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The extraordinary botanical diversity of inselbergs in Madagascar

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Abstract

RABARIMANARIVO, M.N., B. RAMANDIMBISOA, N.H. RAKOTOARIVELO, P.B. PHILLIPSON, S. ANDRIAMBOLOLONERA, M.W. CALLMANDER & S. POREMBSKI (2019). The extraordinary botanical diversity of inselbergs in Madagascar. *Candollea* 74: 65–84. In English, English and French abstracts. DOI: http://dx.doi.org/10.15553/c2019v741a8

Inselbergs are isolated mountains, mainly granitic or gneissic rock outcrops rising abruptly above surrounding plains. Malagasy inselbergs are often dome-shaped and occur in varying degrees of isolation, but they sometimes form inselberg landscapes, which comprise dozens of individual outcrops. Despite being typical landscape features on Madagascar's high plateau, little data are available on their detailed plant cover. Recent extensive fieldwork, which was conducted between 2010 and 2014, mainly on the central plateau, has resulted in a better knowledge about the floristic composition and habitats of Malagasy inselbergs. The most speciose vascular plant genera were *Cynorkis* Thouars (18), *Cyperus* L. (15) and *Euphorbia* L. (14). Malagasy inselbergs are centres of diversity for succulents (notably species of the genera *Aloe* L., *Euphorbia* and *Kalanchoe* Adans.), carnivorous plants (species of *Drosera* L. and *Utricularia* L.) and resurrection plants (notably species of *Xerophyta* Juss.). The most speciose habitat types were ephemeral flush vegetation and monocotyledonous mats. The latter habitat supports a large number of succulents and resurrection plants. In total 724 taxa out of 338 genera and 107 families have been recorded. Moreover, the variability in floristic composition between different regions is remarkable. Detrimental human impacts include quarrying, grazing, fire and the collection of plants for ornamental purposes (species of *Pachypodium* Lindl. and *Orchidaceae*) and as medicine (species of *Aloe*, *Drosera madagascariensis* DC., *Myrothamnus moschatus* (Baill.) Baill.). For the first time, recommendations are made for the conservation of Malagasy inselbergs.

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Résumé

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Les inselbergs se définissent comme des affleurements rocheux isolés composés principalement de granite et de gneiss, couverts d'une végétation qui se démarque nettement de celles aux alentours. Les inselbergs malgaches ont souvent une forme de dôme et se rencontrent dans différents degrés d'isolement, présentant parfois des paysages d'inselbergs qui comprennent des douzaines d'affleurements individuels. Bien que constituant des éléments typiques et fréquents de paysage des Hauts-Plateaux de Madagascar, peu de données sur les détails de leur couverture végétale sont disponibles. Un récent travail de terrain extensif, principalement dans le plateau central, a permis d'obtenir une meilleure connaissance de la composition floristique et des habitats des inselbergs malgaches. Les genres possédant le plus grand nombre d'espèces incluent *Cynorkis* Thouars (18), *Cyperus* L. (15) et *Euphorbia* L. (14). Les inselbergs malgaches forment des centres de diversité pour les plantes succulentes (notamment les espèces d'*Aloe* L., *Euphorbia* et *Kalanchoe* Ands.), les plantes carnivores (les espèces de *Drosera* L. et *Utricularia* L.) et les plantes reviviscentes (notamment les espèces de *Xerophyta* Juss.). Les types d'habitats les plus riches en espèces sont les prairies marécageuses temporaires et les matelas ou tapis de monocotylédones. Ce dernier habitat comporte un grand nombre de plantes succulentes et de plantes reviviscentes. Un total de 724 taxons comprenant 338 genres et 107 familles ont été recensés. En outre, la variabilité dans la composition floristique entre inselbergs de différentes régions est remarquable. Les activités anthropiques ont des impacts très nuisibles sur l'intégrité écologique des inselbergs comme l'exploitation des carrières, le pâturage, le feu et la récolte des plantes à des fins ornementales (espèces de *Pachypodium* Lindl. et *Orchidaceae*) et médicinales (espèces d'*Aloe*, *Drosera madagascariensis* DC. ou *Myrothamnus moschatus* (Baill.) Baill.). Des recommandations détaillées sont publiées, pour la première fois, en vue de la conservation des inselbergs malgaches.

Keywords

Inselbergs – Madagascar – Conservation – Endemics – Medicinal plants – Resurrection plants – Succulents

Fig. 1. – Inselberg landscape, near Ambalavao.
[Photo: S. Porembski]

Introduction

The vascular plant flora of Madagascar comprises c. 11,220 known species of which approximately 85% are endemic but, this does not include the estimated c. 1,900 undescribed endemic species (Callmander et al., 2011). This richness has long attracted the interest of botanists and ecologists alike. Up to now, detailed floristic inventories have largely been concentrated on different types of forest, whereas vegetation of azonal habitats, such as those of inselbergs, have been rather neglected.

Inselbergs are isolated mountains, mostly granitic and gneissic outcrops that emerge more or less abruptly above the surrounding plains. They form ancient landscape features dating dozens of millions of years that are stable and widespread in both tropical and temperate zones (for overview see Porembski & Barthlott, 2000). Due to their typically harsh environmental conditions, such as lack of soil and high temperatures, inselbergs are characterized by distinctive vegetation types and plant communities which usually differ significantly from those of surrounding areas.

In Madagascar, inselbergs occur in various parts of the island, but they are largely absent from the sedimentary plains of the west. Inselbergs are most frequent on Madagascar's high central plateau, the "Haut-Plateau", where they are common and sometimes have a dominant role in the landscape, either as solitary outcrops or as an inselberg landscape. Here, the extensive reworking of the crystalline basement, has given rise to a complex mix of hills and valleys, with numerous outcropping peaks made up of rocks such as quartz and granite or gneiss (Battistini & Hoerner, 1986), for example near Ambalavao, south of Fianarantsoa (Fig. 1). Historically, the inselbergs of the central plateau have been of particular strategic importance to the Malagasy people, and indeed Antananarivo, the country's capital, has a large granite inselberg at its centre (Fig. 2).

Today, inselbergs offer a potential for tourism (e.g. for rock climbing), but remarkably, given their importance, the flora and vegetation of inselbergs are only superficially known. Prior to our study, only fragmentary data were available (e.g. Rauh, 1973; Fischer & Theisen, 2000). Nevertheless, these data already suggested that Malagasy inselbergs are outstandingly

Fig. 2. – Inselberg in the capital Antananarivo with the "Palais de la Reine". [Photo: S. Porembski]

rich in locally endemic species and possess more habitat specialists than similar habitats in most other tropical regions.

In order to improve our botanical knowledge of inselbergs in Madagascar, we conducted a series of expeditions to a representative selection of inselbergs on the central plateau. During these expeditions, we collected vascular plant specimens, and recorded observations on the status of the vegetation and the exploitation of inselbergs by the local people, documenting our observations photographically. Collected specimens were identified in the relevant herbaria, often in consultation with specialists. The results of this work will provide the much-needed information necessary to inform conservation management activities for the sites visited, and will contribute towards a comprehensive checklist of the Malagasy inselberg flora, to be delivered through the Catalogue of the Plants of Madagascar (Madagascar Catalogue, 2019), which can be consulted for additional information about the species recorded.

Material and methods

The majority of the fieldwork was carried out during the wet season: in March 2010 – during the devastating cyclone "Hubert", November and December 2010 and March 2011, 2012, 2013 and 2014, with additional observations being made during the dry season in May and June 2010.

The selection of inselbergs to be included in the study took into account various considerations, including: accessibility, relative intactness and sites known to be under-collected. The latter resulted from a preliminary survey of inselbergs based on information in relevant literature and from herbarium records, and also resulted in an initial vascular plant checklist. On each inselberg, all typical habitat types were inspected, the species present were noted and representative specimens were collected. Each specimen was georeferenced, photographed in situ and accompanied by descriptive data on its habitat. Dominant species in each habitat type and notable species absences were also recorded, together with signs of anthropogenic impacts. Furthermore, local vernacular names for the plants provided by local informants were recorded, as well as their local uses.

A total of 35 inselbergs were visited (Table 1) on the subhumid Central Plateau and in the eastern and southern rainforest regions (Fig. 3). More than 2,100 herbarium specimens were collected. These have been deposited at TAN, and in most cases, when sufficient material was available, duplicate material has been deposited at MO and P and sent to experts in various plant groups at other institutions. All collected specimen data were entered into Tropicos (2019) and incorporated into the Catalogue of the Plants of Madagascar project (Madagascar Catalogue, 2019), where they are publicly accessible. The checklist presented in this article (Appendix 1) includes only taxa collected during our field investigations which have IUCN Red List threat assessments. For a complete checklist please consult the Madagascar Catalogue – Inselberg flora website [http://www.tropicos.org/projectwebportal.aspx?pagename=Inselberg_Flora&projectid=17].

Results

Nearly all the inselbergs visited belonged to the Bornhardt-type (Twidale, 1981), most of which have a dome-shaped appearance with steeply sloping sides, but some inselbergs in the drier southern regions, i.e. Ankily, Vohidava and Parapaky, have stratified rock structure (for descriptive terms see Battistini & Hoerner, 1986). Most of the inselbergs investigated were completely surrounded by agricultural land – mostly rice paddies, corn or cassava fields, and *savoka* grasslands – sometimes severely degraded due to excessive grazing and frequent burning. Very few were surrounded by forest.

On a broad geographical scale only a rather limited set of habitat types can be distinguished on inselbergs. The different habitats recognised are based mainly on ecological criteria and the physiognomic features of the plants present, notably the presence or absence of therophytes, perennial poikilohydrics and succulents (see Porembski et al., 2000). The habitats present at each site visited were identified and recorded. All habitat types characteristic for tropical inselbergs were encountered on all of the inselbergs studied. However, in contrast to other tropical regions, associated forest was only seen at a single site – the community-run Anja Park near Ambalavao, where a fringing sclerophyllous forest with a dense canopy and many lianas was present in ravines. Sclerophyllous Tapia woodland (characterized by *Uapaca bojeri* Baill. and *Sarcolaenaceae* species) was observed at "Bonnet du Pape" (south of Ambalavao) (Fig. 3: nº 26; Fig. 6D), an inselberg in exceptionally good condition. A brief description of the most typical floristic and physiognomic elements of the inselbergs studied is given below, in relation to the different habitats.

Habitat types

Cryptogamic crusts and drainage channels

Although not studied in detail, preliminary observations have shown that crustose lichens form dense crusts on exposed rocky slopes and boulders with cyanobacteria, and they are responsible for characteristic rock coloration. Epilithic fruticose lichens, species of *Usnea* Dill. and a diversity of cyanobacteria were also generally present. On the Central Plateau, only "lichen-inselbergs" (i.e. with the lichens dominant on exposed rock) occur, whereas "cyanobacteria-inselbergs" (i.e. with cyanobacteria dominating) occur in the humid east.

Epilithic vascular plants

Occasionally succulents were observed that were growing directly on exposed rock. Most frequent were species of *Aloe* L. (e.g. *A. capitata* Baker, *A. deltoideodonta* Baker, *A. divaricata* A. Berger), *Pachypodium* Lindl. (e.g. *P. densiflorum* Baker, *P. horombense* Poiss.), *Euphorbia* L. (e.g. *E. alluaudii* Drake, *E. didiereoides* Denis ex Leandri, and *E. horombensis* Ursch & Leandri: Fig. 4) and *Orchidaceae* of various genera (e.g. *Angraecum pseudofilicornu* H. Perrier, *Oeceoclades beravensis* (Rchb. f.) R. Bone & Buerki and *Sobennikoffia humbertiana* H. Perrier). Some ferns were also be found on exposed rock (e.g. *Pleopeltis macrocarpa* (Bory ex Willd.) Kaulf.).

Crevices and boulders

Depending on their width and depth, crevices and fissures offer rooting opportunities for a variety of perennial species of varying life forms including herbs (e.g. *Peperomia blanda* (Jacq.) Kunth and some *Orchidaceae*), lianas (incl. *Cyphostemma horombense* Desc., *Paederia farinosa* (Baker) Puff), as well as shrubs and trees (e.g. *Ficus menabeensis* H. Perrier, *Entada chrysostachys* (Benth.) Drake, various species of *Senecio* L., and *Vepris pilosa* (Baker) I. Verd.). Most of shrub and tree species encountered are not restricted to inselbergs but they also occur in vegetation surrounding the inselbergs. For example, species of *Sarcolaenaceae*, typical species of Tapia woodland, are frequently observed and collected on inselbergs. Species of *Aloe*, *Cyanotis* D. Don and *Euphorbia* as well as a number of grass species were also found frequently in this habitat, and ferns are usually present as well, with the desiccation-tolerant species such as *Actiniopteris dimorpha* Pic. Serm. (Fig. 5A), certain species of *Asplenium* L., *Pellaea dura* (Willd.) Hook., *P. pectiniformis* Baker and *Cheilanthes viridis* (Forssk.) Sw. being common elements. Under more humid climatic conditions, dense cushions of mosses (e.g. species of *Leucobryum* Hambe) occur in crevices and fissures. The invasive weed *Furcraea foetida* (L.) Haw. *(Asparagaceae)* occasionally forms dense colonies on certain inselbergs like Tangorika (Fig. 6A; Fig. 3: nº 25).

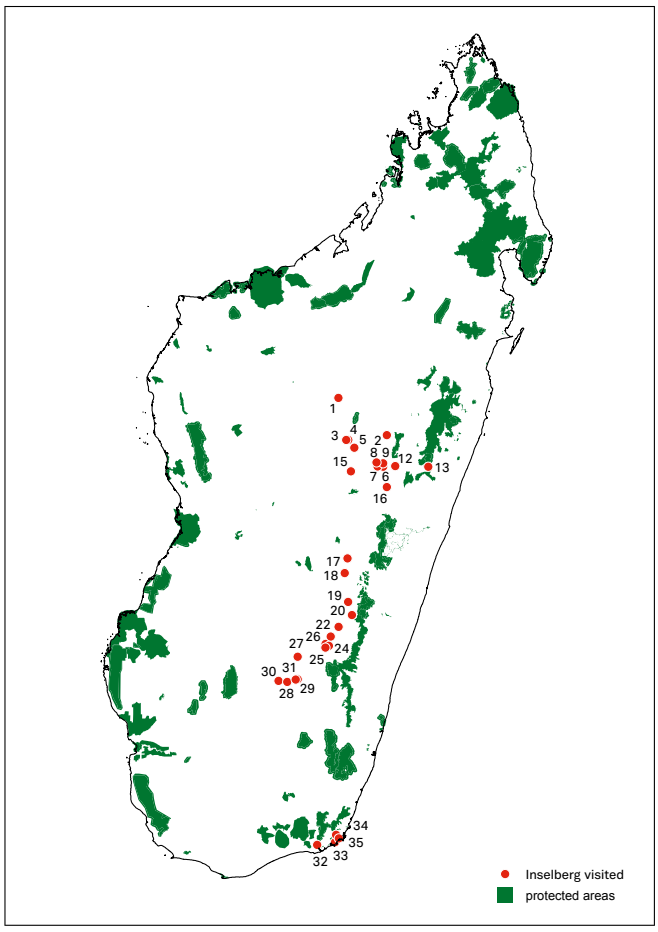

Fig. 3. – Map of the inselbergs visited (numbers refer to Table 1) in Madagascar (mostly around Antananarivo and Moramanga, the centre South and Taolagnaro).

Rock pools and shallow depressions

Few rock pools were recorded, most were less than 1 m² in area and no more than 10 cm in depth at the times of the visits. No inselberg-specific higher plants were recorded. As noted by Fischer & Theisen (2000) rock pools generally lack ephemeral species in Madagascar. Similar to rock pools, shallow depressions were rarely observed, and were usually devoid of plant cover, but occasionally species of *Cyanotis* were recorded.

Monocotyledonous mats

These grasslike mats change their physiognomic appearance according to seasonality (Fig. 6B). Most mat-forming species are desiccation-tolerant. The most typical mat-forming species is the sedge *Coleochloa setifera* (Ridl.) Gilly (*Cyperaceae*) which was seen to have colonized very steeply inclined rocky slopes (Fig. 6C). Typically, individual mats were several square meters in extent, with this single species often covering more than 75% of the ground. The *C. setifera* mats are colonized by many perennial species whereas annuals are rare. Typical co-occurring species were other resurrection plants (e.g. *Myrothamnus moschatus* (Baill.) Baill., poikilohydric species of *Selaginella* P. Beauv. (e.g. *S. echinata* Baker, *S. helicoclada* Alston), *Styppeiochloa hitchcockii* (A. Camus) Cope and species of *Xerophyta* Juss. whose trunks can reach a maximum height of 1.5 m. Succulent plants were also found. On some inselbergs, *Coleochloa setifera* was not dominant, notably at Lohavohitra (Fig. 3: nº 4) and around Fort-Dauphin (e.g. Ambondrondria: Fig. 3: nº 34). Remarkably, *Coleochloa setifera* was absent from certain inselbergs visited in the humid eastern areas (e.g. Andriambavibe, Fig. 3: nº 21). It is not clear whether particular climatic factors are responsible for its absence. *Styppeiochloa hitchcockii* was seen to be the dominant mat-former, or co-dominant with *Coleochloa setifera*, in many parts of Madagascar. This desiccation-tolerant grass frequently forms extensive mats on inselbergs near Antananarivo and in Central Madagascar. Hitherto the widespread occurrence of this species on Malagasy inselbergs has been largely overlooked.

Several species of *Xerophyta* are likewise widespread as mat-formers (Fig. 5B), they are desiccation-tolerant shrubs that are poikilochlorophyllous. The *Xerophyta* mats mainly occur on less steeply inclined slopes and are also colonized by a considerable number of perennials. Epiphytic *Orchidaceae* are common on the trunks of the larger species.

Ephemeral flush vegetation

Ephemeral flush vegetation (EFV) has a meadow-like physiognomy and shows a well expressed seasonality between rainy and dry season. This plant community develops on gently inclined rocky slopes where water constantly seeps during the rainy season and exceptionally even in the dry season. Dominant species are mostly small, short-lived herbs that form a dense vegetation layer over shallow, nutrient poor substrate. Carnivorous plants are common, i.e. *Droseraceae*: *Drosera burkeana* Planch., *D. indica* L., *D. madagascariensis* DC. (Fig. 5C) and *D. natalensis* Diels, as well as *Lentibulariaceae*: with numerous species of *Utricularia* L. (Fig. 5D) and *Orchidaceae*, e.g. *Cynorkis uniflora* Lindl. and species of *Habenaria* Willd. *Cyperaceae* and *Poaceae* are the dominant families, and other characteristic families include *Campanulaceae*, *Eriocaulaceae*, *Gentianaceae*, *Linderniaceae*, *Orobanchaceae* and *Xyridaceae*. Most speciose genus in this habitat was *Exacum* L. with 12 species. In certain rare cases (e.g. at Lohavohitra, Fig. 3: nº 4) where water is continuously seeping throughout the year, the percentage of perennials in EFV is relatively high. Under these circumstances, the prostrate *Lycopodiella affinis* (Bory) Pic. Serm. was recorded. In addition to higher plants, cyanobacteria and mosses cover the ground to various extents.

Table 1. **–** Localities of the 35 inselbergs studied and general notes on their condition (Inselberg numbers refer to Fig. 3; Square brackets in the inselbergs names refer to name of nearest village when the name of the inselberg is unknown).

n°	Inselberg name	Region	Province	Locality	Coordinates	Inselberg condition
1	Marotsipohy	Analamanga/ Betsiboka	Antananarivo/ Mahajanga	Mahatsinjo	17°49'48"S 47°01'34"E	Degraded (fire)
2	Ambatovoloina	Analamanga	Antananarivo	Sambaina	18°30'37"S 47°09'03"E	Good
3	[Bevomanga]	Analamanga	Antananarivo	Bevomanga	18°30'44"S 47°11'04"E	Very degraded (fire, quarry)
4	Lohavohitra	Analamanga	Antananarivo	Andranovelona	18°38'05"S 47°16'58"E	Degraded
5	Andrakitsikitsika	Analamanga	Antananarivo	Ambatomanga	18°56'31"S 47°41'36"E	Degraded
6	Iharamalaza	Analamanga	Antananarivo	Ambohimiadana	19°16'19"S 47°48'18"E	Good
7	Andomotra	Analamanga	Antananarivo	Anjozorobe	18°25'55"S 47°48'12"E	Degraded
8	[Ambanitsena]	Analamanga	Antananarivo	Ambanitsena	18°52'32"S 47°41'33"E	Very degraded
9	[Maharidaza]	Analamanga	Antananarivo	Maharidaza	18°53'31"S 47°43'40"E	Degraded
10	Angavokely	Analamanga	Antananarivo	Carion	18°55'17"S 47°44'19"E	Degraded
11	Angavobe	Analamanga	Antananarivo	Carion	18°55'35"S 47°45'05"E	Good
12	Vatolava	Analamanga	Antananarivo	Carion	18°55'32"S 47°44'01"E	Good
13	Ambatomisondrotra	Analamanga	Antananarivo	Carion	18°55'22"S 47°44'23"E	Good
14	Sambaina	Analamanga	Antananarivo	Marozevo	18°55'56"S 47°56'35"E	Very degraded
15	[Andranomena]	Itasy	Antananarivo	Andranomena Arivonimamo	19°01'08"S 47°13'32"E	Degraded
16	Ambohitrinimasina	Amoron'i Mania	Fianarantsoa	Tsarasaotra	20°25'26"S 47°10'18"E	Good
17	[Anjoman'Ankona]	Amoron'i Mania	Fianarantsoa	Anjoman'Akona	20°39'47"S 47°07'47"E	Good
18	Ilanjana	Haute Matsiatra	Fianarantsoa	Ambohimahasoa	21°07'38"S 47°10'46"E	Very degraded
19	Ambatomisoratra	Haute Matsiatra	Fianarantsoa	Alakamisy Ambohimaha	21°20'21"S 47°14'35"E	Very degraded
20	Langela	Haute Matsiatra	Fianarantsoa	Soaindrana	21°31'54"S 47°01'32"E	Good
21	[Andrainjato]	Haute Matsiatra	Fianarantsoa	Ambalavao	21°41'14"S 46°53'54"E	Degraded
22	Ambalalova	Haute Matsiatra	Fianarantsoa	Anja	21°50'08"S 46°50'14"E	Good (some habitats degraded)
23	Vohitsanavo (west side)	Haute Matsiatra	Fianarantsoa	Anja	21°51'10"S 46°50'03"E	Good
24	Amboalandy (east side)	Haute Matsiatra	Fianarantsoa	Anja	21°51'08"S 46°50'45"E	Good
25	Tangorika (south side)	Haute Matsiatra	Fianarantsoa	Anja	21°52'25"S 46°49'38"E	Good
26	Brioche or Bonnet du Pape	Ihorombe	Fianarantsoa	Voatavo	22°00'53"S 46°21'59"E	Good
27	Ambohibola	Ihorombe	Fianarantsoa	Ihosy	22°22'40"S 46°21'56"E	Good
28	Andreketampanano	Ihorombe	Fianarantsoa	Ihosy	22°23'06"S 46°20'40"E	Good
29	Vohidava	Ihorombe	Fianarantsoa	Ihosy	22°25'17"S 46°12'04"E	Good
30	[Ankily]	Ihorombe	Fianarantsoa	Ihosy	22°24'13"S 46°03'24"E	Degraded (fire, quarry)
31	Andriambavimbe	Alaotra-Mangoro	Toamasina	Anevoka	18°56'26"S 48°28'14"E	Degraded
32	Besivy	Anosy	Toliara	Taolagnaro	25°03'21"S 46°40'29"E	Degraded
33	Pic Saint Louis	Anosy	Toliara	Taolagnaro	25°00'29"S 46°57'55"E	Good (some habitats degraded)
34	Ambondrondria	Anosy	Toliara	Taolagnaro	24°53'38"S 46°58'58"E	Degraded (fire)
35	Ambalavato	Anosy	Toliara	Taolagnaro	24°56'25"S 47°02'43"E	Good

Table 2. – The ten most species-rich families recorded in the study.

Family	# of taxa
Orchidaceae	87
Cyperaceae	45
Rubiaceae	42
Asteraceae	38
Apocynaceae	34
Poaceae	34
Fabaceae	28
Asparagaceae	27
Euphorbiaceae	25
Lamiaceae	21

Table 3. – The ten most species-rich genera recorded in the study (genera with all recorded species endemic to Madagascar in bold print).

Genus	Total of taxa
Cynorkis (Orchidaceae)	18
Cyperus (Cyperaceae)	15
Euphorbia (Euphorbiaceae)	14
***Kalanchoe** (Crassulaceae)*	14
***Aloe** (Asphodelaceae)*	13
Cynanchum (Apocynaceae)	13
Exacum (Gentianaceae)	13
Angraecum (Orchidaceae)	12
***Senecio** (Asteraceae)*	11
***Xerophyta** (Velloziaceae)*	10

Floristic and physiognomic composition

Six hundred and twenty-seven taxa (627) have been identified to species level (or below) and 97 additional morphospecies have been identified, at least some of which are known to represent as yet undescribed species. In total 107 families and 338 genera are represented among these specimens. Sixty-seven percent (67%) of the taxa are endemic to Madagascar (about a third of which are inselberg-endemics), 31% are native but not endemic to Madagascar and 2% are naturalized introductions (Fig. 7A).

Orchidaceae is by far the most speciose family (87 taxa), followed by *Cyperaceae* (45) and *Rubiaceae* (42), a further seven families are represented by more than 20 taxa (Table 2). The 381 taxa in these 10 families represent 48% of the total inselberg flora. *Cynorkis* Thouars (*Orchidaceae*) is the most speciose genus (18 taxa), followed by *Cyperus* L. (*Cyperaceae*) (15 taxa), and with eight other genera with 10 or more taxa. The 133 taxa in these 10 genera represent 18% of the total inselberg flora, and in four of them all represented species are endemic to Madagascar, i.e. *Aloe, Kalanchoe* Adans., *Senecio* and *Xerophyta* (Table 3).

Some species were recorded on most of the inselbergs, notably: *Antherotoma naudinii* Hook. f., *Coleochloa setifera*, *Cynanchum perrieri* Choux, *Hypoxis angustifolia* Lam., *Lysimachia rubricaulis* (Duby) U. Manns & Anderb., *Nematostylis anthophylla* (A. Rich.) Baill., *Tetradenia fruticosa* Benth. and *Xerophyta pectinata* Baker. Other species were highly localized, occurring only on certain inselbergs, such as *Aloe haworthioides* Baker (Fig. 8A) (known from inselbergs around Ihorombe and Haute Matsiatra regions, only recorded during our study from Anja Park, at Vohitsanavo, Fig. 3: nº 23), *A. perrieri* Reynolds (known from inselbergs around Zazafotsy, Fandana and Ihosy, only recorded during our study from "Bonnet du Pape", Fig. 3: nº 26; Fig. 6D), *Linderniella horombensis* (Eb. Fisch.) Eb. Fisch. et al. (recorded from inselbergs around Ambalavao, Fandana and Ihosy during this study, Fig. 3: nº 21, 26, 29), *Pachypodium horombense* (only recorded from inselbergs around Ihosy during our study, Fig. 3: 27–29; Fig. 8B).

Another group of species, e.g. *Myrothamnus moschatus*, have a widespread distribution on inselbergs in Madagascar, but their presence on a given inselberg is unpredictable. Others are regionally localized, but not always present, e.g. *Capitanopsis oreophila* (Guillaumin) Mwanyambo et al. from the Horombe plateau, only recorded from Anja Park, Ambalalova, Vohitsanavo, Amboalandy, Tangorika, and la Brioche. Remarkably, no species was present on all inselbergs studied whereas the number of rather localized species was relatively high.

Life form analysis shows herbaceous species as best represented (61%), followed by shrubs (27%), vines and lianas (7%), while tree species represent only 5% (Fig. 7B). Among the herbaceous species, the most widespread species is the desiccation-tolerant *Cyperaceae Coleochloa setifera*. Desiccation-tolerance is also found in other herbaceous genera, such as: *Lindernia* All., *Linderniella* Eb. Fisch. et al. and *Streptocarpus* Lindl., and in ferns such as: *Asplenium*, *Cheilanthes* Sw., *Doryopteris* J. Sm. and *Selaginella*. We estimate that in total more than 40 desiccation-tolerant vascular plant species occur on Malagasy inselbergs, which is 14% of the estimated world total of c. 300 species desiccation-tolerant plants on rock outcrops (Porembski & Barthlott, 2000).

On all inselbergs studied, numerous leaf and stem succulent species have been recorded that preferentially occurred in monocotyledonous mats, crevices and more rarely as lithophytes. Among the genera that could be recorded more frequently were *Aloe*, *Cynanchum* L., *Cyanotis*, *Euphorbia*, *Kalanchoe*, *Pachypodium*, *Rhipsalis* Gaertn. and *Senecio*. In addition, a number of succulent orchids (e.g. *Aerangis ellisii*

Fig. 4. – *Euphorbia horombensis* Ursch & Leandri (*Euphorbiaceae*) a succulent on open rocks at Vohitsanavo inselberg, Anja Park (Fig. 3: nº 23). [*Razafindraibe et al. 278*] [Photo: S. Porembski]

(B.S. Williams) Schltr., *Angraecum pseudofilicornu*, *Oeceoclades calcarata* (Schltr.) Garay & P. Taylor, *Sobennikoffia humbertiana*) were present.

Threats and Conservation

Among the 627 taxa identified, just c. 28% (177) have been evaluated for the IUCN Red List following IUCN Red list Categories and Criteria (IUCN, 2012) by MBG-GSPM (the IUCN plant red listing authority in Madagascar). Among those 177 species assessed, 76 species (43%) have a threatened status as Critically Endangered [CR] (4), Endangered [EN] (37) or Vulnerable [VU] (35) (see Appendix I for details). Certain families which include many inselberg specialists such as *Asparagaceae, Asphodelaceae, Crassulaceae,* and *Velloziaceae* have not yet had threat assessments conducted any of the species identified (but see Rakotoarisoa et al., 2014 for *Aloe*), nor have any of the inselberg pteridophytes. Undoubtedly, many of these are threatened, especially in cases of particularly rare, locally endemic species, such as *Aloe haworthioides* and *A. perrieri* which both have a limited distribution range. *Genlisea margaretae* Hutch., a carnivorous species that also occurs in East Africa (Fischer et al., 2000), is currently known only from one inselberg in Madagascar, representing a single location (sensu IUCN, 2012). The only locality for this species known to Bosser (1958), who superfluously described it a new species (Madagascar Catalogue, 2019), was destroyed as a viable habitat for the species through urbanization (Rauh, 1973). We visited the site and can confirm this, but found *G. margaretae* at another nearby site. Moreover, 125 species (17 %) of all taxa inventoried are registered in the list of restricted species for trade on CITES Appendices I and II (CITES, 2019), due to their horticultural interest. These are mainly *Asphodelaceae*, *Euphorbiaceae* and *Orchidaceae*, and illegal trade in many of them continues despite their CITES status (Newman, 2003; UNEP-WCMC, 2010; Willis, 2017).

Discussion

Despite our inadequate knowledge about Malagasy inselbergs, it is already clear that they are outstandingly rich in terms of both species diversity and endemicity. Remarkable examples of taxa showing a rich interspecific and/or infraspecific differenti-

ation are to be found within certain genera, e.g. *Aloe*, *Euphorbia* and *Xerophyta*. The reasons for this high diversity in Madagascar are manifold, but two particularly important factors are the extremely large number of scattered outcrops and the high diversity of rock type (e.g. granitic, quartzitic, and calcareous). Furthermore, the existence of other azonal habitats such as white sand savannas which have probably promoted the evolution of particularly rich species-complexes within these genera in Madagascar. In many cases, modern taxonomic revisionary work, such as in some of the genera mentioned above, has served to reveal even higher levels of diversity and local endemism than had previously been documented.

Our results show that Malagasy inselbergs do not differ from other tropical regions regarding the habitat types. As for tropical African and Indian inselbergs, the EFV is the most species rich habitat (Porembski & Watve, 2005). Remarkably speciose are monocotyledonous mats, this is mainly due to the presence of numerous desiccation-tolerant species and succulents (a "succulent paradise" sensu Rauh, 1995). *Coleochloa setifera* is dominant in both Malagasy and East African monocotyledonous mats on inselbergs. This is probably the only case of an inselberg specific species that is shared between Africa and Madagascar.

Our results also show that in general the floristic composition of Malagasy inselbergs resembles those of East African inselbergs (Porembski, 1996; Seine et al., 2000). For certain genera, Malagasy inselbergs are particularly important centres of diversity; this is the case for *Aloe*, *Cynanchum, Euphorbia*, *Exacum, Kalanchoe* and *Xerophyta*. Despite the fact that only a relatively small number of Malagasy inselbergs have been investigated in detail, it is already apparent that their species richness is remarkably high. We assume that further exploration will increase the hitherto known number of species and that the species richness of Malagasy inselbergs will be shown to be among the highest in the world. The number of inselberg-endemics in Madagascar is higher than in most other tropical regions, but can be compared with inselbergs in certain parts of East Africa (e.g. Zimbabwe, see Seine et al., 1995) and South America (SE Brazil, S Venezuela, see Porembski et al., 1998; Gröger, 2000; Porembski, 2005; Gröger & Huber, 2007) which also have high levels of endemism. The considerable degree of species turnover between individual inselbergs in Madagascar is possibly caused by the vicariant replacement of species within certain taxa, notably in the genus *Euphorbia*, but it is not clear whether this is due to limitations in their dispersal efficiency or other factors. In most other tropical regions, beta-diversity of inselbergs is much lower. However, inselbergs in SE Brazil (e.g. Federal States of Rio de Janeiro, Espirito Santo) show a similar extent of species turnover.

It is possible that the long isolation and relative climatic stability have promoted the high rates of endemicity on Malagasy inselbergs. According to Iwamura et al. (2010), Madagascar has had high levels of climatic stability (over 80%) which means that the future predicted climatic conditions remain within the present climate profile of the ecoregion. This high climatic stability overlaps with the areas that are known for their high biodiversity. This may be highly relevant for long term conservation planning in the context of global climate change.

Despite the lack of detailed ecological data for azonal habitats in general, it can be stated that the number of species which are limited to inselbergs is considerably higher than the number of generalist species present. While almost all of the lithophytes and monocotyledonous mats species are habitat specialists, confined to rock outcrops, species found in EFV are more frequently habitat generalists that also occur in marshy places off inselbergs, notably certain *Cyperaceae* and *Poaceae*. The low species diversity in rock pools and their complete lack of habitat specialists is striking compared to inselbergs outside of Madagascar. This is all the more remarkable in the case of *Lindernia*, a genus including several rock pool specialists in tropical Africa, and which comprises nine species in Madagascar (six are endemic), but none are rock pool specialists.

The number of species that also occur on inselbergs outside Madagascar is low. Examples of species that are shared between continental African and Malagasy inselbergs include *Drosera indica* and *Utricularia subulata* L., which are both widespread outside Africa and Madagascar. The data that are currently available indicate that floristic relationship of inselbergs is strongest with Zambezian Region in eastern and southern Africa, doubtless due to their proximity. Examples include the genera *Aloe*, *Anthospermum* L., *Exacum*, *Euphorbia*, *Lindernia*, *Myrothamnus* Welw., *Pachypodium*, *Styppeiochloa* De Winter, and *Xerophyta*, which are all well-represented in the two regions, but by different species, while certain species occur in both regions (e.g. *Coleochloa setifera* and *Genlisea margaretae*). Relationship with West African inselbergs is weaker, but nevertheless some desiccation-tolerant mat-forming species, related to *Coleochloa setifera* (also belonging to the tribe *Trilepideae*), such as *Afrotrilepis pilosa* (Boeckeler) J. Raynal and *Microdracoides squamosus* Hua occur in this part of the continent. Floristic links between Malagasy inselbergs and rock outcrops on the Arabian Peninsula can also be found through the occurrence of *Aloe* and *Xerophyta* at the southern tip of the Arabian Peninsula. It is interesting to note that certain genera which are absent from Malagasy inselbergs are typical elements of the vegetation of inselbergs elsewhere (mostly in tropical Africa), e.g. *Burmannia* L., *Isoetes* L. and *Tripogon* Roem. & Schult. The absence of *Isoetes* is particularly remarkable, as this genus is widespread on tropical and temperate inselbergs, and includes numerous locally endemic species.

Most granite and gneiss inselbergs in Madagascar are located outside the national protected area network,

Fig. 5. – A. *Actiniopteris dimorpha* Pic. Serm. (*Pteridaceae*) a desiccation-tolerant species of fern at Vohidava, Ihosy; **B.** *Xerophyta* sp. (*Velloziaceae*) near Anjoman'Akona, south of Ambositra; **C.** *Drosera madagascariensis* DC. *(Droseraceae);* **D.** *Utricularia* sp. *(Lentibulariaceae*).
[**A:** *Razafindraibe et al. 300*; **B:** *Rakotoarivelo et al. 287*; **C:** *Rabarimanarivo et al. 745*; **D:** *Rabarimanarivo et al. 705*] [Photos: **A:** A. Ramahefaharivelo; **B:** N. Rakotoarivelo; **C–D:** S. Giebelmann]

Fig. 6. – A. Inselberg, south of Anja Park (Tangorika) covered with *Furcraea foetida* (L.) Haw. *(Asparagaceae);* **B.** Mat with *Styppeiochloa hitchcockii* (A. Camus) Cope (*Poaceae*) near Angavokely; **C.** Mats formed by *Coleochloa setifera* (Ridl.) Gilly (*Cyperaceae*) and steep slopes, south of Fianarantsoa; **D.** General overview of "Bonnet du Pape, at Voatavo (Fig. 3: nº 26). [Photos: **A–C:** S. Porembski; **D:** R. Phillipson]

exceptions include those within certain National Parks such as Andringitra and Marojejy. In unprotected areas globally, inselbergs often support the last remnants of natural vegetation in a given area. While certain types of human use of inselbergs have occurred for generations and do not seem to have caused severe damage, in recent times human impact appears has become by far more destructive resulting in steadily growing pressure on these areas, and today most inselbergs in Madagascar exhibit detrimental human impacts. These include: the over-collection of certain useful species which impacts local populations or even threatens local endemics with extinction; use of inselbergs for grazing cattle and goats; uncontrolled bush-fires, usually resulting from the widespread burning of grasslands for agriculture, that may significantly impact the population of individual species and which are also responsible for habitat degradation or destruction as a whole (see Whitman et al., 2011 for a study of the influence of fire and water availability on the occurrence of orchids on Malagasy inselbergs); and quarrying, which results in the destruction of parts of, or even an entire inselberg, impacting available habitats as well as precipitation and water drainage patterns on and around the site (Fig. 8C). Secondary impacts following habitat degradation or destruction include the proliferation of invasive weeds, as our results show for Madagascar and as reported for other tropical regions in Porembski (2000). A particular danger to Malagasy inselbergs is the Neotropical *Furcraea foetida* which has invaded numerous inselbergs on the High Plateau (Fig. 6A), forming large populations by means of vegetative reproduction. This and other invasive species have negative impacts on any remaining pockets of more natural habitats and impede any natural regeneration as well as managed habitat restoration. Remarkably certain Malagasy inselberg endemics (notably certain species of *Kalanchoe*) have been introduced as ornamentals to other tropical regions where they have become invasive.

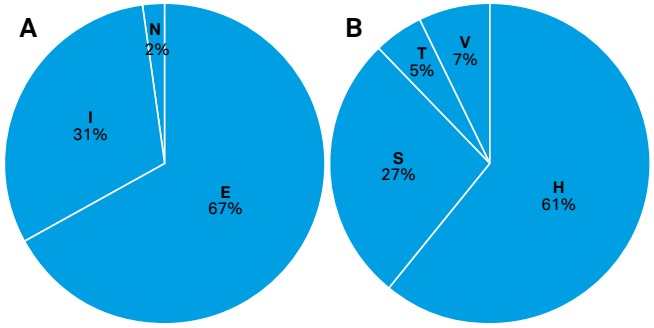

Fig. 7. – A. Distribution of Malagasy inselberg flora; **B.** Life form diversity of Malagasy inselberg flora. [Abbreviations: **E**, Endemic species; **H**, Herbs; **I**, Indigenous non-endemic species; **N**, Naturalised species; **S**, Shrubs; **T**, Trees; **V**, Vines and lianas]

The collection of useful plant species is particularly complex. In addition to plants used by local inhabitants for medicinal purposes that occur predominantly on inselbergs and that we observed in many local markets, such as *Drosera madagascariensis* (Fig. 5C), *Myrothamnus moschatus*, and the different species of *Tetradenia* Benth. and certain *Aloe* spp., the harvesting of *Coleochloa setifera* leaves, which are used to stuff mattresses, was observed, and they were seen for sale in local markets (Fig. 8D). While traditionally harvesting for local needs might have been undertaken at sustainable levels, with increased mobility of the population and potentially higher value of increasingly scarce resources, it seems probable that pressure on these species is probably on the increase. The collection of plants from inselbergs for ornamental purposes is a highly significant danger to inselberg habitats and biodiversity. This poses particular threats to succulent plants (e.g. species of *Aloe* and *Pachypodium*) and orchids which are sought after locally, nationally and internationally, they are commonly sold in local markets and are often illegally exported.

Some inselbergs in the southern part of Madagascar along National Route 7 have touristic importance and particular attention should be given for their protection. For example, inselbergs near Anja Park are managed and protected by the local community (Association AMI) in order to develop ecotourism. This site welcomes ca. 15,000 tourists per year. The money received from ecotourism contributes to the conservation of the local flora and fauna, as well as to the protection of the cultural heritage (e.g. tombs).

Conclusions

Building on the recent dramatic increase in the total surface area of Madagascar under formal protection for conservation (Gardner et al., 2018), efforts are now underway to develop a coherent conservation strategy across the whole country that encompass the broadest range of habitats and as much of the country's extraordinary biodiversity. However, inselbergs have received little attention, and we hope that our study contributes to an increasing awareness of their importance, and that this ultimately results in their effective conservation and, where necessary, their restoration. Consequently, efforts are needed to extend the awareness to the population at large as well as the scientific community and decision-makers, and specifically to facilitate the human populations living nearby to take care of the inselbergs. The involvement of landholders in successful protection, restoration and monitoring of key landscape elements is the most effective way to reach this goal (Burke, 2003a).

Further research on the flora and vegetation of inselbergs in Madagascar is needed. Prior to the current study, Malagasy inselbergs have been investigated in only a limited number of places on the seasonally dry Central High Plateau (Rauh, 1973; Fischer & Theisen, 2000). Many inselbergs have escaped closer inspection, even those near the capital city of Antananarivo. Almost no information exists about inselbergs located in either the humid rainforests (except one in the Alaotra Mangoro Region: Andriambavimbe) or those in the Anosy Region in the south-east. Apart from basic inventory studies, molecular analysis is needed in order to understand patterns of population differentiation between isolated populations of individual species or species-complexes on inselbergs. Further studies, in addition to improving the knowledge base in these areas and better understanding evolutionary processes, also need to focus on species of economic value so that sustainable management practices can be established for these species and their habitats. The documentation of invasive species on inselbergs also needs to be improved so that effective eradication techniques can be developed, followed by the restoration of natural habitats. Few studies exist on the status of individual inselberg plant species, although a study of the carnivorous plant species *Genlisea margaretae* is being undertaken on an inselberg near Andranovelona in order to contribute to the long-term protection of this species.

Current studies are underway that aim toward a better understanding of dispersal processes between mainland Africa and Madagascar. *Coleochloa setifera* was chosen as a model species, since it is one of the most characteristic species on inselbergs both in East Africa and Madagascar. A similar approach could be applied to understand the phylogeography of *Myrothamnus*, which comprises two species that are strict inselberg specialists (*M. moschatus* in Madagascar and *M. flabellifolius* Welw. in East and South Africa).

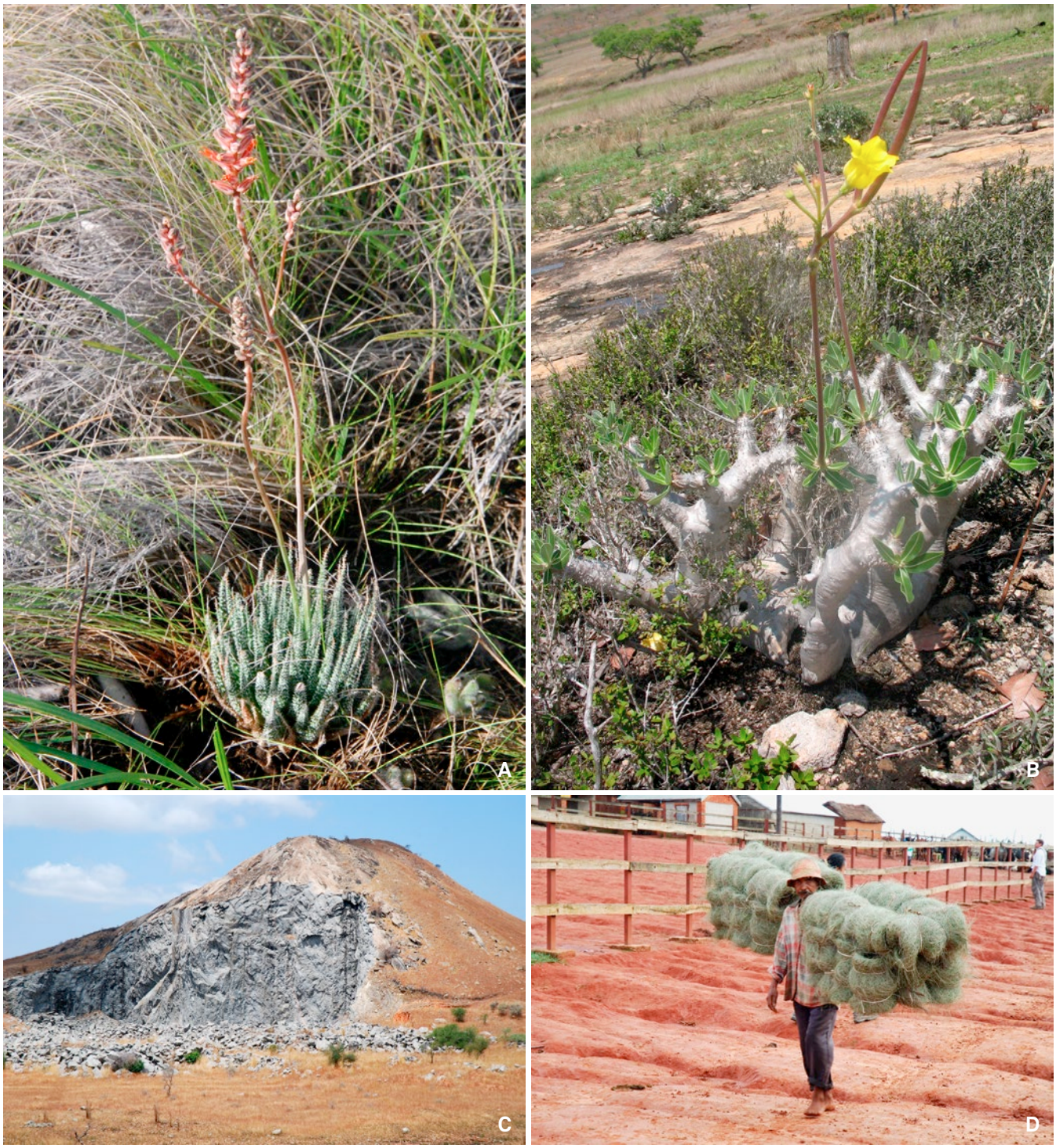

Fig. 8. – A. *Aloe haworthioides* Baker (*Asphodelaceae*); **B.** *Pachypodium horombense* Poiss. (*Apocynaceae*); **C.** Quarry on an inselberg near Zazafotsy; **D.** Leaves of *Coleochloa setifera* (Ridl.) Gilly (*Cyperaceae*) sold at local market in Ambalavao. [**A:** *Razafindraibe et al. 293*; **B:** *Ramandimbisoa et al. 104*] [Photos: **A:** C. Lebo; **B–C:** F. Rajaonary; **D:** S. Porembski]

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Appendix I. List of species recorded during the present study that have IUCN risk of extinction assessments, arranged by family, with annotations of global distribution and threat category for each species (genera endemic to Madagascar in bold print).
[Abbreviations: CR = "Critically Endangered"; EN = "Endangered"; LC = "Least Concern"; NT = "Near Threatened"; VU = "Vulnerable"]

Family	Taxon	Distribution	IUCN Cat.
Anacardiaceae	***Abrahamia*** *buxifolia* (H. Perrier) Randrianasolo & Lowry	Madagascar	NT
Anacardiaceae	*Operculicarya hirsutissima* Eggli	Madagascar	VU
Apocynaceae	*Catharanthus lanceus* (Bojer ex A. DC.) Pichon	Madagascar	NT
Apocynaceae	*Catharanthus ovalis* Markgr.	Madagascar	NT
Apocynaceae	*Catharanthus roseus* (L.) G. Don	Madagascar	LC
Apocynaceae	***Craspidospermum*** *verticillatum* Bojer ex A. DC.	Madagascar	LC
Apocynaceae	***Ischnolepis*** *graminifolia* (Costantin & Gallaud) Klack.	Madagascar	LC
Apocynaceae	*Mascarenhasia lisianthiflora* A. DC.	Madagascar	LC
Apocynaceae	*Pachypodium densiflorum* Baker	Madagascar	VU
Apocynaceae	*Pachypodium horombense* Poiss.	Madagascar	VU
Apocynaceae	*Pachypodium lamerei* Drake	Madagascar	VU
Apocynaceae	*Pentopetia urceolata* Klack.	Madagascar	VU
Apocynaceae	*Secamone oleaefolia* Decne.	Madagascar	LC
Araliaceae	*Polyscias ornifolia* (Baker) Harms	Madagascar	LC
Arecaceae	*Ravenea glauca* Jum. & H. Perrier	Madagascar	VU
Asteraceae	*Helichrysum aphelexioides* DC.	Madagascar	NT
Asteraceae	*Senecio canaliculatus* Bojer ex DC.	Madagascar	VU
Asteraceae	*Senecio erechtitioides* Baker	Madagascar	VU
Asteraceae	*Senecio hildebrandtii* Baker	Madagascar	EN
Asteraceae	*Senecio leandrii* Humbert	Madagascar	VU
Asteraceae	*Senecio mesembryanthemoides* Bojer ex DC.	Madagascar	VU
Asteraceae	*Senecio quartziticolus* Humbert	Madagascar	EN
Balsaminaceae	*Impatiens baronii* Baker	Madagascar	LC
Balsaminaceae	*Impatiens lyallii* Baker	Madagascar	LC
Balsaminaceae	*Impatiens rutenbergii* O. Hoffm.	Madagascar	VU
Bignoniaceae	*Stereospermum euphorioides* DC.	Madagascar	LC
Cannabaceae	*Trema orientalis* (L.) Blume	Africa	LC
Clusiaceae	*Symphonia verrucosa* (Planch. & Triana) Benth. & Hook. f.	Madagascar	VU
Commelinaceae	*Commelina africana* var. *mannii* (C.B. Clarke) Brenan	Africa	LC
Convolvulaceae	*Ipomoea desmophylla* Bojer ex Choisy	Madagascar	LC
Convolvulaceae	*Turbina bracteata* Deroin	Madagascar	LC
Cunoniaceae	*Weinmannia lucens* Baker	Madagascar	LC
Cyperaceae	*Bulbostylis hispidula* (Vahl) R.W. Haines	Africa	LC
Cyperaceae	*Cyperus amabilis* Vahl	Comoros, Australasia/Pacific, Africa, Asia, New World	LC
Cyperaceae	*Cyperus articulatus* L.	Mascarenes, Seychelles, Australasia/Pacific, Africa, Asia	LC
Cyperaceae	*Cyperus cyperoides* (L.) Kuntze	Comoros, Mascarenes, Australasia/Pacific, Africa	LC
Cyperaceae	*Cyperus dubius* Rottb.	Comoros, Mascarenes, Seychelles, Africa, Asia	LC
Cyperaceae	*Fimbristylis dichotoma* (L.) Vahl	Mascarenes, Australasia/Pacific, Africa	LC
Cyperaceae	*Fuirena umbellata* Rottb.	Mascarenes, Australasia/Pacific, Africa, Asia, New World	LC
Cyperaceae	*Pycreus flavescens* (L.) P. Beauv. ex Rchb.	Australasia/Pacific, Africa, Asia, Europe, New World	LC
Dioscoreaceae	*Dioscorea antaly* Jum. & H. Perrier	Madagascar	LC
Dioscoreaceae	*Dioscorea sansibarensis* Pax	Naturalized in Madagascar	NT
Dioscoreaceae	*Dioscorea soso* Jum. & H. Perrier	Madagascar	LC

Family	Taxon	Distribution	IUCN Cat.
Dioscoreaceae	*Tacca leontopetaloides* (L.) Kuntze	Comoros, Africa	LC
Droseraceae	*Drosera indica* L.	Australasia/Pacific, Africa	LC
Ebenaceae	*Diospyros myriophylla* (H. Perrier) G.E. Schatz & Lowry	Madagascar	LC
Ericaceae	*Vaccinium secundiflorum* Hook.	Madagascar	LC
Eriocaulaceae	*Mesanthemum rutenbergianum* Körn.	Madagascar	NT
Euphorbiaceae	*Euphorbia alluaudii* Drake	Madagascar	LC
Euphorbiaceae	*Euphorbia antso* Denis	Madagascar	LC
Euphorbiaceae	*Euphorbia didiereoides* Denis ex Leandri	Madagascar	EN
Euphorbiaceae	*Euphorbia enterophora* Drake	Madagascar	LC
Euphorbiaceae	*Euphorbia horombensis* Ursch & Leandri	Madagascar	EN
Euphorbiaceae	*Euphorbia imerina* Cremers	Madagascar	EN
Euphorbiaceae	*Euphorbia milii* Des Moul.	Madagascar	DD
Euphorbiaceae	*Euphorbia primulifolia* Baker	Madagascar	VU
Euphorbiaceae	*Euphorbia rauhii* Haevermans & Labat	Madagascar	VU
Euphorbiaceae	*Euphorbia stenoclada* Baill.	Comoros, Seychelles	LC
Fabaceae	*Alistilus jumellei* (R. Vig.) Verdc.	Madagascar	VU
Fabaceae	*Crotalaria coursii* M. Pelt.	Madagascar	NT
Fabaceae	*Crotalaria diosmifolia* Benth.	Madagascar	VU
Fabaceae	*Crotalaria tanety* Du Puy et al.	Madagascar	VU
Fabaceae	*Crotalaria uncinella* Lam.	Mascarens, Africa	LC
Fabaceae	*Dalbergia greveana* Baill.	Madagascar	LC
Fabaceae	*Indigofera bojeri* Baker	Madagascar	LC
Fabaceae	*Indigofera mangokyensis* R. Vig.	Madagascar	EN
Fabaceae	*Indigofera pedunculata* Baker	Madagascar	NT
Fabaceae	*Microcharis phyllogramme* (R. Vig.) Schrire et al.	Madagascar	LC
Fabaceae	*Mundulea stenophylla* R. Vig.	Madagascar	LC
Fabaceae	*Ophrestia lyallii* (Benth.) Verdc.	Madagascar	LC
Fabaceae	***Phylloxylon*** *xiphoclada* (Baker) Du Puy et al.	Madagascar	EN
Fabaceae	*Senna leandrii* (Ghesq.) Du Puy	Madagascar	LC
Fabaceae	*Senna viguierella* (Ghesq.) Du Puy	Madagascar	LC
Fabaceae	***Tetrapterocarpon*** geayi Humbert	Madagascar	LC
Fabaceae	*Vigna angivensis* Baker	Madagascar	NT
Fabaceae	*Zornia puberula* Mohlenbr.	Madagascar	LC
Gentianaceae	*Exacum exiguum* Klack.	Madagascar	LC
Gentianaceae	*Exacum gracile* Klack.	Madagascar	EN
Gentianaceae	*Exacum linearifolium* (Humbert) Klack.	Madagascar	EN
Gentianaceae	*Exacum naviculare* Klack.	Madagascar	EN
Gentianaceae	*Exacum spathulatum* Baker	Madagascar	VU
Gentianaceae	*Exacum stenophyllum* Klack.	Madagascar	EN
Gentianaceae	***Tachiadenus*** *carinatus* (Desr.) Griseb.	Madagascar	LC
Gentianaceae	***Tachiadenus*** *gracilis* Griseb.	Madagascar	NT
Gentianaceae	***Tachiadenus*** *longiflorus* Griseb.	Madagascar	NT
Hypericaceae	***Eliea*** *articulata* (Lam.) Cambess.	Madagascar	LC
Iridaceae	*Aristea kitchingii* Baker	Madagascar	NT
Iridaceae	*Gladiolus bojeri* (Baker) Goldblatt	Madagascar	NT
Lamiaceae	***Capitanopsis*** *albida* (Baker) Hedge	Madagascar	EN

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Lamiaceae	*Plectranthus bipinnatus* A.J. Paton	Madagascar	VU
Lamiaceae	*Capitanopsis oreophila* (Guillaumin) Mwanyambo et al.	Madagascar	EN
Lamiaceae	*Stachys brachiata* Bojer ex Benth.	Madagascar	VU
Lamiaceae	*Stachys rubella* Hedge	Madagascar	CR
Lamiaceae	*Tetradenia cordata* Phillipson	Madagascar	VU
Lamiaceae	*Tetradenia goudotii* Briq.	Madagascar	LC
Lamiaceae	*Tetradenia nervosa* Codd	Madagascar	LC
Lentibulariaceae	*Genlisea margaretae* Hutch.	Africa	CR
Lentibulariaceae	*Utricularia bisquamata* Schrank	Africa	LC
Lentibulariaceae	*Utricularia livida* E. Mey.	Africa	LC
Lentibulariaceae	*Utricularia prehensilis* E. Mey.	Africa	LC
Lentibulariaceae	*Utricularia subulata* L.	Africa	LC
Malvaceae	*Grewia nitida* Juss.	Madagascar	EN
Monimiaceae	*Tambourissa purpurea* (Tul.) A. DC.	Madagascar	LC
Montiniaceae	***Kaliphora*** *madagascariensis* Hook. f.	Madagascar	LC
Moraceae	*Ficus politoria* Moon	Madagascar	LC
Orchidaceae	*Aerangis ellisii* (B.S. Williams) Schltr.	Madagascar	LC
Orchidaceae	*Angraecum compactum* Schltr.	Madagascar	LC
Orchidaceae	*Angraecum pseudofilicornu* H. Perrier	Comoros	EN
Orchidaceae	*Angraecum rutenbergianum* Kraenzl.	Madagascar	EN
Orchidaceae	*Angraecum setipes* Schltr.	Madagascar	EN
Orchidaceae	*Angraecum sororium* Schltr.	Madagascar	VU
Orchidaceae	*Bulbophyllum baronii* Ridl.	Madagascar	LC
Orchidaceae	*Cynorkis baronii* Rolfe	Madagascar	LC
Orchidaceae	*Cynorkis cinnabarina* (Rolfe) Hermans & P.J. Cribb	Madagascar	EN
Orchidaceae	*Cynorkis gibbosa* Ridl.	Madagascar	LC
Orchidaceae	*Cynorkis gigas* Schltr.	Madagascar	LC
Orchidaceae	*Cynorkis melinantha* Schltr.	Madagascar	EN
Orchidaceae	*Cynorkis papillosa* (Ridl.) Summerh.	Madagascar	EN
Orchidaceae	*Cynorkis perrieri* Schltr.	Madagascar	EN
Orchidaceae	*Cynorkis uniflora* Lindl.	Madagascar	LC
Orchidaceae	*Eulophia pileata* Ridl.	Madagascar	EN
Orchidaceae	*Eulophia reticulata* Ridl.	Madagascar	LC
Orchidaceae	*Gastrorchis francoisii* Schltr.	Madagascar	VU
Orchidaceae	*Habenaria alta* Ridl.	Madagascar	EN
Orchidaceae	*Habenaria ambositrana* Schltr.	Madagascar	EN
Orchidaceae	*Habenaria hilsenbergii* Ridl.	Madagascar	NT
Orchidaceae	*Habenaria simplex* Kraenzl.	Madagascar	VU
Orchidaceae	*Habenaria truncata* Lindl.	Madagascar	VU
Orchidaceae	*Jumellea intricata* H. Perrier	Madagascar	EN
Orchidaceae	*Jumellea jumelleana* (Schltr.) Summerh.	Mascarenes	EN
Orchidaceae	*Jumellea maxillarioides* (Ridl.) Schltr.	Comoros	EN
Orchidaceae	*Jumellea rigida* Schltr.	Madagascar	VU
Orchidaceae	*Jumellea stenoglossa* H. Perrier	Madagascar	EN
Orchidaceae	*Liparis anthericoides* H. Perrier	Madagascar	VU
Orchidaceae	*Liparis bicornis* Ridl.	Madagascar	EN

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Orchidaceae	*Liparis imerinensis* Schltr.	Madagascar	EN
Orchidaceae	*Liparis listeroides* Schltr.	Madagascar	EN
Orchidaceae	*Liparis longicaulis* Ridl.	Madagascar	VU
Orchidaceae	*Liparis ochracea* Ridl.	Madagascar	EN
Orchidaceae	*Oeceoclades beravensis* (Rchb. f.) R. Bone & Buerki	Madagascar	NT
Orchidaceae	*Oeceoclades calcarata* (Schltr.) Garay & P. Taylor	Madagascar	LC
Orchidaceae	*Oeceoclades pandurata* (Rolfe) Garay & P. Taylor	Madagascar	EN
Orchidaceae	*Oeceoclades perrieri* (Schltr.) Garay & P. Taylor	Madagascar	CR
Orchidaceae	*Orthochilus rutenbergianus* (Kraenzl.) Bytebier	Madagascar	LC
Orchidaceae	*Polystachya perrieri* Schltr.	Madagascar	CR
Orchidaceae	*Satyrium perrieri* Schltr.	Madagascar	EN
Orchidaceae	*Satyrium rostratum* Lindl.	Madagascar	VU
Orchidaceae	***Sobennikoffia*** *humbertiana* H. Perrier	Madagascar	LC
Orchidaceae	***Tylostigma*** *foliosum* Schltr.	Madagascar	EN
Osmundaceae	*Osmunda regalis* L.	Mascarenes, Africa, Asia, Europe, New World	LC
Phyllanthaceae	*Phyllanthus matitanensis* Leandri	Madagascar	LC
Phyllanthaceae	*Uapaca bojeri* Baill.	Madagascar	LC
Piperaceae	*Peperomia trichophylla* Baker	Madagascar	VU
Poaceae	*Eragrostis stolonifera* A. Camus	Madagascar	EN
Poaceae	*Paspalum scrobiculatum* L.	Comoros, Australasia/Pacific, Africa, Asia, New World	LC
Poaceae	*Trichopteryx dregeana* Nees ex Lindl.	Africa	LC
Primulaceae	*Lysimachia rubricaulis* (Duby) U. Manns & Anderb.	Madagascar	NT
Rubiaceae	*Chassalia bojeri* Bremek.	Madagascar	LC
Rubiaceae	*Chassalia princei* var. *brachysepala* Bremek.	Madagascar	LC
Rubiaceae	*Coffea buxifolia* A. Chev.	Madagascar	LC
Rubiaceae	*Gardenia rutenbergiana* (Baill. ex Vatke) J.-F. Leroy	Madagascar	LC
Rubiaceae	*Paederia grandidieri* Drake	Madagascar	LC
Rubiaceae	*Paederia mandrarensis* Homolle ex Puff	Madagascar	EN
Rubiaceae	*Pentanisia veronicoides* (Baker) K. Schum.	Madagascar	VU
Rubiaceae	*Psychotria retiphlebia* Baker	Madagascar	LC
Rubiaceae	*Saldinia aegialodes* Bremek.	Madagascar	VU
Rubiaceae	*Tricalysia cryptocalyx* Baker	Madagascar	LC
Rubiaceae	*Tricalysia dauphinensis* Randriamb. & De Block	Madagascar	VU
Rutaceae	*Vepris pilosa* (Baker) I. Verd.	Madagascar	VU
Sarcolaenaceae	***Leptolaena*** *pauciflora* Baker	Madagascar	LC
Sarcolaenaceae	***Sarcolaena*** *oblongifolia* F. Gérard	Madagascar	LC
Sarcolaenaceae	***Xerochlamys*** *bojeriana* (Baill.) F. Gérard	Madagascar	LC
Sarcolaenaceae	***Xerochlamys*** *tampoketsensis* F. Gérard	Madagascar	VU
Sphaerosepalaceae	***Rhopalocarpus*** *similis* Hemsl.	Madagascar	LC
Talinaceae	***Talinella*** *grevei* Danguy	Madagascar	LC
Vitaceae	*Cayratia triternata* (Baker) Desc.	Madagascar	LC
Xyridaceae	*Xyris labatii* Rakotoar. et al.	Madagascar	LC