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Research Article

Diversity of Commelinaceae in Laos and two new record species: *Amischotolype glabrata* Hassk., and *Commelina maculata* Edgew.

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Abstract

The Commelinaceae diversity in Laos have been published, recorded 23 species belonging to nine genera, two species were the new record species in Laos namely *Amischotolype glabrata*, and *Commelina maculata*. The objective of this research was to study the diversity of Commelinaceae in Laos including the data of distribution, ecology, phenology, and conservation status of each species in Commelinaceae family. The research areas included four National Parks of Laos namely Nam Et–Phou Louey National Plank, Nakai-Nam Theun National Park, Hin Namnor National Park, and Dong Houa Sao National Park. The distribution of Commelinaceae in Laos is based on a study of four areas, Commelinaceae species in NKNT and DHS exhibited the highest similarity index (0.2857) with 10 species found in both National Parks. The ecology of Commelinaceae is highly diverse included dry evergreen forest, deciduous forest, evergreen forest, grassland, hill evergreen, limestone forest, mix deciduous forest, marshy places, open area, and secondary forest, the majority, including 11 species were discovered in marshy places. The Commelinaceae flowering from May to November, the highest flowering occurs in August, with 23 species blooming. The conservation status of Commelinaceae species in this research has been assessed by the IUCN, with five species recorded, including *Commelina benghalensis*, *C. diffusa*, *Cyanotis axillaris*, *Cy. cristata*, and *Floscopa scandens*. All of them have been classified as least concern (LC) species. The conservation status of Commelinaceae by the authors is also assessed using the IUCN Red List criteria, and these species were related to the IUCN Red List, these species of Commelinaceae separated into two groups, rare plants group including nine species namely *Aetheolirion stenolobium*, *Amischotolype glabrata*, *Commelina maculate*, *Cyanotis arachnoidea*, *Dictyospermum ovatum*, *Murdannia japonica*, *Pollia secundiflora*, *P. thrysiflora* and *Rhopalephora scaberrima*. Other species were in a commonly found plant group. The study of the conservation status requires further investigation to confirm its accuracy.

Keywords: biodiversity; Commelinaceae; Laos; plant diversity; taxonomy

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Introduction

The Commelinaceae family is a monocotyledonous plant that is generally referred to as dayflower or spiderwort. It encompasses 36 genera and about 774 species that are extensively spread (POWO, 2024), primarily in tropical and subtropical climates, with significant diversity also found in northern temperate areas worldwide (Cronquist, 1981; Mabberley, 2008; Christenhusz and Byng, 2016). The family consists of annual or perennial herbs that are typically terrestrial, somewhat meaty, and succulent. Perennial plants in this family have rhizomes or stolons. The stems are distinctly separated into nodes and internodes, either simple or branching, occasionally producing roots from the stem. The roots show fibrous, delicate, or tuberous characteristics. (Cronquist, 1981; Faden, 1991; Aona, 2008; Mabberley, 2008; Christenhusz and Byng, 2016; Saensouk and Saensouk, 2020). Commelinaceae was utilized for food, medicine, animal feed, and ornamental purposes (González-Avila *et al*., 2003; Mensah *et al*., 2006; Delang, 2007; Alonso-Castro *et al*., 2011; Myriam *et al*., 2011; Łuczaj *et al*., 2021; Moraes *et al*., 2022; Saensouk and Saensouk, 2023; Sengthong *et al*., 2023). In Laos many species in Commelinaceae exhibit beautiful and attractive characteristics, particularly in the colour and striped patterns of their leaves (Sengthong *et al*., 2023). These plants are cultivated for decorative purposes in gardens or as houseplants, and some are also used for medicinal purposes. Additionally, most species can be easily propagated from cuttings (Saensouk and Saensouk, 2021; 2022).

Laos, situated between latitudes 13°50' and 22°30' N, and longitudes 100°10' to 107°40' E, is known for its abundant biodiversity. It covers a total land area of 236,800 square kilometers and is considered the center of the Greater Mekong Sub-Region (GMS). Laos is located in the Indo-Burma Biodiversity Hotspot and is known for its high biodiversity in Southeast Asia. This is attributed to its wide range of latitude and altitude, extensive forest cover, abundant water resources, and tropical climate, which provide habitats for rare and endangered plant species (MoNRE, 2016). The first investigation of Commelinaceae in Laos was carried out as part of the Flora of Flore Générale de l'Indo-Chine (Cherfils, 1937), which documented the variety of Commelinaceae species and provided descriptions of them.

Newman *et al.* (2007) documented 41 species (2 introduced species) of Commelinaceae in Laos, belonging to 12 genera, including *Amischotolype* Hassk. with six species namely *Amischotolype griffithii* I.M. Turner., *A. hispida* (A. Rich.) D.Y. Hong, *A. hookeri* (Hassk.) H. Hara, *A. mollissima* Hassk., *A. monosperma* (C.B. Clarke) I.M. Turner and *A. neoscandens* Idrees. The genus *Belosynapsis* Hassk. is a synonym of *Cyanotis* D. Don and consists of one species, *Belosynapsis ciliata* (Blume). R.S. Rao is a synonym for *Cyanotis ciliata* (Blume) Bakh.f. *Commelina* Plum. ex L. includes seven species namely *Commelina benghalensis* L., *C. communis* L., *C. diffusa* Burm.f., *C. longifolia* Lam., *C. paludosa* Blume, *C. undulata* R.Br., and *C. zeylanica* Falkenb., *Cyanotis* including four species namely *Cyanotis arachnoidea* C.B. Clarke, *Cy. axillaris* (L.) D. Don ex Sweet, *Cy. cristata* (L.) D. Don, *Cy. vaga* (Lour.) Schult. & Schult.f., *Dictyospermum* Wight including three species namely *Dictyospermum conspicuum* (Blume) J.K. Morton, *D. montanum* Wight, *D. ovatum* Hassk.), *Floscopa* Lour including 2 species namely *Floscopa glomerata* (Willd. ex Schult. & Schult.f.) Hassk. and *F. scandens* Lour., *Murdannia* Royle including ten species namely *Murdannia edulis* (Stokes) Faden, *M. japonica* (Thunb.) Faden, *M. keisak* (Hassk.) Hand. - Mazz., *M. macrocarpa* D Y. Hong, *M. medica* (Lour.). D.Y. Hong, *M. nudiflora* (L.) Brenan, *M. simplex* (Vahl) Brenan, *M. spectabilis* (Kurz) Faden, *M. spirata* (L.) G. Brückn., and *M. triquetra* (Wall. ex C.B. Clarke) G. Brückn.), *Pollia* Thunb. Including four species namely *Pollia hasskarlii* R.S. Rao, *P. japonica* Thunb., *P. secundiflora* (Blume) Bakh.f., and *P. thrysiflora* (Blume) Steud., *Porandra* D.Y. Hong (synonym of *Amischotolype*) includes one species in the genus *Amischotolype*, specifically *Amischotolype neoscandens*. *Rhopalephora* Hassk. has one species, *Rhopalephora scaberrima* (Blume) Faden. *Streptolirion* Edgew. consists of one species, *Streptolirion volubile* Edgew., and the introduced genus *Tradescantia* Ruppius ex L., has two introduced species, *Tradescantia spathacea* Sw., *and T. zebrina* Bosse.

Lee (2016) published the book name A Checklist of Plants in Lao PDR reported 13 genera including 41 species namely *Amischotolype griffithii*, *A. hispida*, *A. hookeri*, *A. mollissima* Hassk., *A. monosperma*, *A. neoscandens, Belosynapsis ciliata* (synonym of *Cyanotis ciliata*), *Commelina axillaris* (L.) D. Don (synonym of *Cyanotis axillaris*), *C. benghalensis*, *C. communis*, *C. cristata*, *C. diffusa*, *C. longifolia*, *C. paludosa*, *C. undulata*, *C. zeylanica, Cyanotis arachnoidea*, *Cy. axillaris*, *Cy. cristata*, *Cy. vaga*, *Dictyospermum conspicuum, D. montanum*, *D. ovatum*, *Floscopa glomerata*, *F. scandens*, *Murdannia edulis*, *M. japonica*, *M. keisak*, *M. macrocarpa*, *M. medica*, *M. nudiflora*, *M. simplex*, *M. spectabilis*, *M. spirata*, *M. triquetra, Pollia hasskarlii, P. japonica*, *P. secundiflora*, *P. thrysiflora*, *Porandra scandens* (synonym of *Amischotolype neoscandens*), *Rhoeo spathacea* (Sw.) Stearn (synonym of *Tradescantia spathacea*), *Rhopalephora scaberrima*, *Streptolirion volubile*, *Tradescantia spathacea* and *T. zebrina*.

The research of Commelinaceae in Laos focused on compiling a checklist of the species and documenting their range. Hence, a thorough investigation into the species diversity of the Commelinaceae family is necessary to enhance our understanding and knowledge of this family in the country. This will aid in accurately identifying species of Commelinaceae and provide valuable information for conservation efforts. This project seeks to investigate the species diversity, distribution, ecology, phenology, and conservation status of Commelinaceae in Laos.

Materials and Methods

Study area

This research focused on four National Parks in Laos namely Nam Et–Phou Louey NP in the north, Nakai-Nam Theun NP and Hin Nam Nor NP in the central region, and Dong Houa Sao NP in the south. Each park has distinct features related to climate, altitude, and habitat (Figure 1).

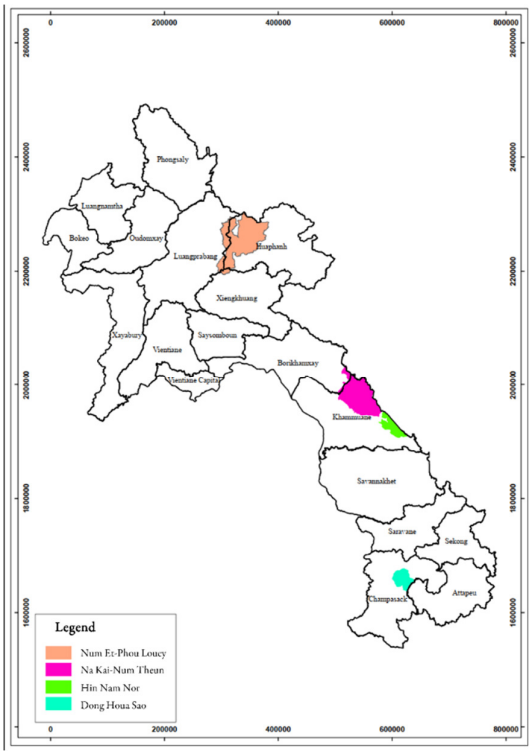

Figure 1. Map of four National Parks located in Laos (Forest Inventory and Planning Division, Laos. 2023)

Nam Et- Phou Louey NP (NEPL)

The Nam Et–Phou Louey National Park is located in northeastern Laos. The region spans 410,720 ha over seven districts and three provinces: Houaphan, Luang Prabang, and Xieng Khouang. The region is predominantly characterized by hills or mountains and serves as the origin of numerous rivers. The name is derived from its prominent geographical features, the Nern and Et Rivers and Phou Louey Mountain ("Forever Mountain") (Department of Forestry, 2017; National Assembly of Laos, 2019; Nam Et- Phou Louey National Park, 2023) (Figure 2A).

The northern border of Vietnam is marked by Son La Province and Dien Bien Province, situated at 20° 82'54" N latitude and 103° 46'09" E longitude. To the south lies Pak Seng district in Lung Prabang Province and Phou Kout district in Xieng Khouang Province at 19° 83'43" N latitude and 103° 03'09" E longitude. In the east, it is close to Xam Neua district, Et district, and Houameuang district in Houaphanh Province at 20° 66'75" N latitude and 103° 87'52" E longitude. To the west, it is near Xam Neua district, Et district, and Houameuang district in Houaphanh Province at 20° 32'27" N latitude and 103° 10'27" E longitude. Altitude ranges from 500 m to 2052 m (Table 1) (Department of Forestry, 2017; National Assembly of Laos, 2019).

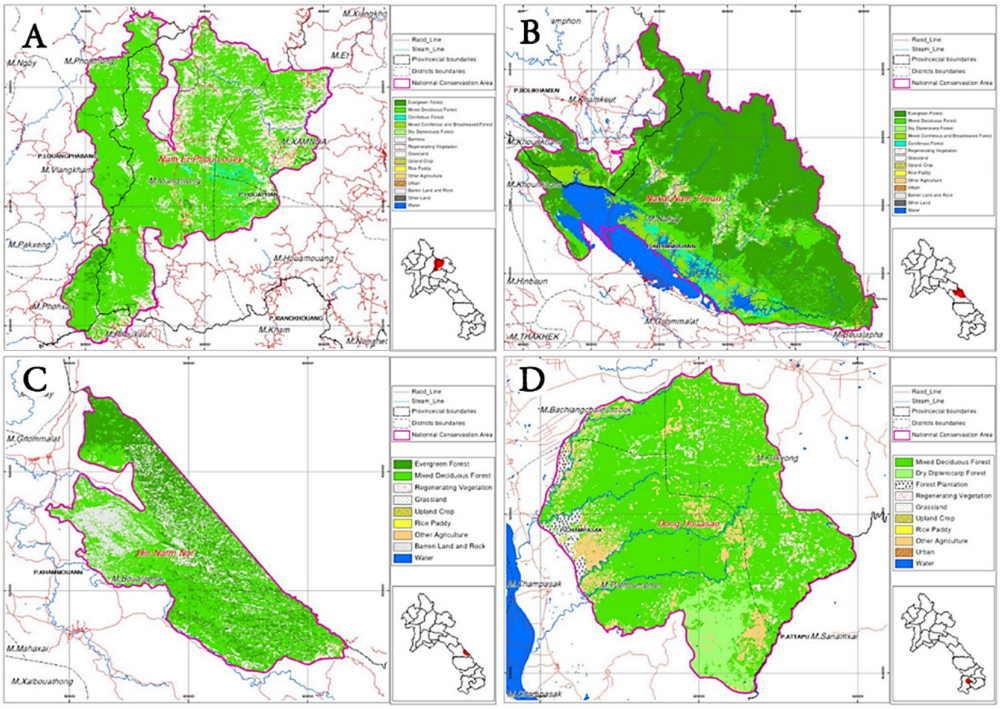

Figure 2. Map of four National Parks; A. Nam Et-Phou Louey NP; B. Na Kai-Num Theun NP; C. Hin Nam Nor NP; D. Dong Houa Sao NP (Forest Inventory and Planning Division, Laos, 2023)

Table 1. Geographic characteristics of the study areas

Geographic characteristics	Study area			
	NEPL	NKNT	HNN	DHS
Province	Houaphan, Luang Prabang, Xieng Khouang	Bolikhamxay Khammouane	Khammouane	Champasak
North Located	20° 82'54" N, 103° 46'09" E	18° 23'21" N, 105° 09'37" E	17° 38'15" N, 105° 46'27" E	15° 11'13" N, 106° 07'35" E
South Located	19° 83'43" N, 103° 87'52" E	17° 35'24.9" N, 105°38'36.4" E	17° 15'01" N, 105° 08'36" E	14° 47'26" N, 106° 10'32" E
East Located	20° 66'75" N, 103°87'52" E	17° 59'18" N, 105° 38'36" E	17° 30'32" N, 105° 57'37" E	14° 58'46" N, 106° 17'50" E
West Located	20° 32'27" N, 103° 10'27" E	18° 01'48" N, 104° 47'21" E	17° 22'03" N, 105° 49'31" E	15° 00'26" N, 105° 55'03" E
Elevation (m)	500 – 2052	500 – 2200	100 – 1429	100 –1300
Total size area (ha)	410,720	427,770	94,121	99,795

(NEPL: Nam Et–Phou Louey National Park; NKNT: Nakai-Nam Theun National Park; HNN: Hin Nam Nor National Park; DHS: Dong Houa Sao National Park) (Department of Forestry, 2021; National Assembly of Laos, 2021).

Na Kai-Num Theun NP (NKNT)

The Na Kai-Nam Theun National Park is situated in the central region of Laos, specifically in Nakai District, Khammouane Province, close the Vietnam border. The Nakai-Nam Theun area spans around 427,770 ha of the Annamite Range and the neighboring Nakai Plateau in Khammouane Province and Bolikhamsai Province (Department of Forestry, 2017) (Figure 2B).

NKNT is located in Khammouane province, encompassing three districts: Nakai, Yommalath, and Boualapha, as well as Bolikhamsai Province's Khamkeut district. Between longitude and latitude as shown: The northern point is at 18° 23'21" N latitude and 105° 09'37" E longitude, the southern point is at 17° 35'24.9" N latitude and 105° 38'36.4" E longitude, the eastern point is at 17° 59'18" N latitude and 105° 38'36" E longitude, and the western point is at 18° 01'48" N latitude and 104° 47'21" E longitude. Altitude ranges from 500 m to 2200 m. (Table 1) (Department of Forestry, 2017).

Hin Nam Nor NP (HNN)

Hin Nam Nor National Park is situated in Bualapha district, Khammouane Province, in central Laos near the Vietnam border. It spans an area of 94,121 ha. The limestone composition of Hin Nam Nor NP sets it apart from other NPs, creating challenges for access and hindering patrols and research efforts. Hin Nam Nor's limestone terrain is primarily covered with forests, especially in the middle section of the mountains extending to the foothills. The limestone features are seen as exposed rocks on the surface, with occasional vegetation. Small and medium trees are typically located at the mid-level, varying based on the gradient's steepness. Large trees thrive in high alpine regions with minimal rock formations. Large trees in foothill regions often have an average height of 25 m, reaching up to 45 m. Limestone formations are interconnected at varying densities, sizes, and elevations (Department of Forestry, 2017) (Figure 2C).

HNN is situated in the Boualapha region of Khammouane province. positioned at specific coordinates of longitude and latitude: The northern point is situated at 17° 38'15" N latitude and 105° 46'27" E longitude, the southern point at 17° 15'01" N latitude and 105° 08'36" E longitude, the eastern point at 17° 30'32" N latitude and 105° 57'37" E longitude, and the western point at 17° 22'03" N latitude and 105° 49'31" E longitude. Altitude ranges from 100 m to 1429 m (Table 1) (Department of Forestry, 2017).

Dong Houa Sao NP (DHS)

The Dong Hua Sao National Park has 99,795 ha. The national park is situated in three districts: Pathoumphone, Paksong, and Bachieng Chaleunsouk, inside Champasak Province in southern Laos. The north is situated at 15° 11'13" N latitude and 106° 07'35" E longitude, the east at 14° 58'46" N latitude and 106° 17'50" E longitude, the south at 14° 47'26" N latitude and 106° 10'32" E longitude, and the west at 15° 00'26" N latitude and 105° 55'03" E longitude (Department of Forestry, 2021; National Assembly of Laos,2021) (Figure 2D).

More than half of the protected area consists of lowland plains with elevations ranging from 100 to 1300 m. The region's flora mostly includes evergreen forest in lowlands and uplands, along with dry dipterocarp woodland and mixed deciduous forest. It is a region characterized by its abundant animals and conservative practices (Table 1) (Department of Forestry, 2021; National Assembly of Laos, 2021).

Plant specimen collection

Surveys and collections of plant specimens from the Commelinaceae family were carried out monthly in study areas from June 2022 to October 2023. The surveys consisted of strolling along trails in accessible regions of national parks. The Commelinaceae plant collections in the field consisted of dry specimens, spirit specimens, and living specimens. Dry specimens were processed using a heater, spirit specimens were immersed in 70% ethyl alcohol, and living specimens of Commelinaceae were grown (Lamxay and Newman, 2012; Boonma *et al*., 2023). The herbarium at the Faculty of Forest Science (Herbarium Acronym: FOF), National University of Laos, and the Walai Rukhavej Botanical Research Institute (WRBRI) at Mahasarakham University in Thailand stored several sorts of specimens. Every species was photographed and had notes included.

Species identification

The identification process was carried out in the herbarium of the Faculty of Forest Science at the National University of Laos. The specimens and photos from the survey were analyzed and contrasted with those in various herbaria in Laos, such as the herbarium of the Faculty of Forest Science, the herbarium of the Faculty of Natural Science at the National University of Laos, and the national herbarium of Laos (Herbarium Acronym: HNL). Furthermore, digital specimens from foreign herbaria such as the Forest Herbarium Bangkok (BKF), Queen Sirikit Botanic Garden Herbarium (QBG), and the Royal Botanic Gardens Kew (K) were also examined.

Ecology study

The ecology of each plant species was documented in the field. The ecological groups comprised dry evergreen forest (DE), deciduous forest (DF), evergreen forest (EF), grassland (GL), hill evergreen (HE), limestone forest (LF), mix deciduous forest (MD), marshy areas (MP), open area (OA), and secondary forest (SF).

Phenology study

Flowering information concerning Commelinaceae was documented during the survey in the research locations. Each month is designated a number from 1 to 12, corresponding to January through December, respectively (Boonma *et al*., 2023).

Conservation status

The assessment of conservation status is divided into two parts: the first evaluates the status of Commelinaceae according to the IUCN Red List criteria (IUCN, 2023), and the second is based on the study results, the researcher reexamined the conservation status in accordance with the IUCN criteria to determine

if it belonged to the category includes rare plants (found in one or two places with a low-density number) and commonly found plants (found in more than two places with a high-density number).

Statistical analysis

The study utilized information regarding Commelinaceae diversity in four national parks to assess plant species similarity across the locations utilizing Jaccard's similarity index. Species similarities were further analyzed using UPGMA (unweighted pair group method with arithmetic mean; Sokal and Michener 1958) cluster analysis (Hammer *et al*., 2001).

$$JI = c / (a + b + c) \quad (1)$$

"a" represents the number of Commelinaceae in region "A", "b" represents the quantity of Commelinaceae in area "B", and "c" represents the quantity of the same species present in both areas "A" and "B".

Results

Diversity of Commelinaceae in Laos

The research on Commelinaceae diversity in Laos focus on the native species, identified nine genera and 23 species, including *Aetheolirion stenolobium* Forman, *Amischotolype divaricata*, *Am. glabrata* Hassk., *Am. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *C. maculata* Edgew., *C. paludosa*, *Cyanotis arachnoidea*, *Cy. axillaris*, *Cy. cristata*, *Dictyospermum ovatum*, *Floscopa scandens*, *Murdannia bracteata*, *M. edulis*, *M. gigantea*, *M. japonica*, *M. medica*, *M. nudiflora*, *M. spectabilis*, *Pollia secundiflora*, *P. thyrsiflora*, and *Rhopalephora scaberrima* (Table 2, Figures 3, 9).

The diversity of Commelinaceae species in Nam Et-Phou Louey NP (NEPL) includes 19 species: *Amischotolype divaricata*, *A. glabrata*, *A. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *C. maculata*, *C. paludosa*, *Cyanotis axillaris*, *Cy. cristata*, *Floscopa scandens*, *Murdannia bracteata*, *M. edulis*, *M. japonica*, *M. medica*, *M. nudiflora*, *M. spectabilis*, *Pollia secundiflora*, *Pollia thyrsiflora*, and *Rhopalephora scaberrima*.

The diversity of Commelinaceae species in Na Kai-Num Theun National Park (NKNT) consists of 13 species: *Amischotolype divaricata*, *A. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *Cyanotis arachnoidea*, *Cy. axillaris*, *Cy. cristata*, *Dictyospermum ovatum*, *Floscopa scandens*, *Murdannia gigantea*, *M. medica*, *M. nudiflora*, *M. spectabilis*.

The diversity of Commelinaceae species in Hin Nam Nor National Park (HNN) consists of nine species: *Aetheolirion stenolobium*, *Amischotolype neoscandens*, *Commelina benghalensis*, *C. diffusa*, *Cyanotis axillaris*, *Cy. cristata*, *Murdannia edulis*, *M. medica*, and *M. spectabilis*.

The diversity of Commelinaceae species in Dong Houa Sao NP (DHS) including 12 species namely*Amischotolype divaricata*, *A. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *C. paludosa*, *Cyanotis arachnoidea*, *Cy. axillaris*, *Cy. cristata*, *Murdannia bracteata*, *M. gigantea*, *M. nudiflora*, and *M. spectabilis*.

Table 2. Species diversity of Commelinaceae in Laos

No.	Species name	Vernacular name	Distribution				Phenology	Ecology	Collector no.	Conservation Status by IUCN	Conservation Status by authors*
			NEPL	NKNT	HNN	DHS					
1	*Aetheolirion stenolobium* Forman	Kap Khuea	–	–	+	–	7-9	LF	AS391	–	Rare
2	*Amischotolype divaricata* Duist.	Ueang Num	+	+	–	+	8-11	OA	AS400	–	Common
3	*Am. glabrata* Hassk.	Kap Num	+	–	–	–	7-10	HE, MP	AS411	–	Rare
4	*Am. neoscandens* Idrees	Ueang Perd	+	+	+	+	7-10	EF	AS392	–	Common
5	*Commelina benghalensis* L.	Kap Khong	+	+	+	+	6-11	OA	AS399	LC	Common
6	*C. diffusa* Burm.	Kap Bi	+	+	+	+	5-10	OA	AS395	LC	Common
7	*C. maculate* Edgew.	Kap	+	–	–	–	8-10	HE, DE	AS417	–	Rare
8	*C. paludosa* Blume	Kap Phai	+	–	–	+	7-9	DE	AS412	–	Common
9	*Cyanotis arachnoidea* C.B. Clarke.	Ueang Hin	–	+	–	+	8-11	OA, MD	AS407	–	Rare
10	*Cy. axillaris* (L.) D. Don ex Sweet.	Kap Na	+	+	+	+	7-10	OA, MP	AS393	LC	Common
11	*Cy. cristata* (L.) D. Don	Kap Na.	+	+	+	+	5-8	DE, MP, EF, DF	AS397	LC	Common
12	*Dictyospermum ovatum* Hassk.	Kap Dok	–	+	–	–	5-7	EF, DE	AS418	–	Rare
13	*Floscopa scandens* Lour.	Ya Kap	+	+	–	–	8-11	OA, MP, DE	AS408	LC	Common
14	*Murdannia bracteata* (C.B. Clarke) J.K. Morton ex D.Y. Hong	Kap Noy	+	–	–	+	5-10	OA, DF	AS413	–	Common
15	*Murdannia edulis* (Stokes) Faden	Phaen Din Yen	+	–	+	–	6-9	MP, DF	AS394	–	Common
16	*M. gigantea* (Vahl) G. Brückn.	Ya Kap Dok	–	+	–	+	6-11	MP, DF, OA	AS409	–	Common
17	*M. japonica* (Thunb.) Faden	Kap Doy	+	–	–	–	5-8	EF, DE, DF, SF	AS416	–	Rare
18	*M. medica* (Lour.) D.Y. Hong	Ya Kap	+	+	+	–	7-9	GL, MP, DF	AS396	–	Common
19	*M. nudiflora* (L.) Brenan	Ya Kap Noy	+	+	–	+	5-10	OA, GL	AS410	–	Common
20	*M. spectabilis* (Kurz) Faden	Ya Kap Dok	+	+	+	+	5-8	OA, DF, GL	AS398	–	Common
21	*Pollia secundiflora* (Blume) Bakh.f.	Ya Kap Yai	+	–	–	–	5-8	MP, HE, DF	AS419	–	Rare
22	*P. thyrsiflora* (Blume) Steud.	Ya Kap	+	–	–	–	5-10	MP, DF, EF, DE	AS415	–	Rare

23	*Rhopalephora scaberrima* (Blume) Faden	Ya Kap Ton	+	–	–	–	6-10	EF, MP	AS414	–	Rare

Abbreviations: Distribution: NEPL = Nam Et–Phou Louey National Park; NKNT = Nakai-Nam Theun National Park; HNN = Hin Nam Nor National Park; DHS = Dong Houa Sao National Park; + = found in the area; – = not found. Phenology: 1 = January; 2 = February; 3 = March; 4 = April; 5 = May; 6 = June; 7 = July; 8 = August; 9 = September; 10 = October; 11 = November; 12 = December. Ecology: DE = dry evergreen; DF = deciduous forest; EF = evergreen forest; GL = grassland; HE = hill evergreen; forest; LF = limestone forest; MD = mix deciduous forest; MP = marshy places; OA = open area; SF = secondary forest. IUCN assessment status for wild species in this study by IUCN Red List Ver. 15.1 (December 2023): CR = critically Endangered; DD = data deficient. EN = endangered; LC = least concern; NT = near threatened.

* Based on the study results, the researcher reexamines the conservation status in accordance with the IUCN criteria to determine if it belonged to the category of rare plant (Rare), commonly found plant (Common)

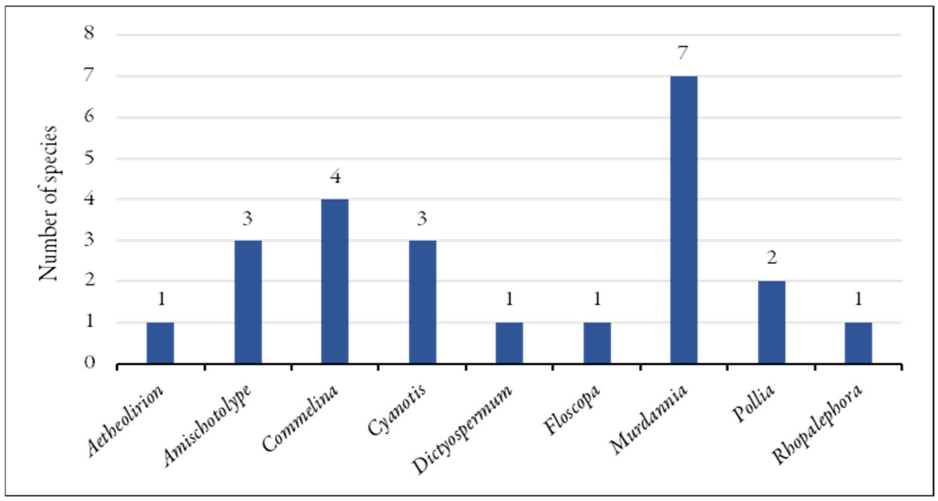

Figure 3. Species diversity of Commelinaceae found in Laos by genus

Distribution of Commelinaceae in Laos

The distribution of Commelinaceae in Laos is based on a study of four areas, each encompassing a four National Parks (NPs): Nam Et-Phou Louey NP (NEPL), Na Kai-Num Theun NP (NKNT), Hin Nam Nor NP (HNN), and Dong Houa Sao NP (DHS). The study examines plants found in each specific area, as well as those found in both or more than two areas. Jaccard's similarity index was utilized to assess the similarity of Commelinaceae in four study areas. Plants in NKNT and DHS exhibited the highest similarity index (0.2857) with 10 species found in both National Parks (NPs) (namely *Amischotolype divaricata*, *A. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *Cyanotis arachnoidea*, *Cy. axillaris*, *Cy. cristata*, *Murdannia gigantea*, *M. nudiflora*, and *Murdannia spectabilis*). In other comparisons, NKNT and HNN showed a similarity index of 0.2414, NEPL and DHS had a similarity index of 0.2381, NEPL and NKNT exhibited a similarity index of 0.2326, and NEPL and HNN had a similarity index of 0.2162. (Table 3).

Table 3. Jaccard's similarity index of four study areas of Commelinaceae in Laos

	NKNT	HNN	DHS
NEPL	0.2326	0.2162	0.2381
NKNT		0.2414	0.2857
HNN			0.2222

(NEPL: Nam Et–Phou Louey National Park; NKNT: Nakai-Nam Theun National Park; HNN: Hin Nam Nor National Park; DHS: Dong Houa Sao National Park)

The UPMG cluster analysis dendrogram demonstrates the resemblance of Commelinaceae species in four NPs. The study shows that Commelinaceae in NKNT and DHS have the highest similarity due to similarities in temperature and forest types. NEPL closely follows, however HNN stands out as the location with the least similarity to others. The difference in distribution is a result of its unique habitat, primarily in limestone regions, distinct from other areas. Figure 4. The UPMG cluster analysis dendrogram and Jaccard's similarity index demonstrate consistent results.

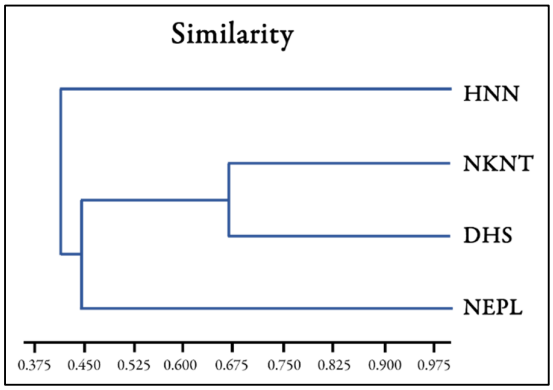

Figure 4. UPGMA cluster analysis dendrogram of Commelinaceae in Laos, similarity index based on Jaccard Index, with cophenetic correlation = 0.9591.
(NEPL: Nam Et–Phou Louey National Park; NKNT: Nakai-Nam Theun National Park; HNN: Hin Nam Nor National Park; DHS: Dong Houa Sao National Park)

Ecology study

The ecology of Commelinaceae is highly diverse. The majority, including 10 species (namely *Amischotolype glabrata*, *Cyanotis arachnoidea*, *Cy. cristata*, *Floscopa scandens*, *Murdannia edulis*, *M. gigantea*, *M. medica*, *Pollia secundiflora*, *P. thyrsiflora*, and *Rhopalephora scaberrima*) were discovered in marshy places, same as in open areas (namely *Amischotolype divaricata*, *Commelina benghalensis*, *C. diffusa*, *Cyanotis arachnoidea*, *Cy. axillaris*, *Floscopa scandens*, *Murdannia bracteata*, *M. gigantea*, *M. nudiflora* and *M. spectabilis*), nine species in deciduous forests (namely *Cyanotis cristata*, *Murdannia bracteata*, *M. edulis*, *M. gigantea*, *M. japonica*, *M. medica*, *M. spectabilis*, *Pollia secundiflora*, and *P. thyrsiflora*), seven species in dry evergreen forests(namely *Commelina maculata*, *C. paludosa*, *Cyanotis cristata*, *Dictyospermum ovatum*, *Floscopa scandens*, *Murdannia japonica*, and *Pollia thyrsiflora*), six species in evergreen forests (namely *Amischotolype neoscandens*, *Cyanotis cristata*, *Dictyospermum ovatum*, *Murdannia japonica*, *Pollia thyrsiflora*, and *Rhopalephora scaberrima*), and four species in hill evergreens (namely *Amischotolype glabrata*, *Commelina maculata*, *Pollia thyrsiflora* and *P. secundiflora*) three species in grasslands (namely *Murdannia medica*, *M. nudiflora*, and *M. spectabilis*), one species in limestone forests (namely *Aetheolirion stenolobium*), secondary forests (namely *Murdannia japonica*), and mixed deciduous forests (namely *Cyanotis arachnoidea*). Almost all species of Commelinaceae grow in moist and open areas, so our research relates to the previous study (Figure 5).

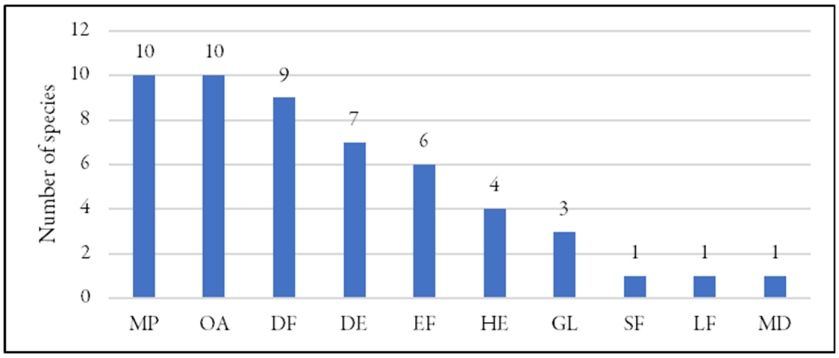

Figure 5. Number of Commelinaceae found in the types of ecology
(DE: dry evergreen forest; DF: deciduous forest; EF: evergreen forest; GL: grassland; HE: hill evergreen; LE: limestone forest; MD: mix deciduous forest; MP: marshy places; OA: open area; and SF: secondary forest.)

Phenology study

The Commelinaceae are found in four National Parks in Laos and flower from May to November. The highest flowering occurs in August, with 22 species blooming (namely *Aetheolirion stenolobium*, *Amischotolype divaricata*, *Am. glabrata*, *Am. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *C. maculata*, *C. paludosa*, *Cyanotis arachnoidea*, *Cy. axillaris*, *Cy. cristata*, *Floscopa scandens*, *Murdannia bracteata*, *M. edulis*, *M. gigantea, M. japonica*, *M. medica*, *M. nudiflora*, *M. spectabilis*, *Pollia secundiflora*, *P. thyrsiflora*, and *Rhopalephora scaberrima*), followed by July with 19 species (namely *Aetheolirion stenolobium*, *Amischotolype glabrata*, *Am. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *C. paludosa*, *Cyanotis axillaris*, *Cy. cristata*, *Dictyospermum ovatum*, *Murdannia bracteata*, *M. edulis*, *M. gigantea, M. japonica*, *M. medica*, *M. nudiflora*, *M. spectabilis*, *Pollia secundiflora*, *P. thyrsiflora*, and *Rhopalephora scaberrima*), September with 18 species (namely *Aetheolirion stenolobium*, *Amischotolype divaricata*, *Am. glabrata*, *Am. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *C. maculata*, *C. paludosa*, *Cyanotis arachnoidea*, *Cy. axillaris*, *Floscopa scandens*, *Murdannia bracteata*, *M. edulis*, *M. gigantea, M. medica*, *M. nudiflora*, *Pollia thyrsiflora*, and *Rhopalephora scaberrima*), October with 14 species (namely *Amischotolype divaricata*, *Am. glabrata*, *Am. neoscandens*, *Commelina benghalensis*, *C. diffusa*, *C. maculata*, *Cyanotis arachnoidea*, *Cy. axillaris*, *Floscopa scandens*, *Murdannia bracteata*, *M. gigantea, M. nudiflora*, *Pollia thyrsiflora*, and *Rhopalephora scaberrima*), June with 12 species (namely *Commelina benghalensis*, *C. diffusa*, *Cyanotis cristata*, *Murdannia bracteata*, *M. edulis*, *M. gigantea, M. japonica*, *M. nudiflora*, *M. spectabilis*, *Pollia secundiflora*, *P. thyrsiflora*, and *Rhopalephora scaberrima*), May with nine species (namely *Commelina paludosa*, *Cyanotis cristata*, *Dictyospermum ovatum*, *Murdannia bracteata*, *M. japonica*, *M. nudiflora*, *M. spectabilis*, *Pollia secundiflora*, and *P. thyrsiflora*) and November with five species (namely *Amischotolype divaricata*, *Commelina benghalensis*, *Cyanotis arachnoidea*, *Floscopa scandens*, and *Murdannia gigantea*. Therefore, Commelinaceae grow during the rainy season, and almost all species flower in the middle of the rainy season in Laos (Figure 6).

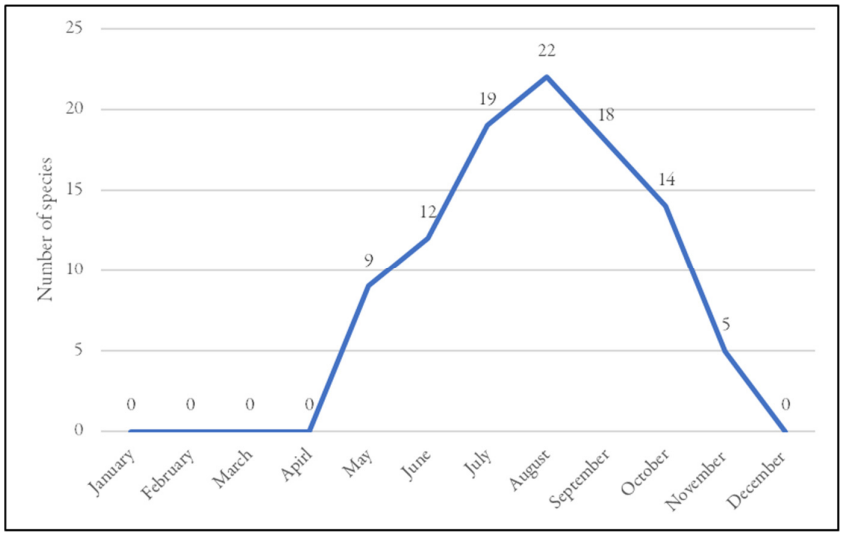

Figure 6. Phenology range of Commelinaceae found in Laos

Conservation status

The IUCN has evaluated the conservation status of Commelinaceae species in this study, identifying 5 species: *Commelina benghalensis*, *C. diffusa*, *Cyanotis axillaris*, *Cy. cristata*, and *Floscopa scandens*. All of them have been categorized as species of least concern (LC) according to the IUCN in 2023.

The authors evaluated the conservation status of Commelinaceae using the IUCN Red List criteria (2023), identifying five species listed on the IUCN Red List. *Aetheolirion stenolobium*, *Amischotolype glabrata*, *Commelina maculata*, *Dictyospermum ovatum*, *Murdannia japonica*, *Pollia secundiflora*, *P. thyrsiflora*, and *Rhopalephora scaberrima* are among the uncommon species that are exclusively found in one specific location. The study of Commelinaceae is restricted, therefore, further dispersion data is needed to determine their conservation status.

Two species newly recorded in Laos

Amischotolype glabrata Hassk., Flora 46 (1863) 392; *Campelia glabrata* Hassk., Pl. Jungh.: 154. 1852, *non* Kunth. Type: Malaysia, Penang, *SN 1822* (K!). *Forrestia glabrata* (Hassk.) Hassk., Flora. 47: 630. 1864. Figure 7.

Distribution. – Andaman Is., Assam, Bangladesh, Borneo, Cambodia, China South-Central, China Southeast, East Himalaya, Hainan, India, Jawa, Lesser Sunda Is., Malaya, Myanmar, Nansei-shoto, Nicobar Is., Sumatera, Taiwan, Thailand, Tibet, Vietnam, Laos.

Ecology. – marshy places in hill evergreen; alt. ca 1000 m.

Phenology. – flowering and fruiting specimens were collected in October.

Note. – *Amischotolype glabrata* stands out due to its smooth leaves, with dense clusters of numerous flowers forming large, compact, often round heads on upright stems. Additionally, it produces smooth capsules and a calyx that changes to a deep purplish-red hue (Thitimetharoch, 2004).

Specimens examined. –Houaphan Province [Hiem District, Na Phon Village, 20°34′50.70″N, 103°37′04.40″E, 1,108 m, 16 Oct. 2023, Sengthong *et al.* AS411 (FOF)].

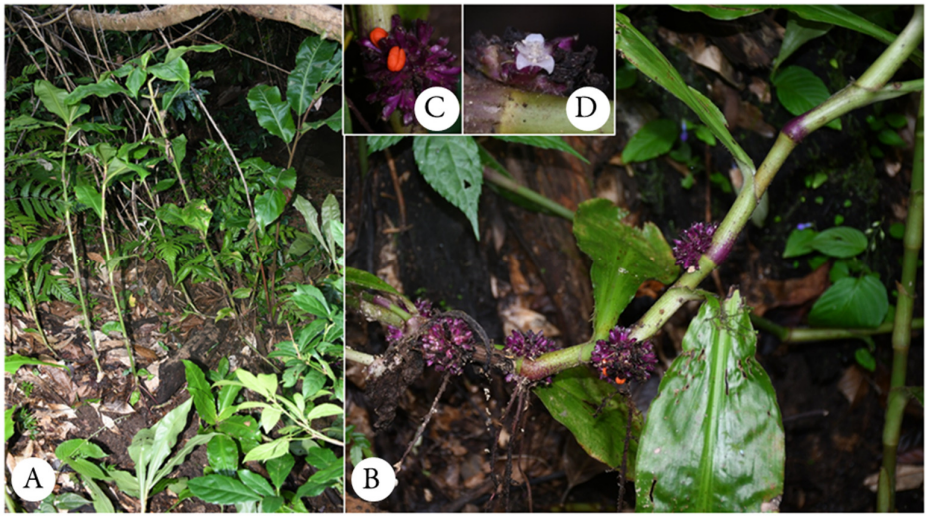

Figure 7. *Amischotolype glabrata* Hassk., A. habitat; B. stem and inflorescences; C. seed; D. flower

Commelina maculata Edgew. Trans. Linn. Soc. London 20: 89 (1846). Type: Himalaya, Edgeworth, M.P. [155], India (K [K000794528] digital image!). Figure 8.

Distribution. –Assam, China South-Central, East Himalaya, India, Malaya, Myanmar, Nepal, Tibet, West Himalaya, Laos.

Ecology. –hill evergreen and dry evergreen forest; alt. ca 900 m.

Phenology. – flowering and fruiting specimens were collected in October.

Note. – *Commelina maculata* closely resembles *C. paludosa*, but it can be distinguished by its creeping stems near the base, which produce numerous slender branches that root at nodes. Its leaves are smaller, typically measuring 4–10 × 1.5–2.5 cm, and it has fewer and smaller involucral bracts, often only 2 -4 forming heads. (Hong and De Filipps, 2000).

Specimens examined. – Houaphan Province [Hiem District, Sa Kok Village, 20°36′27.60″N, 103°36′89.70″E, 1,108 m, 17 Oct. 2023, Sengthong *et al.* AS417 (FOF)].

Figure 8. *Commelina maculata* Edgew, A. habitat; B. inflorescences and flowers; C. lower leaf surface

Key to species of Commelinaceae in Laos

1a. Plants twining ..... *Aetheolirion stenolobium*
1b. Plants not twining 2
2a. Inflorescences perforating the sheaths 3
2b. Inflorescences not perforating the sheaths 5
3a. Inflorescences a very small compact head, with 1–4 capsules ..... *Amischotolype neoscandens*
3b. Inflorescences a moderate to large, compact head, with 10–50 capsules 4
4a. Capsule obovoid, shorter than sepals by (1–)2.5–5(–6) mm ..... *Amischotolype glabrata*
4b. Capsule ovoid, longer than sepals by 5–9 mm ..... *Amischotolype divaricata*
5a. Petals connate into a tube basally 6
5b. Petals free 8
6a. Plants aquatic; cincinni axillary; enclosed in the leaf sheaths ..... *Cyanotis axillaris*
6b. Plant terrestrial; cincinni terminal and axillary; not enclosed in the leaf sheaths 7
7a. Perennials covered with silky hairs ..... *Cyanotis arachnoidea*
7b. Annuals variously pubescent but never covered with silky hair ..... *Cyanotis cristata*
8a. Filament bearded 9
8b. Filament glabrous 15
9a. Plant without basal rosettes; all thin root 10
9b. Plant with basal rosettes; roots thin, sometime mixed with moderately thick and/or tuberous ones 11
10a. Main stem developed; pedicels thin but straight ..... *Murdannia nudiflora*
10b. Main stems abortive, with rosulate leaves; pedicels curved or straight ..... *Murdannia bracteata*
11a. Flowering shoot terminal, central in the rosette 12
11b. Flowering shoot axillary from the rosette leaves 14
12a. Cincinni composed of dense secund flowers, root thick but not tuberous *Murdannia gigantea*
12b. Cincinni and flowers not as above, at least some roots tuberous 13
13a. Leaves less than 10 mm wide, tubular sheathing bracts glabrous ..... *Murdannia medica*
13b. Leaves more than 10 mm wide, tubular sheathing bracts puberulent ..... *Murdannia spectabilis*
14a. Flowering shoots with bladeless sheathing bracts ..... *Murdannia edulis*
14b. Flowering shoots with well-developed leaves ..... *Murdannia japonica*
15a. Bracts spathaceous, enclosing at least one cincinnus, cincinni solitary or paired 16
15b. Bracts not spathaceous, not enclosing the cincinni, cincinni numerous 19
16a. Proximal margin of involucral bracts open or folded but not basally connate, base cordate or rounded ..... *Commelina diffusa*
16b. Proximal margin of involucral bracts connate, becoming funnelform 17
17a. Capsule 3-valved; seeds 2 per valve; leaves obviously petiolate, leaf blade ovate to broadly ovate, less than 7 cm ..... *Commelina benghalensis*
17b. Capsule 2- or 3-valved; seeds 1 per valve; leaves sessile, leaf blade lanceolate to ovate-lanceolate, to 15 cm 18
18a. Plants robust, to 1 m tall; leaf sheath mouth densely brown hirsute ciliate; cincinni5–10 ..... *Commelina paludosa*
18b. Plants slender, short; leaf sheath mouth glabrous or sparsely whitish hispid ciliate; Cincinni three or four (or several) ..... *Commelina maculata*
19a. Plant stoloniferous; fruits berry–like, indehiscent, metallic coloured when ripe 20
19b. Plant not stoloniferous; fruits capsular, dehiscent, commonly brown when ripe 21
20a. Inflorescences equal in length or longer than the distal leaves;

stamens dimorphic ..... *Pollia secundiflora*
20b. Inflorescences shorter than the distal leaves; stamens all equal ..... *Pollia thyrsiflora*
21a. Hook-hair absent on leaves; stamens 6, all fertile ..... *Floscopa scandens*
21b. Hook-hair present on leaves; stamens 3 or 6, when 6, both fertile and sterile 22
22a. Leaves congested distally on the shoots; stamens 3; capsules glabrous ..... *Dictyospermumovatum*
22b. Leaves not as above; stamens 6, 3 fertile and 3 sterile; capsules pubescent ..... *Rhopalephorascaberrima*

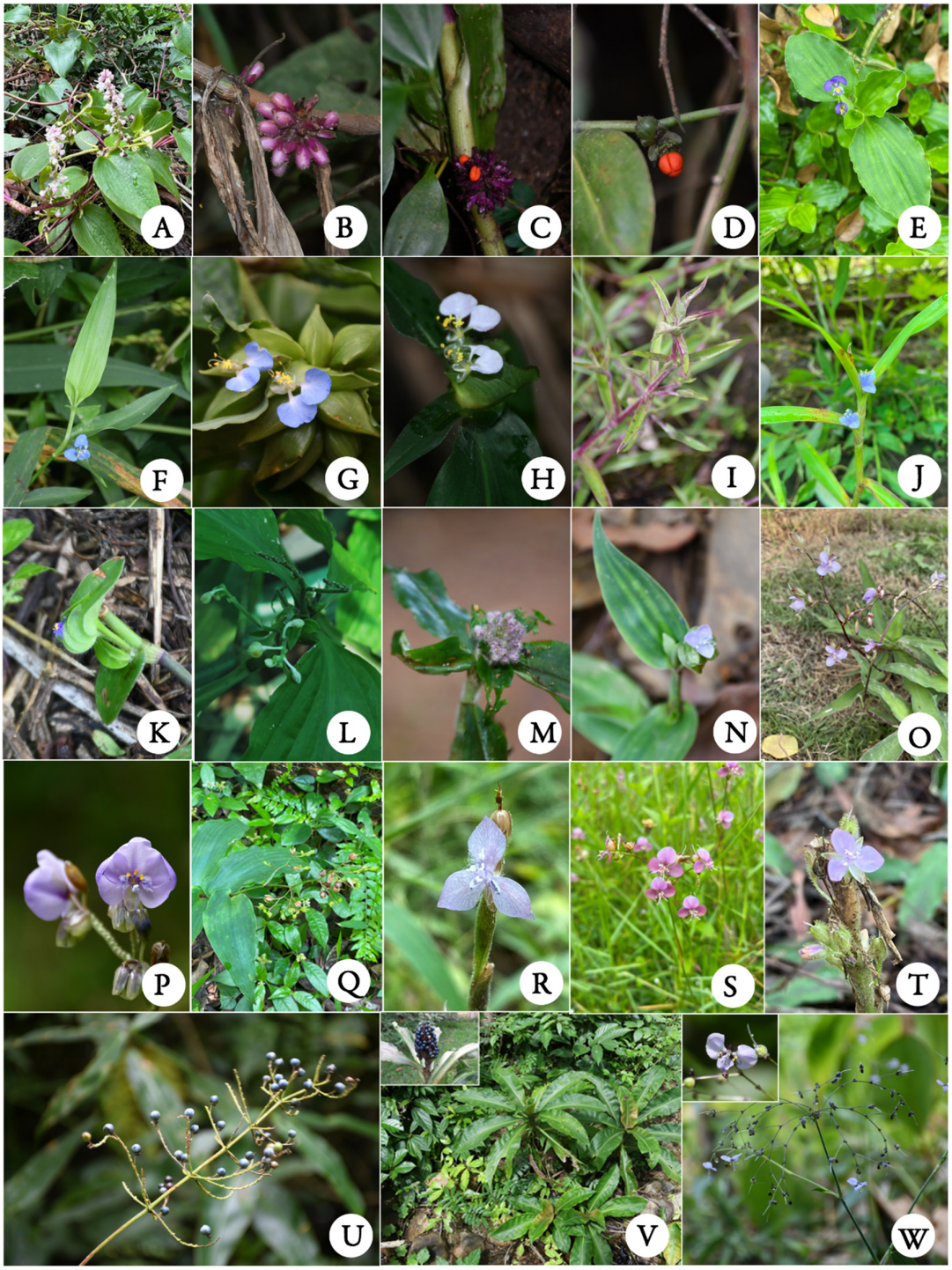

Figure 9. The diversity of Commelinaceae in Laos. (A) *Aetheolirion stenolobium*; (B) *Amischotolype divaricata*; (C) *Am. glabrata*; (D) *Am. neoscandens*; (E) *Commelina benghalensis*; (F) *C. diffusa*; (G) *C. maculata*; (H) *C. paludosa*; (I) *Cyanotis arachnoidea*; (J)*Cy. Axillaris*; (K)*Cy. Cristata*;(L) *Dictyospermum ovatum*; (M) *Floscopa scandens*; (N) *Murdannia bracteata*; (O) *M. edulis*; (P) *M. gigantea*; (Q) *M. japonica*; (R) *M. medica*; (S) *M. nudiflora*; (T) *M. spectabilis*; (U) *Pollia secundiflora*; (V) *P. thyrsiflora*; (W) *Rhopalephora scaberrima*

Discussion

In Laos, the Commelinaceae family exhibits diversity in four National Parks: Nam Et-Phou Louey NP (NEPL), Na Kai-Num Theun NP (NKNT), Hin Nam Nor NP (HNN), and Dong Houa Sao NP (DHS). A total of 24 species from nine genera have been identified, all of which are native to the region. In comparison to Newman *et al.* (2007) who identified 41 species (two introduced species), this study identified 21 species that were also found in both studies. Additionally, this research not only documented the introduced species but also discovered two new species for the flora of Laos, namely *Amischotolype glabrata* and *Commelina maculata* found in NEPL.

The findings of this study revealed that the distribution of Commelinaceae in NKNT and DHS exhibited the greatest resemblance in terms of plant species. This similarity can be attributed to the shared ecological conditions and temperature in both areas.

Commelinaceae have diverse ecological preferences, including marshy places, open areas, dry evergreen forests, deciduous forests, evergreen forests, hill evergreens, grasslands, limestone forests, secondary forests, and mixed deciduous forests. Almost all species of Commelinaceae flourish in damp and exposed habitats, consistent with previous study (Cronquist, 1981; Faden, 1991; Mabberley, 2008; Christenhusz and Byng, 2016), thus reinforcing the relevance of our research.

Commelinaceae can be found in four National Parks in Laos, with flowering mainly happening from May to November. August had the most flowering activity, with 22 species blooming, followed by July and September with 19 and 18 species respectively. In October, 14 species were observed blossoming, compared to 12 species in June, 10 species in May, and five species in November. Commelinaceae primarily bloom during the rainy season in Laos, with the highest flowering activity happening in the middle of the rainy season. The results offer important information on the timing of natural events in Commelinaceae in the area and enhance our comprehension of their ecological patterns.

The conservation status of species in the Commelinaceae family Our research has found five species that are associated with the IUCN Red List: *Commelina benghalensis*, *C. diffusa*, *Cyanotis axillaris*, *Cy. cristata*, and *Floscopa scandens*. The species *Aetheolirion stenolobium*, *Amischotolype glabrata*, *Commelina maculata*, *Dictyospermum ovatum*, *Murdannia japonica, Pollia secundiflora*, *P. thyrsiflora,* and *Rhopalephora scaberrima* were identified as rare, as they were only observed in one specific study site. Our study of Commelinaceae is limited in breadth. Further research is needed to validate the distribution and examine the population trends of the species in various habitats and locales to better understand their conservation status. Some species of Commelinaceae seem stable, but the scarcity of specific species highlights the importance of ongoing monitoring and conservation to protect biodiversity in this plant family.

Conclusions

Our study provides insights into the richness, distribution, ecological preferences, phenological behavior, and conservation status of Commelinaceae in Laos, specifically within four National Parks. We documented 23 indigenous species from nine genera, contributing to the current understanding of this botanical family. Comparing with past studies revealed both commonalities and unique findings, such as the identification of two species previously unrecorded in the flora of Laos. The study highlights the ecological adaptability of Commelinaceae, which flourish in a wide range of habitats, especially damp and open areas. The phenological research showed a clear flowering pattern, with the highest activity observed during the rainy season, especially in August. This data offers vital insights into the ecological processes of Commelinaceae in the area. Our assessment of the conservation status revealed other species that may be rare, highlighting the necessity for additional research and conservation initiatives to safeguard their existence. Although certain species seem stable based on current evaluations, our study's restricted breadth emphasizes the necessity of more

extensive research to comprehensively grasp the conservation requirements of Commelinaceae in various habitats and geographical areas. Our study improves understanding of Commelinaceae ecology and highlights the importance of continuous monitoring and conservation initiatives to safeguard the biodiversity of this plant family in Laos.

Authors' Contributions

The article was conceptualization by AS and SS, AS writing – original draft, SS writing – review and editing. PS (Piyaporn Saensouk) and PS (Phetlasy Souladeth) have read and approved the final version of the manuscript. All authors have read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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