

NEW RECORDS IN THE FLORA CHECKLISTS OF LAOS, RESULTING FROM A SURVEY OF PHOU HIN POUN NATIONAL BIODIVERSITY CONSERVATION AREA

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The flora of Laos remains one of the least known within the Indo-Burma biodiversity hotspot. A floristic inventory was carried out in Phou Hin Poun National Biodiversity Conservation Area, an under-explored area of the Khammouane Limestone. This study provides a list of 27 taxa that are additions to the most recent country checklists. The Ebenaceae, Euphorbiaceae and Myrtaceae are the families with the highest species number. In this list, four species are endemic to Indochina (Cambodia, Laos and Vietnam): *Cynometra dongnaiensis* Pierre, *Jasminum vidalii* P.S.Green, *Memecylon chevalieri* Guillaumin and *Pothos gigantipes* Buchet ex P.C.Boyce. These results illustrate the paucity of our knowledge of the region surveyed and of the flora of Laos in general.

Keywords. Additions, canopy access, endemics, forest, Khammouane Limestone, Laos, new records.

INTRODUCTION

Most of the territory of Laos belongs to Indo-Burma *sensu* Myers *et al.* (2000), which extends from eastern Bangladesh to the coastal lowlands of southern China, and southwards to the north of the Isthmus of Kra, including most of Thailand. The region has been recognised as one of 34 world biodiversity hotspots, both containing high levels of biodiversity and requiring priority for conservation measures (Mittermeier *et al.*, 2004; BirdLife International, 2007; de Bruyn *et al.*, 2014).

The flora of Laos remains one of the least known in the region. The Ministry of Agriculture and Forestry and Science, Technology and Environment Agency of Laos (2003) estimated 8000–11,000 species of flowering plants, but the most recent checklist

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(Zhu, 2017), which is largely based on the that of Newman *et al.* (2007), enumerates only 5005 species, excluding introduced species. This limited knowledge is in large part owing to poor botanical exploration, hampered by the Indochinese wars and also a lack of local expertise. As emphasised by Newman *et al.* (2007), the intensity of plant exploration in Laos until the early 1990s was comparatively lower (roughly three specimens per 100 km²) than in neighbouring countries such as Vietnam or Thailand (14 and 50 specimens per 100 km², respectively). Until now, floristic inventories in Laos have lagged behind. By contrast, in Vietnam more than 200 new vascular plant taxa, including 13 new genera, were described between 1993 and 2003 (Regalado *et al.*, 2005).

The topography of Laos is shaped by the easternmost foothills of the Himalayas to the north and the Annamite range to the east, along the Vietnamese border. Two-thirds of the country are dotted with karst formations. In the centre of Laos, the Khammouane Limestone forms a spectacular belt of karst, 290 km long and 30–120 km wide, which stretches north-west to south-east across the full width of the country (Kiernan, 2009). This formation extends into Vietnam to form the larger central Indochina limestone belt (Rundel, 2001). With highly distinctive ecosystems rich in endemic species, limestone karsts are “arks” of biodiversity (Clements *et al.*, 2006), and often contain high levels of endemism.

Recently, an attempt was made to document the biodiversity of one such under-explored karst formation in Laos, using canopy-accessing facilities provided by the Canopy Raft (formerly called Radeau des Cîmes¹). Previously, the Canopy Raft organised such expeditions in Central and South America and in Africa (Hallé & Pascal, 1991; Hallé *et al.*, 1998, 1999, 2000). This is the first time that such a canopy survey has been carried out in Asia.

In 2012, the Canopy Raft and the Lao National Council of Sciences organised a survey of the karst valley in Khammouane province. It involved a multidisciplinary and international group of 35 scientists divided into six teams covering a wide range of fields: botany, entomology, herpetology, mammalogy, ornithology and virology. About half of the participants were national counterparts, including lecturers and students from the National University, curators and technicians from the National Herbarium of Laos, and researchers from the Institut Pasteur, Vientiane.

The data presented here result from a larger project devoted to the study of the flora and fauna of Phou Hin Poun National Biodiversity Conservation Area (NBCA). Examination of this material is still in progress. The richness of botanical collections, the lack of reference herbarium specimens and the rarity of relevant taxonomic literature make the work of taxonomic identification rather lengthy. This paper presents a list of 27 taxa collected in the karst formations and adjoining vegetation of Phou Hin Poun NBCA that are new national additions to the latest checklists (Newman *et al.*, 2007; Zhu, 2017).

¹ Founder members: Professor Francis Hallé, botanist, scientific director; Dany Cleyet-Marrel, aeronaut, designer, aerostat inventor; and Gilles Ebersolt, architect, inventor of the Treetop Raft.

METHODS

Fieldwork location

Phou Hin Poun NBCA (17.746°N, 104.8°E), also known as Khammouane Limestone NBCA, was created in 1993. It covers an area of about 1500 km² in the south-west of the Upper Hin Boun catchment (UNEP–WCMC & IUCN, 2014–2017). The area is characterised by well-developed closed depressions, and large underground streams and caves (Kiernan, 2009). The mean annual rainfall in Khammouane province is about 2250 mm, whereas the driest areas of the central lowlands receive only 1400 mm (Rundel, 2001).

A base camp was built in the north-east of Phou Hin Poun NBCA, in the upper valley of the Hin Boun River, a tributary of the Mekong, near the village of Ban Nathan (Fig. 1), a few kilometres from the famous Konglor Cave.

Enclosed by sandstone cliffs to the east and karst to the west, the valley is remarkable for its ecological contrasts and the diversity of its habitats, each of which provides access to a distinct flora. Plants were collected in the area surrounding the base camp (17°59'N, 104°49'E), ranging between 200 and c.700 m in altitude, in the following habitats: piedmont evergreen forests (f), dry dipterocarp forests on karst scree and dry summit forests on karst outcrops (k), riparian forests (rh) and secondary growth (s) (Fig. 2).

Plant collecting

In 2012, botanical explorations were carried out during two field trips, each of 2 weeks' duration: in January during the dry season, and in May at the onset of the rainy season. Some herbaceous groups, such as Begoniaceae and Gesneriaceae, tend to flower later in the rainy season. These groups are likely to be under-represented in our results. Fertile plant specimens from the most inaccessible forest sites were collected from the canopy using the facilities provided by the Canopy Raft team (Fig. 3), as well as from the ground with the contribution of three professional trekkers and tree climbers. More than 800 plant specimens were collected (with at least three duplicates of most numbers, therefore amounting to some 2500 samples), and may represent more than 500 species. The plant samples were referenced and preliminarily identified, at least to genus, by the botanical team (the authors) using literature available at the base camp. Duplicates of each specimen were collected, and the vouchers deposited at HNL, NUoL and P. A partial set of duplicates was deposited at HIFP.

Taxonomic identification work was done at P, with the help of existing volumes of printed regional floras such as the *Flora of Thailand* (Santisuk, 1970 to present) and *Flore du Cambodge, du Laos et du Vietnam* (Aubréville *et al.*, 1960 to present); historical reference works, namely the *Flore Générale de l'Indochine* (Lecomte, 1907–1950) and *Flore Forestière de la Cochinchine* (Pierre, 1833–1905); online floras, mainly the *Flora of China* (Wu *et al.*, 1994–2013) and *Flora Malesiana* (Steenis, 1948 to present); and other relevant taxonomic literature, such as revisions of individual taxa. Identification is quite often made difficult by the lack of an updated comprehensive flora, and the need

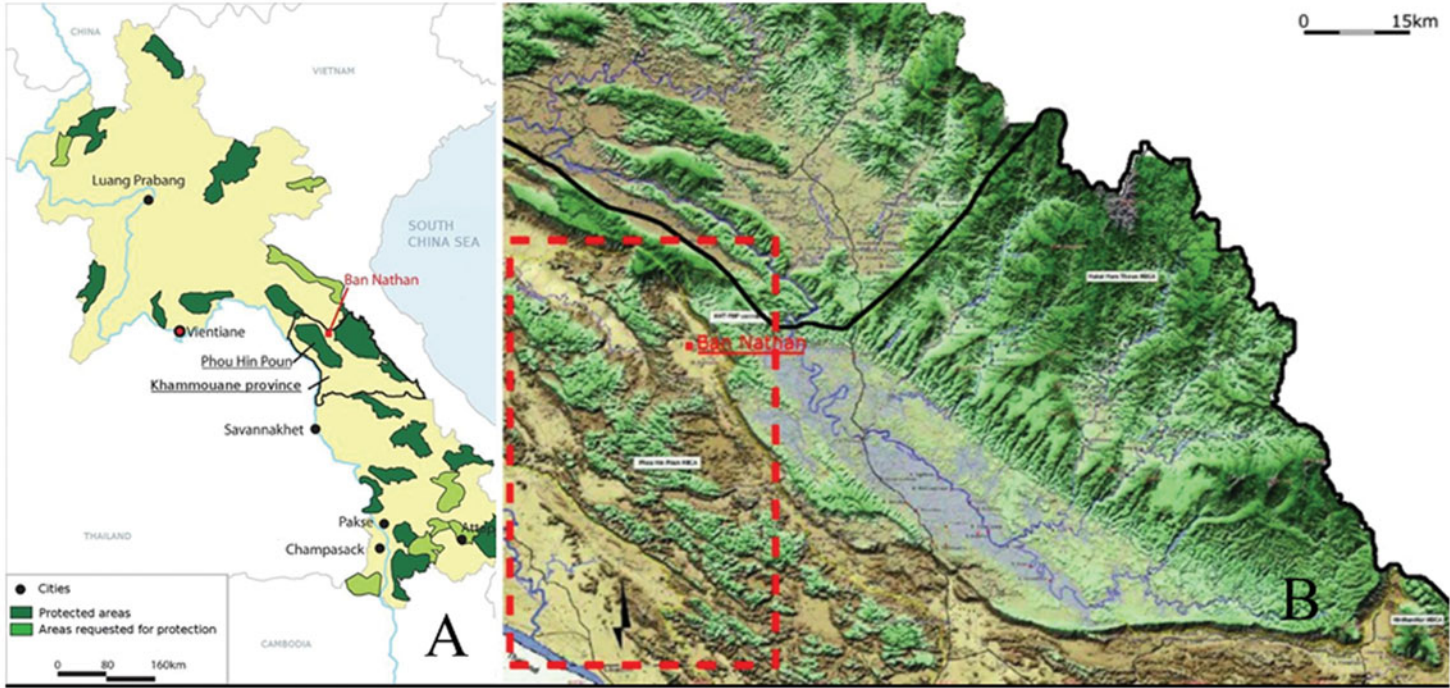


FIG. 1. Fieldwork location. A, Phou Hin Poun National Biodiversity Conservation Area, Khammouane province, Laos; B, location of Ban Nathan and the study site outlined in red.

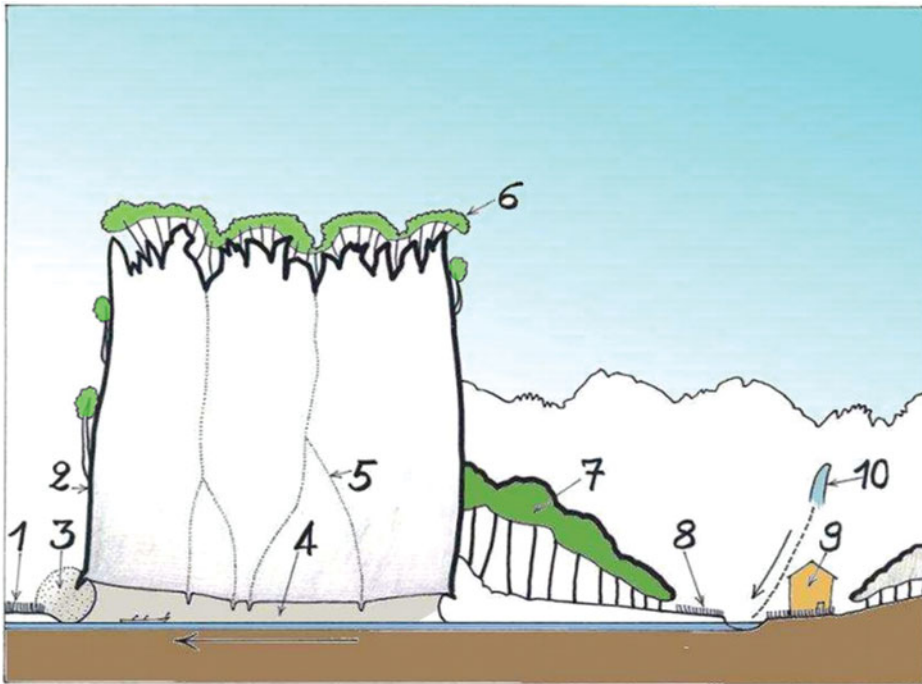


FIG. 2. The variety of landscapes in the study area. 1, Rice-growing plain in the lower valley; 2, karst cliff; 3, mist at the resurgence of the underground river; 4, the underground river and the direction of the current; 5, infiltration in the karst; 6, summit forest, including dipterocarp and *Lagerstroemia* forest; 7, piedmont forest; 8, tobacco crop in the upper valley; 9, tobacco driers; 10, Maitok waterfall at the source of the Hin Boun river.

to refer to several reference taxonomic works covering different regions. Comparisons with already identified specimens, type specimens whenever available, made it possible to ascertain the identifications. Advice was also sought from taxonomists at P and L. Identifications of which we could not be fully confident are indicated by 'cf'. We retain them in the list, because they may be of interest to specialists of the respective families (Annonaceae, Apocynaceae, Ebenaceae, Myrtaceae, Phyllanthaceae and Rhamnaceae). The family names were updated by reference to the Angiosperm Phylogeny Group III classification (Angiosperm Phylogeny Group, 2009).

The distribution of taxa is based on *Species 2000 & ITIS Catalogue of Life* (Roskov *et al.*, 2017), and when not available, it was completed by information from GBIF (2016). For synonyms, synonymic checklists by Hassler (2017) were used as a reference.

RESULTS

To date, 27 of 245 species identified (11%) are additions to the most recent country checklists (Newman *et al.*, 2007; Zhu, 2017), and the number may amount to 35 if our tentative (cf.) identifications of 8 species are confirmed (Table 1).



FIG. 3. The cinébulle (the coloured hot air balloon with a small propeller engine) in flight, and the Bulle des Cimes (the white helium balloon) on the ground. Between the two balloons is a rope attached to the tree crowns on which the Bulle moves.

The 27 species belong to 25 families and 30 genera, showing a relatively high diversity of a rather small sample. The Ebenaceae, Euphorbiaceae and Myrtaceae are the families with the highest species number (Figs 4, 5). The best represented genera are *Diospyros* and *Syzygium*, with three species each.

They are mostly trees (71%, 25 species) and treelets (14%, 5 species), and were mostly found in forest and karst habitat (71% and 9%, respectively). In secondary growth including disturbed habitats, we found contrasting results, collecting rather common trees such as *Barringtonia racemosa* (L.) Spreng. (Lecythidaceae) but also a rare species, viz. *Jasminum vidalii* P.S.Green (Oleaceae), omitted from previous checklists and known so far only from the type specimen.

By comparing the 27 species (excluding doubtful identifications) with available taxonomic distribution information (Roskov *et al.*, 2017), it appears that:

1. The majority (74%) of these additions are known to occur in Vietnam.
2. At least four species are endemic to Indochina (Cambodia, Laos and Vietnam): *Cynometra dongnaiensis* Pierre, described by Rundel (2001) as a tree reaching 20 m in height, reported only from Cambodia and southern Vietnam; *Jasminum vidalii*, a climber known only from the type specimen collected by Vidal in 1954 in the province of Vientiane (Green, 1999); *Memecylon chevalieri* Guillaumin, a tree described by Guillaumin in the *Bulletin de la Société Botanique de France* (1921),

TABLE 1. Additions to the botanical checklists of Laos, collected in the Phou Hin Poun National Biodiversity Conservation Area, Khammouane province^a

Taxon	Habit	Habitat	Voucher number(s) (<i>FH</i>) ^b	Distribution					
				Cambodia	Vietnam	China	Thailand	Malaysia	Indonesia
Acanthaceae									
<i>Phlogacanthus turgidus</i> (Fua ex Hook.f.) Lindau	Shrub	Secondary growth	4763		Vietnam				
Anacardiaceae									
<i>Mangifera macrocarpa</i> Blume	Tree	Forest	4897				Thailand	Malaysia	Indonesia
Annonaceae									
<i>Mitrephora</i> cf. <i>calcareae</i> Diels	Treelet	Forest	5243		Vietnam				
<i>Pseuduvaria rugosa</i> (Blume) Merr.	Tree	Forest	5457				Thailand	Malaysia	Indonesia
Apocynaceae									
<i>Alstonia</i> cf. <i>curtisii</i> King & Gamble	Treelet or shrub	Karst	5310				Thailand		
Araceae									
<i>Pothos gigantipes</i> Buchet ex P.C.Boyce	Climber	Secondary growth	5032	Cambodia	Vietnam				
Cannabaceae									
<i>Celtis philippensis</i> Blanco	Tree	Forest	5519		Vietnam	China	Thailand	Malaysia	Indonesia
Convolvulaceae									
<i>Merremia bambusetorum</i> Kerr	Climber	Forest	4944	Cambodia	Vietnam	China	Thailand		
Dichapetalaceae									
<i>Dichapetalum gelonioides</i> (Roxb.) Engl.	Tree	Forest	5517		Vietnam	China	Thailand	Malaysia	Indonesia

TABLE 1. (Continued)

Taxon	Habit	Habitat	Voucher number(s) <i>(FH)</i> ^b	Distribution					
				Cambodia	Vietnam	China	Thailand	Malaysia	Indonesia
Ebenaceae									
<i>Diospyros hasseltii</i> Zoll.	Tree	Forest	5472	Cambodia	Vietnam	China	Thailand	Malaysia	Indonesia
<i>Diospyros pilosiuscula</i> G.Don	Tree	Forest	5418		Vietnam		Thailand		
<i>Diospyros</i> cf. <i>sumatrana</i> Miq.	Tree	Forest	5433				Thailand	Malaysia	Indonesia
Euphorbiaceae									
<i>Endospermum chinense</i> Benth.	Tree	Forest	5511, 5530, 5353, 5308		Vietnam	China	Thailand		
<i>Excoecaria oppositifolia</i> Griff.	Tree	Forest	5069, 5086, 5469		Vietnam		Thailand		Indonesia
<i>Sumbaviopsis albicans</i> (Blume) J.J.Sm.	Tree	Forest	5079, 5117, 5413		Vietnam		Thailand	Malaysia	Indonesia
Fabaceae									
<i>Cynometra dongnaiensis</i> Pierre	Treelet	Forest	4993, 5236	Cambodia	Vietnam				
Fagaceae									
<i>Quercus oxyodon</i> Miq.	Tree	Forest	5420		Vietnam	China			
Lamiaceae									
<i>Premna coriacea</i> C.B.Clarke	Tree	Forest	5475		Vietnam		Thailand		
Lauraceae									
<i>Litsea pierrei</i> Lecomte	Tree	Forest	5317	Cambodia	Vietnam	China	Thailand		

TABLE 1. (Continued)

Taxon	Habit	Habitat	Voucher number(s) (<i>FH</i>) ^b	Distribution					
				Cambodia	Vietnam	China	Thailand	Malaysia	Indonesia
Lecythidaceae									
<i>Barringtonia racemosa</i> (L.) Spreng	Tree	Secondary growth	5434		Vietnam	China	Thailand	Malaysia	Indonesia
Melastomataceae									
<i>Memecylon chevalieri</i> Guillaumin	Tree	Forest	5459	Cambodia	Vietnam				
Meliaceae									
<i>Dysoxylum grande</i> Hiern	Tree	Forest	5151		Vietnam	China	Thailand	Malaysia	Indonesia
Moraceae									
<i>Ficus sundaica</i> Blume	Tree	Karst	5301, 5520	Cambodia	Vietnam		Thailand	Malaysia	Indonesia
<i>Streblus macrophyllus</i> Blume	Tree	Forest	5435		Vietnam	China	Thailand	Malaysia	Indonesia
Musaceae									
<i>Musa itinerans</i> Cheesman	Herb	Karst	4935		Vietnam	China	Thailand		
Myristicaceae									
<i>Knema furfuracea</i> (Hook.f. & Thomson) Warb.	Tree	Forest	5103, 5470		Vietnam	China	Thailand	Malaysia	Indonesia

TABLE 1. (Continued)

Taxon	Habit	Habitat	Voucher number(s) (<i>FH</i>) ^b	Distribution					
				Cambodia	Vietnam	China	Thailand	Malaysia	Indonesia
Myrtaceae									
<i>Syzygium</i> cf. <i>balsameum</i> (Wight) Wall. ex Walp.	Tree	Rheophyte	4872		Vietnam		Thailand		
<i>Syzygium megacarpum</i> (Craib) Rathakr. & N.C.Nair	Tree	Forest	5464	Cambodia		China	Thailand		
<i>Syzygium</i> cf. <i>oblatum</i> (Roxb.) Wall. ex Steud.	Tree	Forest	5465	Cambodia	Vietnam		Thailand	Malaysia	Indonesia
Oleaceae									
<i>Jasminum vidalii</i> P.S.Green	Climber	Secondary growth	5009						
Phyllanthaceae									
<i>Antidesma velutinum</i> Tul.	Tree	Forest	5363	Cambodia			Thailand	Malaysia	
<i>Phyllanthus</i> cf. <i>harmandii</i> Beille	Treelet	Karst	5476	Cambodia			Thailand		
Rhamnaceae									
<i>Ziziphus</i> cf. <i>angustifolia</i> (Miq.) Hatus. ex Steenis	Tree	Forest	5458				Thailand	Malaysia	Indonesia
<i>Ziziphus</i> cf. <i>pubinervis</i> Rehder	Tree	Forest	5123			China			
Rubiaceae									
<i>Rothmannia sootepensis</i> (Craib) Bremek.	Treelet	Forest	5467				Thailand		

^a Editor's note: Tagane *et al.* (the following article in this issue of the *Edinburgh Journal of Botany*) independently report the occurrence in Bolikhamxay province of four species in this table, namely, *Celtis philippensis* Blanco, *Dichapetalum gelonioides* (Roxb.) Engl., *Diospyros pilosiuscula* G.Don and *Pseuduvaria rugosa* (Blume) Merr.

^b All herbarium numbers are labelled *FH* (Francis Hallé). Vouchers were deposited at HNL, NUoL and P.

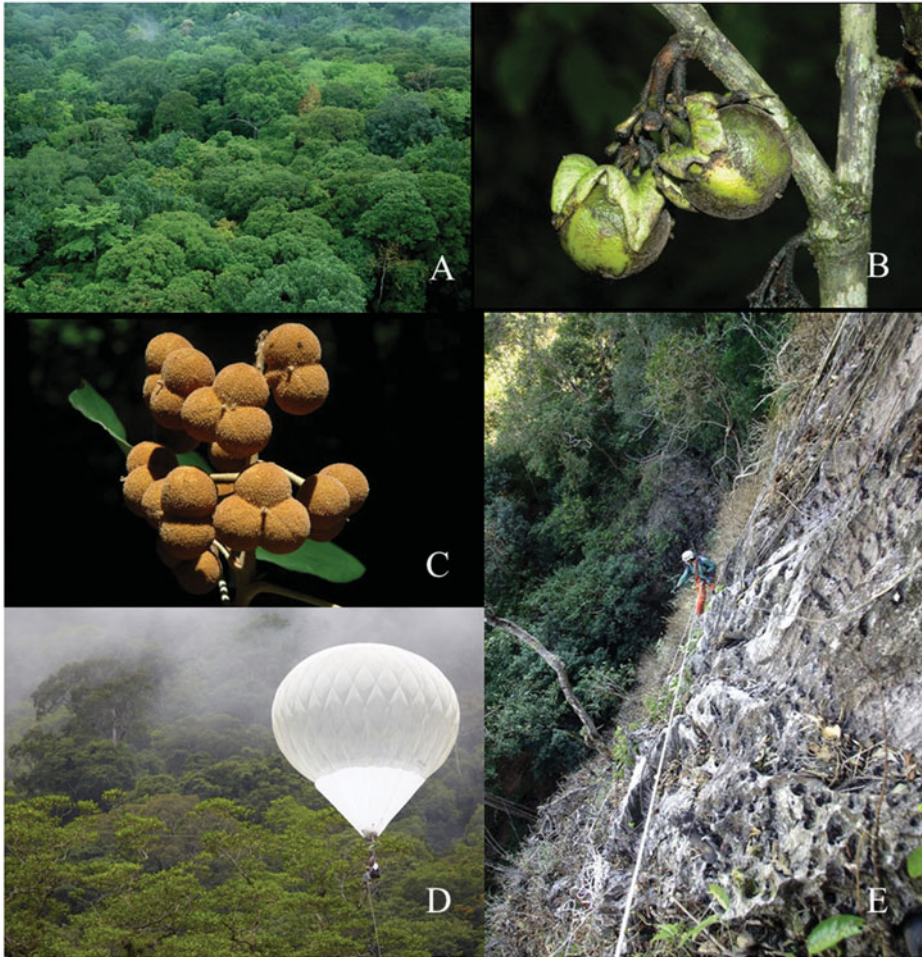


FIG. 4. A, Canopy view from the cinébulle, piedmont forest; B, *Diospyros hasseltii* Zoll.; C, *Sumbaviopsis albicans* (Blume) J.J.Sm.; D, collecting with the Bulle des Cimes on an *Endospermum chinense* Benth. crown; E, surveying the karst cliff particularly difficult to access.

then in the *Flore Générale de l'Indo-Chine* (1921), from Cambodia and southern Vietnam; and *Pothos gigantipes* Buchet ex P.C.Boyce, a climber studied by Boyce (2000) in his work on this genus in Thailand and Indochina.

3. Most of the remaining species (22%) are found in Thailand, Malaysia and Indonesia. Species such as *Pseuduvaria rugosa* (Blume) Merr. (Annonaceae; Fig. 5F), *Dysoxylum grande* Hiern (Meliaceae) and *Rothmannia sootepensis* (Craib) Bremek. (Rubiaceae) have never been reported from the Indochinese Peninsula (Cambodia, Laos and Vietnam).
4. Besides *Jasminum vidalii*, several of these additions to the most recent checklists have already been reported from Laos: *Barringtonia racemosa* in *Flore Générale*

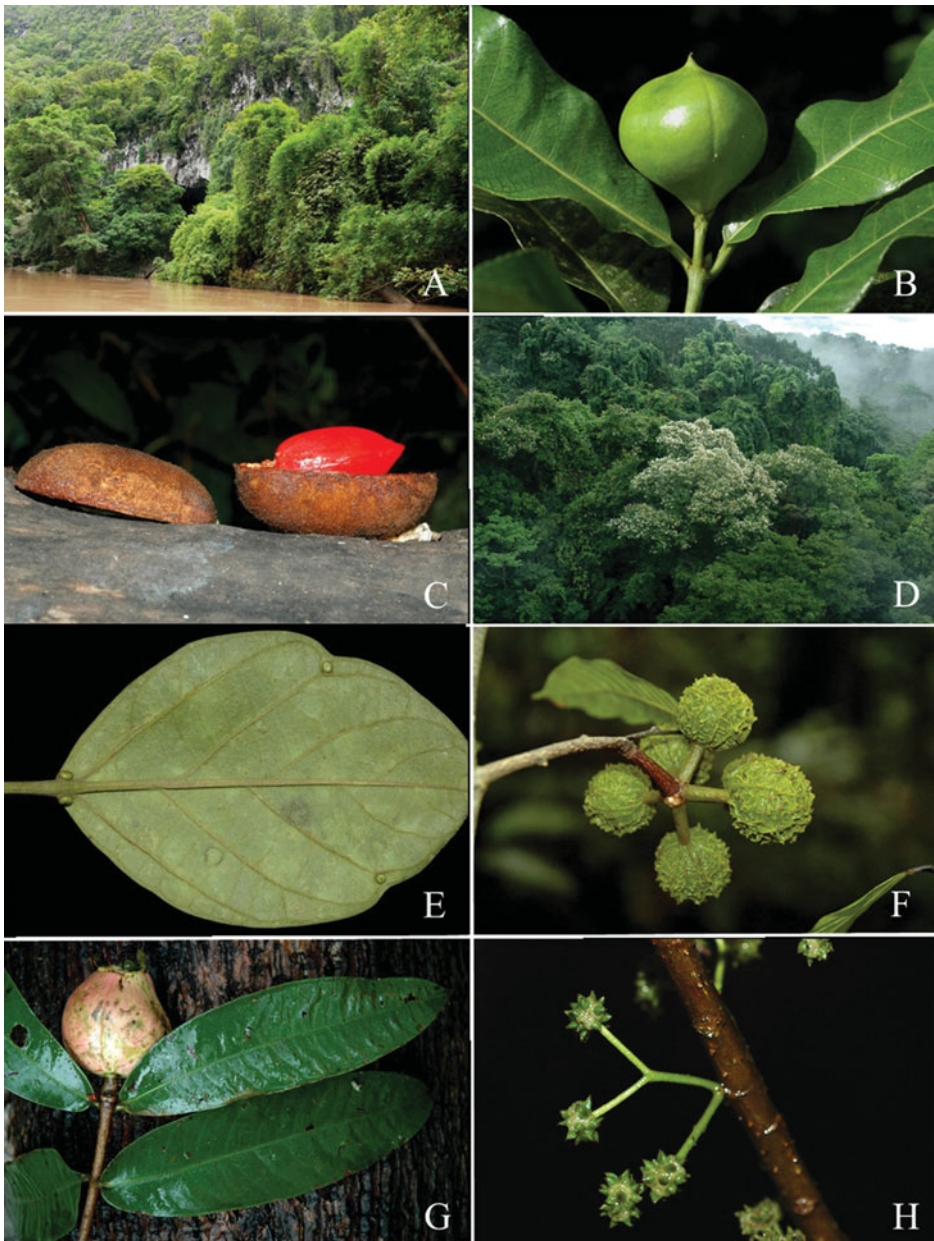


FIG. 5. A, Karst forest overlooking the river; B, *Excoecaria oppositifolia* Griff.; C, *Knema furfuracea* (Hook.f. & Thomson) Warb.; D, canopy view from the cinébulle, crown in bloom; E, laminar glands of *Endospermum chinense* Benth.; F, *Pseuduvaria rugosa* Blume (Merr.); G, *Syzygium megacarpum* (Craib) Rathakr. & N.C.Nair; H, *Oreocnide integrifolia* (Gaudich.) Miq.

de l'Indo-Chine (Gagnepain, 1921) and in the monograph of the genus by Payens (1967); *Syzygium megacarpum* (Craib) Rathakr. & N.C.Nair (Fig. 5G) and *Syzygium oblatum* (Roxb.) Wall. ex Steud. in Soh & Parnell's revision of Indochinese *Syzygium* (2015).

DISCUSSION

Taxonomic comments on selected species

The region's geographical position at the transition between several biogeographical regions, its history of dramatic changes in land area, and its habitat fragmentation in a mountainous landscape explain the high biodiversity of the area. Moreover, eastern Asia served as a late Tertiary or Quaternary refugium for many taxa (Manchester *et al.*, 2009; Lohman *et al.*, 2011).

Various floristic influences converge and meet in Laos. Plants belonging to the 'temperate' flora of the lower mountain regions of the Himalayas and southern China (the Sino-Himalayan floristic region) mix along Annamite reliefs with the 'tropical' flora elements of the western Malesian floristic region. Examples of these influences are reflected in our botanical findings.

Several taxa of the Sino-Himalayan floristic region, whose current distribution is centred in a region extending from Nepal or Assam to southern China, reach, in Laos, their southern distribution limits. They include, for instance, *Quercus oxyodon* Miq. (Fagaceae, also in Vietnam) and *Merremia bambusetorum* Kerr (Convolvulaceae, also in Cambodia, Thailand and Vietnam).

Many tropical Asian taxa, belonging to the Indo-Malesian flora, reach in Laos (or Vietnam) their northern distribution limits, such as *Antidesma velutinum* Tul. (Phyllanthaceae), *Excoecaria oppositifolia* Griff. (Euphorbiaceae) and *Ficus sundaica* Blume (Moraceae). Our new record of *Mangifera macrocarpa* Blume (Anacardiaceae) significantly extends northwards the distribution range of this species, which mostly occurs in western Indonesia, Malaysia, Singapore and peninsular Thailand.

Last, these preliminary results illustrate our limited knowledge of the flora of the area surveyed and of the flora of Laos in general. It is noteworthy that such a small sample contains so many species that have never been encountered here before.

ACKNOWLEDGEMENTS

We thank the Laotian government authorities for permission to collect material, and the curator of HNL, Ms Somsanith Bouamanivong; Soulivanh Lanorsavanh, (Department of Biology, NUoL), a Rubiaceae specialist; and NUoL students Thatsaphone Phaxaysombat and Phaivone Thamuangkhoun, for their valuable fieldwork contributions. We are grateful to the directors and staff of P who welcomed us during the identification work, especially Dr Thierry Deroin. We would like to thank Dr Paul Keßler (Hortus Botanicus Leiden), who kindly identified some Annonaceae specimens. We thank two anonymous reviewers for their helpful suggestions.

This inventory was conducted at the request of the National Science Council, with financial support mainly from the MAVA Foundation. We also thank the Institut Français de Pondichéry (India) and CIRAD, through its AMAP French Research Laboratory and the Delegation for International Scientific Exchanges, for their support.

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*Received 1 August 2017; accepted for publication 31 October 2017;
first published online 12 December 2017*