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Cover: A mesmerising Indian Luna moth *Actias selene* is dancing through the starry night (by Vincent van Gogh) moonlit sky, displaying its ballistic display of feather tail. Digital artwork by Vyshnavee Sneha Jaijar.



Inventory of traditional medicinal plants and ethnobotanical knowledge from Hassan District, Karnataka, India

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Abstract: Global healthcare has long benefited from traditional medical systems. Hassan District, which is geospatially located in the Western Ghats, has a long history of using traditional medicines owing to the region's rich plant diversity. This study aims to document medicinal plants and their uses in Hassan District, Karnataka, based on information obtained from 172 traditional practitioners. Semi-structured interviews and conversations were conducted using a questionnaire to gather information about traditional medicine. The popularity and significance of each plant species were quantitatively assessed. A total of 220 species in 205 genera and under 93 families were reported for potential ethnomedicinal purposes, with a larger portion of them being herbs (74 species), followed by trees (60 species). Wild plants are the primary source of herbal remedies, with 181 species. Fabaceae and Apocynaceae are the major plant families, with 24 and 14 species, respectively. Leaves (41%) were the most used plant part in ethnomedicinal formulations, followed by fruits (14%), roots (12%), and bark (9%). The highest fidelity level of 96.3% was recorded for *Rauvolfia serpentina* for snakebite and 96% by *Aloe vera* for dermatological diseases. A total of 56 species were identified within the IUCN Red List evaluation. These findings hold significant potential, offering valuable insights for future phytochemical and pharmacological investigations, as well as informing strategies for medicinal plant conservation and sustainable utilisation.

Keywords: Ethnic communities, disease, ethnobotany, fidelity level, healers, leaves, phytochemicals, questionnaire, traditional medicine, Western Ghats.

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Author details: MR. AMARA K.V. and G.M. PRASHANTH KUMAR specialised in cryptogamic botany, plant taxonomy, and ethnobotany. DR. RAJKUMAR H. GARAMPALLI, currently professor and chairman of the Department of Studies in Botany, University in Mysore, Manasagangotri, Mysore is specialised in ethnobotany and medicinal plants.

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INTRODUCTION

Indigenous or traditional knowledge is defined as knowledge that has been accumulated over many generations by people for the appropriate use of their lands, natural resources, and surroundings; it is demonstrated in their innovations, practices, and way of life (Jain 2005). Traditional medicine is a collection of the knowledge, skills, and practices based on the theories, beliefs, and experiences indigenous to various cultures, whether explicable or not, used in the maintenance of health as well as the prevention, diagnosis, improvement, or treatment of both mental and physical illnesses (WHO 2002). Approximately 80% of people in developing countries depend on traditional medicine for primary health care, with plant extracts comprising about 85% of these treatments (Farnsworth 1988; WHO 2021). Natural products have historically been a rich source of novel drug leads, with many modern pharmaceuticals derived directly or indirectly from natural sources (Li et al. 2009). An estimated 39% of the 520 newly approved medications between 1983 and 1994 were natural compounds, and of those, 74% were found through the process of bio-prospecting, which involves using plants that are utilised in traditional medicine (Wangchuk 2008). India, one of the twelve mega-diversity nations in the world, is a major centre of origin and diversity, with more than 17,000 flowering plants, of which more than 7,000 have been reported to have medicinal properties (NMPB 2015). Rural Indian communities, distant from urban centres, rely on traditional herbal medicine for primary healthcare, owing to the affordability and accessibility of medicinal plants (Kamboj 2000). The Western Ghats of India are one of the world's biodiversity hotspots due to their species richness and endemism. Traditional knowledge encompasses a wealth of socio-cultural traditions and associated knowledge systems developed, and transmitted through generations, forming an integral part of community identities (World Intellectual Property Organisation [WIPO], n.d.). A rich tradition of usage of medicinal plants among the tribes and ethnic people makes India one of the ethnobotanical hotspots of the world. Researchers were successful in exploring ethnomedicinal information in different regions of the Western Ghats of Karnataka (Bhandary et al. 1995; Mahishi et al. 2005; Bhat et al. 2014; Yogeesha & Krishnakumar 2023). Hassan District presents a valuable region for ethnomedicinal research, characterised by its abundant plant diversity and the presence of diverse ethnic communities, including the Hakki-pikki, Soliga, Medhar, and Budbudike. Notably,

172 experienced traditional healers have been identified within the district, with a significant portion expressing concern over the declining use of traditional medicinal practices (Venkatesh & Garampalli 2023). Although a few reports are available from the study area on wild medicinal plants, ethno-veterinary medicinal plants, and ethnobotany (Ravikumar & Theerthavathy 2012; Doddamani et al. 2023), a detailed record of local communities' traditional knowledge on medicinal plants is lacking, which could be helpful for future pharmacological screening and conservation aspects. Hence, this study was undertaken to address the existing lacunae in ethnomedicinal documentation of the region.

MATERIALS AND METHODS

Study area

The present study was carried out during 2020–2022 to document traditional medicinal plant knowledge from Hassan District, Karnataka, India (Figure 1). The study area lies between 12.132–13.331°N and 75.331–76.812°E, with a total area of 6,814 km², and 2,574 inhabited villages. As per the Census of India 2011, Hassan District has 433,453 households and a population of 1,776,421, of which 883,667 are males and 892,754 are females. The geography is a mix of Malnad (mountainous), semi-Malnad (plains), and maidan, making it one of the most biodiversity-rich districts in India. Characterised by a wide array of vegetation types—evergreen forests, shola forests, stunted prickly forests, dry deciduous, grasslands, dry scrub, and dry thorn forests—the Hassan District also supports diverse ethnic communities such as the Hakki-Pikki, Soliga, Medhar, and Budbudike. The majority of the population resides in rural areas, and most of the families in rural areas practice traditional medicine for various ailments.

Identifying traditional healers

Data on traditional healers in the study area was obtained by referring to the People's Biodiversity Registers of local regions, which were procured from the Social Forestry Division, Hassan. A total of 172 renowned healers were shortlisted for interviews after discussions with the BMC (Biodiversity Management Committee), members of urban & local government bodies, non-governmental organisations, village residents, school teachers, and patients visiting the traditional practitioners. Informants and healers were chosen mostly based on their popularity among locals and their expertise in traditional medicine.



Figure 1. A detailed study area map of the Hassan District.

Collection of data

Shortlisted traditional healers were contacted and visited with the help of BMC members and villagers, and the theme of the study was explained. Semi-structured interviews and conversations were conducted using a questionnaire to gather information about the traditional medicine, and consent signature was obtained after collecting the data on the questionnaire. Both qualitative and quantitative data were gathered using a questionnaire (Image 1) which included information like vernacular name, botanical name of the plant, mode of collection, part used, disease cured, mode of preparation of the formulation, and success rate. The interviews and questionnaire studies were conducted two to three times among informants in order to verify and confirm the authenticity of their plant-based knowledge. Data about the practitioner's age, gender, educational level, and language used were also obtained. Plant specimens were collected to ensure accurate identification and herbarium preparation.

Identification of plant species

Plant specimens, accompanied by digital photographs and field documentation, were gathered for subsequent herbarium preparation, and taxonomic identification. Processed plant specimens were dried and poisoned with 5% HgCl_2 to mount on herbarium sheets with detailed labelling by following the methods described by Jain & Rao (1977). Collected medicinal plants were identified with the help of local flora (Saldanha & Nicolson 1976; Saldanha 1984; Saldanha 1996). The plant names were rechecked for authenticated and updated nomenclature by visiting World Flora Online

(<http://www.worldfloraonline.org>) and Royal Botanic Gardens, Kew (<http://www.mpns.kew.org>), and the synonyms were removed to avoid taxonomic inflation. The conservation status was examined as per the IUCN Red List of Threatened Species (IUCN 2024).

Quantitative analysis of ethnobotanical data

Several quantitative indices, such as the informant consensus factor (ICF), use value (UV), family use value (FUV), fidelity level (FL), and relative popularity level (RPL), were used to analyze the ethnobotanical data.

Informant consensus factor (ICF)

The ICF value analyses the reporter's agreement with the species of medicinal plants and the degree of variation in the way those plants are used to treat diseases that have been reported. Before determining the ICF value, diseases must be generally classified into several groups. When a species' maximal ICF value is near to 1, it means that a significant share of the local population uses it to treat a certain ailment. Conversely, a species' low ICF index, which is almost equal to 0, indicates that the informants treat reported illnesses with this species at random. The formula was used to determine the ICF value (Heinrich et al. 2009).

$$ICF = (Nur - Nt) / (Nur - 1)$$

Nur = total number of use report for each disease category

Nt = the number of species used in said category.

Use value (UV)

The use value (UV) establishes the proportional significance of plant species' applications (Phillips &


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**Inventory of traditional medicinal plants and ethnobotanical knowledge from Hassan district,
Karnataka, India**

Date collection sheet

Ethno-medicinal usage	
Plant local name:	Part used:
Disease cured:	Source of plant:
Mode of preparation/ Formulation:	
Success rate:	

Details of the plant:	
Botanical Name:	Collection location:
Family Name:	Part collected:
Abundance of availability:	
Season of availability:	
Description:	

Information of the practitioner	
Name :	Age:
Gender:	
Educational background:	Years of experience:
Address:	

Declaration:

As I'm is a resident of Village and above mentioned information are given by me and are true to my knowledge.

Signature

Image 1. Questionnaire used for field study.

Gentry 1993).

$$UV = \sum U_i / N$$

UV = use value of individual species.

Ui = number of uses reported for each species.

N = number of informants who reported that species.

Relative frequency of citation (RFC)

The relative importance of a species in a study area is indicated by its RFC. The number of informants mentioning a beneficial species (FC) divided by the total number of informants in the survey (N) yields this indicator (Phillips & Gentry 1993).

$$RFC = \frac{FC}{N} \quad (0 < RFC < 1)$$

Fidelity level (FL)

FL is the proportion of informants in a study location who indicate using specific plant species to treat a given disease (Friedman et al. 1986). The maximum FL indicates the frequency and high use of the plant species for treating a particular ailment by the informants of the study area.

$$FL (\%) = \frac{N_p}{N} \times 100$$

Np = number of informants claimed a use of certain plant species for a particular disease.

N = total number of informants citing the species for any disease.

Data processing and interpretation

MS Excel 2010 was used for tabulation analysis. The results were presented as percentages, diagrams, cross-tabulation, and graphs.

RESULTS AND DISCUSSION

Demographic features of the informant

A total of 172 traditional healers were interviewed in the present study from 112 villages across 61 gram panchayats, with 80.23% being male, and the rest female. The majority of the healers were in their middle and upper-middle age group. The literacy rate of healers and practitioners (72.7%) is much lower than that of the overall district's literacy rate, which stands at 88.36%. Due to the geospatial location of Hassan District in the Western Ghats region, the area is inhabited by a significant number of traditional healers, a testament to the fact that the region's abundant medicinal plants have sustained this practice. Of the healers surveyed,

112 (65%) learned traditional medicine from their ancestors, and 36 (21%) gained their knowledge from other practitioners in their vicinity, either as apprentices or through observation. Sixteen (9%) healers from the region acquired knowledge by self-practice or experimentation, and eight (5%) by reading books. Around 31% of healers provide free services to patients, whereas 57% accept payment, with 12 healers charging fixed fees for different disease categories. Additionally, 12% of the healers have a custom of receiving products like clothes, rice, grains, and coconuts. The findings show that the practice of traditional medicine is reducing with time, with allopathic medicine taking over the majority of the study area, which corroborates an earlier report (Venkatesh & Garampalli 2023).

Taxonomic distribution of medicinal plants

A total of 220 species from 205 genera and 93 families were reported for possible ethnomedicinal use. Table 1 and Images 2–4 displays information on the scientific name, popular name, family name, habit, longevity, disease treated, conservation status, and part used, as well as the application route, mode, and procedures. The study mainly focuses on important medicinal plants of the area and specifically angiosperms. According to plant habit, herbs (74 species) were determined to be the most utilised plants (Figure 2), followed by trees (60 species), climbers (44 species), shrubs (38 species), and parasitic angiosperms, and epiphytes (4 species) in descending order. The use of herbs as medicinal plants in higher proportion was also reported in other parts of world (Tabuti et al. 2003; Muthu et al. 2006; Uniyal et al. 2006; Ralte et al. 2024) due to their availability.

Among 220 plants listed in the present study, 181 plants were categorised as wild plants, while 24 as cultivated and 15 plants were available in both wild, and cultivated habitats. The most represented families in the study area with maximum number of utilised medicinal plants in the study were Fabaceae (24 species), Apocynaceae (14 species), Rutaceae (9 species), Menispermaceae (6 species), Acanthaceae, Araceae, Asteraceae, Euphorbiaceae, Rubiaceae, Solanaceae, Verbenaceae, & Zingiberaceae (5 species each), Asparagaceae, Cucurbitaceae, Lamiaceae, Loranthaceae, Malvaceae, & Poaceae (4 species each), and Amaranthaceae, Apiaceae, Combretaceae, Convolvulaceae, Meliaceae, Phyllanthaceae, Rhamnaceae, & Zygophyllaceae (3 species each). The other 11 families are represented by two genera each and 55 families have a single genus. Earlier reports also suggest that the family Fabaceae is recognised for its global distribution and classification as

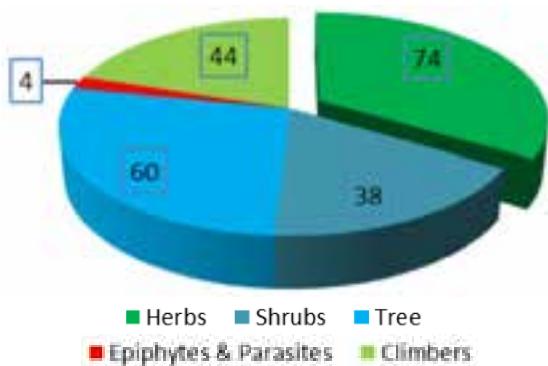


Figure 2. Plants habit.

the third largest plant family (Maroyi 2023). There are substantial investigations concerning its biochemical and pharmacological constituents (Wink 2013), and it has been the major contributor of medicinal plant species (Prabhu et al. 2014).

Plant part(s) used and mode of application

Ethnomedicinal information about the formulations in the study area revealed that leaves were the most used (41%), followed by fruits (14%), roots (12%), and bark (9%). Sap and latex are the least used parts with just 1% of medicines prepared from them (Figure 3). The results of the present survey corroborate with earlier reports where, aerial parts, especially leaves, are preferred for harvesting in herbal practices to protect plants, and ensure sustainability (Giday et al. 2009). Leaves are abundant, easily harvested, regenerate

quickly, are available year-round (Baidya et al. 2020), and contain many secondary metabolites which are effective in treating ailments related to digestive system, urinary and genital system, nervous system, respiratory system and cardiovascular system (Focho et al. 2009).

The present survey results also revealed that oral administration (61.75%) is usually recommended for the majority of ailments. Topical applications (37.51%) are recommended for skin conditions, snake bites, and wound healing, and inhalation is used to treat 0.7% formulations, which is in concurrence with earlier similar studies in other regions (Ignacimuthu et al. 2006; Luitel et al. 2014; Umair et al. 2017). Oral administration was favoured for better absorption and utilisation of bioactive compounds, and might be due to the prevalence of internal diseases in the study area (Benkhaira et al. 2021). To create a formulation for the treatment of different illnesses, traditional healers construct formulations in a variety of forms, such as decoction, powder, paste, infusion, extract, juice, poultice, tea, and ash, among others.

Informant consensus factor (ICF)

In the present study, reported illnesses were categorised into 12 distinct disease groups to calculate the ICF (Table 2) based on their use report. Among different disease categories, gastrointestinal diseases and dermatological were dominated with 102 and 88 use reports, respectively. Around 62 plant species were used to treat gastrointestinal diseases, followed by 42 species for dermatological diseases. The highest ICF

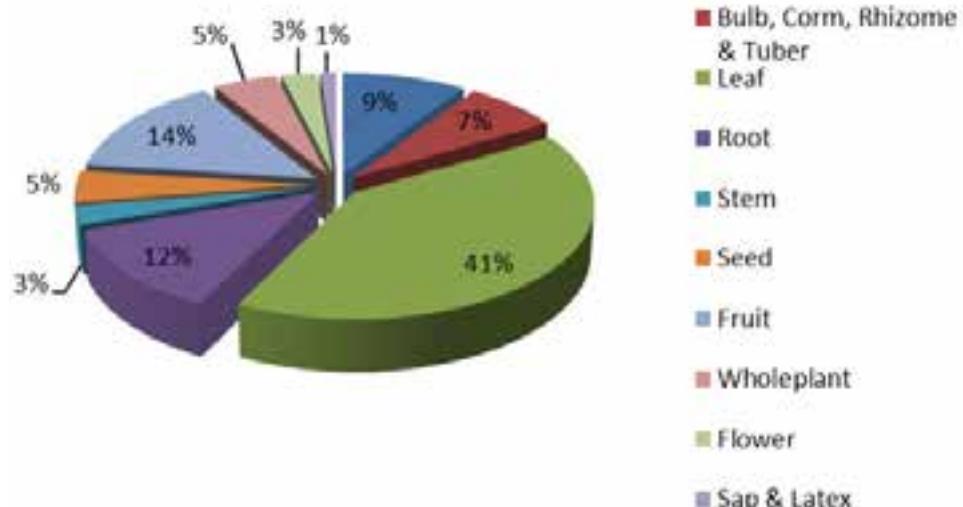


Figure 3. Plant parts used.

Table 1. Traditional medicinal plants of Hassan District.

	Local name	Scientific name	Family	Life habit and habitat/ forms			Part used	Disease treated	Application mode	Formulation or mode of preparation	UV	RFC
1	Gulaganji	<i>Abrus precatorius</i> L.	Fabaceae	W	C	A	Seeds	Paralysis	Topical	Seed paste is applied over affected area	0.38	0.18
2	Uthharani	<i>Achyranthes aspera</i> L.	Amaranthaceae	W	H	P	Whole plant	Ear fluid & earache	Topical	Filtered diluted plant extract is used as ear drop	0.66	0.22
							Leaves	Snake bite & scorpion bite	Topical	Leaf paste is applied over the bitten area		
3	Vanamugli	<i>Acmella oleracea</i> (L.) R.K.Jansen	Asteraceae	W	H	A	Leaf & Fruit	Toothache & mouth ulcers	Topical	Flower & leaf paste is diluted and gargled 3-5 time per day.	0.10	0.01
							Flowers	Toothache	Topical	Pills made from crushed flowers kept on affected teeth		
4	Irole Kande	<i>Adenia hondala</i> (Gaertn.) W.J.de Wilde	Passifloraceae	W	C	P	Leaves and roots	Skin diseases	Topical	Paste of leaves and roots applied over affected area	0.25	0.04
5	Katamahara gida	<i>Aeginetia indica</i> L.	Orobanchaceae	W	H	P	Whole plant	Diabetes & liver diseases	Oral	Juice is taken orally to empty stomach	0.11	0.02
6	Bilvapatre	<i>Aegle marmelos</i> (L.) Corrêa	Rutaceae	W/C	T	P	Fruits	Dysentery, diarrhea & piles	Oral	Ripened/ semi ripened fruit pulp grinded with milk and taken	0.50	0.11
7	Pashana bedhi	<i>Aerva lanata</i> (L.) Juss. ex Schult.	Amaranthaceae	W	H	A	Root	Kidney stone	Oral	Leaf juice is taken orally twice in a day for 3 days	0.61	0.14
8	Bhootahale	<i>Agave Americana</i> L.	Asparagaceae	W/C	H	P	Fruit	Kidney stone	Oral	Fresh fruits are chopped, boiled in salt solution & eaten	0.25	0.07
9	Mudrasada	<i>Aglaia lawii</i> (Wight) C.J.Saldanha	Meliaceae	W	T	P	Bark	Fever, influenza & cough	Oral	Bark decoction is taken orally	0.16	0.03
10	Ankole mara	<i>Alangium salvifolium</i> (L.f.) Wangerin	Cornaceae	W	T	P	Bark	Hernia	Topical	Bark paste with honey is taken orally	0.25	0.04
11	Lolesara	<i>Aloe vera</i> (L.) Burm.f.	Asphodelaceae	C	H	P	Leaves	Liver & spleen infection	Oral	Fresh leaf juice taken orally	0.75	0.26
							Leaves	Skin infections & wounds	Topical	Leaf paste is applied over affected area		
12	Dumbarasme	<i>Alpinia galanga</i> (L.) Willd	Zingiberaceae	C	H	P	Rhizome	Hypertension & heart diseases	Oral	Rhizome juice taken orally	0.54	0.16
13	Haale mara	<i>Alstonia scholaris</i> (L.) R.Br.	Apocynaceae	W	T	P	Bark	Fever	Oral	Bark decoction is taken orally	0.33	0.07
14	Hongone soppu	<i>Alternanthera sessilis</i> (L.) DC.	Amaranthaceae	W	H	A	Leaves	Blurred vision & kidney stone	Oral	Leaves are eaten raw or cooked to prepare recipe as leafy vegetable	0.22	0.03
15	Suvarnagedde	<i>Amorphophallus bulbifer</i> (Roxb) Bl	Araceae	C	H	A	Corms	Piles & gastritis	Oral	25 grams of washed corms are taken raw to empty stomach	0.40	0.09
16	Kaadu dhraakshi	<i>Ampelocissus tomentosa</i> (B.Heyne & Roth) Planch.	Vitaceaa	W	C	P	Root	Edema & wound healing	Topical	Root paste is applied over the affected area	0.15	0.02
							Leaves	Headlice	Topical	Leaf juice is applied to head and washed with warm water		
17	Kagemari gida	<i>Anamirta cocculus</i> (L.) Wight & Arn.	Menispermaceae	W	C	P	Leaves & stem	Headache & fever	Topical	Paste is applied over forehead and chest respectively	0.12	0.02

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18	Nelabevu	<i>Andrographis paniculata</i> (Burm.f.) Nees	Acanthaceae	W	H	A	Leaves	Fever, cough & cold	Oral	Whole plant is soaked overnight, and the solution is consumed empty stomach	0.50	0.12
19	Kaasina sarada gida	<i>Andrographis serpyllifolia</i> (Vahl) Wight	Acanthaceae	W	H	P	Whole plant	Viper bite	oral	Whole plant grinded with cow urine taken orally immediately after bite	0.23	0.05
20	Datthuri	<i>Argemone mexicana</i> L.	Papaveraceae	W	H	P	Stem & root	Mycosis	Topical	Stem latex and dried root powder paste is applied over affected area	0.35	0.10
							Root	Asthma	Oral	Dried root powder taken with milk twice a day		
21	Uganiballi	<i>Argyreia elliptica</i> (Roth) Choisy	Convolvulaceae	W	C	P	Latex	Wound healing & skin infections	Topical	Latex mixed grinded with ginger is applied over affected area	0.23	0.05
22	Havumaari gedde	<i>Arisaema tortuosum</i> (Wall) Schott & Endl. var. <i>tortuosum</i>	Araceae	W	H	A	Rhizome	Rheumatis & Bone fracture	Oral	Rhizome decoction is taken orally	0.24	0.03
23	Eeshwari balli	<i>Aristolochia indica</i> L.	Aristolochiaceae	W	C	P	Leaves	Biliousness	Oral	Diluted leaf juice taken orally	0.66	0.24
							Whole Plant	Arthritis	Topical	Plant paste with limestone powder is packed around affected joint		
							Root	Menstrual inducing & abortifacient	Oral	Diluted root juice is taken orally		
							Root	Skin infections	Topical	Root paste is applied over affected area		
24	Shathavari	<i>Asparagus racemosus</i> Willd.	Asparagaceae	W	S	P	Leaves	Diarrhoea & dysentery	Oral	Young leaves are eaten raw	0.52	0.09
25	Adavi nimbe	<i>Atalantia monophylla</i> (Roxb.) A.D.C.	Rutaceae	W	T	P	Leaf	Paralysis & skin infection	Topical	Dried leaves grinded paste is applied over affected area	0.45	0.09
26	Beevu	<i>Azadirachta indica</i> A.Juss.	Meliaceae	C/W	T	P	Leaves	Chickenpox	Topical	Leaves paste applied over body & leaves used in bathing water	0.52	0.11
							Leaves, bark, fruit	Dental & gastritis	Topical	Leaves are eaten raw		
27	Ganjimullu	<i>Azima tetracantha</i> Lam.	Salvadoraceae	W	S	P	Leaves	Clogged ear & mouth ulcers	Topical	Leaf juice dropped into ears. Leaf juice gargled for ulcers	0.22	0.04
28	Golisoppu	<i>Bacopa monnieri</i> (L.) Pennell	Plantaginaceae	W	H	P	Leaves	Dementia & Delayed speech	Oral	Leaf crushed with ginger is made into pill taken twice a day for 7 weeks	0.33	0.06
29	Ingudi mara	<i>Balanites aegyptiaca</i> (L.) Delile	Zygophyllaceae	W	T	P	Bark	Tumour	Oral	Bark decoction is administered orally	0.22	0.06
							Fruits	Jaundice & piles	Oral	Fruits are soaked in warm water overnight & taken orally		
30	Mullu jaaji	<i>Barleria buxifolia</i> L.	Zygophyllaceae	W	T	P	Leaves & root	Dry cough	Oral	Boiled decoction is used in gargle	0.46	0.10

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31	Mullu goranti	<i>Barleria prionitis</i> L.	Acanthaceae	W	S	P	Root	Tooth decay	Oral	Root crushed, boiled in water and decoction is used in gargle	0.29	0.05
32	Samudrakai	<i>Barringtonia racemosa</i> (L.) Spreng.	Lecythidaceae	W	T	P	Leaves	Cough & asthma	Oral	Vapors from Boiling leaf decoction is inhaled and taken orally	0.15	0.03
33	Basavanapadha	<i>Bauhinia racemosa</i> Lam.	Fabaceae	W	T	P	Leaves & Bark	Diarrhea, ringworms & tapeworms	Oral	Decoction of leaf & bark taken orally	0.60	0.20
34	Mandarahoovu	<i>Bauhinia variegata</i> L.	Fabaceae	W	T	P	Leaves	Jaundice	Oral	Leaf juice taken orally	0.42	0.09
35	Gajjalige	<i>Biancaea decapetala</i> (Roth) O. Deg.	Fabaceae	W	T	P	Root	Arthritis	Topical	Root paste is applied to affected area	0.15	0.03
							Leaves & Seeds	Jaundice	Topical & oral	Leaf paste is rubbed over body 30 min before bathing & seeds decoction is taken orally		
36	Punrnava	<i>Boerhavia diffusa</i> L.	Nyctaginaceae	W	H	P	Whole plant	Odema, diuretic, asthma & urinary disorders	Oral	Leaf & root dried powdered decoction is taken orally	0.59	0.16
37	Guggal mara	<i>Boswellia serrata</i> Roxb.	Burseraceae	W	T	P	Leaves	Arthritis	Topical	Leaf paste packed over affected joints. Powdered resin is sprayed on burning charcoal & the smoke is inhaled against cold	0.55	0.18
38	Bisila Balli	<i>Bridelia scandens</i> (Roxb.) Willd.	Euphorbiaceae	W	S	P	Root	Piles	Oral	Root powder is taken orally with coconut water	0.32	0.07
39	Murkallu mara	<i>Buchanania cochinchinensis</i> (Lour.) M.R.Almeida	Anacardiaceae	W	T	P	Seeds & bark	Impotence & premature ejaculation	Oral	Decoction from mixture of dried seeds & bark is taken orally	0.12	0.02
40	Mutthuga	<i>Butea monosperma</i> (Lam.) Taub.	Fabaceae	W	T	P	Seeds	Abortive	Oral	Seed extract taken orally for 3 days	0.25	0.04
							Bark	Piles	Oral	Bark paste is applied over the protruded hemorrhoids		
41	Maragadegida	<i>Cadaba fruticose</i> (L.) Druce	Capparidaceae	W	S	P	Leaf	Worm infestation & constipation	Oral	Leaf juice is taken orally	0.33	0.08
42	Dodda naathada gida	<i>Callicarpa tomentosa</i> (L.) L.	Verbenaceae	W	T	P	Leaves & bark	Mouth ulcers & fever	Topical	Bark paste is applied over forehead & chest for fever & Leaf decoction is gargled for ulcers	0.25	0.08
43	Yekka	<i>Calotropis procera</i> (Aiton) W.T.Aiton	Apocynaceae	W/C	S	P	Leaves	Wound healing	Topical	Milky sap is applied on the wound directly	0.62	0.26
							Leaves	Balagraha/ malnutrition	Topical	Leaves along with Basil leaves are dried, powdered and paste is applied over & tagged in a white cloth to neck.		
44	Thotteballi	<i>Capparis zeylanica</i> L.	Capparaceae	W	C	P	Lf & Fr	Wounds & boils	Topical	Paste is applied over affected area	0.41	0.09

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45	Bettha menasu	<i>Capsicum frutescens</i> L.	Solanaceae	C	S	P	Fruits	Cough	Oral	Fruits crushed with leaves of <i>Rubia cordifolia</i> and taken orally	0.19	0.02
46	Undimara	<i>Carallia brachiata</i> (Lour.) Merr.	Rhizophoraceae	W	T	P	Leaf	Oral ulcer & bad breathe	Oral	Leaves are chewed and swallowed	0.31	0.07
47	Kaage kaayi	<i>Careya arborea</i> Roxb.	Lecythidaceae	W	T	P	Bark, leaves, fruits	Sinus	Topical	Bark decoction is used as nasal drop	0.42	0.13
48	Chikka Kavali hanu	<i>Carissa spinarum</i> L.	Apocynaceae	W	S	P	Fruit	Sore throat & cough	Oral& topical	Fruits are eaten raw & leaf paste applied over throat	0.15	0.03
49	Baine mara	<i>Caryota urens</i> L.	Arecaceae	W	T	P	Sap	Gastric, stomach, & urinary problems.	Oral	Freshly collected Sap is taken orally	0.25	0.04
50	Kakke	<i>Cassia fistula</i> L.	Fabaceae	C/W	T	P	Bark Root	Dysentery Migraine	Oral Topical	Bark crushed and juice is taken orally Root crushed and filtered extract is used as nasal drops	0.71	0.31
51	Akashaballi	<i>Cassytha filiformis</i> L.	Lauraceae	W	C	P	Stem Fruit	Hair fall Conjunctivitis	Topical Topical	Stem is dried and powdered, paste is applied to hair 1 hour prior to bath Ripened fruit juice pulp used as eye drop	0.45	0.14
52	Nithyapushpa	<i>Catharanthus roseus</i> (L.) G.Don	Apocynaceae	C	S	P	Leaves & flowers Nithyapushpa	Diabetes Menorrhagia	Oral	Fresh leaves & petals are eaten raw Leaf juice taken with coconut milk twice a day	0.52	0.30
53	Buddhi mara	<i>Celastrus paniculatus</i> Willd.	Celastraceae	W	C	P	Leaf & Seeds	Insomnia	Topical	Thick paste is applied over forehead	0.56	0.20
54	Ondhelaga	<i>Centella asiatica</i> (L.) Urban	Apiaceae	W	H	A	Leaves	Cardiac problems	Oral	Leaf juice is taken with honey or cow milk	0.62	0.29
55	Pushakara moola	<i>Cheilocostus speciosus</i> (J.Konig) C.Specht	Costaceae	W	H	A	Rhizome	Diabetes, headache & body heat	Oral	Rhizome juice prepared kept overnight and taken orally	0.15	0.03
56	Nelasekkare/ Bhumisakkare	<i>Chlorophytum laxum</i> R.Br.	Asparagaceae	W	H	A	Tuber	Bronchitis & piles	Oral	Tuber juice is taken orally	0.23	0.04
57	Huragalu mara	<i>Chloroxylon swietenia</i> DC.	Rutaceae	W	T	P	Leaf & Bark Leaf & Bark	Contusions & painful joints. Wounds & rheumatism	Oral Topical	Bark decoction is taken orally Leaf paste is applied on wounds and in rheumatism	0.16	0.02
58	Sandhuballi	<i>Cissus quadrangularis</i> L.	Vitaceae	C	C	P	Whole plants	Fracture, paralysis & leg pain	Topical	Whole plant is crushed and dressed on the affected part for 12 hours daily till cure	0.53	0.16
59	Herilkayi	<i>Citrus medica</i> L.	Rutaceae	C	T	P	Fruits	Cardiac problems & diabetes	Oral	Fruit peel is boiled with salt and decoction is administered orally	0.46	0.08
60	Baari jwarada balli	<i>Clematis gouriana</i> Roxb.	Ranunculaceae	W	C	P	Leaves	Leprosy & fever	Topical	Leaf paste applied over forehead & chest for fever and over affected area for leprosy	0.33	0.06

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61	Nantuballi	<i>Clematis zeylanica</i> (L.) Poir.	Ranunculaceae	W	C	P	Leaves	Cold & headache	Inhalation	Leaf & stem grinded, boiled, vapour is inhaled	0.15	0.02
62	Naramballi	<i>Cleome gynandra</i> L.	Cleomaceae	W	H	A	Leaves	Migraine	Topical	Leaf juice is used as nasal drops	0.45	0.15
63	Gantubharangi	<i>Clerodendrum serratum</i> (L.) Moon	Verbenaceae	W	S	P	Leaves & flower	Stomach worm	Oral	Young shoot & buds paste is taken orally.	0.35	0.05
64	Shankapushpa	<i>Clitoria ternatea</i> L.	Fabaceae	W	C	P	Leaves	Stress & depression	Oral	Leaf juice is taken orally	0.22	0.05
65	Dadgiballi	<i>Cocculus hirsutus</i> (L.) Diels	Menispermaceae	W	C	P	Root	Diabetes	Oral	Dried root powder decoction is taken to empty stomach for 3 months	0.56	0.12
							Leaves	Leucorrhoea	Oral	Leaf juice taken with milk twice a day		
66	Kesavina beru	<i>Colocasia esculenta</i> (L.) Schott.	Araceae	C	H	A	Tuber	Hairfall	Topical	Corm paste is applied 30 minutes prior to bath	0.22	0.06
67	Hasaraani	<i>Convolvulus arvensis</i> L.	Convolvulaceae	W	C	A	Leaves	Constipation	Oral	Leaf juice is taken orally	0.09	0.01
68	Senabu	<i>Corchorus capsularis</i> L.	Tiliaceae	C	S	A	Root	Dysentery	Oral	Root paste with curd taken orally	0.10	0.01
69	Vishamunguli	<i>Crinum viviparum</i> (Lam.) R.Anvari & V.J.Nair	Amaryllidaceae	W	H	A	Leaves & bulb	Skin diseases & herpes	Topical	Paste mixture with salt is applied to affected area	0.15	0.02
70	Medhugoli hambu	<i>Cryptolepis dubia</i> (Burm.f.) M.R.Almeida	Apocynaceae	W	C	P	Root	Myalgia & arthritis	Oral	Root decoction is taken orally	0.45	0.11
71	Kowte kaayi	<i>Cucumis sativus</i> L.	Cucurbitaceae	W	H	A	Fruits	Whitlow	Topical	Make a whole in the fruit, put infected finger into it and kept it inside for an hour.	0.36	0.06
72	Nela tengu	<i>Curculigo orchoides</i> Gaertn.	Hypoxidaceae	W	H	A	Roots	Diabetes	Oral	Root extract is taken orally before food	0.23	0.02
73	Arishina	<i>Curcuma longa</i> L.	Zingiberaceae	C	H	A	Rhizome	Antiseptic	Topical	Rhizome juice or powder paste is applied over wound	0.65	0.22
							Rhizome	Gastritis	Oral	Powder is mixed in warm water & taken to empty stomach		
74	Amara balli	<i>Cuscuta reflexa</i> Roxb.	Convolvulaceae	W	C	P	Whole plant	Epilepsy & Anxiety	Oral	50 ml of Leaf & stem decoction with 5 gms of sugar taken orally	0.18	0.06
75	Yemme gedde	<i>Cyanotis tuberosa</i> (Roxb.) Schult. & Schult.f.	Commelinaceae	W	H	A	Tuberous root	Diabetes	Oral	Root paste with lemon juice administered orally to empty stomach for 30 days	0.29	0.06
76	Haadeballi	<i>Cyclea peltata</i> Hook.f. & Thoms.	Menispermaceae	W	C	P	Leaves	Leucorrhoe	Oral	Leaf paste given early in the morning orally for 7 days	0.45	0.13
77	Majjige hullu	<i>Cymbopogon citratus</i> (DC.) Stapf.	Poaceae	C/W	H	P	Leaves	Gastritis	Oral	Leaves are crushed and juice is drink with mixing in hotwater Leaves are boiled in water and salt for 20 min., filtered and drank	0.32	0.09

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78	Garike	<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	W	H	P	Leaves	Urinary problems & kidney stone	Oral	Leaf juice with milk taken orally	0.15	0.02
79	Konnari gedde	<i>Cyperus rotundus</i> L.	Cyperaceae	W	H	A	Whole plant	Intestinal worms & bowel complaints	Oral	Plant juice is taken orally to empty stomach	0.21	0.04
80	Beete	<i>Dalbergia Latifolia</i> Roxb.	Fabaceae	W	T	P	Bark	Fever	Oral	Bark boiled & decoction taken orally	0.12	0.03
81	Mardhuballi	<i>Dalbergia volubilis</i> Roxb.	Fabaceae	W	C	P	Leaves	Mouth ulcer & sore throat	Topical	Leaf juice is gargled thrice a day	0.09	0.01
82	Ummatthi/ Kolave hoo	<i>Datura stramonium</i> L.	Solanaceae	W/C	S	P	Leaves	Toothache	Topical	Seeds paste wrapped in cloth & kept over affected teeth (should not swallow saliva)	0.64	0.26
							Leaves	Herpes	Topical	Leaf & seed paste is applied over affected area		
83	Meese kayi gida	<i>Decalepis hamiltonii</i> Wight & Arn.	Apocynaceae	W	C	P	Root	Intestinal ulcers & gastritis	Oral	Root powder decoction is administered orally	0.59	0.23
84	Badhanike	<i>Dendrophthoe falcata</i> (L.f.) Ettingsh	Loranthaceae	W	S	P	Whole plant	Kidney stones & abortifacient	Oral	Dried powdered fruit taken with milk or buttermilk	0.15	0.03
85	Handiballi	<i>Derris scandens</i> (Roxb.) Benth.	Fabaceae	W	C	P	Stem	Myalgia	Oral	Dried stem powder decoction is taken orally with milk	0.35	0.07
86	Kaadu gumbala	<i>Dioscorea pentaphylla</i> L.	Dioscoreaceae	W	C	P	Tubers	Boils & burns	Topical	Tuber paste with coconut oil is applied over affected area	0.16	0.02
87	Boothkannu	<i>Diploclyisia glaucescens</i> (Blume) Diels	Menispermaceae	W	C	P	Leaf	Biliousness	Oral	Dried & powdered leaf is taken orally with milk	0.12	0.01
88	Lingathonde balli	<i>Diplocyclos palmatus</i> (L.) C.Jeffrey	Cucurbitaceae	W	C	A	Fruit	Infertility	Oral	Fruit juice is taken orally	0.09	0.01
89	Bandarike	<i>Dodonaea viscosa</i> Jacq.	Sapindaceae	W	S	P	Leaves	Bone fracture & arthritis	Topical	Leaf paste is packed over affected area	0.12	0.01
90	Kadu erulli	<i>Drimia indica</i> (Roxb.) Jessop	Asparagaceae	W	H	P	Bulb	Asthma	Oral	Boiled bulb decoction is taken orally	0.20	0.03
91	Krimi nashini	<i>Drosera indica</i> L.	Droseraceae	W	H	P	Whole plant	Corns & calluses	Topical	Grinded paste is applied over affected area	0.08	0.01
92	Brahmadande	<i>Echinops echinatus</i> Roxb.	Asteraceae	W	H	A	Leaves & root	Roundworm treatment	Oral	Mixer of root and leaves powder is consumed with milk to empty stomach.	0.32	0.10
93	Gurugadha soppu	<i>Eclipta prostrata</i> L.	Asteraceae	W	H	P	Whole plant	Liver problems, catarrh & cough	Oral	Leaf juice taken orally	0.62	0.18
94	Eleadike soppu	<i>Ehretia microphylla</i> Lam.	Boraginaceae	W	S	P	Leaves	Stomach pain & diarrhea	Oral	Leaf juice taken orally	0.10	0.01
95	Tupra	<i>Elaeocarpus serratus</i> L.	Elaeocarpaceae	W	T	P	Fruit	Food poisoning & dysentery	Oral	Fruit paste with butter taken orally	0.35	0.12
96	Vayu vidanga	<i>Embelia ribes</i> Burm.f.	Primulaceae	W	S	P	Fruits	Stress, headache & insomnia	Topical	Fruit juice taken orally	0.32	0.08
97	Kadu kottamri soppu	<i>Eryngium foetidum</i> L.	Apiaceae	W	H	A	Leaves	Constipation & intestinal worms	Oral	Leaf decoction made with jiggery is taken orally	0.10	0.01

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98	Akki gida	<i>Euphorbia hirta</i> L.	Euphorbiaceae	W	H	A	Root	Fever & stress	Oral	Root & leaf juice taken orally (Not more than 3 days)	0.25	0.05
							Leaves	Respiratory disorders & asthma	Oral	Leaf boiled in water, filtered, taken orally thrice a day (Not more than 3 days)		
99	Kalli	<i>Euphorbia tirucalli</i> L.	Euphorbiaceae	W	T	P	Leaves	Arthritis	Topical	Latex / milk is applied over the joints	0.19	0.03
100	Aralimara	<i>Ficus religiosa</i> L.	Moraceae	C	T	P	Leaves	Asthma & cough	Oral	Leaf boiling decoction is inhaled & fresh leaf juice is taken orally	0.32	0.10
							Bark	Paralysis	Topical	Bark paste is massaged over affected area		
101	Punarpuli	<i>Garcinia gummi-gutta</i> (L.) N.Robson	Clusiaceae	W/C	T	P	Fruit	Ulcers & weight loss	Oral	Juice made from fruits is taken orally	0.25	0.06
102	Bikke hannu	<i>Gardenia latifolia</i> Ait.	Rubiaceae	W	T	P	Fruit	Tooth decay & snake bite	Oral	Fruits are chewed & fruit juice is taken as antidote during snakebite	0.26	0.03
103	Kamsadhaballi	<i>Getonia floribunda</i> Roxb.	Combretaceae	W	C	P	Leaves	Fever	Oral	Leaf decoction taken orally	0.12	0.01
104	Thurike soppu	<i>Girardinia diversifolia</i> (Link) Fris.	Urticaceae	W	H	P	Root	constipation, gastritis	Oral	Decoction of the roots, mixed with <i>Centella asiatica</i> and taken orally	0.32	0.06
							Root	Hydrocele & oedema	Leaves	Leaves dried powdered boiled & paste applied over affected region (fresh leaves should not be touched with bare hands)		
105	Gowri gida	<i>Gloriosa superba</i> L.	Colchicaceae	W	H	A	Leaves & rhizome	Head lice	Topical	Rhizome & leaves are grinded to paste and applied to hairs with castor oil	0.55	0.16
							Tuber, seeds	Snakebite	Topical	Rhizome paste applied over bitten area		
106	Vadimadige	<i>Glycosmis pentaphylla</i> (Retz.) DC.	Rutaceae	W	S	P	Leaves & root	Liver damage & jaundice	Oral	Juice of leaf & root mixture is taken orally	0.15	0.02
107	Tadasalu	<i>Grewia tiliifolia</i> Vahl	Tiliaceae	W	T	P	Leaves & bark	Bone fracture & wound healing	Topical	Paste is plastered around the affected area	0.26	0.08
108	Madhunashini	<i>Gymnema sylvestre</i> (Retz.) R.Br. ex Sm.	Asclepiadaceae	W	C	P	Lf & Rt	Diabetes & bad cholesterol	Oral	Thoroughly boiled Decoction made from leaf & root is taken to empty stomach	0.33	0.10
109	Panchagini gedde	<i>Habenaria roxburghii</i> Nicolson	Orchidaceae	W	H	A	Tubers, leaves	Snake bite	Topical	Tubers eaten raw or juice is taken orally	0.12	0.03
110	Gandasaathi	<i>Hedychium spicatum</i> Sm	Zingiberaceae	C	H	A	Leaf, rhizome	Cough, asthma & bad breathe	Oral	Boiling decoction vapors are inhaled thrice a day	0.25	0.05
111	Mavina badanike	<i>Helianthus elastica</i> (Desr.)	Loranthaceae	W	P	P	Leaves	Kidney stone & abortifacient	Oral	A cup of leaf juice is taken orally early in the morning	0.12	0.02

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112	Sogade beru	<i>Hemidesmus indicus</i> (L.) R.Br. ex Schult.	Apocynaceae	W	H	P	Root	Impotence, infertility & blood purification	Oral	Root decoction with milk is taken orally	0.62	0.25
							Root	Impotence, urinary tract infection & skin infections	Oral	Juice of Root & leaf mixer is taken orally		
113	Kodasige	<i>Holarrhena pubescens</i> Wall. ex G.Don	Apocynaceae	W	T	P	Bark & seed,	Gastritis, intestinal worms & diarrhea	Oral	A teaspoon of dried bark & seed powder with a pinch of salt in water is kept overnight & taken on empty stomach	0.15	0.02
114	Thapsi	<i>Holoptelea integrifolia</i> (Roxb.) Planch.	Ulmaceae	W	T	P	Bark	Ringworm & scabies	Topical	Bark paste applied over affected area	0.12	0.01
115	Haasige mara	<i>Humboldtia brunonis</i> Wall.	Fabaceae	W	T	P	Leaves	Diabetes & arthritis	Oral	Decoction is taken orally and packed over joints for arthritis	0.08	0.01
116	Kaadubrami	<i>Hydrocotyle sibthorpioides</i> Lam.	Apiaceae	W	H	A	Leaves	Fever & edema	Oral & topical	Leaf juice taken orally, paste is applied over chest for fever & over legs for edema	0.11	0.01
117	Koolavalike	<i>Hygrophila auriculata</i> Schumach.	Acanthaceae	W	H	A	Leaves & root	Dysuria, renal calculi & diuretic	Oral	Pills made from grinded root and leaves, taken orally twice a day	0.12	0.01
118	Nojehullu	<i>Imperata cylindrica</i> (L.) P.Beauv.	Poaceae	W	H	P	Rhizome	Hematuria & hypertension	Oral	Cleaned rhizome is eaten raw or cooked	0.15	0.02
119	Kadu bellulli	<i>Iphigenia indica</i> (L.) A.Gray ex Kunth	Liliaceae	W	H	A	Whole plant	Gout	Oral	Juice is taken orally	0.08	0.01
							Corm	Acne & eczema	Topical	Paste is applied over affected area		
120	Kemou Kepula	<i>Ixora coccinea</i> L.	Rubiaceae	C	S	P	Flowers	Body heat	Oral	Petals juice mixed with milk and taken orally	0.25	0.02
121	Kaadu nallige	<i>Jasminum angustifolium</i> (L.) Willd.	Oleaceae	W	C	P	Leaves	Bone fracture	Oral	Leaves are grinded with egg white and taken orally	0.05	0.01
122	Mallige	<i>Jasminum sambac</i> (L.) Aiton	Oleaceae	C	S	P	Leaves	Wet dreams	Oral	Leaves grinded and mixed with buttermilk, taken to empty stomach for 7 days	0.09	0.01
123	Howtlukayi gida	<i>Jatropha curcas</i> L.	Euphorbiaceae	W/C	S	A	Leaves & fruit	Paralysis & arthritis	Topical	Crushed and boiled mixture is massaged over affected area	0.19	0.03
							Sap	Eczema & ringworm	Topical	Sap is applied over affected area		
124	Patrajeeva	<i>Kalanchoe pinnata</i> (Lam.) Pers.	Crassulaceae	W	H	P	Leaves	Leprosy	Topical	Leaf paste with turmeric is applied over the body	0.20	0.04
125	Mehandi	<i>Lawsonia inermis</i> L.	Lythraceae	C	S	P	Leaves	Heat exhaust	Topical	Leaves are grinded and paste is applied over the head and leave overnight	0.15	0.03

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126	Thumbe	<i>Leucas aspera</i> (Willd.) Link	Lamiaceae	W	H	P	Leaves	Fever	Oral	Leaves grinded and consumed with honey	0.65	0.29
							Leaves & stem cuttings	Scabies & rosacea	Topical	Leaves & stem decoction taken orally		
							Leaves & stem cuttings	Snake bite & scorpion sting	Oral	Leaves & stem decoction taken orally		
127	Bela	<i>Limonia acidissima</i> L.	Rutaceae	W/C	T	P	Leaves	Constipation & gastritis	Oral	Leaf juice is taken orally to empty stomach	0.16	0.03
128	Sampige	<i>Magnolia champaca</i> (L.) Baill. ex Pierre	Magnoliaceae	C	T	P	Leaves & flowers	Psoriasis	Topical	Leaves & flowers are grinded with coconut oil and paste is applied to the affected region	0.10	0.01
129	Kumkumadha mara	<i>Mallotus philippensis</i> (Lam.) Müll.Arg.	Euphorbiaceae	W	T	P	Leaves	Semen leakage	Oral	Leaves paste prepared with camphor is taken orally with honey	0.29	0.06
							Fruit	Intestinal worms	Oral	Fruit powder with raw milk is taken orally		
130	Bevu	<i>Melia dubia</i> Cav.	Meliaceae	W/C	T	P	Leaves	Skin infections	Topical	Leaf paste is applied over affected area	0.20	0.04
							Leaves	Food poison	Oral	Leaf juice with pinch of salt is taken to empty stomach		
131	Kadu kepula	<i>Memecylon umbellatum</i> Burm.f.	Melastomataceae	W	T	P	Leaves	Gonorrhoea	Oral	Leaf decoction boiled kept overnight and taken orally	0.15	0.02
132	Menthe	<i>Mentha arvensis</i> L.	Lamiaceae	C	H	P	Leaves	Indigestion, nausea, cold, bad breath & loose gums	Oral	Leaves are eaten raw	0.11	0.01
133	Nagasampige	<i>Mesua ferrea</i> L.	Calophyllaceae	W	T	P	Flowers	Piles	Oral	A teaspoon of Flowers paste with butter taken thrice a day	0.06	0.01
134	Anachae mara	<i>Miliusa velutina</i> (Dunal) Hook.f. & Thomson	Annonaceae	W	T	P	Bark	Gout	Topical	Bark paste is applied over affected joints	0.15	0.02
							Bark & leaves	Aphrodisiac	Oral	Leaf and bark decoction is taken orally		
135	Muttidhare muni	<i>Mimosa pudica</i> L.	Fabaceae	W	H	P/A	Root	Carbuncles	Topical	Roots grinded with lemon, pepper & garlic and applied over carbuncles	0.25	0.06
							Seeds & root	Piles, enlarged prostrate & sinus.	Oral	10 ml of diluted decoction of seeds & root is taken orally twice a day		
136	Pagade mara	<i>Mimusops elengi</i> L.	Sapotaceae	W	T	P	Bark	Tooth ache & tooth decay	Topical	Bark and leaves chewed with pinch of salt	0.08	0.01
							Leaves	Tooth cavity & loose gums	Topical	Crushed leaf with salt made into pill and kept over affected teeth		
							Fruits	Gastritis & intestinal ulcers	Oral	Ripened fruits are eaten raw.		

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137	Midi hagala	<i>Momordica dioica</i> Roxb. ex Willd.	Cucurbitaceae	W	C	A	Leaves	Fever	Oral	One glass leaf extract twice a day is consumed for 2 days	0.25	0.08
138	Noni	<i>Morinda citrifolia</i> L.	Rubiaceae	C	T	P	Fruit	Menstrual problems	Oral	Fermented fruit juice is taken orally	0.22	0.05
139	Nasgunni	<i>Mucuna pruriens</i> (L.) DC.	Fabaceae	W	C	P	Seeds	Snake bite & scorpion sting	Topical	Seed powder paste is tightly packed over bitten are	0.23	0.06
140	Karibevu	<i>Murraya koenigii</i> (L.) Sprengel	Rutaceae	C	T	P	Leaves	Iritis & cooling	Topical	Use neem water as eye drops and wash it with it.	0.32	0.12
							Leaves	Piles & edema	Topical	Leaf juice taken orally		
141	Tavare beru	<i>Nelumbo nucifera</i> Gaertner.	Nelumbonaceae	W	H	P	Leaves & rhizome	body heat, diabetes & insomnia	Oral	Juice of leaves & rhizome with buttermilk is taken orally	0.05	0.01
142	Durvasane mara	<i>Nothapodytes foetida</i> (Wight) Sleumer	Icacinaceae	W	T	P	Leaves	Cancer	Oral	Leaf decoction is administered orally	0.32	0.09
143	Thaavare	<i>Nymphaea nouchali</i> Burm.f.	Nymphaeaceae	W	A	P	Rhizome & leaves	Menorrhagia & diarrhea	Oral	Juice is taken orally	0.08	0.01
144	Thulasi	<i>Ocimum tenuiflorum</i> L.	Lamiaceae	C	H	P	Leaves & flower	Diabetes, blood pressure, nausea & vomiting	Oral	Fresh leaves & flowers are eaten raw	0.32	0.08
145	Kedige	<i>Pandanus odorifer</i> (Forssk.) Kuntze	Pandanaceae	W	S	P	Roots	Jaundice	Oral	Roots boiled in water are made into small pieces to be taken daily to empty stomach for 21 days.	0.09	0.01
146	Kosale hullu	<i>Panicum antidotale</i> Retz.	Poaceae	W	H	A	Whole plant	Sore throat	Topical	Grass is grinded with ash and applied over affected area	0.10	0.01
147	Thalavara	<i>Pergularia daemia</i> (Forssk.) Chiov.	Apocynaceae	W	C	P	Leaves	Asthma	Oral	Leaves crushed with salt, made into a pill & taken orally	0.19	0.03
148	Chatnisoppu / Pandara basale	<i>Persicaria chinensis</i> L.H.Gross	Polygonaceae	W	H	P	Leaves	Cataracts	Topical	Leaves Grinded & mucilage is filtered and used as eye drop during morning	0.08	0.01
149	Neerunji mara	<i>Ochreinauclea missionis</i> (Wall. ex G. Don) Ridsd.	Rubiaceae	W	T	P	Leaves	Rheumatism & paralysis	Topical	Leaf paste is applied over affected area	0.09	0.03
							Bark	Constipation & piles	Oral	Bark decoction taken orally		
150	Jalahippali	<i>Phyla nodiflora</i> (L.) Greene	Verbenaceae	W	H	A	Leaves	Constipation	Oral	Leaf juice is taken orally twice a day before food	0.10	0.01
151	Nelanelli	<i>Phyllanthus amarus</i> Schumach. & Thonn.	Phyllanthaceae	W	H	A	Leaves	Jaundice	Oral	Leaf juice taken orally twice a day	0.61	0.26
152	Bettadha nelli	<i>Phyllanthus emblica</i> L.	Phyllanthaceae	W	T	P	Fruit	Diarrhea & jaundice	Oral	Fruit pulp eaten raw	0.56	0.25
							Fruit, leaves	Hairfall & dandruff	Topical	Thick juice of leaf & fruit and applied as oil kept overnight		
153	Karihuli	<i>Phyllanthus reticulatus</i> Poir.	Phyllanthaceae	W	S	P	Bark	Syphilis	Topical	Bark paste is applied over affected area	0.15	0.03
							Fruits	Diabetes & diarrhea	Oral	Fruits are eaten raw		

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154	Hippali	<i>Piper longum</i> L.	Piperaceae	C	C	P	Fruit	Menstrual problems (menorrhagia & dysmenorrhea)	Oral	Pepper powder is taken orally with honey	0.60	0.24
155	Doddapathre	<i>Plectranthus amboinicus</i> (Lour.) Spreng.	Lamiaceae	C	H	A	Leaves	Bronchitis & asthma	Oral	Leaves eaten raw	0.12	0.03
156	Antu mallige	<i>Plumbago zeylanica</i> L.	Plumbaginaceae	W	H	P	Root	Poor appetite	Oral	Fresh roots are grinded with cardamom, mixed with tender coconut & drank in empty stomach	0.71	0.30
							Root	Wound healing, arthritis & tumor	Topical	Root paste is applied over the affected area		
157	Poude Mullu	<i>Polycarphaea corymbosa</i> (L.) Lam	Caryophyllaceae	W	H	A	Whole plant	Urinary calculi	Oral	Juice made with cow milk is taken orally, twice a day for 15 days	0.11	0.02
158	Gadde gonisoppu	<i>Portulaca pilosa</i> L.	Portulacaceae	W	H	A	Leaves	Fever & diuresis	Oral	Leaf juice is taken orally	0.15	0.03
159	Amarakeshi	<i>Potamogeton nodosus</i> Poir.	Potamogetonaceae	W	H	P	Leaves	Tuberculosis	Oral	Leaf juice is taken orally	0.08	0.02
160	Adke beelu	<i>Pothos scandens</i> L.	Araceae	W	C	P	Whole plant	Herpes & muscle cramp	Topical	Plant paste/ juice is applied over affected area	0.35	0.12
161	Gummadiballi	<i>Pueraria tuberosa</i> (Willd.) DC	Fabaceae	W	C	P	Tuber	Menorrhagia & Asthma	Oral	Tuber is eaten raw	0.26	0.08
162	Sarpagandha	<i>Rauvolfia serpentina</i> (L.) Benth. ex Kurz	Apocynaceae	W	S	P	Root	Snakebite, insomnia & diabetes	Oral	Root paste with curd in a copper vessel taken orally	0.62	0.28
163	Marakesu	<i>Remusatia vivipara</i> Schott	Araceae	W	E	P	Root	Pruritus & arthritis	Topical	Root paste is applied over affected area	0.06	0.01
164	Nagamallige	<i>Rhinacanthus nasutus</i> (L.) Kurz	Acanthaceae	W	S	P	Root & leaves	Eczema & scabies	Topical	Root & leaf paste with sea salt is applied over affected area	0.10	0.01
165	Kadu gulabi	<i>Rosa multiflora</i> Thunb.	Rosaceae	W	S	P	Leaves	Stress & anxiety	Oral	Leaf juice is taken orally	0.06	0.02
166	Gantubharangi	<i>Rotheeca serrata</i> (L.) Steane & Mabb.	Verbenaceaa	W	S	P	Leaves	Malarial fever & eye inflammation	Oral	Leaf juice is taken orally for Malarial fever & Diluted juice is used as drops for eyes.	0.10	0.01
167	Manjishta	<i>Rubia cordifolia</i> L.	Rubiaceae	W	C	P	Stem	Dermatitis & skin ulcers	Topical	Spiny twig is rubbed over the affected area, leaf paste applied after that	0.65	0.30
							Root	Blood purification & bad cholesterol	Topical	Root powder mixed in water & taken orally		
168	Naagadale	<i>Ruta graveolens</i> L.	Rutaceae	C	H	P	Leaves	Headache, joint pain, tendonitis & ligament damage	Topical	Leaf paste is applied on affected area and dressed with a cloth	0.54	0.24
169	Goddu mumbe	<i>Sansevieria roxburghiana</i> schult. & schult.f	Asparagaceae	W	H	P	Leaves	Cardiac problems	Oral	Leaf juice is taken orally	0.08	0.01
170	Srigandha	<i>Santalum album</i> L.	Santalaceae	C/W	T	P	Stem	Pimples, acne & blackheads	Topical	Stem paste with aloe vera applied over pimples	0.30	0.20

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171	Antawala	<i>Sapindus laurifolius</i> Vahl	Sapindaceae	W/C	T	P	Fruits	Leprosy	Topical	Paste of whole dried fruit is applied over the affected area	0.19	0.13
							Fruits	Abortifacient	Oral	Fruits soaked in water overnight and taken orally		
172	Ashoka	<i>Saraca asoca</i> (Roxb.) Willd.	Fabaceae	W	T	P	Bark	Dysentery	Oral	Pills prepared from grinded bark taken orally to empty stomach	0.15	0.06
173	Konadhaballli	<i>Sarcostigma kleinii</i> Wight & Arn.	Icacinaceae	W	C	P	Fr & Se	Rheumatism	Topical	Dried powdered paste is applied over affected area	0.12	0.02
							Bark	Leprosy & ulcer	Oral	Powdered bark is taken to empty stomach with honey		
174	Gundu badanike	<i>Scurrula parasitica</i> L.	Loranthaceae	W	P	P	Leaves	Schizophrenia & diabetes	Oral	one teaspoon of leaves powder is taken with coconut water	0.10	0.01
175	Kaadu seege	<i>Senegalia caesia</i> (L.) Maslin, Seigler & Ebinger	Fabaceae	W	C	P	Bark	Skin infections	Topical	Bark paste is applied over affected area	0.25	0.12
176	Segee kayi	<i>Senegalia rugata</i> (Lam.) Britton & Rose	Fabaceae	W	C	P	Fruit & seed	Hairfall & dandruff	Topical	Dried & powdered mixture is used as shampoo.	0.25	0.15
177	Aavarike	<i>Senna auriculata</i> (L.) Roxb.	Caesalpiniaceae	W	S	P	Root	Fever	Oral	Dried root powder is mixed with Water & taken orally	0.69	0.30
							Leaf & fruit	Diabetes	Oral	Paste mixed with lemon taken orally		
178	Agati	<i>Sesbania grandiflora</i> (L.) Poiret	Fabaceae	W	T	P	Leaves	Gastritis & body heat	Oral	Leaf juice is taken with buttermilk	0.20	0.01
							Flowers	Hairfall	Topical	Petal paste/ juice with castor oil is applies to hair one hour prior to bathing.		
179	Kadlegida	<i>Sida cordifolia</i> L.	Malvaceae	W	H	P	Leaves	Lumpy skin	Topical	Leaves are grinded with garlic & lemon, applied over the affected area	0.55	0.18
180	Baralukaddi	<i>Sida rhombifolia</i> L.	Malvaceae	W	S	P	Leaves	Inflammation, gastritis & fever.	Oral	Leaf & seeds warm decoction is taken orally	0.32	0.12
							Leaves	Rheumatism	Topical	Root paste is applied over the affected area		
181	Kalthambari	<i>Smilax zeylanica</i> L.	Smilacaceae	W	C	P	Fruit	Dental cavity	Topical	Dried fruit pill is placed over affected teeth in early stage	0.60	0.21
							Root	Arthritis	Oral	Root decoction is taken orally		
182	Ganaganike	<i>Solanum nigrum</i> L.	Solanaceae	W	H	P	Leaves & fruits	Diabetes	Oral	Leaves & fruits boiled with and taken orally to empty stomach	0.25	0.06

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				W	H	P						
183	Sunde gida	<i>Solanum virginianum</i> L.	Solanaceae	W	H	P	Fruit	Whitlow	Topical	Insert the affected finger into a ripe fruit.	0.20	0.03
							Leaves, fruit	chest pain & asthma	Oral	Decoction of fruit & root taken orally		
							Seeds	Tooth decay	Oral	Seeds pestle with pepper, made into a capsule & kept over affected teeth		
184	Moodugatti-nagida	<i>Sphaeranthus indicus</i> L.	Asteraceae	W	H	A	Leaves	Jaundice & liver problems	Oral	Leaf juice taken orally	0.55	0.19
185	Vanapaatha	<i>Stephania japonica</i> (Thunb.) Miers	Menispermaceae	W	C	P	Leaves	Dizziness & headache	Oral	Leaf juice taken with milk & sugar taken orally	0.18	0.02
186	Hegalu balli	<i>Stephanotis volubilis</i> (L.f.) S.Reuss, Liede & Meve	Apocynaceae	W	C	P	Leaves	Sneezing	Oral	Vapors from boiling leaf decoction is inhaled	0.16	0.01
187	Vishakoralu	<i>Strychnos nux-vomica</i> L.	Loganiaceae	W	T	P	Seed	Anxiety & migraine	Oral	Diluted seed decoction is taken orally	0.45	0.13
188	Nerale	<i>Syzygium cumini</i> L.	Myrtaceae	W	T	P	Bark & leaves	Dysentery	Oral	Leaf & bark juice is taken orally with raw milk	0.25	0.10
189	Hunase	<i>Tamarindus indica</i> L.	Fabaceae	W/C	T	P	Fruit	Constipation & diarrhoea	Bark & fruits	Bark decoction is taken orally	0.35	0.12
190	Pavatike	<i>Tarenna asiatica</i> (L.) Kuntze ex K.Schum.	Rubiaceae	W	T	P	Leaves	Boils & wounds	Topical	Leaf paste applied over affected area	0.15	0.05
191	Kaadu uddhu	<i>Teramnus labialis</i> (L.f.) Spreng.	Fabaceae	W	C	P	Leaves	Paralysis	Topical	Leaf paste with coconut oil is applied over affected area	0.16	0.02
192	Tare mara	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Combretaceae	W	T	P	Fruit	Hepatitis & jaundice	Oral	Fruit powder is taken orally with milk	0.32	0.17
193	Alale	<i>Terminalia chebula</i> Retz.	Combretaceae	W	T	P	Fruit	Loose & bleeding gums & mouth ulcers	Oral	Fruit powder is chewed with beetle leaf	0.19	0.09
							Fruit	Dementia & Diabetes	Oral	Powdered fruit is taken orally with milk		
194	Buduri mara	<i>Thespesia populnea</i> (L.) Sol. ex Corrêa	Malvaceae	W	T	P	Leaves	Skin infections	Topical	Leaf paste is applied over affected area	0.12	0.01
195	Chakranike	<i>Thottea siliquosa</i> (Lam.) Ding Hou	Aristolochiaceae	W	S	P	Roots	Vomiting & dysentery	Oral	Roots grinded and taken orally with lemon juice, twice daily for 2 days	0.40	0.12
196	Amruthaballi	<i>Tinospora cordifolia</i> (Thunb.) Miers	Menispermaceae	W/C	H	P	Leaves	Diabetes	Oral	Fresh leaves are eaten raw to empty stomach	0.59	0.15
							Leaves	Fever	Oral	Leaves grinded with cumin and eaten		
197	Kaadu menasu	<i>Toddalia asiatica</i> (L.) Lam.	Rutaceae	W	L	P	Root	Wounds & skin infections	Oral	Root paste is applied over affected area	0.62	0.21
							Fruit	Dry cough Asthma	Oral	Dried fruit powder decoction is administered orally		
198	Mullukombu balli	<i>Trapa natans</i> var. <i>bispinosa</i> Roxb	Trapaceae	W	H	A	Fruits	Menorrhagia & gonorrhoea	Oral	Fruits eaten raw	0.12	0.01

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199	Neggin mullu	<i>Tribulus terrestris</i> L.	Zygophyllaceae	W	H	A	Root	Male infertility & sensuality	Oral	Root juice taken orally	0.25	0.04
							Fruit & leaves	Cardiac problems	Oral	Dried & powdered mixture is mixed in water & taken orally before meals twice a day		
200	Kagemari kayi	<i>Trichosanthes tricuspidata</i> Lour.	Cucurbitaceae	W	C	P	Fruit	Migraine & ozaena	Oral	Fruit is crushed and used as nasal drop	0.16	0.03
							Root	Arthritis	Topical	Root paste is applied over affected area		
201	Kadu bende	<i>Triumfetta rhomboidea</i> Jacq.	Malvaceae	W	S	P	Leaves & fruits	Skin infections	Topical	Fruit & leaf paste grinded with salt applied over affected area	0.10	0.01
							Leaves	Intestinal ulcers	Topical	Leaf juice is taken orally		
202	Aadu mut- tada balli	<i>Tylophora indica</i> (Burm.f.) Merr.	Apocynaceae	W	C	P	Leaves	Asthma & rhinitis	Oral	Leaves crushed and sap is used as nasal drops	0.35	0.07
203	Anejondu	<i>Typha angustifolia</i> L.	Typhaceae	W	H	P	Rhizome	Kidney stones &menstruation problems	Oral	Fresh rhizome is eaten raw to empty stomach	0.08	0.01
204	Gullegida	<i>Utricularia stellaris</i> L.f.	Lentibulariaceae	W	A	A	Whole plant	Kidney stone	Oral	Plant decoction taken orally	0.06	0.01
205	Kariballi	<i>Uvaria narum</i> Wall.	Annonacea	W	S	P	Bark	Jaundice	Oral	Bark decoction in with sugar is taken orally	0.12	0.02
206	Kari jaali	<i>Vachellia nilotica</i> (L.) P.J.H.Hurter & Mabb.	Fabaceae	W	T	P	Fruits	Ulcer	Oral	Dried fruit powder taken orally along with honey or milk.	0.70	0.28
							Bark	Piles	Oral	Bark decoction is taken orally		
							Twig	Dental problems	Topical	Twig used as tooth brush. Small pieces are chewed for decay & loose gums		
207	Bandanike	<i>Vanda tessellata</i> (Roxb.) Hook. ex G.Don	Orchidaceae	W	H	P	Leaves	Indigestion & piles	Oral	Leaf juice is taken orally	0.06	0.01
208	Haruge	<i>Ventilago maderaspatana</i> Gaertn	Rhamnaceae	W	T	P	Bark	Leprosy & scabies	Topical	Bark paste is applied over affected area.	0.45	0.15
							Seeds	Diabetes	Oral	A teaspoon of seed powdered taken on empty stomach with a cup of milk.		
209	Kaadujeera	<i>Vernonia anthelmintica</i> (L.) Willd.	Asteraceae	W	S	P	Seeds	Leprosy	Topical	Seed paste applied over affected area	0.11	0.01
210	Hasiru bandu	<i>Viscum orientale</i> Willd.	Loranthaceae	W	P	P	Leaves	Migraine	Topical	Leaf paste is applied over forehead	0.08	0.02
211	Lakki	<i>Vitex negundo</i> L.	Verbenaceae	W	S	P	Leaves	Snake bite	Oral	Leaf juice taken orally	0.60	0.21
							Leaves	Asthma	Inhalation	Leaves burned and fumes inhaled		
212	Hegalu balli	<i>Wattakaka volubilis</i> Stapf.	Apocynaceae	W	C	P	Leaves	Snake bite	Topical	Leaf paste is packed over the bitten area	0.20	0.03
213	Ashwagandha	<i>Withania somnifera</i> (L.) Dunal	Solanaceae	W	S	P	Root	Stress & neural problems	Oral	Root decoction is taken orally	0.59	0.17
							Leaves & flowers	Infertility & kidney problems	Oral	Juice along with cow milk taken orally		

	Local name	Scientific name	Family	Life habit and habitat/ forms			Part used	Disease treated	Application mode	Formulation or mode of preparation	UV	RFC
214	Beppale mara	<i>Wrightia tinctoria</i> R.Br.	Apocynaceae	W	T	P	Latex & leaves	Toothache & decay	Topical	Leaves crushed in stem latex is made into a pill and kept over affected teeth	0.39	0.17
215	Beetadhavarike	<i>Xylia xylocarpa</i> Roxb. Taub.	Fabaceae	W	T	P	Bark	Vermifuge & dysentery	Oral	Decoction of bark is given orally	0.16	0.02
216	Kadu shunti	<i>Zingiber montanum</i> (J.König) Link ex A.Dietr.	Zingerberaceae	W	H	A	Rhizome	Indigestion & stomach bloating	Topical & oral	Rhizome with pinch of salt is chewed	0.42	0.12
							Rhizome	Arthritis & gout	Topical & oral	Juice taken orally & Paste is applied over affected area		
217	Shunti	<i>Zingiber officinale</i> Roscoe	Zingiberaceae	C	H	B	Rhizome	Cold & cough	Oral	Crushed rhizome is boiled in water with salt & pepper. Drink the Decoction.	0.61	0.21
218	Bore hannu	<i>Ziziphus jujuba</i> Mill.	Rhamnaceae	W	S	P	Fruit	Weight loss, bad cholesterol & hypertension	Oral	Fruit pulp kept overnight, crushed in table salt solution and taken orally.	0.26	0.12
219	Choori mullu	<i>Ziziphus oenopolia</i> (L.) Mill.	Rhamnaceae	W	S	P	Leaves	Wound healing	Topical	Leaf paste is used in dressing of wounds	0.19	0.07
							Fruit	Sore throats, dysentery & uterus inflammation	Oral	Fruits are juice is taken orally		
220	Jollu soppu	<i>Zornia gibbosa</i> Span.	Fabaceae	W	H	A	Leaves	Diabetes	Oral	Leaves are chewed and swallow to empty stomach	0.12	0.02

Habit: H—Herb | S—Shrub | C—Climber | T—Tree | Habitat: W—Wild | C—cultivated | Longevity: A—Annual | P—Perennial.

Table 2. Informant consensus factor (ICF) & fidelity level (FL).

Category of diseases	Number of use-report	Number of taxa used	ICF	Plants with the highest Fidelity (%)
Gastrointestinal diseases	102	62	0.40	<i>Cymbopogon citratus</i> (0.68), <i>Aegle marmelos</i> (0.62), <i>Momordica dioica</i> (0.59), <i>Garcinia gummi-gutta</i> (0.58)
Respiratory diseases	38	28	0.27	<i>Solanum virginianum</i> (82.0), <i>Euphorbia hirta</i> (71.6)
Muscles & Bone disorders	40	32	0.20	<i>Plumbago zeylanica</i> (61.5), <i>Grewia tiliifolia</i> (54.1)
Urinary disorders	23	20	0.14	<i>Cynodon dactylon</i> (86.7), <i>Boerhavia diffusa</i> (72.4)
Sexual disorders	32	21	0.35	<i>Aristolochia indica</i> (19.6), <i>Diplocyclos palmatus</i> (16.6)
Glandular disorders	41	28	0.32	<i>Tinospora cordifolia</i> (92.3), <i>Cheilocostus speciosus</i> (86.4), <i>Curculigo orchioides</i> (65.4)
Ear, Nose, Eyes and Mouth(ENEM)disease	29	20	0.32	<i>Vachellia nilotica</i> (66.2), <i>Terminalia chebula</i> (45.3), <i>Gardenia latifolia</i> (39.8)
Dermatological	88	42	0.52	<i>Aloe vera</i> (96.0), <i>Rubia cordifolia</i> (85.6), <i>Melia dubia</i> (66.2)
Nervous disorders	16	13	0.20	<i>Withania somnifera</i> (77.6), <i>Strychnos nux-vomica</i> (66.8)
Cardiovascular disorders	12	10	0.18	<i>Centella asiatica</i> (36.3), <i>Citrus medica</i> (35.0)
Snake & scorpion bite	14	13	0.07	<i>Rauvolfia serpentina</i> (96.3), <i>Habenaria roxburghii</i> (65.6)
Infectious	26	18	0.32	<i>Zingiber officinale</i> (62.3), <i>Leucas aspera</i> (61.9)

value was recorded for dermatological diseases (0.52), followed by gastrointestinal disease (0.40) categories, while the lowest ICF value was recorded for snake & scorpion bites (0.07), and urinary disorders (0.14)

categories. These findings reveal that dermatological and gastrointestinal disorders are frequent in the study area. Similar results have been reported in different studies (Ayyanar & Ignacimuthu 2011; Umair et al. 2017)

Table 3. IUCN Red List categories of medicinal plants in Hassan District.

	Scientific name	Family	IUCN status
1	<i>Hygrophila auriculata</i> Schumach.	Acanthaceae	Least Concern
2	<i>Crinum viviparum</i> (Lam.) R.Ansari & V.J.Nair	Amaryllidaceae	Least Concern
3	<i>Centella asiatica</i> (L.) Urban	Apiaceae	Least Concern
4	<i>Hydrocotyle sibthorpioides</i> Lam.	Apiaceae	Least Concern
5	<i>Calotropis procera</i> (Aiton) W.T.Aiton	Apocynaceae	Least Concern
6	<i>Carissa spinarum</i> L.	Apocynaceae	Least Concern
7	<i>Decalepis hamiltonii</i> Wight & Arn.	Apocynaceae	Endangered
8	<i>Holarhena pubescens</i> Wall. ex G.Don	Apocynaceae	Least Concern
9	<i>Pergularia daemia</i> (Forssk.) Chiov.	Apocynaceae	Least Concern
10	<i>Colocasia esculenta</i> (L.) Schott.	Araceae	Least Concern
11	<i>Caryota urens</i> L.	Arecaceae	Least Concern
12	<i>Eclipta prostrata</i> L.	Asteraceae	Least Concern
13	<i>Sphaeranthus indicus</i> L.	Asteraceae	Least Concern
14	<i>Garcinia gummi-gutta</i> (L.) N.Robson	Clusiaceae	Least Concern
15	<i>Gloriosa superba</i> L.	Colchicaceae	Least Concern
16	<i>Cuscuta reflexa</i> Roxb.	Convolvulaceae	Least Concern
17	<i>Alangium salvifolium</i> (L.f.) Wangerin	Cornaceae	Least Concern
18	<i>Cheilocostus speciosus</i> (J.Konig) C.Specht	Costaceae	Least Concern
19	<i>Cyperus rotundus</i> L.	Cyperaceae	Least Concern
20	<i>Drosera indica</i> L.	Droseraceae	Least Concern
21	<i>Euphorbia tirucalli</i> L.	Euphorbiaceae	Least Concern
22	<i>Mallotus philippensis</i> (Lam.) Müll.Arg.	Euphorbiaceae	Least Concern
23	<i>Biancaea decapetala</i> (Roth) O. Deg.	Fabaceae	Least Concern
24	<i>Butea monosperma</i> (Lam.) Taub.	Fabaceae	Least Concern
25	<i>Cassia fistula</i> L.	Fabaceae	Least Concern
26	<i>Dalbergia latifolia</i> Roxb.	Fabaceae	Vulnerable
27	<i>Derris scandens</i> (Roxb.) Benth.	Fabaceae	Least Concern
28	<i>Mimosa pudica</i> L.	Fabaceae	Least Concern

	Scientific name	Family	IUCN status
29	<i>Saraca asoca</i> (Roxb.) Willd.	Fabaceae	Vulnerable
30	<i>Senegalia caesia</i> (L.) Maslin, Seigler & Ebinger	Fabaceae	Least Concern
31	<i>Tamarindus indica</i> L.	Fabaceae	Least Concern
32	<i>Vachellia nilotica</i> (L.) P.J.H.Hurter & Mabb	Fabaceae	Least Concern
33	<i>Barringtonia racemosa</i> (L.) Spreng.	Lecythidaceae	Least Concern
34	<i>Iphigenia indica</i> (L.) A.Gray ex Kunth	Liliaceae	Least Concern
35	<i>Magnolia champaca</i> (L.) Baill. ex Pierre	Magnoliaceae	Least Concern
36	<i>Aglaia lawii</i> (Wight) C.J.Saldanha	Meliaceae	Least Concern
37	<i>Azadirachta indica</i> A.Juss.	Meliaceae	Least Concern
38	<i>Nelumbo nucifera</i> Gaertner.	Nelumbonaceae	Least Concern
39	<i>Vanda tessellata</i> (Roxb.) Hook. ex G.Don	Orchidaceae	Least Concern
40	<i>Aeginetia indica</i> L.	Orobanchaceae	Least Concern
41	<i>Pandanus odorifer</i> (Forssk.) Kuntze	Pandanaceae	Least Concern
42	<i>Phyllanthus emblica</i> L.	Phyllanthaceae	Least Concern
43	<i>Bacopa monnieri</i> (L.) Pennell	Plantaginaceae	Least Concern
44	<i>Carallia brachiata</i> (Lour.) Merr.	Rhizophoraceae	Least Concern
45	<i>Ochreinauclea missionis</i> (Wall. ex G. Don) Ridsd.	Rubiaceae	Vulnerable
46	<i>Aegle marmelos</i> (L.) Corrêa	Rutaceae	Near Threatened
47	<i>Chloroxylon swietenia</i> DC.	Rutaceae	Least Concern
48	<i>Citrus medica</i> L.	Rutaceae	Least Concern
49	<i>Glycosmis pentaphylla</i> (Retz.) DC.	Rutaceae	Least Concern
50	<i>Azima tetracantha</i> Lam.	Salvadoraceae	Least Concern
51	<i>Santalum album</i> L.	Santalaceae	Vulnerable
52	<i>Mimusops elengi</i> L.	Sapotaceae	Least Concern
53	<i>Capsicum frutescens</i> L.	Solanaceae	Least Concern
54	<i>Typha angustifolia</i> L.	Typhaceae	Least Concern
55	<i>Callicarpa tomentosa</i> (L.) L.	Verbenaceae	Least Concern
56	<i>Balanites aegyptiaca</i> (L.) Delile	Zygophyllaceae	Least Concern

for the highest values recorded for said categories. High ICF values suggest effective treatments and could help identify promising plant taxa for novel phytocompounds (Giday et al. 2009).

Fidelity level (FL)

The fidelity level (FL) of the most significant plant species employed for various disease categories was

determined (Table 2). Higher FL of a species shows the extensive use of a plant species to treat a specific disease in the study area. The highest FL of 96.3% by *Rauvolfia serpentina* for snakebite and 96% by *Aloe vera* for dermatological diseases was recorded. Species like *Cymbopogon citratus* (0.68%), *Solanum virginianum* (82.0%), *Cynodon dactylon* (86.7%), *Cheilocostus speciosus* (86.4%), *Withania somnifera* (77.6%), and

Vachellia nilotica (66.2%) recorded the highest FL for gastrointestinal diseases, respiratory diseases, urinary disorders, diabetes, nervous disorders, and dental problems, respectively. *Aristolochia indica* (19.6%) and *Diplocyclos palmatus* (16.6%) exhibited lower FL for sexual disorders, indicating the less common usage of those plants in the study area.

Higher FL% for widely used species indicated that many people used them frequently, whereas lower FL% indicated that the informants did not agree on the same species. Prior researchers analysed ethnobotanical data using FL% as a quantitative measure (Ayyanar & Ignacimuthu 2011). Higher preference species can be used for pharmaceutical research to confirm their utility because they are frequently biologically active and have potent therapeutic qualities (Trotter & Logan 1986). Low FL% plants should not be disregarded either, as doing so might risk traditional knowledge, and despite their rarity, they may still have a number of medicinal applications (Chaudhary et al. 2006).

Relative frequency of citation (RFC) and use value (UV)

The RFC index verifies the frequency of citations for a medicinal plant species used to treat various diseases. Maximum RFC was calculated for *Cassia fistula* (0.31), *Senna auriculata* (0.30), *Rubia cordifolia* (0.30), *Plumbago zeylanica* (0.30), *Leucas aspera* (0.29), and *Centella asiatica* (0.29), indicating that they were reported by the highest number of informants, resulting in a high FC.

It can be correlated that high RFC values indicate widespread use and strong traditional knowledge of a plant, often due to its availability, and therapeutic benefits (Faruque et al. 2018). These species should be prioritised for phytochemical and pharmacognostic studies for drug discovery, as they are culturally significant, and locally effective (Ahmad et al. 2017).

Use value results ranged from 0.05–0.71 (Table 1). The maximum UV was reported for *Cassia fistula* (0.71), followed by *Senna auriculata* (0.69), *Achyranthes aspera* (0.66), *Aristolochia indica* (0.66), and *Leucas aspera* (0.65). These findings demonstrate the widespread usage of these species in the treatment of numerous diseases by local healers, as well as indigenous peoples' awareness, making medicinal plants the first choice for disease therapy. The lowest UV was recorded for *Nelumbo nucifera* (0.05), *Vanda tessellata* (0.06), *Rosa multiflora* (0.06), and *Mesua ferrea* (0.06), indicating less usage or minimal consciousness of healers about those plants.

The present study results on use value corroborate

with earlier reports on ethnomedicinal plants, which showed similar conclusions (Vendruscolo & Mentz 2006; Siram et al. 2023; Tamang et al. 2023). The UV index measures the relative importance of plant species in a population (Uniyal et al. 2006). Higher UV indicated widespread availability and familiarity among locals (Haq et al. 2023), often making these plants the first choice for treatment (Rahman et al. 2016).

CONSERVATION STATUS

Ethnomedicinal plant species are classified according to the IUCN Red List. Only 56 of the 220 species recognised at the species level are on the IUCN Red List (Table 2). In the study region, 51 species were considered least concerned (LC), *Dalbergia latifolia* Roxb., *Ochreinauclea missionis* Wall. ex G.Don Ridsd., *Santalum album* L., *Saraca asoca* Roxb. Willd. (four species) were found to be 'Vulnerable' and *Aegle marmelos* (L.) Correa (one taxon) was found to be 'Near Threatened', and *Decalepis hamiltonii* Wight & Arn. (one taxon) as 'Endangered'. Listing of *Decalepis hamiltonii* in the endangered category can be correlated with its distribution in the forests of hotter areas of India, which is an example of the effect of large-scale and indiscriminate collection of wild populations, which results in a rare, and threatened status of medicinal plants (Ali et al. 2016). Conservation efforts should be directed towards saving these species before they become rare in the region.

CONCLUSION

The survey revealed that many medicinal plant species are used by local traditional healers to treat various diseases. Most traditional medicinal practices are restricted to rural areas of the surveyed region. They still depend upon the traditional and tribal medicinal system to manage their health care needs. Medicinal plants are the main ingredient in their medicines; apart from these, herbal resources, minerals, and animal resources are also utilised for the preparation of medicines. They inherit the traditional medicinal plants knowledge either vertically from their forefathers (passed down through generations) or horizontally by acquiring knowledge from other practitioners in their vicinity, as apprentices, or through observation.

A tribal community, Hakki Pikki from the study area, has manufactured hair oil under the brand name 'Adhivaasi' and sells it as a remedy for hair fall as well as topical massage oil for muscle, joint, and minor diseases. Various plants that are recorded in the study area, like

*Abrus precatorius L.**Adenia hondala (Gaertn.) W.J.de Wilde**Aerva lanata (L.) Juss. ex Schult.**Andrographis paniculata (Burm.f.) Nees**Arisaema tortuosum (Wall.) Schott**Aristolochia indica L.**Asparagus racemosus Willd.**Atalantia monophylla (Roxb.) A.DC.**Bacopa monnieri (L.) Pennell**Boerhavia diffusa L. nom. cons.**Boswellia serrata Roxb.**Butea monosperma (Lam.) Taub.**Capparis zeylanica L.**Centella asiatica (L.) Urban**Cheilocostus speciosus (J.Konig) C.Specht*

Image 2. Important medicinal plants of Hassan District. © Authors.

*Chloroxylon swietenia DC.**Clerodendrum serratum (L.) Moon.**Coccus hirsutus (L.) W.Theob.**Cyclea peltata Hook.f. & Thoms**Decalepis hamiltonii Wight & Arn.**Diplocyclos palmatus (L.) C.Jeffrey**Drimia indica (Roxb.) Jessop**Eclipta prostrata (L.) L..**Eryngium foetidum L.**Gardenia latifolia Ait.**Gloriosa superba L.**Gymnema sylvestre R. Br.**Hemidesmus indicus (L.) R.Br.**Iphigenia indica (L.) A.Gray ex Kunth**Kalanchoe bhidei T.Cooke*

Image 3. Important medicinal plants of Hassan District. © Authors.



Memecylon umbellatum
Burm.f.



Mucuna pruriens (L.) DC.



Nothopadytes nimmoniana
(Grah.) Mabb.



Plumbago zeylanica L.



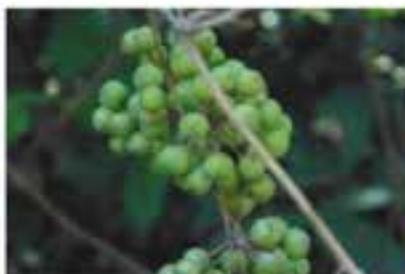
Rubia cordifolia L.



Ruta graveolens L.



Sapindus laurifolius Vahl



Smilax zeylanica L.



Solanum virginianum L.



Tarenna asiatica (L.) Kuntze ex
K.Schum



Terminalia bellirica L.



Tribulus terrestris L.



Tylophora indica (Burm f.)
Merill.



Vachellia nilotica (L.)
P.J.H.Hurter & Mabb.



Wrightia antidysenterica (L.) R.Br.

Image 4. Important medicinal plants of Hassan District. © Authors.



Image 5. Field study, interaction with local people, and collection of plant material. © Authors.

Habenaria roxburghii and *Ochreinauclea missionis* are still scientifically not evaluated for potential pharmacological activity, and drug discovery. The findings of the present study highlight the importance of preserving traditional knowledge, exploring the potential of medicinal plants for drug discovery and conservation of medicinal plants listed under the IUCN Red List threatened categories.

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An annotated checklist of lianas in Manipur, India

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Abstract: The taxonomic inventorization of lianas growing in the state of Manipur (India) has been attempted since 2013. A checklist prepared from different published literature enumerates the occurrence of 98 lianas in the state. Of these, 11 species could not be traced in the field; however, 17 are represented by herbarium specimens housed at the herbarium CAL. All the taxa enumerated are presented here with their phenology, voucher number, accession number, and place of occurrence in the study area. Photographs of some selected less known species are provided to enable quick identification. Conservation and maintenance of germplasm of these unique growth forms are critically important for ensuring their long-term survival and potential future use.

Keywords: Angiosperms, conservation, diversity, enumeration, gymnosperm, Indo-Myanmar, northeastern India, phenology, taxonomy, woody climbers.

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Author contributions: First author (LMC) collected the specimens from the field, worked out, identified, prepared the specimens for the herbarium and drafted the manuscript. Corresponding author (DB) supervised the work, checked the manuscript and communicated it to the journal.

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INTRODUCTION

Lianas, the woody climbing plants, are one of the most interesting growth forms (Image 1) in the plant world owing to their curious habit (Schnitzer & Bongers 2002). They are dominantly found in the tropical regions of the globe. Using support from trees and other vertical objects, they reach the forest canopy to access maximum sunlight for their food assimilation. They own varied climbing mechanisms and have several modified adaptive features to fasten themselves with the other plants, viz., hooks, stem twiners, tendrils, and thorns (Bongers et al. 2002; Gerwing et al. 2006).

Lianas are important structural and functional components of plant communities in most tropical and temperate forests. They are important contributors to the species diversity of the forests and perform significant role in regeneration of the forest and carbon sequestration (Schnitzer & Bongers 2002). Lianas constitute around 25% of woody species diversity in lowland tropical moist and wet forests. Despite their contribution to the diversity of forests, they are also used as foods and arboreal pathways for many forest animals particularly, primates (Gentry 1991; Schnitzer & Bongers 2002). In addition to this, they are also widely used by the local people for medicine, house construction, and artisan work (Bongers et al. 2002). Considering the importance of this growth-form, it was felt to prepare a comprehensive checklist of lianas in the state of Manipur.

In this study, a checklist of the lianas growing in Manipur state was prepared obtaining data from different literature (Hooker 1875–1894; Deb 1957, 1961a,b; Chaudhuri & Naithani 1985; Singh et al. 2000; Chanu & Bhattacharyya 2017, 2020, 2023), all known collections housed in Eastern Regional Centre, Botanical Survey of India (ASSAM), Shillong and Central National Herbarium, Botanical Survey of India (CAL), Howrah, and extensive field visits in the study area from 2013–2020. This study reveals the occurrence of 98 species of lianas in the state out of which 11 are in doubt.

MATERIALS AND METHODS

Study area

Manipur, the northeastern state of India, is situated at the confluence of two important biodiversity hotspots of the world — the Himalayas and the Indo-Burma. The state is bordered by Nagaland on the northern side, Mizoram in the southwestern, Assam on the

western side, and shares an international border with Myanmar in the eastern side (Figure 1). The state lies between 24.664° N and 93.906° E. Total geographical area covered by the state is about 22,327 km² with an elevation ranging from 40–2994 m. The state comprises lush green valleys to towering peaks and is the tapestry of biodiverse elements. According to the Forest Survey of India report (Anonymous 2019), the recorded forest area of the state is 17,418 km², which constitutes about 78% of the total geographical area of the state. The state's major area is covered by various types of forests, viz., subtropical deciduous forests, subtropical semi-evergreen forests, montane wet temperate forests, subtropical dry temperate forests, and subtropical pine forests (Singh 2014). The state is famous for Loktak Lake, a Ramsar site wetland, which is exclusively unique for Phumdi/Phumthi/Phum—the floating islands. In addition to this, the state is also famed for Siroi Lily *Lilium mackliniae* Sealy, the state flower, and the Sangai or Dancing Deer *Rucervus eldii eldii* (McClelland, 1842)—both endemic to the state.

Data collection and analysis

Several random field explorations have been conducted since 2013 in different natural habitats of Manipur. Surveys were also done in some areas covered under wildlife sanctuaries and reserved forests of the state, viz., Yangoupokpi-Lokchao Wildlife Sanctuary, and Nongmaiching Reserved Forest. Explorations were conducted in almost all the seasons in forest-dominated and species-rich areas of the state. Collections were mainly made during their flowering and fruiting periods to facilitate easy identification of the species. The specimens were tagged with voucher numbers during the collection and all the relevant field data — such as the elevation, habitat, phenology, their occurrence in the field, and the mode of their climbing mechanism were noted. A total of 44 localities were visited for the collection purposes (Figure 1, Table 1).

Identification of species

The collected specimens were assigned collection numbers, pressed, dried, poisoned, and mounted on the herbarium sheets following the routine herbarium practices (Jain & Rao 1977; Singh & Subramanium 2008). Identifications of the specimens were done based on their vegetative and reproductive characters with the aid of different existing literature (Hooker 1875–1894; Deb 1957, 1961a,b; Chaudhuri & Naithani 1985; Singh et al. 2000; EFloras of India 2017).

The reproductive parts of the specimens were

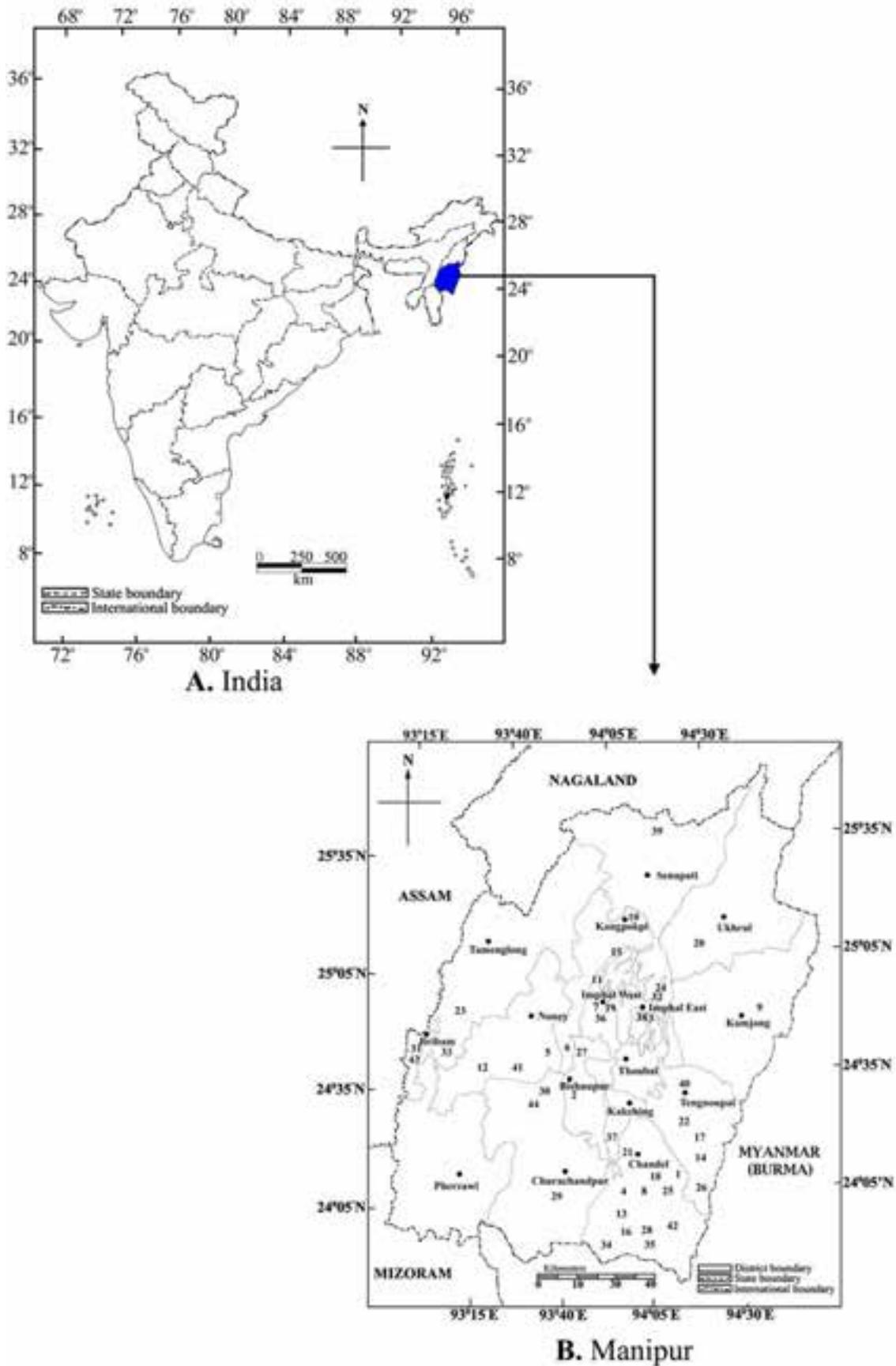


Figure 1. Map showing collection sites in the study area Manipur [number in the map (B) corresponds to number in Table 1].

Table 1. Collection sites with their elevation (the locality number corresponds to number in Figure 1B).

	Place of occurrence	Altitude (in m)
1	Beru Anthi	880
2	Bishempur	820
3	Canchipur	777
4	Chakpi karong	1000
5	Charoi Chakotloi	1126
6	Chiru village	1097
7	Hiyangthang	800
8	Gohok village	1000
9	Kamjong	913
10	Kangpokpi	1097
11	Khonghampat	793
12	Khoubum	1260
13	Khubung khunau	1000
14	Khudengthabi	1450
15	Khurkhul	901
16	Khuyam khulen	1000
17	Kwatha Lamgai	1450
18	Lamkang Khunthak	1293
19	Lilong Chajing	786
20	Litan	1318
21	Litantampak khul	790
22	Lokchao	1293
23	Makru	1260
24	Moirang purel	740
25	Mongsang Pantha	1293
26	Moreh	800
27	Nambol ching	780
28	Nepali kuthi	783
29	Ngaloi	1082
30	Ngarian hill	1340
31	Ningsingkhul	80
32	Nongmaiwing hill	795
33	Pangkhotpai village	64
34	Sajik Tampak	1000
35	Salluk	1232
36	Samurau	768
37	Serou	898
38	Singjamei	786
39	Tadubi	1700
40	Tengnaupal	1450
41	Thangal	1340
42	Thorcham	1340
43	Uchathol	80
44	Vanok	832

dissected under an Olympus SZ61 Stereo Zoom Dissecting Microscope and studied critically comparing with the existing relevant standard taxonomic literature. After preliminary identification, the same was again confirmed by comparing and checking against the authentic specimens housed in Central National Herbarium, Botanical Survey of India (CAL) and Eastern Regional Centre, Botanical Survey of India, Shillong (ASSAM). Images of type specimens available at different authentic e-platforms were also browsed. Correct names and synonymy were checked and updated from the authentic online resources, including IPNI (2025), POWO (2025), Tropicos (2025), and WFO (2025). In the present study, all the species are enumerated with their respective families, phenology, place of occurrence, voucher number, and accession number and arranged alphabetically in a tabular form (Table 2) following APG IV Classification (2016). The voucher specimens were deposited in the herbarium of Eastern Regional Centre, Botanical Survey of India (ASSAM), Shillong. Duplicate copies were kept in the Central Herbarium of Assam University, Silchar (AUSCH).

RESULTS

In this present study, a total of 87 liana species are documented from Manipur State (Table 2). Out of 98 lianas enumerated from the state on the basis of literature review (Hooker 1875–1894; Deb 1957, 1961a,b; Chaudhuri & Naithani 1985; Singh et al. 2000; Chanu & Bhattacharyya 2017, 2020, 2023), 11 species could not be located in the field or found as herbarium specimens (Table 3). Hence, the occurrence of these 11 species are treated here as doubtful in the state.

Among the rest of the 87 species, 70 species (including three varieties and one subspecies) were located across different habitats within the study area, under 25 families and 53 genera while, other 17 species are only reported on the basis of the herbarium specimens. Of these, 86 species belong to angiosperms, while a single species represents gymnosperm. The most dominant family recorded (Figure 2) was Fabaceae (22 species under 16 genera), followed by Vitaceae (10 species under 3 genera), Apocynaceae (7 species under 7 genera), and Combretaceae (6 species under a single genus). The most abundant genera recorded were *Combretum* Loefl. and *Tetrastigma* K. Schum. (6 species each), followed by *Clematis* L. and *Mucuna* Adans. (4 species each).

Photographs of some selected lesser-known species are provided in Image 2.



Image 1. A—*Mucuna macrocarpa* | B—*Uncaria sessilifructus* | C—*Phanera scandens* | D—*Tetrastigma leucostaphyllum* | E—*Entada rheedii*.
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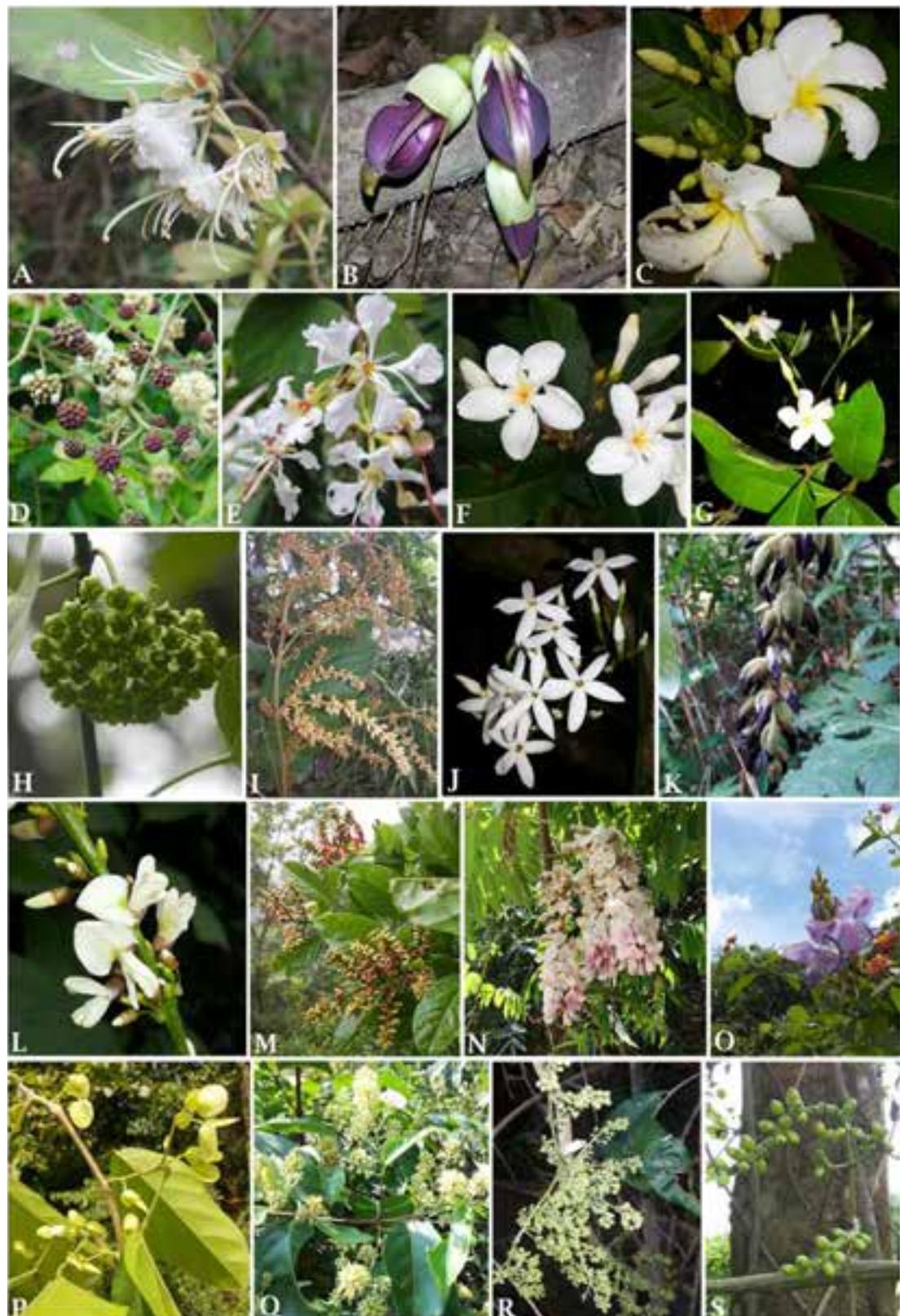


Image 2. A—*Hiptage benghalensis* | B—*Mucuna macrocarpa* | C—*Chonemorpha fragrans* | D—*Senegalia pennata* (Syn. *Acacia pennata*) | E—*Cheniella tenuiflora* (Syn. *Phanera tenuiflora*) | F—*Melodinus cochinchinensis* | G—*Trachelospermum asiaticum* | H—*Stephanotis volubilis* (Syn. *Dregea volubilis*) | I—*Spatholobus parviflorus* | J—*Jasminum lanceolaria* | K—*Mucuna bracteata* | L—*Brachypterum scandens* (Syn. *Derris scandens*) | M—*Callerya cinerea* | N—*Derris taiwaniana* (Syn. *Millettia pachycarpa*) | O—*Dysolobium grande* | P—*Dalhousiea bracteata* | Q—*Combretum punctatum* var. *squamosum* | R—*Cyclea bicristata* | S—*Gnetum montanum*. © Longjam Malemnganbee Chanu.

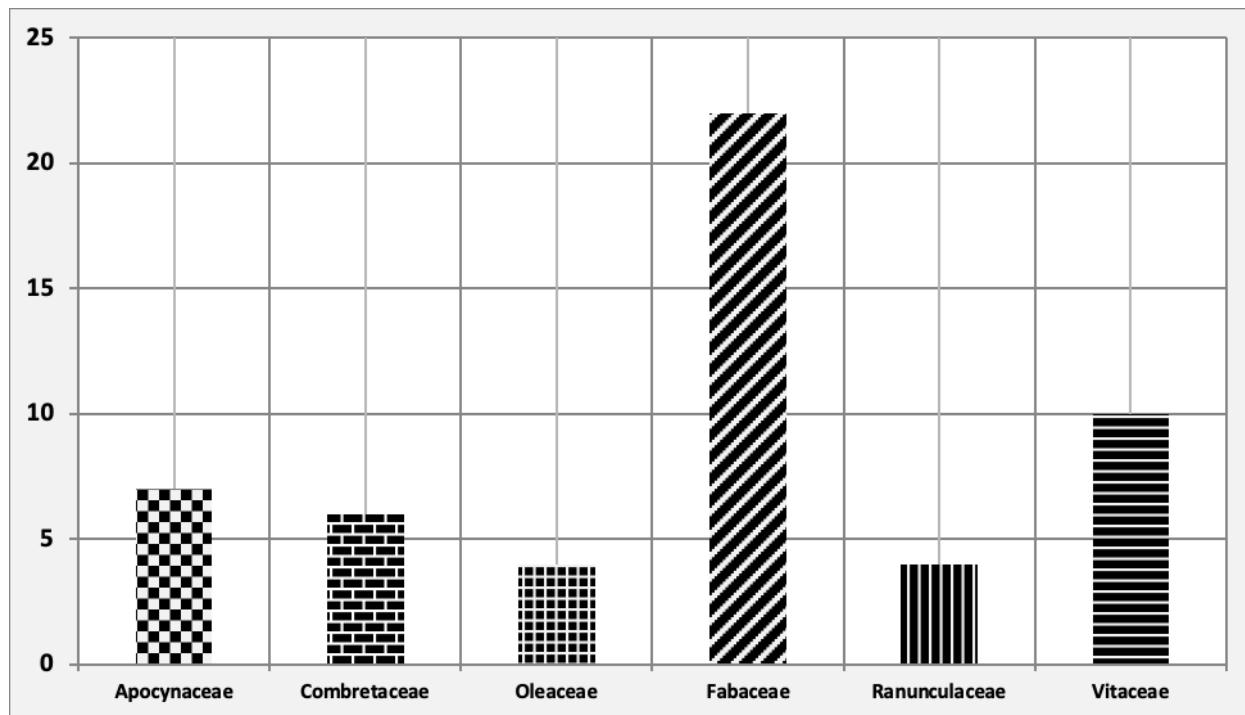


Figure 2. Dominant families occurring in the state of Manipur (family with four or more spp.).

DISCUSSION

This field-based enumerative study, the first of its kind in the state, provides essential baseline data on the diversity, distribution, and phenology of liana species. The study site falling along the Indo-Myanmar border shows high floristic diversity and abundance of lianas. Various biotic and abiotic factors have placed many previously recorded species at risk, with several no longer traceable in the field. The decline in liana diversity and forest regeneration is primarily attributed to human activities such as deforestation, *jhum* cultivation, forest floor burning, and timber extraction. The data presented here not only bridges the gaps in knowledge regarding liana diversity in the region but also serves as a foundation for conservation efforts aimed at monitoring and managing forest resources.

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Table 2. Enumeration of lianas species in Manipur State with their respective phenology, place of occurrence, voucher number and accession number.

	Family	Scientific name	Phenology	Place(s) of occurrence	Voucher number	Accession number (ASSAM)
1	Acanthaceae	<i>Thunbergia coccinea</i> Wall. ex D.Don	Fl.: May-Jun Fr.: Jul-Sep	30	L. M. Chanu 25459	94673
2		<i>Thunbergia grandiflora</i> Roxb.	Fl.: Jun-Sep Fr.: Oct-Mar	40	L. M. Chanu 25381	94674
3	Apocynaceae	<i>Aganosma cymosa</i> (Roxb.) G. Don	Fl.: May-Aug Fr.: Sep-Dec	2	L. M. Chanu 25367	98208
4		<i>Chonemorpha fragrans</i> (Moon) Alston	Fl.: May-Jul Fr.: Jul-Dec	35, 22	L. M. Chanu 25352 & 25368	94676
5		<i>Decalepis khasiana</i> (Kurz) Ionta ex Kambale	Fl.: May-Jun Fr.: Jun-Oct	1	L. M. Chanu 25443	94679
6		<i>Melodinus cochinchinensis</i> (Lour.) Merr.	Fl.: Jun-Jul Fr.: Jul-Dec	44	L. M. Chanu 25458	94677
7		<i>Periploca calophylla</i> (Wight) Falc.	Fl.: Jun — Jul Fr.: Aug-Nov	30	L. M. Chanu 25403	94678
8		<i>Stephanotis volubilis</i> (L.f.) S.Reuss, Liede & Meve [Syn. <i>Dregea volubilis</i> (L.f.) Benth. ex Hook.f.]	Fl.: Apr-Jun Fr.: Jun-Jan	26	L. M. Chanu 25497	94675
9		<i>Trachelospermum asiaticum</i> (Siebold & Zucc.) Nakai	Fl.: Apr-Jun Fr.: Jul-Dec	35	L. M. Chanu 25351	93458
10	Bignoniaceae	<i>Campsis grandiflora</i> (Thunb.) K.Schum.	Fl.: Jun-Aug Fr.: Sep-Feb	19	L. M. Chanu 25462	94680
11		<i>Pyrostegia venusta</i> (Ker Gawl.) Miers	Fl.: Feb-Apr Fr.: Apr - Jul	27	L. M. Chanu 25432	94681
12	Capparaceae	<i>Stixis suaveolens</i> (Roxb.) Pierre	Fl.: Apr - May Fr.: May - Oct	3	L. M. Chanu 25465	94686
13	Celastraceae	* <i>Celastrus monospermus</i> Roxb.	Fl.: Jan- Feb Fr.: Feb - Mar	Hill near Kohima	G. Watt 618 (CAL!)	86322
14		<i>Celastrus paniculatus</i> Willd. subsp. <i>paniculatus</i>	Fl.: May-Jul Fr.: Aug - Dec	28, 21	L. M. Chanu 25356 & 25374	94687
15		<i>Celastrus stylosus</i> Wall.	Fl.: Mar-May Fr.: Jun-Nov	30	L. M. Chanu 25460	98205
16	Combretaceae	* <i>Combretum griffithii</i> Van Heurck & Mull. Arg.	Fl.: Dec-Jan Fr.: Jan - Feb	Jirighat	A. Meebold 5366 (CAL!)	NA
17		<i>Combretum indicum</i> (L.) DeFilipps	Fl.: Mar-May Fr.: Jun-Dec	38, 40	L. M. Chanu 25344 & 25528	94689
18		<i>Combretum latifolium</i> Blume	Fl.: Apr-Jun Fr.: Jul-Oct	4	L. M. Chanu 25302	98204
19		<i>Combretum punctatum</i> var. <i>squamosum</i> (Roxb. ex G.Don) M.Gangop. & Chakrab.	Fl.: Apr-Jun Fr.: Jul-Dec	31, 16	L. M. Chanu 25382 & 25413	94688
20		<i>Combretum sundaicum</i> Miq.	Fl.: Apr-Jun Fr.: Jul-Dec	5	L. M. Chanu 25359	94641
21		<i>Combretum wallichii</i> DC. var. <i>flagrocarpum</i> (C.B.Clarke) M.G.Gangop. & Chakrab.	Fl.: Apr-Jun Fr.: Jul-Dec	24	L. M. Chanu 25477	94690
22	*Connaraceae	* <i>Rourea minor</i> (Gaertn.) Merr.	Fl.: Oct-Nov Fr.: Nov-Dec	Laimatak	A. Meebold 6252 (CAL!)	NA
23	Convolvulaceae	<i>Argyreia nervosa</i> (Burm. f.) Bojer	Fl.: Apr-May Fr.: May-Oct	36, 2	L. M. Chanu 25492 & 25434	94691
24		<i>Argyreia wallichii</i> Choisy	Fl.: Sep-Nov Fr.: Dec-Jun	8	L. M. Chanu 25324	94637
25		<i>Camonea umbellata</i> (L.) A.R.Simões & Staples [Syn. <i>Merremia umbellata</i> (L.) Hallier f.]	Fl.: Oct-Nov Fr.: Dec-Jun	14	L. M. Chanu 25488	94692
26	Cucurbitaceae	<i>Hodgsonia macrocarpa</i> (Blume) Cogn.	Fl.: Mar-Apr Fr.: Apr-May	Koubru	Deb 2271 (CAL!)	NA
27		<i>Trichosanthes tricuspidata</i> Lour.	Fl.: Jun-Aug Fr.: Sep-Nov	14, 35	L. M. Chanu 25487 & 25508	94693

	Family	Scientific name	Phenology	Place(s) of occurrence	Voucher number	Accession number (ASSAM)
28	Fabaceae	<i>Aganope thyrsiflora</i> (Benth.) Polhill	Fl.: May–Jul Fr.: Jul–Aug	25	L. M. Chanu 25415	98207
29		<i>Brachypterum scandens</i> (Roxb.) Wight & Arn. ex Miq. [Syn. <i>Derris scandens</i> (Roxb.) Benth.]	Fl.: Mar–Jul Fr.: Aug–Oct	11	L. M. Chanu 25347	94670
30		<i>Callerya cinerea</i> (Benth.) Schot	Fl.: May–Jul Fr.: Aug–Dec	25, 40	L. M. Chanu 25315 & 25321	94666
31		<i>Cheniella tenuiflora</i> (G.Watt ex C.B.Clarke) R.Clark & Mackinder [Syn. <i>Phanera tenuiflora</i> (C.B. Clarke) de Wit]	Fl.: Sep–Oct Fr.: Oct–Mar	4, 6	L. M. Chanu 25303 & 25316	94684
32		<i>Dalbergia pinnata</i> (Lour.) Prain	Fl.: Mar–Apr Fr.: May–Oct	13	L. M. Chanu 25339	94668
33		<i>Dalbergia stipulacea</i> Roxb.	Fl.: Mar–Apr Fr.: May–Oct	33, 15	L. M. Chanu 25390 & 25425	94669
34		<i>Dalhousiea bracteata</i> (Roxb.) Graham ex Benth.	Fl.: Apr–Jun Fr.: Jul–Sep	33	L. M. Chanu 25385	94667
35		* <i>Derris cuneifolia</i> Benth.	Fl.: Apr–May Fr.: May–Jul	Makru	G. Watt. 6929 (CALI)	132433
36		<i>Derris taiwaniana</i> (Hayata) Z.Q.Song [Syn. <i>Millettia pachycarpa</i> Benth.]	Fl.: Mar–May Fr.: Jun–Nov	6, 42, 29	L. M. Chanu 25312, 25326 & 25334	94643
37		<i>Dysolobium grande</i> (Wall. ex Benth.) Prain	Fl.: Jun–Jul Fr.: Jul–Apr	37, 40	L. M. Chanu 25440, 25446 & 25498	94671
38		<i>Entada rheedii</i> Spreng.	Fl.: May–Jun Fr.: Jul–Dec	36, 20	L. M. Chanu 25346 & 25342	94702
39		<i>Millettia extensa</i> (Benth.) Benth. ex Baker	Fl.: Mar–Apr Fr.: Apr–Aug	37, 1	L. M. Chanu 25439 & 25445	94672
40		<i>Mucuna bracteata</i> DC. ex Kurz	Fl.: Nov–Jan Fr.: Feb – May	12	L. M. Chanu 25491	94644
41		<i>Mucuna imbricata</i> (Roxb. ex Lindl.) DC. ex Baker	Fl.: Mar–Apr Fr.: May–Nov	34, 12	L. M. Chanu 25309 & 25514	94645
42		<i>Mucuna macrocarpa</i> Wall.	Fl.: Mar–Apr Fr.: May–Nov	8, 13, 14	L. M. Chanu 25323, 25341 & 25503	94646
43		* <i>Mucuna pruriens</i> (L.) DC.	Fl.: Oct–Nov Fr.: Nov–Feb	Sugnu	Deb 2596 (CALI)	NA
44		<i>Phanera scandens</i> (L.) Lour. ex Raf.	Fl.: Sep–Oct Fr.: Oct–Dec	34, 5	L. M. Chanu 25307, & 25313	94683
45		<i>Phanera vahlii</i> (Wight & Arn.) Benth.	Fl.: Apr–May Fr.: May–Jul	33	L. M. Chanu 25388	94685
46		<i>Pueraria montana</i> var. <i>lobata</i> (Willd.) Maesen & S.M. Almeida ex Sanjappa & Predeep	Fl.: Jul–Aug Fr.: Sep–Dec	8, 9, 43	L. M. Chanu 25327, 25345 & 25383	94649
47		<i>Senegalia pennata</i> (L.) Maslin [Syn. <i>Acacia pennata</i> (L.) Willd.]	Fl.: Jun–Jul Fr.: Jul–Dec	35, 17	L. M. Chanu 25354 & 25494	94701
48		<i>Spatholobus parviflorus</i> (Roxb. ex G.Don) Kuntze	Fl.: Jun–Jul Fr.: Aug–Jan	8, 41	L. M. Chanu 25446 & 25457	94650
49		<i>Toxicopueraria peduncularis</i> (Benth.) A.N.Egan & B.Pan [Syn. <i>Pueraria peduncularis</i> (Graham ex Benth.) Benth.]	Fl.: Oct–Nov Fr.: Nov–Apr	8	L. M. Chanu 25322	94648
50	Gnetaceae	<i>Gnetum montanum</i> Markgr.	Fl.: Feb–Mar Fr.: Apr–Oct	33, 32, 17	L. M. Chanu 25386, 25399 & 25484	94694
51	Hernandiaceae	<i>Illigera trifoliata</i> (Griff.) Dunn	Fl.: Mar–May Fr.: Jun–Nov	8, 6	L. M. Chanu 25321 & 25314	94695
52	Malpighiaceae	<i>Aspidopterys elliptica</i> (Blume) A.Juss.	Fl.: Jun–Jul Fr.: Aug–Oct	30	L. M. Chanu 25451	98209
53		<i>Aspidopterys nutans</i> (Roxb. ex DC.) A.Juss.	Fl.: May–Jun Fr.: Jul–Dec	21, 19	L. M. Chanu 25375 & 25464	94696
54		<i>Hiptage benghalensis</i> (L.) Kurz	Fl.: Mar–Apr Fr.: Apr–Jun	29, 13	L. M. Chanu 25333 & 25338	94697
55	Malvaceae	<i>Ayenia elegans</i> (Ridl.) Govaerts	Fl.: Sep–Oct Fr.: Nov–Feb	31	L. M. Chanu 25384	94661
56		<i>Ayenia grandifolia</i> (DC.) Christenh. & Byng [Syn. <i>Bytneria aspera</i> Colebr. ex Wall.]	Fl.: Oct–Nov Fr.: Dec–Feb	16	L. M. Chanu 25414	98206
57	Menispermaceae	<i>Cyclea bicristata</i> (Griff.) Diels	Fl.: Mar–Apr Fr.: Apr–Jun	39, 25	L. M. Chanu 25330 & 25418	94698

	Family	Scientific name	Phenology	Place(s) of occurrence	Voucher number	Accession number (ASSAM)
58	Oleaceae	<i>Jasminum caudatum</i> Wall. ex Lindl.	Fl.: Oct–Nov Fr.: Nov–Apr	6	L. M. Chanu 25320	94663
59		* <i>Jasminum coarctatum</i> Roxb.	Fl.: Jan–Mar Fr.: Mar–Jun	s.l.	Deb 914 (CAL!)	NA
60		<i>Jasminum dispermum</i> Wall.	Fl.: Mar–Apr Fr.: May–Oct	39	L. M. Chanu 25331	94664
61		<i>Jasminum lanceolaria</i> Roxb.	Fr.: May–Oct Fr.: May–Oct	4	L. M. Chanu 25337	94638
62	Passifloraceae	<i>Adenia cardiophylla</i> (Mast.) Engl.	Fl.: May–Jun Fr.: Jul–Aug	28, 5	L. M. Chanu 25353 & 25362	94703
63		* <i>Adenia trilobata</i> (Roxb.) Engl.	Fl.: Oct–Nov Fr.: Nov–Dec	Khoupum	A. Meebold 1907 (CAL!)	NA
64	Ranunculaceae	* <i>Clematis buchananiana</i> DC.	Fl.: Dec–Jan Fr.: Jan–Mar	Lingli	G. Watt 6672 (CAL!)	579
65		<i>Clematis gouriana</i> Roxb. ex DC.	Fl.: Oct–Nov Fr.: Dec–May	7, 32, 10	L. M. Chanu 25399 & 25509	94704
66		* <i>Clematis montana</i> Buch.Ham. ex DC.	Fl.: Mar–Apr Fr.: Apr–Jun	Siroh	G. Watt 6439 (CAL!)	59
67		<i>Clematis zeylanica</i> (L.) Poir.	Fl.: Oct–Nov Fr.: Nov–Dec	Bishempur	A. Meebold 6142 (CAL!)	NA
68	Rhamnaceae	<i>Gouania leptostachya</i> DC.	Fl.: Jun–Jul Fr.: Aug–Jan	30, 32	L. M. Chanu 25361 & 25393	94662
69	Rubiaceae	<i>Paederia foetida</i> L.	Fl.: Jun–Jul Fr.: Aug–Oct	25	L. M. Chanu 25417	94651
70		* <i>Uncaria macrophylla</i> Wall.	Fl.: Oct–Nov Fr.: Nov–Dec	Jirighat	A. Meebold, 5686 (CAL!)	NA
71		<i>Uncaria sessilifructus</i> Roxb.	Fl.: Sep–Nov Fr.: Dec–May	34	L. M. Chanu 25305	94652
72	Rutaceae	<i>Toddalia asiatica</i> (L.) Lam.	Fl.: Apr–May Fr.: Jun–Nov	18	L. M. Chanu 25422	94660
73	*Sabiaceae	* <i>Sabia campanulata</i> Wall.	Fl.: Mar–Apr Fr.: May–Jun	Siroh hill	G. Watt 6463 (CAL!)	97401
74	Smilacaceae	<i>Smilax ovalifolia</i> Roxb. ex D.Don	Fl.: Apr–May Fr.: Jun–Nov	4	L. M. Chanu 25369	94657
75		<i>Smilax perfoliata</i> Lour.	Fl.: Mar–Apr Fr.: May–Oct	21, 23	L. M. Chanu 25377 & 25311	94658
76		<i>Smilax zeylanica</i> L.	Fl.: Apr–May Fr.: Jun–Nov	29	L. M. Chanu 25335	94659
77	Urticaceae	<i>Poikilospermum suaveolens</i> (Blume) Merr.	Fl.: Mar–Apr Fr.: May–Jul	6	L. M. Chanu 25329	94703
78	Vitaceae	* <i>Cissus adnata</i> Roxb.	Fl.: Jan–Feb Fr.: Feb–Mar	Irong	A. Meebold 5573 (CAL!)	NA
79		* <i>Cissus assamica</i> (M. A. Lawson) Craib	Fl.: Jun–Sept Fr.: Aug–Nov	Imphal	Deb 1085 (CAL!)	NA
80		<i>Cissus repanda</i> (Wight & Arn.) Vahl	Fl.: Apr–May Fr.: May–Aug	28, 14	L. M. Chanu 25350 & 25500	94653
81		<i>Nekemias rubifolia</i> (Wall.) J.Wen & Z.L.Nie [Syn. <i>Ampelopsis rubifolia</i> (Wall.) Planch.]	Fl.: Apr–May Fr.: May–Sep	1	L. M. Chanu 25441	94639
82		* <i>Tetrastigma bracteolatum</i> (Wall.) Planch.	Fl.: Feb–Mar Fr.: Apr–Aug	Bishenpur	A. Meebold 6089 (CAL!)	NA
83		* <i>Tetrastigma dubium</i> (M.A.Lawson) Planch.	Fl.: Feb–Apr Fr.: Apr–Aug	Siroh	G. Watt 6355 (CAL!)	NA
84		<i>Tetrastigma leucostaphyllum</i> (Dennst.) Alston [Syn. <i>Tetrastigma lanceolarium</i> (Roxb.) Planch.]	Fl.: Apr–May Fr.: May–Aug	6, 5	L. M. Chanu 25315 & 25520	94654
85		<i>Tetrastigma leucostaphyllum</i> (Dennst.) Alston	Fl.: Apr–May Fr.: Jun–Nov	21, 40	L. M. Chanu 25373 & 25529	94655
86		<i>Tetrastigma obovatum</i> Gagnep.	Fl.: Apr–May Fr.: May–Aug	11	L. M. Chanu 25348	94640
87		<i>Tetrastigma rumicispermum</i> (M.A.Lawson) Planch.	Fl.: Apr–May Fr.: May–Jul	4, 5	L. M. Chanu 25371 & 25542	94656

*—taxa represented only by herbarium specimens | NA—No accession number and number(s) given under the column 'Place(s) of occurrence' corresponds to number at Table 1 and Figure 1B.

Table 3. List of doubtful species in terms of their occurrence in the Manipur State.

	Scientific name	Family	Locality, Collector and Collection number	Reference of the report
1	<i>Abrus precatorius</i> L.	Fabaceae	Leimkhong (Deb 490); Lamboi (Mukerjee 3347)	Singh et al. (2020); Deb (1961a)
2	<i>Aspidopterys indica</i> (Willd.) W.Theob.	Malpighiaceae	Sakok (Meebold 7143); Chatrik (Mukerjee 3692) & s. l. (Deb 1270)	Singh et al. (2020); Deb (1961a)
3	<i>Beaumontia grandiflora</i> Wall.	Apocynaceae	Koubru, Manipur (Deb 2262)	Deb (1961a)
4	<i>Beaumontia longituba</i> Craib	Apocynaceae	Saithonng (Mukerjee 6615)	Deb (1961a)
5	<i>Combretum albidum</i> G.Don (Syn. <i>Combretum ovalifolium</i> Roxb.)	Combretaceae	Jirighat (Meebold 5699)	Singh et al. (2020)
6	<i>Epigynum auritum</i> (C.K.Schneid.) Tsiang & P.T.Li (Syn. <i>Trachelospermum auritum</i> C.K.Schneid.)	Apocynaceae	Kangpokpi, Maopang (s.coll. s.n.)	Deb (1961a)
7	<i>Millettia fruticosa</i> (DC.) Benth. ex Baker	Fabaceae	s.l. (C.B. Clarke s.n.)	Deb (1961a)
8	<i>Mucuna interrupta</i> Gagnep. [Syn. <i>Mucuna nigricans</i> (Lour.) Steud.]	Fabaceae	Sugnu (Deb 2596); Ukhru (Mukerjee 2515)	Singh et al. (2020); Deb (1961a)
9	<i>Mucuna monosperma</i> DC. ex Wight	Fabaceae	Chingmeirong (Deb 1176)	Deb (1961a)
10	<i>Senegalia pruinescens</i> (Kurz) Maslin, Seigler & Ebinger (Syn. <i>Acacia pruinescens</i> Kurz.)	Fabaceae	Chingmeirong (Deb 767)	Deb (1961a)
11	<i>Thunbergia fragrans</i> Roxb.	Acanthaceae	s.l. Manipur valley (Deb 310, 775)	Deb (1961a)

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New records and typification in family Poaceae from western Himalaya, India

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Abstract: In the present study, authors provide the new geographical records of four species, namely *Anthoxanthum flexuosum*, *A. horsfieldii*, *Eragrostis tenuifolia*, and *Tripogon longearistatus* for the first time in the western Himalaya. A detailed taxonomic description, notes on habitat, morphology, and distribution along with a map are also provided. Additionally, we designated the lectotype for the name *Anthoxanthum horsfieldii*.

Keywords: *Anthoxanthum*, Chloridoideae, *Eragrostis*, lectotypification, morphology, Pooideae, taxonomy, *Tripogon*.

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Author contributions: ST—conceptualization—lead, field survey; Data curation—lead; Investigation—equal; Methodology—equal; Writing - original draft—lead. DP—formal analysis—supporting, field survey; Investigation—supporting; Methodology—supporting; Writing—original draft—equal. SS—data curation—equal; Formal analysis—equal; Methodology—equal; Writing—original draft—supporting. SPT—conceptualization—equal; Formal analysis—equal, writing.

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INTRODUCTION

Poaceae is the large and nearly ubiquitous family of monocotyledonous flowering plants, known as grasses. The family includes the cereal grasses, bamboos, and the grasses of natural grassland, cultivated lawns and pasture. It is the fifth largest angiosperm family with 752–855 genera, 11,300–12,379 species (Mabberley 2017; Banki et al. 2025), grows in all continents, up to 5,700 m elevation, in desert to freshwater and marine habitats (Kellogg 2015). The grass family is considered as a natural group and divided into 12 subfamilies (GPWG 2001; Soreng et al. 2017) out of which, 10 subfamilies are found in India that contain around 267 genera, and 1,501 species (Kellogg et al. 2020). Poaceae is dominant in Western Ghats with 600 species belonging to 170 genera, followed by western Himalaya with ca 583 species from 143 genera, and northeastern India with ca. 475 species from 145 genera (Shukla 1996). In western Himalaya, Collett (1902) described grasses of Shimla in his "Flora Simlensis", Stewart (1945; 1967) documented grasses of northwestern Himalaya and grasses of Kashmir Himalaya; Kachroo et al. (1977) included Poaceae and other families in his "Flora of Ladakh"; Aswal & Mehrotra (1994) provided a detailed account of the family Poaceae from Lahul & Spiti; Kandwal & Gupta (2009) listed the grasses of Uttarakhand, and Pusalkar & Singh (2012) studied Flora of Gangotri National Park, and therein documented the grass flora of that area. In recent years, field investigations have been carried out by many taxonomists in the western Himalaya. These investigations have contributed to the discovery of many new species to science and new records for Indian flora as well as for western Himalaya.

During the revisionary studies of family Poaceae from the western Himalaya, the authors gathered several fascinating specimens from various localities. After critical studies of these specimens, perusal of relevant literature, and consultation with herbarium collections, the new geographic records of *Anthoxanthum flexuosum* (Hook.f.) Veldkamp, *A. horsfieldii* (Kunth ex Benn.) Reeder, *Eragrostis tenuifolia* (A. Rich.) Hochst. ex Steud., and *Tripogon longearistatus* Hack. ex Honda in western Himalaya are reported for the first time based on specimens collected from Uttarakhand, and Himachal Pradesh. Furthermore, we resolved the ambiguity on nomenclature type of name *A. horsfieldii* and designated the lectotype.

MATERIALS AND METHODS

Several field surveys were conducted in the western Himalaya (Jammu & Kashmir, Ladakh, Himachal Pradesh, and Uttarakhand) from 2019–2024. All voucher specimens collected were herbarized following herbarium techniques as described in Jain & Rao (1976), and were deposited in the LWG herbarium. The taxonomical and nomenclatural analysis were performed through the consultation of protogues and relevant literature (e.g., Hooker 1896; Bor 1960; Schouten & Veldkamp 1985; Wu & Phillips 2006), images of type collections, and online databases such as Tropicos (2024) & JSTOR (2024). The morphological descriptions are based on collected specimens, old herbarium specimens and their images from BSD, CAL, DD, and LWG. For the critical study, specimens were dissected and observed using a Leica S8 APO stereozoom microscope equipped with MC 120 HD camera. The distribution map was prepared by using DIVA-GIS based on geo referenced data (latitudes and longitudes) that were taken during field trips and from herbarium specimens (Hijmans et al. 2001). All herbarium codes (acronyms) in this communication are according to Index Herbariorum (Thiers 2025).

RESULTS AND DISCUSSION

Taxonomy and new records

1. *Anthoxanthum flexuosum* (Hook.f.) Veldkamp, Blumea 30: 347 (1985).

≡*Hierochloe flexuosa* Hook.f., Fl. Brit. India 7: 222 (1896)

Type: [INDIA], Sikkim, Bijean, 1889, King's collector s.n. (holo. K000032281, digital image!).

Habit perennial, rhizomatous, 50–80 cm tall. Culms 60–75 cm long. Leaf sheath smooth. Leaf blade 5–10 cm long, 0.40–0.44 cm wide. Ligule 3.3–3.6 mm long, smooth; apex obtuse, erose. Panicle, 5–14 cm long, 5–8 cm wide, very lax, flexuous, branched: lower panicle branch paired, 5.0–7.5 cm long, capillary, spiculate on upper 1/3–1/2. Spikelets 6.0–6.8 mm long, 3.4–3.8 mm wide, laterally compressed, brownish; glumes subequal, first and second florets male, upper floret bisexual. Lower glumes 4.1–4.9 mm long, 1.8–2.0 mm wide, 3-nerved, 1-keeled, lanceolate, glabrous; apex acute. Upper glumes 4.7–5.5 mm long, 2.2–2.4 mm wide, 3-nerved, 1-keeled, lanceolate, glabrous; apex acute. First floret male: callus scanty hairy; hairs 0.5–0.7 mm long, lemma 4.6–5.3 mm long, 5-nerved, 1-keeled, narrowly elliptic, villous with golden-brownish hairs, shortly awned; palea

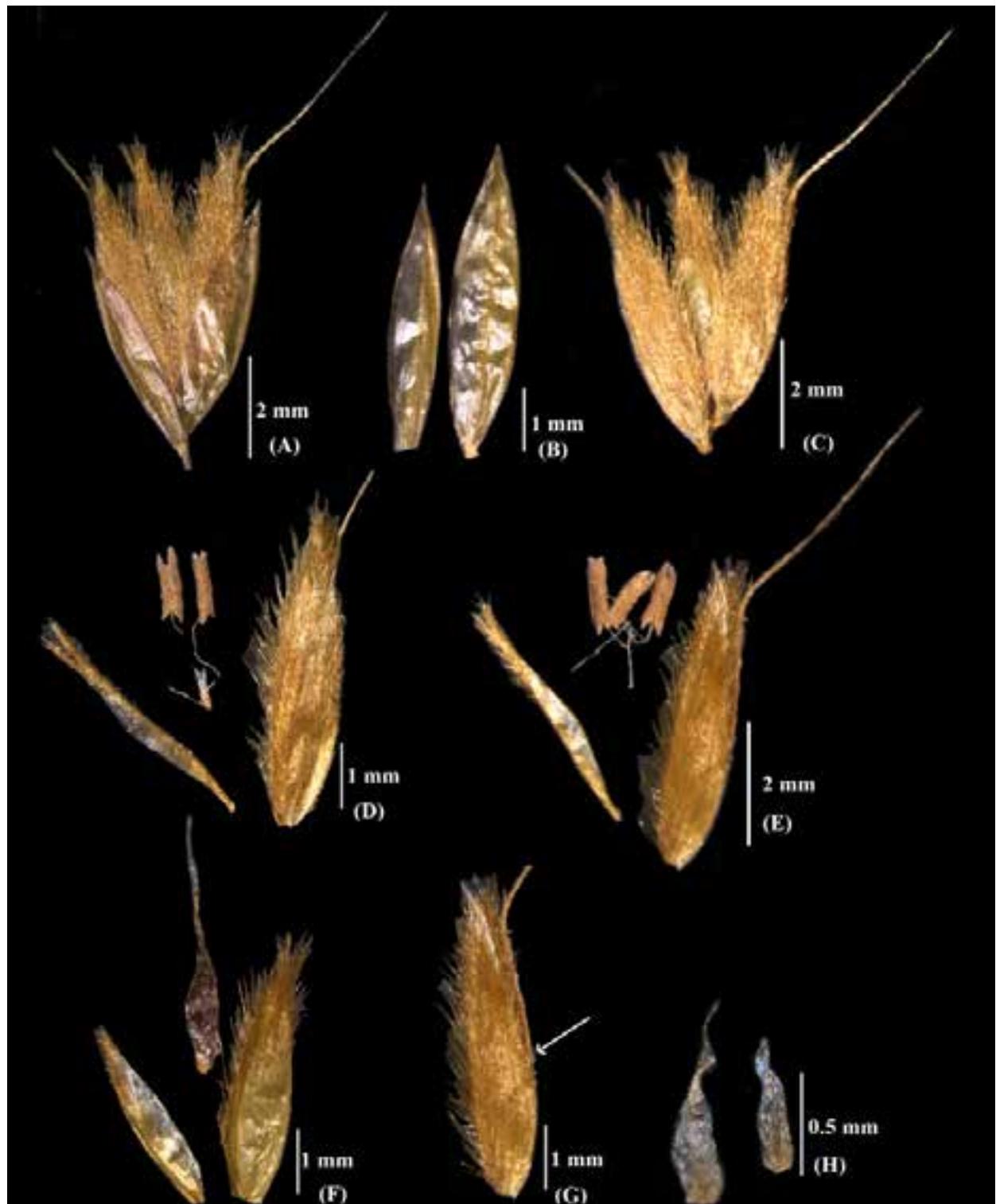


Image 1. *Anthoxanthum flexuosum*: A—Spikelet | B—Glumes | C—Florets | D—Lower florets with removed lemma, palea, anthers, and ovary | E—Middle floret with removed lemma, palea, and anthers | F—Upper floret with palea and ovary | G—Lemma of middle floret with position of awn insertion point (arrow sign) | H—Lodicule. © Dileshwar Prasad.

3.5–4.2 mm long, villous on upper 1/3; apically slightly bifid or with 2-toothed; awn 1.2–3.2 mm long, straight, inserted above the middle, proceeding above the florets and glumes; anthers 1.0–1.5 mm long. Second floret male: callus scanty hairy; hairs 0.5–0.7 mm long, lemma 4.6–5.8 mm long, 5-nerved, 1-keeled, narrowly elliptic, villous with golden-brownish hairs, awned, apically bifid; palea 2.9–4.3 mm long, villous on upper 1/3; awn 5.6–7.2 mm long, geniculate, inserted around the middle or at lower 2/3, conspicuously exceeding above the florets and glumes; anthers 1.0–1.5 mm long. Upper floret bisexual: callus glabrous, lemma 2.8–4.1 mm long, 5-nerved, 1-keeled, villous with golden-brownish hairs on upper half, not anwed; palea 2.3–3.3 mm long, villous at apex, 1-nerved; lodicules-2; ovary glabrous; stamens-3, anthers 1.0–1.2 mm long (Image 1 & Image 3A).

Flowering and fruiting: July–November.

Habitat and distribution: *Anthoxanthum flexuosum* was previously known from type locality, Bijean in Sikkim and considered an endemic species of that area (Bor 1960). Extensive investigations revealed that it is also found in western Himalaya, where it was collected from Manali, Himachal Pradesh. During the revision of specimens we have located one more specimen of *A. flexuosum* K (K003585835), which was collected from Nepal. It is, perhaps, one of the rare species of *Anthoxanthum*, distributed from western to central and eastern Himalaya, and grows in dry, and sunny places on the *Agrostis-Festuca-Poa* grassland at 3,400–4,800 m (Image 7).

Notes: The genus *Anthoxanthum* belongs to subtribe *Anthoxanthinae* (Pooideae, Poeae) (Soreng et al. 2022). *Anthoxanthum* species produce coumarin, which makes them sweetly scented (Kellogg 2015). *Anthoxanthum flexuosum* was originally described as *Hierochloe flexuosa* by Hooker (1896) based on specimens collected from Bijean, Sikkim by King's collector. While searching the original material, we have located single specimens at K (K000032281), and the same was also cited as holotype (holo., n.v.) by Veldkamp (1985). It is characterised by having panicle lax & loose, lower & upper glumes 3-nerved, subequal and acuminate, first & second florets male, and upper floret bisexual, lemma villous with golden hairs, awn of second lemma geniculate and 5.6–7.2 mm long, anthers 1.0–1.2 mm long. It is similar to the *A. laxum* by having lax panicle with spreading branches and glumes subequal, but differ from later by its lower and upper glumes 3-nerved (vs 1-nerved), and awn of second lemma geniculate, and 5.6–7.2 mm long (vs straight and 2–3 mm long).

Specimens examined: *A. flexuosum*: INDIA. Himachal Pradesh, Manali, between Marhi & Rohtang, 32.354° N, 77.224° E, 3,400 m, 30.viii.2021, R.Yadav, S.Sharma & S.Tiwari 339400 (LWG!); *A. laxum*: INDIA. Uttarakhand, Bageshwar, Pindari Valley, 3 km after Dwali, 30.196° N, 79.999° E, 2,810 m, 28.ix.2021, D.Prasad & S.Sharma 339363 (LWG); *A. odoratum*: INDIA. Jammu & Kashmir, Baramulla, Nathatop, 33.078° N, 75.321° E, 2,200 m, 18.vii.2019, S.Jaiswal, R.Yadav & S.Tripathi 316393 (LWG!); Himachal Pradesh, Kullu, Kothi, 32.3186° N, 77.1936° E, 2,545 m, 04.viii.2019, D.Prasad & R.Yadav 316218 (LWG!).

2. *Anthoxanthum horsfieldii* (Kunth ex Benn.) Reeder, J. Arnold Arbor. 24: 325 (1950).

≡*Ataxia horsfieldii* Kunth ex Benn., Pl. Jav. Rar. (Bennett) 8 (1838)

≡*Hierochloe clarkei* Hook.f., Fl. Brit. India 7: 223 (1896); Bor, Fl. Assam 5: 167 (1940)

≡*Anthoxanthum clarkei* (Hook.f.) Ohwi, Bull. Tokyo Sc. Mus. 18: 8 (1947); Bor, Grasses Burma, Ceylon, India, Pakistan 431 (1960); Jain & Pal, J. Bombay Nat. Hist. Soc. 72: 94 (1975). Type: India, Meghalaya, Khashi Hills, Lailan Kote, 1,675 m, C.B. Clarke s.n. (holo. K).

Type (lectotype): [INDONESIA]. Java, Loekot, Skoland Jane, T. Horsfield 339 (lecto. BM000797885, isolecto. BM000797886; L0043611, digital images!), step-I designated by Schouten & Veldkamp (1985), step-II designated here.

Habit perennial, rhizomatous with creeping and branching rhizome, 60–100 cm high. Culm 40–75 cm long, simple or branched. Node glabrous. Leaf sheaths split-overlapping, smooth; margin hairy. Ligules 2.0–3.9 mm long, membranous, glabrous; apex truncate, lacerate. Leaf blades 15–25 cm long, 5–10 mm wide, flat, adaxial scabrous, abaxial glabrous or scaberulous, flaccid, aromatic, margin scabrid. Panicle 4.5–10.6 cm long, 0.7–2.2 cm wide, elliptic in outline, continuous or interrupted at basal part, branched, nodding; lower branch in whorls of 2, branch smooth, 2–3 cm long, ascending, bearing 5–15 spikelet. Rachis obscure, smooth. Spikelet 5.2–7.8 mm long, 1.9–2.4 mm wide, lanceolate, bearing 2-sterile floret and 1-fertile floret, short rachilla between sterile floret; glumes persistent, unequal; lower sterile floret dissimilar, compressed, barren, without significant palea; upper fertile floret bisexual. Lower glume 3.0–4.5 mm long, 1.0–1.2 mm wide, 1-veined, 1-keeled, elliptic, navicular; apex acute; hyaline margin, smooth. Upper glume 4.6–7.8 mm long, 1.9–2.2 mm wide, 3-nerved, 1-keeled, obovate, navicular, glabrous; apex acute; margin hyaline. First



Image 2. *Anthoxanthum horsfieldii*: A—Ligule | B—Lower panicle branch | C—Spikelet | D—Spikelet with removed glumes | E—Glumes | F—Glumes, lateral view | G—Floret | H—Middle floret | I—J—Upper floret | K—Ovary. © Dileshwar Prasad.

floret sterile: lemma floret 5.0–5.7 mm long, 5-nerved, 1-keeled, membranous, compressed, conduplicate, pubescent, golden hairs on all over surface, awned; apex acute; margin narrowly hyaline, ciliate; awn 1.6–2.0 mm long, inserted above the middle on dorsal surface, straight, scabrous-antrorse. Second floret sterile: lemma 4.8–5.3 mm long, 1-nerved, 1-keeled, membranous, compressed, pubescent, golden hairs on all over

surfaces, awned; apex acute; margin narrowly hyaline, ciliate; awn 7.5–8.4 mm long, geniculate, inserted from above middle on dorsal surface, scabrous-antrorse, column 2.3–2.5 mm long, twisted, subula 6.2–6.4 mm long. Upper floret bisexual: lemma 2.4–3.3 mm long, 5-nerved, without keel, lateral nerve obscure, oblong, rounded, smooth; palea 2.2–3.3 mm long, 1-nerved, linear, membranous; stamens-3, anthers 1.8–3.2 mm

long, ovary glabrous; lodicules absent. (Image 2 & Image 3B)

Flowering and fruiting: August–September.

Habitat and distribution: *Anthoxanthum horsfieldii* is a common grass of southeastern Asia, known from China, Japan, Myanmar, Malesia, Taiwan, Philippines to the Thailand (Schouten & Veldkamp 1985; Wu & Phillips 2006). Along with these, the distributional ranges are also extended to the Khasi Hills and the Western Ghats, India (Hooker 1896; Bor 1960). In the present study, we recorded the new localities of *A. horsfieldii* in the Garhwal Himalaya, Uttarakhand which expanded its distribution range to the western Himalaya. It grows mainly in sunny, dry places, *Casuarina* forest, and subalpine grassland; at 1,400–3,300 m in the Java Island, Indonesia (Schouten & Veldkamp 1985), on mountainous, grassy, and sunny or shaded places; at 2,500–3,300 m in China (Wu & Phillips 2006); forest margins, dry, and sunny places; at ca. 1,800 m in the western Himalaya (Image 7).

Notes: Kunth (1829) published the name *Ataxia horsfieldii* without any description, regarded as a descriptogenerico-specifica, based on specimens collected by Horsfield from Java (Indonesia), which was mentioned in Brown (1823) as “399.Horsfield”. However, the name was invalid. Bennett & Brown (1838) then validated and confirmed as already observed by Chase (1943), even though she believed Horsefield to be the original author. Maximowicz (1888) and Mez (1921) transferred it into genera *Hierochloë* and *Anthoxanthum*, respectively. The combination, proposed by Mez (1921), was invalid as it was merely referred to Kunth for his basionym (see Veldkamp 1985). Later, it seems to be validated by Reeder (1950) as he referred to Chase (1943), and indirectly to Bennett & Brown (1838).

During the systematic study of *A. horsfieldii*, we noticed that Schouten & Veldkamp (1985) unintentionally referred two specimens and lectotypified the name *A. horsfieldii*. Thus it requires a second-step lectotypification in accordance with Art. 9.17 of ICN (Turland et al. 2018). Schouten & Veldkamp (1985) referring to the type of *A. horsfieldii* wrote “Type: Horsfield 339 (BM, holo. (holotype), K, P) Java”. There are two specimens of Horsfield 339 at BM (BM000797885 and BM000797886). According to Art. 9.17 of ICN (Turland et al. 2018), the type citation by Veldkamp & Schouten should be considered as first step of lectotypification, as they did not designate any particular specimen from both the specimen for the name *A. horsfieldii*. Therefore, for the stability of the name *A. horsfieldii*, a subsequent typification is warranted to resolve this nomenclatural ambiguity. Therefore, from the two specimens of

Horsfield 339 at BM, the best-preserved specimen BM000797885 is designated here as the second-step lectotype of the name *A. horsfieldii*, and the other specimen BM000797886 as the isolectotype. Moreover, the other syntype is also traced at L, which could also be regarded as an isolectotype.

Specimens examined: INDIA. Uttarakhand, Chamoli, Nagnath-Pokhari, 30.329° N, 79.209° E, 1,800 m, 28.viii.2019, S. Jaiswal 326992 (LWG!).

3. *Eragrostis tenuifolia* (A. Rich.) Hochst. ex Steud., Syn. Pl. Glumac. 1: 268 (1854).

Poa tenuifolia A. Rich., Tent. Fl. Abyss. 2: 425 (1850–1851).

Type (lectotype): [ETHIOPIA], in locis in cultis Vallium prope Adoam, 18.ix.1837, Schimper 92 (P), designated by Phillips (1995).

Habit perennial, mat forming, tufted, 10–62 cm long. Culms 6–50 cm long. Leaf sheaths 3–10 cm long, mouth bearded. Ligule's fringe of cilia. Leaf blades 6–28 cm long, 0.2–0.5 cm wide, linear to lanceolate, adaxial surface scabrid to sparsely ciliate, abaxial surface glabrous. Panicles 4–12 cm long, 2.5–5.0 cm wide, broadly ovate, open with alternate branches; axils ciliate, at maturity glandular in the axils; pedicels 3–7 mm long, glandular. Spikelets 4–12 mm long, 0.9–2.1 mm wide, 6–13 flowered, lanceolate to oblong, with serrulate margins, greenish black or grey; rachilla zigzag; florets closely imbricate, disarticulating from below upwards. Glumes ovate to lanceolate, often nerveless or nerve obscure, apex acute to obtuse. Lower glumes 0.3–0.7 mm long, 0.2–0.3 mm wide. Upper glume 0.8–1.2 mm long, 0.4–0.6 mm wide. Lemmas 1.5–2.1 mm long, 0.9–1.2 mm wide, elliptic-lanceolate, chartaceous, 3-nerved, 1-keeled, keel scabrid above middle; apex acute to mucronate. Paleas 1.4–1.8 mm long, 0.3–0.6 mm wide, persistent, elliptic to oblanceolate, 2-nerved, 2-keeled, scaberulous along keels, apex obtuse to truncate. Anthers 3, 0.6–1.0 mm long, cream-coloured. Caryopses 0.7–1.2 mm long, c. 0.8 mm wide, ellipsoid to oblongoid, ventrally flattened to grooved, truncate at ends, deep reddish. (Image 4 & Image 5)

Flowering and fruiting: March–October

Habitat and distribution: *Eragrostis tenuifolia* is native to Indochina, southern Asia, Madagascar, and tropical Africa, and was introduced in Mexico (Villasefior & Espinosa-Garcia 2004), Australia, Malesia, New Guinea, Philippines, and southern America (Veldkamp 2002). Since it is a widely spreading grass, the first author saw it in Forest Research Institute (FRI) campus, and on the way to Mussoorie, Dehradun. During the study of old



Image 3. Representative specimens: A—*Anthoxanthum flexuosum* | B—*Anthoxanthum horsfieldii*. © Dileshwar Prasad.

collections of family Poaceae, it is found that previously it was also collected from Rudraprayag in 2018. In India, it is commonly found in association with *E. nigra* (Vivek et al. 2021). At highland and montane elevations of 500–2,500 m, it is frequently growing as a weed, and ruderal in the wet zone, particularly beside roadsides, and in woods and wastelands (Moulik 1997).

Earlier in India, it was reported from Andhra Pradesh, Bihar, Daman & Diu, Gujarat, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Mizoram, Odisha, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal (Kellogg 2020; Prasanna et al. 2020), and recently also recorded from Telangana (Jalander & Swamy 2023) (Image 7).

Notes: *Eragrostis tenuifolia* has open panicle with bearded axils; a large, dark, serrate spikelets with a relatively short nerveless lower glume; a floret with widely divergent lemma and palea; a lemma with submarginal usually short lateral nerves; a 3-lobed palea; creamy anthers and strongly flattened caryopsis

that is often exposed that distinguished it from rest of the Indian species. It shows similarity with *E. curvula* (Schrad.) Nees, *E. pilosiuscula* Ohwi and *E. pilosa* (L.) P.Beauv. by its open panicle and long axil hairs but differs from *E. curvula* by its serrate margins of the spikelets, ventrally flattened to grooved caryopsis (vs dorsally compressed caryopsis) and anthers 0.6–0.9 mm long (vs 0.9–1.25 mm long), and from *E. pilosa* by its caryopsis (laterally flattened in *E. pilosa*). *E. tenuifolia* is similar to *E. ferruginea* (Thunb.) P.Beauv. in its caryopsis, however in *E. ferruginea* sheath margins and the axils of the inflorescence are glabrous, not pilose. Similar to *E. nigra* Nees ex Steud., this species often has dark green spikelets but differs by having more narrowly lanceolate spikelets and toothed lemma.

Specimens examined: INDIA. Uttarakhand, Rudraprayag, Jakholi, 30.273° N, 78.962° E, 657 m, 27.ix.2018, S. Tripathi 315817 (LWG!); same locality, 30.273° N, 78.963° E, 660 m, 27.ix.2018, S. Tripathi 315819 (LWG!); New forest (FRI campus), 30.342° N, 77.997°



Image 4. *Eragrostis tenuifolia*: A—Habit | B—Panicle. © Smita Tiwari.

E, 681 m, 27 April 2024, S. Tiwari 346552 (LWG!); same locality, 30.346° N, 77.593° E, 685 m, 27 April 2024, S. Tiwari 346553 (LWG!); same locality, 30.345° N, 78.000° E, 694 m, 27.iv.2024, S. Tiwari 346554 (LWG!); way to Mussoorie, 30.443° N, 78.087° E, 1,662 m, 28.iv.2024, S. Tiwari 346555 (LWG!); same locality, 30.449° N, 78.082° E, 1,843 m, 28.iv.2024, S. Tiwari 346557 (LWG!).

4. *Tripogon longearistatus* Hack. ex Honda, Bot. Mag. Tokyo 41: 11 (1927).

≡*Tripogon longearistatus* Nakai, Veg. Isl. Quelpaert: 19: 147 (1914), nom. nud.

=*Tripogon longearistatus* Honda var. *japonicas* Honda, Bot. Mag., Tokyo 41: 12 (1927).

Type (lectotype): KOREA, Cheju-do, Quelpaert, 1908, Taquet 3425 (lecto. TI [TI00016318 digital image!], designated by Vivek et al. (2021).

Habit Perennials, 7–20 cm high. Culms 5–12 cm, erect; leaf sheaths 3–8 cm long, glabrous. Ligules ciliolate membranous. Leaf blades 3–16 cm long, c. 0.1 cm wide, linear, convolute, glabrous or scabrid adaxially and glabrous abaxially; apex acuminate. Panicle 5–15

cm long, slightly flexuous, spikelets loosely arranged in rachis; distant by their own length. Spikelets 4–10 mm long, 1.0–1.5 mm wide, linear to lanceolate, pale green, 4–7 flowered. Callus bearded. Rachilla 0.4–0.8 mm long, straight or zig zag. Lower glumes 2.8–4.3 mm long, 0.5–0.7 mm wide, 1-nerved, 1-keeled, linear-lanceolate, slightly toothed on one side, apex sub-acute to acute. Upper glumes 3.5–5.2 mm long 0.5–0.7 mm wide, 1-nerved, 1-keeled, lanceolate-oblong, apex acuminate or mucronate. Lemmas 2.5–4.8 mm long, 0.5–0.8 mm wide to sinus, 3-nerved, elliptic-lanceolate, apex bifid; median awn 4.5–8.3 mm long, scabrid, reflexed, teeth absent; lateral veins 0.1–0.2 mm long, awns arising from outer margins. Paleas 2.5–3.0 mm long, 0.4–0.6 mm wide, 2-keeled, lanceolate, hyaline, not winged, keels ciliolate, apex truncate. Stamen 1, anther 1–1.2 mm long. Ovary 0.2–0.5 mm long (Image 6).

Flowering and Fruiting: September–December

Habitat and distribution: The native range of *Tripogon longearistatus* is China, Japan, and Korea. In India, it was previously reported from Meghalaya and Sikkim. It is a perennial species and grows primarily on rocky slopes,



Image 5. *Eragrostis tenuifolia*: A—Leaf blade | B—Leaf sheath with ligule | C—Node | D—Lower panicle branch | E—Branch axils | F—Panicle branches | G—I—Spikelets | J—Lower half of spikelet | K—Lemma and palea (Lateral view) | L—Lemma | M—Palea | N—Caryopsis. © Smita Tiwari.

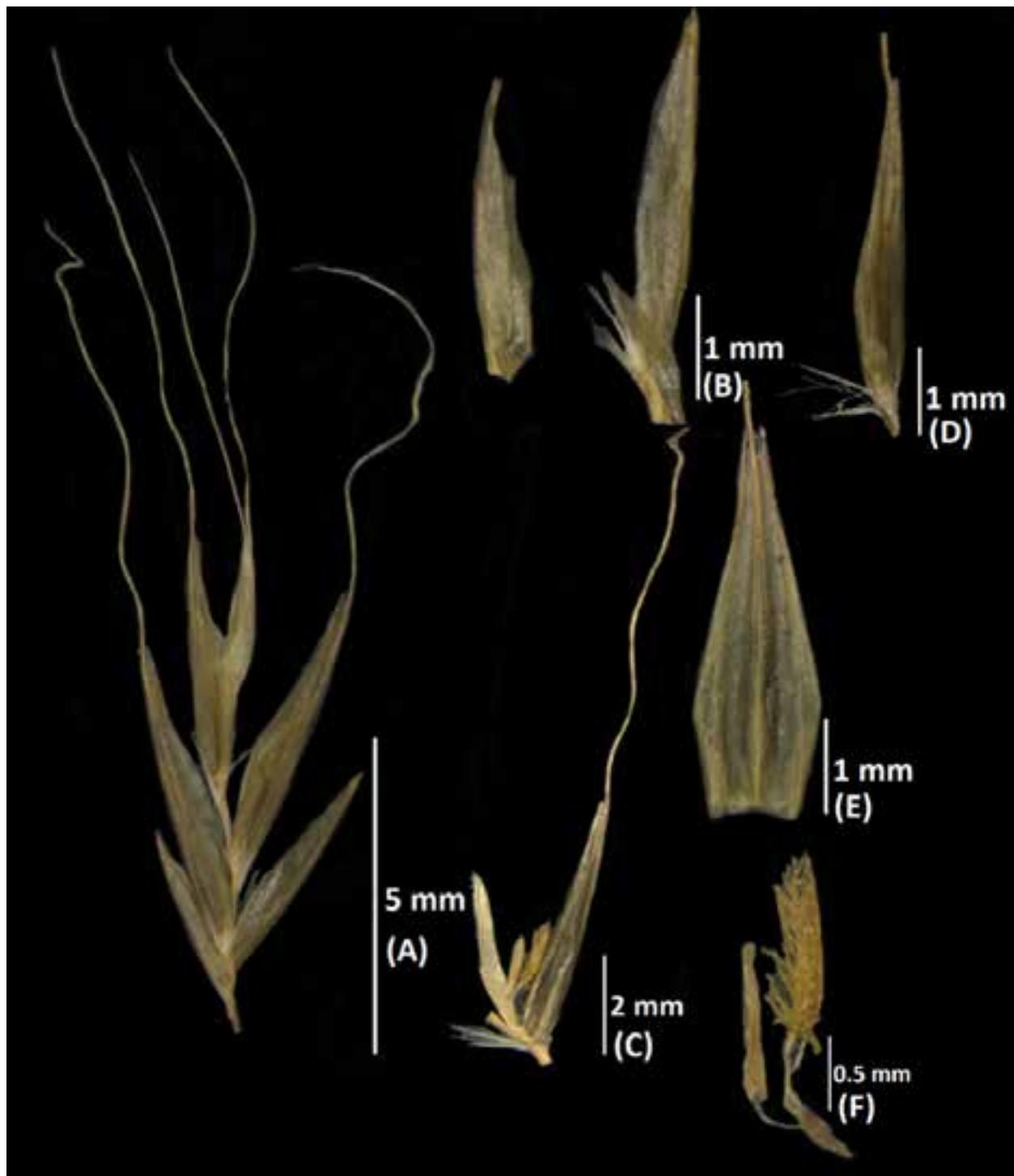


Image 6. *Tripogon longearistatus*: A—Spikelet | B—Glumes | C&D—Floret | E—Lemma | F—Stamens & Ovary. © Smita Tiwari.

and also on riverbeds at an altitude of 300–1,500 m (Thoiba & Pradeep 2020). We report it from Nainital, Uttarakhand which represents the new geographic record in the western Himalaya (Image 7).

Notes: *Tripogon longearistatus* shares similarities

with *T. filiformis* Nees ex Steud., in its habit but can easily be distinguished by its widely spaced long spikelets (vs closely imbricate spikelets) with stiff strongly reflexed awns, lateral awns absent or if present then only about 0.1–0.2 mm long, extension of lemma lateral nerves,

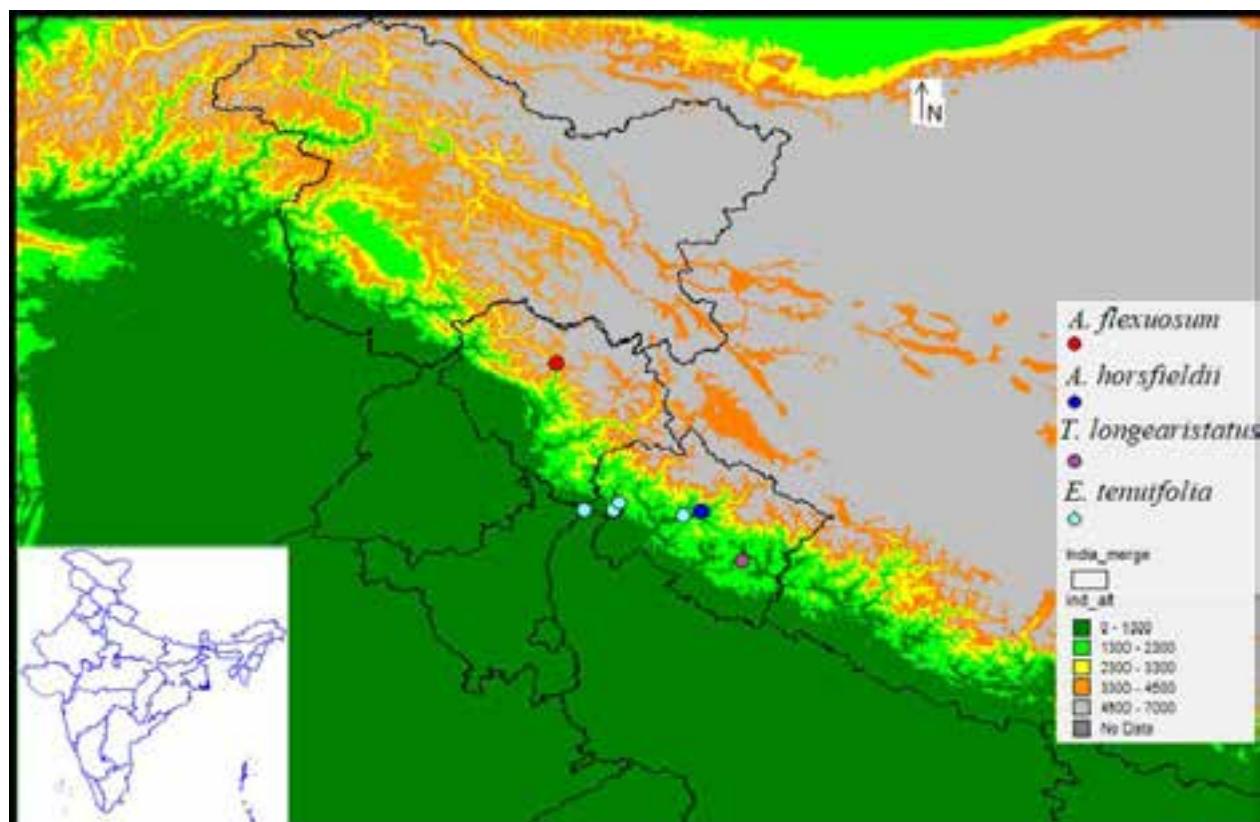


Image 7. Distribution of *Anthoxanthum flexuosum*, *Anthoxanthum horsfieldii*, *Tripogon longearistatus*, and *Eragrostis tenuifolia* in western Himalaya, India. © Sangam Sharma by QGIS.

(vs lateral awns 1–4 mm long), lemma 2- lobed with lemma teeth absent (vs lemma 4-lobed with lemma teeth 0.3–0.7 mm long), and having solitary anther. The higher altitude form of *T. filiformis* having median awn twice as long as the lemma, lateral awns half the size of median awn, and possesses only one anther (Phillips & Chen 2002). Lower altitudes form have very short lateral awns having three anthers (Noltie 2000). There is little overlap in their geographical range. According to Phillips & Chen (2002), *T. longearistatus* is limited to the eastern lowlands, whereas *T. filiformis* is found at high elevations in China. *T. filiformis* is characterized by its filiform, lax, and densely pilose leaves on both surfaces. However, in *T. longearistatus*, leaf blade is scabrid adaxially, and glabrous abaxially.

Specimen examined: INDIA. Uttarakhand, Nainital, on way to DSB campus, 29.655° N, 79.762° E, 1,968 m, 31.ix.2018, S. Tripathi 315910 (LWG!).

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Collection and lipid analysis of marine unicellular cyanobacteria: a case study from the southeastern coast of India

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Abstract: Cyanobacteria are capable of surviving in extreme environments such as rocky shorelines, drought, desiccation, osmotic stress, salinity stress, UV radiation, and nitrogen starvation. The study collects and analyse cyanobacterial samples from ponds, seashores, and salt pans along the southeastern coastline of Tamil Nadu—specifically from Mimal, Thondi, Tuticorin, and Tiruchendur. The study involved the isolation and purification of samples using various techniques, including plating, cell disruption, and mechanical separation methods. Cultures were incubated at optimal temperature, photoperiod, and light intensity using artificial sea nutrient and blue-green (BG11) media. Samples were subjected to phototactic movement on 0.4% soft agar plates under both field and laboratory conditions for rapid isolation. Once visible filaments or single colonies were observed, unicellular cells were isolated using a micromanipulator, resulting in the collection of 17 cyanobacterial and three green algal strains. Identification was carried out to the genus level unless distinct species-level characteristics were evident, based on the morphological criteria described for Cyanophyta. Among the 20 strains screened, four marine microalgae exhibited lipid contents of 15% or higher and were classified as high lipid-yielding strains. These selected strains were further evaluated for functional group composition using Fourier Transform Infrared spectroscopy.

Keywords: 16S rRNA, BDUM19, BLAST, diversity, isolation, Lipid and FTIR, marine cyanobacteria, microalgae, physio-chemical, survey, *Synechococcus* sp.

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INTRODUCTION

Cyanobacteria are a diverse group of prokaryotes containing chlorophyll a and capable of performing oxygenic photosynthesis. They contribute substantially to global biological nitrogen fixation (Haselkorn & Buikema 1992). Traditionally, cyanobacterial identification has relied on morphological characteristics, including the shape and size of trichomes, cell types, the size, and position of heterocysts & akinetes, and the planes of cell division (Rippka et al. 1979). Within the nostocalean genera, species differentiation is primarily based on the morphology of trichomes, heterocysts, and akinetes (Hindák 2000).

According to Garrity & Stanley (2001), cyanobacteria are classified into five taxonomic groups or subsections. The dichotomous key used for this classification is based on morphological criteria, including whether the organism is unicellular or quasi-multicellular (trichomatous), the mode of cell division (binary or multiple), and the presence or absence of baeocyte formation. Baeocytes are single-celled reproductive units formed through multiple fission. The baeocyte finally develops into a vegetative cell. Additionally, determine whether specialised cells such as akinetes and heterocysts are present or absent, whether there are any branches in the trichome and whether they are real or not (Chaurasia 2015). The modern taxonomic system of cyanobacteria involves morphological, physiological, biochemical, and genetic characterisations based on axenic strains (Stanier et al. 1971; Waterbury 2006).

Cyanobacteria can survive in extreme environments like rocky coasts, hot springs, dryness, dehydration stress, osmotic stress, salinity stress, UV stress, oxidative stress, heat & cold shock, anaerobiosis, and nitrogen deficiency (Sinha & Hader 1996). A vital component of the global nutrient cycle is cyanobacteria. By supplying other living things with carbon and nitrogen, their capacity to fix atmospheric CO₂ through photosynthesis, and N₂ through nitrogen fixation, sustains life on Earth. This highlights the essential function that cyanobacteria play in maintaining life on Earth by being essential to the marine food chain as well as the control of climate and nutrient levels (Sinha et al. 1995). Some cyanobacteria form heterocysts and can fix atmospheric nitrogen (Bonnet et al. 2010).

The distribution of cyanobacteria in the water is influenced by a number of factors, including competition, light, temperature, nutrients, symbiotic relationships, and predation. Understanding the interactions between these components will help us better understand how cyanobacteria impact marine ecosystems, including

nitrogen cycle, primary production, and harmful algal blooms. Basic knowledge of ecological factors is important for understanding the ecology and biodiversity of cyanobacteria (Silambarasan et al. 2012). With this in mind, marine cyanobacteria were studied on seashore, and salt pan samples from the southeastern coast of Tamil Nadu, India. In the present study, cyanobacteria strains were collected from the Thondi, Mimal, Tiruchendur, and Tuticorin regions. The isolated strains were purified, identified, cultured in the laboratory, and pure strains were deposited in the National Repository for Microalgae and Cyanobacteria - Marine (NRMC-M), Bharathidasan University

MATERIALS AND METHODS

Examination and sample collection of Marine Cyanobacteria

Samples of cyanobacteria were collected from ponds, shorelines, and salt pans along the southeastern coast of Tamil Nadu, including Thondi, Mimal, Tiruchendur, and Tuticorin. The geographical coordinates of each sampling site were recorded. Specimens were collected using sterile forceps and stored in polyethene bags, and vials, following the method described by Thajuddin & Subramanian (2005).

Isolation, Purification and Maintenance of Marine Cyanobacteria

Unialgal cyanobacterial isolates were obtained using a combination of isolation techniques developed during this study. All samples were serially diluted, vortexed, and plated onto soft agar (0.8% concentration) using a sterile micropipette. The plates were then incubated under continuous illumination to promote the clear spread of unialgal cyanobacterial filaments. Individual filaments were carefully isolated using sterile needles with the aid of a microscope-assisted micromanipulator. The resulting unialgal strains were preserved in both liquid and solid agar media at the NRMC(M) using ASN III growth medium, maintained at a pH of 7.5 ± 0.2. Liquid cultures (100 ml volume) were maintained in triplicate and subcultured every 15 days. Strain purity was assessed every 45 days. Culture flasks were manually agitated every 24 hours and inspected for any physical contamination. For long-term preservation, ASN III agar medium was dispensed into rubber-sealed glass bottles. All culture flasks and agar bottles were stored in a culture room maintained at 25 ± 2°C, under white fluorescent light at an intensity of 20 µmol photons m⁻² s⁻².

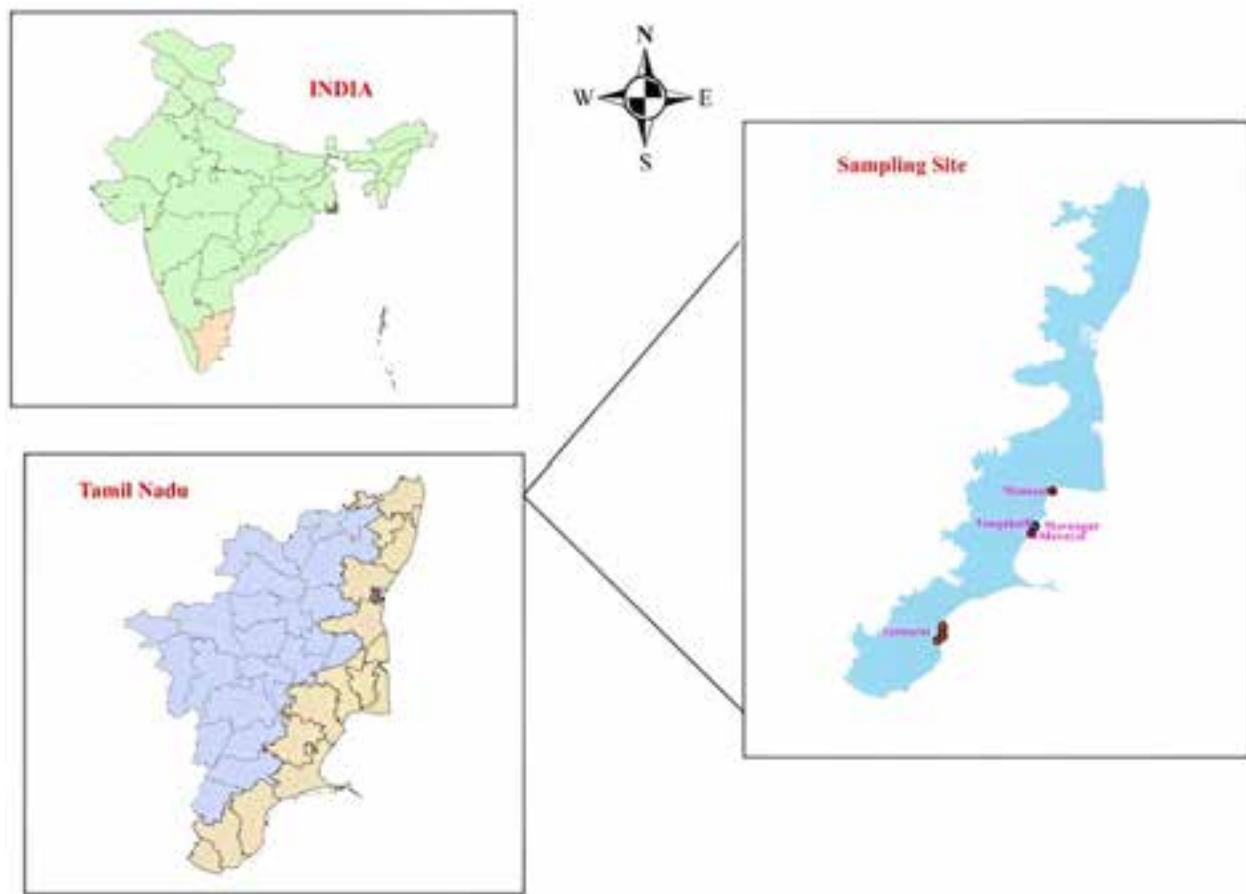


Figure 1. Sampling location of marine cyanobacteria from southeastern coast of Tamil Nadu, India.

Morphological Observation and Identification Marine Cyanobacteria

Morphological documentation of an unicellular axenic cyanobacterial isolates was carried out using an inverted light microscope (Leica DMI 3000B). Identification was performed up to the genus level, unless distinct species-level characteristics were evident. Taxonomic identification was based on morphological features following the classification system of Cyanophyta (Desikachary 1959).

Growth and Maintenance of Marine Cyanobacteria

Isolated marine cyanobacterial cultures were grown in ASN III medium (Rippka et al. 1979) in Erlenmeyer flasks, under continuous illumination using white fluorescent light at an intensity of 1500 lux. Cultures were maintained at $25 \pm 2^\circ\text{C}$ in a controlled culture facility and preserved at the NRMC (M).

Analysis of physicochemical parameters

The physico-chemical parameters like temperature, pH & salinity, Calcium, Magnesium, and Ammonia

were estimated by the standard method- APHA 1998 (Rice et al. 2012). Temperature was measured with a mercury thermometer with an accuracy of 0.5°C . The pH was measured using a calibrated pH pen with an accuracy of 0.1. Salinity was measured with a hand-held refractometer (Strickland & Parsons 1972). The pH was measured by using a calibrated pH pen (pHep, Hanna Instruments, Mauritius Ltd., Portugal) with an accuracy of ± 0.1 .

Molecular characterisation of cyanobacteria

Molecular characterisation of the selected strains was carried out using the partial gene sequence of 16S rRNA.

Extraction of DNA and 16S rRNA gene amplification by PCR of Marine Cyanobacteria

Total genomic DNA was extracted from selected strains using the xanthogenate nucleic acid isolation method described by Tillett & Neilan (2000). To obtain the complete sequence of the 16S rRNA gene, PCR amplification was performed in three regions using

different primer sets. One such amplified region utilised the forward primer 16S A2F (AGAGTTTGATCCTGGCTCAG) and the reverse primer S17R (GGCTACCTTGTACGAC) as described by Seo & Yokota (2003), specifically for marine cyanobacterial isolates. Primers were synthesised by Eurofins Genomics India Pvt. Ltd. (Bangalore). PCR reactions were carried out in a final volume of 50 μ l containing 1 μ l (10 pmol) of each primer, 1 μ l of 1.25 mM dNTPs, 1 μ l (50 ng) of cyanobacterial DNA, and 1 unit of DreamTaq DNA polymerase (Thermo Scientific, USA), using the buffer provided by the manufacturer. Amplification was performed in a DNA thermal cycler (Applied Biosystems, CA, USA). The thermal cycling conditions for 16S rRNA gene amplification were as follows: an initial denaturation at 95°C for seven minutes; followed by 30 cycles of denaturation at 95°C for one minute, annealing at 58°C for one minute, and extension at 72°C for one minute; with a final extension step at 72°C for 10 minutes. Following PCR, 10 μ l of the amplified product was resolved on a 1.2% low-melting-point agarose gel (Sigma, USA), stained with ethidium bromide, and visualised under UV transillumination using a Bio-Rad documentation system.

Sequencing of 16S rRNA gene

The nucleotide sequences of the PCR amplicons were determined using a Mastercycler® pro S (Eppendorf) and an ABI 3130 genetic analyser (Applied Biosystems) available at Genurem Bioscience LLP, Bangalore. Sequence identity was established by comparing the obtained sequences with reference sequences available in public databases using the BLAST algorithm (Altschul et al. 1997).

Bioprospecting of marine cyanobacteria for lipid production

A total of 20 marine cyanobacteria, new isolates obtained through this study, were screened for bioprospecting of lipids. The strains represented unicellular and filamentous forms. The selected strains were grown in Erlenmeyer flasks with continuous illumination using white fluorescent light at an intensity of 1,500 lux at 25 \pm 2 °C in a controlled culture room and lipid content was estimated gravimetrically at the end of the tenth day. All the extractions were carried out in triplicates.

Extraction of total lipids from Marine Cyanobacteria

A known mass of the cyanobacterial sample was obtained by centrifugation at 5,000 \times g for 10 minutes. The resulting pellet was rinsed twice with distilled water

and dried in a hot air oven at 50°C. A known weight of the dried biomass was then pulverised using a mortar and pestle for the extraction of total lipids, employing a binary solvent mixture of chloroform and methanol in a 2:1 ratio. Lipid extraction from the pellet was carried out repeatedly until complete extraction was achieved. The pooled extract was centrifuged at 5,000 \times g for 10 minutes, and the supernatant was transferred to a fresh tube. To remove water-soluble impurities, one-third volume of 1% NaCl solution was added to the supernatant, and vortexed thoroughly. To eliminate residual moisture, the extract was passed through a column packed with sodium sulphate crystals. The resultant filtrate was dried using a rotary evaporator (EVATORII), and the total lipid yield was calculated gravimetrically following the method of Bligh & Dyer (1959).

FTIR analysis of lipids from marine cyanobacteria

Crude total lipid isolated from the chosen strain was homogenized using a mortar and pestle to conform to the lipid functionality. 150 mg of the mixture was analysed using a Spectrum 8900 IR spectrometer (Shimadzu, Japan). The following were the scanning settings: spectral range of 4000–400 cm^{-1} , resolution of 32 scans cm^{-1} .

RESULTS AND DISCUSSION

Identification and Isolation of Cyanobacteria from Marine Environments

Floating and substrate-attached cyanobacteria were carefully located and isolated using sterile forceps, following the method of Nikam et al. (2010). A total of 50 samples were collected during the survey from the coastal regions of Mimal, Thondi, Tiruchendur, and Tuticorin (Figure 1). Microalgae belonging to seven different families, Chlorellaceae, Dunaliellaceae, Merismopediaceae, Synechococcaceae, Pseudanabaenaceae, Spirulinaceae, and Oscillatoriaceae have been found in the seawater ecosystems of Rameswaram, and Tuticorin Districts. Each species has its unique size and shape, which allows it to be placed in different families. Each species has its importance in the ecosystem in which it lives. Standardised taxonomic keys were used to identify the transformed unicellular marine cyanobacteria species based on their morphological characteristics (Desikachary 1959). All the strains deposited in the repository have been updated in the germplasm database (www.nfmc.bdu.ac.in), given unique identification

numbers, and geographically tagged (Table 1).

Identification of Cyanobacteria

The identified unicellular species of cyanobacteria belong to seven genera (Table 1). These marine cyanobacteria families all contribute to primary production, nitrogen fixation, and nutrient cycling, all of which are essential to their respective habitats. Comprehending these families facilitates the recognition of their ecological importance, possible economic worth (e.g., *Spirulina*), and contributions to global biological processes. The majority of the species have been found in the families Chlorellaceae and Dunaliellaceae. These families include microalgae species such as *Dunaliella* sp. BDUC001, *Dunaliella* sp. BDUT10, and *Chlorella* sp. BDUC003. The cyanobacteria species were classified as *Aphanocapsa* sp. BDUM42 belongs to the family

Merismopodiaceae, *Synechococcus* sp. BDUM19 belongs to Synechococcaceae, *Pseudanabaena* sp. BDUM034 belongs to Pseudanabaenaceae, *Spirulina* sp. BDUT005 classified under the family Spirulinaceae. Also, the family Oscillatoriaceae, including species such as *Oscillatoria* sp. BDUM4, *Phormidium* sp. BDUD059, *Phormidium* sp. BDUD072, *Phormidium* sp. BDUT80, *Phormidium* sp. BDUC002, *Phormidium* sp. BDUD008, *Phormidium* sp. BDUD058, *Phormidium* sp. BDUM116, *Phormidium* sp. BDUT003, *Phormidium* sp. BDUT02, *Phormidium* sp. BDUT1, *Phormidium* sp. BDUC002, *Phormidium* sp. BDUC003, *Phormidium* sp. BDUC80 were shown in Image 1.

Analysis of physico-chemical variables

The details of the environmental parameters prevailing in the seashore and saltpan areas of Mimal, Tamil Nadu, India.

Table 1. Habitat and geographical origin of marine cyanobacteria and microalgae from southeastern coast of Tamil Nadu, India.

	Place of collection	Habitat	GPS	Organisms
1	Mimal	A dense collection of marine algae from the ocean is known as the dark green floating mat	9.909° N 79.144° E	<i>Pseudanabaena</i> sp. BDUM03
2	Odavayal	Stagnant sea water	9.909° N 79.144° E	<i>Aphanocapsa</i> sp. BDUM42
3	Mimal	Marine cyanobacteria generate a dark green floating mat.	10.278° N 79.319° E	<i>Synechococcus</i> sp. BDUM19
4	Marungur (Thondi)	Salt evaporation pond	9.909° N 79.135° E	<i>Oscillatoria</i> sp. BDUM4
5	Odavayal (Thondi)	Salt evaporation pond	9.832° N 79.089° E	<i>Phormidium</i> sp. BDUM7
6	Mimal	Sea shore	9.909° N 79.144° E	<i>Phormidium</i> sp. BDUD059
7	Marungur (Thondi)	Salt evaporation pond	9.909° N 79.135° E	<i>Phormidium</i> sp. BDUD072
8	Vengakudi (Mimal)	Salt evaporation pond	9.903° N 79.129° E	<i>Phormidium</i> sp. BDUD008
9	Marungur (Thondi)	Formation of mats in the backwater sea	9.832° N 79.089° E	<i>Phormidium</i> sp. BDUD058
10	Mimal	Sea shore	9.909° N 79.144° E	<i>Phormidium</i> sp. BDUM11669
11	Tuticorin	The saltpan's dark green floating mat	8.843° N 79.160° E	<i>Phormidium</i> sp. BDUT003
12	Tuticorin	A jelly formation in saltpan's corner	8.843° N 79.160° E	<i>Spirulina</i> sp. BDUT005
13	Tuticorin	Inside the PVC pipe-salt pan, greenish	8.787° N 78.159° E	<i>Dunaliella</i> sp. BDUT10
14	Tuticorin	Saltpan	8.843° N 79.160° E	<i>Phormidium</i> sp. BDUT02
15	Tuticorin	Stagnant water-saltpan	8.843° N 79.160° E	<i>Phormidium</i> sp. BDUT1
16	Tiruchendur	Mud that is dark green in the saltpan	8.693° N 79.104° E	<i>Chlorella</i> sp. BDUC003
17	Tiruchendur	Floating on the surface of the rock like green	8.693° N 79.104° E	<i>Phormidium</i> sp. BDUC003
18	Tiruchendur	Mud that is blue-green in the saltpan region	8.734° N 78.159° E	<i>Dunaliella</i> sp. BDUC001
19	Tiruchendur	Yellowish-green foam that floats in the form of cyanobacteria	8.693° N 79.104° E	<i>Phormidium</i> sp. BDUC002
20	Tiruchendur	Saltpan foam with dark green mud	8.734° N 78.159° E	<i>Phormidium</i> sp. BDUC80

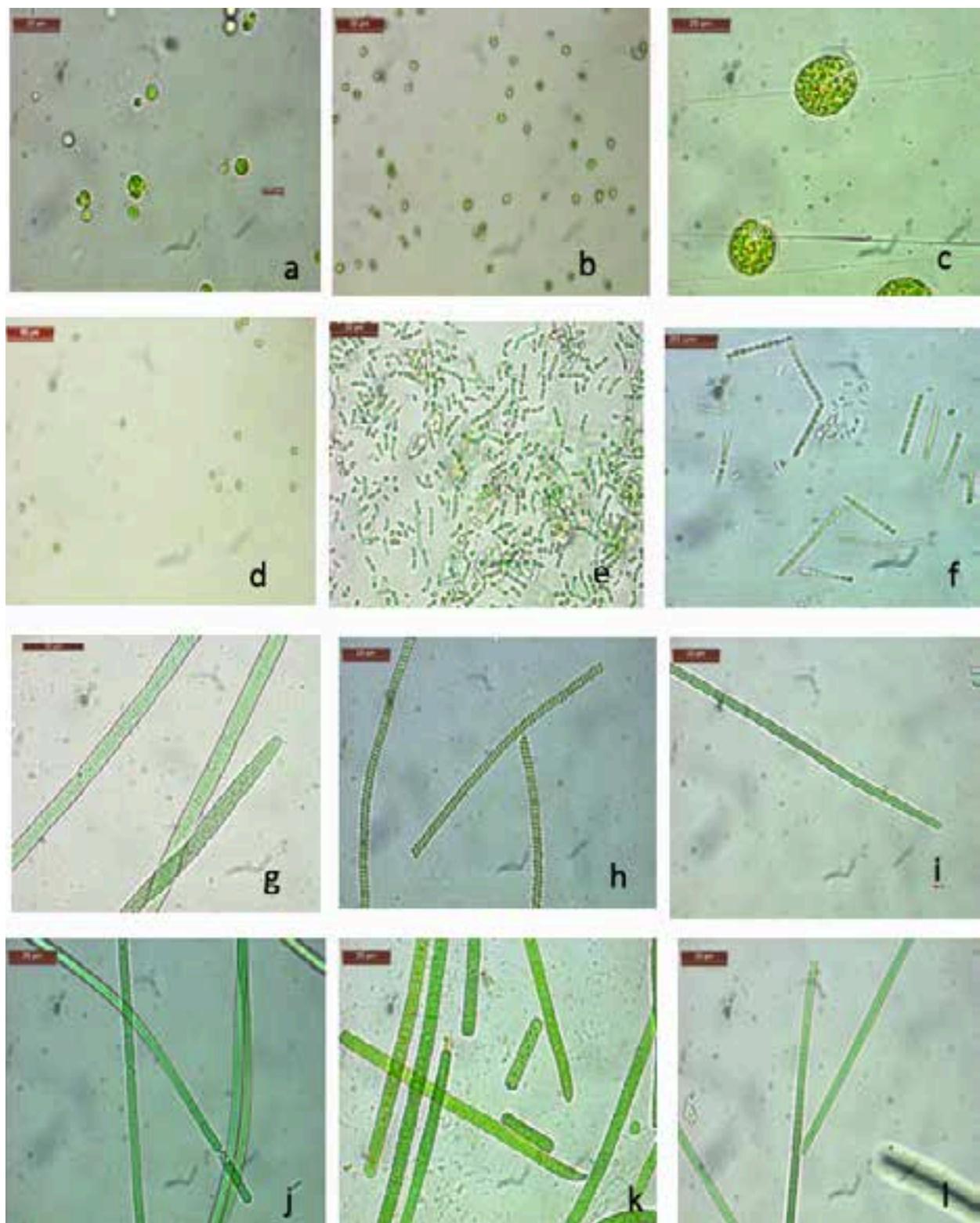


Image 1. Microphotographs of Marine unicellular cyanobacteria from different marine regimes of Rameshwaram and Tuticorin Districts. a—*Aphanocapsa* sp. BDUM42 | b—*Dunaliella* sp. BDUC001 | c—*Dunaliella* sp. BDUT10 | d—*Chlorella* sp. BDUC003 | e—*Synechococcus* sp. BDUM19 | f—*Pseudanabaena* sp. BDUM034 | g—*Osillatoria* sp. BDUM4 | h—*Spirulina* sp. BDUT005 | i—*Phormidium* sp. BDUD059 | j—*Phormidium* sp. BDUD072 | k—*Phormidium* sp. BDUT80 | l—*Phormidium* sp. BDUC002. © Selvam Selvapriya.

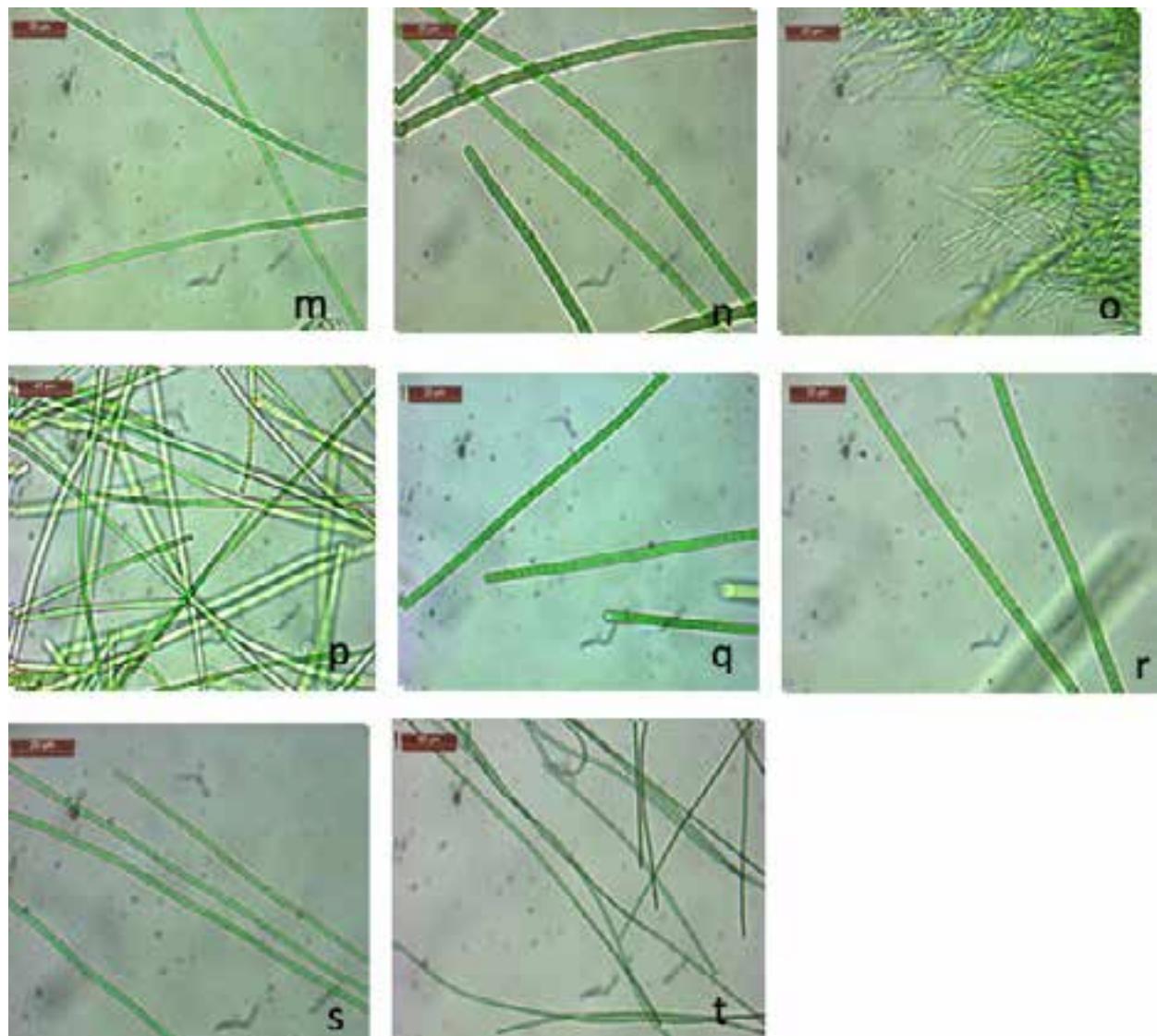


Image 1. cont. Microphotographs of Marine unicellular cyanobacteria from different marine regimes of Rameshwaram and Tuticorin Districts.
m—*Phormidium* sp. BDUD008 | n—*Phormidium* sp. BDUD058 | o—*Phormidium* sp. BDUM116 | p—*Phormidium* sp. BDUC003 | q—*Phormidium* sp. BDUC003 | r—*Phormidium* sp. BDUT1 | s—*Phormidium* sp. BDUT02 | t—*Phormidium* sp. BDUM7. © Selvam Selvapriya.

Thondi, Tuticorin, and Tiruchendur are presented in Table 2. The physico-chemical characteristics of these sites revealed significant spatial variation, reflecting the ecological diversity of these coastal regimes. Temperature ranged from a minimum of $29 \pm 2^\circ\text{C}$ in Tuticorin to a maximum of $36 \pm 2^\circ\text{C}$ in Tiruchendur. Such thermal variation plays a key role in regulating cyanobacterial metabolism, enzymatic activity, and growth dynamics. Salinity also exhibited substantial variation, with the highest range recorded in Mimisal (40–47 PPT), followed by Thondi (25–50 PPT), while Tuticorin showed a more stable, and lower value (30 PPT). Salinity influences osmotic regulation and species distribution, especially in hypersaline habitats where

only well-adapted cyanobacteria can thrive.

The pH levels ranged from slightly neutral in Tuticorin (7.0) to highly alkaline in Mimisal (up to 11.0), indicating strong buffering capacities, and intense biological activity in some areas. Alkaline environments are particularly conducive to the growth of specific cyanobacterial taxa such as *Spirulina* and *Oscillatoria*. Calcium concentrations varied between 298 and 454 mg L⁻¹, with the highest level recorded in Tuticorin. Similarly, magnesium levels ranged from 267 mg L⁻¹ in Mimisal to 362 mg L⁻¹ in Tuticorin. Both values are within acceptable environmental limits. Magnesium, often paired with calcium in natural waters, is a critical component for chlorophyll synthesis and serves as a

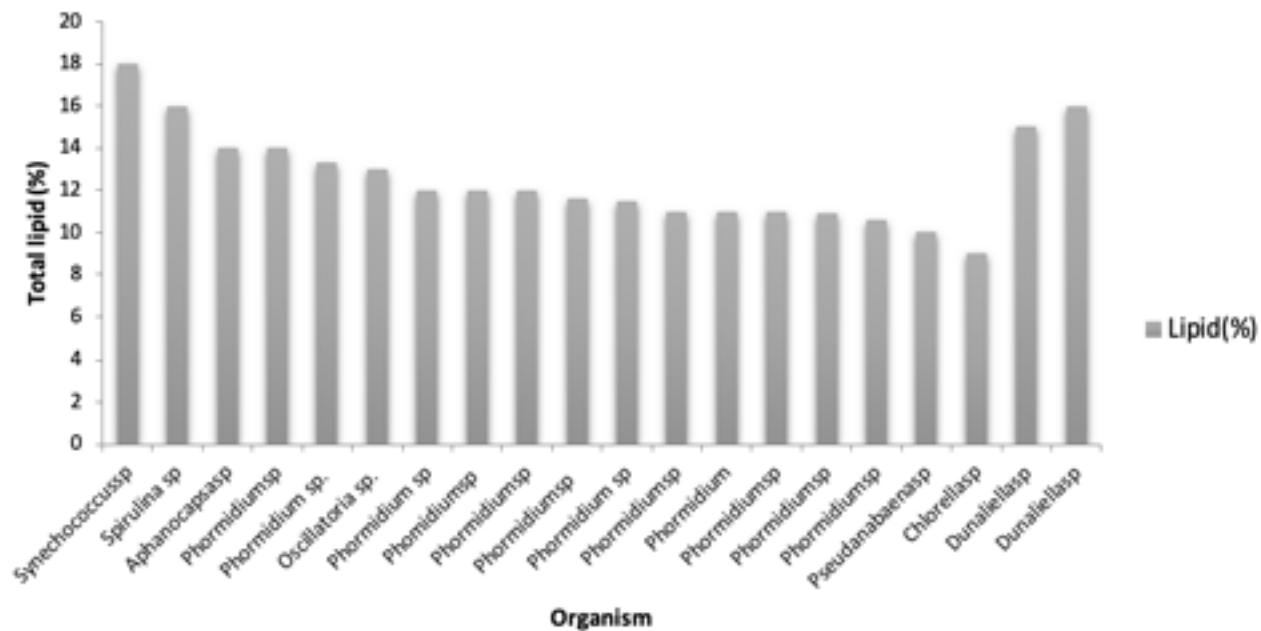


Figure 2. Lipid production of marine unicellular cyanobacteria.

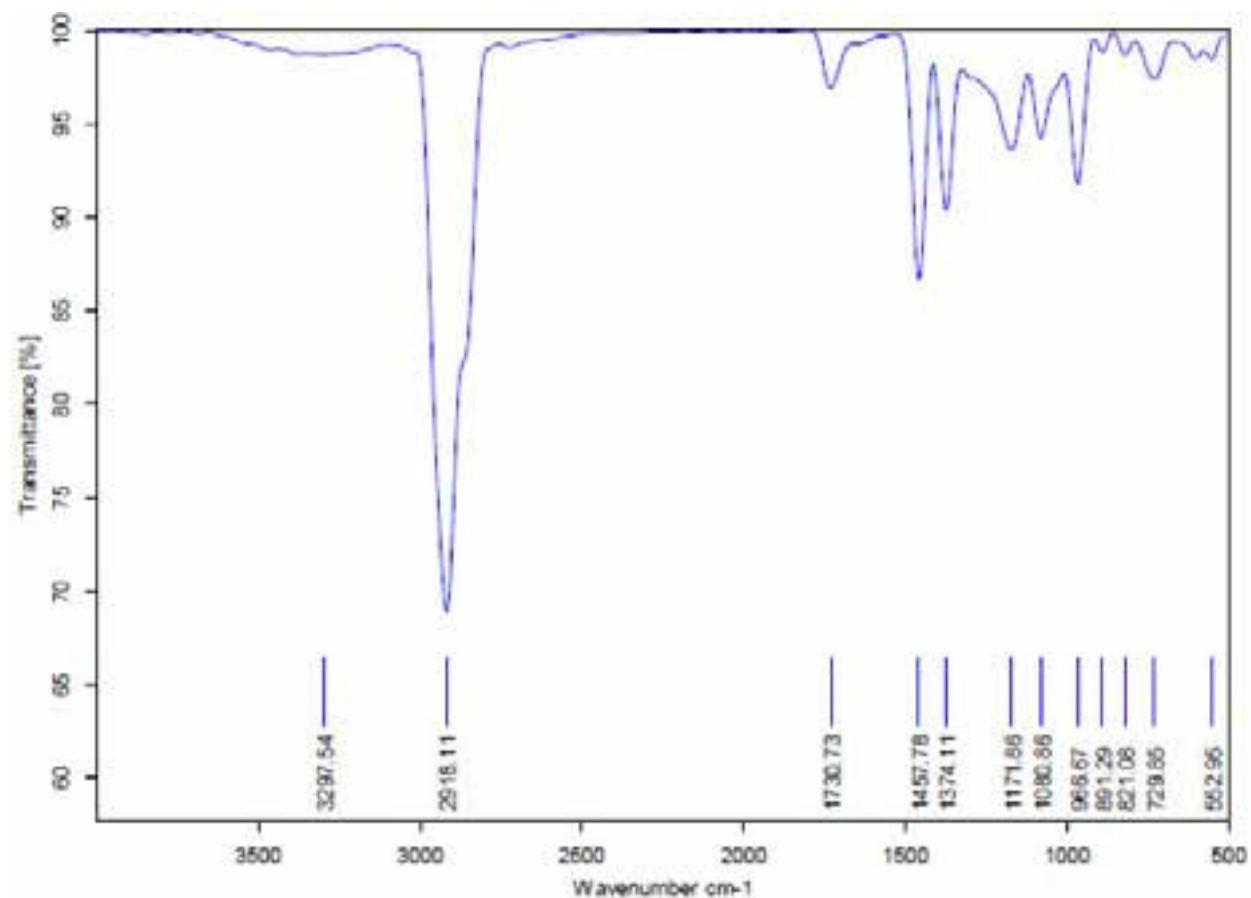


Figure 3. FTIR analysis of cyanobacterial strains for lipid production.

Table 2. Physico-chemical parameters of seashore and saltpan areas—Mimisal, Thondi, Tuticorin, and Tirchendur.

Parameters	Mimisal	Thondi	Tuticorin	Tirchendur
Temperature	31±2 °C	35±2 °C	29±2 °C	36±2 °C
Salinity (PPT)	40–47	25–50	30	28–33
pH	7.3–11	7.3–10	7–8	8–9
Calcium (mg L ⁻¹)	343	423	454	298
Magnesium (mg L ⁻¹)	267	351	362	287
Chloride (g L ⁻¹)	23	27	19	17
Ammonia (mg L ⁻¹)	0.05	0.03	0.02	0.01

limiting factor for the growth of marine microalgae and cyanobacteria.

Chloride concentrations were found to be 23, 27, 19, and 17 g L⁻¹ in Mimisal, Thondi, Tuticorin, and Tiruchendur respectively, aligning with standard marine values. Chloride ions are ecologically significant in maintaining the ionic balance and regulating salinity in marine ecosystems. Ammonia levels across all sites were within prescribed environmental limits, ranging from 0.01 mg L⁻¹ in Tiruchendur to 0.05 mg L⁻¹ in Mimisal. Although present in low concentrations, ammonia provides an important nitrogen source for cyanobacteria, especially under nutrient-depleted conditions.

Molecular identification of Marine Cyanobacteria

An organism's genetic makeup defines a species' characteristics. Therefore, the smaller ribosomal subunit, 16S rRNA, is well known for conserved regions, and the genomic DNA extraction process was performed for marine cyanobacteria in which a prospective strain demonstrated strong band formation following agarose gel electrophoresis, suggesting the high genomic DNA content. Thus, it is thought that one of the helpful tools for molecularly characterising the specified isolates is the amplification of such a segment of genomic DNA. The current results were in line with operational taxonomic groups based on 16S rRNA genes that are part of the *Synechococcaceae* family (Taton et al. 2006). Moreover, strains in the genus *Synechococcus* exhibit significant divergence and are dispersed widely over the cyanobacteria evolutionary tree (Turner et al. 1999). 16S rRNA gene sequences from a potential strain were annotated, trimmed for high-quality sequences, and subjected to a BLAST search analysis (<http://www.ncbi.nlm.nih.gov/BLAST>). Individual accession numbers have been allocated to the sequences, which were submitted

to the NCBI with Accession Number OP237032

Identification of Lipid-Producing Marine Cyanobacterial Isolates

Twenty marine cyanobacteria were screened for lipid accumulation as part of a bioprospecting initiative aimed at discovering new bio-based resources. (Figure 2). Four marine cyanobacteria possessed a maximum lipid of 15 % and above, and were designated as high lipid yielders. *Synechococcus* sp. BDUM19, a unicellular marine cyanobacterium that does not experience stress, produced 18% of the high lipid output species.

The lipid content analysis of cyanobacterial and microalgal isolates revealed considerable interspecific variation, with total lipid percentages ranging from approximately 10% to 18% of dry biomass (Figure 2). *Synechococcus* sp. exhibited the highest lipid content (~18%), followed closely by *Dunaliella* sp. and *Spirulina* sp., which recorded lipid levels around 16% and 15%, respectively. These results highlight the potential of these taxa as promising candidates for lipid-based biotechnological applications, particularly in biofuel production. *Aphanocapsa* sp. also showed substantial lipid accumulation (~14%), reinforcing its utility as a bioresource. In contrast, *Chlorella* sp. demonstrated the lowest lipid yield (~10%), suggesting limited application in high-lipid-demand processes unless optimised. Among the multiple isolates of *Phormidium* sp., lipid levels remained relatively consistent, ranging between 11% and 14%, indicating a stable but moderate lipid-producing capacity within the genus. Notably, *Pseudanabaena* sp. and *Oscillatoria* sp. also recorded moderate lipid levels. The presence of high lipid-yielding strains across diverse genera underscores the significance of strain-specific screening in selecting suitable candidates for bioenergy and value-added product development.

Lipid Profiling of Marine Cyanobacteria using FTIR Spectroscopy

The strains were assessed for the functional group analysis using FTIR spectroscopy. The Lipid of the tested strain pertained to major functional groups namely carboxyl, hydroxyl, and amine groups. Spectroscopy of the lipid for *Synechococcus* sp BDUM19 showed a peak at 2918 - Stretching of > CH 2 (asymmetric) and COO- which indicates the functional group of lipid (Figure 3).

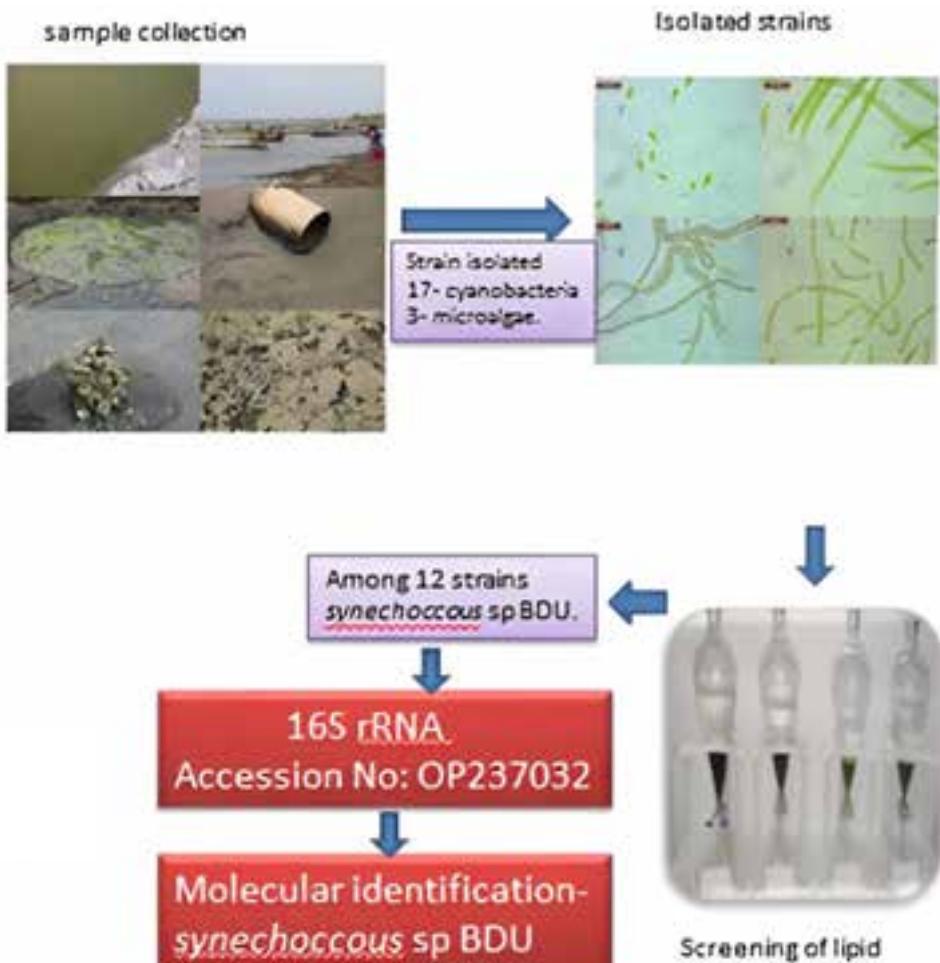


Image 2. Marine cyanobacteria collection and lipid analysis (southeastern coast of India).

CONCLUSION

In the present study, it was observed that the diverse ecosystems of coastal and estuarine regions support varying levels of cyanobacterial diversity. These environments, characterised by dynamic physicochemical conditions, offer distinct ecological niches that influence species composition and abundance. Optimal levels of sunlight, temperature, salinity, humidity, and nutrient availability, particularly nitrogen & phosphorus, create favourable conditions for the proliferation of cyanobacteria. The interplay of these environmental factors contributes significantly to the spatial and temporal variability in cyanobacterial distribution across the studied sites. In each sample (Image 2), over 20 cyanobacteria species and isolates with various morphologies were identified. Morphological identification of cyanobacteria showed that both filamentous and unicellular growth were observed. The sequences were submitted to NCBI, and individual

accession numbers were assigned with accession number OP237032. The selected strain is assessed for the functional group analysis using FTIR spectroscopy pertaining to major functional groups, namely carboxyl, hydroxyl, and amine groups. These groups are essential for cyanobacterial activity and lipid synthesis. The amine group is necessary for the metabolism of proteins and nitrogen, the carboxyl group aids in the formation of fatty acids, and the hydroxyl group maintains the stability of compounds. It is noteworthy that the most productive lipid producers are unicellular types.

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Range expansion of Indian Grey Hornbill population: a case study based on land use, land cover, and vegetation changes in Vadodara, Gujarat, India

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Abstract: The Indian Grey Hornbill *Ocyceros birostris*, commonly known to occur in dry deciduous forests and open woodlands, has seen a notable population rise in urban areas of Gujarat, including Vadodara, over the past 14 years. Prior to 2010, no Grey Hornbills were observed amidst the green canopy of the city, but the species has since established a thriving breeding population within city limits. This study attempts to link this shift to land use and land cover change (LULCC), where urban expansion and altered vegetation seem to have created suitable habitats. Traditionally, urbanization is known to lead to biodiversity loss, and habitat degradation, but as far as Vadodara City is concerned, it has offered a unique case of species adaptation. The presence of the Grey Hornbill in urban areas highlights the complex interactions between species distribution and environmental changes, particularly as altered vegetation structures, and food availability could have driven its appearance in city environs. This study explores how the LULCC, normalised difference vegetation index, and climate change are influencing Grey Hornbill's dependency on urban spaces, offering insight into the resilience of species amidst anthropogenic pressures, and changing landscapes.

Keywords: Anthropogenic pressure, Bucerotidae, environmental changes, green canopy, LULCC, NDVI, *Ocyceros*, urbanization.

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Author contributions: PD was primarily responsible for the conceptualisation of the research problem, designing the experimental methodology, performing data collection through field surveys, and conducting the statistical analysis. He also prepared the first draft of the manuscript and created all tables and figures. GP provided expert guidance on the study design and methodology, supervised all stages of the research, and offered critical insights during the interpretation of results. She extensively reviewed and edited multiple drafts of the manuscript to enhance clarity.

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INTRODUCTION

There are 63 species of hornbills in the world (IUCN 2024). The Indian subcontinent is known to be inhabited by 10 hornbill species, with nine species—Great Hornbill *Buceros bicornis*, Malabar Pied Hornbill *Anthracoceros coronatus*, Indian Grey Hornbill *Ocyceros birostris*, Malabar Grey Hornbill *Ocyceros griseus*, Oriental Pied Hornbill *Anthracoceros albirostris*, Wreathed Hornbill *Rhyticeros undulatus*, Rufous-necked Hornbill *Aceros nipalensis*, Austen's Brown Hornbill *Anorrhinus austeni*, & Narcondam Hornbill *Rhyticeros narcondami*—found in India and one species, the Sri Lanka Grey Hornbill *Ocyceros gingalensis*, found in Sri Lanka.

The Grey Hornbill, a common hornbill found on the Indian sub-continent often appears in pairs. This mostly arboreal species with a length of around 60 cm, is a medium-sized hornbill. The greyish-brown upper parts of the body with pale supercilium, darker ear coverts, and a prominent short pointed casque make it easily identifiable.

Grey Hornbills are known to occur in the forested tracts of lowland plains up to 600 m elevation in the Indian subcontinent. They are found from northeastern Pakistan and southern Nepal eastward to northwestern Bangladesh, and southward throughout most of India except in Assam (Hornbill Specialist Group 2024). The species is mostly found in dry deciduous forests, open woodlands and thorn forests (Rasmussen & Anderton 2012), has now become a common species in gardens and parks in many urban areas of central Gujarat (Ganpule et al. 2022), especially areas with many fig trees. Here, concurrent occurrence of Grey Hornbill has been reported from urban to semi urban areas of Vallabh Vidhyanagar (Nena 2020), Mehsana (Patel et al. 2021), Navsari (Bhusara et al. 2022), and also to a lesser extent in Surat, Anand, and Ahmedabad districts of Gujarat.

The division of Avian Biology, Department of Zoology, The M.S. University of Baroda has been conducting regular birdwatching trips/surveys for students for several decades. The first report regarding the presence of the Grey Hornbill in the city limits came in 2010 (Verma 2010). Since this report was filed, over the last 14 years, the population has risen remarkably from a single sighting on the outskirts of Vadodara City to an established breeding population by 2024. This led us to investigate the reasons for the increase from none to the established breeding population of Grey Hornbills in the city.

Altered vegetation structure, fluctuations in food availability, conducive reproductive sites, and elevated

population densities are the primary motivators driving species relocation between habitats. Historical evidence indicates that rapid land use change and climatic transformations are the drivers to instigate shifts in the species distributions (Telwala et al. 2013). Furthermore, given the criticality of species' capacity to adapt to changing climatic conditions for survival (Serra-Diaz et al. 2014), the major threats to biodiversity are the rapid pace of climate change and the direct human activity-induced degradation of natural habitats. Satellite-derived Normalised Difference Vegetation Index (NDVI) maps are becoming important tools in ecological studies to show response of environmental changes and linking vegetation to animal performances (Pettorelli 2005). Further, LULCC is a critical factor known to affect biodiversity significantly (Sodango et al. 2017). Land cover delineates the spatial distribution of various surface features such as forests, agricultural lands, urban expansions, water bodies, and others. On the other hand, land use refers to the manner in which humans use and change land for various purposes, such as industry, housing, and agriculture (DeFries et al. 2004). These days, the conversion of forests into agricultural land, residential area, industrial locations, mainly due to urbanization has brought with it a number of negative effects, such as the loss of biodiversity, degraded soil, and polluted environmental geographic areas (Lemarkoko 2011).

Two approaches were used to find out changes in the environment of Vadodara which have attracted Grey Hornbills to the city. In this paper, attempts have been made to find out the probable influence of LULCC in attracting Grey Hornbill to the city and establish a breeding population. This is the first comprehensive attempt to look at Grey Hornbill's adaptation in urban areas like Vadodara in accordance with the LULC changes. Further, as climate is also considered an important factor influencing range extension of species (Ancillotto et al. 2016) attempts were made to look into possible change in the same over the last 23 years. Here the annual rainfall, annual maximum temperatures (T_{\max}) as well as annual minimum temperatures (T_{\min}) have been considered over the past 23 years.

MATERIAL AND METHODS

Study area

Vadodara (Image 1) is located in western India at 22.293° N & 73.193° E, at an elevation of 35.5 m between the fertile land of the river Narmada and Mahi.

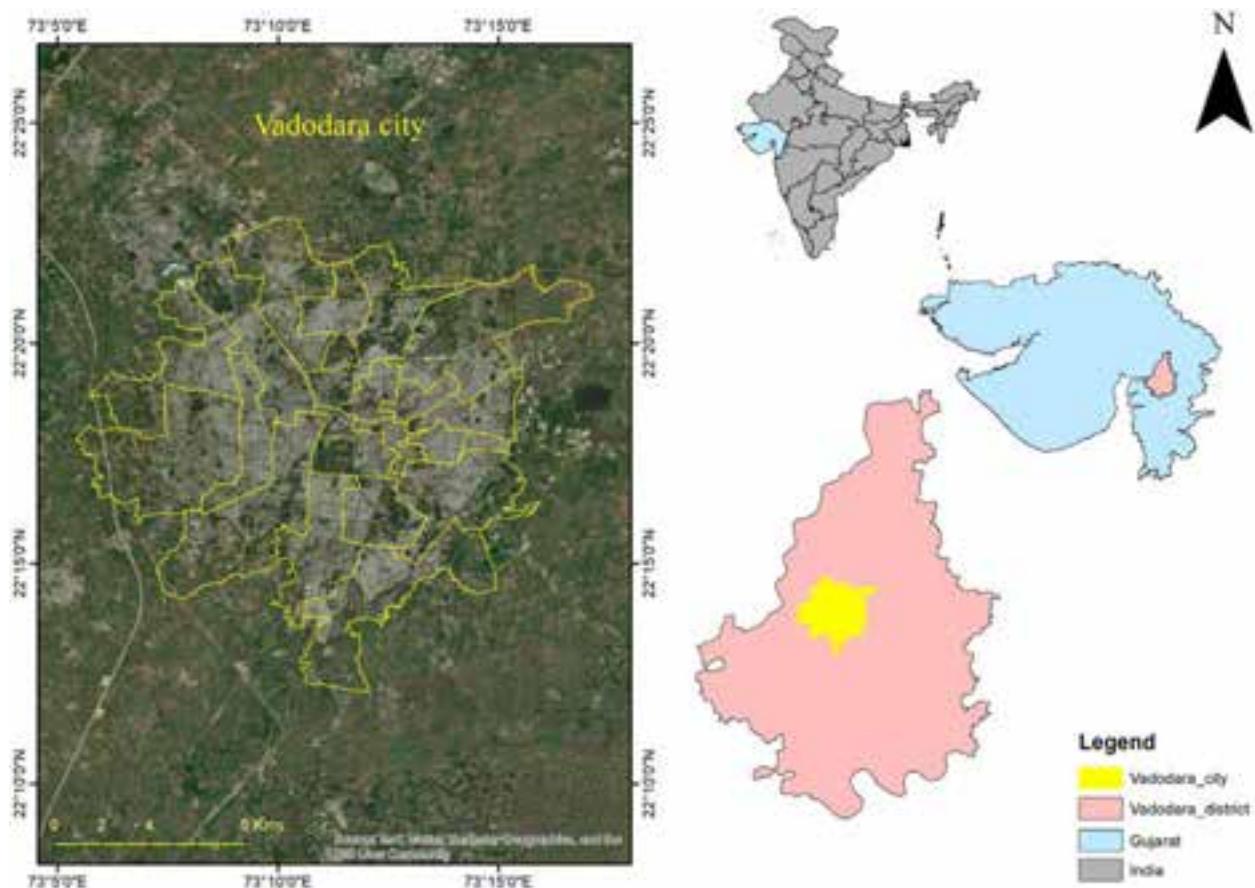


Image 1. Study area location of Vadodara in Gujarat, India.

A small river, Vishwamitri, cuts the city in two parts. Vadodara is the third most populated city in the Indian state of Gujarat after Ahmedabad and Surat. Vadodara is known as Banyan City owing to the presence of a large number of Banyan Trees *Ficus benghalensis*. The city is growing at a fast rate with the development of industrial areas and business centres, as well as residential areas, producing a strong gradient of suburbs. It has palaces, parks, ponds, residential areas with patches of vegetation in, and around them. The city receives an average rainfall of 931 mm. The mean temperatures in Vadodara ranges between maximum 40.4°C in summer to minimum 20.4°C in winter; occasionally rising to 44°C and dropping to minimum 9.8°C (Vadodara Municipal Corporation accessed on 08.ix.2024).

Methodology

The study was conducted in Vadodara City from January 2021–July 2024. Primary data were collected through field surveys and secondary data were obtained from the eBird website and enthusiastic bird watchers. To understand the distribution of Grey Hornbills in the

city, the city area was divided into 180 grids (1 x 1 km). Throughout the study, rapid, and broad field surveys were conducted almost monthly (except during the lockdown) through the point count method (Bibby et al. 2000). The presence of Grey Hornbills was mainly explored in the residential area, roadside area, gardens, and near water bodies. All the observations are tagged on Google Earth. Secondary data from eBird is also used to understand the status of Grey Hornbills in the city. The majority of the primary observations were performed on foot or by riding a motorcycle.

For the collection of NDVI and LULCC data, shape file for Vadodara was outlined for 208.84 km² and the data for years 2010, 2015, and 2020 were collected. This helped in finding out temporal and spatial changes at specific time intervals. As cloud cover is at its lowest and vegetation cover is good in January, satellite images of Landsat 7 and Landsat 8 for Vadodara City were downloaded from the USGS Earth Explorer site (<https://earthexplorer.usgs.gov> assessed on 01.i.2023) for respective years to find out changes over the last 15 years. In order to create LULCC and NDVI maps ArcGIS

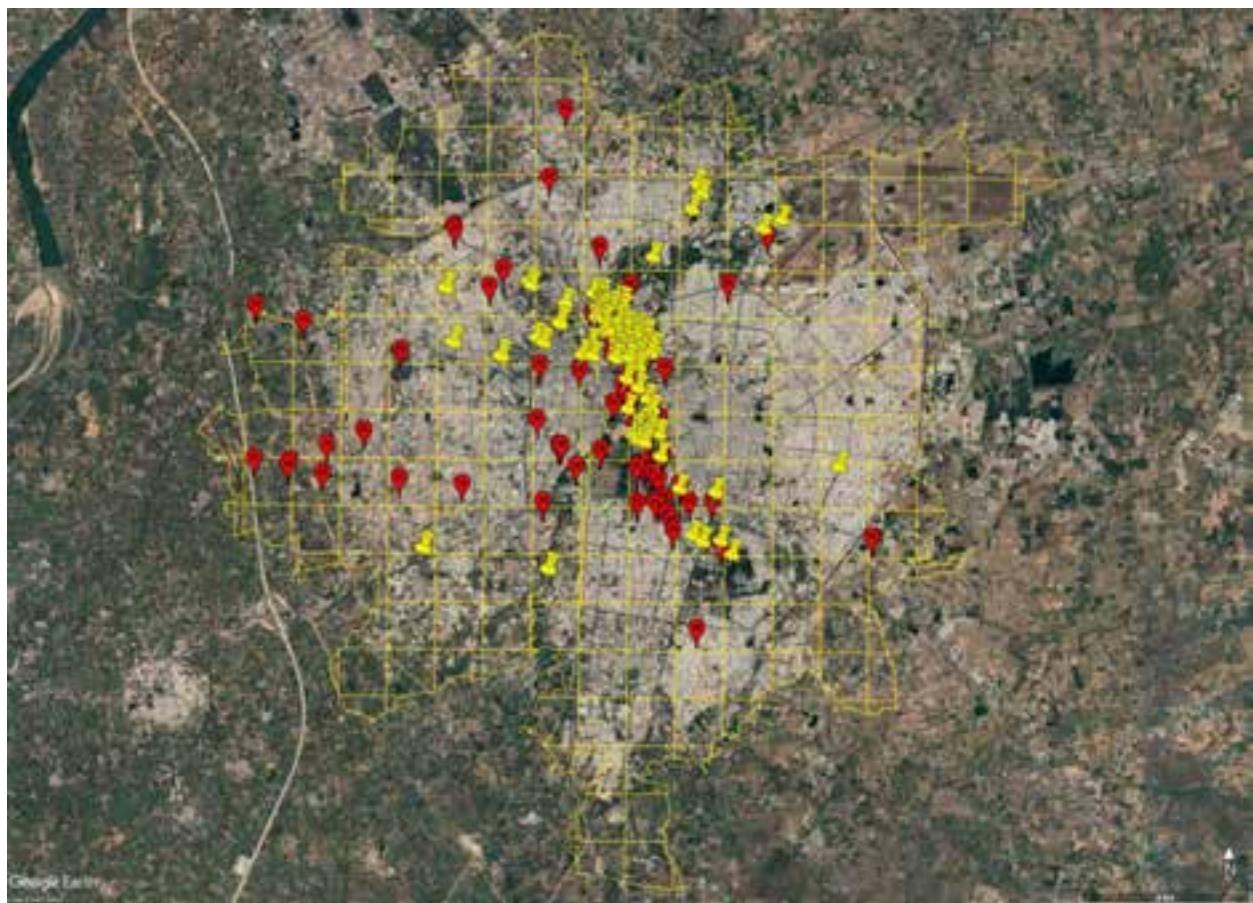


Image 2. Primary (yellow indicators) and secondary (red indicators) records of Indian Grey Hornbill in Vadodara City 2021–2024.

10.8 software is used. NDVI utilizes data from satellite sensors that detect near-infrared (NIR) and red (R) light. NDVI values range from -1 to +1, with higher values indicating healthier, dense vegetation, and lower or negative values indicating sparse vegetation or non-vegetated surfaces such as open areas. LULCC data from different years delineate the temporal and spatial distribution of various land surfaces, and how the human influence changes the same.

Further, climate data were collected in GRD file format from the Indian Meteorological Department's (IMD) website for the years 2000 to 2023 (Pai et al. 2014). These include annual rainfall, minimum, and maximum temperature data. That GRD data was converted into CSV format, using code, and run in Python software. The generated CSV file was loaded into ArcGIS to extract spatially accurate climatic data for Vadodara City.

RESULTS

Out of 180 grids, Grey Hornbills were reported from 41 grids, including three in the centre of the city, which had the maximum sightings. Although Grey Hornbills showed local movements, most of these were noted in restricted areas only. Grey Hornbills were observed in all months, but their movement was low during breeding months. Fourteen nests were noted between 2022 and 2024, indicating the presence of a breeding population (Image 2). No data on nesting could be recorded in 2021 due to the COVID-19 lockdown.

In the checklist of birds of Vadodara District (Padate et al. 2001), the Grey Hornbill was not reported from the district. By 2010, there was only a single sighting of the Grey Hornbill, reported from the outskirts of the city. Between 2010 to 2015, six sightings were recorded within the city limits by birdwatchers and uploaded on the eBird website, while between 2015 to 2020, it increased remarkably to 65 (Table 1). Simultaneously, the second author also began observing them and receiving information about their presence in the

university campus, its surrounding areas, as well as other vegetated patches from the students of avian biology. By the time popularity of eBird also started increasing, leading to more records being added.

Image 2 shows locations of both primary and secondary data of sightings of Grey Hornbill during the study period from 2021–2024. This image shows that over the years, Grey Hornbills have established themselves in the central vegetated patches of Vadodara. When the changes in NDVI values over the last 15 years are compared (Figure 2), it can be noted that in 2010 the values ranged -0.44 to 0.82, whereas in 2015 and 2020 they ranged -0.39 to 0.89 and -0.21 to 0.79, respectively. The increase in NDVI values indicates that the vegetation of the area is changing. It is important to note that the green patches in the northern, western, and southern parts of the city are mainly agricultural lands where Grey Hornbills were not recorded during the survey.

As per LULCC in the year 2010 (Figure 3a, Table 2), the built-up area encompassed 90.58 km², constituting approximately 43% of the total area, while vegetation cover was spread over 28.66 km², representing around 14%. Other land patterns, including agricultural land, barren land, and water bodies, occupied 44.45 km² (21%), 42.29 km² (20%), and 2.86 km² (1%) respectively (Table 2). By 2015 (Figure 3b, Table 2), the built-up area had expanded to 96.68 km², accounting for 46% of the total area while vegetation cover decreased just by 1% to 27.85 km² (13%), and agricultural land, barren land as well as water bodies occupied 40.05 km² (19%), 42.69 km² (20%), and 1.56 km² (1%), respectively (Table 2). By 2020 (Figure 3c, Table 2) the built-up area further increased to 107.42 km², now constituting 51% of the total area but vegetation cover also expanded to 44.54 km² (21%). Conversely, agricultural land decreased to 26.89 km² (13%), while barren land, and water bodies occupied 28.80 km² (14%) and 1.16 km² (1%), respectively (Table 2).

Table 1. eBird website records of hornbill sightings in Vadodara.

Year	No. of hornbills	Year	No. of hornbills
2010	Nil	2017	5
2011	Nil	2018	18
2012	1	2019	13
2013	Nil	2020	26
2014	1	2021	42
2015	4	2022	82
2016	3	2023	83

Changes in annual rainfall

The rainfall fluctuated from year to year (Figure 3), showing significant oscillations with an equation of $y = -7.4609x + 15950$ and $R^2 = 0.0225$. A linear trend line suggests a slight downward trend in rainfall over the years.

Changes in T_{\max} and T_{\min}

T_{\max} : The average maximum temperature stayed mostly around 33–35°C throughout the period. The trend line shows a slight downward trend, with an equation of $y = -0.0293x + 34$, and $R^2 = 0.2232$ (Figure 4), indicating a minor decrease in the average maximum temperatures over time.

T_{\min} : The average minimum temperature remained between 19–22 °C over the years. The trend line shows a slight upward trend, with an equation of $y = 0.056x + 20.353$ and $R^2 = 0.5935$ (Figure 4). This suggests a more pronounced increase in the minimum temperatures over time.

DISCUSSION

The Grey Hornbill, generally adapted to live in the dry deciduous forest, open woodlands, thorn forests,

Table 2. Total area and percentage of LULCC of Vadodara City for 2010, 2015, 2020.

	Year	2010		2015		2020	
		Land type	Total area (in km ²)	%	Total area (in km ²)	%	Total area (in km ²)
1	Agriculture land	44.45	21	40.05	19	26.90	13
2	Barren land	42.29	20	42.69	20	28.80	14
3	Built-up area	90.58	43	96.68	46	107.42	51
4	Vegetation	28.66	14	27.85	13	44.54	21
5	Waterbodies	2.86	1	1.57	1	1.16	1
6	Grand Total	208.84	100	208.84	100	208.84	100

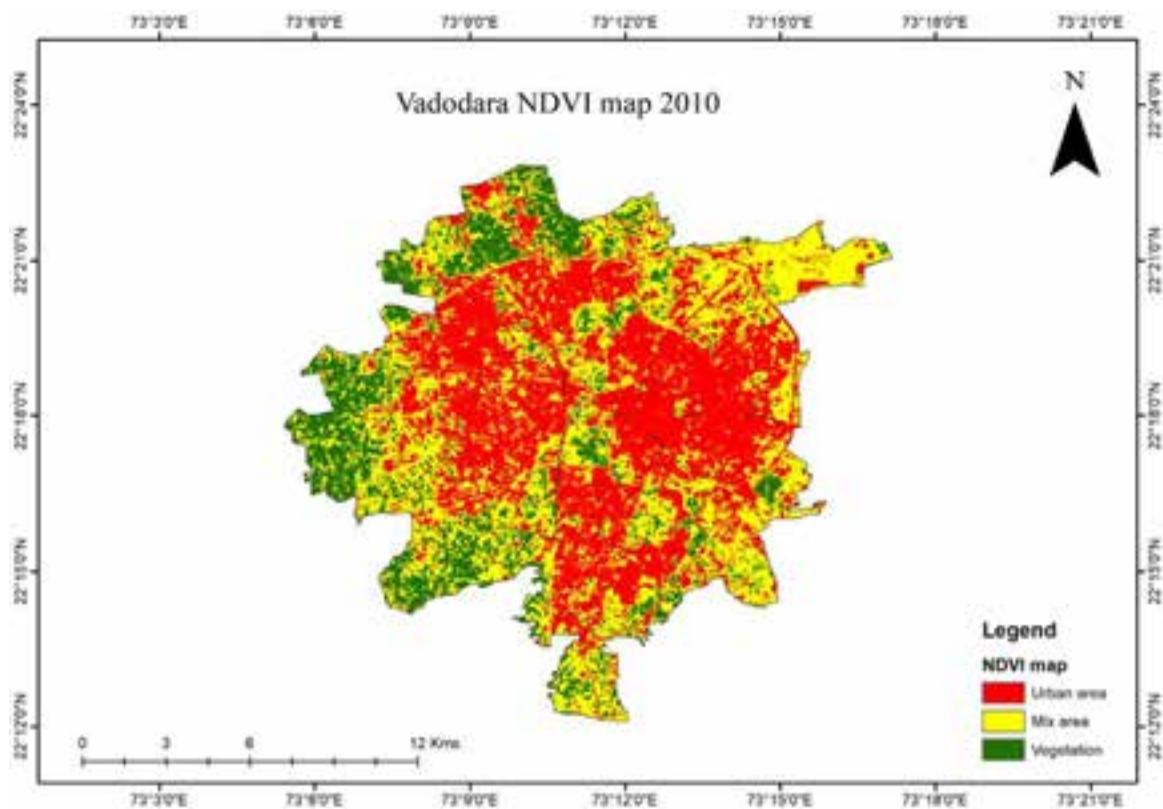


Figure 1(a). Vadodara City NDVI map 2010.

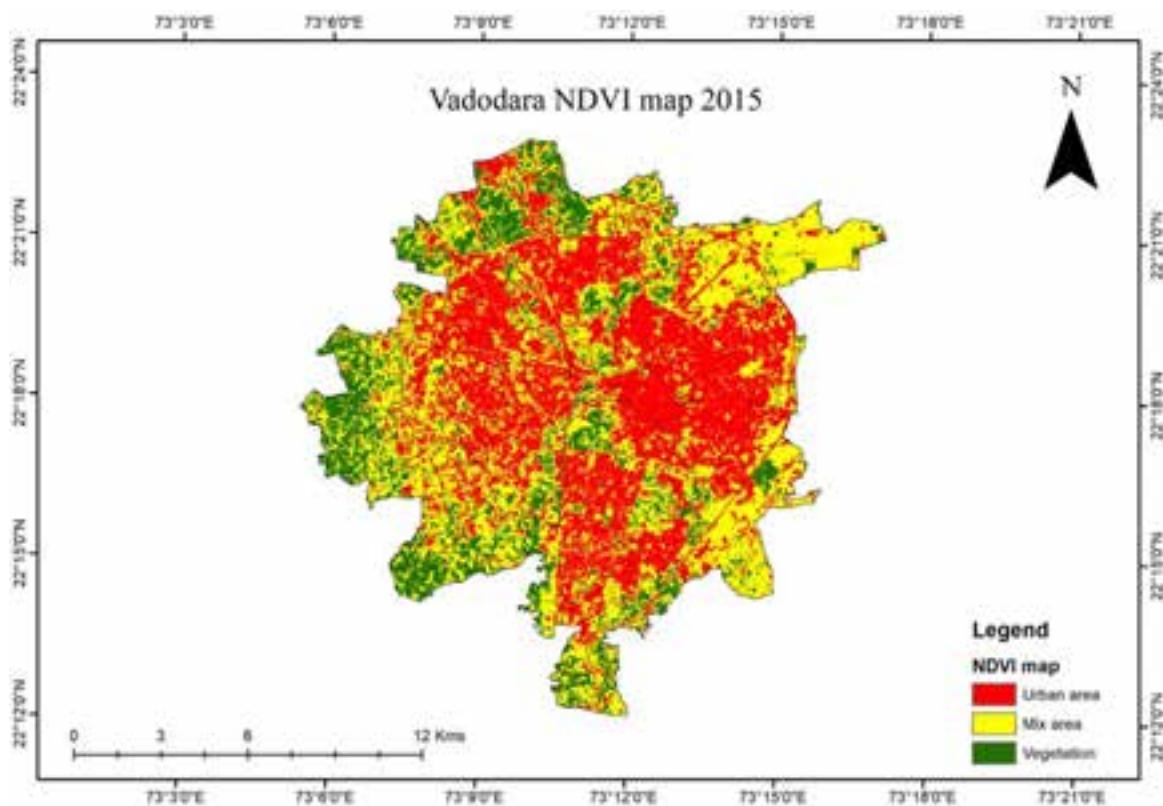


Figure 1(b). Vadodara City NDVI map 2015.

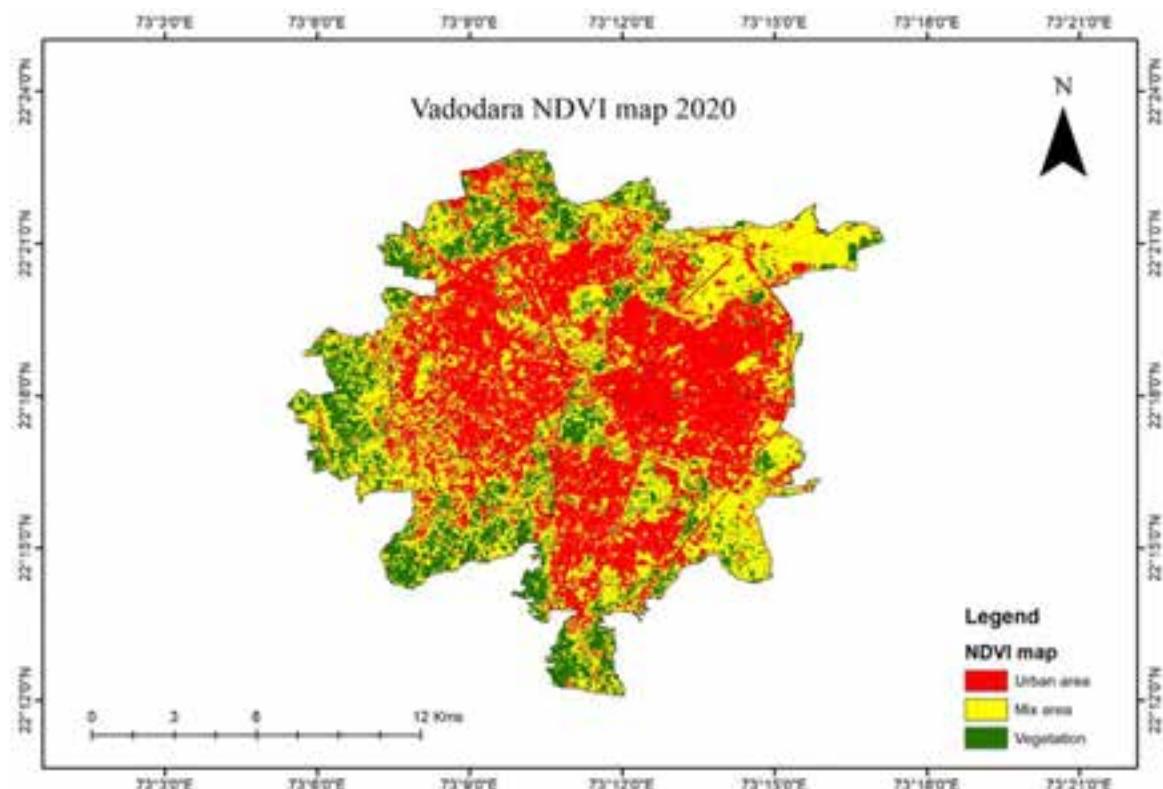


Figure 1(c). Vadodara City NDVI map 2020.

and shrublands (Rasmussen & Anderton 2012), has recently started appearing in urban gardens and parks (Ganpule et al. 2022; Hornbill Specialist Group 2024) of Gujarat. Here, Grey Hornbill regularly occurs in the eastern forested tribal belt. State of India's Birds 2023 (SOIB) shows that the long-term trend for Grey Hornbill is not conclusive due to insufficient data for the Gujarat State (<https://stateofindiabirds.in/species/inghor2/>). But this kind of long-term trend documented from the Vadodara region of Gujarat provides some inputs to conclude the rapidly increasing long-term trend for Grey Hornbill at national level.

In Vadodara City, a slow and steady increase in appearance in the Grey Hornbill population in the vegetated patches has been noted after 2010. By 2024, they have established themselves as a viable breeding population. Recent reports indicate that they are also adaptable to nesting in urban concreted forests (Kasambe 2020).

Veech (2011) reported that the process of range expansion is influenced by habitat ecology. Croplands, urban land, and shrubland are examples of habitats that are physically open, and probably offer year-round food supplies. Possible factors that influence range extension include habitat loss in their traditional range, population

change, poor prior documentation, and habitat change in the new area (Rappole et al. 2011). As far as the previous area for Grey Hornbill in Gujarat is concerned, it is the tribal belt where the flesh of Hornbills is traditionally used for pregnant women to relieve labour pain. This kind of poaching practice might have forced the Grey Hornbills to move away from their habitat. In many other areas of India, the flesh of different species of Hornbills is also used for various medicinal purposes (Chakravorty et al. 2011; Samal et al. 2020). Thus, one of the most probable reasons for shifting beyond its known ranges is the threat due to poaching. Further, changes in the seasonal food availability, influenced by climatic change-related factors, such as mean annual precipitation, or monthly means for night-time-low temperatures during the breeding season, cannot be ruled out. Fluctuations in temperatures and rainfall in a particular area are likely to affect biodiversity. High temperatures and lower rainfall can cause biodiversity loss, and fragmentation (Mantyka-Pringle et al. 2012). The changes in the temperature and rainfall pattern in Vadodara City were examined. T_{\max} and annual rainfall in Vadodara City are somewhat decreasing while T_{\min} is slightly increasing. Thus, we observe that temperature and rainfall could have negligible influence on Grey Hornbill in our study

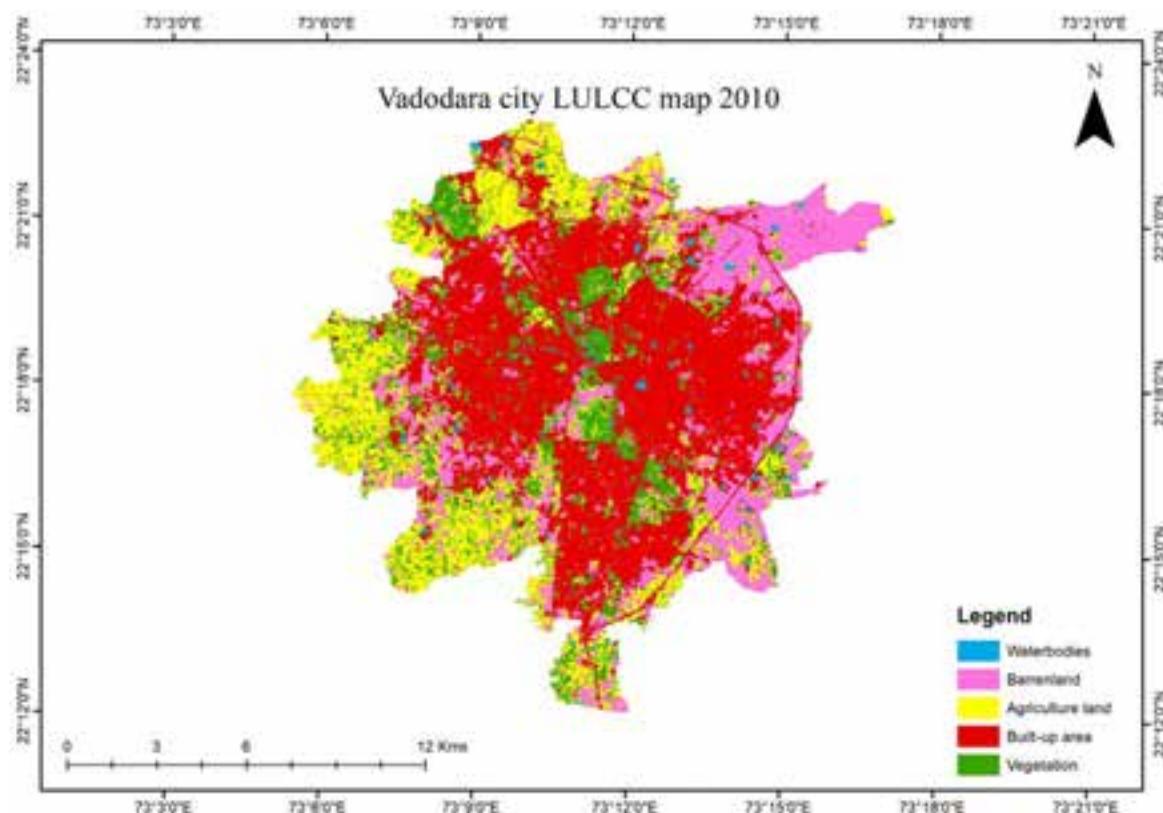


Figure 2(a). Vadodara City LULCC map 2010.

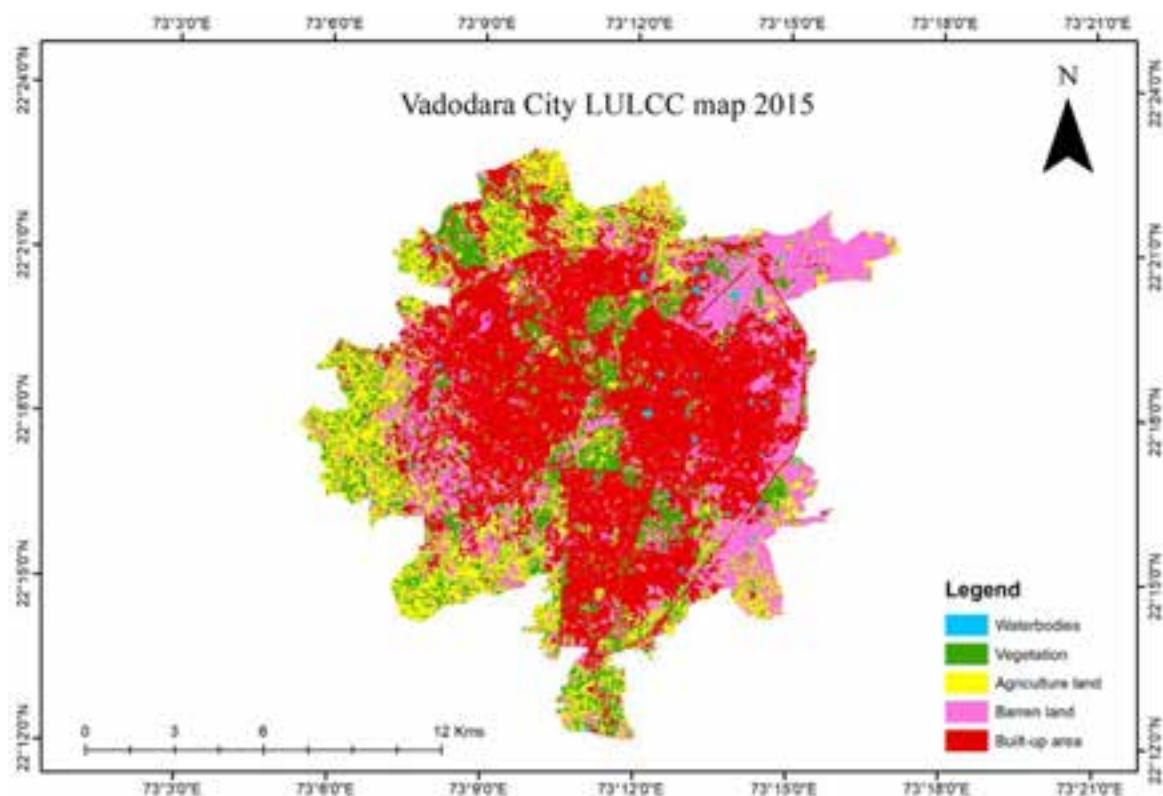


Figure 2(b). Vadodara City LULCC map 2015.

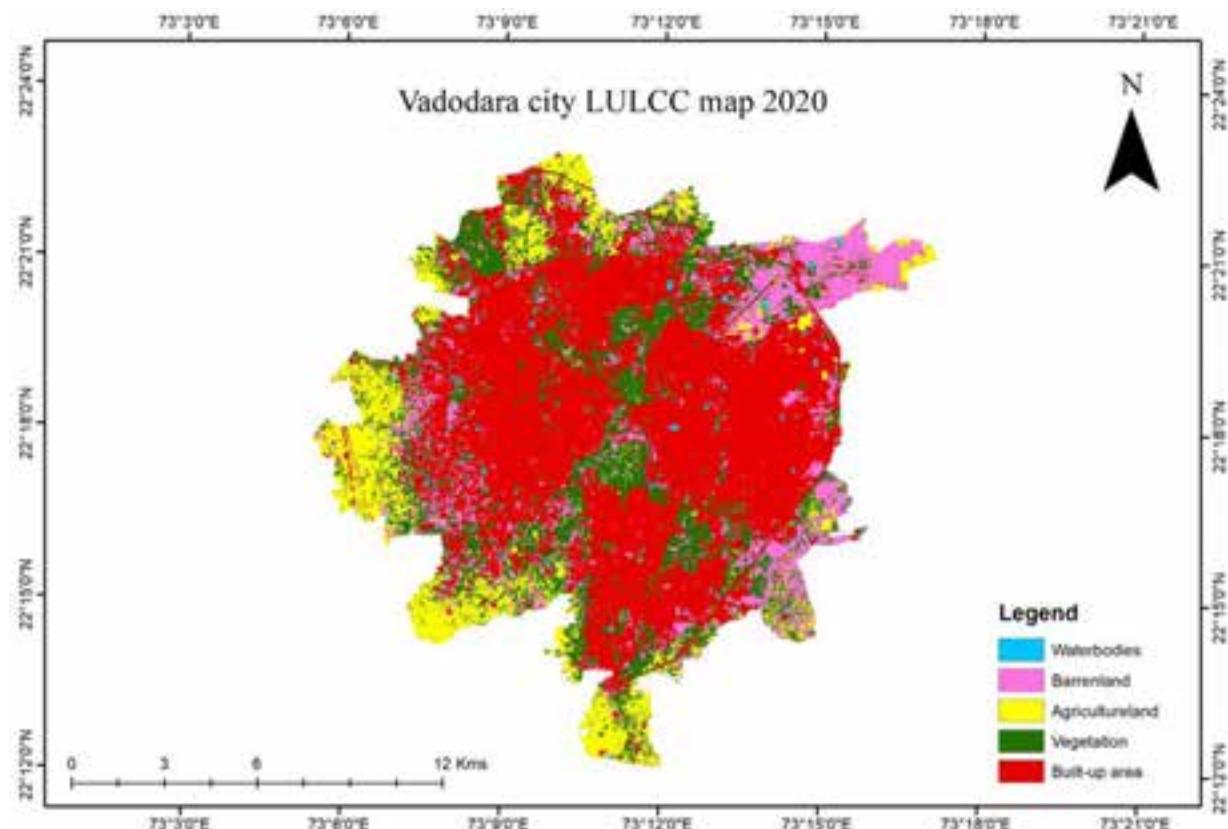


Figure 2(c). Vadodara City LULCC map 2020.

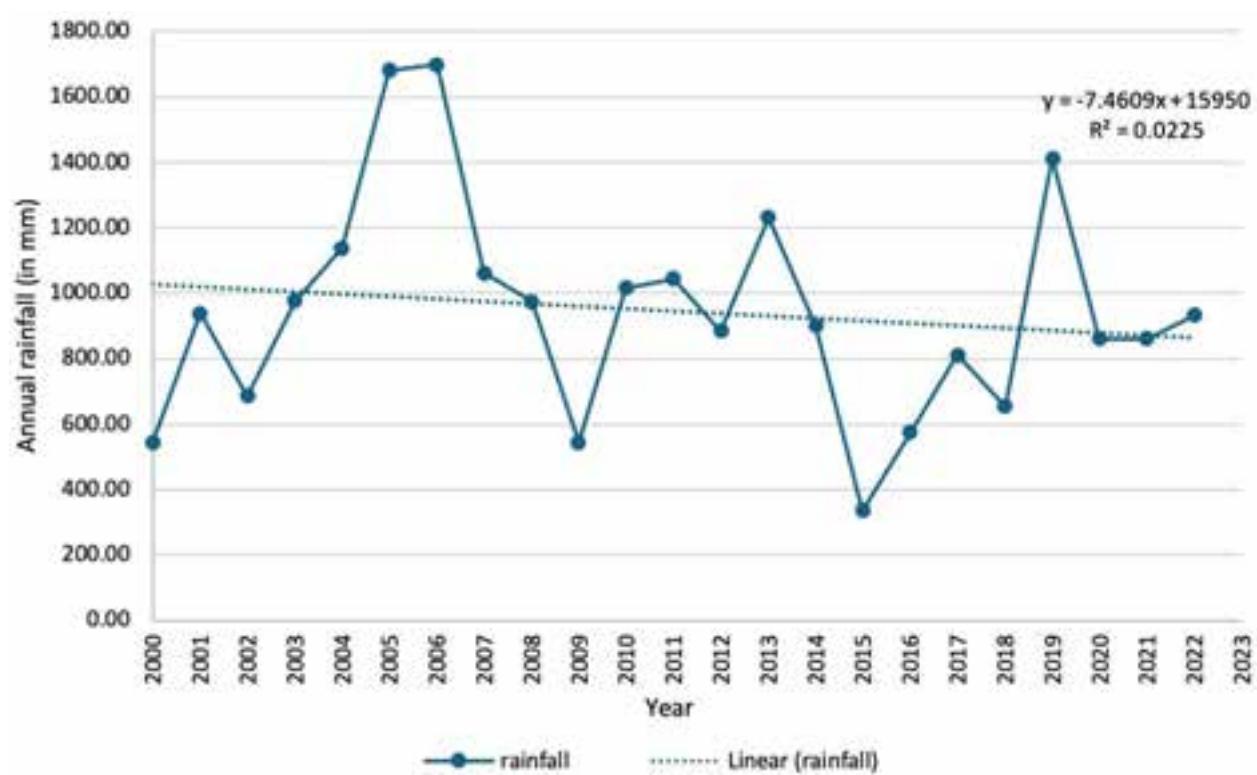


Figure 3. Annual rainfall since 2000 to 2023 in Vadodara City.

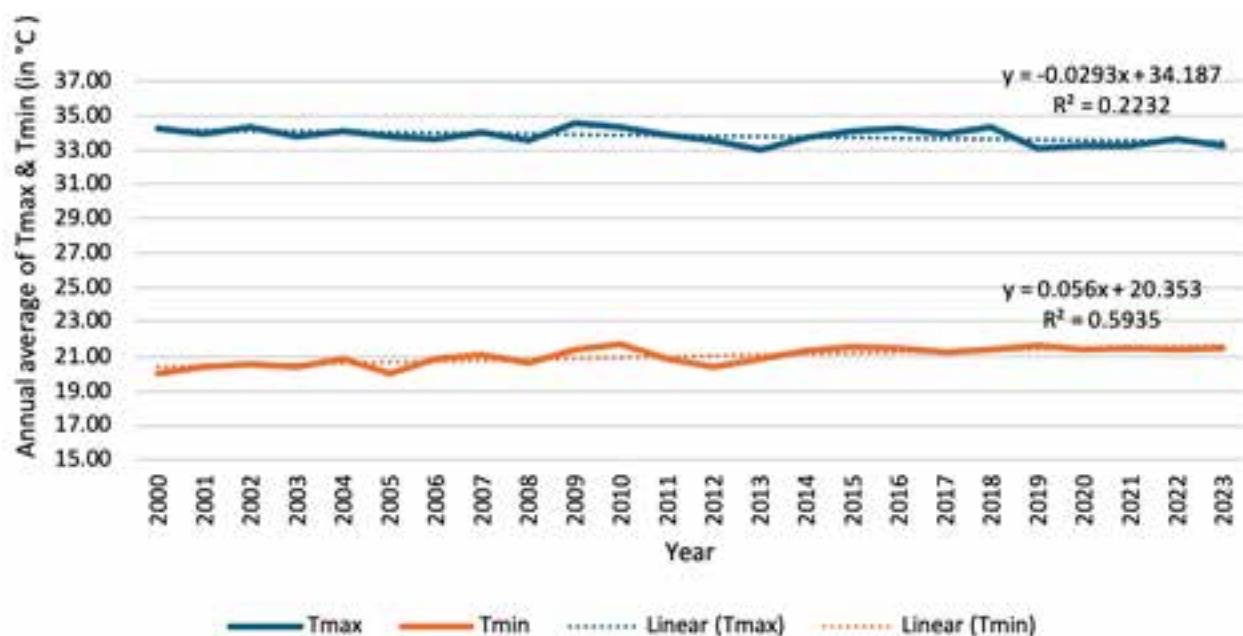


Figure 4. Annual average of T_{\max} & T_{\min} since 2000 in Vadodara City.

location. Although, climate has been identified as the primary driver of several species' range expansions, even if habitat availability is likely to have an impact. Pigot et al. (2010) discusses the progress of range expansion (pace of spread and saturation) as unevenly over vast regional and geographical scales, indicating that the process is very uncertain, and dynamic. Based on the distribution pattern of common and uncommon species, modern processes have influenced the distribution patterns of species richness at large geographical scales. This implies that when studying ecological trends at vast geographical scales, anthropogenic activity cannot be excluded as a potential driving component (La Sorte 2006). Temperature and rainfall could have negligible influence on Grey Hornbills in our study area but in 2010, the landscape was characterized by extensive vegetative areas and minimal urban spread. As mentioned by Grimm et al. (2008) and Yao et al. (2019), the urban built-up areas surged while vegetation cover declined in 2015 — a clear sign of rapid urbanization. The trend shifted by 2020; The change in the trend witnessed during 2020 had shown a remarkable increase in both vegetation and built-up areas, also a reduction in mixed (areas having a composition of barren land, agricultural land, and water bodies) areas. This indicates that during this period, despite urban development encroaching into mixed areas, proactive efforts contributed to a simultaneous increase in vegetation cover, showcasing a potential path forward for sustainable urban growth. The increased influence of urbanization with improved

vegetation cover has been reported in several areas globally (Zhao et al. 2016; Wang et al. 2022). The increase in the vegetation cover in Vadodara City may be attributed to either new town planning laws, where planting vegetation near new construction is mandatory.

Further, with the help of LULCC%, we can also say that in Vadodara, built-up area has increased at a greater rate by converting agriculture and mixed lands, which shows a decrease in the spread over the years, as is also observed in Delhi (Naikoo et al. 2020). Hence, it can be assumed that the vegetational changes in the city area helped the Grey Hornbills to establish a breeding population. This species seems to have expanded its range over the green patches along the riverine and drainage system around Vadodara.

Vadodara, known as the city of 'Vad' (Banyan) and other old natural vegetation, provided food as well as shelter to this species. Though LULC changes are reported to impact biodiversity negatively, in Vadodara, these changes appear to have helped the entry of Grey Hornbills in the city limits to establish a breeding population during the last decade.

CONCLUSION

According to the study, it reveals a significant rise in the presence and distribution of Grey Hornbills in Vadodara City over the past decade, with recorded breeding activity between 2022 to 2024. Initially

unreported in the region, their numbers have grown steadily, particularly in the central vegetated patches of the city, as supported by both direct observations, and citizen science data (eBird). Although sightings remain mostly restricted to specific green patches 14 nests in different areas strongly indicate the establishment of a breeding population. Vegetation dynamics, as shown by rising NDVI values, and land use data, suggest that urban greenery has increased in some areas despite overall urban expansion. This likely contributes to the Grey Hornbill's ability to persist and breed within the city. Their absence from agricultural lands suggests a preference for urban green spaces over rural or open landscapes. Climatic variables, including slight decreases in maximum temperatures and minor increases in minimum temperatures, along with fluctuating rainfall patterns, do not appear to significantly limit the species' distribution at present, but needs continued monitoring. Overall, the findings underscore the Grey Hornbill's adaptability to urban environments and highlight the importance of conserving, and enhancing urban green spaces to support biodiversity within rapidly growing cities like Vadodara.

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A pioneer study of orchids on Nusa Barung Island of Indonesia

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Abstract: This is the first study specifically on orchids in the Nusa Barung Island Wildlife Reserve. Nusa Barung Island has restricted access. We conducted a 14-day exploration across seven transects, covering a total distance of 12 km. Previous research only recorded five species of orchids, whereas our findings identified 17 species, of which 80 % were new records for this island. Three species of terrestrial orchids were found, namely *Eulophia picta*, *Nervilia plicata*, and *N. simplex*, while the other 14 species were epiphytes/lithophytes. *Vanda limbata* is abundant and can be found growing on cliffs, while other epiphytes can be found on tree trunks & branches in Jeruk Bay, and Kandangan Bay.

Keywords: Epiphytes, Orchidaceae, small island, transects, terrestrial orchids, *Vanda limbata*, wildlife reserve.

Abstrak: Ini adalah studi pertama yang secara khusus meneliti anggrek di Suaka Margasatwa Pulau Nusa Barung. Akses ke Pulau Nusa Barung sulit dan terbatas. Kami melakukan eksplorasi selama 14 hari menyusuri tujuh transek, dengan total jarak 12 km. Penelitian sebelumnya hanya mencatat lima jenis anggrek, sedangkan temuan kami mengidentifikasi 17 jenis, di mana 80% adalah catatan baru untuk pulau ini. Tiga jenis anggrek tanah ditemukan, yaitu *Eulophia picta*, *Nervilia plicata*, dan *N. simplex*, sementara 14 jenis lainnya adalah epifit/litofit. *Vanda limbata* ditemukan melimpah dan dapat ditemukan tumbuh di tebing, sementara epifit lainnya dapat ditemukan di batang dan cabang pohon yang tumbuh di Teluk Jeruk dan Teluk Kandangan.

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Author contributions: Toni Artaka conceptualised research, methodology, data curation, and writing. Tri Atmoko was a principal investigator, conceptualised the methodology, served as supervisor, data curation, writing lead, and funding recipient. Bina SS, Suryadi, and Fajar DNA were involved in data curation and writing.

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INTRODUCTION

Indonesia is an archipelagic country with more than 17 thousand islands (Indonesian Government 2024). Of that number, 111 are the outermost small islands, one of which is Nusa Barung Island (Presidential Decree of Indonesia 2017). The uninhabited Nusa Barung Island is a wildlife reserve that humans rarely visit due to its relatively difficult accessibility. To reach it, one must cross the Indian Ocean, which is known for its large waves, unpredictable weather, and the island itself has limited freshwater sources. These are the limiting factor for biodiversity research activities on this island, resulting in a lack of data on its flora and fauna, including the orchid species (Orchidaceae).

Indonesia is one of the World's orchid biodiversity centers (Vitt et al. 2023). The country has a natural distribution of more than 5,500 orchid species or about one-fifth of the species in the world (Chase et al. 2017; Wati et al. 2023). Of these, 731 species are found on the island of Java, and 231 are endemic (Comber 1990). Orchids are an important part of the ecosystem and have high economic and conservation appeal with their morphological, ecological, and adaptation to various environmental conditions (Sharma et al. 2024). Orchids are able to survive and thrive in various habitats on Earth (Ziegler 2011).

Much research on orchid diversity on the island of Java has been conducted in past (Comber 1990; Nurfadilah et al. 2016; Rindyastuti et al. 2018; Sadili 2019), but these surveys were not conducted specifically on Nusa Barung Island. General information on plant diversity in Nusa Barung was collected by Jacobs (1958) and Partomihardjo & Ismail (2005). Both provided basic knowledge of the plant species in Nusa Barung Island, although their exploration area was limited. The previous study (Partomihardjo & Ismail 2005), only explored the coastal areas at limited locations. The present study included several inland areas that had not been visited before. This information is essential considering the unique ecosystem on Nusa Barung Island, which is a small island dominated by karst.

This biodiversity database provides invaluable information that will serve as a foundation for managing conservation areas. This study is hence, a valuable first step in gathering biodiversity data on Nusa Barung Island for managers. This paper is the result of the first study aimed at identifying and documenting orchid species on Nusa Barung Island.

STUDY SITE AND METHODS

The study was conducted for two weeks in July 2024 on Nusa Barung Island, a 76.4 km² wildlife reserve located in the Indian Ocean. Administratively, it is located in Puger District, Jember Regency, East Java (Figure 1). Based on DEM SRTM data (<https://earthexplorer.usgs.gov/>), this island has an altitude ranging 0–279 m with flat as well as undulating topography. Based on our general observations, forest types include coastal, lowland, karst, and mangrove forests. Based on NASA POWER data (<https://power.larc.nasa.gov/>) for the past 10 years, the weather patterns are as follows: annual rainfall ranging 1,129–2,421 mm/ year, an average air temperature of 26.9 °C (min-max: 24.1–28.8 °C), and an average air humidity of 81.1 % (min-max: 77.3–85.1 %).

Exploration was carried out following a standard methodology, for example, in field tracking was conducted on the observation transects and its surroundings with a width of approximately 15 m from the transect. Fourteen days were spent to cover seven routes with a total distance of approximately 12 km, in Plirik-Monyetan (2,083 m), Kedok Watu (2,508 m), Kandangan Bay (1,530 m), Jeruk Bay (2,549 m), Ketimo (715 m), Pucung Prau (1,140 m), and Cambah Bay-Sumber Gempol (1,544 m). Observations were made on terrestrial and epiphytic orchids. The epiphytic orchids on the high branches were observed with a binocular and documented with DSLR digital camera with tele lens. This study was mostly limited to the observation of individual orchids on high branches more than 20 m from the ground. The orchids found were identified and documented; the number of individuals/clumps was counted, and certain individuals were collected for further identification in Herbarium Wanariset (WAN). We identified the species by referring to the field guide provided by Comber (1990) and Artaka (2019).

RESULTS AND DISCUSSION

During the survey, 17 species of orchids of 13 genera were found (Table 1; Image 1). Three species found were terrestrial orchids, namely, *Eulophia picta* (Image 1F), *Nervilia plicata* (Image 1I), and *N. simplex* (Image 1J). The other species include the epiphyte and lithophyte groups. *Vanda tricolor* in Kandangan Bay uses the Bayur Tree *Pterospermum javanicum* as its host, while *Luisia zollingeri* (Image 1H), found around Kandangan Bay, attaches to the trunk of the *Dysoxylum* sp. The presence of *Vanda limbata* (Image 1P), is abundant, growing

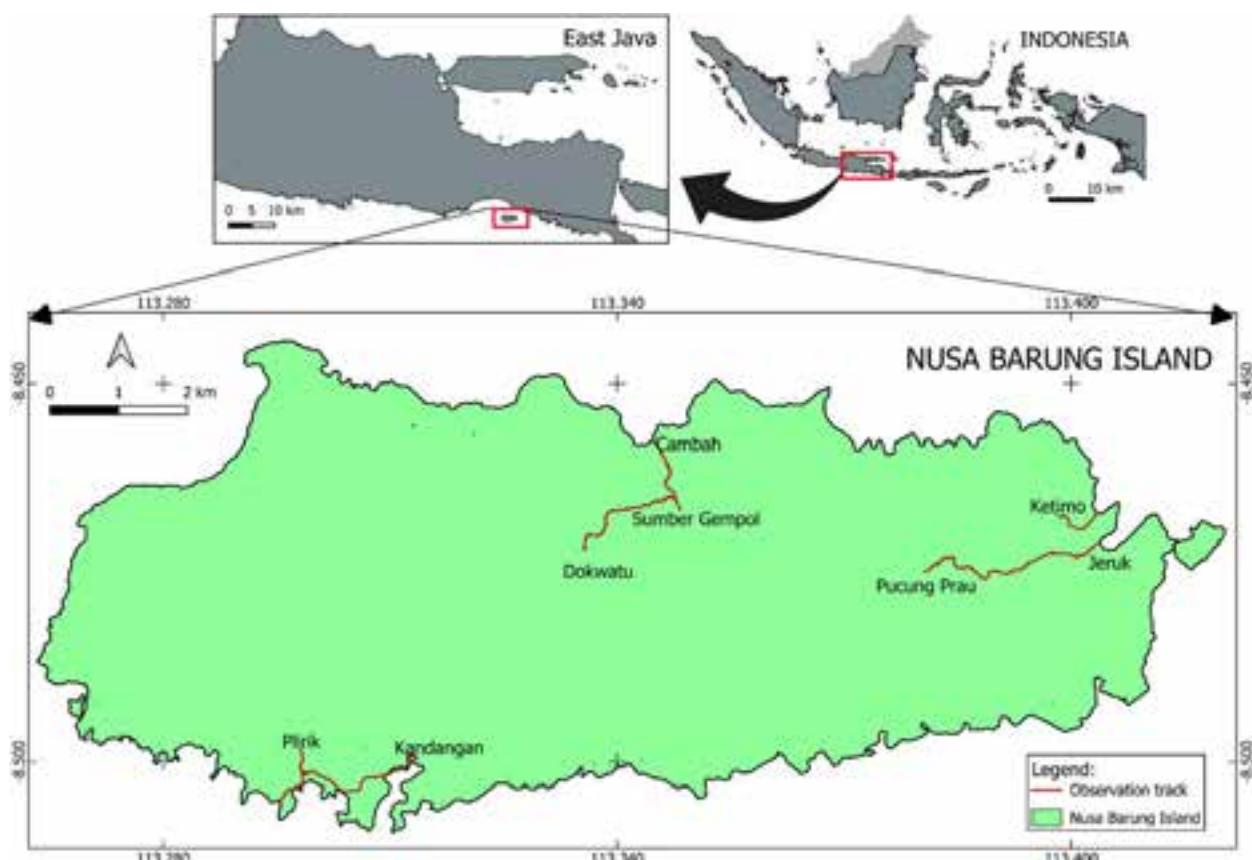


Figure 1. The study site, Nusa Barung Island in Indonesia.

on cliffs and rocks around Jeruk Bay. Meanwhile, those around Kandangan Bay grow as epiphytes with *Rhynchostylis retusa* (Image 1L), on the *Syzygium* sp. as a host.

Although we did not create a permanent plot to calculate abundance, based on individual/clump counting, several orchid species were found in small numbers, such as *Cymbidium* sp., *Dendrobium crumenatum*, *Liparis parviflora*, and *Polystachya concreta* (Table 1). Protection and prevention of illegal harvesting of this species needs to be done more because it has high vulnerability and potential for local extinction.

Vanda limbata was most commonly found in this study mainly in Kandangan Bay and Jeruk Bay. That is in line with the results of previous studies. During the exploration activities, Jacobs (1958) also reported the discovery of *V. limbata* in Nusa Barung, alongside species such as *Taeniothallis* sp. and *Aerides* sp. Partomihardjo & Ismail (2005) conducted a survey and found *V. limbata*, *Dendrobium crumenatum*, *Phaius flavus*, and *Taeniothallis* sp. among a total of 282 flora species. We

were unable to find *Phaius flavus* in this survey.

Indonesia has a high diversity of *Vanda*. Out of 90 species of *Vanda* in the world (POWO 2025), 20 species grow naturally in Indonesia (Metusala 2011). This is a species that was initially known to be endemic to the island of Java until it was later found in Bali, the Nusa Tenggara Islands, Sulawesi, and Maluku (Metusala 2011). This species exhibits a relatively diverse habitat distribution, ranging from karst cliffs and seashores to attaching itself as an epiphyte on large tree trunks at altitudes exceeding 500 m (Yulia & Budiharta 2011). Setiawan (2018) also noted the presence of *V. limbata* as an epiphyte on tamarind trees *Tamarindus indica* planted as shade trees in Bangkalan, Madura Islands (East Java).

Sempu Island, a small island also located south of Java Island, has at least seven orchid species, one of which is also found on Nusa Barung Island, namely *Dendrobium crumenatum* (Sadili 2019); other species are *Ascochilus emarginatus*, *D. subulatum*, *Thrixspermum subulatum*, *T. acuminatissimum* (Rindyastuti et al. 2018), *Taeniothallis biocellatum* (Nurfadilah et al. 2016), and

Table 1. Species and distribution of orchids in the Nusa Barung Island Wildlife Reserve, Indonesia.

	Species	Habitus	Individuals/ Clump					
			A	B	C	D	E	F
1	<i>Aerides odorata</i> Lour. (Image 1A)	Epiphytic	6	40	18			
2	<i>Arachnis sulingi</i> (Blume) Rchb.f. (Image 1B)	Lithophytic			18			
3	<i>Cymbidium</i> sp. (Image 1C)	Epiphytic				1		
4	<i>Dendrobium crumenatum</i> Sw. (Image 1D)	Epiphytic				1		
5	<i>Dendrobium macrostachyum</i> Lindl. (Image 1E)	Epiphytic			4			
6	<i>Eulophia picta</i> (R.Br.) Ormerod (Image 1F)	Terrestrial					8	
7	<i>Liparis parviflora</i> (Blume) Lindl. (Image 1G)	Epiphytic				2		
8	<i>Luisia zollingeri</i> Rchb.f. (Image 1H)	Epiphytic	7		1			
9	<i>Nervilia plicata</i> (Andrews) Schltr. (Image 1I)	Terrestrial			23			
10	<i>Nervilia simplex</i> (Thouars) Schltr. (Image 1J)	Terrestrial		8		4		
11	<i>Polystachya concreta</i> (Jacq.) Garay & H.R.Sweet (Image 1K)	Epiphytic			2			
12	<i>Rhynchostylis retusa</i> (L.) Blume (Image 1L)	Epiphytic	4		26			
13	<i>Taeniophyllum hasseltii</i> Rchb.f. (Image 1M)	Epiphytic	18		3			
14	<i>Taeniophyllum</i> sp. (Image 1N)	Epiphytic			6			2
15	<i>Thrixspermum ciborskii</i> J.J.Sm. (Image 1O)	Epiphytic					2	8
16	<i>Vanda limbata</i> Bl. (Image 1P)	Lithophytic, Epiphytic	66				abundant	
17	<i>Vanda tricolor</i> Lindl. (Image 1Q)	Epiphytic	4	15	2			

A—Kandangan Bay | B—Plirik-Monyetan | C—Cambah Bay-Sumber Gempol | D—Kedok Watu | E—Jeruk Bay | F—Pucung Prau.

Grosourdya appendiculata (Sadili 2019). When compared to the closest location on the mainland of Java Island, as many as five species of orchids in Nusa Barung are the same as those found in Bromo Tengger Semeru National Park (Artaka 2019), and three species are the same as in Meru Betiri National Park (Puspitaningtyas 2007). This phenomenon shows that distribution of propagules from the main island affects the biodiversity of Nusa Barung Island as a result of the dispersion by biotic and abiotic agents, as well as native species that already existed in this area when the island was separated from it due to rising sea levels (Schrader et al. 2020).

This survey only covered a small part of Nusa Barung Island, hence it is assumed that more orchid species may still exist on the island, waiting to be discovered. Several obstacles during the survey included the limitation in collecting epiphytic orchid species that grow attached to the crown of large trees at a height of more than 20 m. Another obstacle was that only a few orchid species were found flowering during the survey, which coincided with the dry season in Indonesia (April–September) without flowers, which is a problem for further identification at the species level. The specimens without flower were identified only at the genus level, except for the species that have important identification character on their

vegetative organs (e.g., leaf, bulb and root).

Several species, although not with generative organs, can still be identified at the species level based on the special vegetative characteristics they have, such as the *Eulophia picta* species. That species is easily recognized even when it is not flowering because it has a distinctive habitus and tubers (pseudobulbs). The *E. picta* was only found with as many as eight individuals growing on sandy coastal soil media shaded by the canopy of the *Hibiscus tiliaceus* tree in Jeruk Bay. The tubers have a depth of 5–7 cm in the sandy soil and are characterized by fine-haired roots.

Dendrobium macrostachyum is commonly found attached to trees around the rain-fed lake (Sumber Gempol). This species is recognized because of its distinctive habitat, and it always grows hanging. Preferring shady and windy habitats, it grows together with *Polystachya concreta*, *Luisia zollingeri*, and *Taeniophyllum hasseltii*.

The *Cymbidium* species was found dead on the forest floor. The genus *Cymbidium* is recognized from its oval pseudobulbs covered by leaf sheaths. It is very difficult to determine the species without a flower. Same is the case with *Taeniophyllum* sp., which was also found in vegetative phase.

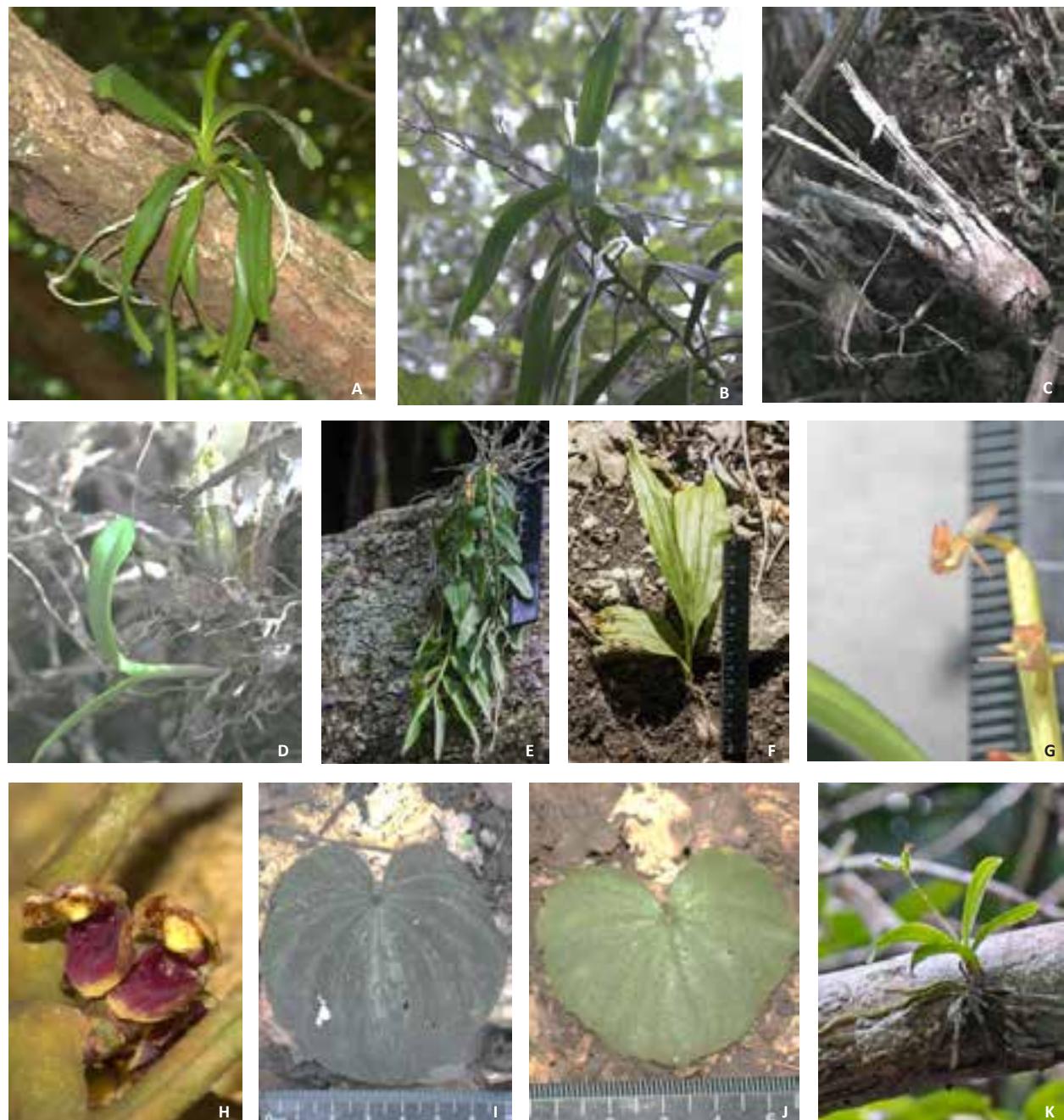


Image 1. Orchid species found on Nusa Barung Island: A—*Aerides odorata* | B—*Arachnis sulingi* | C—*Cymbidium* sp. | D—*Dendrobium crumenatum* | E—*Dendrobium macrostachyum* | F—*Eulophia picta* | G—*Liparis parviflora* | H—*Luisia zollingeri* | I—*Nervilia plicata* | J—*Nervilia simplex* | K—*Polystachya concreta*. © Toni Artaka.

Further surveys are recommended during the transition from the rainy to the dry season (October–March) to obtain more complete information on orchid species with possibly different phenological times. Several terrestrial orchids typical of the lowlands primarily grow with completed generative parts during these seasons (Artaka 2019). Expansion of the exploration area is also needed to reach the inland

forest areas that have not been visited yet. This study also supports area managers for an updated biodiversity database, primarily as a source of natural orchid germplasm to support cultivation.

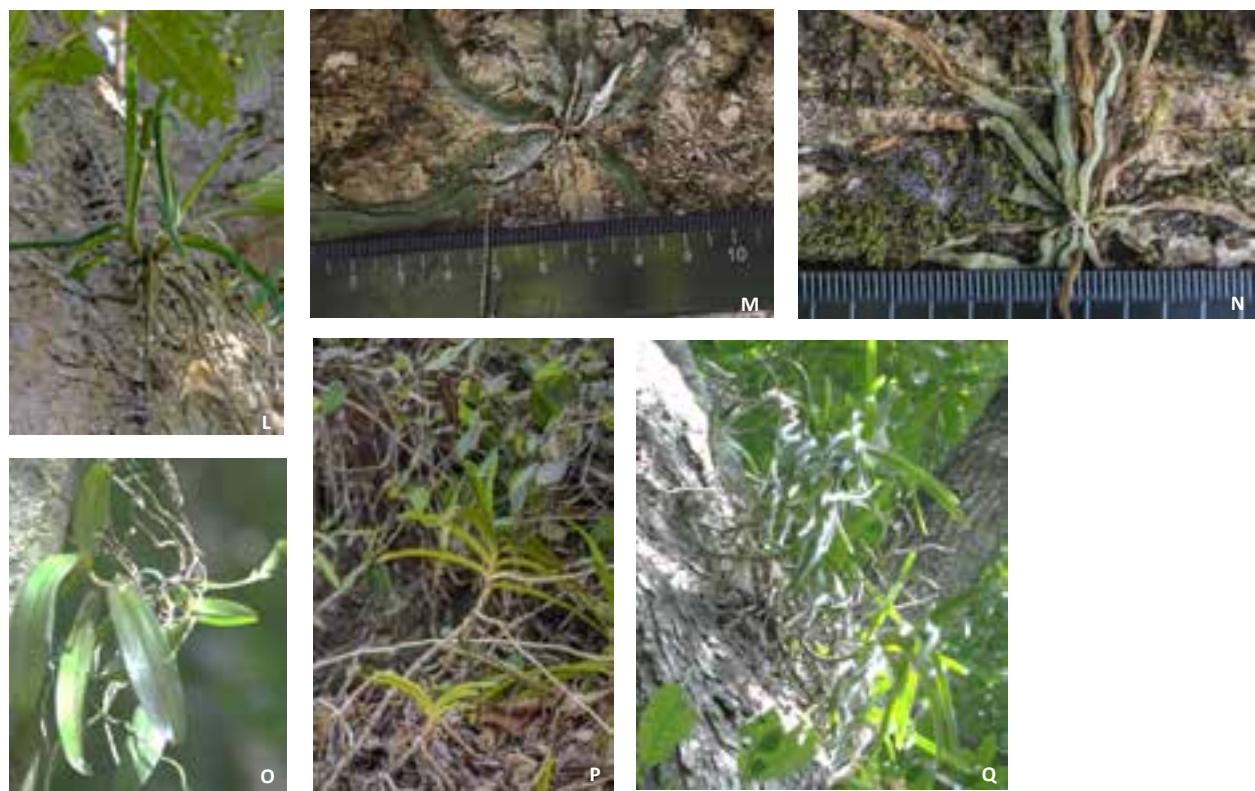


Image 1 cont. The orchid species found on Nusa Barung Island: L—*Rhynchostylis retusa* | M—*Taeniophyllum hasseltii* | N—*Taeniophyllum* sp. | O—*Thrixspermum raciborskii* | P—*Vanda limbata* | Q—*Vanda tricolor* © Toni Artaka.

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A bibliometric visualization of trends in Philippine sharks studies published in Scopus-indexed journals over the past five decades

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Abstract: Sharks are one of the oldest vertebrates with a lineage over 400 million years, have drastically declined in population due to increased fishing pressure and demand for shark products. Some species of sharks are top hunters essential for maintaining marine biodiversity and ecological balance. The Philippines, a global biodiversity hotspot, hosts approximately 200 shark species, which are ecologically and economically significant, supporting fisheries, and ecotourism. Shark populations in the country have drastically declined partly due to increased fishing pressure and the demand for shark products, such as fins, meat, and oil. Addressing these challenges requires a deeper understanding of research trends and priorities to guide effective conservation, and management strategies. This study utilizes bibliometric methods to analyze trends in Philippine shark research from 1974–2024, using data sourced from Scopus. A total of 93 peer-reviewed documents were analyzed for publication trends, international collaborations, and emerging research themes. The analysis revealed a steady increase in publication output, peaking in 2019, with a subsequent decline during the COVID-19 pandemic, reflecting disruptions in research activities. This study underscores the need for sustained research efforts, enhanced international collaborations, and a focus on underexplored themes such as movement patterns, genetic connectivity, and population structure. By identifying research trends and gaps, this bibliometric analysis provides critical insights to inform evidence-based strategies for shark conservation and sustainable management in the Philippines.

Keywords: Anthropogenic disturbance, elasmobranch, marine conservation, ocean sustainability, RStudio, sustainable development.

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INTRODUCTION

Sharks are considered as evolutionarily conservative group, comprising approximately more than 1,200 species that have functioned successfully in diverse ecosystems for 400 million years (Abdulla 2004). Sharks play a pivotal role in maintaining the balance of marine ecosystems, occupying different trophic levels that regulate the abundance and behaviour of mesoconsumers, and other marine species (Heithaus et al. 2008). Beyond their ecological significance, sharks are vital natural resources in the Philippines, supporting fisheries, and ecotourism industries. Growing fishing pressure have fueled global population declines in recent decades, threatening both ecosystems, and livelihoods. Shark fisheries in the Philippines started out in small numbers and only for subsistence. The Philippines started supplying the growing international market for shark meat, skin, and fins beginning in the 1960s (Alava et al. 214). These pressures underscore the need for vigorous conservation and management strategies (Oposa & Techera 2023). Additionally, organizations such as the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) have implemented regulations to control international trade of threatened shark species.

The National Plan of Action for Sharks (NPOA-Sharks) emphasizes the role of shark resources in marine biodiversity conservation and sustainable resource use for future generations. The effectiveness of the strategy is dependent on tight collaboration among implementing agencies and stakeholders. It necessitates the gathering and continuing synthesis of suitable data at the proper resolution, including commercial data, and data resulting in improved species identification, and eventually, abundance indices. One of the overall goals of NPOA sharks is to identify substantial gaps in scientific knowledge, as well as difficulties, challenges, and concerns regarding shark conservation and management (Department of Agriculture, Bureau of Fisheries and Aquatic Resources 2009). This was further supported by International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) by expressing the need for improved management of sharks (Lack & Sant 2009).

Globally, shark populations have shown accelerated declines due to overfishing and habitat degradation (Dulvy et al. 2008; Ward-Paige et al. 2010; McCauley et al. 2015), with one quarter of shark and ray species now classified as threatened by the International Union for Conservation of Nature (IUCN) Red List (Dulvy et al. 2014).

The IUCN Red List assessments are regarded as reliable tools to determine the conservation status of species because they use a comprehensive and scientifically rigorous approach to estimate extinction risk (Rodrigues et al. 2006). The goal of the assessment is to provide information and analyses on the status, trends, and threats to species in order to inform conservation actions. Current assessments of sharks have been undertaken during regional Red List workshops coordinated by the IUCN Shark Specialist Group (SSG) in the past 5–10 years (Dulvy et al. 2014). Critical gap persists in scientific data on shark fisheries in the Philippines, hindering informed decision-making, and effective management (Muallil & Hapid 2020).

Bibliometrics offers a powerful tool to track and analyze the evolution of research topics over time, enabling the identification of trends, gaps, and opportunities. By examining attributes such as authorship, institutional collaboration, and emerging themes, bibliometric analyses provide critical insights into scientific output, and research dynamics (Small 2003). The Bibliometrix package, through its BiblioShiny interface, has gained prominence as an accessible and comprehensive tool for performing such analyses (Celik et al. 2021). An example of bibliometric study on sharks can be reviewed in demonstrated how their findings draw attention to the disparities in media, and scientific coverage of shark research. Citations are dispersed equally among research groups, but mentions of policies, news, and tweets are more likely to concentrate on particular subjects.

This study used bibliometric analysis to assess trends in Philippine shark research over the past five decades, with the goal of enhancing shark conservation and management. Specifically, this study seeks to identify and analyze: (1) publication and citation, (2) country collaboration, and (3) emerging research theme. By addressing these objectives, the study provides a foundation for informed conservation strategies and highlights research priorities to support sustainable shark management.

METHODS

Scope and Limitation

This study acknowledges various limitations, which may have an impact on its conclusions. First, the search was restricted to peer-reviewed journal articles, book chapters, and reviews (Figure 1). The data source is limited to Scopus-indexed papers, which may exclude

significant research, particularly conference proceedings and publishing in non-indexed journals. Second, while bibliometric methods provide useful insights, they do not fully reflect the intricacies of specific research, such as quality or methodological rigor. Finally, the chosen date range (1974–2024) invariably influences the observed trends, perhaps obscuring earlier or later advancements in the sector.

Data Collection

This study employed a bibliometric approach to analyse trends in Philippine shark studies indexed in Scopus from 1974 to 2024 (Figure 1). The data was collected using the Scopus database on 28 March 2025. We used the following keyword search combination (Philippines OR Indo-pacific OR Luzon OR Visayas OR Mindanao AND “sharks” OR “elasmobranchs”) AND (“Philippine Sharks” OR “Sharks in the Philippines”). A total enumeration sampling technique was utilised, ensuring that all relevant articles within the search parameters were included. The retrieved data was exported in a comma separated values (CSV) file format for further analysis.

Data Processing

The exported data underwent rigorous cleaning to ensure accuracy and relevance. Duplicate entries and non-relevant records were removed (Figure 1). The cleaned dataset was structured and organised to facilitate detailed analysis of publication trends, citation, and collaboration networks. Data on authorship, institutional affiliations, and keywords were standardised to ensure consistency and compatibility with analysis tools.

Analytical Tools

The primary tools used for the analysis were: RStudio to run Bibliometrix package and VOSviewer. Bibliometrix provided quantitative and qualitative insights into publication trends, citation metrics, and collaboration patterns. Its Biblioshiny interface enabled interactive visualisations of bibliometric data. VOSviewer was employed for network analysis, creating visual representations of co-authorship networks, keyword co-occurrence patterns, and thematic maps. These tools allowed for an in-depth exploration of research dynamics and thematic evolution over time.

Metrics Analysed

Several key metrics were evaluated in this study. Annual scientific production was analysed to identify trends in the number of publications over time. Citation

analysis provided insights into the academic impact of the research by assessing annual citation rates. International collaboration networks were visualised to map partnerships between the Philippines and other countries, highlighting key collaborators. Trend topic analysis focused on keyword frequency and duration to uncover evolving research priorities. Additionally, thematic mapping was conducted to classify research themes into four categories—motor, niche, basic, and emerging/declining—based on their centrality (relevance) and density (development).

Visualization

A range of visualisation techniques was applied to present the results effectively. Line graphs were generated to depict trends in annual scientific production and citation counts. Bubble plots illustrated the frequency and duration of prominent research topics. Thematic maps provided a comprehensive view of research themes, categorising them based on their development, and relevance. Network diagrams were used to visualise international collaborations and keyword co-occurrence patterns, enabling an understanding of the data.

RESULTS

A total of 267 documents matched the searched keyword; after thoroughly cleaning the dataset, we were able to gather 93 published documents. The remaining documents consisted of journal articles, book chapter, and reviews. There were two single-authored documents, 6.38 co-authors per document, and 58.51 international co-authorship. The documents were published from 1974 to 2024 (Table 1).

Annual Scientific Production

After the first publication in 1974, no shark studies were published annually until 2000 (Figure 2). Research output increased steadily from 2010, reaching its peak in 2019 with 16 documents. A decline was recorded in 2022, marking one of the lowest outputs with five documents during 2019–2024, followed by a recovery in 2023 with 11 documents.

Average Citation per Year

The annual citation trends for Philippine shark studies from 1974 to 2024 show variability across the years. Citations peaked in 2007 with average citation per year (ACpY) of 6.4, indicating high academic impact during this period (Figure 3). A decline followed until 2011

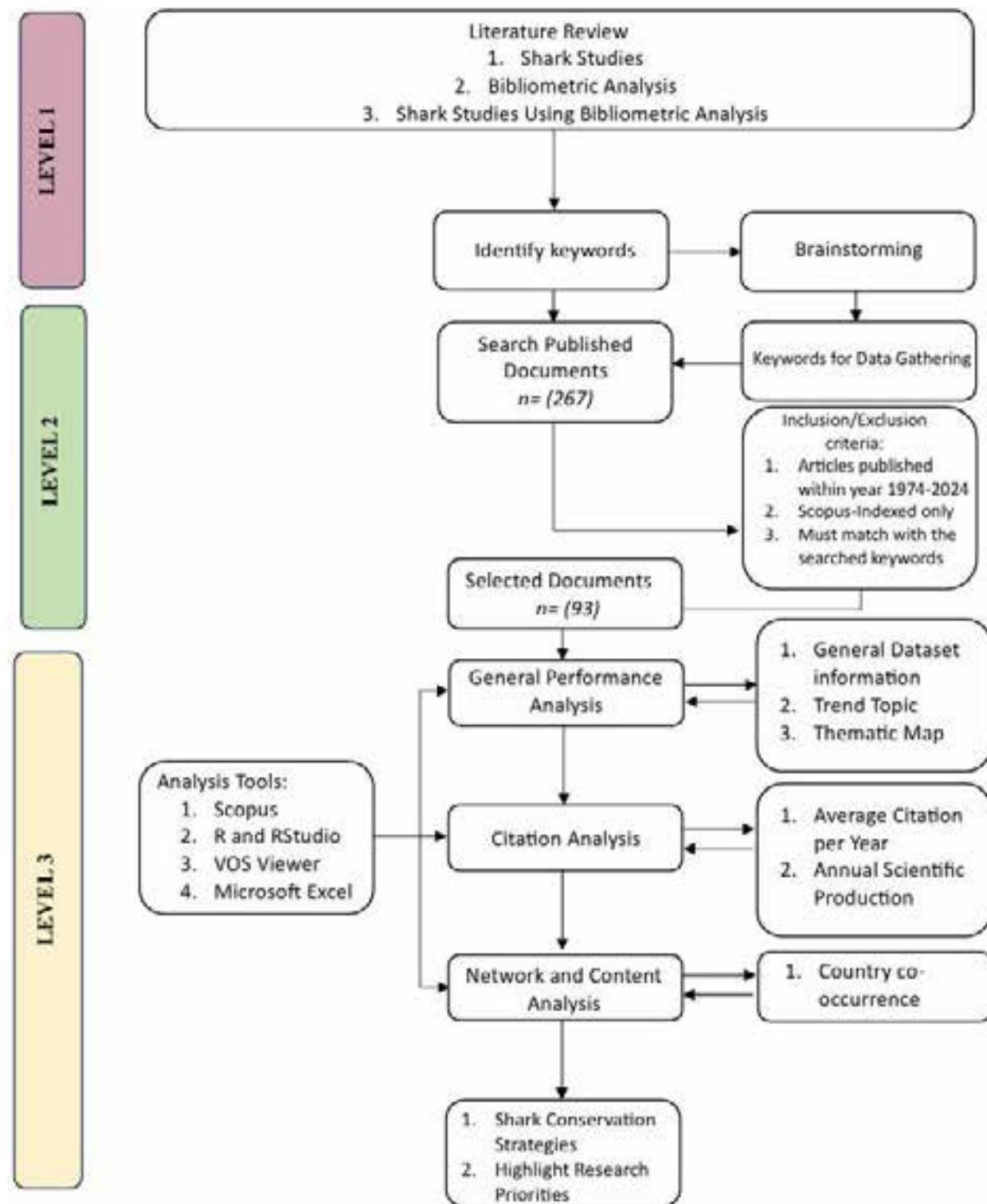


Figure 1. Research procedure of this study adopted from the published article of Hartafan et al. (2024).

with ACpY of 1.5, after which citation rates gradually increased in the following year, reaching another peak in 2012 with 3.7 ACpY. Post-2017, a steady decrease in citations is evident, with minimal citation activity

observed by 2024.

Country Partnership

Key collaborators in Philippine shark research included

Table 1. Summary of bibliometric data for Philippine shark studies indexed in Scopus.

Description	Results
Key Information About Data	
Timespan	1974–2024
Sources (Journals, Books, etc.)	56
Documents	93
References	5095
Types of Documents	
Article	90
Book chapter	1
Review	2
Contents of Documents	
Keywords plus (ID)	639
Author's keywords (DE)	326
Authors Collaboration	
Single-authored document	2
Co-authors per document	6.38
International co-authorships	58.51

the United States, Australia, the United Kingdom, Japan, South Africa, France, China, Italy, Canada, and Indonesia (Figure 4). The strongest collaboration was with the United States, reflecting frequent contributions to shark-related research.

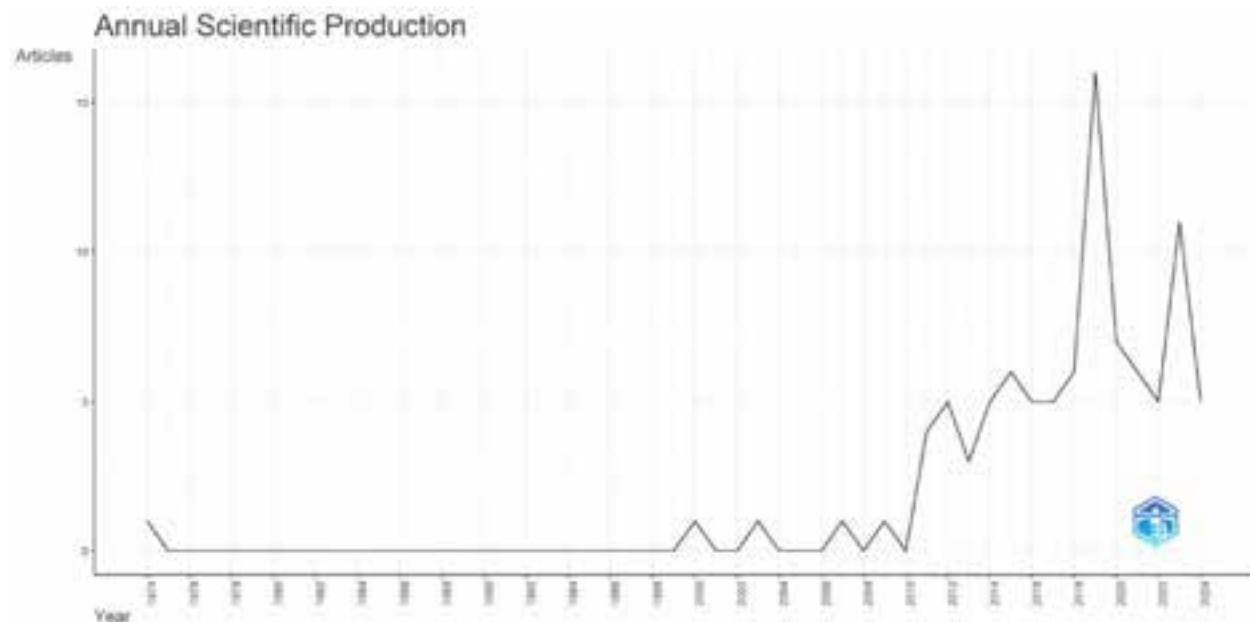
Trend Topics

The analysis identified key terms in Philippine shark studies. From 2011 to 2014, terms like “animal behavior”, and “Chondrichthyes” were frequent, especially in the year 2013. From 2016 onwards “endangered species”, “tourism”, and “environmental protection” became prominent. “Species conservation” and “population density” were the most frequent terms in recent years. Larger bubbles in the analysis indicate higher term frequency (Figure 5).

Emerging or Declining Themes

The thematic map (Figure 6) of Philippine Shark studies categorizes research topics into four distinct quadrants based on centrality (relevance) and density (development). The motor themes, located in the top-right quadrant, are highly developed and central to the research, including topics such as “elasmobranchs”, “demographic history”, and “whale shark”. These core themes drive the bulk of research activities and are critical to advancing the field. In the top-left quadrant, niche themes such as “movement patterns”, “acoustic telemetry”, “pelagic thresher shark”, and “genetic connectivity” are well-developed but less central, reflecting specialised research areas with limited broader application.

The bottom-right quadrant contains basic themes, which are central but less dense themes. These include “conservation”, “population structure”, and “migration”,

**Figure 2. Annual scientific production of research articles on Philippine sharks indexed in Scopus from 1974 to 2024.**

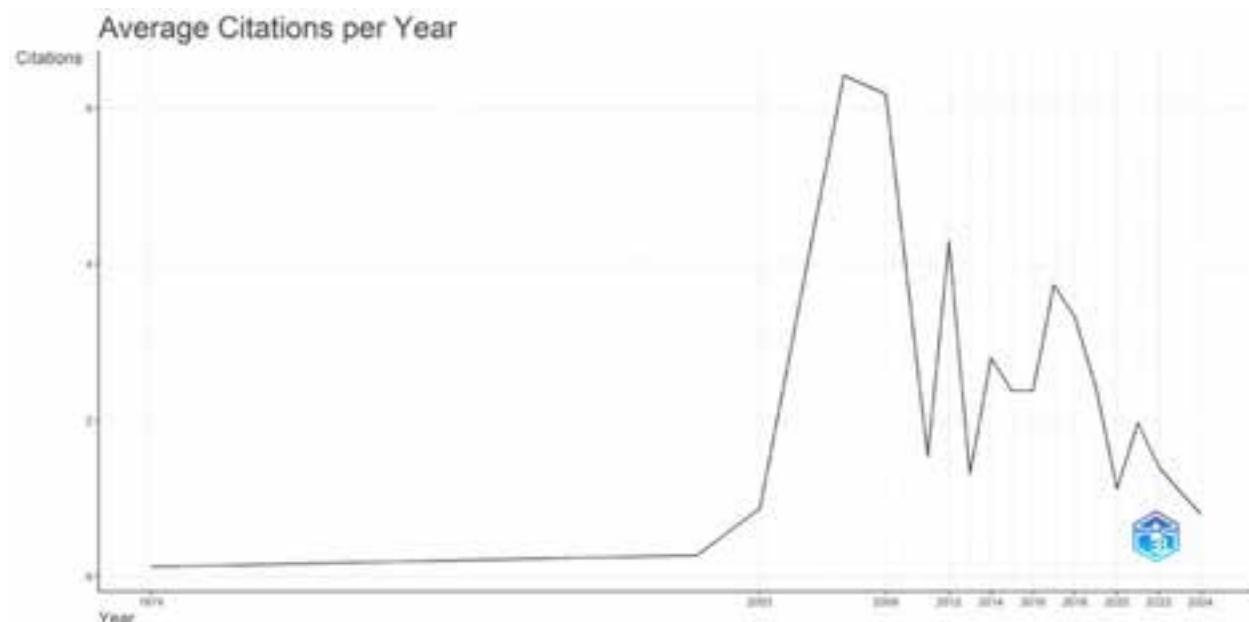


Figure 3. Annual citation trends of Philippine shark studies indexed in Scopus (1974–2024).

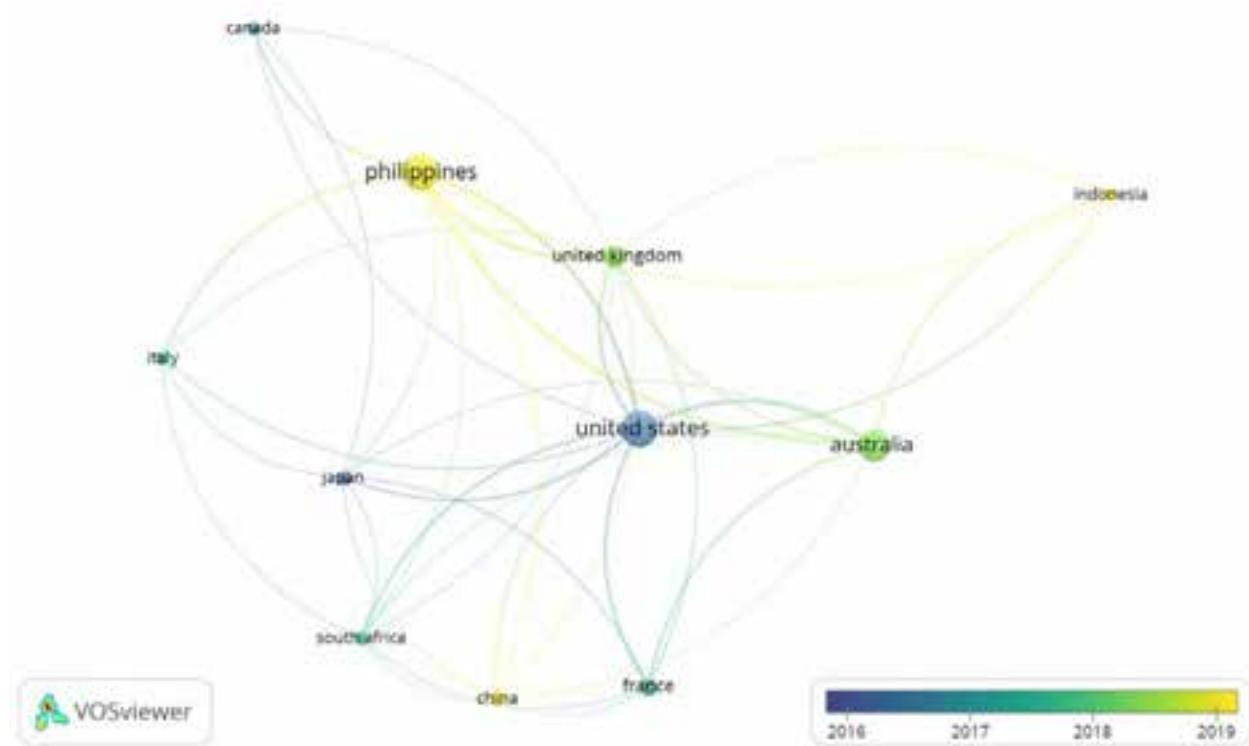


Figure 4. International collaboration network in Philippine shark studies (1974–2024).

which form the foundational topics, are mostly discussed and well-developed. In the bottom-left quadrant, emerging or declining themes such as “new species”,

“climate change”, and “endangered species” are identified as less central, and less developed, indicating research areas that are either gaining traction or losing

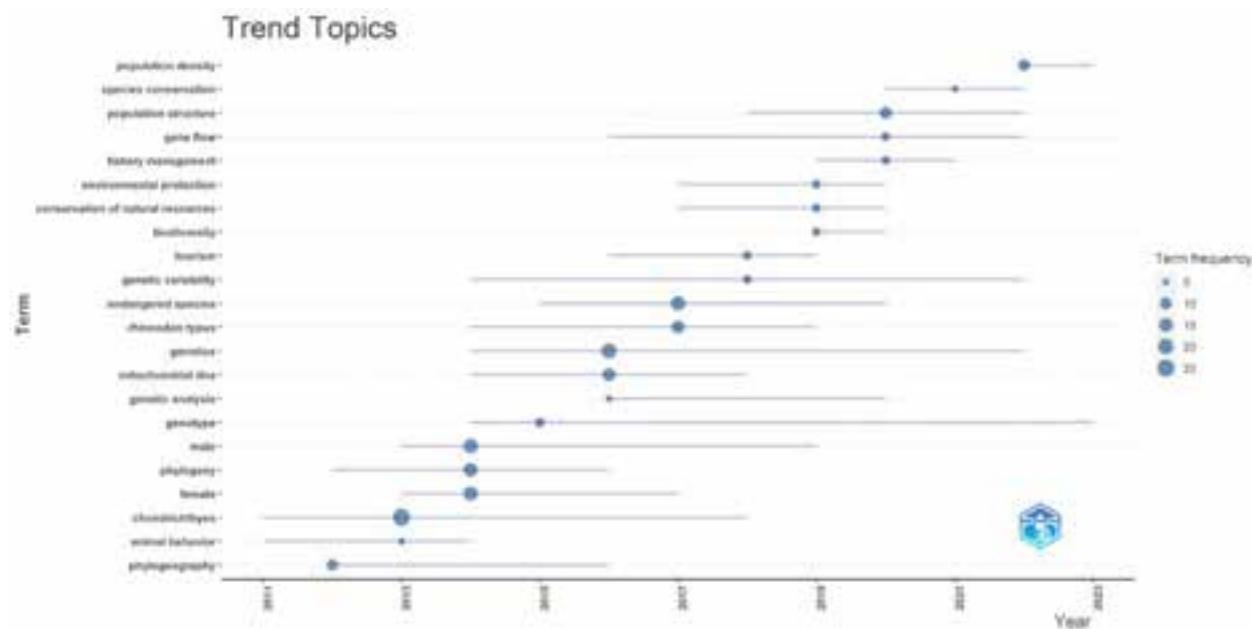


Figure 5. Trend topics in Philippine shark studies, illustrating the evolution of research focus over time from 1974 to 2024. Bubble sizes represent term frequency, with larger bubbles indicating higher occurrences.

relevance. This thematic map provides a comprehensive overview of the multidimensional focus of Philippine shark studies, highlighting well-established themes while identifying opportunities to expand foundational and emerging areas of research.

DISCUSSION

The Philippine shark studies' yearly scientific output from 1974 to 2024 showed a varying pattern: Early research was scarce, with no articles published annually until 2000, and then publications increased 16 documents in 2019, probably due to increased awareness of shark conservation and domestic policies like whale shark protection (Araujo et al. 2018). The COVID-19 pandemic interrupted research in 2020–2022 (Rutz et al. 2020), which caused a steep drop in publications, and a recovery in 2023 indicates a gradual return to pre-pandemic research levels. These high citation rates likely reflect the academic impact of key publications addressing significant topics such as genetics and conservation strategies (Heithaus et al. 2008). The post-2017 decline in citations may indicate a shift in focus or reduced visibility of subsequent studies.

The nodes in the findings may represent individual pieces of publication, journals, researchers, institutions or key words. Edges represent the existence or type of relationship between pairs of nodes (Aria & Cuccurullo

2017). The analysis of international collaboration networks revealed that the Philippines served as a central node in studying Philippine sharks, collaborating extensively with top 10 major countries: the United States, Australia, the United Kingdom, Japan, South Africa, France, China, Italy, Canada, and Indonesia. The strongest partnership was with the United States, reflecting shared interests in marine biodiversity and conservation efforts. Moreover, visualisation of temporal data can color code network nodes to the year of publication allowing the identification of trajectories and trends in a given field (Arruda et al. 2022). The partnership between countries in studying Philippine sharks are essential for conservation and diversity of these species (Department of Agriculture, Bureau of Fisheries and Aquatic Resources 2009; Oposa & Techera 2023). Collaborations with Australia and the United Kingdom emerged as more recent, somewhere around 2018, while earlier partnerships were established with China and Indonesia alongside with the Philippines. This network underscores the importance of international partnerships in advancing shark research and conservation, particularly for a biodiversity hotspot like the Philippines. The analysis of trend topics highlighted the evolution of research priorities in Philippine shark studies. Early research from 2011 to 2014 focused on foundational topics such as "gene flow", "animal behavior", and "Chondrichthyes" reflecting efforts to establish baseline knowledge about shark species. From

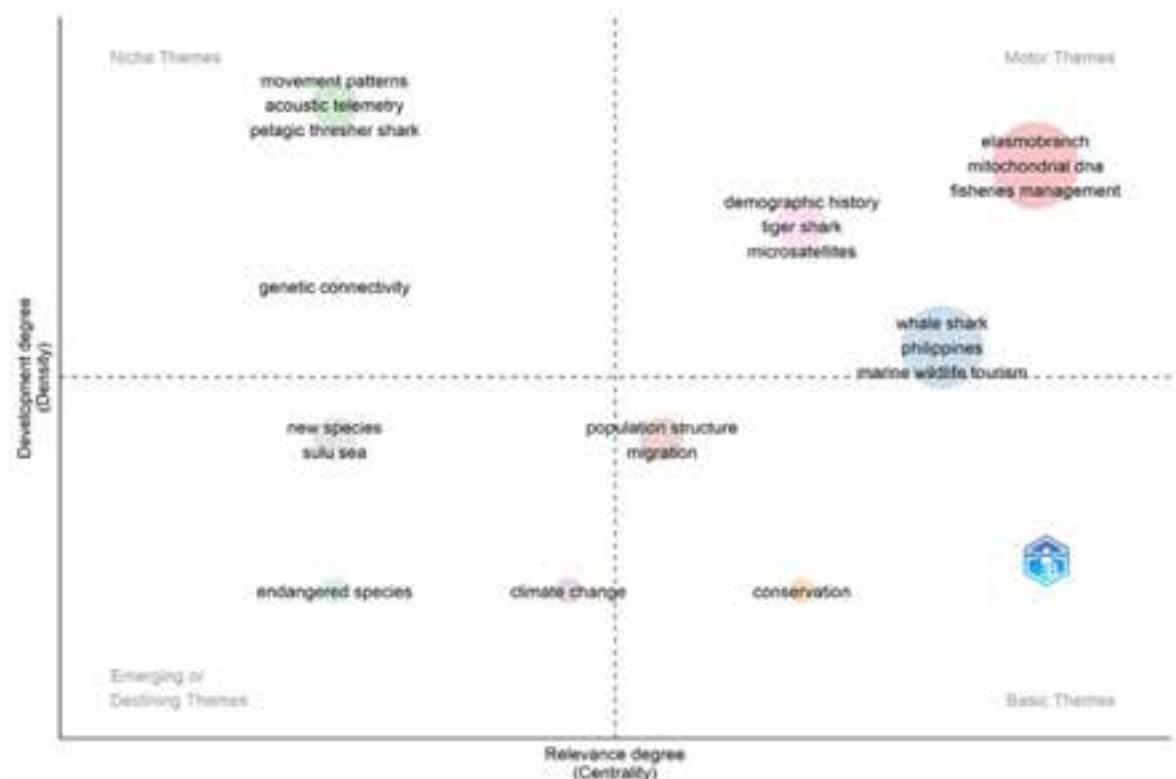


Figure 6. Thematic map of Philippine shark studies, highlighting motor themes, niche themes, basic themes, and emerging or declining themes.

2016 onward, a shift toward conservation-oriented topics such as “endangered species”, “tourism”, and “environmental protection” became evident. This transition aligns with increasing global concerns about shark population declines and the need for sustainable management practices for both extractive and non-extractive purposes for their meat, oil, skin, and fins, and is a tourism draw for a few coastal sites (Dulvy et al. 2014; Oposa & Techera 2023).

Our findings of this study have significant implications for shark conservation and management in the Philippines. The increasing focus on species conservation and ecosystem-based management highlights the growing recognition of sharks’ ecological importance, their impacts on fisheries, ecotourism, and international market (Alava et al. 2014; Oposa & Techera 2023). However, the decline in research output and citations in recent years emphasizes the need for sustained funding and capacity building to maintain momentum in shark research. Sustainable funding is important as it encourages comprehensive, long-term studies that examine the intricate relationships between environmental, social, and economic systems, which is critical for addressing diverse sustainability concerns. Secure financing enables academics to take

interdisciplinary approaches and integrate scientific and social disciplines, resulting in more comprehensive solutions (Mobjörk & Linnér 2006). Strengthening international collaborations, particularly with countries that have advanced marine research infrastructure, can further enhance the quality, and impact of Philippine shark studies. Moreover, addressing underdeveloped themes such as population structure, migration, and climate change could provide insights into sustainable resource use and conservation strategies. Expanding research on niche themes like movement patterns and genetic connectivity can also contribute to integrating socio-economic considerations into shark conservation efforts, fostering stakeholders’ engagement and support. This study highlights significant trends and gaps in Philippine shark research, offering insights to guide future studies and conservation strategies. By leveraging international collaborations and addressing underdeveloped themes, researchers & policymakers can advance shark conservation & management, ensuring the sustainability of marine resources, and ecosystems in the Philippines.

CONCLUSION AND RECOMMENDATION

This study highlighted the significant growth of Philippine shark research, particularly from 2010, peaking in 2019 due to increased conservation awareness, and supportive policies such as whale shark protection. Collaborative networks, particularly with countries like the United States, Australia, and the United Kingdom, have played a crucial role in advancing shark research, and conservation efforts. The shift in research focus from foundational topics, such as species classification and behavior, to conservation-oriented priorities like species tourism, conservation, and population density reflects the increasing urgency to address shark population declines, and sustainable management practices.

To sustain and enhance Philippine shark research, it is crucial to maintain funding and build capacity to support ongoing efforts. Strengthening international collaborations, especially with countries that have advanced research infrastructure, can further improve research quality and outcomes. Expanding research on niche topics such as movement patterns and genetic connectivity can integrate socio-economic considerations into conservation strategies, fostering greater community engagement, and support. These actions are essential for ensuring the long-term sustainability of shark populations and marine ecosystems in the Philippines.

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First camera-trap evidence of Dhole *Cuon alpinus* Pallas, 1811 (Carnivora: Canidae) from the Kaziranga-Karbi Anglong landscape, Assam, India

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Abstract: India is experiencing a decline in wildlife species due to habitat loss, deforestation, and climate change. Species once thought to be extirpated from certain areas are being rediscovered, offering hope for conservation efforts. The Dhole *Cuon alpinus* is listed as 'Endangered' on the IUCN Red List and under Schedule I of the Indian Wildlife (Protection) Act, 1972. The Kaziranga-Karbi Anglong landscape is located in the Indo-Burma biodiversity hotspot. Photographic evidence of a Dhole from the Kaziranga-Karbi-Anglong landscape, Assam, is reported, where the species was previously extirpated. Reconnaissance surveys were conducted in four identified corridors: Panbari, Haldhibari, Kanchanjuri, and Amguri. Based on these findings, camera traps were deployed. The identified corridor between Kaziranga and Karbi Anglong is crucial for wildlife movement, particularly during floods. Both large and small animals utilize these corridors to disperse to Karbi-Anglong when water levels rise. As floodwaters recede, some animals return to their original habitats, while others disperse to new areas. A total of six photographs of a single Dhole were captured in the Amguri Corridor, highlighting the critical role of wildlife corridors in supporting the movement and survival of elusive carnivores like Dholes in fragmented, non-protected landscapes.

Keywords: Asiatic Wild Dog, biodiversity hotspots, Brahmaputra floodplain, corridors, distribution, endangered species, fragmentation, northeastern India, trail camera, world heritage sites.

Assamese: ভাৰতৰ্য্যত বাসস্থানৰ হ্রাস, বনাঞ্চল ধূংস আৰু জলবায়ু পৰিবৰ্তনৰ বাবে বনাপাণীৰ সংখ্যা ক্রমাগতভাৱে কমি আহিছে। অৱশ্যা, সম্পত্তি কিছু প্ৰজাতি যিবোৰক নিৰ্দিষ্ট অঞ্চলৰ পৰা বিচুল্পন বুলি যিবোৰা কৰা হৈছিল, মেঘীৰাৰ পুনৰ অৱস্থিতিৰ প্ৰমাণ হৈছ। এই অৱস্থিতিয়ে বনাপাণী সংৰক্ষণৰ নতুন আশাৰ সৃষ্টি কৰিছে। এন এটা উজ্জ্বলযোগী প্ৰজাতিৰ হৈছ ধৰণ বা বাং কুকুৰ (*Cuon alpinus*)। IUCN ৰেড লিস্টত এই প্ৰজাতিটোক 'বিপন্ন হৈলাগ' প্ৰজাতিৰ নতুন আশাৰ সৃষ্টি কৰিছে। এন এটা উজ্জ্বলযোগী প্ৰজাতিৰ আহৰণ আৰু অঞ্চল-বাসী জৈৱবিচৰণ হটস্পটৰ অগৰত, তাত বাং কুকুৰৰ ফটোগ্ৰাফিক প্ৰমাণ পোৱা গৈছে। উজ্জ্বলযোগী যে এই অঞ্চলৰ পৰা হৈয়াৰ আগতে এই প্ৰজাতিটো বিলুপ্ত হৈ পৰা বুলি ধাৰণা কৰা হৈছিল। পথমে এই অঞ্চলৰ চারিটো কৰিডোৰ - পাৰবৰী, হালবৰীবৰী, কাঞ্চনজুতি আৰু অমগুৰি প্ৰান্তৰিক ভৰ্তীপ সম্পৰ্ক কৰা হৈছিল। পৰৱৰ্তী সময়ত এই কৰিডোৰসমূহত কোমৰা ট্ৰেং স্থাপন কৰা হৈছিল। এই গৱেষণাট আমতিৰি কৰিডোৰত এটা বাং কুকুৰৰ মুঠ ছয়টা আলোকচিতৰ ধৰা পৰিষিল। কৰিডোৰত আৰু কৰিডোৰসমূহত বনাপাণীৰ চৰাচৰৰ বাবে অতি শুক্রপূৰ্ণ ভূমিকা পালন কৰে, বিশেষজ্ঞ বনাপাণীৰ সময়ত। সামৰিৰ কৰ বাটিলে বিভিন্ন আকাৰৰ প্ৰাণীয়ে কৰিব আংলালৈ যাবোল এই কৰিডোৰসমূহ বোহাৰ কৰা। বনাপাণীৰ অৱসন্ন হলে কিছুমান প্ৰাণীয়ে নিজ মূল বাসস্থানলৈ উত্তি যায়, অনহাতে কিছুমান নতুন অঞ্চললৈ স্থানান্তৰিত হয়। বাং কুকুৰৰ এই পুনৰ আবিষ্কাৰে প্ৰমাণ কৰিছে যে কৰিডোৰসমূহ খণ্ডিত আৰু অসংৰক্ষিত অঞ্চলসমূহত বাং কুকুৰৰ দৰে দুৰ্লভ মাংসভোজী প্ৰাণীৰ চলাচল আৰু বাসস্থানৰ সুবিধা প্ৰদানত শুক্রপূৰ্ণ ভূমিকা পালন কৰে।

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INTRODUCTION

The Dhole *Cuon alpinus* (Pallas, 1811), also known as the Asiatic Wild Dog, is a social canid (Pocock 1936; Johnsingh 1982; Habib et al. 2021) and a communal hunter, occasionally forming packs of up to 30 individuals (Fox 1984). Depending on prey availability, they may also hunt alone or in pairs (Cohen et al. 1978; Venkataraman et al. 1995). The Dhole is listed as 'Endangered' on the IUCN Red List (Kamler et al. 2015) and as a Schedule I species under the Indian Wildlife (Protection) Act, 1972. Historically, the Dhole's distribution ranged from the Tian Shan and Altai mountains (in the Russian Federation), Mongolia, and Kazakhstan (Thenius 1954) southwards through China, Tibet, Nepal, India, and Indochina (Selvan et al. 2013). Currently, the Dhole's distribution is confined to central & eastern Asia, India, Nepal, Bhutan, Bangladesh, China, Myanmar, Indonesia, Thailand, and Malaysia (Johnsingh 1985; Kamler et al. 2015; Srivaths et al. 2019; Kao et al. 2020). Understanding the distribution of Dhole is therefore crucial for guiding effective conservation strategies and ensuring the species' long-term persistence across its range.

Although Dholes have been extensively studied in India, much of the research has primarily focused on their feeding ecology, genetics, and demography (Cohen 1978; Johnsingh 1982, 1985, 1992; Venkataraman 1995; Karanth & Sunquist 2000; Acharya 2007; Borah et al. 2009; Pal et al. 2018; Ghaskadbi et al. 2022; Modi et al. 2021 & 2022). But studies in northeastern India remain relatively limited (Babu & Venkataraman 2001; Gopi et al. 2010, 2012; Lyngdoh et al. 2014). The Dhole has been recorded in northeastern states such as Arunachal Pradesh, Assam, Meghalaya, Mizoram, Nagaland, & Sikkim and in the eastern state of West Bengal (Choudhury 1998, 2006; Durbin et al. 2008; Bashir et al. 2014; Singh et al. 2020). In Nagaland, a pack of Dholes was observed by birdwatchers on 21 May 2011, far from the Myanmar border, and this sighting was confirmed by the Nagaland Forest Department (Conservation India 2011).

The distribution range of the species has reduced to less than 25% of its former global range due to threats such as retaliatory killing, habitat loss, and prey depletion (Wolf & Ripple 2017; Ghimirey et al. 2024). Previous global assessments in 1990 reported that Dhole presence was confined only to the northern bank of the Brahmaputra River and have undergone extirpation in the south (Ginsberg & Macdonald 1990; Singh et al. 2020). Recent records of Dholes from Dampa Tiger Reserve in Mizoram and other areas of northeastern

India, including non-protected regions, provide evidence of the species' persistence in the region (Singh et al. 2020). Here, the photographic record of the species in Kaziranga-Karbi Anglong landscape (KKAL), Assam, India is reported.

STUDY AREA

The KKAL of Assam spreads over 25,000 km², touching the neighbouring states of Meghalaya and Nagaland in northeastern India. The landscape is a complex mosaic of protected and non-protected areas. It comprises the Karbi plateau in Karbi Anglong, located on the southern side of the Brahmaputra River in Assam, with Kaziranga Tiger Reserve situated at the foothills of the Karbi Anglong District (Image 1). The landscape is severely fragmented with patches of protected areas that support globally threatened wildlife species. The landscape is connected with nearby protected areas such as Nameri Tiger Reserve (Assam) and Pakke Tiger Reserve (Arunachal Pradesh) to the northern side, Laokhowa Burhachapori Wildlife Sanctuary (Assam) to the western side, Nambor Wildlife Sanctuary (Assam), and Ntanki National Park (Nagaland) to the southern side through several corridors. Thus, understanding wildlife presence and corridor usage is important for better management of corridor functionality in the landscape. The four primary corridors connecting KKAL with the protected areas to the southern side are Panbari (92.20 km²), Haldhibari (117.24 km²), Kanchanjuri (109.83 km²), and Amguri (49.83 km²).

METHODS

A reconnaissance survey was conducted across these corridors, and based on the findings, camera traps were strategically deployed to monitor the mammalian species present. Camera traps were systematically placed along animal trails to maximize the chances of detecting wildlife species. A pair of camera traps was deployed within each 2 × 2 km² grid, ensuring at least one camera trap station in every grid. Infrared and White flash Cuddeback (H1453 IR and C1 model) camera traps were used during the study. A total of 83 camera traps were deployed across an area of 276 km² covering the four corridors of the KKAL. The study was conducted from February 2021 to December 2022, with continuous monitoring of animal movements, spanning a total of 15,278 camera-trap days. The primary aim of this study was to determine the structural and functional connectivity of wildlife corridors within the landscape.

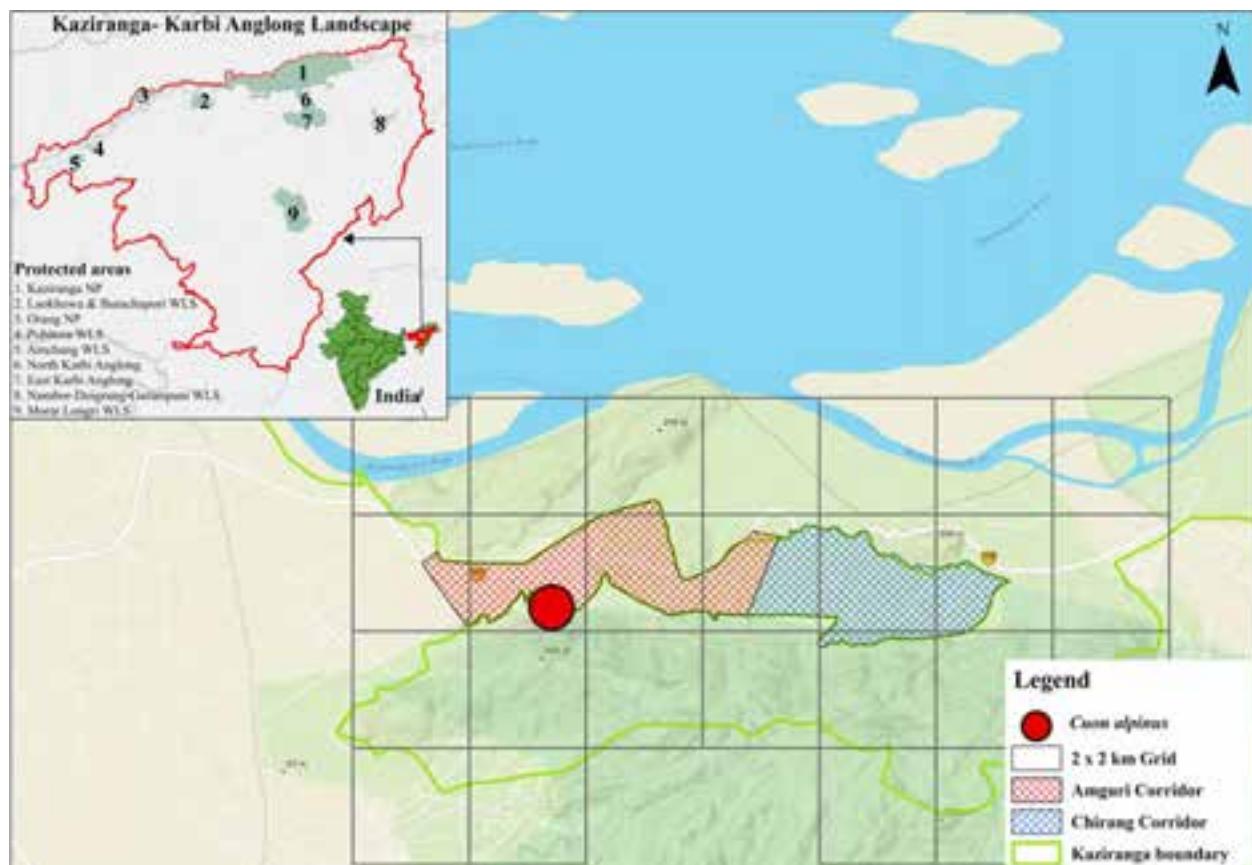


Image 1. Dhole *Cuon alpinus* occurrence in the Kaziranga-Karbi Anglong landscape, Assam, India.

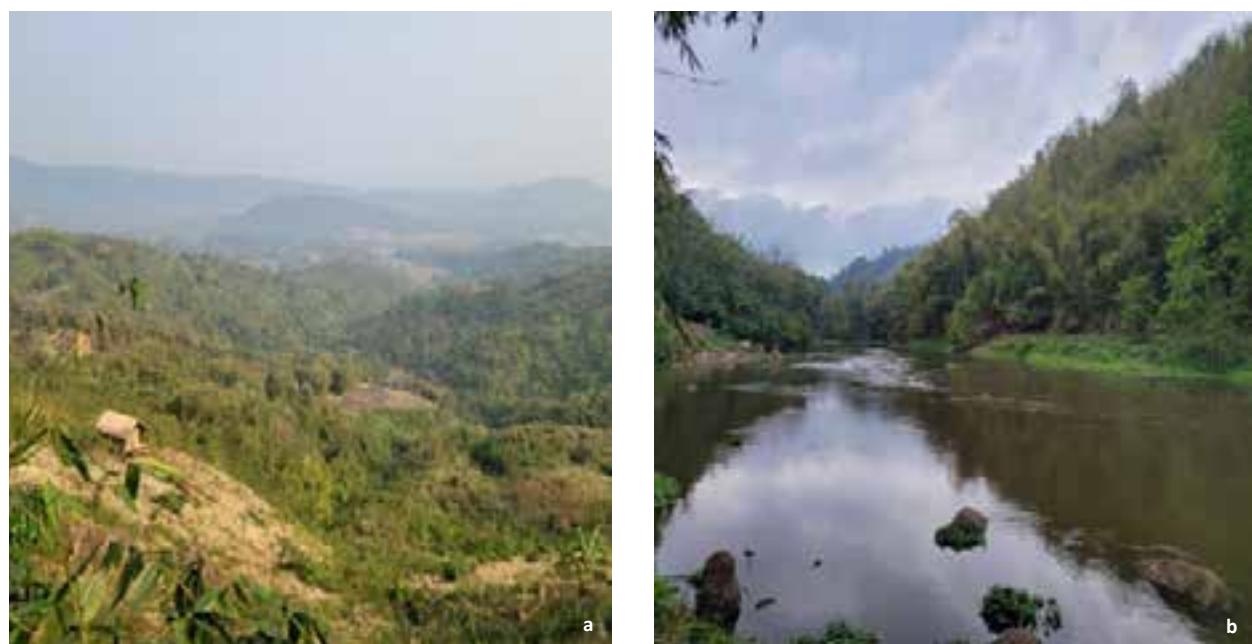


Image 2. a—Heterogeneous and undulating terrain of the Karbi Anglong hills, characterized by mixed forest cover and anthropogenic clearings | b—Kalioni River flowing through a forested valley in Karbi Anglong, serving as a vital ecological corridor and freshwater source in the landscape. © Mujahid Ahamad



Image 3. Camera trap images of Dholes captured in the Amguri Corridor, Kaziranga-Karbi Anglong landscape, Assam, India.

While the study focused on broader connectivity patterns for multiple species, it also sought to assess habitat use, and movement of mammals.

RESULTS

A total of six photos were captured of a single individual, with the first capture time on 31 October 2022, at 11:55:05 AM. The individual returned through the same route at 11:56:37 AM, and the location (26.562° N, 93.04333° E) was within the Amguri Corridor (Image 3). This was the only instance where we captured a Dhole on camera in the landscape during the study period. The location of the photo-captured Dhole was approximately 375 m from the National Highway 37, with the nearest human settlement located at about 270 m. The habitat consists of moist mixed deciduous forest, dominated by teak *Tectona grandis* (Champion & Seth 1968).

DISCUSSION

This study provides the first photo evidence of Dholes by camera traps in KKAL, confirming the species' occurrence in this region. The southern region of the Brahmaputra River serves as a critical habitat for Dholes, a species that was extirpated in the 1990s (Ginsberg & Macdonald 1990). Recent sightings have been documented in Mizoram, Meghalaya, Nagaland, and Assam (Singh et al. 2020). In Assam, evidence on Dhole occurrence is limited. The most reliable record

comes from Jeypore-Dihing Reserve Forest in Dibrugarh District, where Kashmira Kakati observed a Dhole in 2010, as described by Singh et al. (2020). Although secondary sources suggest occurrences in the Patharia Hills Reserve Forest, Karimganj district, these accounts lack reliability to confirm the species' presence (Talukdar & Choudhury 2017). The recent records of Dholes from Dampa Tiger Reserve in Mizoram and other areas of northeastern India, including non-protected regions, provide evidence of the species' persistence in the region (Singh et al. 2020). While the KKAL likely provides suitable habitat for Dholes due to its forested and hilly terrain, large portions of Kaziranga's open grasslands are likely less suitable for the species (Durbin et al. 2008; Bashir et al. 2014; Singh et al. 2020). This variability highlights the heterogeneous nature of the landscape in terms of its suitability as a Dhole habitat.

The persistence of the species in KKAL highlights the possibility of nearby source populations. One such source population is in Ntanki National Park in Nagaland (Srivaths et al. 2020). Such dispersal is possible through the fragmented habitats of the Karbi Anglong District, which may act as a corridor facilitating movement between populations. Protected areas such as Morat Longri, northern Karbi Anglong, and eastern Karbi Anglong serve as ideal habitat patches that could support dispersal and provide stepping-stone habitats for wide-ranging species (Image 1). These protected areas and surrounding forests are likely to play a critical role in maintaining the metapopulation dynamics of Dholes in the region. The lack of recent sightings or reports from the area highlights the challenges posed by habitat

fragmentation and reduced connectivity. Therefore, it is crucial to identify and conserve potential source and sink populations within the larger landscape to ensure the persistence of Dholes.

The persistence of Dholes in this landscape is threatened by habitat fragmentation, reduced prey base, and retaliatory killings associated with Mithun depredation in Nagaland (personal communication with local communities during fieldwork December 2022). The fragmentation of corridors, particularly in the Karbi Anglong District, has likely disrupted the connectivity between source populations. This disruption may result in the isolation of small, vulnerable groups or even solitary dispersing individuals, thereby increasing their susceptibility to extirpation (Ginsberg & Macdonald 1990). While it is possible for a dispersing individual to establish a breeding pair and contribute to population growth, the lack of landscape connectivity poses a critical threat to long-term genetic viability. Furthermore, a decline in the prey base due to hunting of ungulates and competition with livestock has significantly reduced the availability of natural prey for Dholes (Wolf & Ripple 2017). These compounded threats highlight the urgent need for immediate policy intervention to address habitat fragmentation and ensure the persistence of both Dholes and their prey.

This study highlights the critical role of corridors in facilitating wildlife movement, ensuring habitat connectivity, and supporting species dispersal, especially during seasonal changes and extreme events like floods. In the absence of tigers and leopards, the Dhole assumes the role of apex predator in the ecosystem (Johnsingh 1992). Dholes are essential for regulating prey populations, and their persistence indicates the connectivity of the landscape. To ensure their conservation, future research should focus on understanding the movement ecology and connectivity of Dholes, as well as how corridor conservation benefits other species (Singh et al. 2020; Rodrigues et al. 2021).

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Distribution, habitat use and conservation status of Smooth-coated Otter *Lutrogale perspicillata* along the Cauvery and Kabini rivers, Karnataka, India

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Abstract: We documented the distribution and habitat use of the Smooth-coated Otter *Lutrogale perspicillata* along the Cauvery and Kabini rivers in Karnataka, India. In November–December 2024, we conducted systematic surveys covering approximately 80–100 km of each river using trained volunteer teams. Data collection included direct sightings and indirect signs (spraints, tracks, and holts). The Cauvery survey yielded 68 observations, including 21 direct sightings totalling 76 individual otters (mean group size = 3.3). The Kabini survey documented 42 observations, including 12 direct sightings totalling 39 individuals (mean group size = 2.8). Statistical analyses revealed no significant difference in otter presence between areas with and without fishing activity ($p = 0.428$), challenging prior assumptions about human-otter conflict. Areas with multiple human activities maintained substantial otter presence, with 44.4% of holts found in areas with three different types of human activity.

Keywords: Citizen science, conflict mitigation, dynamite fishing, freshwater ecosystem, habitat assessment, human-wildlife interactions, otter adaptability, river conservation, sand mining, volunteer surveys.

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Author contributions: Conceptualisation: Sugandhi Gadadhar, Raghunath Belur, Allison Amavisca. Methodology, analyses, validation and writing: Allison Amavisca. Supervision and project administration: Raghunath Belur, Sugandhi Gadadhar

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INTRODUCTION

The Smooth-coated Otter *Lutrogale perspicillata* is one of 13 otter species worldwide and among three found in India (Reuther 1999). Listed as 'Vulnerable' on the IUCN Red List (Khoo et al. 2021) and a Schedule 1 species in the Wildlife (Protection) Amendment Act (2022) due to an observed population decline of up to 30% across its range, the species faces multiple anthropogenic threats. In India, *L. perspicillata* occurs in all major river systems south of the Himalaya, where it serves as an apex predator in freshwater ecosystems (Hussain & Choudhury 1997).

The Cauvery River and its tributary, the Kabini, represent critical habitat for *L. perspicillata* in southern India (Image 1). Whilst several studies have documented otter populations within the Cauvery Wildlife Sanctuary (Shenoy et al. 2006; Khan et al. 2009), no systematic surveys have been conducted along the Kabini River. The human-wildlife interaction poses a significant threat to otter populations in this region, with declining fish stocks due to pollution, sand mining, and unsustainable fishing practices intensifying negative interactions between otters and fishing communities (Meena 2002; Anoop & Hussain 2004).

METHODS

Study Area

The surveys covered the Cauvery River from downstream of Srirangapatna Town to Sathegala Bridge and the Kabini River from Kabini Dam to T. Narsipura (Image 1). Both rivers flow through agricultural landscapes and human settlements outside protected areas. The climate is semi-arid with average temperatures above 25°C and annual rainfall of 60–100 cm (Jayaram 2000). Riparian vegetation includes *Terminalia arjuna* and *Salix tetrasperma*, with varying levels of human activity such as fishing, sand mining, and recreation. Representative habitat types from both rivers are shown in Image 2.

Data Collection

Surveys were conducted between November–December 2024 using methodology adapted from Hussain & Choudhury (1997), and Anoop & Hussain (2004). We divided the rivers into 1-km segments for walking and boat-based (coracle) surveys. Following standardised protocols (Reuther et al. 2000), observations included:

- direct sightings (location, group size, &

behaviour),

- indirect signs (spraints, tracks, & holts),
- habitat characteristics (substrate type, vegetation cover, & water quality), and
- human activities (fishing, sand mining, & recreation)

Habitat assessments were conducted at accessible locations, recording substrate composition, vegetation cover, distance to water, and human activity signs following methods established by Mason & Macdonald (1986). Examples of otter sign documentation methods are shown in Image 3.

Statistical Analysis

All analyses were performed using Python (version 3.8). We used independent t-tests to compare otter presence between areas with and without fishing activity. ANOVA tests evaluated the impact of multiple human activities, while chi-square tests examined relationships between human activities and various otter signs (Zar 1999).

RESULTS

Survey Overview

The Cauvery River survey yielded 68 total observations across approximately 75 km of river length. This included 21 direct sightings totalling 76 individual otters, with a mean group size of 3.3 (± 1.2 SD) otters. We documented 30 instances of otter prints, 20 spraint sites, and 13 tail marking locations (Table 1). Additionally, we identified 16 potential holt sites along this stretch.

The Kabini River survey covered approximately 85 km and produced 42 total observations. This included 12 direct sightings totalling 39 individual otters, with a mean group size of 2.8 (± 0.9 SD). We recorded 33 instances of prints, 24 spraint sites, and 10 tail markings (Table 1). Twelve potential holt sites were identified along this stretch.

While the Cauvery survey documented higher overall abundance compared to Kabini (Table 2), this difference was not statistically significant ($t = -0.796$, $p = 0.428$), suggesting that despite varying levels of human activity between the two rivers, otter populations appear to persist at similar densities.

Human-Otter Interactions

Statistical analyses revealed no significant difference in otter presence between areas with and without fishing activity ($t = -0.796$, $p = 0.428$; Table 2). The

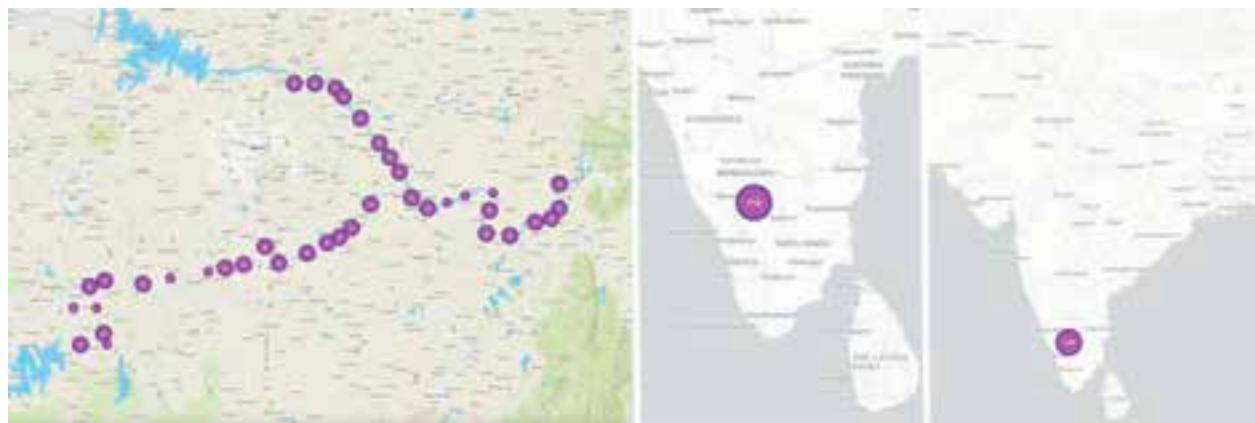


Image 1. The study area locations within Karnataka, India.



Image 2. Representative habitat types from both rivers: top left—Cauvery River showing typical sandy/rocky substrate and vegetation | top right—Kabini River showing characteristic riparian habitat. © Shreehari N (top left) | Sugandhi Gadadhar (top right) | Darshini MB (bottom left) | Raghu Nath Belur (bottom right).

pattern varied between rivers. In the Cauvery River, areas without fishing activity showed slightly higher mean otter sightings (1.42 ± 2.51 SD) compared to areas with fishing (0.60 ± 1.32 SD). Conversely, in the Kabini, areas with fishing activity showed higher mean otter sightings (1.20 ± 2.09 SD) compared to areas without

(0.68 ± 1.64 SD) (Table 3, Figure 1).

Habitat Use

We recorded distinctive patterns in habitat selection across both river systems (Table 4). Riparian vegetation areas accounted for 51.8% of all otter signs, followed by



Image 3. Examples of otter sign documentation: a—Spraint site | b—Student volunteers collecting data | c—Tail markings | d—Typical holt entrance | e—Otter pug marks. © a, c, e—Raghunath Belur | b—Renu Priyadarshani M | d—Athira A Sajan.

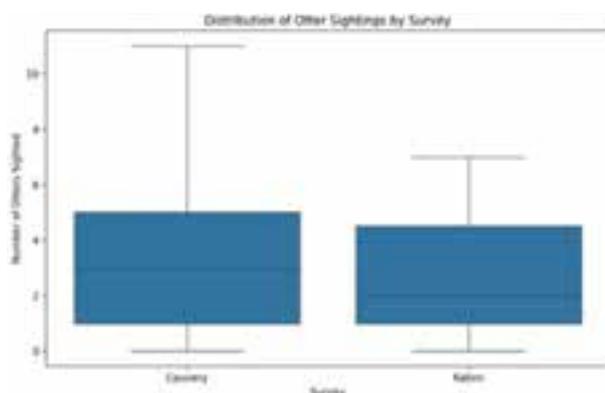


Figure 1A. Distribution of otter sightings by river.

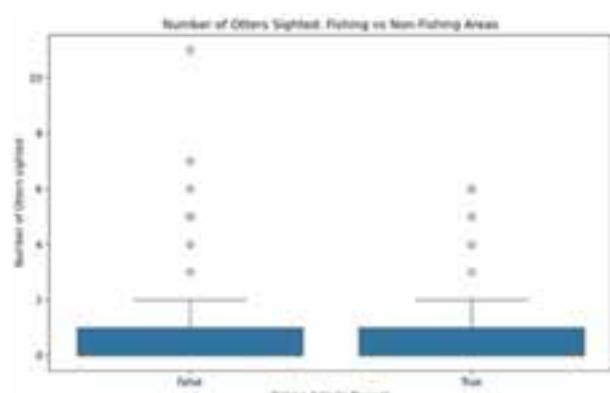


Figure 1B. Comparison of otter sightings in areas with/without fishing activity.

sandy banks (39.3%) and water/pool areas (27.7%). Holts were primarily constructed in loose sand ($\chi^2 = 12.4$, $p < 0.001$) with thick vegetation cover (mean canopy cover $76.3\% \pm 12.5$ SD). The distribution of otter evidence varied with human activity levels, as shown in Image 4. Breeding populations were confirmed in both river systems through observations of pups and family groups. Mean group sizes were $3.3 (\pm 1.2$ SD) for Cauvery and $2.8 (\pm 0.9$ SD) for Kabini, comparable to those reported in other studies (Hussain & Choudhury 1997; Anoop & Hussain 2004).

DISCUSSION

Otter Distribution and Adaptability

Our findings challenge common assumptions about otter avoidance of human-modified landscapes. The lack of a significant correlation between human activities and otter presence ($p > 0.05$; Table 2) suggests that *L. perspicillata* may be more adaptable to anthropogenic disturbance than previously documented (Hussain & Choudhury 1997; Anoop & Hussain 2004). Several key observations from our surveys evidence this adaptability:

First, the presence of active den sites in areas with multiple human activities (44.4% of dens found in areas with three different types of human activity) indicates that otters are not completely avoiding high-disturbance

Table 1. Summary statistics for both rivers showing: Number of observations | Direct sightings | Indirect signs | Mean group sizes | Survey effort.

Cauvery River		Number of Otters sighted	Number of print instances	Number of spraint instances	Number of tail mark instances
Sample Size		76.0	30.0	20.0	11.0
Mean		1.118	1.867	1.381	1.154
Median		0.0	1.5	1.0	1.0
Mode		0.0	1.0	1.0	1.0
Std Dev		2.159	1.024	0.898	0.769
Min		0.0	1.0	0.0	0.0
Max		11.0	4.0	4.0	3.0
95% CI Lower		0.591	1.478	0.962	0.67
95% CI Upper		1.644	2.256	1.8	1.638
Kabini River		Number of Otters sighted	Number of print instances	Number of spraint instances	Number of tail mark instances
Sample Size		39.0	13.0	14.0	6.0
Mean		0.929	2.062	1.412	1.111
Median		0.0	1.5	1.0	1.0
Mode		0.0	1.0	1.0	1.0
Std Dev		1.844	1.853	1.191	1.1
Min		0.0	0.0	0.0	0.0
Max		7.0	6.0	4.0	3.0
95% CI Lower		0.347	1.043	0.781	0.214
95% CI Upper		1.51	3.082	2.043	2.008
Total Survey		Number of Otters sighted	Number of print instances	Number of spraint instances	Number of tail mark instances
Sample Size		115.0	43.0	34.0	17.0
Mean		1.045	1.935	1.395	1.136
Median		0.0	1.5	1.0	1.0
Mode		0.0	1.0	1.0	1.0
Std Dev		2.047	1.374	1.04	0.919
Min		0.0	0.0	0.0	0.0
Max		11.0	6.0	4.0	3.0
95% CI Lower		0.657	1.522	1.048	0.719
95% CI Upper		1.434	2.347	1.741	0.554

Table 2. Statistical comparison between areas with and without human activity.

	Mean (Human Activity)	Mean (No Activity)	Sample Size (Human Activity)	Sample Size (No Activity)	t-statistic	p-value	Cohen's d	Chi-square	df
Number of Otters sighted	1.164383562	0.810810811	73	37	0.851068861	0.396614152	0.173189299	1.448414599	1
Number of prints	1.931034483	1.941176471	29	17	-0.02363883	0.98124758	-0.007379626	0.037784729	1
Number of spraints	1.391304348	1.4	23	15	-0.02452817	0.980566774	-0.008371945	0.282092752	1
Number of tail marks	1.230769231	1	13	9	0.556234201	0.584221084	0.251557647	0.175558181	1



Image 4. Heat maps showing percentage of sites with different types of otter evidence and number of human activities present.

zones. Rather than abandoning these areas, otters appear to modify their behaviour, potentially becoming more nocturnal or adjusting their activity patterns to minimize direct contact with humans. Our findings align more closely with recent work suggesting behavioural adaptation to human presence (Anoop & Hussain 2004; Khan et al. 2009).

Second, while areas without fishing showed slightly higher mean otter sightings (1.17 compared to 0.87 in fishing areas), this difference was not statistically significant. This suggests that otters can maintain viable populations even in areas with regular fishing activity, contrary to previous assumptions about fishing-otter conflict driving local extinctions.

Third, the documentation of successful breeding, evidenced by observations of pups and family groups in both river systems, indicates that these populations are not just persisting but reproducing in human-modified landscapes. The mean group sizes observed (3.3 in Cauvery and 2.8 in Kabini) are comparable to those reported in less disturbed habitats, suggesting that human activity is not significantly impacting social structure or reproductive success.

Table 3. Comparison of otter presence in fishing vs non-fishing areas by river.

	mean	count	std	
Cauvery fishing absent	1.42	43	2.51	T-statistic: -1.7595779613762803
Cauvery fishing present	0.6	25	1.32	P-value: 0.0831459021468832
Kabini fishing absent	0.68	22	1.64	T-statistic: 0.886289848030455
Kabini fishing present	1.2	20	2.09	P-value: 0.3813371725366115

This adaptability to human presence has important implications for conservation strategies, suggesting that management efforts should focus on reducing direct threats (such as snares and dynamite fishing) rather than attempting to completely separate otter, and human activities. This apparent tolerance of human presence should not be interpreted as resilience to all forms of disturbance, as significant threats from habitat modification, particularly sand mining, and river bank alterations, continue to impact these populations.

Human-Wildlife Interaction

To address ongoing negative interactions between fishing communities and otters, we convened a workshop in November 2024, bringing together experts on species and human-wildlife interaction specialists. Participants included representatives from the IUCN Otter Specialist Group, Royal Zoological Society of Scotland (RZSS), Institute for Wildlife Conservation (ICAS), Budongo Conservation Field Station (BCFS), and several Indian research institutions. The workshop findings, when combined with our survey data, reveal important insights for conservation planning.

Our statistical analyses found no significant correlation between fishing activities and otter presence ($p = 0.428$; Table 2), challenging common assumptions about human-wildlife negative interactions in these systems. This aligns with workshop discussions that identified broader ecosystem threats rather than direct human-otter competition as key conservation challenges. While fishermen often perceive otters as a significant threat to their livelihood (Trivedi & Variya 2023), our data suggests a more complex reality. This aligns with workshop discussions that identified broader ecosystem threats rather than direct human-otter competition as key conservation challenges (Figure 2).

The workshop identified five interconnected areas for mitigation (Image 5):

Improvements to fishing technology and practices: Our survey documented the widespread use of

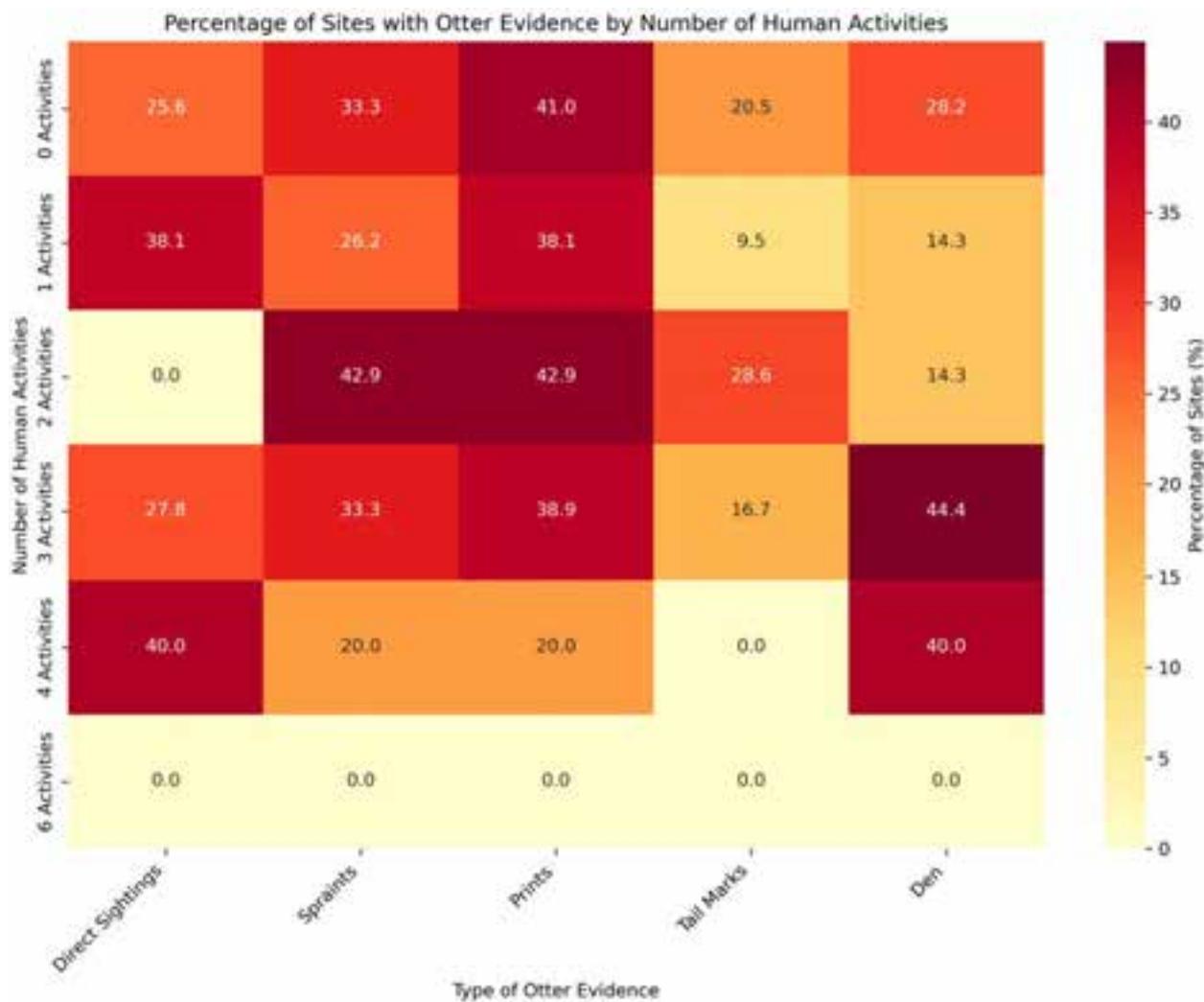


Figure 2. Conceptual model showing relationship between human activity types and otter presence.

Table 4. Habitat characteristics at otter presence sites vs random sites: Substrate composition | Vegetation cover | Distance to water.

Habitat Type	Total Sites	Sites with Direct Sightings	Sites with Spraints	Sites with Prints	Sites with Tail Marks	Total Sites Percentage	Sites with Direct Sightings Percentage	Sites with Spraints Percentage	Sites with Prints Percentage	Sites with Tail Marks Percentage
riparian vegetation	58	58	16	24	7	51.8	51.8	14.3	21.4	6.2
sandy bank	44	44	20	26	17	39.3	39.3	17.9	23.2	15.2
water/pool	31	31	7	5	2	27.7	27.7	6.2	4.5	1.8
human settlement area	12	12	4	7	3	10.7	10.7	3.6	6.2	2.7
rocky area	12	12	7	1	0	10.7	10.7	6.2	0.9	0
other	5	5	2	2	1	4.5	4.5	1.8	1.8	0.9

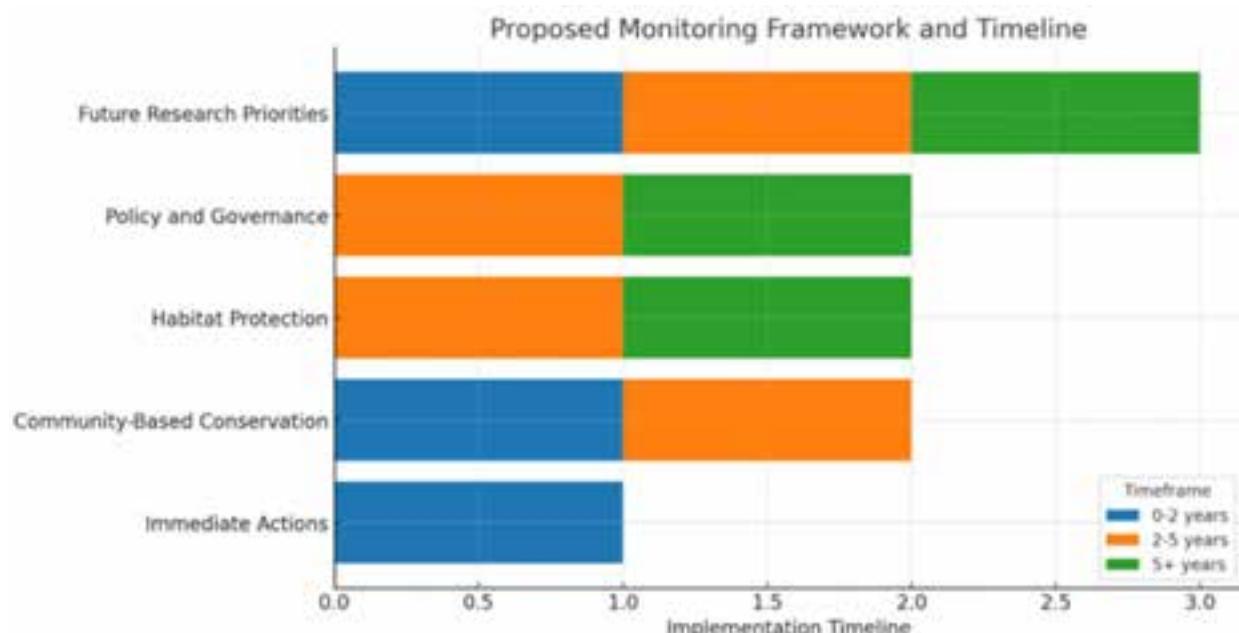


Figure 3. Proposed monitoring framework and timeline.

traditional fishing nets which are vulnerable to otter damage. Workshop participants proposed testing acoustic deterrents and stronger nets – solutions that could be particularly relevant along the Cauvery River where we recorded higher instances of human-otter negative interactions than the Kabini River.

- Legal/legislative changes: Survey data revealed ongoing sand mining and dynamite fishing, particularly along the Cauvery. Workshop participants emphasized the need for stronger inter-state regulations, as rivers often form state boundaries, complicating enforcement.

- Alternative livelihoods/compensation: The finding that areas with multiple human activities still maintain otter populations (44.4% den presence in areas with three activities) suggests potential for sustainable coexistence through properly managed alternative livelihoods, like ecotourism.

- Stakeholder relationship building: Our observation that otters adapt rather than avoid human presence (mean group size 3.3 in Cauvery despite higher human activity) supports workshop recommendations for engaging fishermen as conservation allies rather than adversaries.

- Education and awareness: The successful engagement of university students in our surveys demonstrates the potential for citizen science to build local capacity and awareness. Workshop participants emphasized expanding such programs to fishing communities.

These findings collectively suggest that successful conservation of *L. perspicillata* in human-modified landscapes requires an integrated approach addressing both immediate human-wildlife negative interactions and broader ecosystem threats. Our survey results indicate otters can persist alongside human activities when properly managed, while workshop recommendations provide practical pathways for improving coexistence.

Conservation Implications

Based on our survey findings and workshop outcomes, we developed a comprehensive monitoring framework to guide future conservation efforts (Figure 3). This framework emphasizes the need for both immediate interventions and long-term strategies, with clear timelines, and responsible stakeholders identified for each action. The framework particularly highlights the importance of integrating community-based monitoring with systematic scientific surveys, allowing for adaptive management as new information becomes available. Drawing from this framework and previous research (MacDonald & Mason 1990; Hussain 1993), we recommend:

Immediate actions:

1. Addressing direct threats
 - increased enforcement against dynamite fishing, which has been documented as a threat to otters in the Cauvery system (Shenoy et al. 2006),

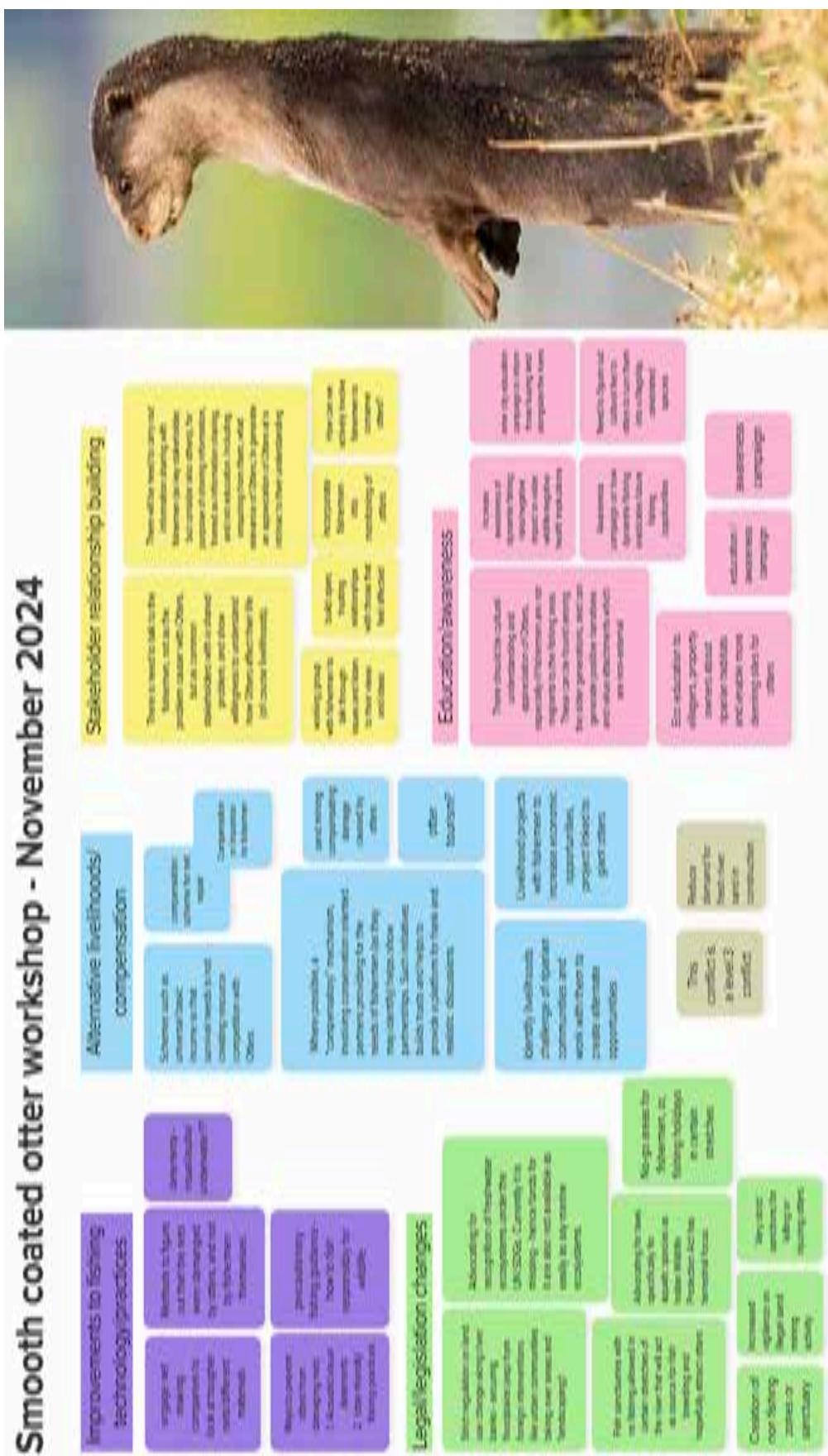


Image 5. Mural collaboration results.

- protection of documented holt sites (n = 28 across both rivers), and
 - regulation of sand mining operations.
2. Community-based conservation
- implementation of fishing gear improvements based on successful models (Khan et al. 2009),
 - development of community-managed insurance schemes, and
 - engagement of local fishermen in otter monitoring.

Long-term strategies:

- 1. Habitat protection
 - preservation of dense riparian vegetation,
 - protection of sandbanks used for denning, and
 - maintenance of river connectivity following Hussain & Choudhury's (1997) recommendations
- 2. Policy and governance
 - inter-state coordination for river protection,
 - integration of otter conservation into river management plans, and
 - implementation of evidence-based sand mining regulations.

Future research priorities building on current findings, we recommend:

- expansion of surveys to additional river systems,
- long-term monitoring of identified populations,
- assessment of genetic connectivity between populations, and
- evaluation of mitigation measure effectiveness

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An annotated checklist of the genus *Amorphophallus* Blume ex Decne. (Araceae): an update on the distribution and conservation status of its species

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Abstract: Araceae's most remarkable genus is *Amorphophallus*, which is propagated for food, ornamental, and herbal medicine due to its medicinal properties. This checklist includes 241 accepted species of *Amorphophallus*, featuring their scientific names, covered countries, conservation and distribution status, ecological habitats, and biogeographical regions. Around 83% of *Amorphophallus* species are native, and 17% were endemic, and found in Burundi, Benin, Cambodia, Cameroon, Congo, China, Equatorial Guinea, India, Indonesia, Laos, Myanmar, Madagascar, Malaysia, Nigeria, Philippines, Thailand, and Vietnam. Thailand is the most species-rich country (66 spp.), while Indo-Malay is the most species-rich biogeographic region (56.65%). Furthermore, limestone areas are the typical ecological habitat in which *Amorphophallus* species can be found (9.76%). IUCN Red List of Threatened Species documents the genus as 'Critically Endangered' (4.15%), 'Vulnerable' (2.90%), 'Endangered' (0.83%), 'Near Threatened' (0.83%), 'Least Concern' (0.83%), 'Data Deficient' (0.83%); 76.35% (184 species out of 241) were not evaluated because the report's scope for assessing threatened plants might be inadequate, and 13.70% have no record. This inventory from digital databases will assess a more holistic strategic conservation plan of *Amorphophallus* species worldwide.

Keywords: Amorphous, biogeography, diversity, ecological habitat, endemic, global databases, native, occurrences, phallus, worldwide.

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INTRODUCTION

One of the globally biggest families is the Araceae (Moodley et al. 2016; Bulawin et al. 2024), and one of the largest genera of the family Araceae is *Amorphophallus* (Claudel 2021; Bulawin et al. 2024). About 241 accepted species of *Amorphophallus* are distributed worldwide (IPNI 2022; GBIF 2022; WCVP 2022; Bulawin et al. 2022–2024), and 70% of species can be found in southeastern Asia (Claudel et al. 2019). Most species are limited, and only a few are distributed over a large area (Grob et al. 2003). *Amorphophallus* species are native in southern and southeastern Asia, northern Australia & Oceania, China, Taiwan, Bangladesh, India, Sri Lanka, Laos, Burma, Thailand, Vietnam, Borneo Island, Java Island, Malaysia, Philippines, Celebes Island, Sumatra, New Guinea, Fiji, and Samoa extending from tropical and subtropical climates (Sivila & Santos 2021).

Amorphophallus is derived from the Greek word amorphous which means deformed, and phallus meaning penis (Yuzammi 2009). Most parts of the plant manifest varied and unique appearances, one of which is the plant's height (Claudel et al. 2017). *Amorphophallus* is well known for its colossal flowers and decaying flesh odor (Liu et al. 2017). The colorful spathe of the inflorescence is essential for breeding and laying eggs of the insects (Ulrich et al. 2016). The spadix at the center of the flower emits heat and odor that entices pollinators (Diaz & Kite 2006; Barthlott et al. 2009). The essential part of the flower is the appendix, an organ that draws the attention of insects for pollination (Chartier & Gibernau 2009). The tuber is the underground stem that serves as a storage organ and for plant propagation. *Amorphophallus* plant commonly grows with an individual leaf (Mc Pherson & Hetterscheid 2011), and the lamina has elliptical leaflets with acute to acuminate apex, similar to the leaves of young trees, and a lichen-like pattern covers the petiole (Claudel et al. 2019). The conspicuous characteristics of *Amorphophallus* that can be readily identified are the mark arrangement or pattern and the shade of the petiole (Gustini et al. 2017).

In the Philippines, India, Sri Lanka, and other southeastern Asian countries, *Amorphophallus* is used for human consumption, not only as an ornamental plant (Sivila & Santos 2021), but also for medicinal purposes. Tubers, young branches, and inflorescence are the parts of *Amorphophallus* that are edible, and can be used in traditional healing (Anil et al. 2011; Phornvillay et al. 2015; Mastuti et al. 2018; Sookchaloem et al. 2018). *Amorphophallus* was a secondary food source,

next to rice, and was utilized in land-clearing ceremonies as an offering of food in some countries (Mursyidin et al. 2022). It is also used in making chips (Misra et al. 2010) and pasta (Chua et al. 2010). Essential parts of plants can be utilized as a source of medicine and food ingredients (Rivai et al. 2022). Traditionally, it has been used as an herbal medicine due to its medicinal properties (Sharma et al. 2022).

The contemporary inventory of accepted *Amorphophallus* species with scientific names, number of occurrences, countries, conservation & distribution status, ecological habitat, and biogeography is introduced in this world checklist. This study utilized digital databases to have a general checklist of *Amorphophallus*, distribution, and conservation status globally. Through this checklist, the different accepted species of *Amorphophallus* worldwide, the countries where the species were found, conservation status, habitat, and biogeography regions where the species were distributed are identified. This study will serve as a basic standard of information regarding the genus diversity, distribution, and global conservation to improve strategic management, and a sustainable plan.

MATERIALS AND METHODS

Knowledge about the ecology, characteristics, and habitats of most plants is limited or nonexistent. The plant's global databases help address some of the plant's growth forms (Taseski et al. 2019). This study provides a worldwide inventory of the accepted species of *Amorphophallus*, covered countries, conservation & distribution status, ecological habitat, and biogeographic regions (Table 3). All the acquired information on *Amorphophallus* species came from digital articles, online herbaria (Table 2) (Internet Directory for Botany 2022; NYBG 2022), and public access databases on biodiversity (Table 1) (Pelser et al. 2011 onwards; CATE Araceae 2022; GBIF 2022; IAS 2022; IPNI 2022; POWO 2022; Tropicos 2022; WCSP 2022; WCVP 2022; WFO 2022). Only the taxonomically accepted species of *Amorphophallus* were included in this paper. The checklist did not include synonyms and varieties. The well-known online international system, open access that provides a database for plant biodiversity is the Global Biodiversity Information Facility (GBIF) (Reyserhove et al. 2020). The scientific names of accepted species of *Amorphophallus* were obtained from the GBIF (2022) and cross-checked against the World Checklist of Vascular Plants (WCVP 2022), International



Image 1. The biogeographic realms of the world (Olson et al. 2001) used in the study of *Amorphophallus* species (Source: www.scribblemaps.com).

Plant Names Index (IPNI 2022), and other online herbaria. Also, the number of occurrences, covered countries, biogeographic regions, and conservation status were added in the analysis. The information on distribution and ecological status of *Amorphophallus* species was acquired from the Plant of the World Online (POWO 2022), International Plant Names Index (IPNI 2022), and online herbaria worldwide. In this checklist, various online herbaria, biodiversity databases, and protoglosses were also utilized to verify the information of *Amorphophallus* species.

The status of occurrences was zero when a survey of a taxon at a specific time and place encountered no specimens. The NR abbreviation was used for no record occurrences based on online herbarium databases. Covered countries were documented by using ISO 3166-1 alpha-2 code (https://www.nationsonline.org/oneworld/country_code_list.htm). These countries where the various species of *Amorphophallus* were found aligned according to the counterpart biogeographic regions (Image 1), such as Neotropical—NE, Nearctic—NT, Afrotropical—AT, Palearctic—PA, Australasia—AS, and Indo-Malay—IM (Olson et al. 2001). On the one hand, the detailed conservation status was according to the IUCN Global Red List Category. The following abbreviation was used for the conservation status

of *Amorphophallus* species: UA—Unassessed, DD—Data Deficient, LC—Least Concern, NT—Near Threatened, VU—Vulnerable, EN—Endangered, and CR—Critically Endangered. For those *Amorphophallus* species without a record, the NR abbreviation was used. Information about the distribution status of *Amorphophallus* species used the abbreviation EC for endemic *Amorphophallus* and NA for native species of *Amorphophallus*. The ecological habitat of various species of *Amorphophallus* were indicated (Figure 7), and those *Amorphophallus* species with unknown ecological habitat or no record based on online herbarium databases were given the abbreviation UK.

RESULTS AND DISCUSSION

Out of 241 species of *Amorphophallus* worldwide (Table 3) (Bulawin et al. 2022–2024), around 7,463 total occurrences of *Amorphophallus* species were recorded in global databases from different countries. Other countries had zero occurrences due to the absence of encountered specimens when a survey of a taxon at a specific time and place was conducted, and some species had no record in global databases. The species with the highest occurrences were

Table 1. Databases used for a worldwide checklist of *Amorphophallus* species.

Database	Webpage URL
CATE Araceae	https://cate-araceae.myspecies.info/
Co's Digital Flora of the Philippines	https://www.philippineplants.org/
Global Biodiversity Information Facility (GBIF)	https://www.gbif.org/
International Aroid Society	https://www.aroid.org/
International Plant Names Index (IPNI)	https://www.ipni.org/
World Checklist of Selected Plant Families (WCSP)	https://wcsp.science.kew.org/home.do
Plants of the World Online (POWO)	https://powo.science.kew.org/
The World Flora Online (WFO)	https://www.worldfloraonline.org/
Tropicos	https://www.tropicos.org/home
World Checklist of Vascular Plants (WCVP)	https://wcvp.science.kew.org/taxon/979828-1

A. paeoniifolius (12.31%), *A. abyssinicus* (10.49%), *A. baumannii* (5.21%), *A. dracontiodes* (4.98%), *A. konjac* (4.66%), *A. galbra* (4.45%), *A. aphyllus* (3.95%), *A. titanum* (2.99%), and *A. variabilis* (2.33%). *Amorphophallus paeoniifolius* had the highest occurrences of all the species of *Amorphophallus*, which was known for its geographical extent. This species can be cultivated in many regions, including southeastern Asia (Gao et al. 2017; Bulawin et al. 2022). Most of the species with highest occurrences could be found in the following countries: Nigeria, Togo, Indonesia, Burkina Faso, Guinea, United States, and Belgium in Afrotropic, Indo-Malay, Nearctic, and Palearctic regions (Image 1). Table 3 presents the worldwide checklist of *Amorphophallus* species based on digital databases and herbarium records.

There were various accepted species of *Amorphophallus* from different countries worldwide. The most species-rich country based on the record of digital databases was Thailand with (66 species), followed by France (39 species), Vietnam (34 species), United States (34 species), Indonesia (32 species), Malaysia (30 species), Laos (28 species), India (22 species), Philippines (21 species), and China (18 species) (Figure 2). Manifesting distinct habitats for the diversity and bioresources of the species (Sungkajanttranon et al. 2018) made Thailand the most species-rich country of *Amorphophallus* species. Figure 3 presents the number of *Amorphophallus* species by country based on online herbarium and databases.

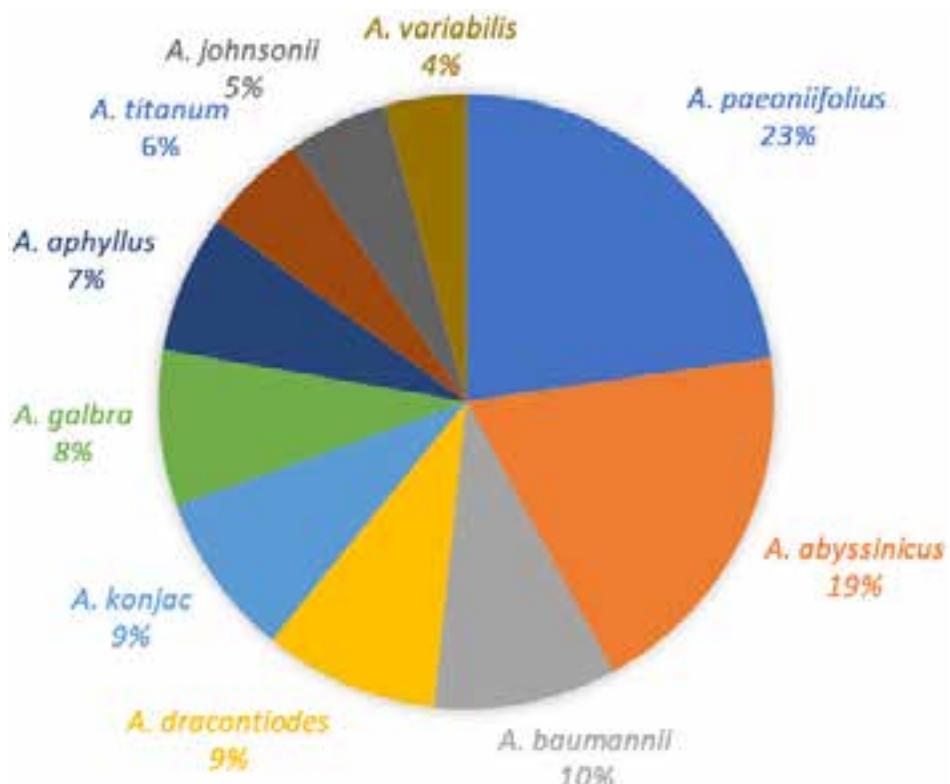
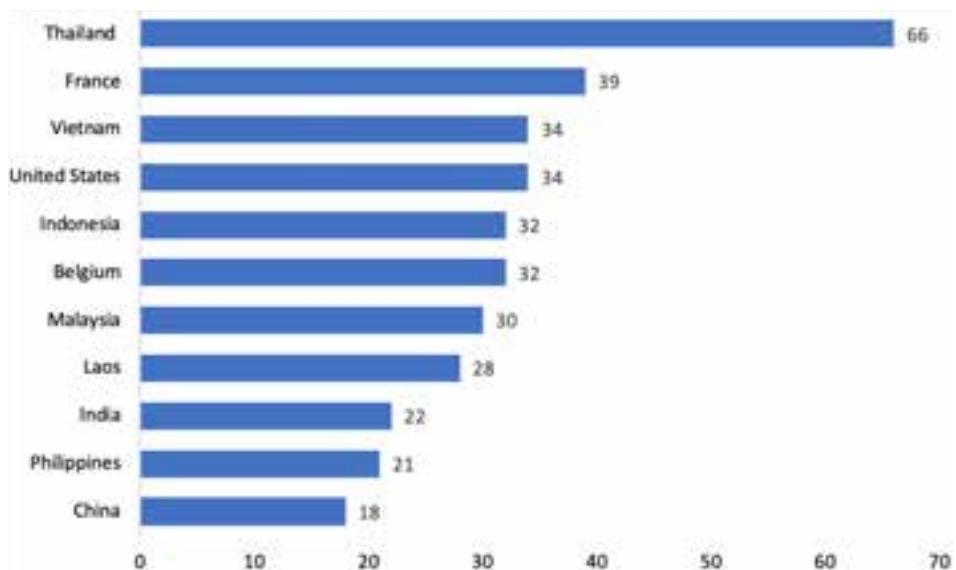
The generally recognized and accepted assessment criteria to identify the condition of the species for

Table 2. Herbaria used for the confirmation of *Amorphophallus* species [NYBG Steere Herbarium (2022) | Internet Directory for Botany (2022)].

Institution	Location	Herbarium code
Adelaide Botanic Garden	Australia	AD
Berlin-Dahlem Botanical Garden	Germany	B
Bonn Botanic Garden	Germany	BONN
Botanic Garden of Marburg University	Germany	MB
Calicut University Botanical Garden	India	CALI
Chinese National Herbarium	China	PE
Fairchild Tropical Botanic Garden	USA	FTG
Forest Herbarium	Thailand	BKF
Gothenburg Botanical Garden	Sweden	GB
Hamburg Botanical Garden	Germany	HBG
Herbarium Bandungense Jurusan Biologi	Indonesia	ITB
Herbarium Bogoriense	Indonesia	BO
Herbarium, Institute of Botany, Academia Sinica, Taipei	Taiwan	HAST
Herbarium Universiti of Kebangsaan	Malaysia	UKMB
Huntington Botanical Gardens	California	HNT
Institute of Tropical Biology	Vietnam	VNM
Leiden Botanic Garden	Netherlands	L
Missouri Botanic Garden	USA	MO
National Herbarium of the Netherlands or Herbarium Hamburgense	Netherlands	HBG
National Taiwan University Herbarium	Taiwan	TAI
Royal Botanic Garden	Australia	K
Saint Petersburg University	Russia	LECB
Shivaji University	India	SUK
Wageningen Herbarium	Netherlands	WAG

conservation design are the IUCN Red List of Threatened Species (Yudaputra et al. 2022). Based on the digital databases, 76.35% of *Amorphophallus* species were unassessed for conservation status, and 13.70% have no record. Around 4.15% of *Amorphophallus* species globally are CR, 2.90% VU, 0.83% EN, 0.83% NT, 0.83% LC, and 0.83% DD (Figure 4). This result shows that *Amorphophallus* species are included in the list of protected flora (Wulandari et al. 2022) since some were Critically Endangered, Vulnerable, Endangered, and Near Threatened according to IUCN Red List Criteria (2022).

Native species occur naturally in a region; endemic species are native and restricted to a specific area (Dempsey 2022). Globally, 83% of *Amorphophallus* species were native, and 17% were endemic (Figure 5). Based on the record of digital databases, the 10 most countries with native species of

Figure 1. Species of *Amorphophallus* with higher number of occurrences.Figure 2. Countries with a higher number of *Amorphophallus* species.

Amorphophallus were Vietnam (35 species), followed by Malaysia (31 species), Laos (30 species), Thailand (27 species), Indonesia (24 species), India (21 species), China (16 species), Myanmar (13 species), Democratic Republic of Congo (10 species), and the Cambodia

(nine species). The 10 countries with endemic species of *Amorphophallus* were the following: Thailand (34 species), Philippines (20 species), Madagascar four species, Malaysia two species, Nigeria one species, Equatorial Guinea (one species), the Democratic

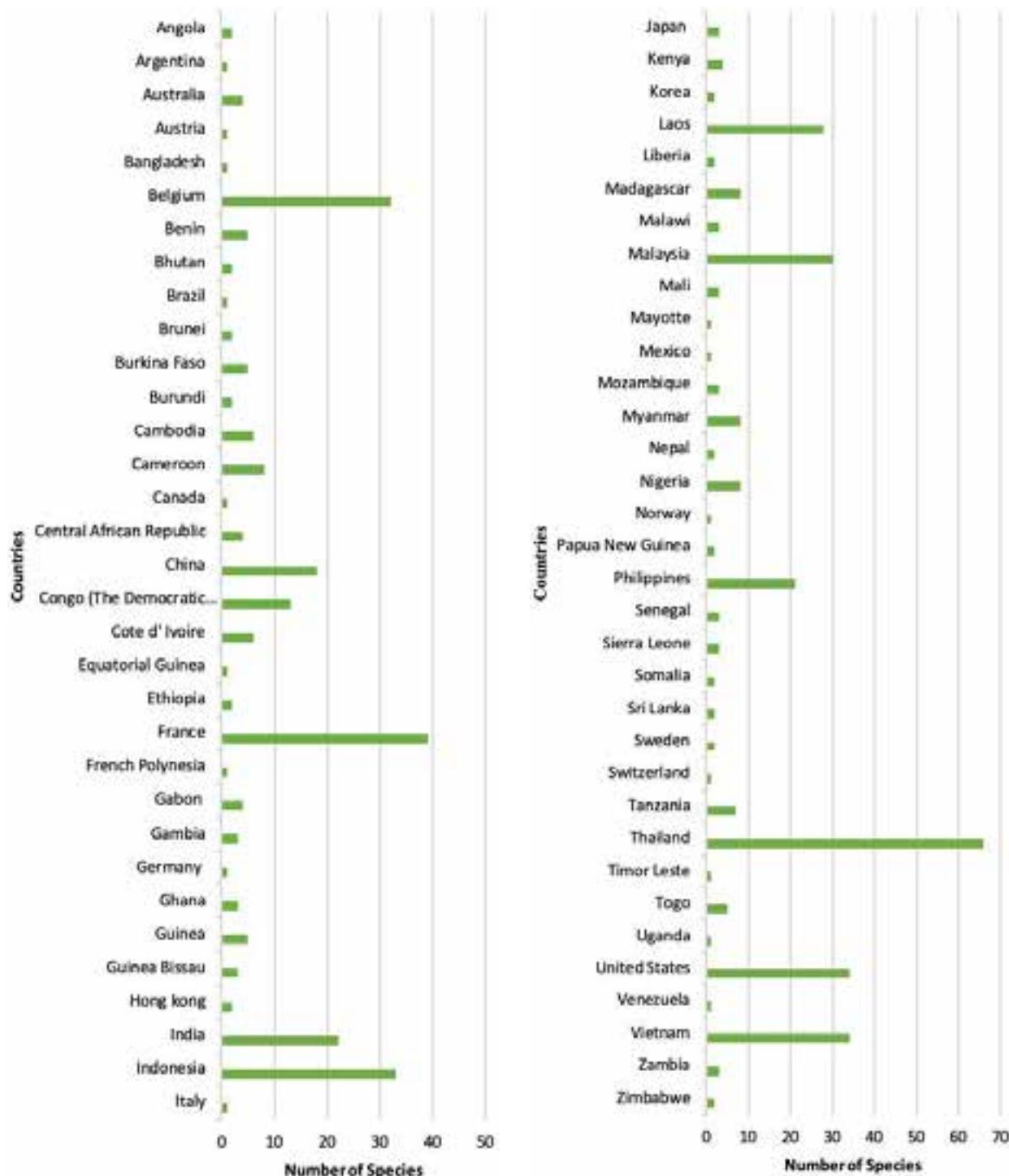


Figure 3. The number of *Amorphophallus* species by country based on online herbarium and databases.

Republic of Congo (one species), Cameroon (one species), Benin (one species), and Burundi (one species) (Figure 6). Most *Amorphophallus* had a broader extent of endemism because of a large scope of geographic adaptation that made it a diverse species (Anil et al. 2014).

Most of the ecological habitat of the *Amorphophallus* species was unknown based on digital databases, with 49.83% (Figure 7). Followed by others or different ecological habitats with 5.72%. Few of *Amorphophallus* species grown in limestone (9.76%), followed by deciduous forest (5.72%), savannah (4.04%), secondary

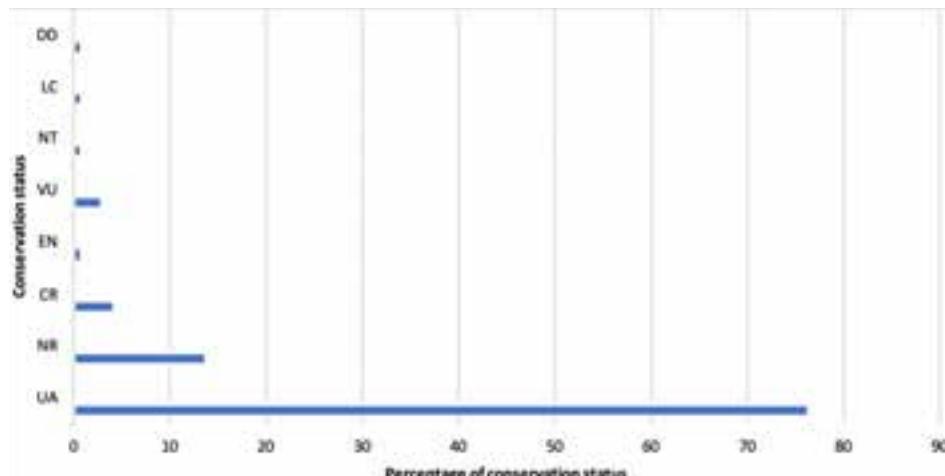


Figure 4. Conservation status of *Amorphophallus* species based on the International Union of Conservation of Nature (IUCN 2022).

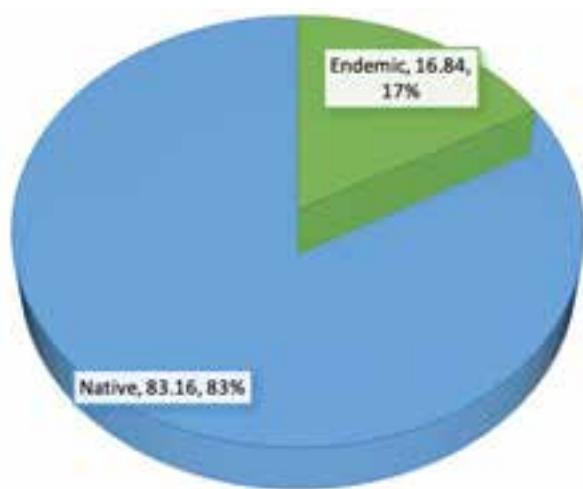


Figure 5. Percentage of *Amorphophallus* species distribution.

forest (3.70%), primary forest (3.03%), dipterocarp forest (2.69%), shady area (2.69%), under bamboo (1.35%), forest margin (1.35%), open forest (1.01%), open woodland (1.01%), lowland forest (1.01%), rich soil with added loam (0.67%), and low land (0.67%). Some species occur in limestone areas rich in decaying organic matter (Nguyen et al. 2016). Additionally, they are primarily found in secondary forests rather than primary forests, as they are considered pioneer species, and few have evolved in open fields (Liu et al. 2017).

Amorphophallus species are abundant in the biogeographical regions of Indo-Malay (56.65%), followed by the Palearctic (19.34%), the Afrotropics (11.85%), Nearctic (9.83%), Australasia (1.16%), and lastly the Neotropics (1.16%). No *Amorphophallus* species are distributed in Oceania and Antarctic biogeography regions. Indo-Malay includes those countries in southern,

southeastern Asia, and the southern part of eastern Asia. Most of the *Amorphophallus* species have been discovered in southeastern Asia (Bulawin et al. 2022), and this result suggests that *Amorphophallus* species were abundant in Indo-Malay biogeography.

Based on the occurrences, it appears that the genus *Amorphophallus* has lower occurrences than other genera in the family Araceae, such as *Anthurium*, *Arisaema*, *Arum*, *Caladium*, *Calocasia*, *Dieffenbachia*, *Monstera*, *Philodendron*, *Syngonium*, *Xanthosoma*, and *Zantedeschia*, especially when it is not in season. The development or maturity of *Amorphophallus* varies across different species, and it is a seasonal plant that undergoes an annual cycle of activity and dormancy (Mc Pherson & Hetterscheid 2011).

Besides, *Amorphophallus* species need an appropriate environmental condition to grow because several factors can affect their growth and distribution such as habitat type, altitude, light, humidity and temperature (Wulandari et al. 2022). These were the reasons why some species of *Amorphophallus* have zero or absence of occurrences in some other countries (Sungkajantranon et al. 2018; Wulandari et al. 2022). *A. paeoniifolius* (Figure 1) had a higher percentage of occurrences because of its comestible tuber and medicinal properties (Anil et al. 2011). It is known for its geographical extent, as this species can be cultivated in many regions (Bulawin et al. 2022).

In describing the rate of biodiversity of a particular ecosystem, evaluation of plants, geographical distribution in terms of species richness, species evenness, endemism, and conservation status is fundamental (Batuyong et al. 2020). Out of 10 countries with a higher number of *Amorphophallus* species,

Table 3. Worldwide checklist of *Amorphophallus* species based on digital databases and herbarium records.

Species	Number of occurrences	Country	IUCN Red List status	Status of distribution	Ecological habitat	Biogeographic region
1. <i>A. aberrans</i> Hett.	5	TH, FR	UA	EC in TH	Dry savannah forest	IM, PA
2. <i>A. abyssinicus</i> (A.Rich.) N.E.Br.	783	BE, CD, BF, TZ, CI, CM, GN, NG, TG, CF	UA	NA to NG, BF, NE, TG, ZM, CM, NA, CF, TD, ET, ZA, TZ, UG, ZW	UK	PA, AT
3. <i>A. adamsensis</i> Magtoto, Mones, Ballada, Austria, R.M.Dizon, Alangui, Regina	NR	PH	NT	EC in PH	UK	IM
4. <i>A. albispathus</i> Hett.	17	TH, BE, MY, US	UA	EC in TH	Limestone	IM, PA, NT
5. <i>A. albus</i> P.Y.Liu & J.F.Chen	23	CN, FR, CH, BE, SE	UA	NA to CN	Open forest	PA
6. <i>A. allenii</i> A. Galloway, Malkm. Huss., Prehsler & Claudel	0	TH	NR	NA to TH	UK	IM
7. <i>A. amygdaloïdes</i> Hett. & Sizemore	5	TH	UA	EC in TH	UK	IM
8. <i>A. andranogidroensis</i> Hett. & Mangelsdorff	2	MG	UA	EC in MG	Deciduous forest	AT
9. <i>A. angolensis</i> (Welw. ex. Schott) N.E.Br.	79	GA, CD, CF, AO, CN	UA	NA to AO, GA, SD, CD	UK	AT, PA
10. <i>A. angulatus</i> Hett. & A.Vogel	11	MY	UA	NA to Borneo	UK	IM
11. <i>A. angustispathus</i> Hett.	4	MM	UA	NA to MM	UK	IM
12. <i>A. ankarana</i> Hett. Ittenb. & Bogner	25	MG, BE, FR	UA	EC in MG	Limestone	AT, PA
13. <i>A. annulifer</i> Hett.	2	ID	UA	NA to Java	UK	IM
14. <i>A. antsingyensis</i> Bogner, Hett. & Ittenbach	27	MG	UA	EC in MG	Primary & secondary forest/ limestone	AT
15. <i>A. aphyllus</i> (Hook.) Hutch.	295	BJ, SN, GM, SL, GN, GW, ML, BE, TG, CI	UA	NA to BF, CF, TD, GW, ML, SN, SL, TG	Savannah/dry forest	AT, PA
16. <i>A. arcuspadix</i> A.Galloway, Ongsakul & Petra Schmidt	1	FR	UA	NA to LA	UK	PA
17. <i>A. ardi</i> Yuzammi & Hett.	NR	ID	NR	NA to Sulawesi	UK	IM
18. <i>A. asper</i> (Engl.) & Gehrm.	7	ID	UA	NA to Sumatra	UK	IM
19. <i>A. asterostigmatus</i> Bogner & Hett.	13	TH	UA	EC in TH	Limestone	IM
20. <i>A. atrorubens</i> Hett. & Sizemore	2	TH	UA	EC in TH	Limestone	IM
21. <i>A. atroviridis</i> Hett.	9	TH, BE	UA	EC in TH	Limestone	IM, PA
22. <i>A. bangkokensis</i> Gagnep	2	TH	UA	EC in TH	Low-lying waste ground	IM
23. <i>A. barbatus</i> A.Galloway & Ongsakul	0	LA	NR	NA to LA	UK	IM
24. <i>A. barthlottii</i> Ittenb. & Lobi	6	CI, LR	UA	NA to CI, LR	UK	AT
25. <i>A. baumannii</i> (Engl.) N.E.Br.	389	BE, GH, TG, SN, BF, NG, GW, SL, GM, NG	UA	NA to NG, BF, NE, NG, SN, SL, CF, TD, GM, GH, GW, LR, TG	Savannah/ open woodland/and stony soil	PA, AT
26. <i>A. beccarii</i> Engl.	26	ID, FR	UA	NA to Sumatra	UK	IM, PA
27. <i>A. bequaertii</i> De Wild.	4	CD	UA	EC in East CD	Primary forest	AT
28. <i>A. blumei</i> Schott, 1863	0	IN	NR	NR	UK	NR
29. <i>A. bognerianus</i> Sivad & Jaleel	2	IN	UA	NA to East Himalaya	UK	IM
30. <i>A. bolikhampayensis</i> A.Galloway, Ongsakul & Petra Schmidt	1	FR	UA	NA to LA	UK	PA
31. <i>A. bonaccordensis</i> Sivad. & N.Mohanan	4	IN	UA	NA to IN	UK	IM
32. <i>A. borneensis</i> (Engl.) Engl. & Gehrm	18	MY, ID, BE, BN	UA	NA to Borneo	UK	IM, PA,
33. <i>A. boyceanus</i> Hett.	1	TH	UA	EC in TH	UK	IM
34. <i>A. brachyphyllus</i> Hett.	10	MY	UA	EC in Bau area, Kuching Div.	Lowland forest/ Limestone/ evergreen forest	IM
35. <i>A. brevipetiolatus</i> A.Galloway, Ongsakul & Petra Schmidt	0	LA	NR	NA to LA	UK	IM

Species	Number of occurrences	Country	IUCN Red List status	Status of distribution	Ecological habitat	Biogeographic region
36. <i>A. brevispathus</i> Gagnep.	11	TH	UA	EC in TH	Limestone	IM
37. <i>A. bubenensis</i> J.T.Yin & Hett.	0	CN	NR	NA to CN South Central	UK	PA
38. <i>A. bufo</i> Ridl.	7	MY	UA	NA to Malaya	UK	IM
39. <i>A. bulbifer</i> (Roxb.) Blume	161	IN, US, CN, TH, BE, FR, NP, BT, ID	UA	NA to IN, CN, BD, IN, MM, NP	UK	IM, NT, PA,
40. <i>A. calabicus</i> N.E.Br.	34	CM, NG, BJ, CD, GA, UG	UA	NA to NG, CM, KE, UG, CP	UK	AT
41. <i>A. calcicola</i> Tamayo, M.N., Magtoto, Liezel, L.M., Sumalino, M. JR., Reyes, T.D. Jr., Austria, C.M.	NR	PH	CR	EC in PH	Forest/limestone	IM
42. <i>A. canaliculatus</i> Ittenb., Hett. & Labin	6	GA	UA	NA to GA	UK	AT
43. <i>A. candidissimus</i> X.Gong & H.Li	0	VN	NR	NA to VN	UK	IM
44. <i>A. carneus</i> Ridl.	9	MY, TH	UA	NA to MY, TH	Limestone	IM
45. <i>A. carnosus</i> Engl.	9	VN	UA	NA to VN	UK	IM
46. <i>A. caudatus</i> Bustamante, R.A.A., Mansibang, J.A., Hetterscheid, W.L.A., Tamayo, M.N.	NR	PH	CR	EC in PH	Low land forest	IM
47. <i>A. chlorospathus</i> Kurz ex Hook.f.	3	IN, MM	UA	NA to IN, MM	UK	IM
48. <i>A. cicatricifer</i> Hett.	6	TH	UA	EC in Kanchanaburi	Evergreen forest	IM
49. <i>A. cidariooides</i> J.R.Callado, Medecilo & Hett.	NR	PH	NR	EC in PH	Watery areas	IM
50. <i>A. cirrifer</i> Stapf.	9	TH	UA	EC in TH	Deciduous forest/open forest	IM
51. <i>A. claudelii</i> A.Galloway & Ongsakul	1	FR	UA	NA to LA	UK	PA
52. <i>A. coaetaneus</i> S.V.Liu & S.J.Wei	18	VN, FR, CN, US	UA	NA to CN, VN	Forest valley	IM, PA, NT
53. <i>A. commutatus</i> (Schott) Engl.	56	IN	UA	NA to IN	UK	IM
54. <i>A. consimilis</i> Blume	80	SN, GM, BJ, ML, FR, GW, BE	UA	NA to GM, SN	Low land	AT, PA
55. <i>A. corrugatus</i> N.E.Br.	43	TH, US, VN	UA	NA to CN, MM, TH	Primary forest/evergreen forest	IM, NT
56. <i>A. costatus</i> Hett.	5	MY, ID	UA	NA to Borneo	UK	IM
57. <i>A. coudercii</i> (Bogner) Bogner	5	KH, VN	UA	NA to KH	UK	IM
58. <i>A. crinitus</i> A.Galloway, Luu, Malkm.-Huss., Prehsler & Claudel	0	VN	NR	NA to VN	UK	IM
59. <i>A. crispifolius</i> A.Galloway, Ongsakul & Petra Schmidt	0	LA	NR	NA to LA	UK	IM
60. <i>A. croatii</i> Hett. & Galloway	2	LA	UA	NA to LA	UK	IM
61. <i>A. cruddasianus</i> Prain	5	MM, TH, US	UA	NA to MM, TH, LA	UK	IM, NT
62. <i>A. curvistylis</i> Hett.	7	TH	VU	EC in Kanchanaburi	Limestone/deciduous forests	IM
63. <i>A. declinatus</i> Hett.	7	PH	UA	EC in PH	UK	IM
64. <i>A. decus-silvae</i> Backer & Alderw.	27	ID, US	UA	NA to Jawa	UK	IM, NT
65. <i>A. discophorus</i> Backer & Alderw.	5	ID	UA	NA to Jawa	UK	IM
66. <i>A. dracontiooides</i> (Engl.) N.E.Br.	372	BJ, TG, CI, BF, GH, NG, GN	UA	NA to NG, BF, CF, GM, GH, CI, NE, TG	Dry savannah	AT
67. <i>A. dunnii</i> Tucher	52	CN, HK, BE, DE, FR, US	UA	NA to CN	UK	IM, PA, NT
68. <i>A. dzui</i> Hett.	6	VN	UA	NA to VN	UK	IM
69. <i>A. eburneus</i> Bogner	23	MY	UA	EC in Padawan (Kuching Div.) and Tebedu (Samarahan Div.).	Lowland forest/limestone	IM
70. <i>A. echinatus</i> Bogner & Mayo	3	TH, LA	DD	EC in Kanchanaburi	Dense, moist forest	IM
71. <i>A. eichleri</i> (Engl.) Hook.f.	24	BE, FR, CD, CF, BR, CM	UA	NA to CD	Primary rain forest	PA, AT, NE

Species	Number of occurrences	Country	IUCN Red List status	Status of distribution	Ecological habitat	Biogeographic region
72. <i>A. elatus</i> Hook.f.	9	TH, FR, MY	UA	NA to MY, TH	Evergreen forest/ deciduous forest	IM, PA
73. <i>A. elegans</i> Ridl.	5	MY, TH	UA	NA to MY, TH	Evergreen forest/ limestone	IM
74. <i>A. elliottii</i> Hook.f.	12	SL, TH	UA	NA to SL	Forest between low grass	AT, IM
75. <i>A. erythrorrhachis</i> Hett., Pronk & R.Kaufmann	3	MG	UA	NA to MG	UK	AT
76. <i>A. excentricus</i> Hett.	8	TH, US	UA	NA to MY, TH	Evergreen forest	IM, NT
77. <i>A. fallax</i> (Serebryany) Hett. & Claudel	6	VN, LA	UA	NA to VN	UK	IM
78. <i>A. ferruginosus</i> A.Galloway	0	LA	NR	NA to LA	UK	IM
79. <i>A. flammeus</i> M.A.Calaramo, M.A.R. Batuyong, N.F.Bulawin, G.J.D.Alejandro	NR	PH	VU	EC to PH	Limestone forest thickets with loamy substrate	IM
80. <i>A. flotoi</i> (S.Y.Hu) Govaerts	67	TH, US, LA, FR, KH	UA	NA to KH, VN, LA, TH	UK	IM, NT, PA
81. <i>A. fontarumii</i> N.F.Bulawin, M.M.Medecilo-Guiang, G.J.D.Alejandro	NR	PH	CR	EC to PH	Limestone	IM
82. <i>A. forbesii</i> (Engl.) Engl. & Gehrm.	1	ID	UA	NA to Sumatra	UK	IM
83. <i>A. fornicatus</i> Hett., J.R.Collado & Wistuba	NR	PH	NR	EC to PH	Secondary forest	IM
84. <i>A. fuscus</i> Hett.	5	TH, BE	UA	NA to TH	Limestone	IM, PA
85. <i>A. galbra</i> F.M.Bailey	332	AU, PG, ID, US	UA	NA to PG, AU,	UK	AS, IM, NT
86. <i>A. gallaensis</i> (Engl.) N.E.Br.	14	KE, SO, IT, ET	UA	NA to KE, SO, ET	Dry Savannah/ open woodland	AT, PA
87. <i>A. gallowayi</i> Hett.	4	FR, LA, VN	UA	NA to LA	UK	IM, PA
88. <i>A. gigas</i> Teijsm. & Binn.	39	ID, US	TD	NA to Sumatera	UK	IM, NT
89. <i>A. glaucophyllus</i> Hett. & Serebryany	0	TH	NR	EC in Kanchanaburi	UK	IM
90. <i>A. gliruroides</i> Engl.	1	TH	UA	NA to MM	UK	IM
91. <i>A. glossophyllus</i> Hett.	9	VN, FR	UA	NA to VN	UK	IM, PA
92. <i>A. goetzei</i> (Engl.) N.E.Br.	20	TZ, MW, MZ, CD	UA	NA to MZ, TZ, CD	Evergreen forest/ River valleys	AT
93. <i>A. gomboczianus</i> Pic. Serm.	24	ET, ZM	UA	NA to ET	Savannah/ open woodland/ forest margin/proximity of river	AT
94. <i>A. gracilior</i> Hutch.	3	NG, BJ	UA	EC in BJ, NG	Primary rain forest/swamps	AT
95. <i>A. gracilis</i> Engl.	2	ID	UA	NA to Sumatera	UK	IM
96. <i>A. haematospadix</i> Hook.f.	20	MY, FR, TH, US	UA	NA to MY, TH	Limestone	IM, PA, NT
97. <i>A. harmandii</i> Engl. & Gehrm	45	TH, KH, LA	UA	NA to KH, LA, TH, VN	Deciduous forest/ under bamboo	IM
98. <i>A. hayi</i> Hett.	1	VN	DD	NA to VN, CN	Secondary forest	IM
99. <i>A. hemicyptus</i> Hett. & J.F.Maxwell	0	KH	NR	NA to KH	Deciduous forest/ Hardwood forest/	IM
100. <i>A. henryi</i> N.E.Br.	172	TH, CN, AR, BE, US	UA	NA to TH	Limestone/mixed forest/bamboo plantation	IM, PA, NE, NT
101. <i>A. hetterscheidii</i> Ittenb. & Lobin	3	CD, CF	UA	NA to CF, GA, CD	UK	AT
102. <i>A. hewittii</i> Alderw.	66	MY, ID	UA	NA to Borneo	UK	IM
103. <i>A. hildebrandtii</i> (Engl.) Engl. & Gehrm	104	MG	LC	NA to MG	UK	AT
104. <i>A. hirsutus</i> Teijsm. & Binn.	9	ID, IN, FR	UA	NA to Sumatera	UK	IM, PA
105. <i>A. hirtus</i> N.E.Br.	73	TH, CN, JP	UA	NA to TH	Dense grassland	IM, PA
106. <i>A. hohenackeri</i> (Schott) Engl. & Gehrm.	30	IN	UA	NA to IN	UK	IM
107. <i>A. hottae</i> Bogner & Hett.	12	MY	UA	NA to Borneo	UK	IM

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108. <i>A. impressus</i> Ittenb.	10	MW, TZ BE	UA	NA to MW, TZ	UK	AT, PA
109. <i>A. incurvatus</i> Alderw.	0	ID	NR	NA to Sumatera	UK	IM
110. <i>A. infundibuliformis</i> Hett., A.Dearden & A.Vogel	10	MY	UA	NA to Borneo	Lowland/ dipterocarp	IM
111. <i>A. interruptus</i> Engl. & Gehrm.	39	VN	CR	NA to VN	UK	IM
112. <i>A. johnsonii</i> N.E.Br.	210	GH, CI, BF, BN, ML, NG, LR, TG, GN, CM	UA	NA to NG, BF, GH, PG, CI, LR, ML	Savannah	AT, IM
113. <i>A. josefbogneri</i> Hett.	1	TH	UA	EC in South Western Thailand: Kanchanaburi	UK	IM
114. <i>A. julaihii</i> Ipor, Tawan & P.C.Boyce	3	MY	UA	NA to Borneo	UK	IM
115. <i>A. juliae</i> P.C.Boyce & Hett.	0	MY	NR	EC to Sarawak	UK	IM
116. <i>A. kachinensis</i> Engl. Gehrm.	22	CN, MM, TH, LA	UA	NA to CN, LA, MM, TH	Limestone	PA, IM
117. <i>A. khammouanensis</i> A.Galloway	0	LA	NR	NA to LA	UK	IM
118. <i>A. kienluongensis</i> V.D.Nguyen, Luu & Hett.	0	VN	VU	NA to VN	UK	IM
119. <i>A. kiusianus</i> (Makino) Makino	130	JP, CN, HK, US, BE, KR	VU	NA to CN, JP, TW	UK	PA, IM, NT
120. <i>A. konjac</i> K. Koch	348	CN, US, JP, MX, PH, NO, KR, FR, AT	UA	NA to CN	Forest margin/ secondary forest	PA, NT, NE, IM
121. <i>A. konkanensis</i> Hett., S.R.Yadav & K.S.Patil	7	IN	UA	NA to IN	UK	IM
122. <i>A. koratensis</i> Gagnep	18	LA, TH, KH	UA	NA to KH, LA, TH	Deciduous/ dipterocarp forest	IM
123. <i>A. krausei</i> Engl.	93	TH, MM, FR, LA	UA	NA to BD, CN, LA, MM, TH	Deciduous/ depterocarp forest/ Evergreen forest	IM, PA
124. <i>A. kuznetsovii</i> (Serebryanyi) Hett. & Claudel	1	VN	UA	NA to VN	UK	IM
125. <i>A. lacourii</i> Linden & André	120	TH, VN, FR, US, KH, LA, AU, BE	UA	NA to KH, LA, TH, VN	UK	IM, PA, NT, AS
126. <i>A. lambii</i> Mayo & Widjaja	27	MY, FR, IN, BE, TH	UA	NA to Borneo	UK	IM, PA
127. <i>A. lanceolatus</i> (Serebryanyi) Hett. & Claudel	2	VN	UA	NA to VN	UK	IM
128. <i>A. lanuginosus</i> Hett.	3	VN	CR	NA to VN	UK	IM
129. <i>A. laoticus</i> Hett.	9	LA	UA	NA to LA	Evergreen/ deciduous forest	IM
130. <i>A. lewallei</i> Malaisse & Bamps	11	BI, VE	CR	EC in Burundi	Savannah	AT, NE
131. <i>A. linearis</i> Gagnep	12	TH	UA	EC in TH	Evergreen/ deciduous/ dipterocarp forest/ bamboo forest	IM
132. <i>A. linguiformis</i> Hett.	3	ID	UA	NA to Borneo	UK	IM
133. <i>A. longicomus</i> Hett. & Serebryanyi	1	VN	UA	NA to VN	UK	IM
134. <i>A. longiconnectivus</i> Bogner	8	IN	UA	NA to IN	UK	IM
135. <i>A. longispathaceus</i> Engl. & Gehrm	3	PH	UA	EC in PH	UK	IM
136. <i>A. longistylus</i> Kurz ex Hook.f.	2	IN	UA	NA to Andaman Is.	UK	IM
137. <i>A. longituberous</i> (Engl.) Engl. & Gehrm	52	TH, MY, FR, BE	UA	NA to BD, TH, MY	Evergreen/ Deciduous/ Dipterocarp forests	IM, PA
138. <i>A. lunatus</i> Hett. & Sizemore	2	TH	UA	EC in TH	Secondary forest	IM
139. <i>A. luzoniensis</i> Merr.	6	PH	UA	EC in PH	UK	IM
140. <i>A. lyratus</i> (Roxb.) Kunth	0	IN	NR	NA to IN	UK	IM
141. <i>A. macrophyllus</i> (Gagnep. Ex Serebryanyi) Hett. & Claudel	7	TH, FR, VN	UA	NA to TH VN	UK	IM, PA

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142. <i>A. macrorhizus</i> Craib	58	TH, CN	UA	EC in TH	Deciduous/Dipterocarp forests	IM, PA
143. <i>A. malkmus-husseinii</i> A.Galloway, Prehsler & Claudel	0	LA	NR	NA to LA	UK	IM
144. <i>A. mangelsdorffii</i> Bogner	8	MG, BE	UA	NA to MG	UK	AT, PA
145. <i>A. manta</i> Hett. & Ittenbach	3	ID	UA	NA to Malaya and Sumatera	UK	IM
146. <i>A. margaritifer</i> (Roxb.) Kunth	24	IN	UA	NA to IN, BD, MM	UK	IM
147. <i>A. margretae</i> Ittenb.	1	CD	UA	NA to CD	UK	AT
148. <i>A. maximus</i> (Engl.) N.E.Br.	41	TZ, SO, KE, MZ, ZW, BE, CM, MW	UA	NA to KE, MZ, SO, TZ, ZW	UK	AT, PA
149. <i>A. maxwellii</i> Hett.	11	TH, BE	UA	EC in Kanchanaburi	Deciduous forest/limestone	IM, PA
150. <i>A. mekongensis</i> Engl. & Gehrm.	6	LA, VN	UA	NA to LA, VN	UK	IM
151. <i>A. merrillii</i> K.Krause	3	PH	UA	EC in PH	UK	IM
152. <i>A. mildbraedii</i> K.Krause	5	CM	UA	NA to CM	UK	AT
153. <i>A. minimus</i> Bustamante, R.A.A., Claudel, C., Altomonte, J.C.A., Udasco, L.C. Jr., Tamayo, M.N.	NR	PH	CR	EC in PH	Montane / dipterocarp/secondary forests	IM
154. <i>A. minor</i> Ridl.	2	MY	UA	NA to MY	UK	IM
155. <i>A. mossambicensis</i> (Schott ex Garcke) N.E.Br.	10	ZM, TZ, MZ, CD, US, ZW	UA	NA to MZ, TZ, ZM, CD, ZW	Savannah	AT, NT
156. <i>A. muelleri</i> Blume	106	TH, ID, IN, MM, MY, FR, US, TL	UA	NA to IN, TH, ID, MY, BN, MM	Secondary forests	IM, PA, NT
157. <i>A. mullendersii</i> Malaisse & Bamps	5	CD	UA	NA to AO, CD	Savannah/ Gallery forests	AT
158. <i>A. myosuroides</i> Hett. & A.Galloway	4	LA, BE, FR	UA	NA to LA	UK	IM, PA
159. <i>A. mysorensis</i> E.Barnes & C.E.C. Fisch.	11	IN	UA	NA to IN	UK	IM
160. <i>A. napalensis</i> (Wall.) Bogner & Mayo	49	IN, NP, TH, BT, BD, BE, US	UA	NA to IN BD, NP	UK	IM, PA, NT
161. <i>A. napiger</i> Gagnep.	15	TH, LA	UA	NA to KH, LA, TH, VN	Deciduous forests	IM
162. <i>A. natolii</i> Hett., Wistuba, V.B.Amoroso, Medecilo & Claudel	NR	PH	CR	EC in PH	Limestone	IM
163. <i>A. niahensis</i> P. C. Boyce & Hett.	4	MY	UA	NA to Borneo	Limestone/shady area	IM
164. <i>A. nicolaii</i> Hett.	0	VN	NR	NA to VN	UK	IM
165. <i>A. nicolsonianus</i> Sivadasan	11	IN	UA	NA to IN	UK	IM
166. <i>A. obovoideus</i> Alderw.	0	ID	NR	NA to Sumatera	UK	IM
167. <i>A. obscurus</i> Hett. & Sizemore	4	TH	UA	EC in Ubon Ratchathani	UK	IM
168. <i>A. ochroleucus</i> Hett. & V.D.Nguyen	8	FR, VN	NT	NA to VN	UK	PA, IM
169. <i>A. oncophyllum</i> Prain ex Hook.f.	0	CN	NR	NA to Andaman Is.	UK	PA
170. <i>A. ongsakulii</i> Hett. & A.Galloway	6	LA, FR, BE	UA	NA to LA	UK	IM, PA
171. <i>A. operculatus</i> Hett. & Sizemore	8	FR, TH	UA	EC in Chumphon	UK	PA, IM
172. <i>A. operatus</i> Hett.	1	VN	UA	NA to VN	UK	IM
173. <i>A. paeoniifolius</i> (Dennst.) Nicolson	919	AU,IN, ID, PH, TH, PF, PG, YT, CN	LC/UA	NA to IN, BD, MY, ID, CN, LA, KH, MM, PH	Secondary forest/shady places	AS, IM, AT, PA
174. <i>A. palawanensis</i> Bogner & Hett.	21	PH	CR	EC to PH	Rich soil with added loam	IM
175. <i>A. paucisectus</i> Alderw.	2	ID	UA	NA to Sumatera	UK	IM
176. <i>A. pendulus</i> Bogner & Mayo	18	MY, ID	UA	NA to Borneo	UK	IM
177. <i>A. perakensis</i> Engl.	2	MY	UA	NA to Malaya	UK	IM
178. <i>A. perrieri</i> Hett. & Wahlert	16	MG, US	UA	NA to MG	Semi-deciduous forest	AT, NT

Species	Number of occurrences	Country	IUCN Red List status	Status of distribution	Ecological habitat	Biogeographic region
179. <i>A. pilosus</i> Hett.	6	VN	UA	NA to VN	UK	IM
180. <i>A. plicatus</i> Bok & H.J.Lam	3	ID	UA	NA to Sulawesi	UK	IM
181. <i>A. polyanthus</i> Hett. & Sizemore	6	TH, US	UA	NA to TH	Deep shade, near base of rocky outcrop	IM, NT
182. <i>A. prainii</i> Hook. f.	53	MY, TH, US, ID, BE, IN	UA	NA to LA, MY, TH, Sumatera	Evergreen forest/Limestone	IM, NT, PA
183. <i>A. preussii</i> (Engl.) N.E.Br.	30	CM	VU	EC in CM	Primary shady forests	AT
184. <i>A. prolificus</i> Hett. & Galloway	3	TH	UA	EC in Central TH	UK	IM
185. <i>A. pulchellus</i> Hett. & Schuit	0	LA	NR	NA to Laos	Limestone	IM
186. <i>A. purpurascens</i> Kurz ex Hook.f.	8	MM	UA	NA to MM	UK	IM
187. <i>A. pusillus</i> Hett. & Serebryanyi	6	VN	UA	NA to VN	UK	IM
188. <i>A. putii</i> Gagnep	17	TH, MM, US	UA	NA to MM, TH	Evergreen forests/Shaded places	IM, NT
189. <i>A. pygmaeus</i> Hett.	13	TH, US	UA	EC in Prachuap Khiri Khan	Limestone	IM, NT
190. <i>A. rchanensis</i> Ipor, A.Simon & Meekiong	4	MY	UA	NA to Borneo	UK	IM
191. <i>A. ravenii</i> V.D.Nguyen & Hett.	0	LA	NR	NA to LA	UK	IM
192. <i>A. rayongii</i> Hett. & Medecilo	NR	PH	NR	EC in PH	Near the beach	IM
193. <i>A. reflexus</i> Hett. & A.Galloway	3	TH	UA	EC in Khampaeng Phet.	Limestone	IM
194. <i>A. rhizomatous</i> Hett.	8	LA, GQ, GA, GN, NG	UA	NA to LA, VN	UK	IM, AT
195. <i>A. richardsiae</i> Ittenb.	4	ZM	UA	NA to ZM	UK	AT
196. <i>A. rostratus</i> Hett.	1	PH	UA	EC to PH	Secondary forest	IM
197. <i>A. rugosus</i> Hett. & A.L. Lamb	0	MY	NR	NA to Borneo	UK	IM
198. <i>A. sagittarius</i> Steenis	3	ID	UA	NA to Jawa	UK	IM
199. <i>A. salmoneus</i> Hett.	5	PH	UA	EC in PH	Limestone	IM
200. <i>A. saraburensis</i> Gagnep	1	TH	UA	EC in Saraburi	Monsoonal savannah	IM
201. <i>A. saurus</i> Hett.	5	FR, TH, US	UA	EC in N. E. TH Loei	UK	PA, IM, NT
202. <i>A. scaber</i> Serebryanyi & Hett.	6	VN, LA	UA	NA to VN	UK	IM
203. <i>A. schmidiae</i> Hett. & A.Galloway	1	LA	UA	NA to LA	UK	IM
204. <i>A. scutatus</i> Hett. & T.C. Chapm.	4	TH	UA	EC in Phetchabun	UK	IM
205. <i>A. serrulatus</i> Hett. & A.Galloway	1	TH	UA	EC in Northern Thailand	UK	IM
206. <i>A. shamsalilianus</i> J.V.Gadpay., Somkuwar & A.A.Chaturv.	0	IN	NR	NA in IN	UK	IM
207. <i>A. sinuatus</i> Hett. & V.D.Nguyen	2	FR, VN	UA	NA to VN	UK	PA, IM
208. <i>A. sizemoreae</i> Hett.	3	TH, US	UA	EC in Nakhon Sawan	UK	IM, NT
209. <i>A. smithsonianus</i> Sivadasan	11	IN	UA	NA to IN	UK	IM
210. <i>A. sparsiflorus</i> Hook.f.	3	MY	UA	NA to Malaya	UK	IM
211. <i>A. spectabilis</i> (Miq.) Engl.	11	ID	UA	NA to Jawa	UK	IM
212. <i>A. staudtii</i> (Engl.) N.E.Br.	23	CM, CI	UA	NA to CM, CD	Primary rainforest/shaded rich soils	AT
213. <i>A. stuhlmannii</i> (Engl.) Engl. & Gehrm	46	TZ, CD, KE	UA	NA to KE, TL, CD	UK	AT
214. <i>A. subcymbiformis</i> Alderw.	1	ID	UA	NA to Sumatera	UK	IM
215. <i>A. sumawongii</i> (Bogner) Bogner & Mayo	25	TH, FR, BE, US	UA	EC in Sa Ksaeo, Wathana Nakhon	Dry dipterocarp forest	IM, PA, NT
216. <i>A. suwidjianus</i> Ipor, Tawan & Meekiong	0	ID	NR	NA to Borneo	UK	IM
217. <i>A. sylvaticus</i> (Roxb.) Kunth	31	IN, LK	UA	NA to IN, LK	UK	IM

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218. <i>A. symonianus</i> Hett. & Sizemore	14	FR, TH	UA	EC in Loei, Udon Thani	Limestone/medium shade	PA, IM
219. <i>A. synandrifer</i> Hett. & V.D.Nguyen	1	VN	CR	NA to VN	UK	IM
220. <i>A. taurostigma</i> Ittenb., Hett. & Bogner	43	MG, BE	VU	EC in MG	Shady humus pockets	AT, PA
221. <i>A. tenuispadix</i> Hett.	9	TH, FR, US	UA	EC in south western & Peninsular TH	Rocks at the foot of the hill	IM, PA, NT
222. <i>A. tenuistyliis</i> Hett.	12	TH, US	UA	NA to KH, TH	Open mixed bamboo & deciduous forests/limestone	IM, NT
223. <i>A. terrestris</i> Hett & Claudel	0	TH	NR	NA to TH	UK	IM
224. <i>A. teuszii</i> (Engl.) Motte	11	CD, AO, LK	UA	NA to AO, CD	UK	AT, IM
225. <i>A. thaiensis</i> (S.Y.Hu) Hett.	18	FR, TH, US	UA	EC in Mae Hong Son	UK	PA, IM, NT
226. <i>A. tinekeae</i> Hett. & A.Vogel	5	MY	UA	NA to Borneo	UK	IM
227. <i>A. titanum</i> (Becc.) Becc.	223	AU, ID, US, BE, CA, SE	EN	NA to Sumatera	UK	AS, IM, NT, PA
228. <i>A. tonkinensis</i> Engl. & Gehrm	22	VN, LA	UA	NA to CN, VN	Dense tropical forests, moist, shaded places	IM
229. <i>A. tuberculatus</i> Hett. & V.D.Nguyen	7	BI	UA	NA to VN	UK	AT
230. <i>A. umbrinus</i> A.Galloway, Luu, Malkm. Huss., Prehsler & Claudel	2	VN	UA	NA to VN	UK	IM
231. <i>A. urceolatus</i> Hett., A.Galloway & Medecilo	NR	PH	NR	EC in PH	Secondary forest/exposed places	IM
232. <i>A. variabilis</i> Blume	174	ID, CN, BE, US	UA	NA to Jawa, Sunda	UK	IM, PA, NT
233. <i>A. venustus</i> Hett., A.Hay & Mood	0	MY	NR	NA to Borneo	UK	IM
234. <i>A. verticillatus</i> Hett.	10	VN, FR, BE, US	VU	NA to VN	UK	IM, PA, NT
235. <i>A. villosus</i> A.Galloway, Luu, Malkm.-Huss., Prehsler & Claudel	0	VN	NR	NA to VN	UK	IM
236. <i>A. vogelianus</i> Hett. & Billensteiner	2	FR	UA	EC to TH Chiang Mai	UK	PA
237. <i>A. xiei</i> H.Li & Z.L.Dao	4	CN	UA	NA to CN South Central	Forest margins/tropical thickets	PA
238. <i>A. yaoi</i> A. Galloway, Hett., & Medecilo	NR	PH	NR	EC in PH	Hilly shaded areas	IM
239. <i>A. yulouensis</i> H.Li	10	CN, FR, TH	UA	NA to CN, IN, MM	Dense primary evergreen valley forests/limestone	PA, IM
240. <i>A. yunnanensis</i> Engl.	111	TH, CN, US, VN, BE, LA, MM	UA	NA to CN, LA, TH, VN	Primary evergreen/Deciduous/secondary forest/forest Margin	IM, PA, NT
241. <i>A. zenkeri</i> (Engl.) N.E.Br.	28	CM	UA	EC in Guineo-Congolese region: Fernando Po	UK	AT

Occurrences: NR—no record | 0—no specimens encountered | Country names ISO 3166-1 alpha – 2 codes | IUCN status: UA—Unassessed | DD—Data Deficient | LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered | CR—Critically Endangered | NR—No Record) | Status of distribution: EC—Endemic | NA—Native | Ecological habitat: UK—Unknown | Biogeographic region: NE—Neotropic | NT—Nearctic | AT—Afrotropic | PA—Palearctic | AS—Australasia | IM—Indo-Malay. (Olson et al. 2001).

Thailand is the most species-rich country because of its suitable environment for its growth, which has tropical, and subtropical climates (Figure 2) (Sivilla & Santos 2021). Species richness of plants is greater in the herbaceous forest area compared to other forest zones (Mbuni et al. 2019).

Based on the record of the United Nations, over a

million species globally are at risk of extinction, and it was a discouraging report (Dapar et al. 2020). As a result of the climate crisis and anthropogenic activities, there is a consistently declining plant biodiversity (Onyancha et al. 2020; Pasta et al. 2020; Calaramo et al. 2022). IUCN Red List Criteria could assess the extinction risk (Yudaputra et al. 2022). It could figure out the

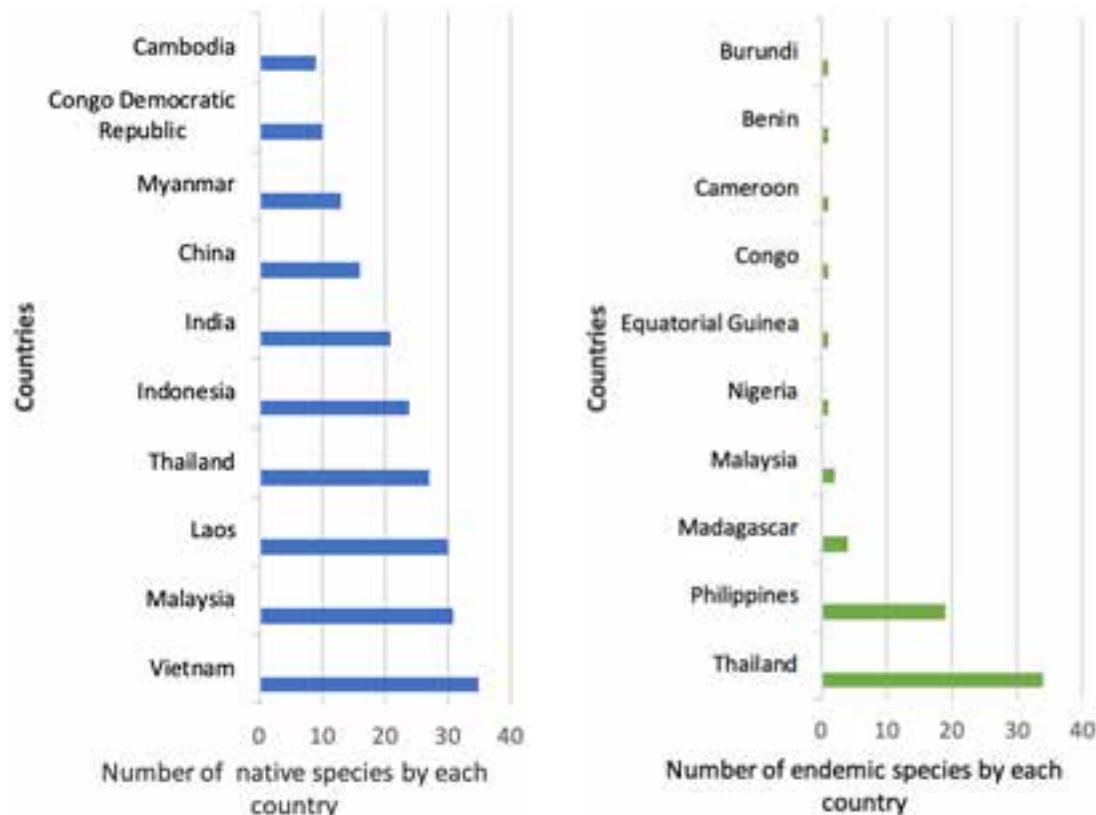


Figure 6. Number of native and endemic species of *Amorphophallus* by country.

danger rate for particular species globally (Brummitt et al. 2015). According to digital databases, 76.35% of *Amorphophallus* species were not evaluated for conservation status, and 13.70% have no record (Figure 4). Around 4.15% of *Amorphophallus* species globally were 'Critically Endangered', 2.90% 'Vulnerable', 0.83% Endangered, 0.83% 'Near Threatened', 0.83% 'Least Concern', and 0.83% 'Data Deficient'. IUCN admitted that the report's scope for assessing threatened plants might be inadequate (Brummitt et al. 2015).

Vietnam had the highest number of native *Amorphophallus* species, while Thailand had the highest number of endemic species, based on digital databases (Figure 6). The natural habitat of Vietnam sustained the diverse vegetation and higher biodiversity (Hung & Potokin 2019), which resulted in more native species surviving in the country. However, endemism is applied to species with a small population size with a very limited ecological distribution (Yudaputra et al. 2022). With the distinct habitat for diversity and bioresources of the species manifested by Thailand (Sungkajantranon et al. 2018) higher number of endemic *Amorphophallus* species were able to survive and grow in the country. Endemic species in a particular area can adapt more

readily and thrive in diverse environmental conditions (Wulandari et al. 2022).

Some *Amorphophallus* species are adapted in a partly shaded area, secondary forest, and grassland (Mc Pherson & Hetterscheid 2011). A few species grow in limestone or karst forest ecosystem (Figure 8) based on digital databases, with 9.76% because some of the *Amorphophallus* species have a shallow root that is susceptible to drought (Misra et al. 2010). *Amorphophallus* needs soil that allows water to drain moderately. For the plant to grow better, appropriate soil nutrients, and proper draining of water in the soil are required (Yuzammi et al. 2018). Also, limestone contains fragments of elements that can enhance soil quality. Because of this, most of the time, *Amorphophallus* species are found in limestone and granite soil (Nguyen et al. 2016).

According to digital databases, *Amorphophallus* species are mostly distributed in the Indo-Malay biogeography region (Figure 9) with 56.65% because 70% of various species of *Amorphophallus* can be found in southeastern Asia (Claudel et al. 2019), which is under Indo-Malay biogeography. The center of distribution of *Amorphophallus* is Thailand because, based on the

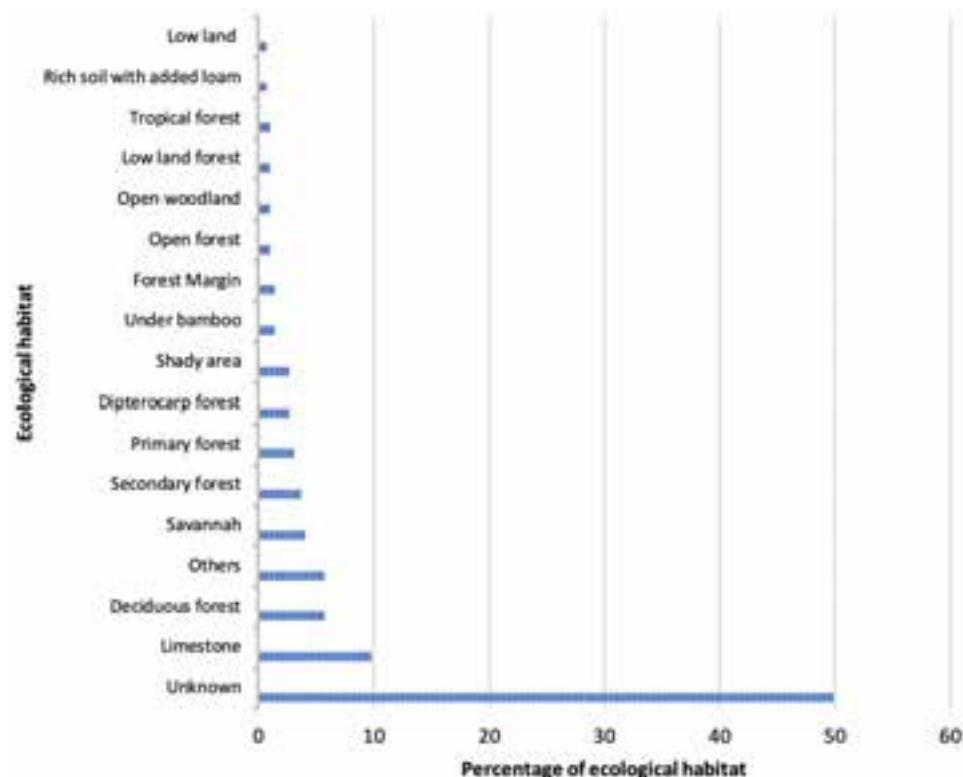


Figure 7. Percentage of each ecological habitat of *Amorphophallus* species.

record of digital databases, Thailand is the most species-rich country due to its ecological status suited for the diversity and bioresources of *Amorphophallus* species.

CONCLUSIONS AND RECOMMENDATIONS

The world checklist of *Amorphophallus* species revealed the current number of accepted species worldwide, their distribution status, ecological habitats, and conservation status. Out of 241 species as of this writing, *A. paeoniifolius* has the most significant number of occurrences, and Thailand is the most species-rich country of *Amorphophallus*. Many *Amorphophallus* species have not been evaluated, which can hinder the accurate assessment of the conservation status of some species. This data needs to be revisited, and more species should be included in the list for further protection. The majority of *Amorphophallus* species were adapted to limestone habitats. Therefore, the limestone ecosystem is one of the areas that people should protect from excessive degradation direct or indirect anthropogenic activities. Moreover, the primary goal of the checklist is to provide a record of all the *Amorphophallus* species worldwide. Ecologists, biogeographers, and taxonomists

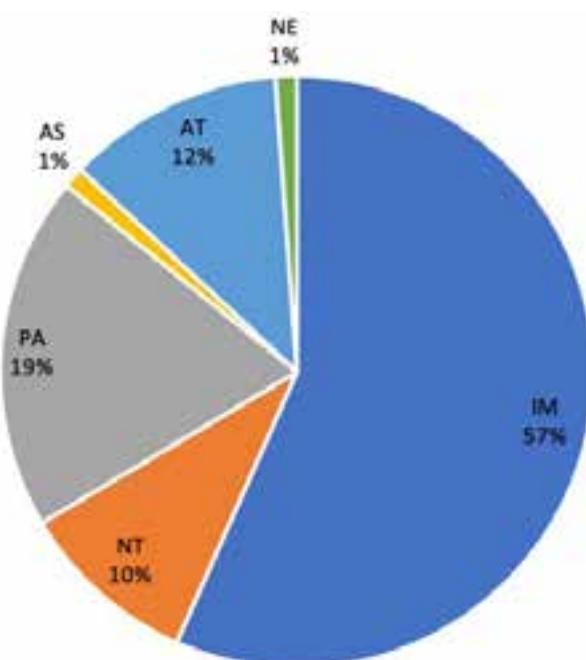


Figure 8. Percentage of *Amorphophallus* species by each geographic region: IM—Indo-Malay | NT—Nearctic | PA—Palaearctic | AS—Australasia | AT—Afrotropic | NE—Neotropic.

must review the digital databases of *Amorphophallus* species and update them to enhance their utility in gaining knowledge about species biodiversity, thereby filling the information gap and making biodiversity details more comprehensive and up-to-date.

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Embelia ribes Burm.f. (Primulaceae) – an ayurvedic plant with ethnobotanical notes from Manipur, India

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Abstract: *Embelia ribes* Burm.f. (Primulaceae) is well known for its medicinal properties in various systems of Indian medicine. The culinary applications of the leaves from Manipur could be the first recorded gastronomic use of the species in India. Future nutritional studies and conservation measures are of immense need to ensure the promotion and sustainable use of this species.

Keywords: Antibacterial, antifertility, antifungal, epipetalous, gastronomic, Langol reserve forest, medicinal value, northeastern India, panicle inflorescence, taxonomic description, wild edibles.

Embelia ribes Burm.f., a member of the family Primulaceae (formerly placed in Myrsinaceae) is recognized for its considerable medicinal properties within the Indian System of Medicines. The species was first described by Nicolaas Laurens Burman in 1768 (Burman 1768). It is distributed from India to southern China, and western & central Malesia (POWO 2025). In India, the plant has been known by various names such as 'Baobarang' or 'Barang' (Urdu), 'Vavding' (Marathi), 'Vidang' (Assamese & Bengali), 'Vayuvidangalu' (Telugu), or 'Vidanga' (Odiya) (Siddiqui & Uddin 2023). Ancient texts, including the Charaka Samhita, document its uses for alleviating abdominal discomfort, flatulence,

and skin ailments (Akbar 2020; Siddiqui & Uddin 2023). The plant is also widely used in treating mouth ulcers, sore throats, pneumonia, obesity, constipation, diarrhoea, kidney stones, snake bites, bronchitis, and promoting wound healing (Raskar et al. 2022). In Kerala, a decoction of the fruit is administered for intestinal worms (Udayan et al. 2008), while in Karnataka, it is used for antimicrobial purposes (Thyloor 2018). The fruit of the plant is also employed in wound healing and snakebite treatment in the Khandesh region of Maharashtra (Chopda & Mahajan 2009). The active compound embelin present in this species is noted for its antibacterial (Chitra et al. 2003), antifungal, analgesic, anti-inflammatory, antioxidant, antidiabetic, anticancer, anti-hyperlipidemic, antifertility, antiprotozoal effects, and anthelmintic antipyretic in different parts of India (Seshadri & Venkataraghavan 1981; Atal et al. 1984; Chitra et al. 1994). The pharmacological and clinical investigations also gave promising results about its antifertility activity without any side effects (Mitra 1995). The increasing demand for the species with indiscriminate large-scale extraction greatly threatens

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the natural population of the species in India (Pownitha et al. 2022).

The species is reported to be vulnerable in the Western Ghats of Tamil Nadu and Karnataka states of India and at lower risk in Kerala State (Ravikumar et al. 2000).

Prior research on *E. ribes* documented the ethnomedicinal and medicinal properties of the species from various states of the country, with no distributional record from Manipur state (Roy & Pramanik 2020; Pownitha et al. 2022). Agrawala et al. (2023) recorded this species distribution in Manipur, but the exact locality was not mentioned. During a recent ethnobotanical field expedition in Langol Reserve Forest area of Manipur, the team encountered three individuals of the plant in flowering and fruiting stages. After proper morpho-taxonomic investigation, the plant was identified as *E. ribes*. Details on taxonomic treatment, photographic illustration, and gastronomic uses of the species is provided here (see Image 1).

TAXONOMIC TREATMENT

Embelia ribes Burm.f., Fl. Ind. 62, t. 23. 1768; C.B.Clarke in Hook.f., Fl. Brit. India 3: 513. 1882; Kanjilal et al., Fl. Assam 3: 169. 1939; Prain, Bengal Pl. 1: 643. 1903; A.S.Chauhan in Hajra, Contrib. Fl. Namdapha 211. 1996; Chowdhery et al. in Giri et al., Fl. Arunachal Pradesh, 2: 119. 2008; Dash & Singh, Fl. Kurung Kumey 543. 2017; Mao et al., Checkl. Fl. Nagaland: 7. 2017; R.Roy & A.Pramanik in S.S.Dash & A.A.Mao, Flora. Pl. India Annot. Checkl. Dicot. 2: 52. 2020; Agrawala et al. in A.A.Mao & P.K.Mukherjee, Fl. Manipur Pict. Guide: 269. 2023. *Antidesma ribes* (Burm.f.) Raeusch. in Nomencl. Bot. Pl. Illustr., ed. 3: 287. 1797. *Embelia sessiliflora* (Burm.f.) Kurz, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 40: 66. 1871. *Samara ribes* (Burm.f.) Benth. & Hook.f. ex. Kurz, in J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 46: 222. 1877. *Ribesiodes ribes* (Burm.f.) Kuntze, Revis. Gen. Pl. 2: 403. 1891.

Description: Medium sized liana spreading 5 m long or even more. Stem woody, ridged, branchlets flexuous, not armed, rusty tomentose. Leaves simple, alternate; lamina elliptic or narrowly obovate, 5.5–6.5 × 2.8–3.5

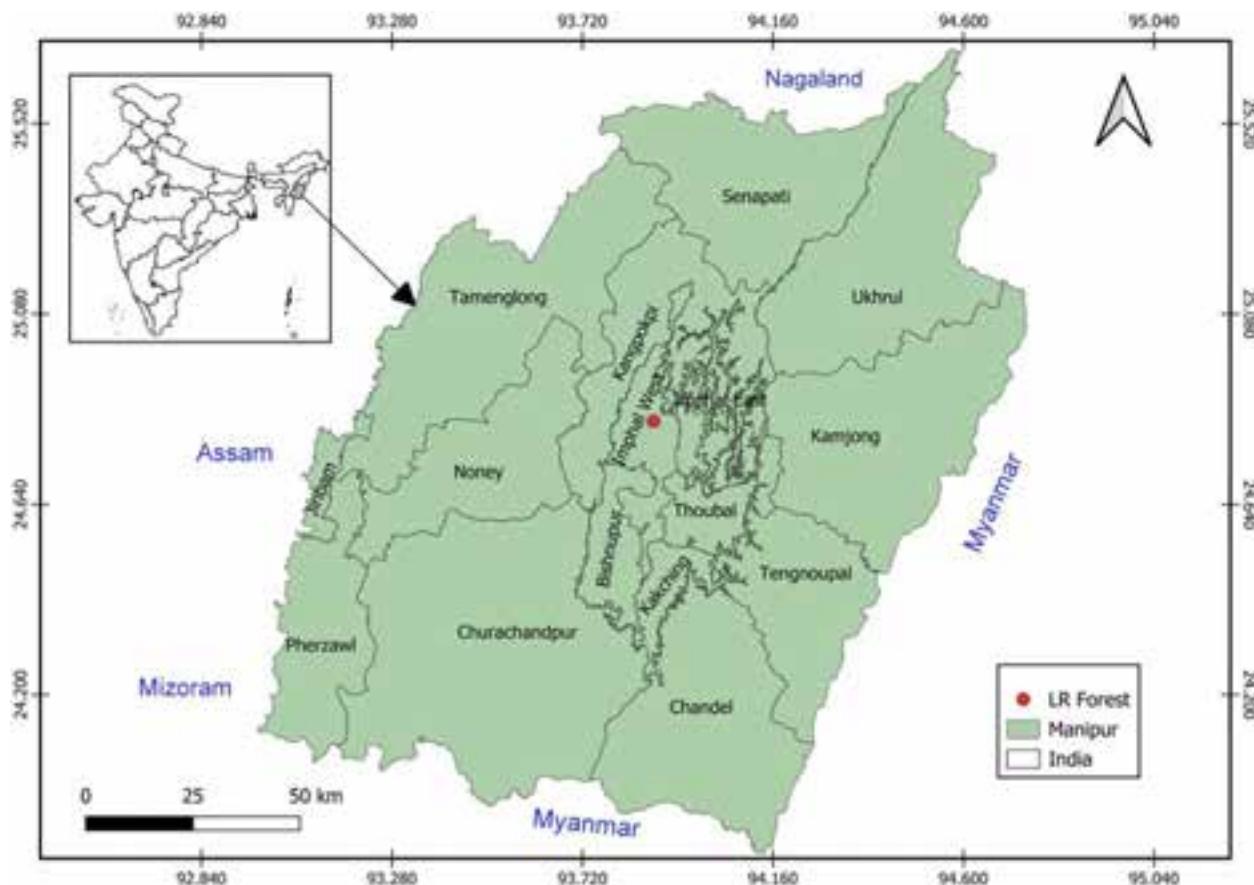


Figure 1. Study site showing distribution of *Embelia ribes* in Langol Reserve Forest, Manipur.



Image 1. *Embelia ribes*: A—Plant in natural habitat | B—Fruiting twig | C & D—Leaves Adaxial and Abaxial view | E—Twig with inflorescence | F—Flower | G & H—Stamens (5, epipetalous). © Robert Panmei.

cm, apex acuminate, base cuneate or rounded, margin entire, revolute, chartaceous to coriaceous, glabrous on both surfaces; petioles narrowly winged to base, 0.8–1 cm long. Inflorescences pinnately pyramidal panicles, terminal, rachis 12–20 cm, puberulent; bracts subulate, sparsely puberulent, black punctate-lineate. Flowers small, greenish-white, pedicels 0.2–0.25 cm long,

sparsely to densely puberulent. Sepals five, deltate, pellucid punctate, glandular ciliate adaxially and on margin, apex acuminate. Petals five, free, elliptic or oblong, chartaceous, punctate, densely glandular inside and along margin, apex acute to obtuse. Stamens five, slightly exserted, epipetalous, anthers ovate, connective black punctate. Ovary ovoid, glabrous, stigma capitate.

Fruits deep reddish, globose or ovoid, ca. 0.3–0.5 cm in diam., smooth.

Flowering & Fruiting: April–June.

Habitat: Growing along the road side in Langol Reserve Forest (24.831° N, 93.884° E), Elevation 817 m (Figure 1).

Specimen examined: Manipur, Imphal, Langol Reserved Forest, RP-98 (Manipur University), dated 27.iv.2024.

Distribution: India (Arunachal Pradesh, Assam, Goa, Karnataka, Kerala, Maharashtra, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim, and Tamil Nadu). Bangladesh, Cambodia, China, Indonesia, Laos, Malaysia, Myanmar, Sri Lanka, Sulawesi, Thailand, Tibet, and Vietnam.

Ethnobotanical notes: The species is locally known as 'Jubabungnui' or 'Jukuibungnui' by the Rongmei tribe of Manipur. The leaves are utilized as a vegetable, with mature leaves being favoured over younger ones. The mature leaves are generally cooked with Rice Bean *Vigna umbellata* (Thunb.) (Ohwi & Ohashi), taro or potato. It is believed that consuming these cooked leaves enhances overall vitality among the Rongmei tribe. Till date, there have been no documented culinary applications of this species in India. The study presents the first recorded gastronomic use of the species from the state of Manipur.

Future studies on nutritional value and conservation initiative by the competent authority could promote the usage and sustainable utilization of the species.

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First record of marine isopod *Synidotea variegata* (Collinge, 1917), (Crustacea: Isopoda: Valvifera) from the Gulf of Kutch, Gujarat, northwestern coast of India

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Abstract: *Synidotea variegata* (Collinge, 1917) is associated with the sea urchin *Stomopneustes variolaris* (Lamarck, 1816), where it is frequently found inhabiting the spaces among the spines, and around the peristomial region. Previously, this species was known only from the southwestern coast of India. This study reports the presence of the isopod *S. variegata* in the Gulf of Kutch, Gujarat, northwestern coast of India.

Keywords: Association, Crustaceans, Crustacean diversity, host infection, marine isopod, range extension, rocky inter tidal.

Valviferan isopods are characterised by a dorsoventrally flattened body and a slight but distinct differentiation of body segments, features that aid in their adaptation to benthic environments. These isopods are distributed circumglobally and are predominantly found in shallow coastal habitats rich in algae and seagrass. Their flattened morphology facilitates movement and concealment among dense vegetation, providing both camouflage from predators, and access to detrital and algal food sources (Poore 2012). Valviferan isopods typically have a body where two or fewer of the rear segments (pleonites) can move, while

the rest are fused. In some species, only up to four pleon segments are visible from the top, marked by partial or complete lines (sutures), though they do not move. The head is usually separate from the first body segment and is not expanded to the sides. Their mouthparts include a maxillipedal palp (a sensory and handling appendage) usually made up of five segments, though sometimes the last segments are fused. The first pair of walking legs (pereopods) is only slightly adapted for grasping, while the remaining legs (second to seventh) are all similar, and used for walking. In males, the reproductive organs (penes) are close together and may be free, partially fused at the base, or completely fused. Their tail limbs (uropods) have a free inner branch (endopod) but lack an outer branch (exopod). The bases of the swimming limbs (pleopods) are all about the same length, and the first pleopod in males is not modified. Females have flat, plate-like structures called oostegites on their front walking legs (either the first four or five pairs), which together form a brood pouch used to carry and protect their developing young (Collinge 1918; Poore & Ton 1993; Song & Min 2017).

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Gujarat State, from western India, covers approximately 2,340.62 km of coastline, i.e., up to 21% of the Indian coastline (TRW-MoPSW 2025). A wide range of maritime ecosystems, such as mangroves, coral reefs, rocky coasts, mudflats, sandy shorelines, and estuaries, have been found throughout Gujarat's coastline, adding to the state's abundant marine biodiversity. A number of researchers have attempted to explore the marine variety of this region (Apte 1998; Singh et al. 2004; Venkataraman 2004; Satyanarayana 2009; Dixit 2010). The diversity of corals and crustaceans in this region receives considerable attention. The state's and the nation's crustacean diversity has been the subject of noteworthy research (Pandya & Vachhrajani 2013; Trivedi et al. 2018; Beleem 2019). Nonetheless, nine species from the Gujarat coast have been identified to date (Trivedi et al. 2015; Valarmathi 2024), representing the diversity of isopods among different groups of crustaceans.

In the present study, *Synidotea variegata* (Collinge 1917) is reported for the first time from Gujarat State, India, and thus also making a new addition in the Gulf of Kutch.

MATERIALS AND METHODS

Live specimens of *Synidotea variegata* (Collinge, 1917) were collected during low tide from the northern Gulf of Kutch, along the Kutch coastline, using hand-picking. Following collection, the isopods were cleaned, photographed, and preserved in 70% ethanol for future research, following Ravinesh & Kumar (2022). Specimen identification was based on the diagnostic characters provided by Yesudas et al. (2021). The samples were deposited in the Zoological Reference Collection at the Zoology Department of R.R. Lalan College, Bhuj (RRLC-ZC).

RESULTS AND REMARKS

Family: Idoteidae Samouelle, 1819

Genus: *Synidotea* Harger, 1878

Type species: *Synidotea variegata* Collinge, 1917 (Image 1a-d)

Synidotea variegata Collinge, 1917 In Yesudas et al. 2021: 84, p. 107 fig. 1-c.

Material examined: 11.ii.2023, 1 Male, length 8.32 mm, max. breadth 3.39 mm rocky intertidal region of Kachchh coast (22.836° N & 69.225° E), near Mandvi, Gujarat, India, coll.. M. Goswami, D. Dudiya.

Diagnosis: Body oblong-ovate, dorsal surface is convex and almost smooth (Image 1). Animal colouration pale to golden yellow. Frontal margin straight, the

posterior region has a deep transverse furrow, and the cephalon wider than the length and narrows posteriorly. Perionites 2-4 are expanded; perionite 5-7 gradually narrow down. First joint of antennule broad, while the second and third are short, broad, and subequal (Image 1a,b,d). Pleotelson nearly 1.5 times as long as wide with narrow rounded apex. A short denticulate spine is found on the outer posterior margin of the uropod, which has nearly straight lateral sides except at the hinge (Image 1). The endopodite, on the other hand, has a straight inner margin and is cut away on the outer side. Uropods are armed with denticulate spine terminally. Rest of the characters agree with the descriptions given by earlier researchers (Collinge 1917; Yesudas et al. 2021).

Colouration: The species is mostly seen under rocks. The body is yellowish coloured, decorated by minute black pigments. The head region is somewhat depressed, circular, with the anterior area somewhat flat. Eyes are laterally placed and oval.

Remarks: This species demonstrates a close relationship to *Synidotea harfordi* Benedict, 1897 and *S.*



Image 1. *Synidotea variegata* (Collinge, 1917), male (RRLC-ZC-46): a—dorsal view | b—ventral view | C—pleotelson: plane and triangular | d—antennular flagellum. © RRLC-ZC.

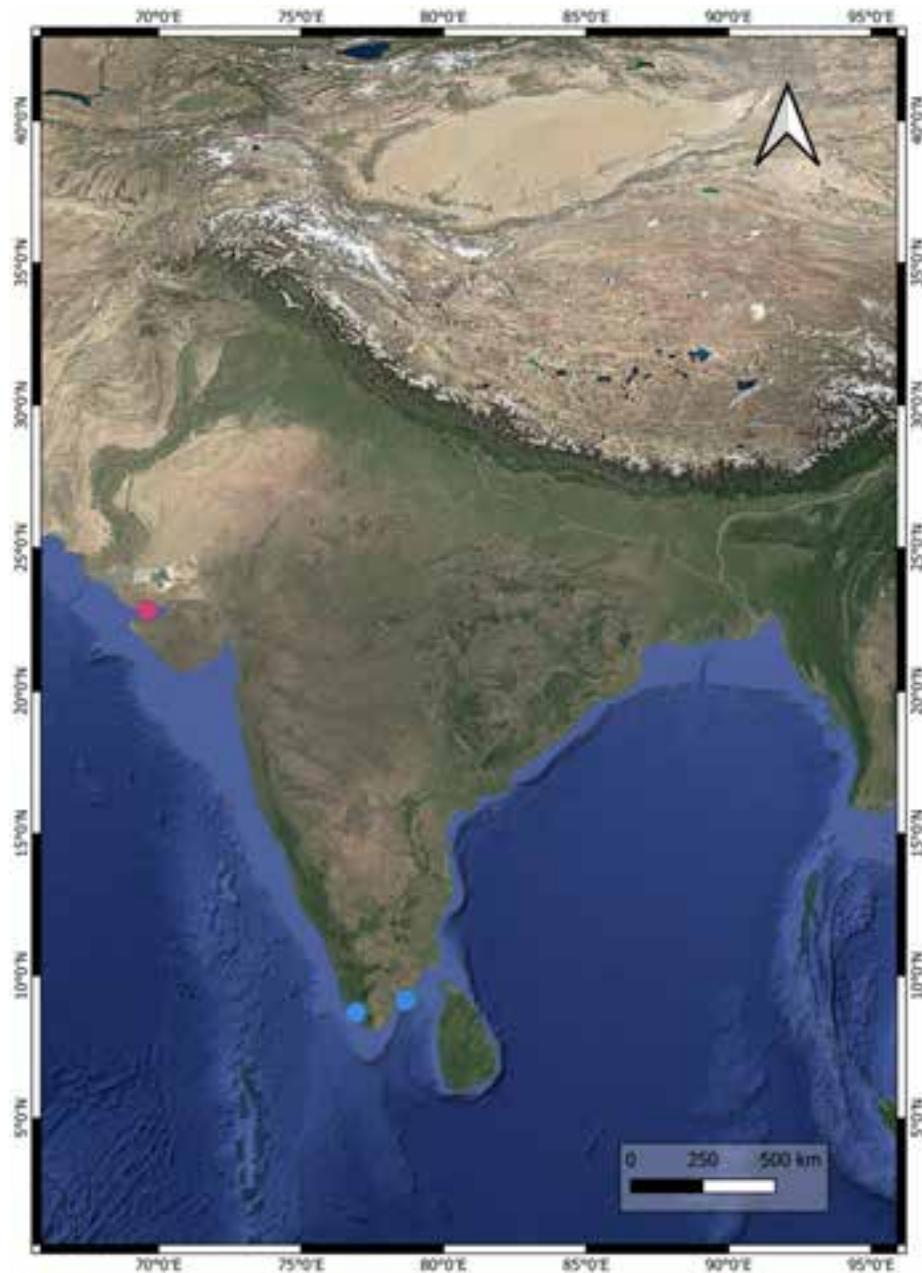


Image 2. A map showing the distribution of *Synidotea variegata* (Collinge, 1917) on the Indian coastline. Filled sky blue circle indicating previous report (Tamil Nadu & Kerala), filled pink circle indicating new distribution report (Mandvi, Gulf of Kutch, Gujarat).

angulata (Collinge, 1917). It varies from both in several structural traits. It coincides with the earlier species in the shape of the cephalon and in possessing the little rounded median notch or depression on the posterior border of the metasome. In the context of mesosomatic and metasomatic segments, it has a resemblance to *S. angulata*.

Distribution: Kerala, Tamil Nadu (Yesudas et al. 2021), and Gujarat (present study) (Image 2).

CONCLUSION

Synidotea variegata (Collinge, 1917) is typically found inhabiting rocky intertidal and shallow subtidal zones, where it shelters among crevices, algae, and sessile invertebrates. This study presents the first confirmed record of *S. variegata* from the Gulf of Kutch, Gujarat, located along the northwestern coastline of India. The discovery significantly extends the known distribution range of the species along the Indian coastline. Until now, *S. variegata* (Collinge 1917) had only been

documented from the southeastern and southwestern regions of India, particularly from the coastal waters of Tamil Nadu and Kerala. Its presence in the Gulf of Kutch suggests a broader ecological tolerance, adaptability to varying salinity and habitat conditions, and may also point to gaps in previous biodiversity assessments in the region. This finding underscores the need for continued monitoring and documentation of marine isopods in underexplored habitats along the Indian coastline.

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Lesser Blue-wing *Rhyothemis triangularis* Kirby, 1889 (Insecta: Libellulidae), a new addition to the dragonfly diversity of Rajasthan, India

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Abstract: The present study reports the first confirmed record of the Lesser Blue-wing *Rhyothemis triangularis* Kirby, 1889 from Udaipur District, Rajasthan, India. Previously unreported in the state, this finding significantly expands this dragonfly's known geographical range into a new area. During the wetland monitoring program in September 2024, an opportunistic sighting of a dragonfly was observed in Jhadol and Gogunda, two adjoining blocks (tehsils) of Udaipur District. The previous findings of this species are mainly from the high rainfall zone, but the present finding is from a drier zone of western India, having low rainfall. The findings contribute to the understanding of the species distribution and ecological preferences, particularly in semi-arid regions like Jhadol and Gogunda block of Udaipur District. These findings contribute to the natural history of the species and highlight the habitat quality and suitability for this species in low-rainfall areas.

Keywords: Habitat preference, new geographic record, Odonata, semi-arid zone, Udaipur, village pond, western India, wetland health assessment.

Development activities around waterbodies have negatively impacted the riparian vegetation and water quality (Córdoba-Aguilar et al. 2019). Dragonflies and damselflies (Odonata) are valuable bioindicators for assessing and monitoring aquatic habitats. These insects, with their sensitivity to environmental changes, can provide insights into water quality, habitat health, and the impacts of various stressors on aquatic ecosystems

(Oertli 2008). The presence of some stenotopic species reflects the effect of vegetation structure, environmental parameters, water quality parameters, and pollutants. Odontes are considered as representatives of health of wetlands, running water, and ponds. Family Libellulidae is one of the largest families within the suborder Anisoptera, encompassing over 1,035 species across 144 genera worldwide (Paulson et al. 2024). The genus *Rhyothemis* is a member of the Libellulidae family, commonly referred to as flutterers due to their distinctive flight pattern. The genus includes 23 species, distributed across Africa, Asia, Australia, and the Pacific region. This species has a wide distribution, encompassing China, Hong Kong, India, Indonesia, Malaysia, the Philippines, Singapore, Sri Lanka, Thailand (Dow & Sharma 2010); Cambodia, and Myanmar (Nu & Bu 2019); Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka (Kalkman et al. 2020; Hopkins 2024). In India *R. triangularis* has previously been recorded from the states like Assam, Himachal Pradesh, Kerala, Karnataka, Odisha, Tamil Nadu, and West Bengal (Mitra 2002; Dow & Sharma 2010; Sajan & Mohapatra 2014; Thakur & Mattu 2015; Dawn 2021; Sadasivan et al. 2022).

In India, the genus *Rhyothemis* is represented by four

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species: *Rhyothemis phyllis*, *R. plutonia*, *R. triangularis*, and *R. variegata*. Among these, *R. variegata* is the most widespread species within the country (Subramanian & Babu 2024).

In this context, the presence of *R. triangularis* in low-rainfall zones such as Jhadol & Gogunda underscores the ecological importance of these wetlands. It offers valuable insight into the species' distribution, habitat preferences, and resilience. As a bio indicator species sensitive to habitat quality and water conditions, its occurrence in this region suggests a relatively healthy wetland ecosystem despite the challenging climatic conditions. These findings enrich the understanding of the species' natural history and support future conservation planning by identifying key habitats outside its traditionally known range. .

MATERIALS AND METHODS

During the wetland health study, a dragonfly survey was conducted as a part of water quality assessment, focusing on species richness, and abundance. The Tropic of Cancer passes below the southern edge of Udaipur District from Dungarpur and Banswara districts. The

area adjacent to this line is frost-free hence suitable for insects, including dragonflies. Udaipur District experiences a semi-arid climate with an average annual rainfall of 600 mm. Temperatures fluctuate significantly between seasons, ranging from a minimum of 2 °C in winter to a maximum of 45 °C in summer.

An Odonata monitoring programme was conducted from August 2023 to September 2024 in Gogunda (24.846° N, 73.426° E) and Jhadol (24.461° N, 73.483° E) blocks of Udaipur District to assess the health of wetlands and streams. Dragonflies and damselflies were searched, identified, and noted from and around the various water bodies of the region. The data was recorded in the notebook. The odonate species along with their key identifying features, were documented and photographed using a Canon 5D mark III camera with a 100 mm fixed lens. Specimens were identified mainly based on the morphological characters and keys provided by Ramachandran & Raju (2020) and Anonymous (2024).

RESULTS

While recording odonate species at a community



Image 1. A seasonal pond in Paneriyon-Ki-Bhagal Village, Jhadol Block, Udaipur District. © Anil Sarsavan.



Image 2. *Rhyothemis triangularis* at Barhamano-ka-Kherwada Village, Jhadol Block Udaipur District, Rajasthan. © Anil Sarsavan.

pond (24.461° N, 73.483° E) in Barhamano-ka-Kherwada Village, Jhadol Block, Udaipur District on 30 August 2024, one individual was observed and suspected to be *Rhyothemis triangularis* because of its wing colouration. Half of the wing area from the base was metallic blue, and the hindwing base was much broader than that of the forewings. This distinctive pattern confirmed it to be a member of the genus *Rhyothemis*. Based on key identification features, the observed dragonfly was confirmed to be *R. triangularis*. On 30 August 2024, a female *R. triangularis* was spotted in a pasture land approximately 500 m away from the Barhamano-ka-Kherwada village pond. Males and females are morphologically similar. Females are characterized by reduced, small anal appendages. Males exhibit a ventral abdominal bulge, prominent secondary genitalia near the thorax-abdomen junction, and large anal appendages, all absent in females. Later, on 02 September 2024, three females and one male *R. triangularis* were recorded in the bushes near a pond in Palidana Village (24.846° N, 73.426° E). One mating pair of *R. triangularis* was observed in the bushes near a pond in Paneriyon-Ki-Bhagal Village (24.833° N, 73.431° E) during the survey period. A total of seven *R. triangularis* individuals (two males and five female) were recorded perched on

various vegetation (*Schoenoplectus* sp., *Chrysopogon zizanioides*, and *Parthenium hysterophorus*) in three locations of Gogunda and Jhadol tehsils of Udaipur District.

DISCUSSION

R. triangularis, commonly called the Lesser Blue-wing, is a striking species known for its distinctive triangular wing markings. Previous studies reported *R. triangularis* inhabiting forest streams (Ramachandran & Raju 2020), the present findings indicate that it can also inhabit seasonal village ponds. All the surveyed ponds are seasonal and primarily used for livestock drinking purposes. All ponds exhibit a diverse mosaic of wetland habitats, supporting a variety of aquatic vegetation. Submerged plants, primarily *Limnophila* species, dominate the underwater environment. The free-floating vegetation is characterized by *Trapa natans*, while *Schoenoplectus* species are the most prevalent emergent plants. Shoreline and upland areas are primarily covered by *Chrysopogon zizanioides* and *Parthenium hysterophorus*. The surrounding landscape is a mosaic of agriculture, pasture, forests, small streams, and small ponds.

This finding significantly expands knowledge of

the geographic distribution of *R. triangularis* and its habitat preferences in village ponds of semi-arid area of Rajasthan. *R. triangularis* has been documented in various biogeographically zones across India, including the Western Ghats, Eastern Ghats, Deccan Peninsula, coastal zone, northeastern zone, and the Himalaya (Dow & Sharma 2010). All three current observations are spread across Gogunda and Jhadol block of Udaipur District, all within a 50 km radius. This demonstrates the species wider distribution throughout the area. The presence of *R. triangularis* species in village ponds, demonstrates the significance of community ponds for the conservation of such Odonata species. This is the first report from the semi-arid region, suggesting a potentially wider range for this species than previously thought.

CONCLUSION

This article presents the first record of *R. triangularis* from Udaipur, Rajasthan, India. The finding contributes to the understanding of the species' geographical range and habitat preferences. Further research is needed to assess the population status and ecological significance of *R. triangularis* in this kind of community-conserved ponds.

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