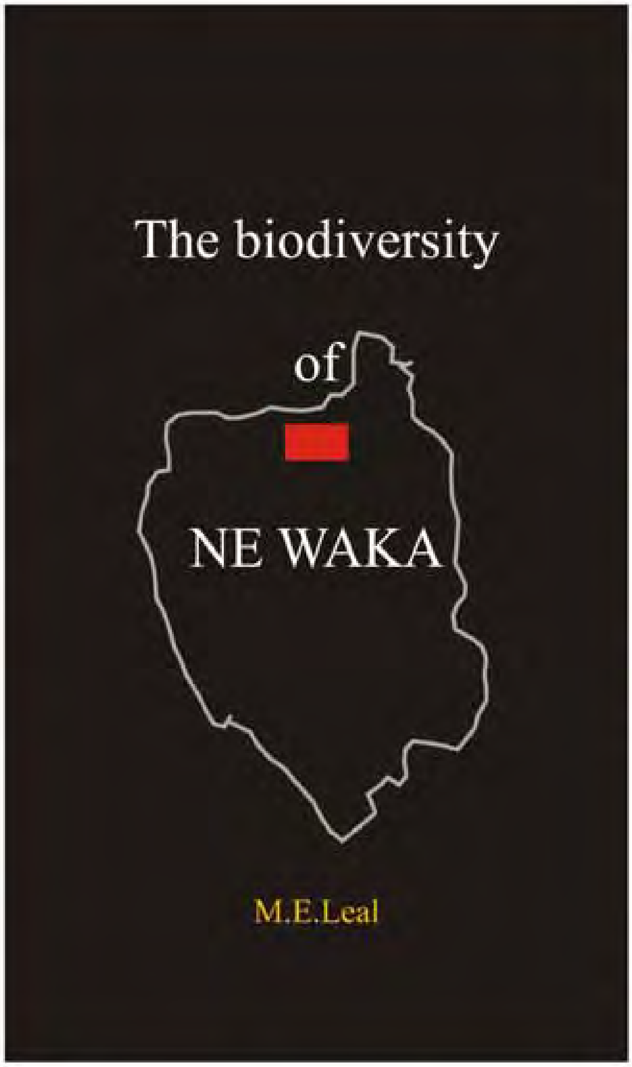
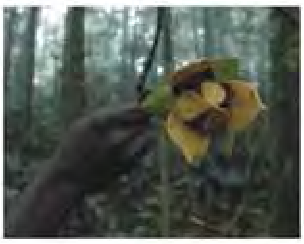




Missouri Botanical Garden

The biodiversity of NE Waka

Preliminary results and observations

Prepared by Dr M.E. Leal

Missouri Botanical Garden
Gabon 2005

Prologue

Missouri Botanical Garden was awarded a Central African Regional Program for the Environment (CARPE) subcontract from the Wildlife Conservation Society (WCS) to perform a series of tasks.

These tasks were defined accordingly:

1. Map biodiversity with special focus on certain taxonomical groups, i.e. Caesalpinioideae and Begonias.

2. Identify Biodiversity Sanctuaries that complement the existing park system.

3. Improve the understanding of the Pleistocene forest refuge history to be able to make recommendations for landscape management

During this fiscal year Missouri Botanical Garden (MBG) has executed botanical activities in the Waka national park assessing the plant biodiversity of the North Eastern section. The first results and observations are presented here (task 1).

The conclusions drawn from this biodiversity assessment in combination with a GIS-analysis helped to identified Biodiversity Sanctuaries bordering the park system. The recommendations are also presented here (task 2).

The author has contacted climate-vegetation modelers, Dr Pietsch from the University of Agricultural Sciences and Dr Lovett from the University of York to meet at the International Botanical Congress (IBC) in Vienna to explore the possibility of developing a model to simulate Pleistocene forest dynamics (task 3).

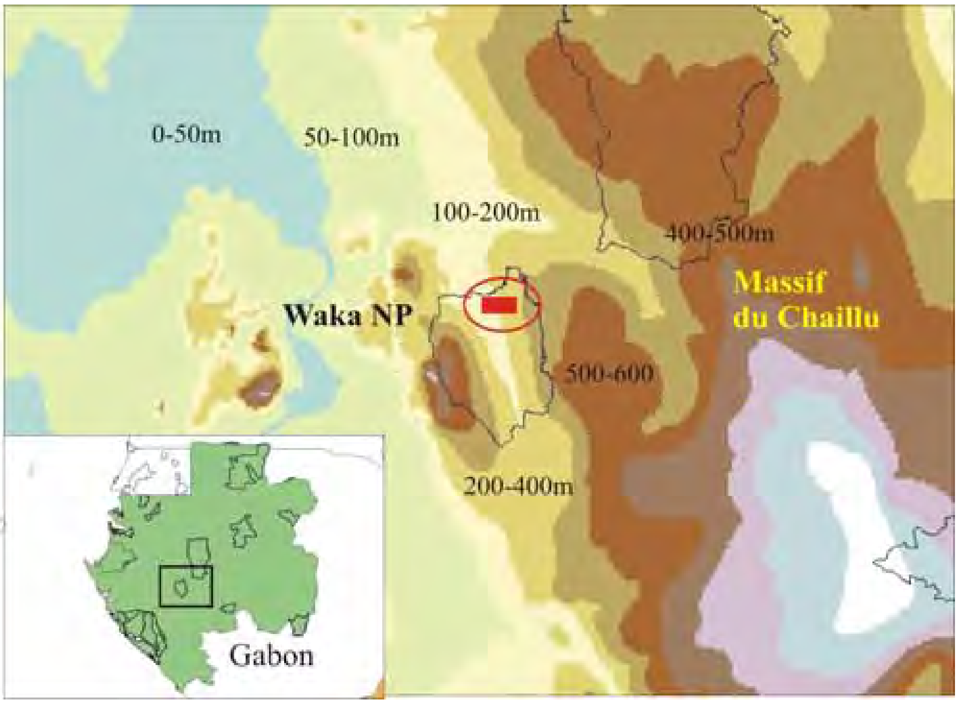
The results and conclusions here presented are preliminary in the sense that the full identification of the plants is still pending. Also the scientific rigor of the conclusions drawn is constrained by the limited number of transects, but general trends are clear and useful for conservation management.

The author is a specialist in the Pleistocene Refuge Forest theory, a connoisseur in vegetation-climate dynamics and expert in the plant biodiversity of Gabon and central Africa.

Miguel E. Leal

August 2005

The biodiversity of **NE Waka**



The geographical position of the study area (red and encircled) in the north-east of Waka.

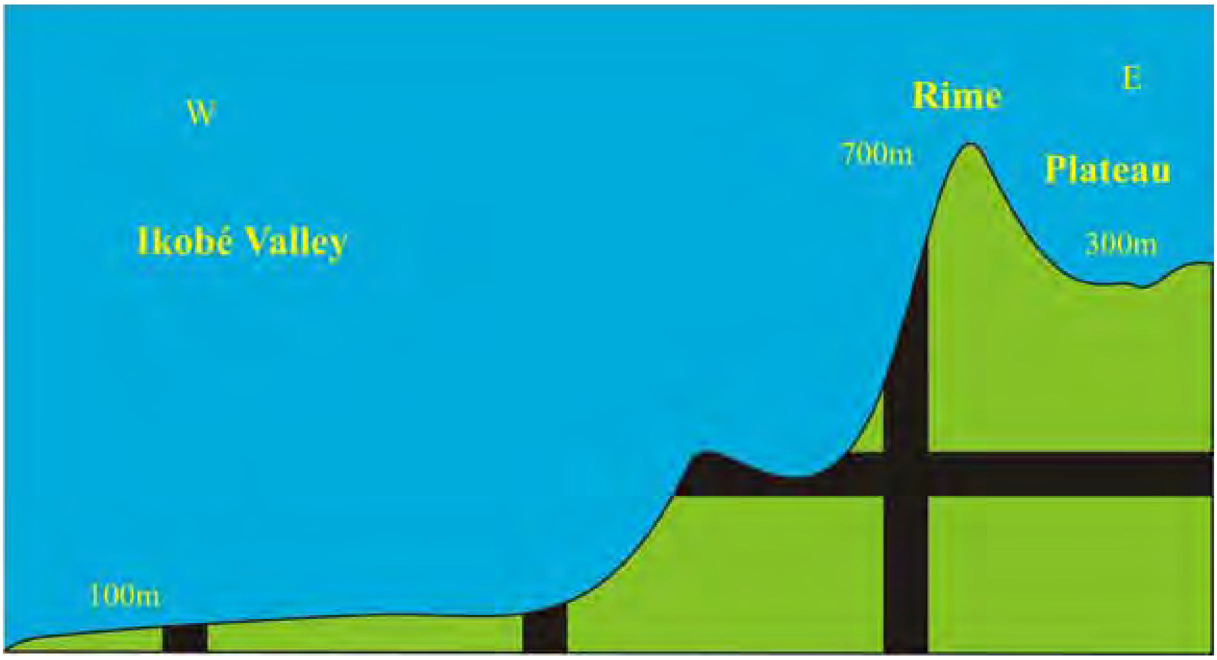
The Ikobé Valley

Waka National Park straddles the only know rift valley of west central Africa, the Ikobé Valley. This valley was part of a larger rift system dating back to the time when South-America and Africa were slowly drifting apart. If the main rifting had taken place along this valley, the western side of Waka NP would now be part of South America.

The floras on both continents became increasingly different, as the Atlantic Ocean steadily widened. It is astonishing to think that (ancestral) species that once inhabited the same valley, like now in the Ikobé Valley became different with time and geographical isolation.

Topographically the Ikobé Valley is clearly visible from a high altitude (next page). The valley is widely U-shaped and the steep slopes on both sides create several impressive waterfalls. At the bottom of the valley runs the Ikobé River at an altitude around 100 m with the rim of the valley at some 700 m. Over the rim altitude drops less strong to some 350 m after which it becomes a strongly undulating plateau.

Rainfall is lowest in this part of the park, but at a local scale the undulating topography is incised by narrow valleys that create shady and moist places, and on the rim the foggy conditions maintain a cool and moist environment.



Cross-section showing the roughly U-shape to the Ikobé Valley.

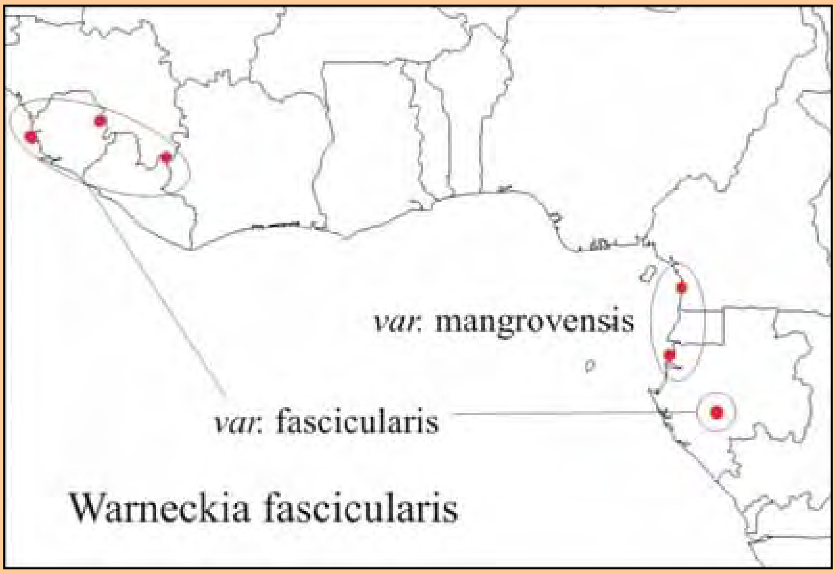
The rift valley visible from a high altitude (map from www-radar.jpl.nasa.gov/ africamap/gabon.htm)

Biological significance

The Waka NP has remained relatively unexplored by botanists. Only some 295 species had been collected in the Waka NP previous to the activities reported here. This number has since been doubled for the park.

Among these collections there were interesting findings (see next page). Recently, a completely new genus has been found for the family of the Flacourtiaceae. This is very exceptional as new genera nowadays are only seldom found.

The NE part of the park was targeted first as it was already and recently logged. The biodiversity assessment had to validate whether the forest was still botanically valuable enough for conservation.



On one of the transects a preliminary identified tree turned out to be a new record for Gabon and central Africa, *Warneckia fascicularis* var. *fascicularis*. The only other known variety was *Warneckia fascicularis* var *mangrovensis* collected along the coast of Gabon and Cameroon. This new record, however, is a sterile specimen i.e. without flowers and fruits. It is still possible that this may be a new species.

Patterns of biodiversity

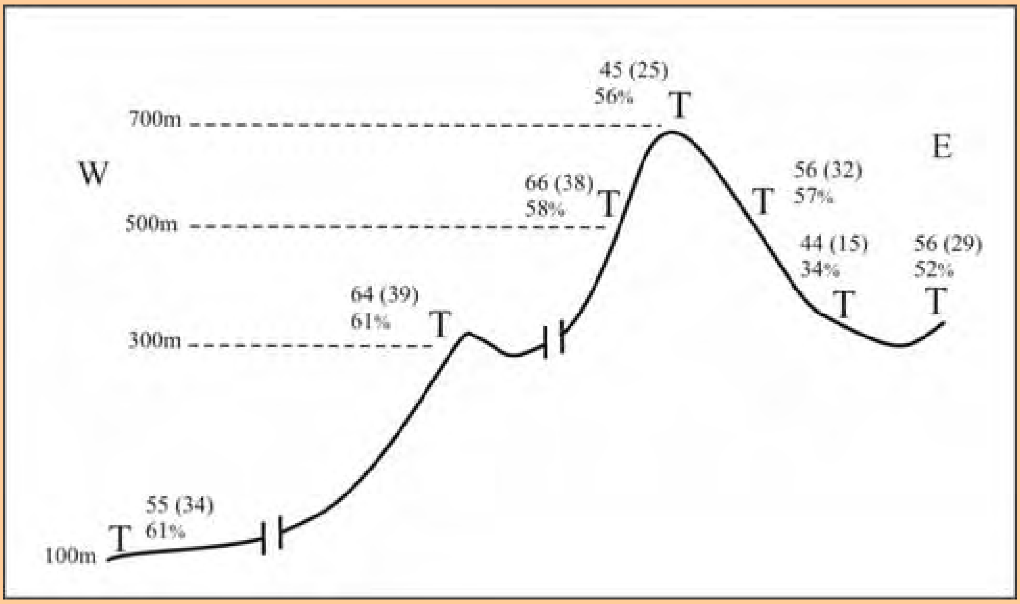
Species are not distributed at random within the rain forest and except for common species most other species are constrained to a certain habitat or environment. Within such a geographically bound environment only the most competitive species will be able to co-exist. The repeated co-occurrence of species at a spatial scale is an indication for underlying environmental arranging forces. In hilly areas two well known arranging forces are altitude and aspect.

In temperate regions the impact of these two forces on the distributions of plant species is clearly visible. With increasing altitude the vegetation changes from oak/beech-dominated forest to pine forest and finally to alpine pastures.

The impact of aspect is evident when comparing south and north facing slopes. The southern slopes are covered by xeric (drought resistant) shrubby/grassy vegetation and north slopes by forest.

In tropical regions the impact of these arranging forces are less clear and the outer appearance of the rain forest changes little along slopes with altitude and aspect. But actually recording plant species along hill slopes or at two opposing sides reveals differences in species composition. How big these differences are is an indication for the biodiversity of an area in general: “the bigger the differences, the greater the biodiversity”.

Therefore, by the means of transects species composition was recorded on both sides of eastern Ikobé Valley ridge, i.e. the west and east facing slope and along these slopes from bottom (100m) to summit (700m).



Profile of the Ikobé Valley and eastern plateau showing the distribution of the transects (T) from bottom to summit and aspect, the figures at each transect are the total number of species, between brackets the number of species restricted to that transect (endemic) and the percentage.

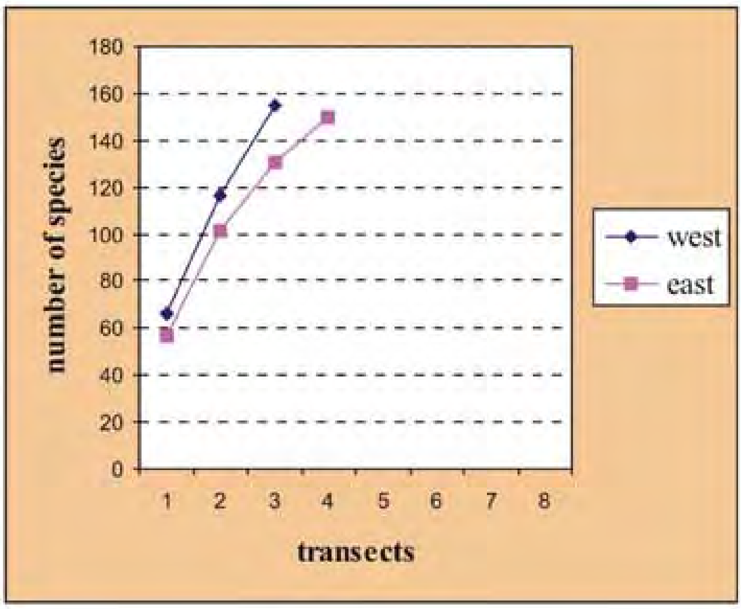
Methods

The transects used to record species composition were 200 m long and 5 m wide. Every individual with a diameter at breast height (dbh) of 5 cm and greater was recorded and identified. For each species which remained unidentified a voucher specimen was taken for further examination in the herbarium of Libreville or Wageningen. Often these specimens were without flowers or fruits in which case species were identified only on sterile e.g. leaf characteristics. Such identifications are less confident and revered to as morpho-species.

Three transects were placed along the west facing slope of the Ikobé Valley at 100m, 300m and 500m, and 4 transects along the east facing slope at 700m, 500m and two at 300m, one at the foot of the rime and one on the plateau (see above). Transects were put in after the altitudinal zone was prospected to estimate the heterogeneity of the environment, and habitat diversity. This procedure ensures to record maximum species diversity present within a certain altitudinal zone and avoids replication, i.e. transects with a similar species composition.

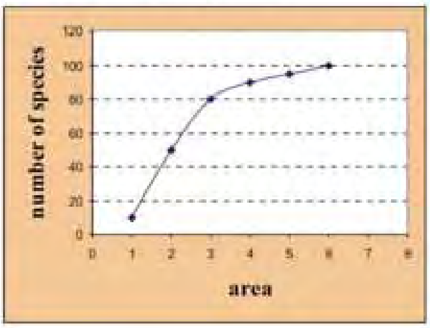
Results

In total species 264 (morpho-) species were recorded on the 7 transects, 155 species on the western slope (3 transects) and 150 species on the eastern slope (4 transects). On average 55 species were recorded per transect. The lowest number was 44 species on the rime at 700m and the highest number was 66 species on the western slope at 500m. 38 species were recorded on both sides. On the western side 4 species were recorded at more than one altitude and on the eastern side 10 species. The majority of the species (178) were restricted to a single transect. The high number of restricted species will most likely decrease when more transects are put in along these slopes.



Species-area curve for the west and east slope of the Eastern Ikobé Valley Ridge (left)

Generally, a maximum of total species is reached for an area after a certain area (below)



Species richness

With 155 species along the west-side species richness seems higher than at the east-side with 150 species (based on total species recorded on all transects). But the difference is small, only 5 species. Besides, on the eastern side there were 4 transects, and removing the species poorest transects raises the total species richness based on 3 transects to 158 species. Hence, the two sides should be considered equally species rich.

Species richness generally tends to increase with sampled area until after a certain surface area a “ceiling” (maximum) is reached, i.e. the species-area curve (above right). Such curves are used to estimate the potential maximum number of species within a certain area. In this case, however, the sampled area is relatively small, 0.7 ha (7 transects=7,000m^2), which limits such an extrapolation, but a within-site comparison is possible.

The species-area curves for the west and east side (see above) are not equally steep. The curve of the eastern side already starts to bend. This suggests that maximum potential species richness is lower on the eastern side. However, there is a difference in sampling.

Putting in plots at a similar altitude on both sides of the rim caused the western plots to be much further apart from each other (3-5 km) than on the eastern side (1 km), because of the widely U-shape of the Ikobé Valley.

Although, the sampling procedure used was designed to maximize species recording and avoid replication, replication is much more likely to occur at a short distance, like on the eastern side than at a long distance, on the western side.

There are three plots around 300m and comparing their species richness shows that the driest transect on the western side is species richer (64 species) than the one on the east side (43 species) and similarly, the transect on the plateau (57 species).

This outcome surprisingly shows the inverse what is generally observed. The transect experiencing the least drought stress is supposed to be the species richest, in this case the transect on the east-side (43 species) and the transect experiencing the highest drought stress the species poorest, i.e. western transect (64 species).

	aspect	W	E(p)	W	E	W	E	
species	altitude	100m	360mp	300mw	350m	500mw	500me	700m
Khaya ivorensis		1						1
Plagiostyles africana		3					1	
Pentaclethra eetveldiana		1	3					
Pycnanthus angolensis		3	1					
Irvingia gabonensis		3	4	1				
Staudtia stipitata		1	5	1	1			
Dacryodes buetneri		1	1	3	2			
Klainedoxa gabonensis		3		2	2	2		
Desbordesia glaucescens		1	1	1	2		3	
Pentaclethra macrophylla		4	4	2	2		1	
Scaphopetalum blackii		8	3	5	2	6	2	
Strombosiopsis tetandra		3	2	2	1	2	1	1
Garcinia smeathmannii		3	5	3	4	3		2
Aucoumea klaineana		3		5	2	5	2	1
Santiria trimera		4	8	3	1	7	4	6
Greenwayodendron suaveolens		5	1	1	2	1		1
Dacryodes macrophylla		1		1	1	2		2
Coula edulis		1		2	4	2	1	1
Heisteria parvifolia		2		1			2	3
Annonidium mannii			1			1		9
Strombosia pustulata			1			3		1
Diogea zenkeri			4	1	3		5	2
Dichostemma glaucescens			7	1		2	4	2
Garcinia mannii			5		1	5		
Sindoropsis letestui			1	1	1		1	
Pausinystalia macroceras			5	1	2	1		
Coelocaryon preussii			1	1			2	
Ganophyllum giganteum				1		1		1
Oubangia africana				4	1	7	3	
Xylopia quintazii				1	1			
Massularia acuminata					1	1		
Grewia coreacea					2	3		
Cleistanthus camerunensis					4	1		1
Bikinia grisea						2	5	
Dacryodes igaganga						2	1	
Anisophyllea purpurascens						1	5	
Cleistopholis patens						1	1	
Scytopetalum klaineanum						1	4	

Common species present at both sides The figures in the row after the species name are the number of individuals. P=plateau

species	aspect / altitude	W 100m	W 300m	W 500m	E 300m (p)	E 300m	E 500m	E 700m
Piptadeniastrum africanum		1		1				
Scottellia klaineana		1		1				
Diospyros spp 1			2	1				
Tetraberlinia bifoliolata			2	1				
Scyphocephalium ochocoa					3	4		
Microdesmis 8a					4	4	5	
Strombosia grandifolia					2	4	2	
Gambeya africana					1	1	1	
Dacryodes normandi					2		1	
Dacryodes klaineana					3	1		1
Carapa procera					1			1
Dactyladenia 9a						1		1
Treculia 9b						1		1

Species present on either the western or eastern side

Aspect and altitude

In a hilly or mountainous area altitude and aspect are strong arranging forces determining species distributions. In NE Waka their force is also apparent. Each species is differently affected by these forces, but three species groups can be distinguished.

The first group consists of common species (14%) which are unaffected by the difference in aspect being present on both sides of the eastern Ikobé Valley Ridge. Altitude here is the principle force causing a gradient in species composition from bottom to summit (see table of **common species**).

At one end of the gradient are species like *Pentaclethra eetveldiana* and *Pcynanthus angolensis* restricted to the bottom, and at the other end species like *Anisophyllea purpurascens* restricted to the higher part of the slopes. The only truly common species is *Santiria trimera* present at all altitude on both sides. Strangely, enough the highest transect seems to be a subset of “common” species from the lower altitudes.

The second group of species (5 %) is more strongly affected by aspect and less by altitude (see table above). 4 species were absent on the eastern side and 10 species are absent on the western side. Many of these species have disjunct distributions along these slopes so altitudinal gradients are not clearly visible.

The disjunctions may have to do with the low sampling density. Putting in more transects could resolve the disjunctions. Alternatively, if these distinctions are genuine this may indicate a similar environment exists on the ridge and at the foot of the valley. This would also explain why in the large table of common species the transect at 700 m seems to be a subset of the species from lower altitudes.

The third and biggest species group is affected by both aspect and altitude (79 %). These species were only recorded on a single transect at only one side of the eastern Ikobé Ridge and they are referred to as the group of endemics (see appendix 1 and appendix 2).

Species turnover

The level of endemism (defined here as species restricted to a single transect) is unusually high partially due to the small number of transects which overestimates endemism. More species may turn out to be less restricted as concluded from this data when more transects are put in along these slopes. This would also change the size of the other two groups as they will become larger at the expense of the group of endemics.

Endemism at the other hand is also very constant between transects over long distances along the western slope and shorter distances along the upper half of the eastern slope (around 60%). The only outliner is the transect at 300m on the eastern slope (34%). This indicates that species turnover with distance (beta-diversity) is high and this may be a characteristic for the Gabonese rain forest, in general since in Mt Mbilan similar figures were observed.

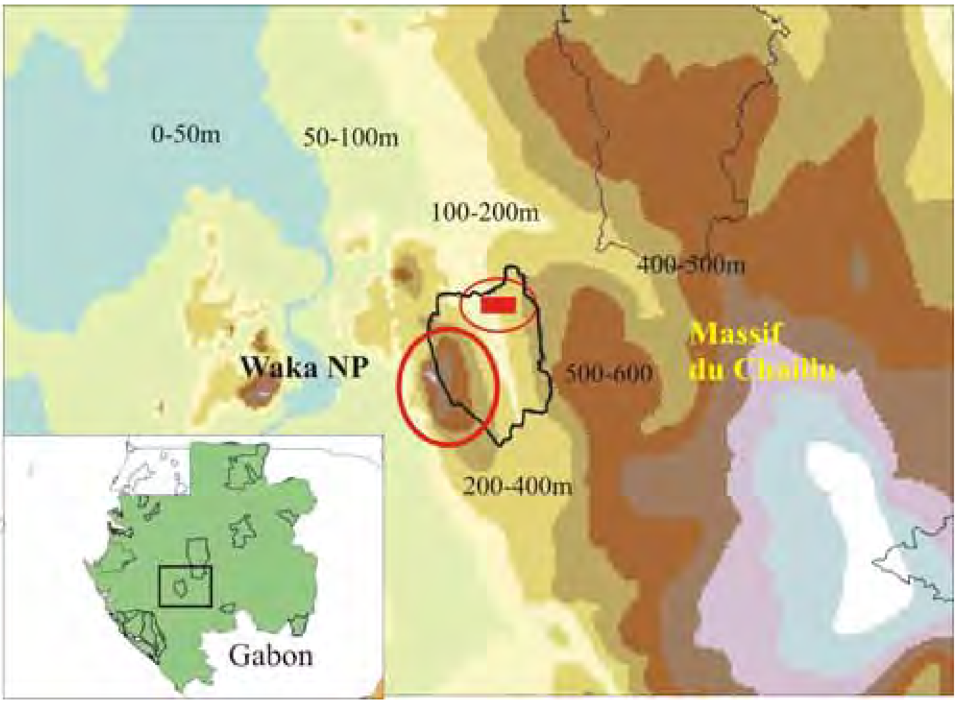
Altitude and aspect are in general strong arranging forces in determining species distributions. In the case of NE Waka species are mainly restricted to a certain altitude or common being present on both the western and eastern side. Aspects seems to be a lesser force, as this this group is relatively small compared to the other two groups.

On the western side endemism as species being restricted to a certain altitude may also be interpreted as endemism restricted to a section of the western slope as being restricted by distance, i.e. as beta-diversity. This kind of species change is still not fully understood, because it is not clearly related with environmental changes along that distance.

Conclusions

NE Waka has been logged in the distant (decades ago on the western side) and recent past (a year ago on the eastern side). These activities show that the density of commercial species was once high in this part of the park, which also hints that biodiversity in general was relatively low. Despite the disturbance biodiversity was still high, but the exclusiveness of species was less high as many of species are also abundantly present outside the park. Species turnover was high ranging from 43 to 61% evenly distributed over the western side and upper half of the eastern side. The analysis showed that the changes in species composition due to aspect are only minor and that altitude is a more important arranging force in this hilly area. Botanically this part of the park is interesting, but not exclusive. This is partially due to the fact that it is the driest part of the park and drought stress is negatively correlated with biodiversity. But, NE Waka still has tourist potential and not only because of the Pygmies. Due to the forestry roads and skidder trails the forest is good accessible, and at the same time the forest has not lost it’s primary look. However, speaking in a conservation perspective some compensation should be given for this logged-over part of the park by extending the park else where.

Identification of Biodiversity Sanctuaries



The geographical location of the potential extension of the park

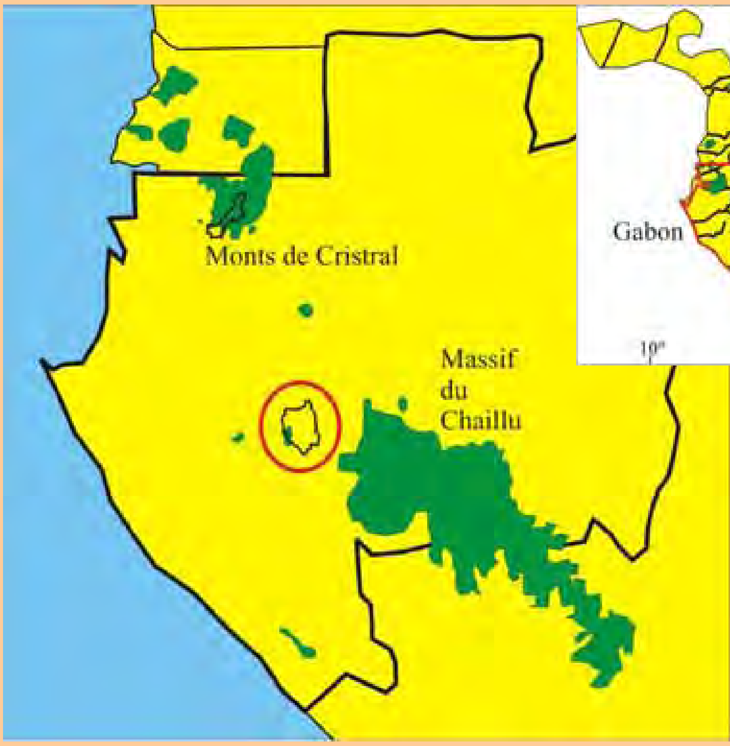
Biodiversity Sanctuaries

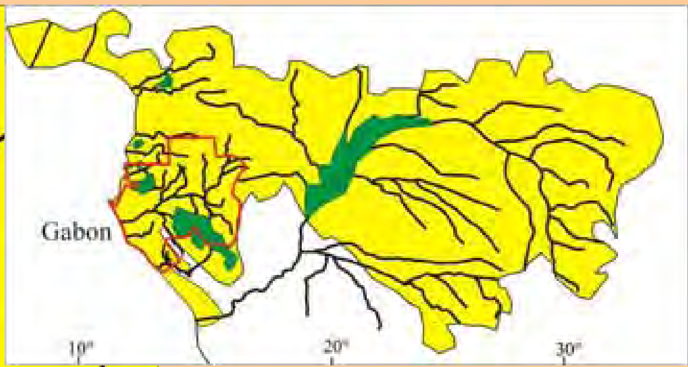
Biodiversity sanctuaries are a tool for conservation to protect valuable areas outside the park system of Gabon. Gabon is famous for its botanical richness which is partly explained by the forest history of the rain forest during the Pleistocene and Holocene (the last 2.3 million years).

During the Pleistocene several periods of global cooling occurred, which led to the aridification of climate over equatorial Africa. The decrease of rainfall caused certain parts of the rain forest to be replaced by grassland. Forest was only able to survive in places where the regional drought stress was compensated by local topography and hydrology.

Topography was important for the survival of the rain forest, because one the characteristics of climate then was the frequent occurrence of low clouds coming in from the sea. Therefore, in elevated areas above 500 m, the rain forest was able to persist as the absence of rainfall was compensated by moisture obtained from mist (see next page).

The surplus of moisture from the mist also prevented streams and rivers coming from the elevated areas to run dry up. This again contributed to the survival of the rain





▲ **The Pleistocene landscape showing the larger forest refugia (green) and the rain forest along the major streams (black lines), and Gabon (red borderline).**

◀ **Waka NP within the Pleistocene landscape of Gabon and the small forest refugium (encircled in red)**

forest in the lowland, where rain forest persisted as gallery forest.

Gabon has been fortunate as a chain of elevated topography stretches through the country parallel to the coast. As more rain forest was able to survive in Gabon also less rain forest species became extinct, which explains why Gabon is so botanically rich.

The reconstruction of the Pleistocene forest landscape has been used as a tool to identify the most valuable parts of the present-day rain forest. These former forest refugia, now hidden within the forest are the oldest part of the rain forest and at least a few millions years old, whereas the forest in between not more than 10,000 years old.

The reconstruction of the Pleistocene forest landscape shows a small forest refugium partially in and west of the Waka NP. This is the oldest forest in and close to the park and valuable to protect it as a Biodiversity Sanctuary (previous page encircled in red). This small forest refugia lays isolated within the Pleistocene forest landscape and may be rich in endemics.

To determine whether is this area is really botanically interesting it should be validated by a biodiversity assessment. If the validation is positive the western border of the park should be extended to incorporate this area. Especially, since the NE part of the park has been severely logged just before its legal status and some compensation for this menace is only reasonable.

Acknowledgements
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Appendix 1

West slope Altitude endemics

species	100m
Irvingia grandifolia	5
Brachystegia mildbraedii	4
Dichapetalum acuminatum	2
Pterocarpus soyauxii	2
Thomandersia hensii	2
Warneckea floribunda	2
Beilschmiedia oblongifolia	1
Berlinia 3b	1
Cleistopholis glauca	1
Cleistopholis staudtii	1
Cola lateritia	1
Copaifera religiosa	1
Dialium 3b	1
Dialium pachyphyllum	1
Diospyros 3b	1
Duboscia macrocarpa	1
Garcinia 3b	1
Garcinia 3b2	1
Garcinia 3c	1
Glossocalyx staudtii	1
Maesobotrya dusenii	1
Maryopsis 3d	1
Panda oleosa	1
Petersianthus macrocarpus	1
Pseudospondias 3b	1
Rhabdophyllum calophyllum	1
Rhodognaphalon brevicuspe	1
Sapindac 3b	1
Sorindeia gabonensis	1
Staudtia 3b	1
Tetrapleura tetraptera	1
Uapaca 3a	1
Uapaca gui	1
Uvariastrium spp	1

species	300m
Microdesmis puberula	5
Euphorbia 2a	4
Necepsia afzelii	3
Plagiosiphon gabonensis	3
Rinorea kamerunensis	3
Bikinia durendii	2
Didelotia africana	2
Diospyros 2a2	2
Drypetes 2d	2
Gilbertiodendron ogoouense	2
Scyphocephalium mannii	2
spp 2	2
Annonac 2a	1
Antrocaryon spp	1
Chytranthus atroviolaceus	1
Cleistanthus 2d	1
Cleistanthus zenkeri	1
Cola 1d	1
Cola spp	1
Corynanthe pachyceras	1
Dactyladenia floribunda	1
Diospyros 2a	1
Diospyros 2b2	1
Diospyros melocarpa	1
Gambeya 2d	1
Gambeya lacourtiana	1
Julbernardia 2b	1
Lecomtadoxa sp	1
Letestua durissima	1
Librevillea klainei	1
Maranthes cf gabunensis	1
Parkia filicoidea	1
Rubia 2d	1
spp 2b	1
Treculia obovoidea	1
Trichoscypha abut	1
Warneckea cinnamomoides	1
Warneckia 2a	1
Xylopia 2d	1

species	500m
Bikinia le-testui	1
Canarium schweinfurthii	1
Anisophyllum spp 2	1
Dactyladenia spp	2
Afrostyrax kamerunensis	1
Cola glaucoviridis	2
Rinoria spp 1	5
Dacryodes heterotricha	3
Dacryodes spp 2	1
Daniellia soyauxii	1
Dialium guineense	1
Diospyros iturensis	1
Drypetes arborescens	1
Drypetes gossweilleri	1
Duguetia spp	1
Eriocoelum spp 1	1
Gambeya spp 1	1
Garcinia gnetoides	1
Garcinia spp 1	1
Garcinia spp 3	1
Homalium spp 1	1
Magnistipula tessmannii	1
Trichilia	1
Monanthotaxis congoensis	1
Myrianthus serratus	1
Newtonia spp 1	1
Octolobus spectabilis	1
Pauridiantha callicarpoides	1
Plagiosiphon emarginatus	1
Rub 2	1
Rub spp 1	1
Sapindac spp	1
spp A	1
spp 1d	1
Synsepalum longecuneatum	1
Trichoscypha oliveri	1
Warneckea wildeana	1
Zanthoxylum heitzii	1

species	300m (p)
Anno 11a	2
Cleineanthus 11b	1
Cleistanthus 11c	2
Daniella klainei	1
Diospyros 11b	1
Diospyros manii	1
Drypetes 11c	1
Enantia chlorantha	1
Eriocoelum 11a	2
Euph 11a	1
Euph 11d	1
Grewia 11c	1
Hesteria 11a	1
Hesteria parvifolia	3
Julbernadia brieyi	2
Maranthes 11c	1
Napoleonea 8c	1
Nauclea poveguinii	1
Odyendya gabonensis	3
Oncoba glauca	1
Parkia bicolor	1
Phyllianthus 11a	1
Rinorea 11a	3
Sorendea 11d	1
Sp11b	1
Sp11b2	1
Treculia 11c	5
Trichoscypha acuminata	1
Xylopia hypolampra	1

P=plateau

species	300m
Calpocalyx dinglei	8
Newtonia leucocarpa	2
Protomegabaria 10d	2
Aralyopsis soyouxii	1
Cylocodiscus gabonensis	1
Dialium 10b	1
Eriocoelum oblongum	1
Gilbertiodendron 10b	1
Librevilia gabonensis	1
Napoleona 9b	1
Sp 10a	1
Strephonema 10b	1
Swartzia fistuloides	1
Trichoscypha 10a	1
Xylopia stautii	1

species	500m
Anisophyllea polyneura	3
Garcinia lucida	3
Hymenostegia pelegrinii	3
Beilchmedia 9c	2
Berlinia 9c	2
Cola 9b	2
Dacryodes 9a	2
Sp 9a	2
Sp 9c	2
Xylopia 9b	2
Afrostyax 9a	1
Beilchmedia 9b	1
Beilschmedia	1
Cola digitata	1
Dialum 9c	1
Dracena 9b	1
Drypetes 9a	1
Duguetia 9b	1
Engomengoma gordonii	1
Eriocoelum 9a	1
Garcinia conraunana	1
Napoleona 9d	1
Rub 9a	1
Rub 9b	1
Rub 9d	1
Rub 9d2	1
Sapium 9c	1
Sorendeia	1
Sp	1
Strephonema 9a	1
Strephonema 9b	1
Zeyherella 9b	1

species	700m
Oubangia 8c	10
Caes 8b	7
Caes 8a	4
Gilbertiodendron 8c	3
Mareya 8a	3
Dacryodes 8c	2
Pausinystalia 8c	2
Annonidium 8b	1
Aphanocalyx microphyllus	1
Blighia 8a	1
Croton mayombensis	1
Dacryodes 8c2	1
Dacryodes 8d	1
Diospyros 8a	1
Euph 8c	1
Ganophyllum 8a	1
Gilbertiodendron 8d	1
Grewia 8d	1
Hylodendron gabunense	1
Maesobotrya sp 1	1
Rubia 8d	1
Tessmannia africana	1
Uapaca 8d	1
Warneckia 8d	1
Zanthoxylum tessmannii	1

Appendix 2 East slope altitude endemics