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A RAINFOREST SURVEY OF AMPHIBIANS, REPTILES AND SMALL MAMMALS AT MONTAGNE D'AMBRE, MADAGASCAR

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Abstract

The Montagne d'Ambre mountain range in northern Madagascar was surveyed for amphibians, reptiles, and small mammals. The rainforest of this region is geographically isolated from the continuous rainforest belt of northern and eastern Madagascar. A total of 24 amphibian, 46 reptile, and 12 mammal species was recorded over two months, by direct sampling and pitfall trapping. Despite previous collecting in this region for more than 100 years, 56% of the species found were new records for Montagne d'Ambre. Possibly seven (three amphibians, three reptiles, one small mammal) of the species recorded are undescribed, and nine are probably endemic to Montagne d'Ambre. The endemic species are Plethodontohyla *sp. nov. 2 and 3,* Brookesia *sp. nov. 1 and 2,* Paracontias brocchii, Zonosaurus haroldmeieri, Liopholidophis *sp. nov.,* Pseudoxyrhopus ambreensis, *and* Microgale parvula. *Published amphibian and reptile species lists for Montagne d'Ambre contained 26–40% errors, which is probably typical for most sites in Madagascar, and cautions against using such sources of data indiscriminately.*

The vast majority of species (83%) were found only in primary forest, and the majority (70%) had restricted altitudinal ranges, either occurring above or below 900 m elevation. The presence of low-altitude specialists at Montagne d'Ambre clearly demonstrates the need to conserve the lower altitude peripheral forests which are most vulnerable to encroachment and degradation.

Keywords: Madagascar, Amphibia, conservation, Mammalia, rainforest, Reptilia.

INTRODUCTION

Montagne d'Ambre, centered at 12°32'S, 49°10'E, is a mountain range running north–south at the extreme northern tip of Madagascar (Fig. 1). It is also referred to as Ambohitra on modern Madagascan maps, and as Amber Mountain on English maps of the last century, but these names are rarely used. The highest peak is at 1475 m altitude, with the foot of the mountain range at 200–300 m. Montagne d'Ambre has a distinctive microclimate. The annual precipitation (e.g. Station Roussettes, mean 2378 mm) is much higher than the surrounding region (e.g. Antsiranana, mean 980 mm) (Nicoll & Langrand, 1989).

The vegetation of Montagne d'Ambre is rainforest, with moist montane forest above 800 m and lowland rainforest below 800 m (vegetation types of White, 1983). The forest below 800 m appears to be transitional in form to the surrounding much drier deciduous forests which are at 0–300 m elevation. Montagne d'Ambre rainforest is completely isolated from the major rainforest block of the north and east. The 110 km of arid habitats which separate Montagne d'Ambre rainforest from the closest rainforests at Ambanja have not been produced by recent human activity. The Montagne d'Ambre Massif is volcanic in origin, composed of basaltic rock formed about 14 M years ago (IUCN/UNEP/WWF, 1987); therefore it is possible that the Montagne d'Ambre rainforest may have been isolated for millions of years.

The Montagne d'Ambre forests were first protected in the 1920s as a forestry station ('Les Roussettes') established in rainforest at 1000 m altitude. The first National Park in Madagascar was created at Montagne d'Ambre in 1958, with a surface area of 18200 ha. The Forêt d'Ambre Special Reserve (4810 ha) was created at the same time. These two protected areas include forest between 417 and 1474 m in elevation. During the development of the forestry station and later the National Park exotic trees (e.g. *Eucalyptus* and pines) were introduced, two small dams built to feed an irrigation system, and about 30 km of roads and paths cut within the forest. All the Montagne d'Ambre forests are currently managed by the Direction des Eaux et Forêt and the World Wide Fund for Nature.

Despite the relatively old ages of the Park and Special Reserve and the interesting biogeographic history of Montagne d'Ambre, some of the vertebrate groups were still poorly known prior to this study. This was especially true for amphibians and reptiles. Specimens had been collected from the region for more than 100 years, with the earliest herpetological collection (deposited in the Paris National Museum in 1883) made by Alluaud and Belly. Typically, however, these specimens lack precise locality data, which is a significant problem because of the wide elevational range and diverse forest types found in the region. Species were often represented by a single specimen, which made it impossible to understand character variation within local populations and increased the risk of taxonomic errors.

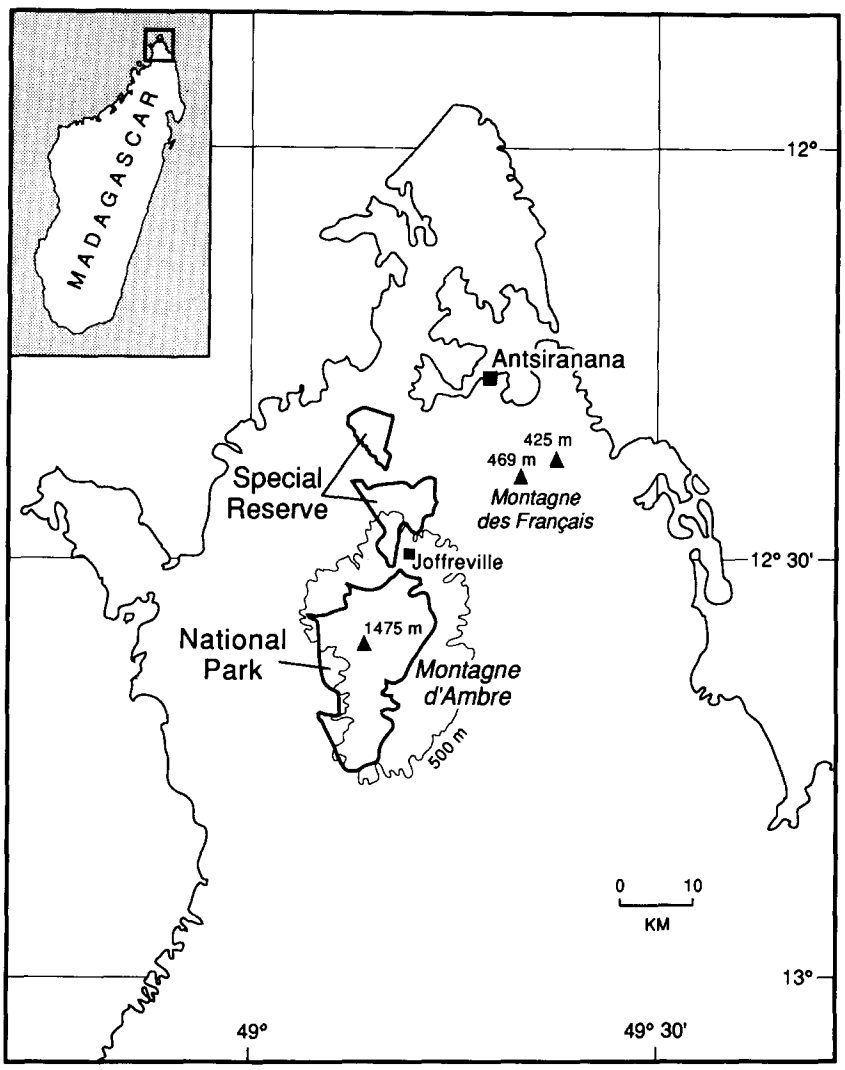

Fig. 1. Map showing locations of study sites.

By 1989 two vertebrate species lists had been published for Montagne d'Ambre by conservation organisations, which listed seven frog, 16 reptile, and five small mammal species (IUCN/UNEP/WWF, 1987; Nicoll & Langrand, 1989). Of these, four reptile and one mammal species were known only from this region. However, because of the scattered literature, some published records inevitably were omitted from these lists.

The results of prior herpetological surveys made by us at other rainforest sites in Madagascar suggested that many more amphibians and reptiles would be found at Montagne d'Ambre. Therefore, because of the biogeographic importance of the region and the lack of adequate information, a survey of amphibians, reptiles, and small mammals was undertaken in 1991–92.

LITERATURE SUMMARY

The amphibian, reptile, and small mammal species recorded in the literature from Montagne d'Ambre are shown in Table 1. We included only records which specifically state 'Montagne d'Ambre' 'Mararaomby', 'Roussettes', 'Ambohitra' and 'Joffreville'. These sites are all within the Montagne d'Ambre mountain range, and may refer to the National Park, Special Reserve, the entire mountain range, or, for the last locality, the town at 12°30'S, 49°12'E. We did not include records for the Antsiranana (Diego Suarez) region because of the very different habitats included in this vague locality. The Antsiranana region could refer to either Antsiranana town, the mostly degraded dry forests which surround Antsiranana, the limestone mountains of Montagne de Francais (10 km southeast of Antsiranana), or Montagne d'Ambre (40 km southwest of Antsiranana). Montagne d'Ambre was consistently used as a collecting locality since the end of the last century, therefore we do not think Montagne d'Ambre was normally included by collectors in the Antsiranana region locality.

The following sources provided Montagne d'Ambre specimen records: frogs (Blommers-Schlösser & Blanc, 1991), *Lygodactylus* (Pasteur & Blanc, 1967), *Paroedura* (Angel, 1942), *Uroplatus* (Bauer & Russell, 1989), *Phelsuma* (Loveridge, 1942; Mertens, 1964), chameleons (Brygoo, 1971, 1978), *Androngo* (Brygoo, 1981), *Amphiglossus* (Brygoo, 1984), *Paracontias* (Brygoo, 1980), *Zonosaurus* (Brygoo & Boehme, 1985), snakes (Guibé, 1958), *Microgale* (MacPhee, 1987), and *Eliurus* (Carlton & Schmidt, 1990). In only a few cases (amphibians and reptile specimens held at the National Museum,

Table 1. Amphibian, reptile and small mammal species recorded at Montagne d'Ambre

Species	Collected specimens		Altitude (m)	Habitat	
	Literature	1991–92 survey		Forest	Non-forest
AMPHIBIA					
Microhylidae					
Stumpffia psologlossa	*	*	600–1250	*	
Stumpffia c.f. *grandis*		*	650	*	
Plethodontohyla laevipes	*	*	900–1200	*	
Plethodontohyla sp. nov. 1		*	650	*	
Plethodontohyla sp. nov. 2		*	650	*	
Plethodontohyla sp. nov. 3		*	650	*	
Cophyla phyllodactyla	*	*	1100–1250	*	
Platypelis grandis		*	650	*	
Ranidae					
Ptychadena mascareniensis	*	*	900–1200		*
Mantellidae					
Laurentomantis horrida		*	1200	*	
Mantidactylus granulatus	*	*	900–1250	*	
Mantidactylus curtus	*	*	650–1150	*	
Mantidactylus wittei		*	900	*	
Mantidactylus femoralis	*	*	650–1150	*	
Mantidactylus liber		*	1150	*	
Mantidactylus ambreensis		*	650–1150	*	
Mantidactylus asper		*	900–1250	*	
Mantidactylus pseudoasper		*	600–900	*	
Mantidactylus bicalcaratus		*	950–1200	*	
Rhacophoridae					
Aglyptodactylus madagascariensis	*	*	900–1200	*	
Boophis luteus		*	650–1150	*	
Boophis madagascariensis	*	*	650–1200	*	
Boophis miniatus		*	650–1150	*	
Boophis untersteini		*	750–950	*	
REPTILIA					
Gekkonidae					
Ebenavia inunguis		*	650	*	
Geckolepis maculata		*	650	*	
Lygodactylus madagascariensis	*	*	650–1200	*	
Phelsuma lineata	*	*	650–1100	*	*
Phelsuma madagascariensis	*	*	800–900	*	*
Paroedura oviceps		*	650	*	
Paroedura stumpffi	*	*	650	*	
Uroplatus alluaudi	*	*	650–950	*	
Uroplatus ebenaui	*	*	650–1200	*	
Uroplatus fimbriatus	*	*	650–800	*	
Uroplatus sikorae		*	650–950	*	
Chamaeleonidae					
Brookesia ebenaui	*	*	650–800	*	
Brookesia stumpffi	*	*	650–1200	*	
Brookesia tuberculata	*	*	900	*	
Brookesia sp. nov. 1		*	650–1200	*	
Brookesia sp. nov. 2		*	650	*	
Calumma boettgeri	*	*	650–1250	*	
Calumma brevicornis	*	*	900–1300	*	
Calumma nasuta	*	*	900		*
Calumma oshaughnessyi	*	*	900–1250	*	
Furcifer pardalis	*	*	650–900	*	*
Furcifer petteri	*	*	650–700	*	*
Scincidae					
Androngo alluaudi	*		?	?	?
Amphiglossus melanopleura		*	900–1250	*	
Amphiglossus melanurus		*	1100	*	
Amphiglossus mouroundavae	*	*	900–1250	*	
Amphiglossus stumpffi		*	650	*	
Mabuya elegans		*	600–850		*
Paracontias brocchii	*	*	900–1250	*	
Paracontias hildebrandti		*	600–700	*	

continued

Table 1 — *contd.*

Species	Collected specimens		Altitude (m)	Habitat	
	Literature	1991–92 survey		Forest	Non-forest
REPTILIA—*contd.*					
Cordylidae					
Zonosaurus haroldmeieri	*	*	700–1000		*
Typhlopidae					
Typhlops c.f. *mucronatus*		*	650	*	
Typhlops microcephalus		*	650–1200	*	
Boidae					
Boa manditra	*	*	650–950		
Colubridae					
Alluaudina bellyi	*	*	650	*	
Geodipsas heimi		*	900–1250	*	
Geodipsas infralineata		*	650	*	
Leioheterodon madagascariensis	*	*	650–1000	*	*
Liophidium rhodogaster	*	*	850–1150	*	
Liophidium torquatus		*	900–950	*	*
Liophidium sp. nov.		*	650	*	
Liopholidophis lateralis		*	600–900	*	*
Liopholidophis sp. nov.		*	900–1250	*	
Lycodryas arctifasciatus		*	650–850	*	
Pararhadinaea albignaci		*	650	*	
Pseudoxyrhopus ambreensis	*	*	900–1200	*	
Pseudoxyrhopus microps		*	650	*	
MAMMALIA					
Tenrecidae					
Microgale brevicaudata		*	650–670	*	
Microgale longicaudata		*	650–1250	*	
Microgale melanorrhachis		*	1125–1250	*	
Microgale parvula	*	*	1125	*	
Microgale talazaci		*	660–1250	*	
Microgale sp.		*	650–1250	*	
Tenrec ecaudatus	*	*	650–1150	*	
Setifer setosus	*	*	650–660	*	
Soricidae					
Suncus murinus		*	1150	*	
Murideae					
Eliurus myoxinus majori	*	*	1150–1200	*	
Eliurus myoxinus webbi	*	*	650–700	*	
Rattus rattus	*	*	650–1125	*	

Paris) were we able to examine museum material to confirm identifications.

IUCN/UNEP/WWF (1987) and Nicoll and Langrand (1989) listed other herpetological species for Montagne d'Ambre for which we are unable to find documentary support (museum specimens or literature descriptions). We suspect *Boa manditra* (formerly *Sanzinia madagascariensis*, see Kluge, 1991) and *Liophidium rhodogaster* are personal observations, *Mantidactylus lugubris* is a misidentification (probably of *M. femoralis* or *M. ambreensis*), while *Homopholis boivini, Amphiglossus ardouini, Boa madagascariensis* (formerly *Acrantophis madagascariensis*, see Kluge, 1991), and *Ithycyphus miniatus* are all literature records for Antsiranana. Two other listed species have subsequently been synonymized: *Mantidactylus flavicrus* is a synonym of *M. femoralis* (Blommers-Schlösser & Blanc, 1991), and *Microgale prolixacaudata* a synonym of *M. cowani* (MacPhee, 1987).

Blommers-Schlösser and Blanc (1991) gave Montagne d'Ambre localities (Montagne d'Ambre, Mararaomby or Les Roussettes) for several frog species which we found were misidentified at the Muséum national d'Histoire naturelle, Paris (see Table 2). *Boophis goudoti* is also recorded from Montagne d'Ambre by Blommers-Schlösser and Blanc (1991), but we found neither voucher specimens nor records at Paris and suspect this species does not exist at Montagne d'Ambre.

STUDY SITES

Fieldwork was centered at two field camps located within primary forest, which facilitated exploration of the full altitudinal range found within the Park (Fig 1). Camp 1, Antomboka River, 12°32.22'S, 49°10.05'E, 1150 m altitude in cloud forest, was occupied from 15 November 1991 to 15 December 1991. During this period the typical forest altitude surveyed was 900–1450 m. Camp 2, Antomboka River Fitsahana, 12°29.33'S, 49°10.28'E, 650 m altitude in lowland rainforest with transition to drier deciduous forest, was occupied from 21 December 1991 to 20 January 1992. During this period the typical forest altitude surveyed was 600–950 m.

Table 2. New identifications of Montagne d'Ambre amphibians in the National Museum, Paris

Museum number MNHP	Family	Species identification	
		New	Previous
1975.2469-70	Rhacophoridae	*Boophis miniatus*	*Boophis majori*
1975.322, 324-5	Mantellidae	*Mantidactylus asper*	*Mantidactylus luteus*
1975.329	Mantellidae	*Mantidactylus asper*	*Mantidactylus luteus*
1975.585-6, 588,	Mantellidae	*Mantidactylus curtus*	*Mantidactylus ulcerosus*
1975.592-3, 596, 599	Mantellidae	*Mantidactylus curtus*	*Mantidactylus ulcerosus*
1975.607, 613-5	Mantellidae	*Mantidactylus curtus*	*Mantidactylus ulcerosus*
1975.587, 590, 596	Mantellidae	*Mantidactylus curtus*	*Mantidactylus betsileanus*

MATERIALS AND METHODS

The survey was timed for the onset of the rainy season when most species are breeding and, therefore, activity is at its highest. Field techniques used to sample animals were (1) pitfall trapping with drift fences; (2) opportunistic day and night searching; (3) refuge examination (under and in fallen logs; under bark; and in leaf litter, soil and talus, and leaf axils of screw palms *Pandanus* and traveller's palm *Ravenala*).

The pitfall traps were buckets (275 mm deep, 290 mm top internal diameter, 220 mm bottom internal diameter), sunk in the ground at intervals along a 100-m drift fence. The handles of the buckets were removed, and small holes (2 mm diameter) were punched in the bottom to allow water to drain. The fence (0.5 m high) was made from plastic sheeting stapled to thin wooden stakes. The fence bottom was buried 50 mm deep into the ground using leaf litter and positioned to run across the middle of each pitfall trap. A pitfall trap was positioned at both ends of the drift fence, with the other nine traps at 10-m intervals. The trap lines were checked each morning and pitfall captures removed from the lines, except in the case of live mammals, which were uniquely marked (by fur clipping) and released at the point of capture. Four lines were used at a time, and sampling was made over 11–16 days. A total of 16 lines were erected during the survey.

Opportunistic searching and refuge examination were made throughout the full elevation range of habitats available at Montagne d'Ambre. The majority of searching was done close to existing trails, although ridges and river banks were also used to orientate search paths. Night searches were made using a head-lamp.

The following information was recorded at the time of capture for each specimen: date, time, longitude and latitude, altitude, microhabitat, and circumstances of capture. Liver and muscle were removed from representatives of almost all species and frozen in liquid nitrogen. A photographic record was made of representative live individuals of all species. Frog calls were recorded for those species found breeding. Specimens were fixed in 10% buffered formalin and later transferred to alcohol. Collected material was deposited at three main centers: the Museum of Zoology, University of Michigan; the Zoology Department, University of Antananarivo; and the Zoology Section, Tsimbazaza Park, Antananarivo.

We followed the most recently published taxonomic revisions, except that we continue to recognise *Mantidactylus ambreensis* Mocquard 1895 (synonymised with *M. femoralis* by Guibé, 1978) and *Microgale melanorrhachis* Morrison-Scott 1948 (synonymised with *M. cowani* by MacPhee, 1987).

We recently examined the *Mantidactylus ambreensis* holotype (MHNP 1893.241), which has a distinct lateral border between the dark dorsal and pale ventral coloration on the flanks. *Mantidactylus femoralis* has a poorly defined border which is usually marbled. Both species were found to be sympatric at Montagne d'Ambre and also Manongarivo (14°02'S, 48°18'E), although *M. femoralis* was rarer. A more detailed diagnosis of *M. ambreensis* will be published elsewhere.

Microgale melanorrhachis was synonymised with *M. cowani* by MacPhee (1987) because of similar dentition. He considered the black dorsal vertebral stripe used to diagnose *M. melanorrhachis* as a polymorphic trait of *M. cowani*. We found that striped individuals have a much paler ventral coloration and are slightly smaller than unstriped individuals at Mantady National Park (18°51'S, 48°27'E), and conclude that these two forms are good species. Pitfall trap data from Mantady suggests that at 1100 m elevation *M. melanorrhachis* is restricted to valley bottoms, whereas *M. cowani* is found in valley bottoms, on slopes and in ridge forest. We found the two species sympatric at Ambatovaky Special Reserve (16°51'S, 49°08'E), but only *M. cowani* in the Tölanaro region (e.g. 24°34'S, 46°49'E), and only *M. melanorrhachis* at Montagne d'Ambre and Manongarivo.

RESULTS

A total of 24 amphibian, 46 reptile and 12 small mammal species were recorded within Montagne d'Ambre National Park and Special Reserve. A complete species list is given in Table 1 along with the altitudinal range for each species and their occurrence in primary and/or secondary forests. The majority of data used to compile Table 1 was provided by collecting specimens through opportunistic searching and refuge examination. Three amphibian, four reptile and possibly one mammal

Table 3. Montagne d'Ambre pitfall lines used to capture amphibians, reptiles and small mammals (capture rate % is number of vertebrate individuals captured per trap day)

Line	Forest Type	Latitude	Longitude	Altitude (m)	Start Date	Days	Trap Days	Capture rate (%)
1	Valley	12°32·17'S	49°10·12'E	1125	19.11.91	16	176	6·3
2	Slope	12°32·17'S	49°09·88'E	1125	20.11.91	15	165	13·3
3	Ridge	12°32·22'S	49°10·17'E	1150	19.11.91	16	176	30·0
4	Valley	12°32·22'S	49°10·10'E	1125	21.11.91	14	154	14·9
5	Ridge	12°32·33'S	49°10·22'E	1150	5.12.91	11	121	47·8
6	Ridge	12°32·38'S	49°10·00'E	1150	5.12.91	11	121	31·4
7	Ridge	12°32·78'S	49°09·68'E	1250	5.12.91	11	121	52·1
8	Ridge	12°32·62'S	49°10·00'E	1125	6.12.91	11	121	53·7
9	Slope	12°29·33'S	49°10·33'E	660	26.12.91	13	143	11·9
10	Valley	12°29·20'S	49°10·28'E	650	26.12.91	13	143	14·7
11	Valley	12°29·17'S	49°10·30'E	650	26.12.91	13	143	18·2
12	Valley	12°29·17'S	49°10·33'E	650	26.12.91	13	143	8·4
13	Slope	12°29·05'S	49°10·22'E	660	7.1.92	12	132	2·3
14	Slope	12°29·00'S	49°10·17'E	670	7.1.92	12	132	19·7
15	Valley	12°29·00'S	49°10·28'E	650	8.1.92	12	132	10·6
16	Valley	12°29·12'S	49°10·22'E	650	8.1.92	11	121	26·4

species are undescribed. Of the 82 species recorded during this survey, 42 (51%) are new records for Montagne d'Ambre. Just three species were found only in secondary habitats, representing 4% of the total fauna, while 68 species (83%) were found only in primary forest.

The pitfall trap lines are characterised in Table 3. A total of 484 vertebrates were captured over 2244 pitfall trap days, giving an overall vertebrate capture rate of 21.6% per trap day. The number of individuals of each species caught by the trap lines is summarized in Table 4. The pitfalls caught five amphibian, 10 reptile, and 11 mammal species.

Table 4. Pitfall trap capture of amphibians, reptiles and small mammals

Species	Number of individuals captured															
	Pitfall line number															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
AMPHIBIA																
Aglyptodactylus madagascariensis		1														
Laurentomantis horrida						1		1								
Plethodontohyla laevipes			3					1								
Plethodontohyla sp. nov. 2									1	1				1	2	1
Stumpffia psologlossa	2	1	3	4		3	1	2	6	10	18	2	1	18	2	21
REPTILIA																
Amphiglossus melanopleura	1					7		2								
Amphiglossus mouroundavae	1		3	1	6	5	1	8								
Amphiglossus stumpffi									1	2	1	5	1	1	4	2
Brookesia stumpffi														1		
Brookesia sp. nov. 1										1						
Paracontias brocchi		1														
Pararhadinaea albignaci												1		1		
Paroedura oviceps									1	1	1	1				
Paroedura stumpffi														1		2
Typhlops microcephalus			2													
MAMMALIA																
Eliurus myoxinus majori				2		1										
Eliurus myoxinus webbi										1						
Microgale brevicaudata									2	3	1	2		1	2	2
Microgale longicaudata			3		15		4	10	1	1	1	1				1
Microgale melannorhachis	9	18	33	12	36	17	52	38								
Microgale parvula				1				1								
Microgale talazaci	3		5	3		4	4	2	3							
Microgale sp. 1			1				1			1	3		2	2	4	2
Rattus rattus								1								
Setifer setosus									1		1					2
Suncus murinus		2			1											

DISCUSSION

Previous studies

Less than half of the species we found at Montagne d'Ambre had been previously reported in the literature from this locality but there was almost no information on their altitude or habitat distributions within the massif. Our survey results were perhaps unexpected because Montagne d'Ambre is considered as one of the most intensively studied rainforest regions of Madagascar, having been visited by collectors for more than 100 years. According to Nicoll and Langrand (1989), just six rainforest sites (Andringitra, Lokobe, Marojejy, Manongarivo, Analamazaotra and Ambohitantely) had more known herpetological species.

Although for most sites in Madagascar there is very little published herpetological information, even less is readily available to conservation organisations. The scattered nature of the literature (often in specialist publications) has meant that previously compiled herpetological species lists have many omissions. In the case of Montagne d'Ambre, this has meant that the herpetological species lists published by IUCN/UNEP/WWF (1987) and Nicoll and Langrand (1989) omitted five amphibian and 12 reptile species.

Errors in the literature, either misidentifications or incorrect localities, were also prevalent. The frog distribution maps of Blommers-Schlösser and Blanc (1991) appear to be based in part on museum material which was not critically examined. Of the 12 species shown on their maps in Montagne d'Ambre, four apparently were misidentified (see earlier), giving a 33% error. Of the 23 herpetological species listed for Montagne d'Ambre in IUCN/UNEP/WWF (1987) and Nicoll and Langrand (1989) six probably do not occur at the site (see earlier) giving a 26% error.

We found errors of similar magnitude during a detailed herpetological study in the Tölanaro (Fort Dauphin) region, in southeastern Madagascar. Specimens were misidentified and localities frequently vague and sometimes obviously incorrect. For example, of the 13 amphibian species reported by Blommers-Schlösser and Blanc (1991) from Fort Dauphin, Ste Luce and Mandena, four species (*Heterixalus tricolor, Mantidactylus boulengeri, M. liber,* and *Aglyptodactylus madagascariensis*) have obviously been misidentified or have incorrect localities, giving a 31% error. Furthermore, earlier collectors used the 'Fort Dauphin' locality to describe many different sites in the region. This is a significant problem because the region includes three completely different habitats: primary rainforest, semi-arid littoral forest, and semi-arid spiny forest. As a result, the habitat and precise locality of each specimen are unknown.

If Montagne d'Ambre and Tölanaro are representative, then the literature contains 26–40% errors (from incorrect localities and misidentifications). In addition the lack of detailed survey data means that most species lists accurately describe just a small fraction of the actual herpetological species diversity. For Montagne d'Ambre, 20% of the herpetofauna was accurately described by IUCN/UNEP/WWF (1987) and Nicoll and Langrand (1989) and 27% of the amphibian fauna by Blommers-Schlösser and Blanc (1991). Disturbingly, both sources are currently being used to determining amphibian and reptile conservation priorities in Madagascar.

Habitat and distribution

Of the 82 species recorded in this survey, 68 (83%) were found only in primary forest. Only four species were found just in non-forest habitats: a ranid frog *Ptychadena mascareniensis* in a crater lake at 1200 m altitude; a chameleon *Calumma nasuta* in a pine plantation; a skink *Mabuya elegans* and a plated lizard *Zonosaurus haroldmeieri* on grassy road banks and in clearings. The other 77 species were all found within primary rainforest. Clearly, most species included in our survey are dependent on primary rainforest habitat and do not do well in degraded or open habitats. This strongly reaffirms the belief that the native forest of Montagne d'Ambre must be conserved to maintain high levels of biodiversity in this region of Madagascar.

The altitudinal distributions of the amphibians, reptiles, and small mammals is restricted in most cases to just a portion of the full altitudinal range found at Montagne d'Ambre. A distinct transitional altitude was found for many species at 900 m. Of the 82 species recorded, 30 were found exclusively at or below 900 m and 27 exclusively at or above 900 m altitude. A minority of the Montagne d'Ambre species (30%) were found both above and below 900 m. The 900 m contour corresponds closely to the transition between lowland rainforest and moist montane forest, which is indicated by White (1983) to be about 800 m. The fauna of Montagne d'Ambre, therefore, appears to be largely composed of both lowland rainforest and moist montane forest specialists.

Some of the Montagne d'Ambre amphibians, reptiles, and small mammals are probably endemic to this mountain range. The following species are known only from Montagne d'Ambre: two microhylid toads—*Plethodontohyla* sp. nov. 2 and *Plethodontohyla* sp. nov. 3; two dwarf chameleons—*Brookesia* sp. nov. 1 and *Brookesia* sp. nov. 2; a skink—*Paracontias brocchii*; a plated lizard—*Zonosaurus haroldmeieri;* two colubrid snakes—*Liopholidophis* sp. nov. and *Pseudoxyrhopus ambreensis*; and a tenrec shrew—*Microgale parvula. Pseudoxyrhopus ambreensis* and *Microgale parvula* were known previously only by their holotypes (Guibé, 1958; MacPhee, 1987), and *Paracontias brocchii* by three specimens (Brygoo, 1980). The Montagne d'Ambre rainforest, isolated by 110 km from the once continuous rainforest belt of northern and eastern Madagascar, may have preserved relict populations of species that disappeared from other regions of the rainforest; or it may have facilitated speciation through geographic isolation. Both of these factors would produce endemics in the Montagne d'Ambre biota.

Some of the other species we found at Montagne

d'Ambre are extremely rare in collections. The leaf-tailed gecko *Uroplatus alluaudi*was previously known from just four specimens, two from Montagne d'Ambre and two from Imotra, the latter being an unknown locality in southcentral Madagascar (Bauer & Russell, 1989). The colubrid snake *Pararhadinaea albignaci* was previously known only from a roadkill holotype collected at Analamazaotra (Perinet), 18°57'S, 48°26'E, East Madagascar (Domergue, 1984). Both these species have potentially large geographic ranges, but appear to be difficult to find. At Montagne d'Ambre, three *Uroplatus alluaudi* and two *Pararhadinaea albignaci* were collected over a period of two months. Another rare species with a potentially large range is the microhylid toad *Plethodontohyla* sp. nov. 1, which we collected at Ambatovaky Special Reserve, 16°51'S, 49°25'E, and Ranomafana National Park, 21°17'S, 47°26'E, as well as at Montagne d'Ambre.

We found many of the Montagne d'Ambre species also at Manongarivo Special Reserve, 14°03'S, 48°20'E, and some Montagne d'Ambre species are also recorded from Lokobe Reserve on Nosy Be Island. This northwestern rainforested region of Madagascar (not including Montagne d'Ambre) is sometimes referred to as the Sambirano Region and is floristically distinct from other regions of Madagascar (Humbert, 1955). The following Montagne d'Ambre species appear to be otherwise restricted to the Sambirano Region: frogs—*Cophyla phyllodactyla, Mantidactylus ambreensis*; geckos—*Lygodactylus madagascariensis, Paroedura oviceps, Paroedura stumpffi*; chameleons—*Brookesia ebenaui, Furcifer petteri*; skinks—*Androngo alluaudi, Amphiglossus mouroundavae, A. stumpffi*; and snakes—*Liophidium* sp. nov. For all species in which it was determined at Montagne d'Ambre, it was very similar to that found at Manongarivo. Despite the disjunct distributions of these Sambirano species, they appear to be ecologically and morphologically similar to the Montagne d'Ambre populations.

Almost all of the Montagne d'Ambre amphibian and reptile species (96%) are endemic to Madagascar, with just three species—a frog *Ptychadena mascareniensis*, a gecko *Phelsuma madagascariensis* and a snake *Leioheterodon madagascariensis*—occurring on other Indian Ocean Islands. For the small mammals 75% of the Montagne d'Ambre species are endemic to Madagascar (non endemics—*Suncus murinus, Rattus rattus* and *Tenrec ecaudatus* (introduced to Seychelles)). The extremely high level of endemicity seen in the fauna, at both the regional or national level, emphasizes the importance of the Montagne d'Ambre protected areas.

Introductions

Several of the species at Montagne d'Ambre may have been accidentally introduced. A single chameleon, *Calumma nasuta,* was found in pine forest close to the forestry station. All the small *Calumma* found in the native forests were *C. boettgeri* (probably more than 1000 were seen during the survey). At Manongarivo, in primary forest we found only *C. boettgeri*, and strongly suspect this species is naturally allopatric with *C. nasuta* in northern Madagascar. *C. nasuta* may have been accidentally introduced to Montagne d'Ambre when trees or other vegetation were transplanted to the gardens and plantations around the Roussettes forest station. Brygoo (1978) reported *C. nasuta* from Montagne d'Ambre and the islands of Nosy Be and Nosy Komba, although the circumstances of capture are not given. These may also be accidental introductions, because both islands are frequently visited by boats. We found *C. nasuta* in degraded habitats in southeastern Madagascar, indicating that it can establish itself in secondary habitats where we have never observed *C. boettgeri.*

Other possibly introduced species include the non-endemic ranid frog *Ptychadena mascareniensis*, which occurs at 'Cursed Lake' in Montagne d'Ambre. Carp were introduced to this and other crater lakes in the Park, and possibly tadpoles or eggs of *P. mascareniensis* were accidentally introduced at the same time. This frog was never found in primary forest, and 'Cursed Lake' is at least 6 km from the forest edge. The two small mammals *Suncus murinus* and *Rattus rattus,* both considered to have been introduced to Madagascar, were caught in primary forest and have obviously successfully invaded deeply into the Park. We also found both these species in primary rainforest at Manongarivo.

Conservation

Although Madagascar is regarded as one of the richest biological countries in the world it is also one of the most threatened. This is especially true for rainforest. Aerial photographs and satellite images show that between 1950 and 1985 50% of the remaining rainforest was destroyed (Green & Sussman, 1990). The forests of Montagne d'Ambre are threatened by fire and clearing for cultivation (Nicoll & Langrand, 1989), with most of this activity occurring at the periphery in the lower altitude forests. Comparing forest cover shown on 1:100000 maps published in the 1950–60s with current forest limits clearly shows that some peripheral forest has been lost over the past 30 years at Montagne d'Ambre, although the actual extent of forest has not yet been measured.

At Montagne d'Ambre the peripheral rainforests of the massif (which are most vulnerable to encroachment or degradation) are at a lower elevation and transitional in nature with respect to the surrounding much drier forest types. In this study we found 37% of the amphibians, reptiles and small mammals to be restricted to forest below 900 m altitude, and therefore largely confined to peripheral areas. A significant portion of the Montagne d'Ambre biodiversity is absent from the more sheltered core areas of the Park and Special Reserve. Deforestation, by fire or cultivation, at the edge of the reserves would eventually lead to the loss of some low-altitude species from the protected areas, and possibly even extinction of the low-altitude Montagne d'Ambre endemic frogs *Plethodontohyla* sp.nov. 1, *Plethodontohyla* sp. nov. 2 and the dwarf

chameleon *Brookesia* sp. nov. 2. It is essential that the peripheral forests should be given high priority in future conservation initiatives—preserving an intact structural core of forest at the expense of peripheral forest will not maintain the region's existing biodiversity.

Accurate inventory studies are vital to understanding patterns of biodiversity both within and between protected areas. Factors limiting the distribution of species, such as altitude, rivers, and other natural boundaries, must all be considered when making management decisions for protected areas. In Madagascar, amphibians, reptiles and small mammals make ideal subjects for identifying patterns of biodiversity which can be applied to reserve management. These groups are typically species-rich, highly adapted to specific native habitats, poor dispersers, and show a high degree of local endemicity.

Although species distribution patterns can have important consequences for reserve management it is vital that inventory data used for such purposes are known to be accurate and relatively complete. In Madagascar most published inventory lists of amphibians and reptiles contain a large degree of error and only report a small fraction of total species diversity. Accurate inventories are needed for all the protected areas of Madagascar to facilitate a comprehensive review of the reserve network's ability to maintain biodiversity.

The high diversity of amphibians, reptiles, and small mammals found at Montagne d'Ambre clearly demonstrates the importance of the Park and Special Reserve within the network of protected areas in Madagascar. Nine species are known only from Montagne d'Ambre, and possibly all nine may be endemic to this mountain range. Because of the high degree of local endemicity and the unique biogeographic isolation of the rainforests, the survival of an interesting and important component of the biodiversity of Madagascar depends on the successful conservation of the Montagne d'Ambre forests.

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