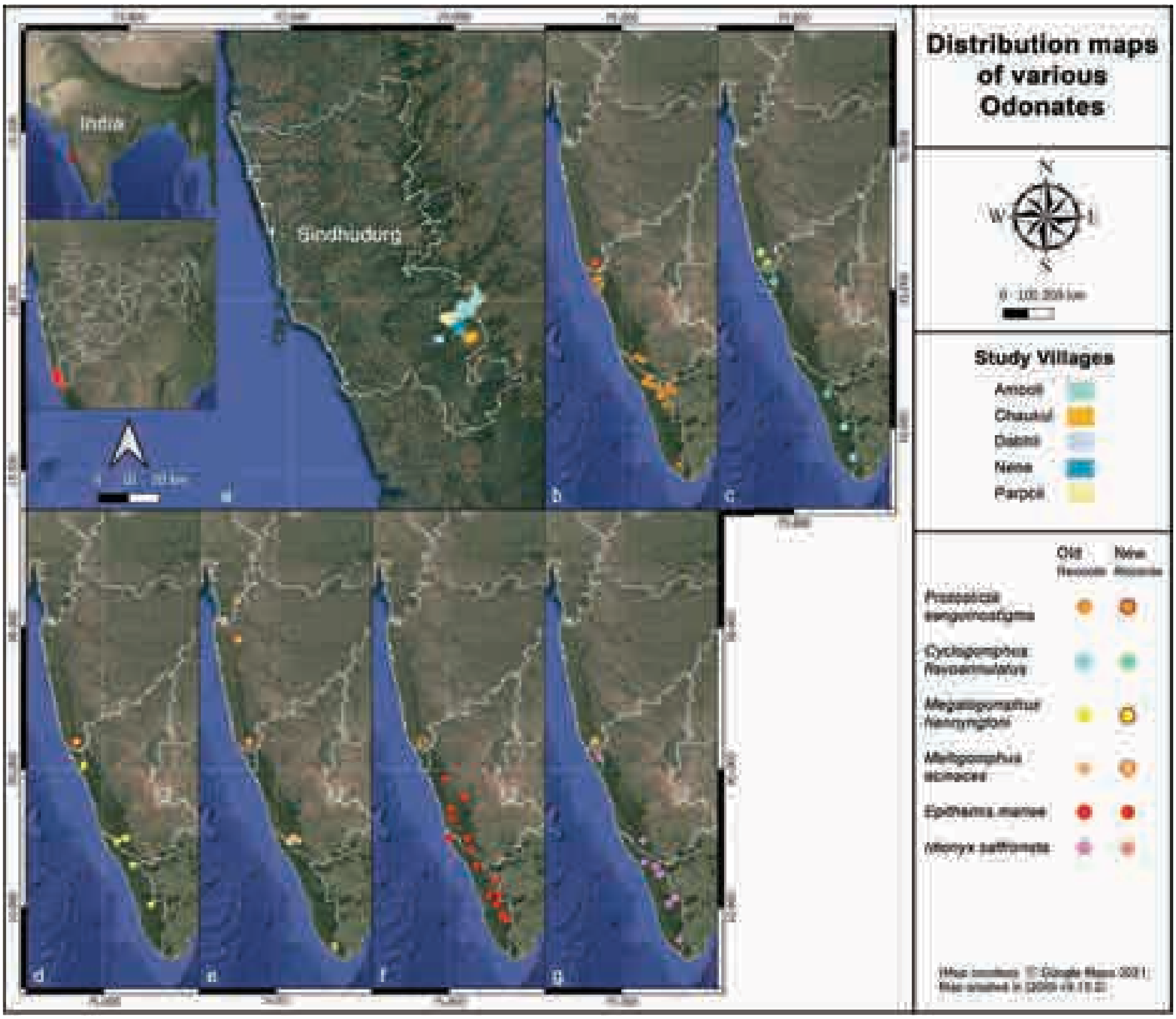

Image 7. Distribution maps: a—Study villages in Sindhudurg District | b—*Protosticta sanguinostigma* | c—*Cyclogomphus flavoannulatus* | d—*Megalogomphus hannyngtoni* | e—*Melligomphus acinaces* | f—*Epithemis mariae* | g—*Idionyx saffronata*.

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SHORT COMMUNICATION

The new addition of Blue Pimpernel of Primulaceae to the state flora of Assam, India

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Abstract: *Lysimachia arvensis* var. *caerulea* (L.) Turland & Bergmeier, a variety belonging to the family Primulaceae is reported as new to the state flora of Assam, northeastern India. The authors encountered the specimen during field survey at Kamrup Rural District of Assam in 2020. This manuscript describes taxonomy and morphology details along with pictorial illustration of the specimen.

Keywords: Assam, diversity, floristic, *Lysimachia arvensis* var. *caerulea,* new addition, palynology.

The genus *Lysimachia* Tourn. ex L., of Primulaceae, has approximately 180 species of plants with an almost cosmopolitan distribution (Hu & Kelso 1996; Liu et al. 2014). Assam, also known as the floristic gateway of northeastern India, consists of two species of this genus. Several floristic works have been done on this rich biodiversity of Assam, among which contributions of Kanjilal et al. (1934–1940), Chowdhury (2005), and Barooah & Ahmed (2014) are noteworthy.

During a floristic survey of Kamrup (R) District of Assam in 2018–2021, a distinct plant population was observed. All the petals of the flowers were covered with marginal hairs and were bright blue in colour. After referring to taxonomic literatures and critically investigating and examining of herbarium samples, a variety, *Lysimachia arvensis* var. *caerulea* (L.) Turland & Bergmeier, was identified as new addition to the flora of Assam. For easy identification of the species, detailed taxonomic description and other pertinent information along with clear photographs have been provided here. Additionally, palynological data have also been incorporated along with scanning electron microscope (SEM) images of pollen grains to assist in future palyno-taxonomic research.

Materials And Methods

Study Area

Kamrup is one of Assam's oldest districts, with a 1,000-year history dating back to the ancient age. It is a one-of-a-kind administrative unit, with jurisdiction on both sides of the great Brahmaputra. The district is presently an administrative district in western Assam, with its headquarters in Amingaon. According to 2011 Census of India report, the district covers a total geographical area of 3,105 km^2 and is situated in between 25.46–26.49 ^{0}N and 90.48–91.50 ^{0}E (Figure 1).

Methods

Several field visits were conducted throughout the

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Figure 1. Kamrup (R) District showing study area.

Kamrup (R) District during 2018–2021. The specimens were gathered from the fields for comprehensive morphological analysis and mounted onto standard herbarium sheets according to the procedure of Jain & Rao (1977). Multiple copies of the plant species were collected preferably in flowering and fruiting condition. The plant specimens were identified consulting various relevant taxonomic literatures. They were also compared with herbarium microfilms available online at the virtual sites provided by Royal Botanic Gardens- Kew Herbarium Catalogue & New York Botanical Garden, ;also with the digital photographs provided by Central National Herbarium (CNH), Howrah. The voucher specimen has been deposited at the Gauhati University Botanical Herbarium (GUBH), Gauhati University for future reference. Photographs were taken in the field and after dissection as well. Fresh pollen samples were collected and dried with the help of silica gel and images were captured using the SEM.

Results And Discussion

***Lysimachia arvensis* var. *caerulea* (L.) Turland & Bergmeier, Willdenowia 41: 185 (2011).**

Anagallis caerulea L., Amoen. Acad. 4: 479 (1759); *Anagallis arvensis* var. *caerulea* (L.) Gouan, Fl. Monsp.: 30 (1764); Parmar, Nelumbo 54: 131 (2012); Patel & Bihola, Life Sciences Leaflets 59: 150 (2015). *Anagallis arvensis* f. *azurea* Hyl., Uppsala Univ. Årsskr. 7: 256 (1945).

Taxonomic description

Description: Annual creeping herb, 10–30 cm in height. Stem quadrangular, branched from base, nodes often swollen. Leaves simple, opposite, each pair equal in size, sessile; lamina narrowly ovate to ovate, 0.7–1.8 × 0.3–1.2 cm with entire margin, apex obtuse to acute. Inflorescence racemose or solitary. Flowers axilary, actinomorphic, bisexual, hypogynous, pentamerous, attractive blue, pedicellate, pedicel recurved in fruit, ca 1.6 cm long. Sepals 5, gamosepalous, 3.7 × 0.8 mm, connate at the base, segments linear-lanceolate, margins hyaline, persistent. Petals 5, united, rotate, blue, 4.5 × 3.1 mm, margin minutely glandular-ciliate. Stamens 5, epipetalous arranged opposite to the petals, almost of same length, basally connate, filaments purplish, with long glandular articulate trichomes; anthers bithecous, sagittate shaped, dorsifixed, oblong. Gynoecium ca 2.8 mm, carpels 5, syncarpous, ovary superior, stigma slightly capitate, style linear, lower part hairy, ovary superior, 5 lobed; placentation free central; bitegmic. Fruit capsule 1–3 cm long, 5-ridged, many-seeded, angular, subglobose, 4–5 mm across, glabrous, tuberculate- rugose (Image 1& 2).

English name: Blue Pimpernel.

Native to: Mainly distributed in European countries as well as middle eastern region and western Himalaya.

Distribution status in the State: Distributed sporadically (Altitudinal Range: 64–48 m approx.)

Flowering and Fruiting: January to August

Habitat: It is found along roadsides with lightly

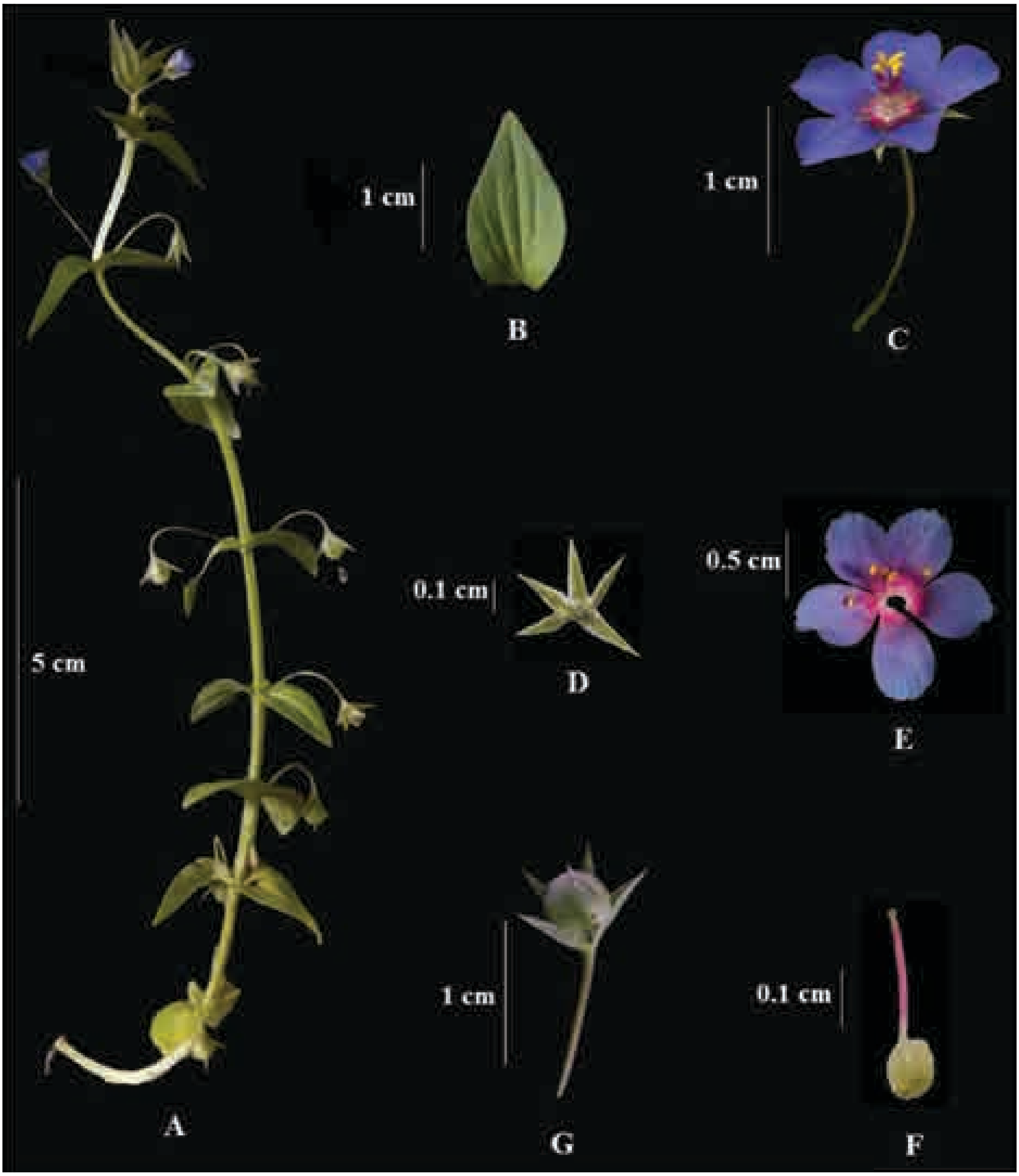

Image 1. *Lysimachia arvensis* var. *caerulea*: A—Habit | B—Leaf (dorsal) | C—Complete flower | D—Calyx | E—Corolla with epipetalous stamens | F—Gynoecium | G—Fruit (capsule). © Barnali Das.

shaded habitats and in crop fields like that of *Brassica*. Associated with *Vicia sativa*, *Vicia hirsuta*, *Fumaria indica*, *Orobanche aegyptiaca*, *Solanum nigrum*, *Brassica nigra*, and *Cannabis sativa*.

Availability status (at the study area): It is found in some localities seasonally; particularly in crop fields or along roadsides.

Specimen examined: Srinagar, Kashmir, 1891, G.A. Gammie, CAL0000031110, image!; Barni village, Rajasthan, 1973, B.V. Shetty, CAL0000052632, image!;

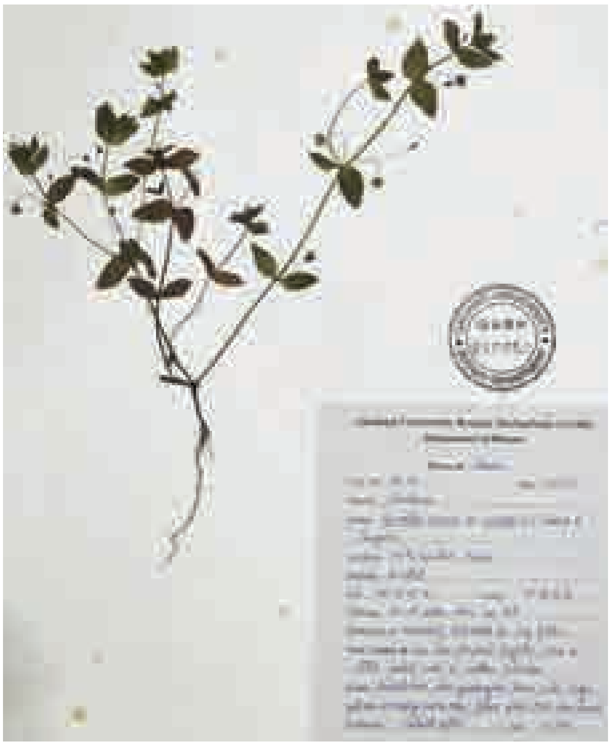

Image 2. Herbarium of *Lysimachia arvensis* var. *caerulea* deposited at GUBH.

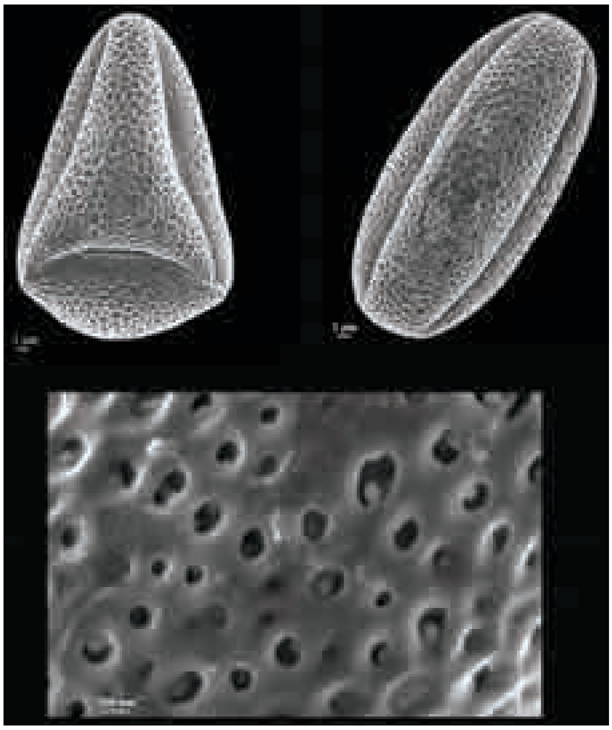

Image 3. *Lysimachia arvensis* var. *caerulea*: A—proximal | B—distal surface view of pollen | C—exine ornamentation.

Ranchi, Bihar, 1981, K.C. Mallick & R.N. Banerjee, CAL0000009231, image!; Tikamgarh, 1990, MP, M. Kishore & M. Prasad, CAL0000013112, image!; Hajo, Kamrup (R), 2021, S. Kalita & B. Das, SK-29, 26.2004^{0}N, 91.6346^{0}E (GUBH!).

Pollen characters: Pollen unit monad, tricolporate, and prolate in shape. The polar axis (P) length is 34.76 µm and the equatorial axis (E) is 17.56 µm; P/E ratio is 1.98. Pollen class is mediae. The exine sculpturing (tectum ornamentation) is reticulate (Image 3).

Note: It is noteworthy mentioning that *L. arvensis* is sometimes mistaken with *L. foemina*, although the species differ in the morphology of petal margins. *L. arvensis* has numerous marginal hairs, whereas, *L. foemina* has glabrous petals with very few or without marginal hairs (Haines 2011). Furthermore, whereas, *L. arvensis* has ovate leaves, longer pedicels and overlapping corolla lobes, *L. foemina* has narrowly lanceolate leaves, shorter pedicels and non-overlapping corolla lobes (Manns & Anderberg 2007). According to our findings, the new variety has blue-coloured, ciliate petals, confirming the specimen's unique identification.

Significance: The present record of a new variety is significant in taxonomy since it might lead to the development of a new species. The findings of the present investigation with flower colour polymorphism are significant, since flower colour serves as a characteristic in diversity of angiosperms and plays a critical role in evolution (Narbona et al. 2021). The present work therefore will embellish the floristic diversity of the entire state that is yet to be documented completely. This will further enrich the floristic composition of Assam and will aid in the conservation of native, rare and threatened species that are struggling to survive owing to habitat degradation caused by anthropogenic interference. Furthermore, the ability of *L. arvensis* var. *caerulea* to

Key to the species

1a. Pedicels longer than subtending leaves, petals with marginal hairs .... *Lysimachia arvensis*
1b. Pedicels shorter or equal to subtending leaves, petals with few or no marginal hairs .... *Lysimachia foemina*

Key to the variety

1a. Flower colour orange or reddish .... *Lysimachia arvensis* var. *arvensis*
1b. Flower colour dark blue or purplish .... *Lysimachia arvensis* var. *caerulea*

indicate the weather as well as the time of day is widely recognized which can aid in revealing the mechanisms of developing folk botanical awareness. Besides, it is also a source of scientific data concerning plant physiology and phenology. Farmers frequently employ such indicator plants in crop planning, particularly when no other signs are accessible (Gibbs & Talavera 2001; Acharya 2011). Thus, realization and conservation of such weather indicator plants are crucial at the time when there is increasing global concern about climate change and its impact on life.

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SHORT COMMUNICATION

A new species of genus *Neocerura* Matsumura, 1929 (Notodontidae: Lepidoptera) from India

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Abstract: A new species *Neocerura convergata* under the genus *Neocerura* Matsumura, 1929 has been described and illustrated. This species is closely related to *N. liturata* Walker, 1855 (type species) and completely conforms to the characterization of the genus. The wing maculation, larger size, and genitalic features make it distinct. The taxonomic account of *N. liturata* Walker, 1855 has also been included. The revival of the genus *Neocerura* Matsumura, 1929 has also been justified.

Keywords: *Neocerura convergata* sp. nov., *Neocerura liturata*, new species, Notodontidae.

Abbreviations: 1A—First anal vein | 2A—Second anal vein | AED—Aedeagus | | CU_1—First cubital vein | CU_2—Second cubital vein | GN—Gnathos | JX—Juxta | M_1—First Medial vein | M_2—Second Medial vein | M_3—Third Medial vein | R_1—First Radial vein | R_2—Second Radial vein | R_3—Third Radial vein | R_4—Fourth Radial vein | R_5—Fifth Radial vein | Rs —Radial sector | Sc —Subcosta | $Sc+R_1$—Subcosta and first radial vein | TG—Tegumen | UN—Uncus | VES—Vesica | VIN—Vinculum | VLV—Valva.

Matsumura (1929) established the genus *Neocerura* with *liturata* Walker as its type species. Gaede (1934), Kiriakoff (1964, 1968), Holloway (1983), Schintlmeister & Pinratana (2007), and Schintlmeister (2008) followed the same nomenclature. Schintlmeister (1997, 2001), and Wu & Fang (2002) treated it as subgenus under genus *Cerura* Shrank, 1802. Schintlmeister (2008) revived it as a distinct genus and distinguished it from other two genera i.e., *Cerura* Shrank, 1802 and *Kamalia* Kocak and Kemal, 2006 on the basis of distinct male genitalic features. The distal end of aedeagus is simple in *Cerura* Shrank, 1802 and with sclerotized processes in *Kamalia* Kocak & Kemal, 2006 and but in the present genus, i.e., *Neocerura* its distal end is bifurcated. In the present studies, the same nomenclature has been adopted and *N. liturata* Walker, 1855 (the type species) along with a new species, namely, *N. convergata* has been described and illustrated in detail under this genus. The new species is closely related to *N. liturata* (Walker, 1855) but can be easily differentiated due to its bigger size and distinct black markings on wings. The male genitalia such as less curved uncus, narrower gnathos and converging distal processes of aedeagus further makes it a distinct species from other species of this genus. While dealing with Indonesian Notodontidae, Schintlmeister (2020) also added a new species, i.e., *N. longinquus* Schintlmeister, 2020 to the present genus and remarked that this genus is represented by five species.

Material and Methods

The material examined was collected from different

ZooBank: urn:lsid:zoobank.org:pub:EA4EBEEE-EA37-45B4-B1DF-64A9041335F1

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localities of northeastern India by using vertical sheet method. The collected specimens were killed, stretched and preserved after proper labeling in Lepidoptera Lab, Punjabi University, Patiala. The external morphological characters were studied from the stretched specimens. The dissections were carried out to explore the male and female genitalic features (Robinson 1976). The permanent slides of fore and hindwings were prepared to study wing venation (Zimmerman 1978). The terminology for naming various genital parts follows Klots (1970).

Results & Discussion

Genus *Neocerura* Matsumura, 1929

Neocerura Matsumura, 1929, *Ins. Mats.*, 4: 89; Gaede, 1934, *Lep. Cat.*, 59: 60; Kiriakoff, 1964, *Genera Insectorum Fasc.*, 217a: 65; id., 1968, *Genera Insectorum Fasc.*, 217C: 113; Schintlmeister & Pinratana, 2007, *Moths of Thailand*, 5: 108; Schintlmeister, 2008, *Palaearctic Macrolepidoptera*, 1: 123.

Neocerura Kiriakoff: Holloway, 1983, *Moths of Borneo*, 4.

Type species: *Cerura liturata* Walker, 1855

Distribution: India (throughout), Nepal, Bangladesh, Myanmar, Sri Lanka, China, Taiwan, Indochina, Malaya, Borneo, Philippines, Sumatra, Java, Bali, Lombek, Flores, Sumba, Sumbawa, Sulawesi, Sumatra, Peleng Island, Salayer Island and as a remote point in Tanimbar (Holloway 1983; Schintlmeister & Pinratana 2007; Schintlmeister 2008, 2020).

Diagnosis: Small- to medium-sized moths; ground colour white with black markings. Labial palpi porrect. Antennae bipectinate, pectinations along entire length of the flagellum. Forewing with black wavy bands; M_3 from lower angle of cell; M_2 near middle of discocellulars; M_1-R_3 well stalked from upper angle of cell; areole present. Hindwing whitish. Legs hairy; fore-tibia with an epiphysis; mid-tibia and hind-tibia, each with a pair of tibial spurs. Male genitalia with uncus hood-like; gnathos petiolate; tegumen, vinculum and valvae weakly sclerotized; aedeagus small with distal end bifurcated.

Neocerura liturata (Walker, 1855)
(Image 1–9)

Cerura liturata Walker, 1855, *List. Lep. Het. Br. Mus.*, 5: 988; Hampson, 1892, *Moths India*, 1: 155.

Neocerura liturata Walker: Matsumura, 1929, *Ins. Mats.*, 4: 89; Gaede, 1934, *Lep. Cat.*, 59: 60; Kiriakoff, 1964, *Genera Insectorum Fasc.*, 217a: 65; id., 1968, *Genera Insectorum Fasc.*, 217C: 113; Holloway, 1983, *Moths of Borneo*, 4; Schintlmeister and Pinratana, 2007, *Moths of Thailand*, 5: 108; Schintlmeister, 2008, *Palaearctic Macrolepidoptera*, 1: 123.

Type locality: Sylhet, Bangladesh

Description: Head with vertex white; frons black. Labial palpi porrect, dressed with black scales. Antenna bipectinate, pectinations along entire length of the flagellum; scape covered with white scales; flagellum black, pectinations black. Thorax, collar and tegula white, spotted with black; collar fringed with black scales; underside white. Legs hairy, covered with black and white scales; fore-tibia with an epiphysis; mid-tibia and hind-tibia, each with a pair of tibial spurs. Abdomen black having a whitish patch on distal end; underside white.

Wing maculation: Forewing with ground colour white; basal area with black spots; antemedial wavy black band; costa with black streaks; medial and postmedial regions with black wavy lines; a patch of black scales on costa near apex; margin banded with black and white cilia; underside white. Hindwing white with few black scales; outer margin banded with black and white cilia; underside white.

Wing venation: Forewing with discal cell more than half the length of the wing, closed; 1A from base of wing, anastomosing with 2A, covering one-third of anal margin; 2A from base of wing, reaching tornus; 3A absent; Cu_2 beyond two-third of cell; Cu_1 well before lower angle of cell; M_3 from lower angle of cell; M_2 above middle of discocellulars; M_1-R_3 well stalked from upper angle of cell; R_2 before upper angle of cell, sending a bar to common stalk of R_5-R_3 to form an areole; R_1 from three-fourth of cell, not reaching apex; Sc from base of wing, not reaching apex. Hindwing with discal cell more than half the length of wing, closed; 1A from base of wing, running parallel to anal margin, not reaching tornus; 2A from base of wing, reaching tornus; 3A absent; Cu_2 beyond two-third of cell; Cu_1 just before lower angle of cell; M_3 from lower angle of cell; M_2 just above middle of discocellulars; M_1 and Rs well stalked from upper angle of cell; Sc+R_1 from base of wing, sending a bar to cell before its middle, not reaching apex.

Wing expanse: Male: 38–50 mm; Female: Not examined.

Body length: Male: 24–26 mm.

Male genitalia: Uncus of moderate size, moderately sclerotized, setosed, distal half broad, curved, ventral side with a setosed projection, making snake-hood like appearance, distal end narrow, rounded; gnathos moderately sclerotized, more than half length of uncus, both projections robust, leaf-like; tegumen U-shaped, weakly sclerotized, each arm narrowing towards both

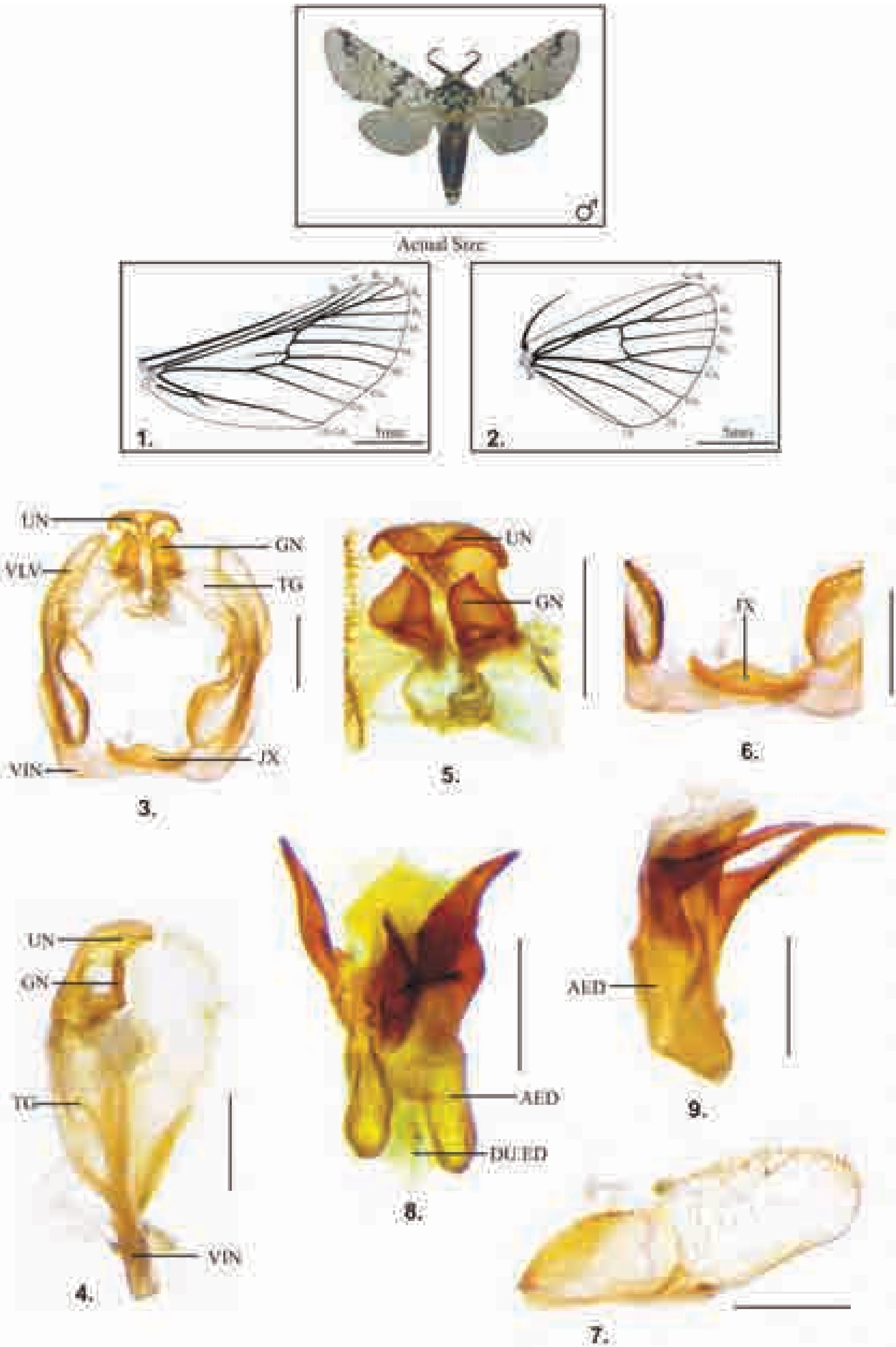

Image 1–9. *Neocerura liturata* (Walker, 1855).
1—Forewing | 2—Hindwing | 3—Male genitalia (ventral view) | 4—Lateral view | 5—Uncus & Gnathos | 6—Juxta | 7—Valva | 8 & 9—Aedeagus (bar line=1mm).

ends; vinculum narrow, weakly sclerotized, without any distinct saccus; juxta narrow, moderately sclerotized, crown-shaped. Valva simple, sleeper-shaped, weakly sclerotized, ventral half more setosed. Aedeagus short, well sclerotized; proximal end with flap-like structures on lateral sides; ductus ejaculatorius entering directly between these two flaps; distal half having highly sclerotized almost equal sized projections; vesica having long flap-like spur representing cornuti.

Material examined: India, Meghalaya: PUP-NT-29a-b, Umtsor, 15.ix.2014, two males (25.8284° N, 91.8493° E); Mizoram: PUP-NT-29c, Thenzawl, 06.ix.2015, one male (23.2808° N, 92.7741° E); Sikkim: PUP-NT-29d, Dodak, 06.v.2014, one male (27.1734° N, 88.1708° E).

Distribution: India: Throughout India; Nepal, Bangladesh, Myanmar, Sri Lanka, China, Taiwan, Indochina, Malaya, Borneo, Philippines, Sumatra, Java, Bali, Lombek, Flores, Sumba; Sumbawa; Sulawesi; Sumatra, Peleng Island, Salayer Island (Holloway 1983; Schintlmeister & Pinratana 2007; Schintlmeister 2008, 2020).

Remarks: This species was originally described by Walker (1855) under genus *Cerura* Shrank and Hampson (1892) followed the same nomenclature. Matsumura (1929) established a new genus *Neocerura* for its proper placement and the same has been followed in the present studies.

Neocerura convergata **sp. nov.**
(Image 10–19)

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Material examined: Holotype: PUP-NT-28a, 11.v.2013, male, India, Arunachal Pradesh, Sessa (27.1074° N, 92.5254° E).

Paratypes: PUP-NT-28b, 11.v.2013, one male, India, Arunachal Pradesh, Sessa (27.1074° N, 92.5254° E); PUP-NT-28c-d, 08.ix.2013, three males, Sikkim, Golitar (27.2299° N, 88.4933° E).

Diagnosis: The wing maculation and genitalic features particularly the shape and size of uncus, gnathos, aedeagus, and distal processes of aedeagus makes it distinct from other known species of genus *Neocerura.* Forewing with 31 mm length, distinctly marked medial and postmedial fascia, median fascia with costal streak to postmedial lines and hindwing with costal region having black patches are the main diagnostic features of the present species. The splendid white colour of forewing with more prominent medial spot and medial fascia without any costal streak to postmedial lines differentiates *N. thomsai* Schintlmeister from it. The absence of brown filled antemedial fascia with a black spot near dorsum and discal spot of forewing differentiates the present species from *N. multifasciata* Schintlmeister and *N. longinquus* Schintlmeister respectively. Male genitalia is with wedge shaped gnathos which is quite robust in *N. liturata* Walker and *N. longinquus* Schintlmeister. The distal bifurcate processes of aedeagus are of moderate breadth with rounded apices whereas these are broader in *N. longinquus* Schintlmeister and narrower in other species. The distal processes are quite narrower and longer with pointed apices in *N. multifasciata* Schintlmeister than in all other species.

Description: Head with vertex white; frons black. Labial palpi porrect, dressed with black scales. Antenna bipectinate along entire length of the flagellum; scape covered with white scales; flagellum black, pectinations black. Thorax, collar and tegula white; thorax and tegula spotted with black; underside whitish with few black scales. Legs hairy, covered with black and white scales; fore-tibia with an epiphysis; mid-tibia and hind-tibia, each with a pair of tibial spurs. Abdomen black with white median streak; distal end with a white patch having a black ring on it; underside white.

Wing maculation: Forewing with ground colour white; basal area with small black streaks; costa with black streaks; a postmedial wavy band; medial and postmedial regions with black wavy lines; veins black in marginal area; a black patch on costa near apex; outer margin chequered with black and white cilia; underside whitish with almost same pattern as on upper side. Hindwing white; costal region having black patches; anal area with few black scales; outer margin banded with black and white cilia; underside whitish.

Wing venation: Forewing with discal cell more than half the length of the wing, closed; 1A from base of wing, anastomosing with 2A, covering one-third of anal margin; 2A from base of wing, reaching tornus; 3A absent; Cu_2 just beyond three-fourth of cell; Cu_1 before lower angle of cell; M_3 from lower angle of cell; M_2 well above middle of discocellulars; M_1 from upper angle of cell; R_5 to R_3 stalked before upper angle of cell, their common stalk anastomosing with M_1 to form a small areole; R_1 well before upper angle of cell, not reaching apex; Sc from base of wing, not reaching apex. Hindwing with discal cell more than half the length of wing, closed; 1A from base of wing running parallel to anal margin, not reaching tornus; 2A from base of wing, reaching tornus; 3A absent; Cu_2 well before lower angle of cell; Cu_1 and M_3 minutely stalked from lower angle of cell; M_2 from middle of discocellulars; M_1 and Rs well stalked from

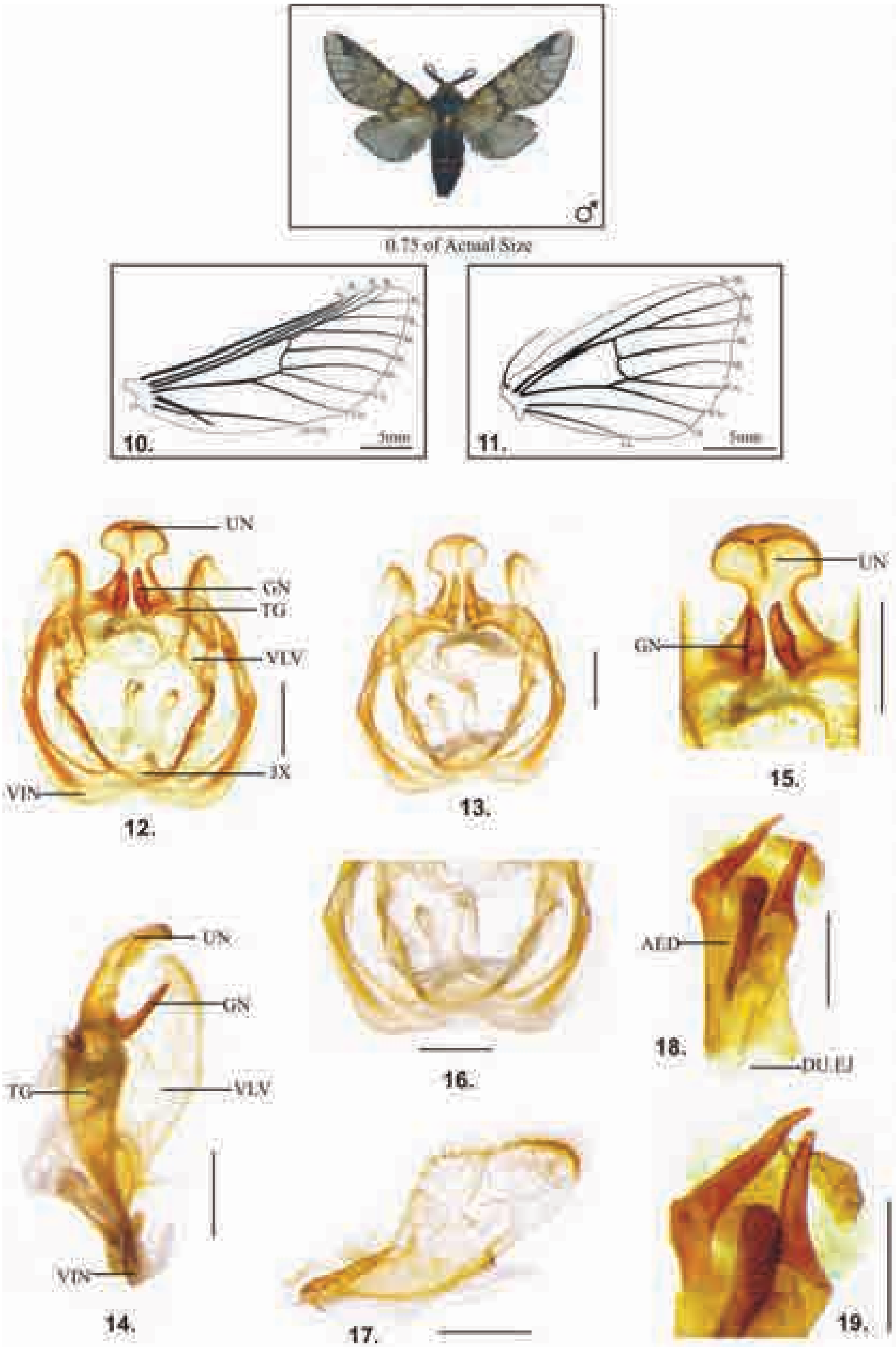

Image 10–19. *Neocerura convergata* sp. nov.
10—Forewing | 11—Hindwing | 12—Male genitalia (ventral view) | 13—Dorsal view | 14—Lateral view | 15—Uncus & Gnathos | 16—Juxta | 17—Valva | 18 & 19—Aedeagus (bar line=1mm).

Key to the studied species of genus *Neocerura* Matsumura, 1925:

1. Wings weakly marked with black. Male genitalia with gnathos robust leaf-like; aedeagus with distal processes diverging outwardly .... ***Neocerura liturata* Walker, 1855**
- Wings distinctly marked with black. Male genitalia with gnathos narrow, wedge-shaped; aedeagus with distal processes converging inwardly .... ***Neocerura convergata* sp. nov.**

upper angle of cell; $Sc+R_1$ from base of wing, conjoined in middle of discal cell, not reaching apex.

Wing expanse: Male: 66 mm; Female: not examined.

Body length: Male: 23 mm.

Male genitalia: Uncus of medium size, weakly sclerotized, setosed, proximal half narrow, distal half laterally dilated making globular appearance, slightly curved near narrow and blunt tip; gnathos narrow, wedge-shaped, moderately sclerotized, dorsally setosed, both projections narrow, almost half the length of uncus, outer walls corrugated; tegumen broad, U-shaped, weakly sclerotized, narrowing towards vinculum; vinculum narrow, slightly produced proximally on both sides, saccus absent; juxta oblong in shape, weakly sclerotized, proximal area with sclerotized triangular projection. Valva simple, weakly sclerotized, setosed; proximal half narrow, distal half broad with rounded apex. Aedeagus small, well sclerotized; ductus ejaculatorius entering from proximal end; distal end with two finger-like, highly sclerotized projections with rounded apices; vesica with a large prominent nail-like sclerotized patch having dentate walls representing cornuti.

Distribution: India: Arunachal Pradesh, Sikkim

Etymology: The present species has been named after the converging distal processes of aedeagus.

Bionomics: It is known only by five specimens from two localities, i.e., Sessa and Golitar in the states of Arunachal Pradesh and Sikkim.

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Threatened Taxa

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SHORT COMMUNICATION

Rediscovery of an interesting preying mantis *Deiphobella laticeps* (Mantodea: Rivetinidae) from Maharashtra, India

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Abstract: *Deiphobella laticeps* (Wood Mason, 1876), is an interesting preying mantis, rediscovered from Maharashtra State, India, after considerable lapse of time since its original description.

Keywords: Deiphobinae, Deiphobini, Dictyoptera, *Fischeria,* rediscovered.

Genus *Deiphobella* GiglioTos, 1916 was erected by Giglio-Tos to accommodate Wood-Mason's species *Fischeria laticeps* which was described in 1876. At present, there are only two species under this genus: *Deiphobella laticeps* (Wood Mason, 1876) and *Deiphobella gardneri* (Werner, 1935). This genus belongs to the family Rivetinidae and the subfamily Deiphobinae as per the recent classification by Schwarz & Roy (2019).

Earlier, Mukherjee et al. (1995) had placed this genus in the family Mantidae, subfamily Mantinae and the tribe Miomantini while in the subsequent classification it was placed in the tribe Rivetinini (Ehrmann 2002). The genus is oriental in distribution and is so far known from India and Sri Lanka only.

Two specimens, one female from Pune, Maharashtra and one male from Bengaluru, Karnataka, were identified as *Deiphobella laticeps* based on the key provided by Mukherjee et al. (1995). The genus *Deiphobella* can be easily identified by its laterally conical eyes and sharp triangular supra-anal plate.

The two species under this genus, *Deiphpbella laticeps* and *D. gardeneri*, are differentiated on the basis of smooth or granular coxa and lower frons (frontal sclerite) with or without black band. *Deiphobella laticeps* has minutely granular fore coxa and a black band on lower frons. According to Mukherjee et al. (1995), the species *Deiphobella laticeps* is known only from Karnataka (Mysuru) in India and Sri Lanka while the other species is known only from Uttar Pradesh (type locality: Chakata Range, Haldwani, now in Naini Tal District, Uttarakhand) in India. Rao et al. (2005) reported the species from Andhra (Kurnool) extending its distribution to the east and the presence of this species in Pune, Maharashtra (Ghate & Ranade 2002), is northward extension of the range of this species. Vyjayandi (2007) reported this species from Kerala, which is further south of Karnataka. Ghate et al. (2012) also enlisted this species in the checklist of Mantodea of Maharashtra. In most of the localities this species was collected from patches of grass.

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Competing interests: The authors declare no competing interests.

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We also checked the original description of *Fischeria laticeps* by Wood-Mason (1876) and the original diagnosis of the genus *Deiphobella* by Giglio-Tos (1916). This helped us to confirm the identity of the species. This paper briefly redescribes and illustrates *D. laticeps* with some terms that are recently introduced by Brannoch et al. (2017).

Taxonomic Position as per Schwarz & Roy (2019)

Superfamily Eremiphiloidea Saussure, 1869
Family Rivetinidae Ehrmann & Roy, 2002
Subfamily Deiphobinae Schwarz & Roy, 2019
Tribe Deiphobini Schwarz & Roy, 2019
Genus *Deiphobella* Giglio-Tos, 1916
Species *Deiphobella laticeps* (Wood-Mason, 1876)
(for synonyms see Ehrmann 2002)

Brief redescription of *Deiphobella laticeps* Female

General body size and colouration: Large, elongate and slender insect; overall colour dark brown but reddish-brown at places,

Head: much broader than long (because of conical projecting eyes). Vertex smooth, without prominent grooves, flat and wide, its upper edge slightly convex above level of eyes and continuous with eyes. Eyes laterally conical (Image 2A). Ocelli small. Antennae long, filiform, many segmented. Lower frons transverse, with black band.

Pronotum: narrow, elongate; supra-coxal dilation moderate. Lateral margins of pronotum denticulate; denticles denser in prozona. Disc of prozona dorsally and ventrally with numerous prominent granules arranged in four rows, two on either side of median sulcus. Anterior one third part of metazona with obtuse median carina. Pronotum narrow at supra-coxal dilation, gradually becoming broader towards posterior end. Overall pronotum more or less parallel sided with few granules on the disc. Metazona much longer than fore coxa (Image 1A,B, 3A,B).

Fore legs: coxae shorter than metazona, dorsally few small granules or tubercles are seen only on well raised carina; internally (antero ventral side) finely granulated; distally little widened; coxal lobes (preapical lobes) divergent. Fore femur slender, dorsal margin with few blunt dark brown tubercles; both edges of femur almost parallel sided with spines present in distal half only, internal (antero ventral) spines – 14; external (postero ventral) spines – 4; discoidal spines – 4; all spines black at tips only. First three discoidal spines are very closely placed whereas fourth spine is smaller and is placed considerably away from the first three. Antero ventrally femora are yellowish, with few blunt tubercles; claw groove (tibial spur groove) is situated in front of middle. Tibia slender, one third shorter than femora; antero ventral spines – left 16/ right 15 and postero ventral spines – 8 (Image 2B,C).

Mid and hind legs: long, slender, smooth, without any spines or spinules on coxa and femora, but few spinules are present on tibia.

Wings: very short in female (brachypterous); fore wings opaque, costal area of fore wings brownish-yellow, anal area smoky, discoidal area smoky brown with a large oval brownish blotch bordered by blackish bands on either side. Hind wings small, smoky brown, costal area dark opaque brown with an apical pale yellow band, on either side of which is a dark brown band; rest of wing translucent with dark brown veins and pale cross veins.

Abdomen: segments longer than broad, except for terminal segment. In female, supra anal plate triangular, pointed and carinate.

Male and female difference

Male shorter in length (but exact length in our specimen is not known as last three segments are broken), and less robust; juxta-ocular lobes well marked; antero-ventral spines on femora 16; spines are thin and slender. Wings well developed. Fore wings narrow, with brown patch in anal region. Hind wings broad, translucent, smoky with dark brown longitudinal veins and white transverse veins. Costal area somewhat opaque brown with a magenta tinge in some part and with a pre-apical pale cream large blotch with its distal and proximal margin dark brown.

In Female the antero-ventral spines on femora are thick, short and stout.

Morphometry (all figures in mm, arranged as Female / Male)

Total length – 132/73 – (male appears very short because three terminal segments are broken).

Pronotum: prozona -10/10 metazona- 28/20; total pronotum -38/28 Fore wings - 21/45; Hind wings 14/42

Fore leg: Coxa 22/15; Femur 25/18; Tibia 8/6. Mid leg: Femur 30/24; Tibia 25/17. Hind leg: Femur 36/32; Tibia 38/29.

Fore leg spination (for female):

F = 4DS/14AvS/4PvS; T = 15-16AvS/8PvS

Materials examined: One male (Bengaluru, Coll. K. Kunte, 28.i.2002) and one female (Chatushrungi Hill, Pune, Coll. Sachin Ranade, 9.iii.2001). Both preserved at Modern College, Pune; accession Nos. MCZM 10 and 11, respectively.

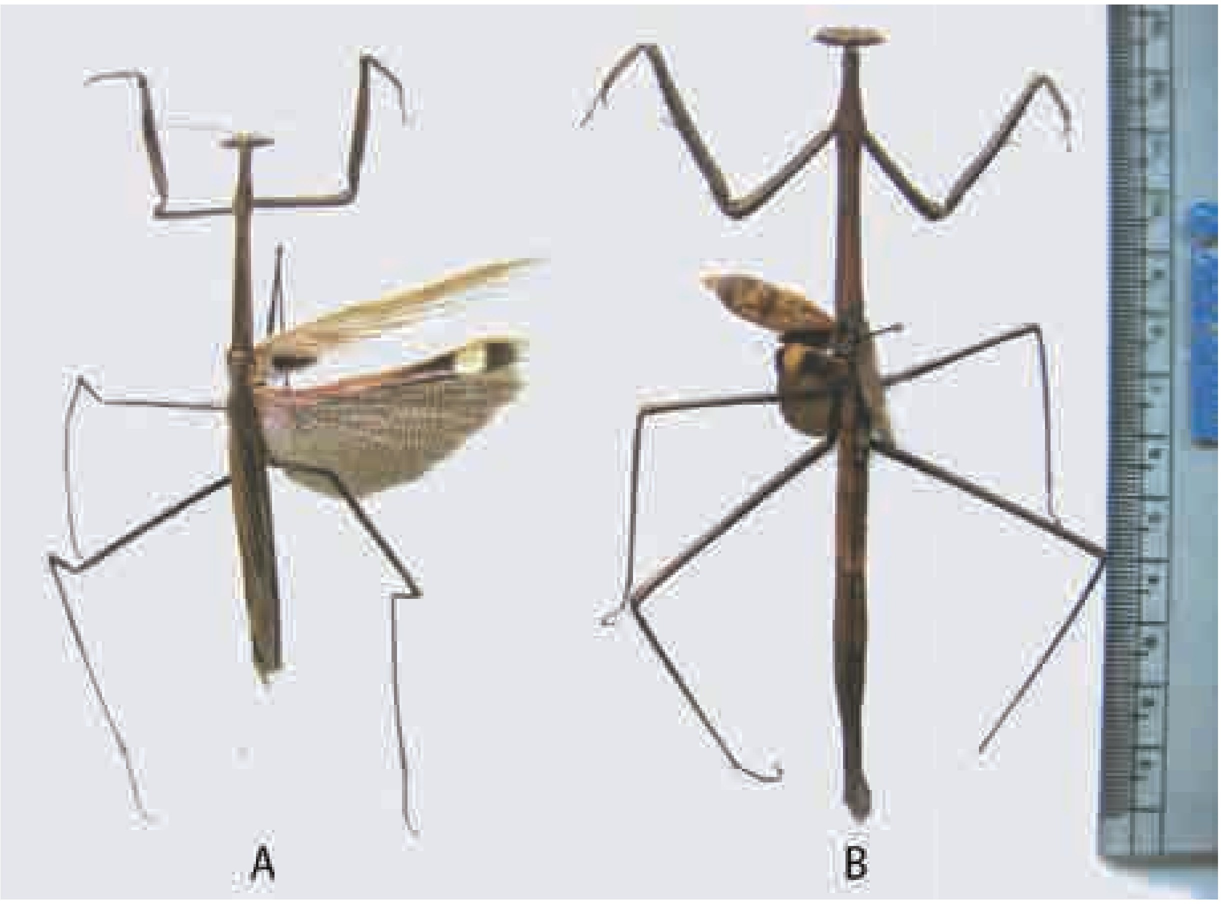

Image 1. *Deiphobella laticeps* male (left) and female (right) habitus: dorsal view. © Hemant Ghate

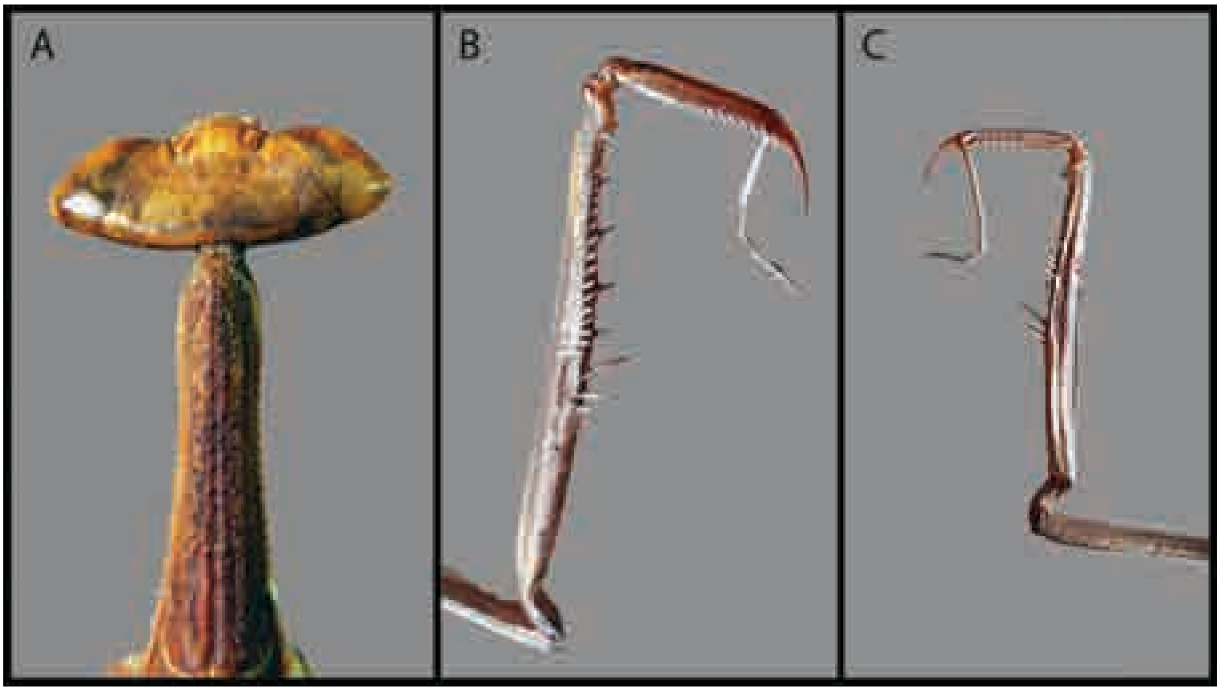

Image 2. *Deiphobella laticeps*: A—head and pronotum | B—anteroventral spines on fore femora | C—posteroventral spines on fore femora. © Hemant Ghate

Image 3. *Deiphobella laticeps* male (left) and female (right) habitus: ventral view. © Hemant Ghate

Discussion

Length of male given by Giglio-Tos (1927) is 121 mm; as our male specimen is damaged we are providing this data. The body length of the male specimen examined by Wood-Mason in the original description is 121 mm; the type locality of this species is given as 'Sheargaon, Kolapur State', now Shirgaon, Kolhapur District of Maharashtra. So, originally this species was described from Maharashtra but this fact was overlooked earlier. Recently the species was reported from various parts of Kolhapur, including Radhanagari (Raut 2017) but in subsequent report of Radhanagari Mantodea there is no mention of this species (Raut et al. 2022)

The species *D. laticeps* is thus far known only from India: Maharashtra (Ghate & Ranade 2002, but see remarks above), Karnataka (Mukherjee et al. 1995), Andhra (Rao et al. 2005), Kerala (Vyjayandi 2007) and Sri Lanka (Mukherjee et al. 1995), but this clearly is due to lack of surveys specifically for Mantodea. The species may be more widely distributed as similar habitats are present elsewhere in Maharashtra. Thorough surveys would certainly add more localities of this rarely observed / reported mantis.

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SHORT COMMUNICATION

Camera trapping records confirm the presence of the elusive Spotted Linsang *Prionodon pardicolor* (Mammalia: Carnivora: Prionodontidae) in Murlen National Park (Mizoram, India)

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Abstract: The Spotted Linsang is an elusive and infrequently recorded small carnivore believed to be distributed widely throughout southern-southeastern Asia. Here, we present the first confirmation of this species from Murlen National Park, Mizoram, a protected area with tracts of subtropical evergreen forest less than 30 km from the western Myanmar border. These records are also the first to confirm the occurrence of the species in the southern portion of northeastern India. Although we could distinguish several individuals despite low camera-trap sampling effort, this population may be threatened by opportunistic and intentional hunting using projectiles and snares meant to kill small game for wildmeat.

Keywords: Conservation, distribution, new record, northeastern India, small carnivore, snares.

The Spotted Linsang *Prionodon pardicolor* is a small, nocturnal carnivoran native to southeastern Asia and parts of eastern southern Asia (Jennings et al. 2015; Duckworth et al. 2016). Based on what little is known of this elusive species, linsangs are solitary and partially arboreal; however, very little is known about their behaviour (Lim 1973; Kuznetzov & Baranauskas 1993; Gaubert 2009). Previously classified as part of the Viverridae, linsangs are now classified in their own family, the Prionodontidae, which is considered a sister taxonomic group to the Felidae (Barycka 2007).

Spotted linsangs inhibit dense moist tropical forests, particularly lowland dipterocarp forests and some grasslands, throughout southeastern Asia (Sunquist 1982). Although information are lacking on their distribution ranges, they are known to occure in eastern Nepal, northeastern India, Bhutan, northern & central Myanmar, northern & central Thailand, Lao PDR, Cambodia, most of Vietnam, and central to southern China (Van Rompaey 1995; Zhang et al. 1997; Walston 2001; Holden & Neang 2009; Choudhury 2014). In India, the species has been recorded in the states of Assam (Choudhury 2004; Borah 2010), Mizoram (Mizo-Envis 2008; no details given), Manipur (Ramakantha 1994; Envis 2005), Nagaland (Choudhury 2002, 2013), Sikkim (Ganguli-Lachungpa 1989; Schreiber et al. 1989), Arunachal Pradesh (Singh et al. 1996; Choudhury 1999; Kumar 1999; Datta et al. 2008), Meghalaya (Khatonier &

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Lyngdoh 2021). Despite its rarity in northeastern India (Choudhury 1999) and the infrequency with which it is generally detected range-wide, the spotted linsang is listed as 'Least Concern' on the IUCN Red List of Threatened Species (Duckworth et al. 2016). However, it is considered a CITES Appendix I species and a Schedule I species by the Indian Wildlife (Protection) Act (1972).

Recently, there have been no direct efforts to research Spotted Linsangs in northeastern India, as only some opportunistic records exist. This report is part of a larger study to assess the diversity of and threats to small carnivores, with particular reference to felids and their relatives, in eastern Mizoram, a biodiversity hotspot of the Indo-Burma region.

Materials and Methods

Our study site occurred in the part of Murlen National Park (MNP) (23.53–23.7^{0}N & 92.21–92.45^{0}E), which is located in the Champhai district of Mizoram and is part of the Indo-Burman Biodiversity Hotspot (Myers et al. 2000). This protected area covers 100 km² and the recorded peak elevation is 1,929 m within the park. (highest point is recorded inside the park by gps) (Amit Kumar Bal's pers. obs.). The predominant forest types occurring in the park are tropical and subtropical mixed evergreen forests, which are distributed across undulating hills and mountainous terrain (Sharma et al. 2017). Several ongoing human activities such as logging, encroachment of livestock inside the park, widespread Jhum cultivation, and illegal hunting using firearms, snares, and other projectiles has severely threatened the wildlife diversity of MNP. (Amit Kumar Bal's pers. obs. between November 2019 – May 2022).

Our sampling occurred as part of an exploratory survey between November 2019 and May 2022. We initially overlaid a grid cell network of 1 × 1 km^2 over the area of MNP and deployed ten Cuddeback (WI, USA) C1 type digital camera-traps (20.0 megapixel) enabled with a white flash. Camera-traps were enabled to take three photos in rapid succession every time the motion sensor was triggered. Each camera-trap was installed for 40 days with a trap night of 400 days. Camera trap stations were spaced 1 km apart from nearby traps (average trap distance = 910 m). Camera-trap sensitivity was set low (minimum value), and units were placed between 1.8–4.5 m away from an animal trail, depending on the angle of intersection, so that each camera had sufficient time to detect an animal (i.e., specifically small carnivores), and take full-frame pictures. Individuals of certain carnivores, including spotted linsangs, were identified from their unique pelage markings/patterns in photographs.

Records

We obtained six images of spotted linsangs from six camera-trap stations over 400 trap nights in and around MNP (Image 1). The first individual was captured on 20 February 2020 (23.6586^{0}N, 93.3004^{0}E) at an elevation of 1,563 m, and the last was photographed on 26 March 2022 (23.6354^{0}N, 93.2907^{0}E) at an elevation of 1,800 m. We used right flanks only to identify a minimum of four different individuals (Image 2) in these six photographs; the other photos of left flanks may or may not have represented additional individuals. These are the first ever confirmed photographic records of this species from Mizoram, validating a previously suspected range extension further south into northeastern India and the Myanmar border (Figure 1). The characteristics of all records are mentioned in the table below (Table 1).

On 28 January 2022, we also discovered the carcass of a Spotted Linsang (Image 3) in the house of a local hunter in the village Murlen. After some discussion with locals to determine the reason for this individual's death, we identified that it was shot and killed by a handheld catapult or slingshot (Image 4), a local weapon that is often used by children in the area to kill birds for food and to sell locally. The hunter initially thought the species was a leopard cat when he first saw it. Despite being a lifelong resident of the region, he told us he had never seen this species before, noting that the bones, claws, and teeth of leopard cats were somewhat valuable for sale locally. He also told us that, as far as he knew, other local hunters had never encountered spotted linsangs before, and thus they don't consume its meat. The specimen was a female, and it measured at 69 cm from snout to tail, of which the tail was 35 cm in length (Image 3).

Conservation Implications

Possibly due to their arboreal, nocturnal nature and ambush predatory tactics (Van Rompaey 1995; Lyngdoh et al. 2011), there are only a handful of camera-trap records of spotted linsangs across their range. Despite their 'Least Concern' status, this may be cause for concern, as habitat loss and degradation, hunting and trade all remain important threats to the species (Schreiber et al. 1989; Lau et al. 2010; Bhupathy et al. 2013). Although the risk of linsangs being killed by hunters or poachers may be lower relative to other more terrestrial, diurnal, and gregarious mammals (Duckworth et al. 2016), the observation we report here still suggests they are vulnerable to local opportunistic hunters (Amit

Figure 1. Range extension of spotted linsang further south into northeastern India added on IUCN global distribution map of Spotted Linsang.

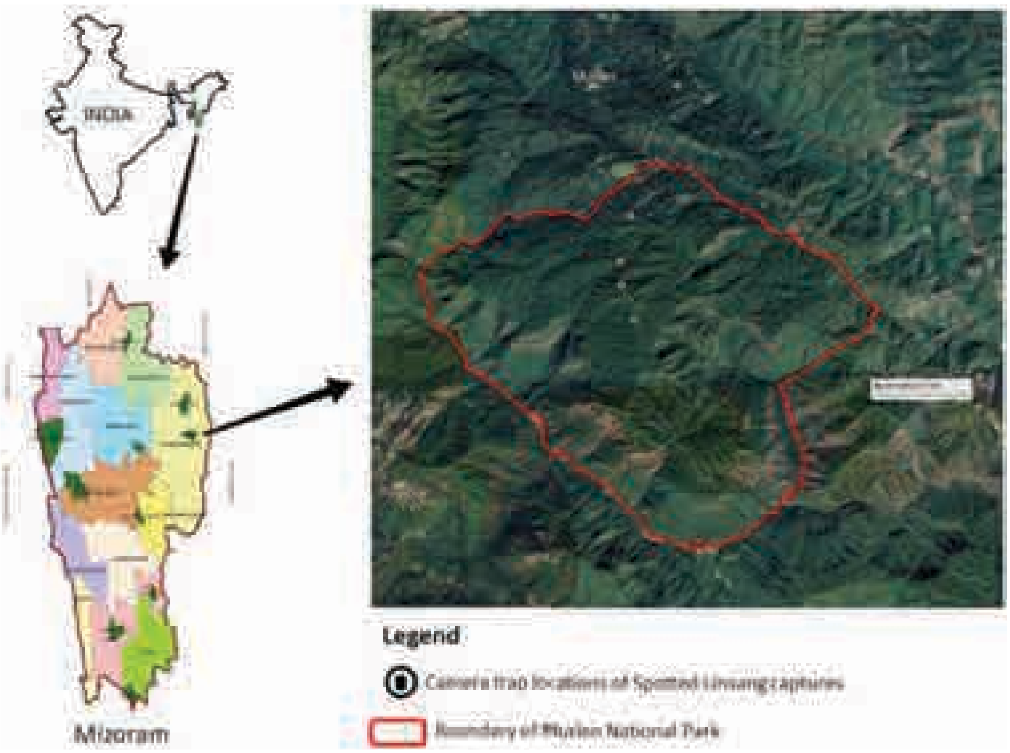

Image 1. Murlen National Park showing camera trap locations of Spotted linsang captures.

Image 2. Four individuals of Spotted Linsang photographed in Murlen national Park, Mizoram.

Table 1. The characteristics of all Spotted Linsang records.

Record No	Individual No (by right flank)	Habitat type	Elevation (in meters)	Time of day	Date
1	01	Bamboo mixed evergreen forest	1563	19:11:00	20.ii.2020
2	02	Bamboo mixed evergreen forest	1745	19:16:00	22.ii.2020
3	(Left Flank)	Bamboo mixed evergreen forest	1458	19:50:00	05.iii.2020
4	(Left Flank)	Bamboo mixed evergreen forest	1763	18:38:00	02.i.2021
5	03	Bamboo mixed evergreen forest	1748	02:28:00	12.v.2021
6	04	Bamboo mixed evergreen forest	1800	03:58:00	26.iii.2022

Kumar Bal's pers. obs. November 2019 to May 2022). In the Lower Subansiri district of western Arunachal Pradesh, indiscriminate noose-traps (i.e., snares) kill spotted linsangs (Lyngdoh et al. 2011), and Datta et al. (2008) suggested they are also killed for ornamental purposes (i.e., their skins & pelts for display) and in retribution for killing poultry. These threats suggest that diverse threats from opportunistic hunting still persist in some parts of the linsang range. To better understand the ecology and potential threats of this little-known species, we urge additional range-wide surveys and local studies specifically targeting linsangs and their behaviour highlighting its proper global conservation context.

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Image 3. Carcass of Spotted Linsang and during the measurement of the specimen. © Amit Kumar Bal.

Image 4. Catapult slingshot which is used to kill the Spotted Linsang. © Amit Kumar Bal.

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NOTE

First sighting record of the Orange-breasted Green-Pigeon *Treron bicinctus* (Aves: Columbiformes: Columbidae) from Chittaranjan, West Bengal, India

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The Orange-breasted Green-Pigeon *Treron bicinctus* is a non-migratory bird species from the family Columbidae. This species favours evergreen and moist deciduous forest types, and it is gregarious, arboreal, and frugivorous, like all other green pigeons (Dave 2014) that forages silently and slowly on trees, usually in pairs or small groups (Tanty et al. 2018). According to Ali & Ripley (1981), it is a resident bird in India with normal seasonal local movements. It is distributed in northern India from eastern Uttarakhand to Assam valley, the lower part of southern Assam hills, Himalayan foothills, and adjacent plains. In peninsular India, it ranges from West Bengal, and Chota Nagpur, southward along the Eastern Ghats, also inhabiting the Western Ghats and associated hill ranges from Kerala northward through Karnataka to Goa. The bird has its global distribution in India, Myanmar, Thailand, Malay Peninsula, and South Vietnam. Its conspecifics are also present in Sri Lanka, Java, and Hainan (Ali & Ripley 1981). However, according to Grimmett et al. (2016), the bird is a resident species of Himalaya, hills of India and Sri Lanka and had a former range in Bangladesh.

First sighting record from Chittaranjan, West Bengal: In this paper, we report the first sighting record of the Orange-breasted Green-pigeon in Chittaranjan (23.85849N & 86.92587E), West Bengal, India, with photographic evidence (Image 1). The bird was sighted on 13 March 2021, at about 1610 h, near the NCC camp on River Road in Chittaranjan. A flock of Orange-breasted Green-pigeons was perching and preening themselves on the upper canopy of the Kassod Tree *Senna siamea*. The river road of Chittaranjan is surrounded by dense vegetation on both sides. At first sight, the flock appeared to be of the commonly found Yellow-footed Green Pigeons. With the help of the photographs successfully captured, we noticed the presence of pale blue-grey nape and yellowish-green crown, yellowish-green underparts and the red feet. The male had an orange breast bordered above by a lilac band, and a grey colour in the central feathers of the tail was also observed in both sexes, which differentiated it from Yellow-footed Green Pigeons. Based on the description in Grimmett et al. (2016), the flock was recognised as Orange-breasted Green Pigeons *Treron bicinctus*.

Records from other Indian regions: Other Indian Records are from Buxa Tiger Reserve, West Bengal (Allen et al. 1996), North Tripura (Choudhury 2010), West Tripura (Bhattacharjee et al. 2013), Bhubaneswar,

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Image 1. Orange-breasted Green-Pigeon *Treron bicinctus*. © Shahbaz Ahmed Khan

Odisha (Tanty et al. 2018), Rajaji National Park, Uttarakhand (Kaushik 2013), Lucknow, Uttar Pradesh (George & Lawrence, 2015), Goa (Baidya & Bhagat 2018), Sharavathy landscape, Karnataka (Barve & Warrier 2013), Gir National Park, Gujarat (Dave 2014), Shinoli village, Maharashtra (Hiragond & Gavade 2012), Point Calimere and Sriharikota (David et al. 2015), and Kasaragod District, Kerala (Rodrigues 2020).

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BOOK REVIEW

Decoding a group of winged migrants!

Review by Priyanka Iyer

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Waders are a group of birds that are awe-inspiring and dainty but many a birder has struggled with identification of this vast group in the Indian subcontinent. To address this concern Harkirat Singh Sangha has written a comprehensive hardbound book titled, "Waders of the Indian Subcontinent".

The book has an excellent compilation of information on 84 species of waders including some of the rare and cryptic species. The book aptly handles wader identification characters with clear illustrations, geographic range with a large enough maps for each species, past works and gives briefs about each of these publications (both pre and post-independence). Some of the other topics relevant to understanding waders, migration, flyways, and all the habitats preferred by waders including specific sites where migratory waders are recorded, are succinctly covered.

Not only does the book cover ecological and historic factors but also gives a brief account of the threats that are affecting waders such as habitat loss and degradation, pollution, hunting, and global warming. This is followed by existing conservation measures/ projects including citizen science initiatives and briefly mentions the Ramsar Convention, Important Bird Areas, Coastal Regulation Zone Notification, and Convention on Migratory Species which gives the avid birder a basic understanding of the existing tools for conservation of this fantastic group.

The chapter on using this book is helpful and states how this book is a labour of love, something that is evident in the product itself for a lot of painstaking effort has gone into the minute details of the book.

The colour plates in the book are a good attempt and there are many illustrations for each species in different moults, stages of development (breeding, non-breeding, juvenile) and variations are also well showcased.

The species accounts have great detail including behaviours, status, conservation, and maps are large as

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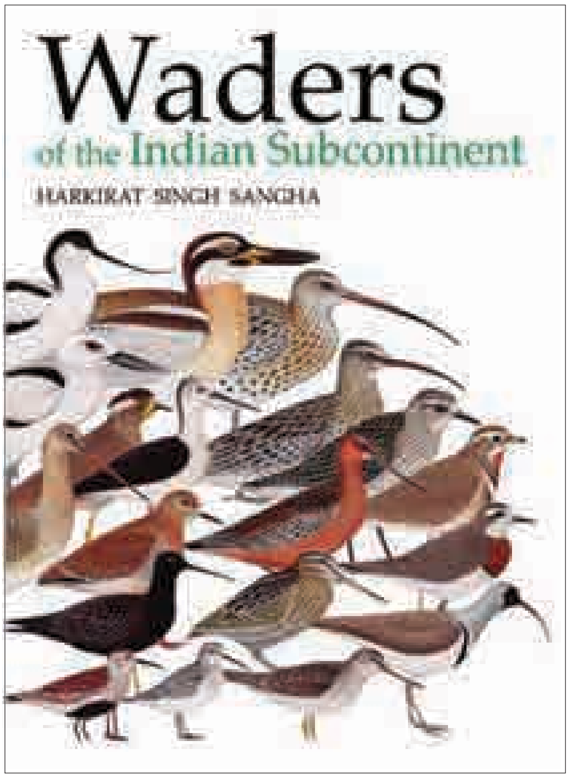

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opposed to the ones seen in field guides. Each species is represented with local names, old names, taxonomy, distribution, field characters, description (different ages/stages), racial variation, measurements, moults, vocalizations, general habits, food/foraging, breeding, habitat, movements, status & conservation, and ample photographs in various life stages, habitats, & natural light setting. This in itself is a testament to the amount of research and detailing that has gone into each species. There is also a special section not seen in field guides regarding confusion species wherein it gives the birder information and fair warning about how species 'a' may get confused with species 'b' for specific reasons. This is especially useful when tackling a group such as waders.

Each species account is very well detailed and the author has not held back any information for lack of space and this makes the book very comprehensive. The layout is neat and each photograph is well placed, including photographs of young chicks in some cases which is again helpful in case of nest sighting in the field. Each photograph is credited individually and the photographers range far and wide. The book has a total of 540 original paintings and 450 colour photographs which in itself is a stupendous task when looking at 84 species. For the purpose of this book the Indian subcontinent refers to Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka, and the Chagos. The book is a treasure trove of information and kudos to the author on this great effort. I would like to add that the book is slightly larger and heavier than a regular field guide but for avid birders it can prove extremely useful.

On the whole the book has covered all aspects connected to waders and has made references to most of the past studies on waders in the Indian subcontinent. It is undoubtedly a great book to not only identify but also understand ecology, behaviour, migration, and conservation of these complex groups.

Some of the aspects that would have improved this publication are some minor grammar issues, spacing consistency, and layout lapses. I am sure some of these challenges can be tackled in the next edition of this book. I would whole-heartedly recommend this book as a great book to start identifying and understanding waders holistically.

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BOOK REVIEW

First steps of citizen science programs in India

Review by Aishwarya S. Kumar [1] & Lakshmi Nair [2]

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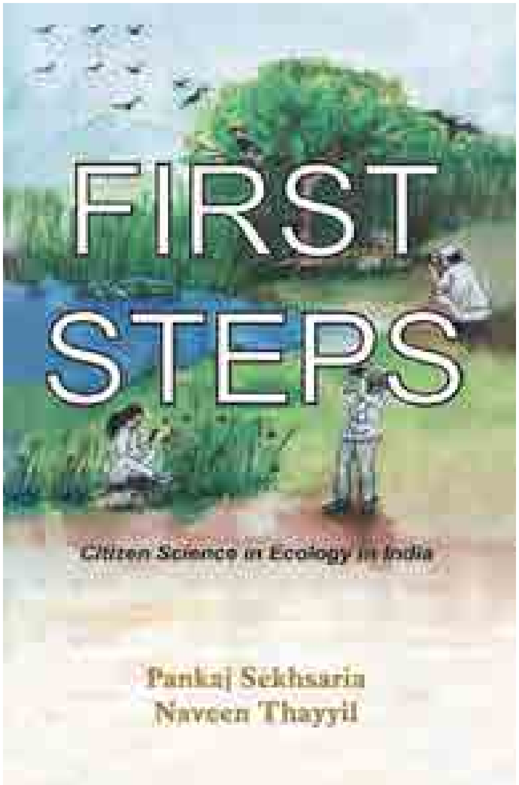

Being perhaps a country with the greatest number of citizen science programs, and with over hundreds participating in each (even thousands in some), India called for a complete compiled information on citizen science. This is where this mini book by Pankaj Sekhsaria and Naveen Thayyil stands out as a boon. First Steps provides a good overview of the ecology-based citizen science (CS) programs in India and meticulously encapsulates their different aspects. The book includes a few additions to the first of its kind initial report by the authors titled 'Citizen Science in ecology in India - an initial mapping and analysis'.

The authors open the book by talking about the popularity of citizen science programs in India (with their reportage finding space in some of the leading dailies of the country), how it has made scientific data accessible to public and, how it has contributed to a crucial component of conservation, i.e., research through crowdsourcing data. Without much delay, they quickly clarify of what to expect from their mini book which includes understanding CS as a concept, its crucial juncture, and what to expect from it as a design tool for problem-solving, future program designing, etc.

The next chapter covers the global history of CS, its contemporary developments and exponential growth ever since Alan Irwin's publication was out in 1995. These included the term 'citizen science' finding a place in the Oxford Dictionary and formation of a dedicated community for CS. Gradually, handbooks were released which, however, hardly did justice to spreading word on citizen science. The authors finally narrow down to the Indian scenario of CS and its practice, with the most popular one- Asian Waterbird Census (AWC) - dating back to 1987. The authors mention how despite this early adoption enough data could not be gathered due to various reasons. However, they also mention of how the scenario has changed for the better over the years.

Both methods of analysis—quantitative and

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qualitative—were used for the study, which the authors present in the following chapters very intricately. Dividing the programs into five different themes according to the areas gathered from them formed the former, while the latter analysed the interviews and categorized them into seven categories. At the end, they put forward their key findings from these analyses while ending on a positive note of how the field of citizen science in ecology is going to expand in India.

The book thus stands true to its nature of being a beginner's guide. Without throwing any scientific jargons at their audience, the authors describe the fundamentals of citizen science. In fact, the chronology maintained to explain all this is the catch. We liked how chapters were further divided into subsections. Also, instead of jumping straight to the research analysis on CS, the book helps build a good fundamental base in CS slowly yet in a concise manner.

The idea of inclusion of a qualitative analysis is helpful to the reader. The interview excerpts with field experts indeed provide nuances of the programs. Importantly, it also addresses many vital questions pertaining to citizen science.

Though the book has been presented well, we feel some careful edits would have made it even better. For example, the book has no footnotes for quick reference. All have been addressed only at the end of the book and hence hindered the natural reading flow. Similarly, technical terms, interview excerpts, among others could have been italicized, which would have made it a better read.

The authors highlight the ambiguity surrounding the term 'citizen science'. However, details on this have not been given. Of the many proposed nomenclatures to replace the former term (from the literature reviews we have done), the book hardly mentions any. For example, the only other mention of an alternative to the term 'citizen science' is Public Participation in Scientific Research (PPSR) which appears in an interview excerpt.

17 CS programs were listed which included outdated programs as well. Even though the authors make a mention of how the data could be redundant, however, in the annexures, they could have included the end dates of these programs too. During a cursory check, some programs which are defunct haven't yet been taken down from their website. This can confuse users and inhibit participation. To add, though the timelines have been explained quite well, a diagram would have been a better representation. A reasoning for including only 17 citizen science programs also seems to be missing.

Yet another major lacuna is that there is only a mere mention of how citizen scientists are divided on the basis of their roles, i.e., as contributors (to data) and collaborators (to data along with researchers). As a beginner's guide to citizen science, a detailed information on these terms should have been included. At least a table mentioning these terms, their definitions and their references would have been beneficial.

Overall, it is a great resource for those new to CS in ecology.

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