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CHECKLIST

Ecological survey of the Lycophytes and Ferns of the Vohimana Reserve, Madagascar

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Background and aims – The Malagasy Vohimana Reserve, is situated in an ecologically sensitive area subject to mining and the pressure from neighbouring communities. The aim of this study is to look at the structure of the plant community, to determine indicator species of undisturbed areas and areas affected by human activities, and to present a checklist of ferns and lycophytes of the reserve.

Methods – The Vohimana Reserve was visited twice and an improved quadrat method of sampling was used; specimens were collected and identified at both TAN and P herbaria. Ecological data were statistically analysed using the Factorial Correspondence Analysis methods.

Key results – One hundred and thirty two lycopod and fern taxa were identified, including four undescribed fern species. The plant community structure suggests a gradation from primary forest to disturbed zones. This can be explained by local ecological factors and topography, as well as the effect of human pressure on the plant community. The narrow altitudinal gradient (780–1,030 m) is not considered as a factor influencing species composition, as shown in analogous studies performed in larger parks or reserves elsewhere in Madagascar.

Conclusion – Despite the human impact on the reserve, the fern and lycophyte diversity indices suggest that it should be classified as an area of significant diversity.

Key words – ferns, lycophytes, diversity, Madagascar, Vohimana Reserve, conservation, biological indicators.

INTRODUCTION

About 85% of the fern and lycophyte diversity is concentrated in tropical areas, especially in mid-elevation cloud forests (Smith et al. 2006, Mehltreter 2008). Too often neglected in ecological studies and taxonomic inventories, ferns and lycophytes form an important component of tropical hygrophilous ecosystems, where they frequently dominate the understory and the epiphytic component. In the palaeotropics, ferns represent one of the most important epiphytic plant groups, making up 36 to 72% of this flora (Benzing 1990, Dubuisson et al. 2009). Epiphytic fern diversity and quantity is also known to be the first to decline when forest ecosystems are disturbed (Hoff & Cremer 1993, Barthlott et al. 2001, Dubuisson et al. 2005). Currently there are 586 lycophyte and fern species known from Madagascar, including 265 endemic species (47.32%) (Rakotondrainibe 2009).

The Vohimana Reserve, 150 km east of Antananarivo, is located in one of Madagascar's biodiversity hot-spots (Vences et al. 2009, Dolch 2009). This reserve is managed by the Malagasy Non-Governmental Organisation "*L'homme et l'environnement*" ("*Man and environment*"), and the study was conducted in the framework of the biodiversity programme of the NGO (http://www.madagascar-environnement.com/strategies-de-programme.html) with the aim of increasing knowledge on the reserve required for its management. This has become necessary due to the ongoing anthropogenic pressures (farming, mining, and the construction of a pipeline) in the area. Approximately 1,200 self-sustained people live in the area and use the traditional unsustainable slash and burn ('tavy') method of cultivation, which is repeated after two years of fallow laying (five years being the minimal duration for nutrient turn-over). The large community does not allow the complete regeneration of the forest. In addition, the construction of a 220 km long pipeline that will carry nickel and cobalt rich laterites from Ambatovy (30 km west of Vohimana) to Toamasina harbor is underway. For this development a road was constructed from the Ambavaniasy village to the future pipeline. The effect of this mining project has not been determined, but the loss of biodiversity will probably be high. Human activities have shown to drastically decrease plant biodiversity in the region: after 48 years of forest recolonisation following deforestation and agricultural activities, less than 25% of the native plant diversity has recovered in the Malagasy Andasibe region (Dolch 2009). Given the current pressure on the reserve, a fern and lycophyte inventory will contribute to the knowledge of the forest diversity before mining exploitation.

Apart from developing a checklist of the ferns and lycophytes of the Vohimana Reserve, studies were conducted to determine the ecological factors explaining fern and lycophyte distribution with the aim of using these plants as indicators to monitor the impact of human activities.

One of the NGO's projects is to restore the forest corridor between the Mantadia National Park (north of Vohimana) and the Vohimana Forest, with native species. As a result of the sensitivity of ferns and lycopods to disturbance (Dubuisson et al. 2005) they can potentially be used as additional ecological indicators when assessing and monitoring the effect of forest disturbance.

MATERIAL AND METHODS

Vohimana is a rural area, 150 km east of Antananarivo (electronic appendix 1A). The area covers 1,635 ha, including a forest core of 600 ha. Settlements are established along the perimeter of the area. The Vohimana Forest is divided by the Vohitra and Sahatandra Rivers and is further fragmented by human activities (electronic appendix 1B).

The study site is composed of environments that include patches of agricultural lands, fallow lands, *savokas* (recolonised bush), and exploited tropical humid forests (electronic appendix 1C).

Species inventories were conducted in July 2006 and April 2008, corresponding respectively to the dryer winter season (July) and the end of the rainy season (April).

Sampling protocols and data management proposed by Rakotondrainibe & Raharimalala (1996) and applied in several studies (Rakotondrainibe & Raharimalala 1996, 1998, 2000, Rakotondrainibe 2000, 2002, 2003), especially in forests within the same phytogeographical zones (Rakotondrainibe & Raharimalala 1998, 2000), were followed.

Based on a vegetation and landscape study of the reserve (Buron 2004), and our own observations, five vegetation types are recognized within the study area:

Dense primary evergreen and wet rain forests – this plant community has not been exposed to excessive human activity, but can be selectively exploited for wood harvesting and hunting.

Herbaceous fallow – defines the first stage of abandoned farmland.

Shrubby fallow (*savoka*) – fallow grassland to shrub up to five meters high.

Secondary or exploited forest – this vegetation type includes forest variously utilized for wood harvesting as well as recolonized forest after the shrubby fallow stage. Several stages of recolonisation can be identified, each being characterized by a specific plant community. When trees are dominant in the plant community, different developmental stages are not distinguished. It is often difficult to distinguish between recolonised and exploited forests.

***Eucalyptus* plantations** – these forests have been established 1925 in and have since been used for timber and the charcoal industry.

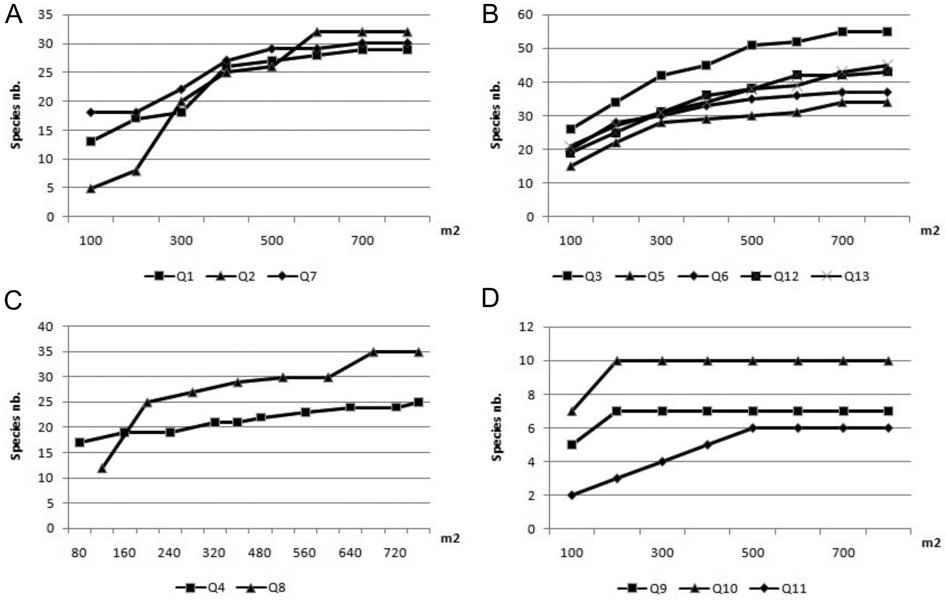

Figure 1 – Species-areas curves for plots, grouped by topographic zone. A, Top-hills and high slopes plots. Q1 stands in a secondary forest. Q2 and Q7 stands in primary forest riverbanks. B, Mid-slopes plots in humid primary forest. Q5 is in an exploited forest. C, River-banks plots. Q4 stands along frequented secondary forest riverbanks, Q8 stands along humid primary forest riverbanks. D, Fallows plots. Q9 and Q10 lie in flat and open bottom slopes with stagnant water. Q11 stands in a dry and mid slope.

Table 1 – Endemism in other similar malagasy forest (Centre and East province) for Pteridophytes (from Rakotondrainibe 1998, 2000).

Forest name	Surface	Altitude (m)	Number of species	Endemism	Year of prospecting
Ambohitantely	1,600 ha	1,300–1,650	154	25.3%	2000
Andranomay (Anjozorobe)		1,300–1,450	130 (in only 6 days, 150 estimated)	31.5%	1998
Vohamina (this study)	1,635 ha (600 ha of forest)	780–1,030	132	34.09%	2006 and 2008

Study areas were selected to represent the topographical and vegetation diversity (electronic appendices 2 & 1D). Plots of 800 m^2 were selected following Rakotondrainibe & Raharimalala (1996). Species number curves support the plot size as maxima area reached between 100 m^2 (fallow communities, fig. 1D : Q9, Q10) and 700 m^2 (primary evergreen and wet rain forest, fig. 1B) plots. Figure 1A & D represent hill top and river bank plots. Each plot was established within a homogeneous vegetation. The 800 m^2 plots were surveyed using eight contiguous sub-plots of 100 m^2. The choice of sub-plots was determined by the topography of the site and the necessity of a homogeneous habitat. Each sub-plot was explored through transect surveys in both directions.

All fern and lycophyte species were recorded. For unknown taxa a voucher specimen was collected for later identification. Growth form, phenology and number of individuals were recorded for each plot. Individual plants were identified with ease in species with short rhizomes and clustered fronds. In species with long-creeping rhizomes, each frond was considered as an individual since individual plants could not be identified. Small epiphytic ferns (Hymenophyllaceae and Polypodiaceae, incl. Grammitidaceae) were recorded as a colony when individual rhizomes could not be distinguished and where plants cover an area of 400 cm^2; when rhizomes could however be identified they were counted and each rhizome was scored as a colony.

This survey method is not entirely satisfactory since it may overvalue creeping terrestrial ferns and undervalue the smaller epiphytic species with creeping rhizomes.

Vouchers collected in the 2006 survey were deposited at the Laboratoire de Biologie Végétale, Faculté des Sciences, Mahajanga University, Madagascar. Vouchers collected in 2008 will be deposited at the National Herbarium (P), Paris, France, while duplicates will be deposited at the National Herbarium of Tsimbazaza (TAN), Antananarivo, Madagascar.

Identifications were based on the Flora of Madagascar (Tardieu-Blot 1951, 1952, 1958a, 1958b, 1971), Zahamena Park inventory (Rasolohery 2003), African fern floras (Burrows 1990, Verdcourt 1999a, 1999b, 2006, Schelpe 1970, Schelpe & Anthony 1986, Roux 2003), as well as a number of monographs (Hennipman 1982, Holttum 1974).

Family and genera, apart from the families Hymenophyllaceae and Cyatheaceae, *Elaphoglossum* and *Lastreopsis* follow Kramer (1990). Ebihara et al. (2006) was followed for the Hymenophyllaceae, Rouhan (2005) for *Elaphoglossum*, Janssen & Rakotondrainibe (2007, 2008) for *Cyatheaceae*, and Rakotondrainibe & Tronchet (2009) for *Lastreopsis*. Smith et al. (2006) was followed in arranging the fern families. Name updates follow Roux (2009).

Abundance classes were attributed using to the following parameters: 1: a single individual or colony; 2: 2–4 individuals or colonies; 3: 5–9 individuals or colonies; 4: 10–19 individuals or colonies; 5: 20–49 individuals or colonies; 6: 50 or more individuals or colonies.

For each plot a diversity index was calculated using the Shannon-Weaver Index (Peet 1974). The same protocol was followed in 2008, allowing specific richness comparisons using the index H'_{spec}.

$$H'_{spec} = \sum (p'_i \, . \, ln\, p'_i)$$

where p_i is the relative frequency of the species i, evaluated for a maximum of 400 individuals (8 sub-plots and 50 individuals maximum for a sub-plot). This index gives a value lower than that of the Shannon-Weaver Index.

A plot/ecological factor matrix (ACM) was developed using mixed quantitative factors (altitude, slope and canopy height) and qualitative factors: vegetation type (fallow and savoka, primary forest, secondary forest), topography (lower slopes, river banks, mid-slopes, hilltops and upper slopes), slope orientation, presence of water (no water in the plot, stagnant water, stream or river). The analysis was conducted using using the R *ade4* package (Thioulouse et al. 1997, Dray & Duffour 2007).

To evaluate the structure of the fern communities, a species frequency/plot matrix was constructed (112 species × 13 plots) and analyzed by Factorial Correspondence Analysis (FCA). The analysis compares species distribution among plots and maximizes the proximity of individual variables (species or plots). Each cell (i, j) of the matrix is weighted by a χ^2 calculation and the individual variables of the weighted matrix are projected on a plan defined by two axes representing the first two factors of importance, explaining the variance. The origin is the center of gravity of the cloud of points. The distribution of points, according to each axis projected, is correlated to the ecological gradient. Close points are interpreted as demonstrating correlation among the considered factors. The R *ade4* package (Thioulouse et al. 1997, Dray & Duffour 2007) and *dudi.coa* command were used to treat the species/plots matrix.

Only species that contributed at least 1.8% of the variance for one or more axis are represented in the FCA projection graphs. Fifty-one representative species were kept, and

Table 2 – Comparison of growth form between Ambohitantely and Andranomay-Anjozorobe forest and Vohimana reserve for the fern flora.
E = epiphytes; ER = epiphytes and saxicolous; T = terrestrial; TR = terrestrial and saxicolous; R = saxicolous.

Growth form	Vohimana	Ambohitantely	Andranomay
E + ER	59.09%	27.30%	43.80%
T+ TR	37.12%	60.40%	44.60%
TE	3.79%	7.10%	8.50%
R	-	5.20%	3.10%

as argued by Rakotondrainibe & Raharimalala (2000), "they represented the most characterized species, excluding species that are too widely distributed, those that are infrequent, and those whose distribution is erratic". The same species number is used in both the check-list and graph to describe the species distribution.

A Hierarchical Classification based on the floristic matrix using the R package *Vegan* (Dixon 2003) and the distance method *Canberra* was established, retaining four clusters.

The hierarchical classification and the FCA based on the same floristic/plot matrix were compared.

RESULTS

One hundred thirty-two (132) lycophyte and fern taxa were recorded within the study area (electronic appendix 3). A few taxa (< 5% of the collected specimens) were not identified to species level (especially Cyatheaceae), because numerous collections were sterile or incomplete. These collections were not incorporated in the analysis. The H_{spev} for each plot is reported in electronic appendix 4A. Fallow plots (Q9, Q10, Q11) were least diverse whereas primary wet forest plots (Q3, Q12, Q13) were the most diverse.

Forty-five lycophyte and fern taxa (34.09%) recorded for the Vohimana Reserve are Malagasy endemics (Rakotondrainibe 2009). The occurrence of endemic lycophytes and ferns in this reserve is slightly higher than in other Malagasy reserves (table 1).

Growth form studies (table 2) show that most taxa are epiphytic (59.09%), followed by terrestrial (37.12%) species. 3.79% of the species are facultative epiphytic, but mostly terrestrial. *Pteris madagascarica* may have a climbing habit, but the only true liana is *Lygodium lanceolatum*, a heliophilous fern found in fallow areas, forest margins, or forest openings.

In fallow plots *Lygodium lanceolatum* mostly climbs on ferns such as *Pteridium aquilinum* and *Dicranopteris linearis*. In forest plots (Q7 & Q13, see electronic appendix 2) where the herbaceous stratum is not well developed, *Lygodium* occurs as isolated populations. This may be the result of old forest clearings, or chablis.

Plot classification based on ecological factors (ACM) – Three axes contribute 63.1% of the variance (fig. 2). The parabolic form of the graph is a result of the ecological gradient (Guttman-effect), opposes, on the first axis, low elevation plots, exposed to full sun (Q9, Q10 and Q11) and largely harbouring herbaceous plants, to steep, mid-slope plots with the highest and densest canopy. Conditions that most likely affect species diversity are light intensity and a stable high humidity (Q3, Q5, Q13, Q12). Hill top plots (Q1, Q2, Q7) are also located on the negative part of the first axis. The lower canopy of these forests and the more frequent occurrence of *Pandanus* trees result in an increase in light intensity.

Plots Q4 and Q8 are both riverbank plots and make a more significant contribution towards axis 3 than other plots (fig. 2B). Larger rivers cause in a break in the forest canopy allowing sunlight to reach the forest floor for the greater part of the day. Running water is present in these plots only (except for two small streams crossing Q3 and Q12, but here the canopy is uninterrupted). Rocks and bare soil along riv-

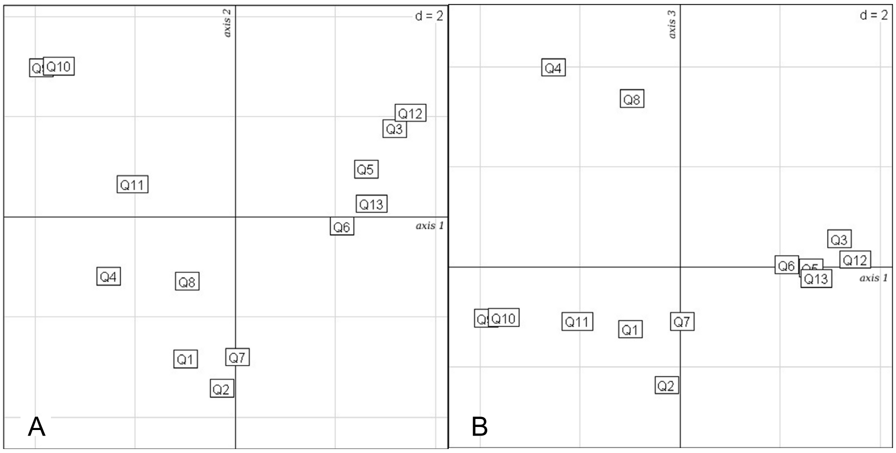

Figure 2 – Multivariate analysis (ACM) of the thirteen plots expressed in function of ecological factors. A, for axes 1 and 2; B, for axes 1 and 3.

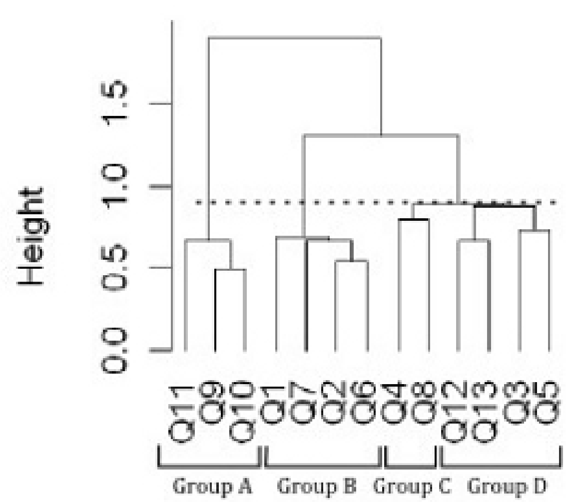

Figure 3 – Hierarchical analysis using Canberra method for matrix analysis and ward method for tree construction of the thirteen plots, based on their fern floristic frequency analysis.

ers contrast with the deep and thick humus rich soils located along the undisturbed lower hill slopes. Fallow plots on flat areas also benefit from the natural movement of humus from higher lying areas.

This survey confirms the existence of different ecological niches among plots.

Hierarchical classification of the floristic frequency matrix analysis – The tree obtained by the plot/floristic analysis is divided in order to obtain four groups (fig. 3). The plot groups can be characterized as: Group A = fallow plots (Q9, Q10, Q11); Group B = hill top plots (Q1, Q2, Q7) and high-middle slope plots (Q6); Group C = river bank plots; Group D = primary wet forest plots (Q3, Q5, Q12, Q13). River bank plots (Group C) appear to be related to Group D (primary wet forest plots).

Four axes were retained for the FCA analysis, projecting the plot/fern frequencies matrix. The analysis accounts for 60.12% of the global variance. The fourth axis is difficult to interpret, but provides interesting information for some fern species, and was thus kept. To make the figures more readable, the variable (plots and species) projection graphs are separated. Each axis reflects the data provided in electronic appendix 4B.

Plot projection – Axes 1 and 2 are plotted in fig. 4A; axes 1 and 3 in fig. 4B; and axes 1 and 4 in fig. 4C. The contribution of each plot towards each axis is provided in electronic appendix 4C.

On axis 1, fallow plots (Group A) are grouped, suggesting a significant similarity in the fern species composition. These plots make a larger contribution towards the axis (electronic appendix 4C) than other plots, except Q4 (disturbed river bank). Fallow plots share a more open vegetation, free of trees and are subject to constant sunshine.

Axis 2 compares hill top plots (Group B) river bank plots (Group C). Hill top plots are characterized by a low forest canopy, small-diameter trees, a dominance of crowded *Pandanus* trees and bamboo lianas. The low canopy allows light to reach the ground more freely. River bank plots occur in primary wet forest at mid- or lower-slopes. These plots have a higher canopy due to the taller trees that may also occur along the river banks.

Axis 3 compares river bank plots (Q4, Q8) which stand in a relatively isolated position. Plots Q12 and Q13 (part of primary wet forest plots) and fallow plots are on the positive part of axis 3. The central position of hill top plots does not allow a precise interpretation for these plots.

For axis 4, the plot opposition (Q8, Q3, Q12 versus Q13, Q7, Q4) can be explained by an orientation effect, or a very local effect: Q8, Q3 and Q12 are on the same northern slope and quite close to each other (see electronic appendix 1C).

Species projections – When the fern species are projected (fig. 5), indicator or typical ferns for each group become evident. A synthesis of the fifty-one characteristic species and their typical habitat contributes at least 1.8% to one or more axes as reported in electronic appendix 5. An ordinated table based on the FCA on the 112 species and the thirteen plots

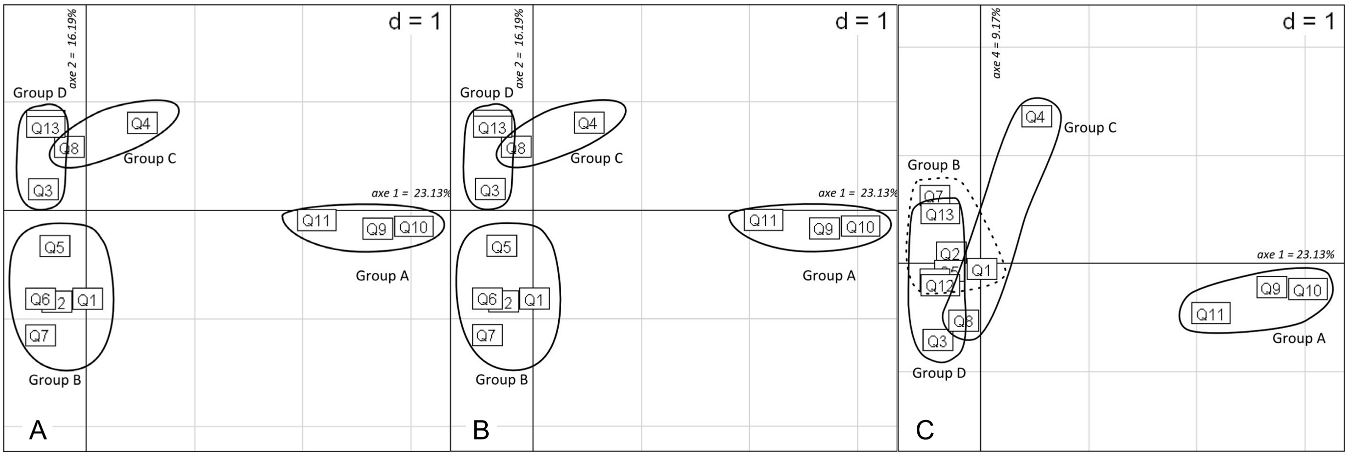

Figure 4 – Plot projection according to Factorial Correspondence Analysis (FCA) of the thirteen plots against 112 fern species matrix frequency. Group A = plots in fallows; Group B = hill top and high-slope plots; Group C = river banks plots; Group D : Mid-slopes in FI (primary forest) A, for axes 1 and 2; B, for axes 1 and 3; C, for axes 1 and 4.

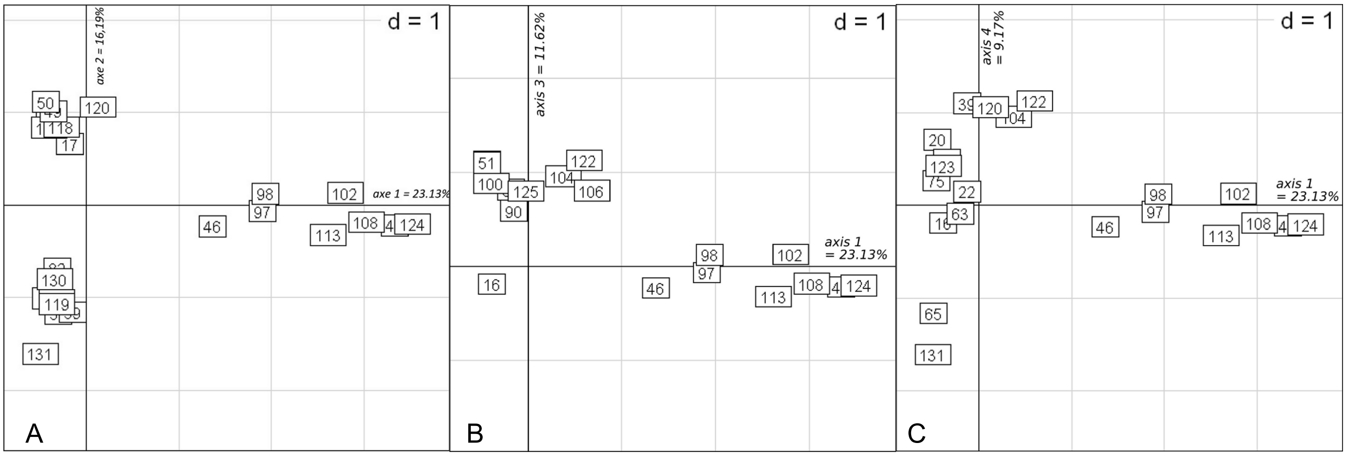

Figure 5 – Factorial Correspondence Analysis (FCA) of the thirteen plots against 112 fern species matrix frequency. Only ferns contributing for at least 1,8% of the variability for one or two axes are shown. Labels correspond to those reported in the check-list (electronic appendix 3. A, for axes 1 and 2; B, for axes 1 and 3; C, for axes 1 and 4.

completes this analysis (electronic appendix 6) and shows ordinated distribution of the whole community among plots.

On axis 1, species occurring in fallow areas plots are in the positive part. Included here are species such as *Pteridium aquilinum*, *Cheilanthes viridis* and *Lygodium lanceolatum*. The river bank fern flora grows on a moist substrate (Rasolohery 2003), in a sunny or lightly shaded areas and include *Osmunda regalis* and *Sphaerostephanos arbuscula*. They all plot on the positive part of axis 1.

Axis 1 clearly separates species and plots with different light requirements. Shade-loving species of primary humid and closed canopy forest plots (*Antrophyum boryanum*, *Didymoglossum montanum* (= *Trichomanes montanum*), *Didymoglossum rotundifolium* (= *Trichomanes rotundifolium*), *Saccoloma henriettae*) all occur along the negative part of axis 1. In plot Q1, positioned on a hill top and at the edge of an ancient fallow area, where light penetrates more than in closed plots, some open space fern species are found. These sun species are the only ferns encountered in fallow plots (Q9, Q10, Q10) (*Lycopodiella cernua*, *Pteridum aquilinum*) (Rasolohery 2003) (see electronic appendix 6).

Dwarf *Didymoglossum* species (leaves not exceeding a few centimeters in length) are also projected on the positive part of axis 2 (fig. 5A), and characterize shade-loving hygrophilous taxa. On the negative part of this axis 2 we find species such as *Cochlidium serrulatum* (= *Xiphopteris serrulata*) and *Schizaea dichotoma*. The latter is characterized by tough leaves with a thick cuticle illustrating xerophilous adaptation. They were principally collected on hilltops as also reported in other inventories (Rasolohery 2003). They are often exposed to full sun. Axis 2 separates hill top species and lower slope forest species. Correlated with the topographic gradient, there are changes in microclimate such as ambient humidity and light intensity.

Axis 3 (fig. 5B) more or less separates terrestrial species such as *Osmunda regalis*, *Sphenomeris chinensis* and *Odontosoria melleri* found in open area, along pathways, on lateritic soils and along river banks. At the opposite, *Belvisia spicata*, *Antrophyum boryanum*, *Asplenium dregeanum* are epiphytic species found in closed canopy forests and lower hill slope areas (Rasolohery 2003).

DISCUSSION

Microclimate influences the ecology and diversity of species in a forest community. Rakotondrainibe & Raharimalala (2000) demonstrated an increase in epiphytism with a rise in humidity and/or altitude. In the Vohimana forest, epiphytes are more common when compared with the Ambohitantely forest or Andranomay forest (table 2). The infrequency of rocks or boulders in Vohimana, except along river banks explains the small number of epilithic or saxicolous species (6.15%). *Pellaea angulosa*, *Odontosoria melleri*, *Pityrogramma calomelanos* were observed on rocks along the river banks. *Pityrogramma calomelanos* also occurs on rocky embankments along the railway line. *Didymoglossum lenormandii*, *Polyphlebium borbonicum* and *Hymenophyllum digitatum* are concentrated along the river banks or in very humid and shady plots. Plants in these locations are dependent on water flow over the rocky face (for Hymenophyllaceae). *Pityrogramma* spp. exhibit more xerophytic features.

It is not surprising that fallow plots have the lowest diversity index, and that the primary wet forest plots the highest (electronic appendix 4A). Secondary or exploited forests show an intermediate index. In each topographical situation, the plots affected by man display the smaller number of species and smaller H'_{spec} index. As noted by Barthlott et al. (2001), ferns are one of the first plant groups to disappear when forests are disturbed. Human activity leads to a significant decrease in species diversity and leads to a homogenization of the fern communities in open areas following tavy cultivation. Only well adapted ferns and lycophyte species survive in full sun and relatively dry areas. These species are often invasive and usually cover large areas (*Pteridium aquilinum* and *Lycopodiella cernua*).

Light intensity plays a major role in the variation of fern diversity within communities. Sunlight is highest in exposed areas, but decreases from secondary forests and up-hills forests to closed canopy primary forests. Exposed sites may

Table 3 – Sørensen similarity between Ambohitantely and Andranomay-Anjozorobe forest and Vohimana reserve for the fern flora.

	Ambohitantely	Andranomay-Anjozorobe
Number of shared species with Vohimana	46	51
Total number of species	154	131
Sørensen similarity coefficent	0.32	0.40

be the result of natural disturbance (tempest, chablis) or to anthropogenic actions. In further analysis ecological factors such as light intensity and duration, rainfall and humidity as well as humus type and thickness should be determined using more accurate measurement devices than possible for this study. Additional data are needed for some taxa (especially Cyatheaceae) in zones such as *Eucalyptus* plantations, rocky riverbanks, and open areas along the Vohimana River not yet explored.

Other factors may also contribute to canopy opening: soils are leached after deforestation over large areas (Drew 1983, Gade 1996), and large forest gaps in a forest dry the ambient atmosphere (Canham et al. 1990), even in tropical regions with a high rainfall.

When natural openings in the forest canopy occur, they can form an enriched mosaic of abiotic conditions in a relatively small area. They also contribute to the natural rejuvenation of forests with light tolerant and terrestrial species establishing in a short time. Vegetation formation is also dependent on topography and influence fern diversity according to the structure of the trees (canopy height, tree size, biological type). *Pandanus* or bamboo stands on hilltops and upper slopes do not carry epiphytic species. This may explain the lower diversity of the fern flora of hill top plots plots (electronic appendix 4A). The larger contribution of hill top and river banks plots and the smaller contribution of fallow plots of fallow plots to axes 2, 3, 4 (electronic appendix 4C) support this conclusion. The loss of an epiphytic flora in areas influenced by human activity is due to the decrease of large diameter trees and their absence in exploited forest and fallows. The large contribution of Q4 to the axis 3 of the plots projection can be interpreted by its mixed features: an undisturbed river bank, a disturbed river bank, and a dense secondary forest overhanging an undisturbed riverbank.

Bare soil can also result from the natural flow of rivers, preventing humus deposition on rocky soil along the rivers, preventing perennial species from establishing in these areas.

Many studies on fern diversity and ecological distribution have been conducted in the Malagasy reserves (Rakotondrainibe 2009). The pteridophyte (lycophytes and ferns) flora of Madagascar is very diverse due to the variation in climate, topography, geology, and vegetation and many mountain ranges harbour a group of unique species. The most comparable forests already surveyed for ferns are the Andranomay-Anjozorobe forest (Rakotondrainibe 1998) and the Ambohitantely forest (Rakotondrainibe 2000). Both are mid-elevation wet forests in the Central Plateau and belong to the same phytogeographical zone, the Center Domain. The three forests are located along an East (Vohimana) – West (Andranomay and Ambohitantely) transect. The Sørensen similarity coefficient shows that the Vohimana Forest fern community is closer to the Andronomay-Anjozorobe community than it is to the Ambohitantely community (table 3). The endemism rate is also higher in Vohimana Forest (34.09%) than that in Ambohitantely, (25.3%) and Andronomay-Anjozorobe (31.5%) (table 2). Fern endemism for the island is 45.2% (Rakotondrainibe 2009, Rakotondrainibe et al. 1996) and 37.4% for the Center Domain. These values are close to the endemism rate in Vohimana Forest.

This relatively well preserved Vohimana forest community requires a detailed management plan that makes provision for the needs of the local population in a sustainable manner. Despite the relatively small area covered by relict primary forest, the overall fern diversity in Vohimana is still significant when compared with other Malagasy parks and reserves. An analysis of the fern community shows a drastic loss in biodiversity when the primary forest is disturbed.

In the Andasibe region, the forest is still very fragmented forest (electronic appendix 1B), and the Vohimana reserve plays a major role, not only because of it natural biodiversity, but also because of the investment of a local NGO and populations in reforestation actions. But the pipeline crossing the Vohimana forest is a very negative offsets of the sustainable development efforts. The current vegetation formations with high diversity will be replaced with very low diversity secondary formations. It is still very necessary to support all the protection actions of these primary formations.

SUPPLEMENTARY DATA

Supplementary data are available in pdf format at *Plant Ecology and Evolution*, Supplementary Data Site (http://www.ingentaconnect.com/content/botbel/plecevo/supp-data),and consists of the following: (1) maps of the Vohimana reserve and its surroundings; (2) characteristics of the selected plots in the Vohimana reserve; (3) check list of ferns and lycophytes in the Vohimana Reserve; (4) specific diversity index and inertia; (5) fifty-one representative species of the Vohimana reserve, for the four biotopes defined by their floristic composition; (6) ordination table of the species repartition.

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