Mine versus Wild : a plant conservation checklist of the rich Iron-Ore Ngovayang Massif Area (South Cameroon)

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CHECKLIST

Mine versus Wild: a plant conservation checklist of the rich Iron-Ore Ngovayang Massif Area (South Cameroon)

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Background and aims – The rapid expansion of human activities in South Cameroon, particularly mining in mountainous areas, threatens this region's exceptional biodiversity. To comprehend the effects of land-use change on plant diversity and identify conservation priorities, we aim at providing a first comprehensive plant checklist of the Ngovayang Massif, focusing on the two richest plant families, Orchidaceae and Rubiaceae.
Location – The Ngovayang Massif Area (NMA) is located in the South Region of Cameroon. It is covered by lowland and submontane rainforest (100 to 1110 m elevation).
Methods – We compiled a dataset of 6116 georeferenced herbarium specimens, of which 2787 belong to Rubiaceae and Orchidaceae. We used rarefaction methods to explore sampling and diversity patterns, and investigated the altitudinal distribution of rare and/or threatened taxa.
Key results – The NMA, which houses about 1500 vascular plant taxa, is the richest documented area for Rubiaceae in Atlantic Central Africa (ACA) and the fifth for Orchidaceae, with respectively 281 and 111 taxa. Among these taxa, 178 (45%) are endemic to ACA and 67 (17%) are considered globally threatened according to IUCN categories and criteria. We show that higher elevation areas (> 750 m), which are also the main areas targeted for mining, are the richest in endangered and/or rare species. Three new records for Cameroon are reported here.
Conclusion – The NMA represents an Important Plant Area of Cameroon as confirmed by its exceptional plant diversity (> 20% of the total Flora of Cameroon), by the concentration of many threatened and/or restricted range species (10 taxa are strict endemics of the massif) as well as by the threat on rare habitats (i.e. the submontane vegetation above ~750 m elevation). A management plan involving *in situ* and *ex situ* conservation actions is urgently needed to reduce the potential threats of future mining activities.

Key words – Biodiversity, endangered species, Important Plant Area, iron and gold exploitation, new records, orchids, Rubiaceae, submontane forest.

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INTRODUCTION

The flora of Cameroon is one of the richest of the African continent, with about 7000 species recorded to date (Onana 2011, Sosef et al. 2017). Only 10.6% of the Cameroonian land is covered by protected areas (UNEP-WCMC 2018), which is smaller than the global protected area coverage of 14.7% (Saura et al. 2017). The knowledge of the distribution and conservation status of African plants is still patchy, and far below the target 2 of the Global Strategy for Plant Conservation which calls for a comprehensive list of the world's threatened plant species by 2020. Cameroon has been relatively well explored for plants compared to most other tropical African countries but prospecting efforts within the country have been very unequal (Onana 2011, Sosef et al. 2017), and the heterogeneous information on plant distribution limits its effective conservation actions.

The Ngovayang Massif Area (NMA, c. 527 km²) is located in Atlantic Central Africa (ACA), which mainly corresponds to the Lower Guinea subregion of White, the floristically richest phytochorion of the Guineo-Congolian region (White 1979, Droissart et al. 2018). The NMA represents a relatively well botanically sampled place in the South Region of Cameroon: more than 6000 herbarium specimens have been collected in this area (compared to the ~90 000 specimens collected in Cameroon, Sosef et al. 2017). This sampling effort represents thus more than 5% of the total number of specimens collected in Cameroon, while the surface of the NMA only represents 0.1% of the country. However, information on the distribution of the flora within the NMA is relatively poor because a large part of the herbarium collections are not precisely georeferenced. In fact, about half of them come from the earliest botanical explorer of the area, the German botanist Georg August Zenker (1855–1922), who collected c. 3000 specimens at "Bipindi". Until now, the only estimation for total number of plant species occurring in the NMA, i.e. 450 vascular plant species, was given by Gonmadje et al. (2011), unfortunately without indication of voucher specimens or sources used to generate this statistic.

The flora of the NMA was addressed in previous studies with more extensive geographic coverage, using a network of permanent sampling plots (1-hectare plot censused). A biogeographical study based on five 1-ha plots and 2673 censused trees with diameter above 10 cm at breast height (Gonmadje et al. 2012) showed that the lowland forests of NMA are dominated by Fabaceae-Caesalpinioideae (also known as Detarioideae), with a high proportion of Guineo-Congolian species (79%), and particularly Lower Guinean species (30%). An extended dataset (fifteen 1-ha plots) obtained by the same team (Gonmadje et al. 2017) has also proven that the decrease of above ground biomass of old-growth forests across an altitudinal gradient in the NMA can at least partially be explained by altitudinal filtering of large-tree species, highlighting the importance of elevational gradient in shaping flora composition.

Currently, the NMA does not have any legal conservation status, but is covered by three exploration permits (EP) with a total coverage of 2972 km² (electronic appendix 1): EP 144 covering the main part of the NMA, EP 195 located on N-NE part of NMA and EP 221 on SE part of NMA. The massif represents one of the largest iron deposits in Central Africa, and prospections have also shown a high percentage of gold in the lowland part, in the south eastern part of the NMA. Magnetite-gneiss ore has been identified as the primary source of iron ore in the NMA. During the prospective phase started near Melombo locality (EP 144) by the Australian exploration company "Legend Mining Limited", a report indicated the potential for a range of 300–500 Mt of magnetite ore, with a grade of 16–40% Fe (Wendt 2012), which confirms the potential of the NMA to host a large tonnage of magnetite deposits that can be economically exploited. Unpublished reports and one publication (Mimba et al. 2014) underlined that the highest concentrations of gold (Au > 100 ppb) are located in lower elevation areas in the south-eastern part of the NMA, in the heavy mineral fraction of stream sediments. The Legend Mining company announced on 5 August 2014 the completion of the sale of its Ngovayang project to the Indian company "Jindal Steel and Power" for a total of $17.5M. In these conditions, it is clear that required impact studies have to be conducted by these mining companies, and be based on appropriate, published and widely accessible data. In this context, the use of the Important Plant Areas (IPA) criteria system can offer a rigorous scientific tool to highlight gaps in the current protected areas network, and to render offsetting mechanisms consistent with conservation outcomes (Saenz et al. 2013, Darbyshire et al. 2017).

The amount, quality and accessibility of floristic data concerning the vascular flora of the NMA have significantly increased during the last 15 years, as a result of both recent efforts to combine several big datasets (Dauby et al. 2016, Sosef et al. 2017) and new botanical prospections relying on an accurate geographic positioning system. However, our knowledge about the spatial distribution of the flora and the conservation status of the species within the NMA remains sparse and has never previously been synthetized to date. The main objectives of the present contribution are thus: (1) to compile a database of all herbarium specimens collected in Ngovayang to date; (2) to produce a verified checklist of the two larger plant families present in the NMA, Rubiaceae and Orchidaceae; (3) to analyze sampling and diversity patterns of these two families in the NMA; (4) to identify threatened species within the NMA. Finally, based on our dataset, we also evaluate whether the NMA meets the criteria of Tropical Important Plant Areas according to Darbyshire et al. (2017). Here, we choose to concentrate our analysis on the Rubiaceae and the Orchidaceae first because the two families are important component of tropical forest; together they represent about 15% of the Cameroonian vascular flora (Onana 2011), and second because our team have extensively reviewed their taxonomy (e.g. Azandi et al. 2016, Zemagho et al. 2017) and geographic distribution (e.g. Droissart et al. 2011, Lachenaud et al. 2013) in Central Africa during the last 20 years.

MATERIAL AND METHODS

Herbarium records database

Based on recent fieldwork, i.e. the 15 field campaigns organized by our team between 2004 and 2017, and using the RAINBIO database (Dauby et al. 2016), we compiled a dataset with all herbarium collections available collected within

Table 1 – Checklist of Orchidaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Distribution categories considered: Wide = widely distributed; NMA = endemic to NMA; Cameroon = endemic to Cameroon; ACA = endemic to Atlantic Central Africa. IUCN Red List Categories considered: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient. New records for Cameroon are indicated by an asterisk (*). Sources for IUCN Red List Category: [a]IUCN (2018), [b]Onana (2011), [c]personal database, unpublished data, [d]Descourvières et al. (2013). One taxon (*Angraecopsis* sp.) not identified to species level is not included in the checklist.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Afropectinariella atlantica (Stévart & Droissart) M.Simo & Stévart	1	ACA	910	NT[a]
Afropectinariella gabonensis (Summerh.) M.Simo & Stévart	16	Wide	440–680	LC[a]
Afropectinariella pungens (Schltr.) M.Simo & Stévart	1	Wide	910	VU[a]
Ancistrochilus thomsonianus (Rchb.f.) Rolfe	2	ACA	570	LC[a]
Ancistrorhynchus brunneomaculatus (Rendle) Schltr.	5	Wide	100	DD
Ancistrorhynchus capitatus (Lindl.) Summerh.	15	Wide	260–1080	LC[b]
Ancistrorhynchus metteniae (Kraenzl.) Summerh.	4	Wide	290–900	LC[b]
Ancistrorhynchus schumannii (Kraenzl.) Summerh.	1	Wide	540	LC[b]
Ancistrorhynchus straussii (Schltr.) Schltr.	6	Wide	140–580	LC[b]
Ancistrorhynchus tenuicaulis Summerh.	4	Wide	550–1080	LC[c]
Angraecum angustum (Rolfe) Summerh.	2	ACA	570–580	EN[a]
Angraecum eichlerianum var. *curvicalcaratum* Szlach. & Olszewski	5	ACA	100–830	LC[c]
Angraecum ngovayangense sp. ined.	1	NMA	850	CR[c]
Bolusiella zenkeri (Kraenzl.) Schltr.	6	Wide	110–550	LC[b]
Brachycorythis kalbreyeri Rchb.f.	2	Wide	680–790	LC[b]
Bulbophyllum acutibracteatum De Wild. var. *acutibracteatum*	1	Wide	100	LC[b]
Bulbophyllum acutibracteatum var. *rubrobrunneopapillosum* (De Wild.) J.J.Verm.	3	Wide	530–640	LC[b]
Bulbophyllum alinae Szlach.	3	Cameroon	140–540	VU[a]
Bulbophyllum calyptratum Kraenzl.	3	Wide	110–900	LC[b]
Bulbophyllum calyptratum var. *graminifolium* (Summerh.) J.J.Verm.	3	Wide	80–110	LC[c]
Bulbophyllum calyptratum var. *lucifugum* (Summerh.) J.J.Verm.	1	Wide	470	DD
Bulbophyllum carnosisepalum J.J.Verm.	1	Wide	140	LC[b]
Bulbophyllum cochleatum Lindl.	16	Wide	140–950	LC[b]
Bulbophyllum colubrinum (Rchb.f.) Rchb.f.	1	Wide	620	LC[b]
Bulbophyllum dolabriforme J.J.Verm.*	1	ACA	910	EN[a]
Bulbophyllum falcatum var. *bufo* (Lindl.) Govaerts	1	Wide	910	LC[b]
Bulbophyllum falcatum var. *velutinum* (Lindl.) J.J.Verm.	8	Wide	100–570	LC[b]
Bulbophyllum fuscum Lindl.	1	Wide	800	LC[b]
Bulbophyllum fuscum var. *melinostachyum* (Schltr.) J.J.Verm.	16	Wide	100–800	LC[b]
Bulbophyllum imbricatum Lindl.	17	Wide	100–830	LC[b]
Bulbophyllum intertextum Lindl.	9	Wide	140–950	LC[b]
Bulbophyllum nigritianum Rendle*	1	Wide	570	DD

Table 1 (continued) – Checklist of Orchidaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Bulbophyllum oreonastes Rchb.f.	6	Wide	100–900	LC[b]
Bulbophyllum porphyrostachys Summerh.	3	ACA	100–140	NT[a]
Bulbophyllum pumilum (Sw.) Lindl.	8	Wide	140–570	LC[c]
Bulbophyllum resupinatum var. *filiforme* (Kraenzl.) J.J.Verm.	2	Wide	80	LC[b]
Bulbophyllum saltatorium var. *albociliatum* (Finet) J.J.Verm.	11	Wide	80–650	LC[b]
Bulbophyllum sandersonii (Hook.f.) Rchb.f.	7	Wide	100–650	LC[b]
Bulbophyllum sandersonii subsp. *stenopetalum* (Kraenzl.) J.J.Verm.	15	Wide	100–550	LC[b]
Bulbophyllum schimperianum Kraenzl.	1	Wide	1030	LC[b]
Bulbophyllum schinzianum Kraenzl. ex De Wild. var. *phaeopogon* (Schltr.) J.J.Verm.	3	Wide	unknown	LC[b]
Bulbophyllum teretifolium Schltr.	1	Cameroon	570	NT[c]
Calyptrochilum christyanum (Rchb.f.) Summerh.	7	Wide	100–570	LC[b]
Calyptrochilum emarginatum (Afzel. ex Sw.) Schltr.	2	Wide	260	LC[b]
Corymborkis corymbis Thouars	3	Wide	unknown	LC[b]
Cribbia confusa P.J.Cribb	1	Wide	620	LC[b]
Cynorkis gabonensis Summerh.	1	ACA	850	NT[c]
Cyrtorchis aschersonii (Kraenzl.) Schltr.	2	Wide	140	LC[b]
Cyrtorchis monteiroae (Rchb.f.) Schltr.	1	Wide	570	LC[b]
Cyrtorchis ringens (Rchb.f.) Summerh.	16	Wide	290–800	LC[b]
Diaphananthe bidens (Afzel. ex Sw.) Schltr.	7	Wide	100–570	LC[b]
Diaphananthe garayana Szlach. & Olszewski	8	Cameroon	100	EN[c]
Diaphananthe ichneumonea (Lindl.) P.J.Cribb & Carlsward	1	Wide	1030	LC[b]
Diaphananthe odoratissima (Rchb.f.) P.J.Cribb & Carlsward	5	Wide	80–100	LC[b]
Diaphananthe spiralis (Stévart & Droissart) P.J.Cribb & Carlsward	1	Wide	unknown	LC[b]
Diaphananthe pellucida (Lindl.) Schltr.	1	ACA	100	VU[c]
Dolabrifolia aporoides (Summerh.) Szlach. & Romowicz	25	Wide	100–980	LC[a]
Dolabrifolia bancoensis (Burg) Szlach. & Romowicz	2	Wide	570	LC[a]
Dolabrifolia disticha (Lindl.) Szlach. & Romowicz	3	Wide	570–720	LC[a]
Dolabrifolia podochiloides (Schltr.) Szlach. & Romowicz	1	Wide	540	LC[a]
Eggelingia gabonensis P.J.Cribb & Laan	7	ACA	570–1030	VU[c]
Gastrodia africana Kraenzl.	1	Cameroon	690	EN[c]
Genyorchis apetala (Lindl.) J.J.Verm.	1	Wide	570	LC[b]
Genyorchis platybulbon Schltr.	4	ACA	100–140	LC[c]
Graphorkis lurida (Sw.) Kuntze	3	Wide	440–680	LC[b]
Kylicanthe cornuata Descourvières, Stévart & Droissart	2	ACA	730–830	VU[c]
Liparis hallei Szlach.	1	Cameroon	230	EN[c]
Liparis platyglossa Schltr.	2	Wide	440–770	LC[b]

Table 1 (continued) – Checklist of Orchidaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Listrostachys pertusa (Lindl.) Rchb.f.	24	Wide	100–680	LC[b]
Manniella gustavi Rchb.f.	2	Wide	600–730	LC[b]
Orestias micrantha Summerh.	2	ACA	unknown	VU[c]
Polystachya adansoniae Rchb.f.	5	Wide	100–660	LC[b]
Polystachya affinis Lindl.	1	Wide	830	LC[b]
Polystachya albescens Ridl.	1	Wide	650	LC[b]
Polystachya batkoi Szlach. & Olszewski	1	ACA	550	VU[b]
Polystachya bipoda Stévart	1	ACA	830	VU[c]
Polystachya calluniflora Kraenzl.	3	Wide	620–1080	LC[b]
Polystachya caloglossa Rchb.f.	2	Wide	470–600	LC[b]
Polystachya camaridioides Summerh.	1	ACA	140	VU[c]
Polystachya coriscensis Rchb.f.	33	Wide	100–620	LC[c]
Polystachya dolichophylla Schltr.	19	Wide	110–620	LC[b]
Polystachya elegans Rchb.f.	12	ACA	140–570	LC[b]
Polystachya fusiformis (Thouars) Lindl.	2	Wide	830–1080	LC[b]
Polystachya golungensis Rchb.f.	1	Wide	950	LC[b]
Polystachya lejolyana Stévart	3	ACA	910–1060	EN[c]
Polystachya letouzeyana Szlach. & Olszewski	1	ACA	580	LC[c]
Polystachya moniquetiana Stévart & Geerinck	1	ACA	910	VU[c]
Polystachya obanensis Rendle	6	Wide	540–660	LC[b]
Polystachya odorata Lindl.	10	Wide	110	LC[b]
Polystachya polychaete Kraenzl.	25	Wide	140–900	LC[b]
Polystachya pyramidalis Lindl.	4	ACA	600–660	LC[c]
Polystachya ramulosa Lindl.	7	Wide	600–1080	LC[b]
Polystachya rhodoptera Rchb.f.	1	Wide	560	LC[b]
Polystachya riomuniensis Stévart & Nguema	3	ACA	620–760	VU[c]
Polystachya seticaulis Rendle	3	Wide	180–570	LC[b]
Polystachya supfiana Schltr.	11	ACA	570–900	LC[c]
Polystachya tessellata Lindl.	2	Wide	100–620	LC[c]
Polystachya victoriae Kraenzl.	3	Wide	680	NT[b]
Rangaeris rhipsalisocia (Rchb.f.) Summerh.	3	Wide	110	LC[b]
Rhipidoglossum curvatum (Rolfe) Garay	1	Wide	unknown	LC[b]
Rhipidoglossum montealenense Descourvières, Stévart & P.J.Cribb	2	ACA	730–910	EN[d]
Solenangis scandens (Schltr.) Schltr.	2	Wide	80	LC[b]
Stolzia elaidum (Lindl.) Summerh.	3	Wide	660–910	LC[c]
Tridactyle anthomaniaca (Rchb.f.) Summerh.	1	Wide	unknown	LC[b]

Table 1 (continued) – Checklist of Orchidaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Tridactyle brevicalcarata Summerh.	3	Wide	570–900	LC[b]
Tridactyle eggelingii Summerh.*	3	Wide	900	EN[c]
Tridactyle lagosensis (Rolfe) Schltr.	1	ACA	570	NT[b]
Tridactyle laurentii Schltr. var. *laurentii*	2	Wide	100–540	LC[b]
Vanilla africana Lindl.	1	Wide	unknown	LC[b]
Vanilla cucullata Kraenzl. ex J.Braun & K.Schum.	1	Wide	unknown	LC[b]
Zeuxine gilgiana Kraenzl. & Schltr.	1	Wide	unknown	LC[b]

or nearby the NMA. We took into consideration records that were explicitly mentioned as collected in NMA plus a radius of 3 km around the massif. We extracted 6116 georeferenced records using the shapefile of the Ngovayang area provided by the Interactive Forest Atlas of Cameroon (WRI 2012). For this paper, we focus our effort on the two larger families, Orchidaceae and Rubiaceae (2787 specimens together), for which the authors have particular taxonomic expertise: all specimens with doubtful identification for these two families were physically checked and verified. The species number estimates for other plant families collected in the NMA are mainly derived from Dauby et al. (2016).

Hereafter, for simplicity, we will use the term 'species' even if they comprise infraspecific taxa (subspecies or varieties).

Sampling completeness and diversity analysis

Sampling intensity and species richness were calculated for Rubiaceae and Orchidaceae using a fixed grid cell size of 0.02° × 0.02° (about 5 km^2) which was a reasonable balance between precision and detail that can be achieved in the NMA. Rarefaction methods were used to calculate an expected number of species (S_k) per grid cell found in subsamples of fixed size (see Droissart et al. 2012 for calculation). For our comparison with raw species richness, we calculate S_k for k = 20 (i.e. the grid cells where at least 20 herbarium specimens have been collected). Richness estimates and sampling completeness for Rubiaceae and Orchidaceae were compared with sample-based rarefaction curves using the R package *iNEXT* (Hsieh et al. 2016). We used the *iNEXT* package to compute the seamless rarefaction (interpolation) and extrapolation (prediction) sampling curves and the associated 95% confidence intervals of individual-based abundance data.

From the compiled herbarium database, we kept 2484 records with location accurate to 1 km for diversity analysis (grid-cells maps), and 1869 records with location accurate to 100 m for altitudinal range analysis. Maps were prepared with ArcMap 10.5.1 (ESRI 2017).

IUCN Red List category and conservation analysis

The conservation status of plant species was taken from existing IUCN assessments on the Red List website (IUCN 2018) or in the literature (e.g. Onana 2011, Onana & Cheek 2011, Onana 2013), when available. Eighty-three of these assessments have been provided or corrected based on the authors' more recent, unpublished data following the IUCN Red List guidelines (IUCN 2017). Most of these preliminary assessments are undergoing publication on the IUCN Red List portal.

To check objectively whether the NMA represents a key site for wild plant and habitat conservation in Central Africa, we applied the Important Plant Area (IPA) criteria using the revised guidelines and methodology recently provided by Darbyshire et al. (2017). A site can qualify as an IPA if it satisfies at least one of three main criteria (threatened species, botanical richness and threatened habitats). For each criterion, all sub-criteria and associated thresholds have been evaluated using the available data.

RESULTS

The rich flora of the Ngovayang Massif Area (NMA)

Our complete NMA dataset consists of 6116 specimens (of which 94% are identified to species), 138 families, 636 genera and 1472 species (see electronic appendix 2). These specimens were mainly extracted from the RAINBIO database (4924 specimens) and the additional specimens (1192) came from field expeditions led by the first and last authors between 2004 and 2017.

Most of the specimens from the NMA were collected during two main periods, between 1890 and 1930 (the contribution mostly of one collector: Zenker, see electronic appendix 3) and between 2004 and 2017 (electronic appendix 4). The last period added 318 species to the list of species previously known from the first collecting period which represents an increase of 21.6% (electronic appendix 3).

The two most represented families of the NMA, both in terms of species diversity and number of collections, are Ru-

Table 2 – Checklist of Rubiaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Distribution categories considered: Wide = widely distributed; NMA = endemic to NMA; Cameroon = endemic to Cameroon; ACA = endemic to ACA. IUCN Red List Categories considered are: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient. Sources for IUCN Red List Category: [a]IUCN (2018), [b]Onana (2011), [c]personal database, unpublished data, [d]Lachenaud et al. (2013), [e]Taedoumg et al. (2011), [f]Verstraete et al. (2013), [g]Sonké et al. (2015), [h]Sonké & Lachenaud (2016), [i]Zemagho et al. (2017), [j]Sonké et al. (2012). [1] Probably specifically distinct from the type variety. [2] *Pausinystalia brachythyrsum*, supposedly an endemic species of the NMA, proves to be identical with *Corynanthe johimbe* (Ntore & Lachenaud, unpublished data). Two taxa (*Canthium* sp. and *Pseudomussaenda* sp.) not identified to species level are not included in the checklist.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Adenorandia kalbreyeri (Hiern) Robbr. & Bridson	2	Wide	unknown	LC[b]
Aidia micrantha (K.Schum.) Bullock ex F.White (*s.l*)	30	Wide	80–840	LC[b]
Aidia rhacodosepala (K.Schum.) E.M.A.Petit	8	Cameroon	390	LC[b]
Aidia rubens (Hiern) G.Taylor	5	ACA	750–840	LC[b]
Aoranthe cladantha (K.Schum.) Somers	9	Wide	unknown	LC[b]
Argocoffeopsis subcordata (Hiern) Lebrun	8	Wide	450–770	LC[b]
Argostemma pumilum Benn.	1	Wide	980	DD
Atractogyne bracteata (Wernham) Hutch. & Dalziel	2	Wide	unknown	LC[b]
Aulacocalyx caudata (Hiern) Keay	17	ACA	90–840	LC[b]
Aulacocalyx jasminiflora Hook.f.	12	Wide	110–1010	LC[b]
Aulacocalyx mapiana Sonké & Bridson	4	Cameroon	200–790	EN[b]
Aulacocalyx talbotii (Wernham) Keay	1	ACA	unknown	LC[b]
Belonophora coriacea Hoyle	12	Wide	430–920	LC[b]
Belonophora ongensis S.E.Dawson & Cheek	3	ACA	730–940	CR[a]
Belonophora talbotii (Wernham) Keay	6	ACA	440–760	VU[a]
Belonophora wernhamii Hutch. & Dalziel	7	ACA	490–570	NT[b]
Bertiera aethiopica Hiern	26	Wide	450–1060	LC[b]
Bertiera batesii Wernham	6	ACA	430–830	LC[b]
Bertiera bicarpellata (K.Schum.) N.Hallé	20	Wide	80–1010	LC[b]
Bertiera bracteolata Hiern	3	Wide	430	LC[b]
Bertiera breviflora Hiern	21	Wide	80–1010	LC[b]
Bertiera elabensis K.Krause	18	ACA	80–540	LC[b]
Bertiera globiceps K.Schum.	7	Wide	570–1060	LC[b]
Bertiera heterophylla Nguembou & Sonké	3	NMA	120–440	CR[c]
Bertiera iturensis K.Krause	1	Wide	unknown	LC[b]
Bertiera laxa Benth.	25	Wide	90–910	LC[b]
Bertiera laxissima K.Schum.	19	Cameroon	450–930	LC[b]
Bertiera lejolyana Nguembou & Sonké	24	ACA	350–1010	LC[b]
Bertiera racemosa var. *elephantina* N.Hallé[1]	3	Wide	500–510	LC[b]
Bertiera retrofracta K.Schum.	39	ACA	80–1010	LC[b]
Calycosiphonia spathicalyx (K.Schum.) Robbr.	3	Wide	unknown	LC[b]
Chassalia bipindensis Sonké, Nguembou & A.P.Davis	36	Cameroon	130–920	LC[b]

Table 2 (continued) – Checklist of Rubiaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Chassalia chrysoclada (K.Schum.) O.Lachenaud	2	Wide	unknown	LC[c]
Chassalia corallifera (A.Chev. ex De Wild.) Hepper	1	Wide	900	LC[c]
Chassalia ischnophylla (K.Schum.) Hepper	4	ACA	110–1030	LC[b]
Chassalia laikomensis Cheek	1	ACA	1080	NT[d]
Chassalia macrodiscus K.Schum.	1	ACA	unknown	LC[b]
Chassalia pleuroneura (K.Schum.) O.Lachenaud	1	Wide	90	LC[b]
Chassalia subnuda (Hiern) Hepper	3	ACA	80–800	LC[b]
Chassalia tchibangensis Pellegr.	1	ACA	870	LC[c]
Chassalia zenkeri K.Schum. & K.Krause	25	ACA	110–620	LC[b]
Coffea brevipes Hiern	6	Wide	770–920	LC[a]
Coffea liberica Hiern	1	Wide	unknown	LC[a]
Coffea mannii (Hook.f.) A.P.Davis	20	Wide	80–1010	LC[a]
Coffea mapiana Sonké, Nguembou & A.P.Davis	9	Cameroon	540–940	VU[a]
Coffea mayombensis A.Chev.	7	Wide	510–1010	LC[a]
Colletoecema magna Sonké & Dessein	4	Cameroon	130–730	EN[c]
Corynanthe johimbe K.Schum.[2]	15	ACA	490–760	LC[c]
Corynanthe macroceras K.Schum.	7	Wide	unknown	LC[b]
Corynanthe pachyceras K.Schum.	11	Wide	unknown	LC[b]
Corynanthe talbotii (Wernham) Å.Krüger & Löfstr.	4	ACA	unknown	VU[b]
Craterispermum caudatum Hutch.	5	Wide	230–640	LC[b]
Craterispermum ledermannii K.Krause	16	ACA	90–810	LC[b]
Craterispermum parvifolium Taedoumg & Sonké	1	ACA	930	VU[e]
Craterispermum robbrechtianum Taedoumg & Sonké	19	ACA	90–1010	LC[e]
Cremaspora thomsonii Hiern	2	ACA	unknown	LC[b]
Cuviera acutiflora DC.	6	Wide	430	LC[b]
Cuviera physinodes K.Schum.	3	ACA	550–800	LC[c]
Cuviera subuliflora Benth.	5	ACA	unknown	LC[b]
Diodella sarmentosa (Sw.) Bacigalupo & Cabral ex Borhidi	1	Wide	540	LC[b]
Empogona gossweileri (S.Moore) Tosh & Robbr.	8	Wide	470–1080	LC[b]
Empogona macrophylla (K.Schum.) Tosh & Robbr.	2	Wide	unknown	LC[b]
Euclinia longiflora Salisb.	7	Wide	510–650	LC[b]
Euclinia squamifera (R.D.Good) Keay	1	ACA	unknown	LC[b]
Eumachia andeliae sp. ined.	2	ACA	570–800	LC[c]
Eumachia coffeosperma (K.Schum.) Razafim. & C.M.Taylor	4	Wide	440–900	LC[c]
Eumachia domatiicola (De Wild.) Razafim. & C.M.Taylor	3	Wide	850–1030	LC[c]
Eumachia insidens (Hiern) Razafim. & C.M.Taylor	4	Wide	380–770	LC[b]

Table 2 (continued) – Checklist of Rubiaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Eumachia letouzeyi (Robbr.) Razafim. & C.M.Taylor	7	ACA	540–850	LC[c]
Eumachia obovoidea (Verdc.) Razafim. & C.M.Taylor	4	Wide	80–430	LC[c]
Eumachia oddonii var. *cameroonensis* (Verdc.) C.M.Taylor[1]	4	Wide	910	LC[c]
Eumachia sciadephora (Hiern) Razafim. & C.M.Taylor	11	Wide	80–1080	LC[b]
Eumachia viridicalyx (R.D. Good) Razafim. & C.M.Taylor	1	ACA	unknown	DD
Gaertnera bieleri (De Wild.) E.M.A.Petit	10	Wide	230–910	LC[b]
Gaertnera letouzeyi Malcomber	2	ACA	730	EN[d]
Gaertnera trachystyla (Hiern) E.M.A.Petit	23	ACA	120–1030	LC[b]
Gardenia imperialis K.Schum.	9	Wide	80–420	LC[b]
Geophila afzelii Hiern	5	Wide	120–520	LC[b]
Geophila lancistipula Hiern	1	ACA	unknown	LC[b]
Geophila obvallata Didr.	3	Wide	80–570	LC[b]
Globulostylis leniochlamys (K.Schum.) Sonké, O.Lachenaud & Dessein	13	NMA	450–910	CR[c]
Globulostylis rammelooana Sonké, O.Lachenaud & Dessein	7	Cameroon	200–730	VU[f]
Globulostylis robbrechtiana Sonké, O.Lachenaud & Dessein	3	ACA	1080	NT[f]
Heinsia crinita (Afzel.) G.Taylor	3	Wide	710	LC[b]
Heinsia myrmoecia (K.Schum.) N.Hallé	4	ACA	unknown	LC[b]
Hekistocarpa minutiflora Hook.f.	2	ACA	520	LC[b]
Hymenocoleus globulifer Robbr.	2	ACA	910–1030	LC[c]
Hymenocoleus hirsutus (Benth.) Robbr.	2	Wide	180–830	LC[b]
Hymenocoleus nervopilosus Robbr.	2	Wide	440–550	LC[c]
Hymenocoleus neurodictyon (K.Schum.) Robbr.	2	Wide	760	LC[b]
Hymenocoleus rotundifolius (A.Chev. ex Hepper) Robbr.	1	Wide	550	LC[c]
Hymenocoleus scaphus (K.Schum.) Robbr.	1	Wide	380	LC[c]
Hymenocoleus subipecacuanha (K.Schum.) Robbr.	6	Wide	110–770	LC[c]
Ixora aneimenodesma K.Schum.	18	ACA	170–920	LC[b]
Ixora batesii Wernham	2	Cameroon	380–910	EN[a]
Ixora bauchiensis Hutch. & Dalziel	1	ACA	750	LC[b]
Ixora euosmia K.Schum.	7	ACA	120	LC[b]
Ixora guineensis Benth.	5	Wide	200–1030	LC[b]
Ixora hippoperifera Bremek.	26	ACA	110–730	LC[b]
Ixora macilenta De Block	5	ACA	110–800	LC[b]
Ixora minutiflora Hiern subsp. *minutiflora*	31	ACA	80–1010	LC[b]
Ixora nematopoda K.Schum.	3	ACA	310–760	LC[b]
Ixora praetermissa De Block	6	ACA	200–910	LC[b]
Ixora synactica De Block	10	Cameroon	190–780	EN[b]

Table 2 (continued) – Checklist of Rubiaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Keetia (?) sp. ined.	1	NMA	690	CR[c]
Keetia leucantha (K.Krause) Bridson	1	Wide	unknown	LC[b]
Keetia mannii (Hiern) Bridson	2	Wide	unknown	LC[b]
Keetia ripae (De Wild.) Bridson	5	Wide	unknown	LC[b]
Keetia venosa (Oliv.) Bridson	3	Wide	unknown	LC[b]
Kupeantha pentamera (Sonké & Robbr.) Cheek	33	ACA	180–920	LC[b]
Kupeantha spathulata (A.P.Davis & Sonké) Cheek	25	NMA	350–920	CR[c]
Lasianthus batangensis K.Schum.	19	Wide	200–1030	LC[b]
Leptactina arborescens (Welw. ex Benth. & Hook.f.) De Block	11	Wide	510	LC[b]
Leptactina involucrata Hook.f.	5	Wide	unknown	LC[b]
Leptactina latifolia K.Schum.	1	ACA	770	LC[c]
Leptactina mannii subsp. *arnoldiana* (De Wild.) Neuba ex Figueiredo	7	ACA	350–900	LC[b]
Massularia acuminata (G.Don) Bullock ex Hoyle	21	Wide	80–710	LC[g]
Massularia stevartiana Sonké, E.Bidault & Droissart	1	ACA	710	EN[g]
Mitragyna ledermannii (K.Krause) Ridsdale	5	Wide	unknown	LC[b]
Morelia senegalensis A.Rich. ex DC.	1	Wide	unknown	LC[b]
Morinda longiflora G.Don	4	Wide	unknown	LC[b]
Morinda lucida Benth.	2	Wide	unknown	LC[b]
Morinda morindoides (Baker) Milne-Redh.	2	Wide	430	LC[b]
Mussaenda arcuata Poir.	5	Wide	unknown	LC[b]
Mussaenda elegans Schumach. & Thonn.	3	Wide	unknown	LC[b]
Mussaenda tenuiflora Benth.	3	Wide	unknown	LC[b]
Nauclea diderrichii (De Wild.) Merr.	2	Wide	unknown	VU[a]
Nichallea soyauxii (Hiern) Bridson	34	Wide	110–940	LC[b]
Oldenlandia lancifolia (K.Schum.) DC	2	Wide	unknown	LC[b]
Otomeria micrantha K.Schum.	2	Wide	540–830	LC[b]
Otomeria volubilis (K.Schum.) Verdc.	1	Wide	unknown	LC[b]
Oxyanthus brevicaulis K.Krause	1	Wide	840	VU[b]
Oxyanthus doucetii Sonké & O.Lachenaud	1	Cameroon	430	VU[h]
Oxyanthus formosus Hook.f.	6	Wide	510–840	LC[b]
Oxyanthus gracilis Hiern	16	Wide	570–1030	LC[b]
Oxyanthus laxiflorus K.Schum. ex Hutch. & Dalziel	35	ACA	80–930	LC[b]
Oxyanthus oliganthus K.Schum.	9	Wide	unknown	VU[b]
Oxyanthus setosus Keay	13	ACA	630–930	LC[b]
Oxyanthus speciosus DC.	2	Wide	unknown	LC[b]
Oxyanthus unilocularis Hiern	6	Wide	430	LC[b]

Table 2 (continued) – Checklist of Rubiaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Parapentas setigera (Hiern) Verdc.	1	Wide	450	LC[b]
Pauridiantha arcuata (S.E.Dawson) Smedmark & B.Bremer	5	Cameroon	470–690	CR[b]
Pauridiantha divaricata (K.Schum.) Bremek.	8	ACA	550–910	VU[a]
Pauridiantha floribunda (K.Schum. & K.Krause) Bremek.	3	ACA	unknown	LC[b]
Pauridiantha makakana (N.Hallé) Smedmark & B.Bremer	19	ACA	440–910	NT[b]
Pauridiantha schumannii (Bremek.) Smedmark & B.Bremer	29	ACA	200–1030	LC[b]
Pauridiantha talbotii (Wernham) Ntore & Dessein	1	ACA	920	LC[b]
Pavetta bidentata Hiern	7	ACA	80–1080	LC[b]
Pavetta camerounensis S.D.Manning	25	ACA	90–1030	LC[b]
Pavetta gabonica Bremek.	9	ACA	570–1040	LC[b]
Pavetta hispida Hiern	11	ACA	110–910	LC[b]
Pavetta kribiensis S.D.Manning	3	Cameroon	110–310	EN[b]
Pavetta longibrachiata Bremek.	1	ACA	700	LC[b]
Pavetta microthamnus K.Schum.	3	Wide	680–800	LC[b]
Pavetta neurocarpa Benth.	11	ACA	200–730	LC[b]
Pavetta owariensis var. *opaca* S.D.Manning[1]	1	ACA	unknown	LC[b]
Pavetta renidens (K.Krause) Bremek.	6	ACA	440–650	LC[b]
Pavetta rigida Hiern	2	ACA	550	LC[b]
Pavetta staudtii Hutch. & Dalziel	4	ACA	unknown	LC[b]
Pavetta suffruticosa K.Schum.	11	ACA	500–940	LC[c]
Petitiocodon parviflorum (Keay) Robbr.	5	ACA	110–730	LC[b]
Pleiocoryne fernandensis (Hiern) Rauschert	4	Wide	unknown	LC[b]
Pouchetia africana A.Rich. var. *aequatorialis* N.Hallé[1]	5	Wide	110–630	LC[c]
Psychotria alatipes Wernham	13	ACA	260–1030	LC[b]
Psychotria anetoclada Hiern	1	ACA	830	LC[c]
Psychotria bifaria Hiern	3	Wide	130–470	LC[b]
Psychotria brandneriana (L.Linden) Robbr.	1	Wide	80	LC[c]
Psychotria breteleri O.Lachenaud	6	ACA	450–930	LC[c]
Psychotria brevifissa O.Lachenaud	7	ACA	570–1010	LC[c]
Psychotria calceata E.M.A.Petit	2	Cameroon	310	LC[b]
Psychotria conica O.Lachenaud subsp. *ngovayangensis* O.Lachenaud	1	NMA	700	CR[c]
Psychotria densinervia (K.Krause) Verdc.	3	ACA	870–1080	EN[a]
Psychotria dewildei O.Lachenaud	5	ACA	930–1030	LC[c]
Psychotria droissartii O.Lachenaud	2	ACA	90–790	VU[c]
Psychotria ebensis K.Schum.	11	ACA	310–910	LC[b]
Psychotria fimbriatifolia R.D.Good	3	Wide	760–910	LC[b]

Table 2 (continued) – Checklist of Rubiaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Psychotria foliosa Hiern	16	ACA	90–1030	LC[b]
Psychotria globiceps K.Schum.	7	ACA	430–1080	LC[b]
Psychotria hexamera (K.Schum.) O.Lachenaud	5	Cameroon	80–900	LC[c]
Psychotria humilis Hiern	1	ACA	560	LC[c]
Psychotria hypsophila K.Schum. & K.Krause	8	Wide	520–930	LC[b]
Psychotria ingentifolia E.M.A.Petit	4	Cameroon	810–910	LC[b]
Psychotria konguensis Hiern	9	Wide	440–930	LC[b]
Psychotria kupensis Cheek	10	ACA	200–1060	LC[c]
Psychotria lagenocarpa K.Schum.	3	ACA	260–560	LC[b]
Psychotria lanceifolia K.Schum.	18	ACA	200–850	VU[a]
Psychotria latistipula Benth.	14	ACA	80–810	LC[b]
Psychotria laxithyrsa O.Lachenaud	1	ACA	700	LC[c]
Psychotria ledermannii (K.Krause) Figueiredo	4	ACA	550–830	LC[c]
Psychotria leptophylla Hiern	20	Wide	90–940	LC[b]
Psychotria letouzeyi E.M.A.Petit	5	ACA	540–1080	LC[c]
Psychotria longicornis O.Lachenaud	2	ACA	800–1080	VU[c]
Psychotria lucens Hiern	4	Wide	550–620	LC[b]
Psychotria maesenii O.Lachenaud	1	ACA	830	VU[c]
Psychotria marantifolia O.Lachenaud	4	Cameroon	80–770	VU[c]
Psychotria pendulothyrsa O.Lachenaud	1	ACA	770	LC[c]
Psychotria potanthera Wernham	2	ACA	800–900	LC[c]
Psychotria raynaliorum O.Lachenaud	5	ACA	80–940	LC[b]
Psychotria retrorsipilis O.Lachenaud	6	NMA	710–1030	CR[c]
Psychotria rhizomatosa De Wild.	2	Wide	840–910	LC[b]
Psychotria rhynchodiscus O.Lachenaud	4	ACA	540–810	LC[c]
Psychotria rubescens (Hiern) O.Lachenaud	3	ACA	730–1030	LC[b]
Psychotria rubripilis K.Schum.	1	Wide	510	LC[c]
Psychotria satabiei O.Lachenaud	17	Cameroon	260–910	LC[b]
Psychotria senterrei O.Lachenaud	2	Cameroon	1010–1030	VU[c]
Psychotria sitae O.Lachenaud subsp. *holochlora* O.Lachenaud	2	ACA	640–1080	VU[c]
Psychotria solfiana K.Krause	16	ACA	230–1010	LC[c]
Psychotria subpunctata Hiern	1	Wide	560	LC[c]
Psychotria taedoumgii O.Lachenaud	2	Cameroon	620–650	NT[c]
Psychotria thonneri (De Wild. & T.Dur.) O.Lachenaud	4	Wide	830–1080	LC[c]
Psychotria varians O.Lachenaud	15	Wide	600–1080	LC[c]
Psychotria venosa (Hiern) E.M.A.Petit	5	ACA	unknown	LC[b]

Table 2 (continued) – Checklist of Rubiaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Psychotria villicarpa O.Lachenaud subsp. *sessilis* O.Lachenaud	9	NMA	540–930	CR[c]
Psychotria vogeliana Benth.	7	Wide	80	LC[b]
Psydrax acutiflora (Hiern) Bridson	4	Wide	unknown	LC[b]
Psydrax arnoldiana (De Wild. & T.Durand) Bridson	1	Wide	unknown	LC[b]
Psydrax subcordata (DC.) Bridson	2	Wide	unknown	LC[b]
Rothmannia hispida (K.Schum.) Fagerl.	12	Wide	110–940	LC[b]
Rothmannia lateriflora (K.Schum.) Keay	16	Wide	110–1010	LC[b]
Rothmannia libisa N.Hallé	3	Wide	540–810	LC[b]
Rothmannia longiflora Salisb.	11	Wide	430	LC[b]
Rothmannia macrocarpa (Hiern) Keay	2	Wide	510–840	LC[b]
Rothmannia octomera (Hook.) Fagerl.	3	Wide	80–910	LC[b]
Rothmannia talbotii (Wernham) Keay	6	Wide	110–810	LC[b]
Rothmannia whitfieldii (Lindl.) Dandy	5	Wide	430	LC[b]
Rutidea decorticata Hiern	7	Wide	650	LC[b]
Rutidea glabra Hiern	10	ACA	200–410	LC[b]
Rutidea hispida Hiern	7	ACA	80–930	LC[b]
Rutidea olenotricha Hiern	1	Wide	unknown	LC[b]
Rutidea rufipilis Hiern	1	ACA	unknown	LC[b]
Rutidea smithii Hiern	3	Wide	unknown	LC[b]
Rytigynia membranacea (Hiern) Robyns	3	ACA	unknown	LC[b]
Rytigynia robusta sp. ined.	1	Wide	1010	LC[c]
Sabicea africana (P.Beauv.) Hepper	4	Wide	80–690	LC[b]
Sabicea apocynacea (K.Schum.) Razafim., B.Bremer, Liede & Saleh A.Khan	1	ACA	930	EN[b]
Sabicea calycina Benth.	5	Wide	540–1040	LC[b]
Sabicea capitellata Benth.	4	Wide	930	LC[b]
Sabicea dinklagei K.Schum.	1	Wide	unknown	LC[b]
Sabicea gabonica (Hiern) Hepper	3	ACA	90–870	LC[b]
Sabicea gigantostipula K.Schum.	2	ACA	810	LC[b]
Sabicea gracilis Wernham	1	Cameroon	90	DD
Sabicea laxa Wernham	2	ACA	unknown	EN[b]
Sabicea medusula K.Schum. ex Wernham	5	Wide	410–730	LC[i]
Sabicea pilosa Hiern	1	ACA	unknown	LC[b]
Sabicea trigemina K.Schum.	1	NMA	unknown	CR[b]
Sabicea venosa Benth.	2	Wide	unknown	LC[b]
Sabicea xanthotricha Wernham	1	ACA	910	EN[a]
Schumanniophyton magnificum (K.Schum.) Harms	3	Wide	750–840	LC[b]

Table 2 (continued) – Checklist of Rubiaceae from Ngovayang Massif Area (NMA), with their geographical and altitudinal range and their IUCN categories.

Species	# specimens	Geographical range	Altitudinal range (m)	IUCN category
Sericanthe auriculata (Keay) Robbr.	10	ACA	200–920	VU[b]
Sericanthe lowryana Sonké & Robbr.	4	Cameroon	660–760	EN[j]
Sericanthe jacfelicis (N.Hallé) Robbr.	1	ACA	710	VU[b]
Sherbournia buccularia N.Hallé	1	ACA	unknown	LC[b]
Sherbournia hapalophylla (Wernham) Hepper	3	Wide	unknown	LC[b]
Sherbournia streptocaulon (K.Schum.) Hepper	8	ACA	730	LC[b]
Sherbournia zenkeri Hua	2	Wide	450	LC[b]
Tarenna bipindensis (K.Schum.) Bremek.	17	Wide	630–660	LC[b]
Tarenna conferta (Benth.) Hiern	5	Wide	unknown	LC[b]
Tarenna eketensis Wernham	4	Wide	650	LC[b]
Tarenna fusco-flava (K.Schum.) S.Moore	1	Wide	unknown	LC[b]
Tarenna grandiflora (Benth.) Hiern	19	Wide	80–760	LC[b]
Tarenna lasiorhachis (K.Schum. & K.Krause) Bremek.	13	Wide	200–550	LC[b]
Tarenna pallidula Hiern	4	Wide	600–900	LC[b]
Tarenna precidantenna N.Hallé	14	Wide	370–920	LC[b]
Tricalysia amplexicaulis Robbr.	3	ACA	570	LC[c]
Tricalysia atherura N.Hallé	1	ACA	630	VU[a]
Tricalysia coriacea (Benth.) Hiern	2	Wide	unknown	LC[b]
Tricalysia elliotii (K.Schum.) Hutch. & Dalziel	1	Wide	560	LC[c]
Tricalysia ferorum Robbr.	1	ACA	130	VU[c]
Tricalysia lasiodelphys (K.Schum. & K.Krause) A.Chev.	8	ACA	790–910	LC[b]
Tricalysia pangolina N.Hallé	2	ACA	650–710	LC[b]
Tricalysia sp. ined.	1	NMA	410	CR[c]
Tricalysia sylvae Robbr.	24	ACA	90–940	LC[c]
Tricalysia vadensis Robbr.	12	ACA	200–770	VU[c]
Trichostachys aurea Hiern	4	Wide	380–950	LC[b]
Vangueriella chlorantha (K.Schum.) Verdc.	27	ACA	90–850	LC[c]
Vangueriella laxiflora (K.Schum.) Verdc.	22	Wide	260–930	LC[c]
Vangueriella letestui Verdc.	1	ACA	unknown	EN[c]
Vangueriella nigerica (Robyns) Verdc.	1	Wide	unknown	LC[b]
Vangueriella nigricans (Robyns) Verdc.	3	Wide	560	LC[b]
Vangueriella zenkeri Verdc.	2	Cameroon	930	EN[b]
Virectaria procumbens (Sm.) Bremek.	3	Wide	430–550	LC[c]

Table 3 – Summary statistics for main areas of Atlantic Central Africa with published inventory data for Orchidaceae and Rubiaceae (SR = species richness).
Areas are classified according to their size (km^2).

Place names	Area (km^2)	Altitudinal range (m)	SR total	SR Orchidaceae	SR Rubiaceae	Sources
Dom, Bamenda Highland (Cameroon)	4.5	1550–1930	356	12	34	Cheek et al. (2010)
Bali Ngemba FR (Cameroon)	10	1800–2200	619	66	35	Harvey et al. (2004)
Mefou "proposed" NP (Cameroon)	10	600–900	863	28	103	Cheek et al. (2011)
Annobón Island (Equatorial Guinea)	17	0–598	365	28	16	Velayos et al. (2014)
Ngovayang (Cameroon)	527	0–1110	1472	111	281	This paper
São Tomé and Príncipe	990	0–2024	1104	124	74	Figueiredo et al. (2011)
Lebialem Highlands (Cameroon)	1223	250–2000	412	33	68	Harvey et al. (2010)
Mount Oku (Cameroon)	1550	1100–3011	920	85	36	Cheek et al. (2000)
Bioko Island (Equatorial Guinea)	2000	0–3011	842	136	170	Velayos et al. (2013)
Mounts Kupe-Manengouba (Cameroon)	2390	500–2411	2412	183	213	Cheek et al. (2004)
Mount Cameroon (Cameroon)	2700	0–4040	2435	147	261	Cable & Cheek (1998)
Gabon	257700	0–1070	5236	400	640	Sosef et al. (2006); Vande weghe et al. (2016)
Cameroon	475000	0–4040	6883	489	718	Onana (2011)

biaceae (2237 specimens, 65 genera, 281 species) and Orchidaceae (550 specimens, 32 genera, 111 species), followed by Fabaceae s. lat. (306 specimens, 56 genera, 92 species) (electronic appendix 5).

A detailed checklist for Rubiaceae and Orchidaceae

We here confirm the presence of 281 Rubiaceae species and 111 Orchidaceae species in the NMA (detailed checklists for these two families are presented in tables 1 & 2). Among areas of comparable size in ACA for which species checklists have previously been published, the NMA ranks first for the diversity of Rubiaceae, and fifth for Orchidaceae (table 3, electronic appendix 6).

Bulbophyllum and *Polystachya* (27 species each, 24% of the total for each) are the most diverse genera of Orchidaceae within the NMA. Thirty-nine orchid species have only been collected once in the NMA and one species new to science is reported from there, *Angraecum ngovayangense* sp. ined. which is endemic to the massif (table 1). This taxonomic novelty is currently being published elsewhere. Three orchid species represent new records for Cameroon (table 1): *Bulbophyllum dolabriforme*, *B. nigritianum* and *Tridactyle eggelingii*.

Among the Rubiaceae, the most diverse genera are *Psychotria* (51 species, 18% of the total) and *Bertiera* (14 species, 5% of the total), ex-aequo with *Sabicea* (14 species as well). Fifty-seven species have only been collected once in the NMA, and nine species are endemic to the NMA (*Kupeantha spathulata*, *Bertiera heterophylla*, *Globulostylis leniochlamys*, *Keetia* (?) sp. ined., *Psychotria conica* subsp. *ngovayangensis*, *P. retrorsipilis*, *P. villicarpa* subsp. *sessilis*, *Sabicea trigemina*, *Tricalysia* sp. ined.). We did not find any new records for Cameroon, but several Rubiaceae species previously thought to have a more northern distribution in Cameroon have been discovered in the NMA thanks to recent prospections: *Aulacocalyx mapiana*, *Chassalia laikomensis*, *Gaertnera letouzeyi* and *Petitiocodon parviflorum*. Four species new to science are also reported from the NMA (see species referred to as "sp. ined." in table 2) and will be published elsewhere.

Sampling and diversity patterns of Rubiaceae and Orchidaceae

The botanical exploration of the NMA and the knowledge of distributional patterns of Rubiaceae and Orchidaceae within the massif is far from complete (fig. 1), but general trends can nevertheless be identified. The 2484 georeferenced specimens collected for the two families are mostly concentrated around eight villages bordering the NMA (fig. 1A), that represent fieldwork starting points. Looking at raw data (fig. 1B & 1C), species richness is correlated with the historical sampling effort (Pearson correlation coefficient R = 0.95). For instance, the grid overlapping the Bipindi locality is by far the most sampled (582 herbarium records) and species-rich (183 Rubiaceae and Orchidaceae species).

When using the subsampling procedure (fig. 1D), the correlation between sampling and richness patterns becomes blurred (Pearson correlation coefficient R = 0.07), and several grid cells scattered all over the NMA present high expected diversity values.

The assessment of sampling completeness through interpolation and extrapolation curves (fig. 2) shows that, in terms of total species richness, Rubiaceae and Orchidaceae are relatively well known in the NMA; observed sample coverage values being over 90% for both families. From the extrapolation curves, one could expect that total species richness is comprised between 298 and 339 species for Rubiaceae and between 124 and 186 species for Orchidaceae (95% lower and upper confidence limits).

The analysis of altitudinal distribution of Rubiaceae and Orchidaceae in the NMA reveals that the observed (or expected) number of species for both families tends to increase along the elevation gradient, the areas above 750 m having the highest values (fig. 3). However, extrapolation values between 250 and 500 m and > 750 m for Orchidaceae, and < 250 m for Rubiaceae must be interpreted cautiously because sample coverage is weak (i.e. below 0.75) at these elevation intervals.

Geographical range and conservation status of Rubiaceae and Orchidaceae

About a quarter (27%) of the Orchidaceae and more than half (53%) of the Rubiaceae recorded in the NMA are endemic to ACA (fig. 4). Nine Rubiaceae and one Orchidaceae are endemic to the NMA.

The proportions of threatened (VU, EN, CR) species are 17% and 18% for Rubiaceae and Orchidaceae, respectively (fig. 5).

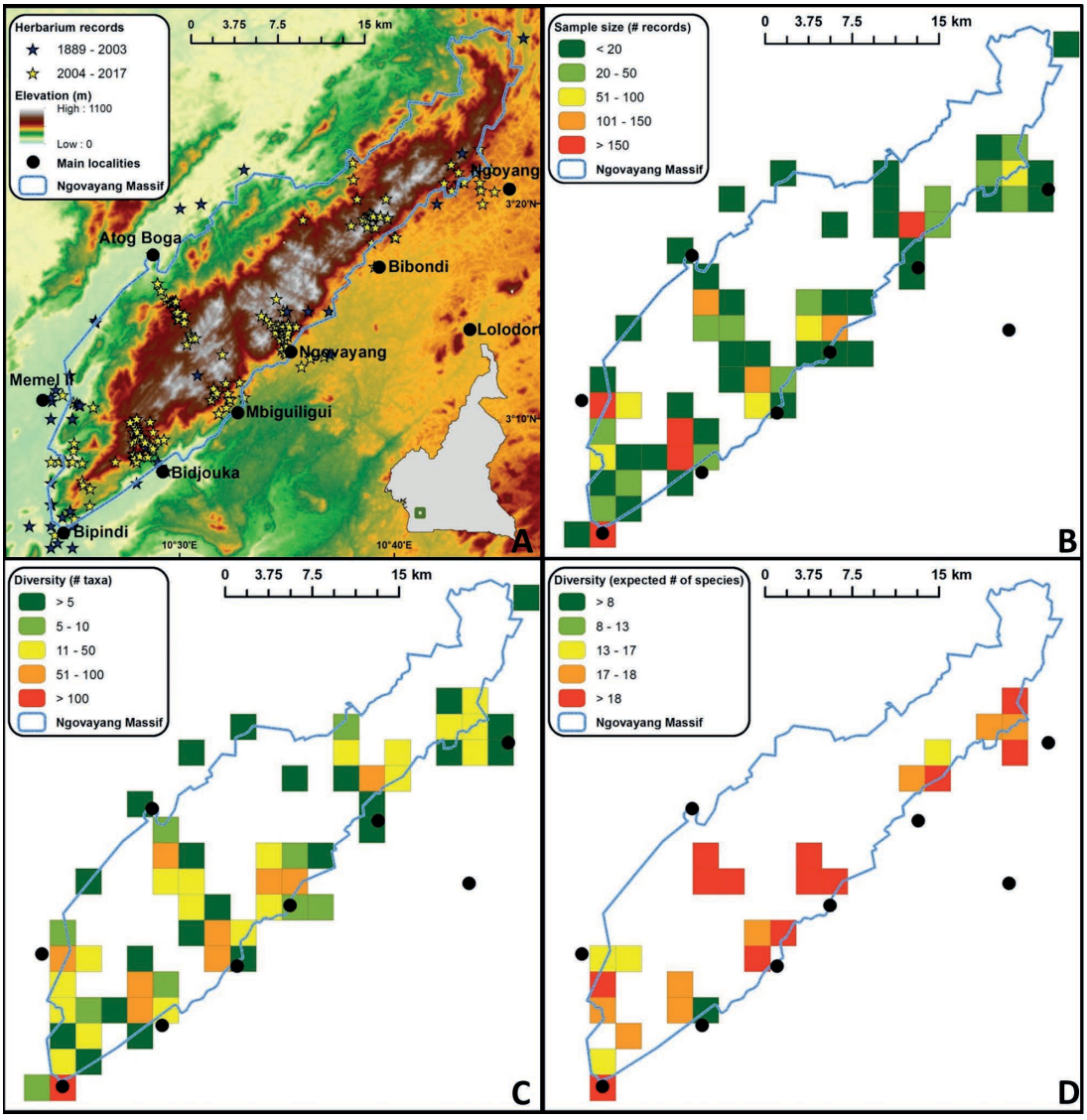

Figure 1 – Botanical exploration of Rubiaceae and Orchidaceae in the Ngovayang Massif Area (NMA): A, localization of historical (1889–2003) and recent (2004–2017) herbarium records made in the NMA; B, number of herbarium records (samples) collected per 0.05° grid-cells; C, number of species collected per 0.05° grid-cells; D, expected number of species calculated for 0.05° grid-cells that contain at least 20 herbarium records ($S_{k=20}$).

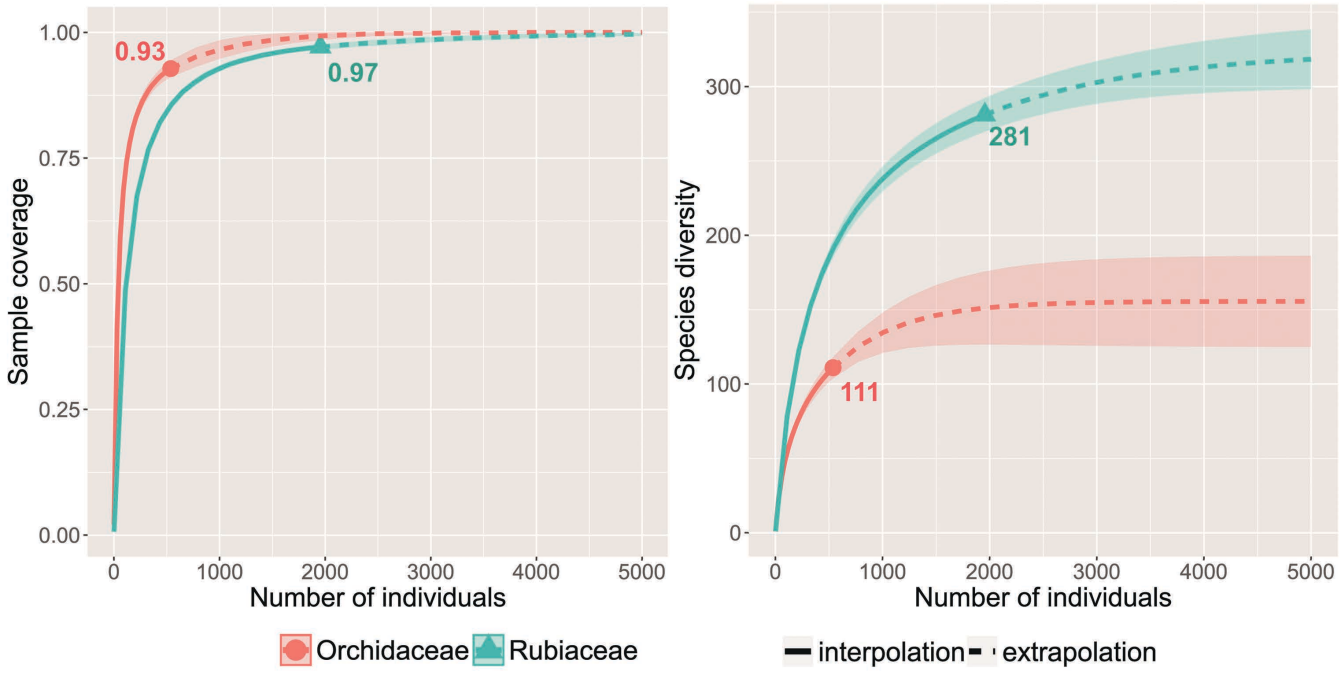

Figure 2 – Sampling completeness (left) and diversity estimates (right) for Rubiaceae and Orchidaceae in the NMA. Rarefaction/interpolation (solid line segment) and extrapolation (dotted line segments) curves are based on abundance data and represented with 95% confidence intervals (shaded areas). The numbers below rarefaction curves indicate the observed sample completeness (left) and species richness (right).

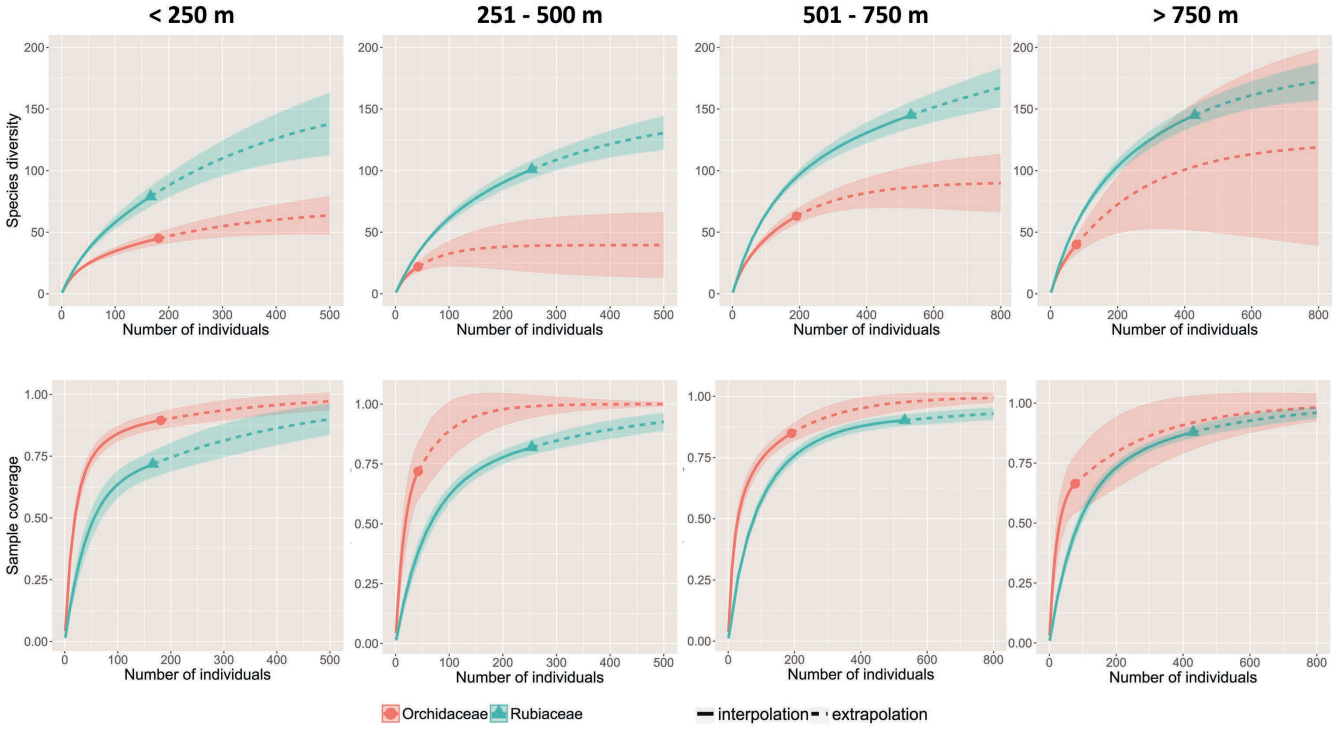

Figure 3 – Diversity estimates (upper graphs) and sampling completeness (lower graphs) for Orchidaceae and Rubiaceae along the elevation gradient in the NMA. Interpolation (solid line segment) and extrapolation (dotted line segments) curves are based on abundance data and represented with 95% confidence intervals (shaded areas).

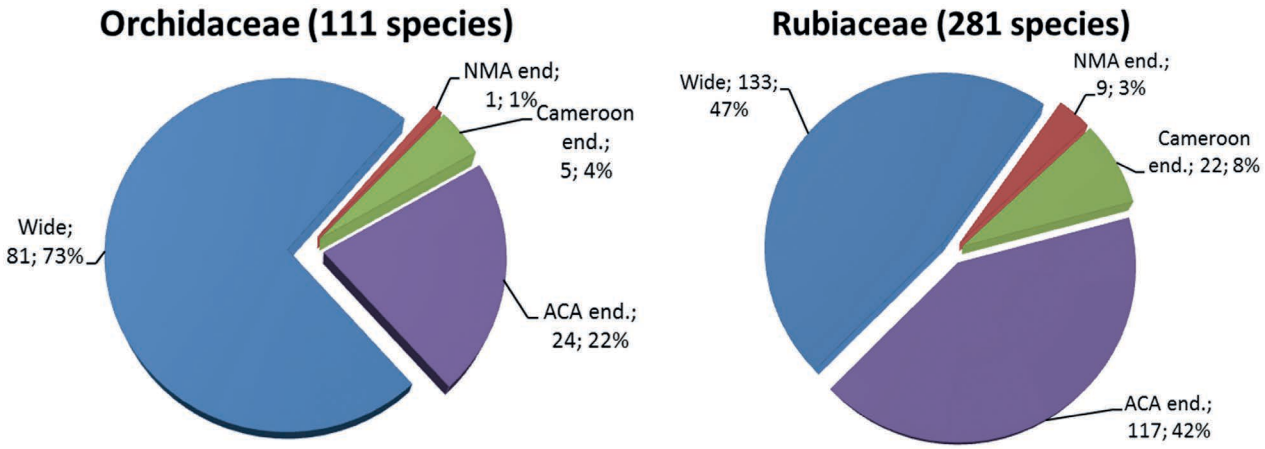

Figure 4 – Geographical range for Rubiaceae and Orchidaceae recorded from the NMA. Distribution categories considered are: Wide = Widely distributed; NMA end. = endemic to NMA; Cameroon end. = endemic to Cameroon; ACA end. = endemic to Atlantic Central Africa.

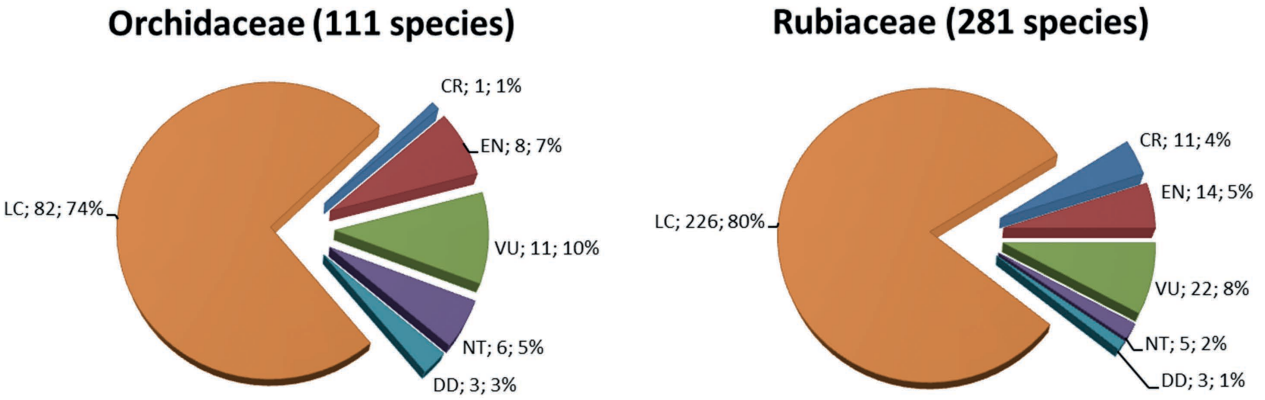

Figure 5 – Proportion of threatened species for Orchidaceae and Rubiaceae recorded from the NMA. IUCN Red List Categories considered are: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient.

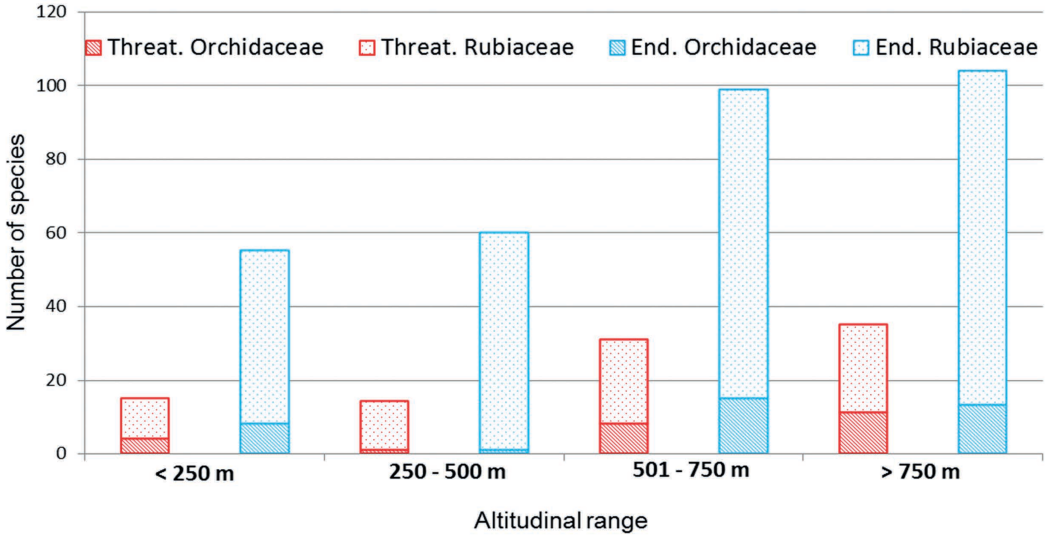

Figure 6 – Number of threatened (= Threat.) species (in red) and species endemic (= End.) to ACA (in blue) along the altitudinal gradient in the NMA.

Table 4 – **Application of Important Plant Area (IPA) criteria to the flora of the Ngovayang Massif Area (NMA).**
IUCN Red List Categories considered are: CR = Critically Endangered; EN = Endangered; VU = Vulnerable. EOO = Extent of Occurrence.

IPA criteria and sub-criteria	Ngovayang Massif Area (NMA)
(A) Threatened species	
A(i) Site contains one or more globally threatened species	Forty-seven Rubiaceae and 20 Orchidaceae are considered globally threatened (CR, EN or VU) according to IUCN category and criteria (tables 1 & 2, this paper). Fourteen assessments (four Orchidaceae, ten Rubiaceae) are currently published on the IUCN global Red List (IUCN 2018).
A(ii) Site contains one or more regionally threatened species	Not evaluated, all species considered here have been assessed globally.
A(iii) Site contains one or more highly restricted endemic species that are potentially threatened	Ten species (1 Orchidaceae, 9 Rubiaceae) are strict endemic to NMA. Twelve species (1 Orchidaceae, 11 Rubiaceae) are assessed as CR (EOO < 100km^2).
A(iv) Site contains one or more range restricted endemic species that are potentially threatened	Twenty-seven species (22 Rubiaceae and 5 Orchidaceae) present in the NMA are endemic to Cameroon. Additionally, 22 species (8 Orchidaceae, 14 Rubiaceae) are assessed as EN (100 km^2 < EOO < 5000 km^2).
(B) Botanical richness	
B(i) Site contains a high number of species within defined habitat or vegetation types	The NMA houses 21.4% of the total number of plant species recorded to date for Cameroon (1472 species in NMA out of a total of 6883 species), all these species are linked with tropical evergreen forest (lowland forest and submontane forest). Thirty-three Rubiaceae and 16 Orchidaceae are characteristic species for submontane forest and were only collected above 750 m in the NMA.
B(ii) Site contains an exceptional number of species of high conservation importance	Thirty-seven species (31 Rubiaceae and 6 Orchidaceae) present in the NMA are endemic to the massif or to Cameroon, which represent 4.5% of the 815 rare or threatened species documented for Cameroon (Onana & Cheek 2011). The NMA represent one of the 15 richest sites for Cameroon (third richest documented site after Mt Cameroon and Mts Kupe/Manengouba).
B(iii) Site contains an exceptional number of socially, economically or culturally valuable species	Not evaluated.
(C) Threatened habitat	
C(i) Site contains globally threatened or restricted habitat/ vegetation type	Not evaluated.
C(ii) Site contains regionally threatened or restricted habitat/vegetation type	Not evaluated.
C(iii) Site contains nationally threatened or restricted habitat/vegetation type, AND/OR habitats that have severely declined in extent nationally	Not precisely evaluated, but considering a lower limit of 750 m, Ngovayang might contain more than 5% of submontane vegetation present in Cameroon. Considering the continuous extend of the submontane forest in the NMA, the site represents one of the 5 "best sites" for that habitat nationally.

The number of restricted range and threatened species increases with altitude (fig. 6), being double the number above 750 m than below 250 m. Above 750 m, our database reports the presence of 35 species threatened with extinction and 104 species endemic to ACA.

The NMA must be considered as an Important Plant Area (IPA) in ACA, as confirmed by its exceptional plant diversity (> 20% of the total flora of Cameroon), by the concentration of many threatened and/or restricted range species (67 taxa are considered globally threatened according to IUCN and ten taxa are strict endemics of the massif) as well as by the threat to rare habitats (i.e. the submontane forest vegetation above ~750 m elevation). The current knowledge of Rubiaceae and Orchidaceae collected in the NMA as well as their habitat (table 4), allows the NMA to qualify for IPA's criterion *A(i, iii, iv) B(i,ii) C(iii)*.

DISCUSSION

The NMA, an Important Plant Area

The NMA houses 21.4% of the total number of plant species recorded to date for Cameroon, while its surface area only represents 0.1% of the country (table 3). It represents the third richest documented site for Cameroon after the Mount Cameroon National Park (2435 plant species, Cable & Cheek 1998) and the Kupe, Mwanenguba and Bakossi Mountains (2412 plant species, Cheek et al. 2004). For the two families here studied in detail (Rubiaceae and Orchidaceae), 17.1% of the species occurring in the NMA are considered threatened according to IUCN red list categories and criteria (IUCN 2012). Additionally, 45% of the Rubiaceae and Orchidaceae

recorded from the NMA are restricted-range species and endemic to ACA. Though no precise vegetation mapping has been made for the NMA to date, we can recognize two main types: the lowland evergreen forest between 0 and 750 m and the submontane vegetation above 750 m (33 Rubiaceae and 16 Orchidaceae were only collected above this elevation in the NMA, table 1 & 2). We also observed particular submontane vegetation associated with rock outcrops during our recent inventories near the locality of Atog Boga, but this habitat remains to date underexplored.

The exceptional plant diversity and endemism level of the NMA should be linked to both environmental/geomorphological gradients and past climatic conditions. The NMA is part of a series of small mountain range stretching along the ocean coast from Southern Cameroon to Congo Brazzaville, and corresponding to several, isolated and putative forest refuges during drier and cooler climatic periods of the Quaternary (Maley 1987, Maley et al. 2018). Based on distribution pattern of endemic orchids to ACA, this series of small mountain ranges has been considered as a unique but discontinuous area of endemism (Droissart 2009). Several species in our checklist such as *Colletoecema magna*, *Kupeantha spathulata*, *Afropectinariella atlantica*, *Polystachya bipoda* and *P. lejolyana* are indeed only present in small hills distributed south of the NMA. In addition, several species, which are otherwise largely restricted to southwest Cameroon, are represented by isolated populations in the NMA, e.g. *Aulacocalyx mapiana*, *Chassalia laikomensis*, *Gaertnera letouzeyi*, *Petitiocodon parviflorum*, *Psychotria taedoumgii*, *Dolabrifolia podochiloides* and *Bulbophyllum teretifolium*. As proposed by Gonmadje et al. (2011), the presence of restricted-range species reaching either the most southern or most northern part of their distribution in the NMA tends to confirm that the massif is located at the junction of various phytogeographical influences. In most cases these restricted-range species occur in relatively high elevation areas (e.g. *Chassalia laikomensis* only above 1000 m) and their discovery in the massif is recent, so other similar findings should be expected in the future. Their presence reinforces the importance of the NMA in terms of conservation, and underlines the necessity of developing conservation strategies for these species whose habitat will be strongly impacted by mining activities in the near future.

Mining threats on the NMA rich biodiversity

Africa is facing an unprecedented mining boom (Edwards et al. 2014) that will potentially have severe impact on the biodiversity of areas with recorded mineral resources. The area affected by mining exploitation depends on the mineral being mined (Edwards 2001), iron exploitation being one of the worse in terms of surface impacted. For biologists, who are usually not involved in the definition of the methods and area to be exploited, it is always extremely difficult to determine what will be the impact of mining on biodiversity and habitats. However, according to aeromagnetic maps produced during the mining exploration stage (electronic appendix 1), the highest concentrations of iron are found in the highest elevation areas of the NMA, i.e above 750 m, which are also the richest in endangered and/or rare species (fig. 6). Before starting the effective mining exploitation of the NMA, it is thus essential to set up mitigation and offsetting mechanisms in order to minimize the impact on the environment. The present work highlights several species on which such mitigation programmes should be addressed first, such as the 12 Critically Endangered (CR) species identified for Rubiaceae and Orchidaceae (tables 1 & 2). We have initiated *ex situ* collections and a seedbank in Yaoundé, but this initiative currently covers only a small fraction of the threatened species of the NMA (less than 10%) due to limited resources. In addition, *ex situ* conservation may be very difficult for some species, e.g. due to their peculiar habitat requirements or low germination rates and, for these species, *in situ* conservation and management plans are urgently required.

CONCLUSION

The NMA represents one of the richest inventoried areas of ACA in terms of plant diversity (table 3). Additional fieldwork in less accessible and/or undersampled areas will certainly reinforce this picture and will allow a better understanding of the distribution and conservation status of plant species within the NMA.

Besides the heterogeneity of sampling highlighted in this work (fig. 1), six species are still classified as Data Deficient (DD) regarding the categories and criteria of the IUCN Red List (tables 1 & 2), showing that fieldwork is required to throw full light on the high plant diversity of the NMA. We suggest that future inventories should involve specialists and be focused on the most diverse plant families identified for the NMA (e.g. Fabaceae s. lat., Apocynaceae s. lat. or Annonaceae; see electronic appendix 5).

SUPPLEMENTARY DATA

Supplementary data are available at *Plant Ecology and Evolution*, Supplementary Data Site (https://www.ingentaconnect.com/content/botbel/plecevo/supp-data) and consist of the following: (1) exploration permits covering the NMA, with Iron ore and gold sampling target areas overlying aeromagnetic image (pdf); (2) Ngovayang Massif Area (NMA) herbarium database (Excel spreadsheet); (3) summary statistic for the ten most active botanists in the NMA (pdf); (4) temporal distribution of collecting efforts in the NMA (pdf); (5) summary statistics for the ten most species-rich families in the NMA (pdf); and (6) species-area curve for total, Rubiaceae and Orchidaceae floras in two countries and 11 sites of Atlantic Central Africa.

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