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THE FIRST COMPREHENSIVE SURVEY OF AMPHIBIANS AND REPTILES AT MONTAGNE DES FRANÇAIS, MADAGASCAR

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***Abstract.*—We surveyed the calcareous massif Montagne des Français in northern Madagascar for amphibians and reptiles. We recorded nine amphibian and 52 reptile species by direct sampling and pitfall trapping in the first detailed survey to focus on this area. Consequently 78.7% of the species found were new records for Montagne des Français. The majority of species (60.7%) were only found in relatively undisturbed areas of forest with diversity peaking at 100-200 m elevation. The most threatened elements of this herpetofauna are the eight species that appear to be locally endemic: *Amphiglossus* sp. nov., *Brookesia* sp. nov., *Heteroliodon fohy*, *Liophidium* cf. *therezieni*, *Bibilava martae*, *Madagascarophis* sp. nov., *Paroedura* sp. and *Paroedura lohatsara* (3-5 of which are undescribed). An additional 28 species are regional endemics, two species are listed as vulnerable on the 2006 Red List of Threatened Species and 14 species are listed on the CITES appendices. We further emphasize the conservation importance of this massif by documenting the presence of four threatened species of lemur that have not previously been recorded from Montagne des Français. This paper contributes to the current understanding of Malagasy patterns of biodiversity by documenting the composition, geographical, seasonal and ecological distribution of the herpetofauna found at this calcareous limestone massif. Located approximately 12 km from the town of Antsiranana, this important biological center of endemism is subject to numerous human-induced environmental problems and should, therefore, be considered a high conservation priority. We strongly suggest that the area be fully included into the system of protected areas in Madagascar.**

***Resumé.*—Un sondage des amphibiens et reptiles a été réalisé dans le massif calcaire de la Montagne des Français situé dans la partie nord de Madagascar. Au total, neuf amphibiens et 52 reptiles ont été documentés par échantillonnage direct et par piège-trappes, au cours du premier sondage de cette zone. D'autant plus, 78.7% des espèces trouvées étaient de nouveau relevés pour la Montagne des Français. La majorité des espèces (60.7%) n'ont été trouvées que dans des zones de la forêt relativement non-perturbées d'une diversité culminant à 100-200 m d'altitude. Les éléments les plus vulnérables de cette herpétofaune sont les huit espèces qui semblent être endémiques: *Amphiglossus* sp. nov., *Brookesia* sp. *nov*., *Heteroliodon fohy*, *Liophidium* cf. *therezieni*, *Bibilava martae*, *Madagascarophis* sp. nov., *Paroedura sp*. et *Paroedura lohatsara* (3-5 d'entre elles ne sont pas décrites). Vingt-huit espèces supplémentaires sont des endémiques régionales, deux espèces sont classées comme vulnérables sur la Liste Rouge des Espèces Menacées 2006 et 14 espèces figurent dans l'appendice de CITES. Nous voudrions mettre l'accent sur l'importance de la protection du massif en documentant la présence de quatre espèces menaces de Lémuriens qui n'avaient pas été documentées auparavant à la Montagne des Français. Cet article contribue à la compréhension actuelle du modèle Malgache de biodiversité, en documentant la composition et la distribution géographique, saisonnière et écologique de l'herpétofaune qui se trouve sur ce massif calcaire. Situé à peu près à 12 km de la ville de Antsiranana, ce centre biologique d'endémisme important est sujet à de nombreux problèmes environnementaux anthropogéniques et devrait donc être considéré d'une haute priorité pour sa protection. Nous recommandons impérativement que la zone soit entièrement inclue dans le système des régions protégées de Madagascar.**

Key Words.—Amphibia; conservation; Madagascar; Montagne des Français; Reptilia

INTRODUCTION

Montagne des Français (Fig. 1) is one of the calcareous massifs (known locally as "tsingy") located in the extreme north of Madagascar. A major component of the "northern complex" (ANGAP 2003), it is situated approximately 12 km from Antsiranana, the administrative capital of the Antsiranana province and is divided between the communes of Ramena and Mahavanona. The altitude of this massif ranges between 100 and 400 m and is characterized by a mosaic of caves, canyons, and corridors. As part of the dry bioclimatic zone defined by Cornet (1974), it is subject to marked seasonal variation, with a distinct and relatively long dry season followed by a wet season lasting from December to April. The annual precipitation of this location is most likely higher than that

FIGURE 1. Montagne des Français is one of the calcareous massifs (known locally as "tsingy") located in the extreme north of Madagascar.

received by Antsiranana, which has a mean of 980 mm (Nicoll and Langrand 1989). As a result the vegetation of Montagne des Français is of a distinctly more mesic type than that of its surroundings, and has been described as transitional between mid-altitude rainforest and dry deciduous western forest (Ramanamanjato et al. 1999). Due to its close proximity to the town of Antsiranana, the majority of forest varies from semi-disturbed to anthropogenically altered habitat with little pristine forest remaining. The forest of this massif is completely isolated from the major dry deciduous forest block of the west and the major rainforest block of the east. It is also completely isolated from three of the five other major localized areas of forest (Ankarana, Daraina, and Montagne d'Ambre) located in the extreme north of Madagascar and partially isolated from the remaining two (Analamera and Orangea). It has been suggested that human invasion [estimated at approximately 2000 years ago (Burney et al. 2003)] and subsequent anthropogenic deforestation is responsible for this current isolation (Ramanamanjato et al. 1999; D'Cruze et al. 2006).

Until recently the Montagne des Français massif received no formal protection. We believe that this is chiefly because the amount of information available for the majority of vertebrate groups found within this massif is surprisingly scarce (but see Robinson et al. 2006 for a chiropteran species list) when compared to other geographical locations (Andreone et al. 2003; D'Cruze et al. 2006). To date the only herpetological records for Montagne des Français document just a few species from scattered sources (e.g., Glaw and Vences 1994; Ramanamanjato et al. 1999). Fieldwork conducted in recent years however, has begun to reveal the extraordinary importance of this northern-most Malagasy limestone massif as a biological center of endemism, with the discovery of a multitude of new botanical, invertebrate, and herpetological taxa (Pintak and Böhme 1988; Andriamampianina et al. 2000; Glaw et al. 2001; Lavranos et al. 2001; Lourenço and Goodman 2006). Consequently, in late 2006, Montagne des Français was nominated as a Durban Vision Potential Site requiring some form of protection (Ministère de l'Environment, des Eaux et Forets 2005) and was granted Temporary Protected Area Status (the first of three steps necessary to create a permanently protected area).

Herein, we report on a detailed survey of amphibians and reptiles that was undertaken in order to: (1) contribute to the existing literature regarding the composition, geographical, ecological, and seasonal distribution of the species found within the massif; (2) highlight the herpetological importance of this area and reinforce the need for its full inclusion as part of the system of protected areas located in the north of Madagascar; and (3) facilitate the creation of an effective management plan for the massif.

MATERIALS AND METHODS

Study sites.—A major component of the fieldwork was carried out by a team of researchers and volunteers over approximately one year and consisted of four sampling periods (two wet and two dry seasons). Each sampling period lasted approximately nine weeks in duration and can be summarized as follows: Wet 1: 7 April-15 June 2005; Dry 1: 28 June-5 September 2005; Dry 2: 5 October-14 December 2005; Wet 2: 3 January-7 March 2006. All four periods concentrated on an area adjacent to Andavakoera village at a base camp situated within semi disturbed forest at 12°19.78'S, 49°22.05'E (GPS data). Operating from an elevation of 140 m, researchers surveyed a wide altitudinal range of this massif including forest at elevations up to 320 m. In addition, a satellite camp facilitated the detailed exploration of other areas of forest that were not within logistical reach from the base camp. Situated at 12°19.68'S, 49°20.23'E, 318 m, this site was occupied for a 10 day period on two separate occasions, which can be summarized as follows: Dry 1: 10 August-20 August 2005; Wet 1: 2 February-12 February 2006. A second team conducted additional fieldwork in the region between the "Kings Lodge" Hotel (12°18'44"S, 49°20'17"E, 20 m) and the remains of the "French Fort" (12°19'34"S, 49°20'09"E, 334 m) located at the peak of

TABLE 1. Location and description of pitfall lines used to capture amphibians and reptiles at massif Montagne des Français in northern Madagascar 2005-2006 (capture rate % is number of vertebrate individuals caught per trap day).

Season	Line	Habitat	Microhabitat	Latitude	Longitude	Altitude (m)	Start date	Finish date	Days	Trap days	Capture rate %
Wet 1	1	disturbed	Canyon	12°19.72'S	49°20.54'E	195	17.04.05	24.04.05	7	77	22.1
Wet 1	2	disturbed	Canyon	12°19.77'S	49°20.62'E	195	17.04.05	24.04.05	7	77	5.2
Wet 1	3	disturbed	Canyon	12°19.80'S	49°20.62'E	195	17.04.05	24.04.05	7	77	11.7
Wet 1	4	Forest	Steep hillside	12°20.24'S	49°21.27'E	170	26.04.05	03.05.05	7	77	15.6
Wet 1	5	Forest	Steep hillside	12°20.27'S	49°21.23'E	185	26.04.05	03.05.05	7	77	23.4
Wet 1	6	Forest	Slight hillside	12°20.27'S	49°21.18'E	185	26.04.05	03.05.05	7	77	24.7
Wet 1	7	Forest	Valley	12°20.86'S	49°21.44'E	82	26.05.05	02.06.05	7	77	2.6
Wet 1	8	Forest	Slight hillside	12°20.97'S	49°21.44'E	79	26.05.05	02.06.05	7	77	1.3
Wet 1	9	Forest	Slight hillside	12°21.09'S	49°21.48E	90	26.05.05	02.06.05	7	77	2.6
Dry 1	10	Forest	Steep hillside	12°20.24'S	49°21.27'E	170	06.07.05	14.07.05	8	88	3.4
Dry 1	11	Forest	Steep hillside	12°20.27'S	49°21.23'E	185	06.07.05	14.07.05	8	88	4.5
Dry 1	12	Forest	Slight hillside	12°20.27'S	49°21.18'E	185	06.07.05	14.07.05	8	88	1.1
Dry 1	13	Forest	Gully	20°19.59'S	49°20.60'E	232	29.07.05	06.08.05	8	88	15.9
Dry 1	14	Forest	Slight hillside	12°19.64'S	49°20.59'E	262	29.07.05	06.08.05	8	88	13.6
Dry 1	15	Forest	Steep hillside	12°19.63'S	49°20.53'E	288	29.07.05	06.08.05	8	88	3.4
Dry 1	16	disturbed	Gully	12°19.58'S	49°20.71'E	291	11.08.05	20.08.05	8	88	2.3
Dry 1	17	Forest	Slight hillside	12°19.72'S	49°20.22'E	318	11.08.05	20.08.05	8	88	1.1
Dry 1	18	Forest	Slight hillside	12°19.68'S	49°20.23'E	314	11.08.05	20.08.05	8	88	1.1
Dry 2	19	Forest	Steep hillside	12°20.24'S	49°21.27'E	170	15.10.05	24.10.05	8	88	4.5
Dry 2	20	Forest	Steep hillside	12°20.27'S	49°21.23'E	185	15.10.05	24.10.05	8	88	9.1
Dry 2	21	Forest	Slight hillside	12°20.27'S	49°21.18'E	185	15.10.05	24.10.05	8	88	3.4
Dry 2	22	disturbed	Canyon	12°19.80'S	49°20.62'E	195	06.11.05	15.11.05	8	88	21.6
Dry 2	23	disturbed	Canyon	12°19.81'S	49°20.56'E	195	06.11.05	15.11.05	8	88	5.7
Dry 2	24	disturbed	Canyon	12°19.85'S	49°20.51'E	195	06.11.05	15.11.05	8	88	20.5
Dry 2	25	Forest	Valley	12°20.86'S	49°21.44'E	82	19.11.05	28.11.05	8	88	0
Dry 2	26	Forest	Slight hillside	12°20.97'S	49°21.44'E	79	19.11.05	28.11.05	8	88	2.3
Dry 2	27	Forest	Slight hillside	12°21.09'S	49°21.48E	90	19.11.05	28.11.05	8	88	1.1
Wet 2	28	Forest	Steep hillside	12°20.24'S	49°21.27'E	170	10.01.06	19.01.06	8	88	22.7
Wet 2	29	Forest	Steep hillside	12°20.27'S	49°21.23'E	185	10.01.06	19.01.06	8	88	26.1
Wet 2	30	Forest	Slight hillside	12°20.27'S	49°21.18'E	185	10.01.06	19.01.06	8	88	30
Wet 2	31	Forest	Gully	20°19.59'S	49°20.60'E	232	22.01.06	31.01.06	8	88	3
Wet 2	32	Forest	Slight hillside	12°19.64'S	49°20.59'E	262	22.01.06	31.01.06	8	88	2.3
Wet 2	33	Forest	Steep hillside	12°19.63'S	49°20.53'E	288	22.01.06	31.01.06	8	88	8
Wet 2	34	disturbed	Gully	12°19.58'S	49°20.71'E	291	03.02.06	12.02.06	8	88	1.1
Wet 2	35	Forest	Slight hillside	12°19.72'S	49°20.22'E	318	03.02.06	12.02.06	8	88	4.5
Wet 2	36	Forest	Slight hillside	12°19.68'S	49°20.23'E	314	03.02.06	12.02.06	8	88	4.5

the massif (13-22 March 2000, 20 February 2003, and 17-24 February 2004). In addition, short excursions were carried out to the Andavakoera region (12°20'02"S, 49°21'31"E, ca. 100 m, 28 February 2004) and the sand dune region locally called Ankoriky (12°17'20"S, 49°22'05"E, ca. 20 m, 16 March 2000).

Field methods.—We used a wide range of sampling methods to collect data for as many species as possible. The main survey techniques we used were pitfall trapping with drift fences, active searching, and refuge examination. We also made a concerted effort to glean information about finding amphibians and reptiles from local people living in the area.

Pitfall traps consisted of buckets (270 mm deep, 290 mm top internal diameter, 220 bottom internal diameter) sunk into the ground, so that the rim was flush with the surface. We removed the handles of the buckets, and small holes (2 mm diameter) were punched in the bottom to allow water to drain. We made the fence (0.5 m high) from plastic sheeting tied to thin wooden stakes, the bottom 50 mm of which we buried into the ground using leaf litter, and

positioned to run directly across the middle of each pitfall trap. We placed traps into the ground at 10 m intervals along 36 transect lines measuring 100 m in length across forest and disturbed habitat and a variety of microhabitats (Table 1).

We checked trap lines each morning and afternoon and we removed pitfall captures from the lines, uniquely marked animals (by scale or toe clipping), and released them at the point of capture. Three pitfall lines were used at a time, with sampling lasting seven to eight days in duration.

We conducted both diurnal and nocturnal active searches throughout the full altitudinal range of habitats available at Montagne des Français. Each active search lasted approximately three hours in length with the majority carried out close to existing trails, ridges, and river banks that were used to orientate search paths. In addition, we hired local guides to explore less accessible areas with the hope of encountering species that tend to select more closed micro-habitats. Because many species retreat to refuges when inactive (Raxworthy 1988), refuge examination was an important sampling method used during this survey. Investigators searched under leaf litter and stones, amongst dead wood, and on tree trunks both day and night to gauge species diversity.

At the time of capture for each individual, we recorded; date, time, altitude, microhabitat, and circumstances of capture. The species we recorded from the area were classified using a system similar to that used by D'Cruze and Sabel (2005) and were summarized as follows: Abundant (large numbers encountered on a regular basis), common (encountered on a regular basis), infrequent (unpredictable, few individuals seen), or rare (rarely seen). We also determined geographical coordinates of localities using a global positioning receiver (GPS). Photographic records (held by the first author) were compared with specimens housed at the University of Antananarivo and were also verified by Dr. A. P. Raselimanana. We collected representative voucher specimens from some sites and are stored at two main centers: the University of Antananarivo (UADBA) and the Zoologische Staatssammlung München (ZSM). Additional specimens were also deposited in the Zoological Museum, Amsterdam (ZMA).

The taxonomy of the herpetofauna follows Glaw and Vences (1994) and subsequently published taxonomic revisions (Vences and Glaw 2001; Bauer 2003; Vences et al. 2004; Schmitz et al. 2005; Glaw and Vences 2006; Glaw et al. 2007). Throughout our survey, we could not identify some taxa to the species level and therefore some specimens may represent undescribed species. Species that greatly resembled described taxa but contradicted the identification keys and determination tables in some way were tentatively identified as "cf." for example *Stumpffia* cf. *roseifemoralis*.

RESULTS

During this survey, we recorded nine amphibian and 52 reptile species in the Montagne des Français massif, giving a total herpetofaunal diversity of 61 species (Table 2). Ten species (16.4%) were abundant, 14 (23%) were common, 14 (23%) were infrequent and 23 (37.7%) were rare (Table 2). Of the 56 species we encountered at Andavakoera, 29 (51.8%) were present during all four of the sample periods, 11 (19.6%) were found only during the wet season and two (3.6%) were found only during dry season (Table 2).

With regard to primary habitat, we found just five species (representing 8.2% of the total fauna) only in anthropogenically disturbed non-forest habitat: *Acrantophis madagascariensis, Hoplobatrachus tigerinus, Langaha madagascariensis, Pelusios castanoides* and *Ramphotyphlops braminus*. In contrast, we found 37 species (60.7%) solely within relatively undisturbed areas of forest, and 16 species (26.2%) were found to occur in both of these highly distinct habitats (Table 2). We found 31 species (50.8%) only in terrestrial situations, 14 (23%) only in arboreal situations, and nine (14.8%) in both (Table 2). We observed six species in both semi-aquatic and terrestrial situations (9.8%) and one species *Pelusios castanoides* (1.6%) was only observed in semi-aquatic situations.

Forty-eight species are new records for the massif; this previously unknown component of the Montagne des Français herpetofauna represents 78.7% of the species sampled in this survey. Maximum herpetofaunal species diversity was recorded at mid-elevation (Fig. 2), within the

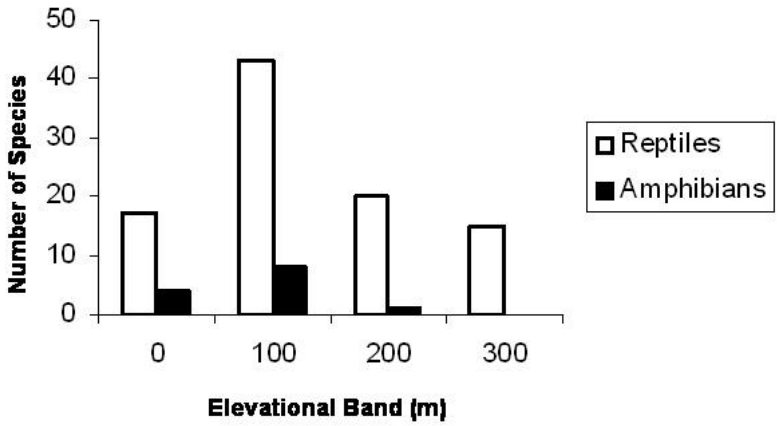

FIGURE 2. The number of reptile (open bars) and amphibian (black bars) species we found at massif Montagne des Français in northern Madagascar 2005-2006 as a function of elevation. The number of species is shown for 100 m elevational increments, with the minimum and maximum elevations (recorded during this survey) used to calculate the average elevational range of each species.

TABLE 2. Conservation status and distribution of the amphibian and reptile species found during surveys of massif Montagne des Français in northern Madagascar 2005-2006. Relative Abundance: A = abundant, C = common, I = infrequent, R = rare. Ecological Distribution: AB = arboreal, T = terrestrial, S = semiaquatic. Habitat: F = Forest, A = anthropogenically disturbed. Seasonal Data: Wet = Wet season, Dry = Dry season, + = present. *Listed as vulnerable in the 2006 IUCN Red List of Threatened Species. **Listed as Critically Endangered by Andreone et al. (2005).

							Andavakoera			
Species	**CITES listing**	**Relative Abundance**	**Ecological Distribution**	**Altitude (m)**	**Habitat**	**Kings Lodge 2000-2004**	**Wet 2005**	**Dry 2005**	**Dry 2005**	**Wet 2006**
Amphibia: Microhylidae										
Stumpffia cf. *roseifemoralis*		R	T, S	140	F		+			+
Stumpffia sp. 1		C	T, S	130-150	F	+	+	+	+	+
Ranidae sensu lato										
Hoplobatrachus tigerinus	II	R	T, S	10	A	+				
Ptychadena mascareniensis		A	T, S	40-199	F, A	+	+	+	+	+
Mantellidae										
Aglyptodactylus securifer		R	T, S	140	F	+	+		+	+
Boophis tephraeomystax		I	AB	130-150	F		+	+	+	+
Laliostoma labrosum		R	T	20-140	F	+	+			+
Mantella viridis **	II	C	T	40-299	F	+	+	+	+	+
Mantidactylus bellyi		A	T, S	130-185	F		+	+	+	+
Reptilia: Pelomedusidae										
Pelusios castanoides		R	S	45	A		+			
Chamaeleonidae										
Brookesia ebenaui	II	R	T	140	F	+				+
Brookesia sp. nov.	(II)	R	T	130-150	F	+				+
Brookesia stumpffi	II	I	T	130-150	F	+	+	+		+
Furcifer pardalis	II	A	AB	0-320	F, A	+	+	+	+	+
Furcifer petteri	II	R	T, AB	230	F	+		+	+	+
Furcifer oustaleti	II	A	AB	0-199	F, A	+	+	+	+	+
Gekkonidae										
Blaesodactylus boivini		A	AB	40-320	F, A	+	+	+	+	+
Ebenavia inunquis		R	T	140-250	F	+			+	+
Geckolepis maculata		C	AB	40-320	F, A	+	+	+	+	+
Geckolepis sp.		R	AB	80	F	+			+	
Hemidactylus frenatus		I	AB	--	--	+				
Hemidactylus mercatorius		I	AB	--	--	+				
Lygodactylus heterurus		C	AB	40-320	F, A	+	+	+	+	+
Paroedura lohatsara		C	T, AB	140-320	F	+	+	+	+	+
Paroedura stumpffi		C	T, AB	40-199	F, A	+	+	+	+	+
Paroedura sp.		I	T	140-320	F	+	+	+	+	+
Phelsuma madagascariensis	II	A	AB	40-320	F, A	+	+	+	+	+
Phelsuma abbotti	II	C	AB	0-320	F, A	+	+	+	+	+
Uroplatus cf. *ebenaui*	II	R	T, AB	140	F			+		+
Uroplatus sp.	II	I	AB	100-150	F	+	+	+	+	+
Gerrhosauridae										
Zonosaurus boettgeri		R	AB	140	F			+	+	+
Zonosaurus tsingy		C	T	140-320	F	+	+	+	+	+
Scincidae										
Amphiglossus sp. nov.		R	T	170-185	F	+	+			+
Amphiglossus ardouini		R	T	185	F					+
Madascincus intermedius		C	T	140-320	F	+	+	+	+	+
Madascincus stumpffi		I	T	130-185	F		+			+
Trachylepis elegans		A	T	0-199	F, A	+	+	+	+	+
Trachylepis tavaratra		A	T	200-320	F, A	+	+	+	+	+
Boidae										
*Acrantophis madagascariensis**	I	I	T	190	A	+	+			+
*Sanzinia madagascariensis**	I	C	T, AB	140-150	F	+	+	+		+
Colubridae sensu lato										
Alluaudina bellyi		R	T	140	F	+	+			+
Dromicodryas bernieri		I	T	140	F				+	+
Dromicodryas quadrilineatus		A	T	40-320	F, A	+	+	+	+	+
Heteroliodon fohy		R	T	170	F	+				
Ithycyphus miniatus		I	T, AB	100-150	F		+	+	+	+
Langaha pseudoalluaudi		R	T	250	F			+		+
Langaha madagascariensis		I	T, AB	120-190	A		+	+	+	+
Leioheterodon madagascariensis		C	T	60-199	F	+	+	+	+	+
Liophidium torquatum		C	T	30-185	F, A	+	+	+	+	+
Liophidium cf. *therezieni*		R	T	140-232	F				+	+
Bibilava lateralis		I	T	140	F		+		+	+
Bibilava stumpffi		R	T	140	F, A		+		+	
Bibilava martae		C	T	140-170	F	+	+	+	+	+
Madagascarophis colubrinus		C	T, AB	60-320	F	+	+	+	+	+
Madagascarophis sp. nov.		R	T	--	--	+				
Mimophis mahfalensis		A	T	0-320	F, A	+	+	+	+	+
Pseudoxyrhopus quinquelineatus		R	T	140-150	F		+			+
Stenophis inopinae		R	AB	120-330	F	+			+	+
Stenophis granuliceps		I	T, AB	60-140	F, A	+	+	+	+	+
Typhlopidae										
Typhlops sp.		I	T	185	F		+	+		+
Ramphotyphlops braminus		R	T	205	A				+	

100-199 m band (51 species), and minimum diversity was recorded within the 300-399 m band (15 species).

We captured 275 vertebrates in pit-fall traps over 3069 trap days, giving an overall vertebrate capture rate of 9% per trap day (Table 3). The pitfalls caught four frog, 11 lizard, and three snake species (Table 3). Five fossorial species (*Amphiglossus* sp. nov., *Amphiglossus ardouini*, *Madascincus intermedius*, *Madascincus stumpffi* and *Typhlops sp.*) were only collected with pitfall traps. Pitfall trapping was notably more successful during the wet season (11.7% capture rate) and was almost double that recorded for the dry season (6.4% capture rate) (Table 3). At least one amphibian and three reptiles represent what appear to be undescribed species. We recorded eight species that appear to be locally endemic to Montagne des Français, a further 28 species that are regional endemics restricted to only a few places in northern Madagascar (Table 4), two species which are listed as vulnerable on the 2006 IUCN Red List of Threatened Species and 14 species

Table 3. Amphibians and reptiles captured in pitfall traps at the massif Montagne des Français in northern Madagascar 2005-2006.

	Amphibia												**Reptilia**									
Pitfall Line Number	*Mantella viridis*	*Mantidactylus bellyi*	*Ptychadena mascareniensis*	*Stumpffia cf roseifemoralis*	**Total Amphibia**	*Amphiglossus* sp. nov.	*Amphiglossus ardouini*	*Furcifer pardalis*	*Geckolepis maculata*	*Liophidium* cf. *therezieni*	*Liophidium torquatum*	*Madascincus intermedius*	*Madascincus stumpffi*	*Paroedura lohatsara*	*Paroedura stumpffi*	*Trachylepis elegans*	*Trachylepis tavaratra*	*Typhlops sp.*	*Zonosaurus tsingy*	**Total Reptilia**	**Total Specimens**
1	1				1										1	15				16	17
2																4				4	4
3	1				1											8				8	10
4		1			1							2	8					1		11	12
5		3			3	1						6	7			1				15	18
6	1				1							9	5			1		3		18	19
7			2		2															0	2
8																1				1	1
9											1					1				2	2
10															2			1		3	3
11												2		1	1					4	4
12												1								1	1
13												3		3			3			9	9
14									1			2		4			2		5	14	14
15									2								1		3	6	6
16														2						2	2
17														1						1	1
18												1								1	1
19												3					1			3	3
20									1			2			3		1	1		8	8
21														1	1	1				3	3
22												2				17				19	19
23												1				4				5	5
24									1			1		2	4	8	2			18	18
25																				0	0
26																2				2	2
27																1				1	1
28	6				6			2				8	3		1					14	20
29	2			1	3				3		1	12	3				1			19	25
30								1	4			8	12	1					3	29	29
31										1		1					1			3	3
32																	2		11	13	13
33									1					1			5			7	7
34																	1			1	1
35												1								1	1
36							1					2					1			4	4
Total	11	4	2	1	18	1	1	3	13	1	1	67	38	16	13	64	21	6	11	256	274

TABLE 4. Regional endemics and distribution of Montagne des Français species (found in this study) at four other protected areas located in the Antsiranana region (see text for literature sources).

Species	Regional Endemic	Montagne d'Ambre	Ankarana	Marojejy	Lokobe
Amphibia					
Microhylidae					
Stumpffia cf. *roseifemoralis*	+			+	
Stumpffia sp.	+				
Ranidae sensu lato					
Hoplobatrachus tigerinus					
Ptychadena mascareniensis		+		+	+
Mantellidae					
Aglyptodactylus securifer	+				
Boophis tephraeomystax					+
Laliostoma labrosum					
Mantella viridis	+				
Mantidactylus bellyi[1]	+	+			
Reptilia					
Pelomedusidae					
Pelusios castanoides					+
Chamaeleonidae					
Brookesia ebenaui		+			+
Brookesia sp. nov.	+				
Brookesia stumpffi		+			+
Furcifer pardalis		+	+	+	+
Furcifer petteri		+	+		
Furcifer oustaleti			+		
Gekkonidae					
Blaesodactylus boivini	+		+		
Ebenavia inunguis		+		+	+
Geckolepis maculata		+		+	+
Geckolepis sp.	+				
Hemidactylus frenatus					
Hemidactylus mercatorius					
Lygodactylus heterurus trilineigularis	+				
Paroedura lohatsara	+				
Paroedura stumpffi	+	+	+		+
Paroedura sp.	+				
Phelsuma madagascariensis grandis	+	+	+		
Phelsuma abbotti chekei			+		
Uroplatus cf. *ebenaui*	+	+	+	+	
Uroplatus sp.		+		+	
Gerrhosauridae					
Zonosaurus boettgeri	+		+		+
Zonosaurus tsingy	+		+		
Scincidae					
Amphiglossus sp. nov.	+				
Amphiglossus ardouini	+				
Madascincus intermedius				+	
Madascincus stumpffi	+	+			+
Trachylepis elegans		+	+		
Trachylepis tavaratra	+	+	+		
Boidae					
Acrantophis madagascariensis				+	+
Sanzinia madagascariensis volontany		+	+		+
Colubridae sensu lato					
Alluaudina bellyi	+	+	+	+	+
Dromicodryas bernieri					+
Dromicodryas quadrilineatus				+	+
Heteroliodon fohy	+				
Ithycyphus miniatus				+	+
Langaha pseudoalluaudi	+				
Langaha madagascariensis					+
Leioheterodon madagascariensis		+	+	+	+
Liophidium torquatum		+	+	+	+
Liophidium cf. *therezieni*	+				
Bibilava lateralis		+			
Bibilava stumpffi				+	+
Bibilava martae	+				
Madagascarophis colubrinus					+
Madagascarophis sp. nov.	+				
Mimophis mahfalensis		+	+		
Pseudoxyrhopus quinquelineatus					
Stenophis inopinae	+		+		
Stenophis granuliceps	+				+
Typhlopidae					
Typhlops sp.					
Ramphotyphlops braminus					+

[1]considered as *M. curtus* in Raxworthy & Nussbaum (1994).

which are listed on the CITES appendices.

DISCUSSION

Habitat and distribution.— We encountered 61 different species during this study, and it is now known that the herpetofauna of the Montagne des Français massif consists of at least one species of chelonian, 28 species of lizard, 23 snakes, and nine anurans. Almost all of these species (95.1%) are endemic to Madagascar, with just two: *Ptychadena mascareniensis* and *Leioheterodon madagascariensis* occurring on other Indian Ocean islands and one: *Pelusios castanoides* occurring on the African mainland.

The marked variation in herpetofaunal composition and abundance observed throughout the year is unsurprising when the degree and length of seasonal climatic variation of this massif is taken into account. However, this observed distribution may be due to the low population densities and cryptic nature of these species. In comparison, it is clear that most species included in this survey are dependent on forest habitat and do not do well in degraded or more open habitats. In terms of vertical positioning within the primary habitat, however, our findings may be subject to sampling bias, as the upper reaches of the canopy could not be easily surveyed for logistical reasons.

Elevational distribution.— Although the relatively small elevational range found within the massif does not make it the best area in Madagascar to study elevational influences on patterns of species distribution,

it is vital for future conservation initiatives focused on Montagne des Français that this ecological aspect is characterized. Our method of determining elevational position of species makes the assumption that each species is distributed continuously between the minimum and maximum elevation recorded. The diversity of amphibians and reptiles increases from the lower elevation, peaking, for both groups, at the 100 m elevational band (100-199 m). Above the 100 m elevational band, diversity drops off quickly until reduced to just 15 species above 300 m.

However, because the base camp was situated at an elevation of 140 m, we note that the Montagne des Français mid-elevational bulge in diversity might represent an artifact of the greater sampling time spent at the 100 m elevational band. More data is clearly needed to confirm elevational trends in herpetofaunal diversity within this massif. We also note that several species endemic to the massif, such as *Paroedura lohatsara* and *Bibilava martae*, were not observed below 140 m. These limited distributions may help to explain why populations of these species are unknown from the four other localized areas of forest situated in the extreme north of Madagascar. We hypothesize that distinct changes in habitat type (e.g., the presence or absence of calcareous formations) rather than climate are responsible for the elevational distribution of the herpetofauna of this massif.

Species recorded by previous surveys.—Only 13 species have been previously reported from Montagne des Français (with almost no information provided on their altitude, habitat or seasonal occurrence within the massif): *Dromicodryas quadrilineatus, Heteroliodon fohy, Bibilava martae, Mantella viridis, Paracontias hildebrandti, Paroedura lohatsara, Paroedura stumpffi, Paroedura sp., Sanzinia madagascariensis volontany, Stenophis granuliceps, Stenophis inopinae, Trachylepis tavaratra* and *Zonosaurus tsingy* (Ramanamanjato et al. 1999; Raselimanana et al. 2000; Vences et al. 2004; Glaw et al. 2005a,b). Therefore, the remaining 48 species recorded in this survey were not known previously from the massif. This unknown component of the Montagne des Français herpetofauna represents 78.7% of the species sampled in this survey and reflects both the high species diversity of the area, as well as the relatively low-intensity surveying that has been conducted previously within the massif. As *Paracontias hildebrandti* was not encountered, we could not confirm its presence within the massif during this survey, most likely because of its low density and cryptic nature.

FIGURE 3. The chameleon *Furcifer pardalis*, commonly encountered throughout the massif Montagne des Francais in northern Madagascar, including the mangrove system.

Range extensions.—Several species encountered during this study require special mention, as their occurrence in Montagne des Français contributes significantly to the current information regarding their distribution in Madagascar. The presence of *Pseudoxyrhopus quinquelineatus* in the massif represents the first record of this species from northern Madagascar and indicates a range extension of ca. 400 km to the north. In addition, prior to this study, *Zonosaurus boettgeri* was only known from a few specimens (Raselimanana et al. 2006). Similarly the highly cryptic *Langaha pseudoalluaudi* was only known from the type specimen collected from a site near Ankarana (Domergue 1988), Amboasary Sud (Nussbaum et al. 1999), and a recent record from Ankarafantsika (Kuchling 2003).

It is also important to document the presence of additional species of conservation importance that were encountered in the immediate vicinity of the massif. Two species, *Chelonia mydas* (CITES appendix I) and a subadult *Crocodylus niloticus* (CITES appendix I) have been caught by fishermen in French Bay (Y. Pareik, pers. comm.) and *Phelsuma* cf. *dubia* (CITES appendix II), *Geckolepis sp.*, *Furcifer pardalis* (Fig. 3), *F. oustaleti* were encountered in the associated mangrove system. The anuran *Heterixalus andrakata* was also encountered in some dunes at the foot of the massif. These findings suggest that additional surveys, focused on the areas surrounding the massif, are required to ensure that fully informed and effective conservation decisions are made.

Comparisons with other sites.—The north of Madagascar is already recognized as one of the more speciose regions of the biodiversity hotspot that is Madagascar (e.g., Raxworthy and Nussbaum 1994; Andreone et al. 2003; Wilmé et al. 2006). Although a series of effectively protected areas currently exist in this region, the majority of these protected areas have not been subject to surveys resulting in published species lists for over a decade or indeed, at all. On the basis of this survey, we provide herein a comparison of the shared herpetofaunal diversity between Montagne des Français and the four protected areas located in the north of Madagascar. Published herpetofaunal inventories are:

Ankarana Special Reserve (Hawkins et al. 1990 reptiles only); Montagne d'Ambre National Park (Raxworthy and Nussbaum 1994); Marojejy National Park (Raselimanana et al. 2000) and Lokobe Strict Nature Reserve (Andreone et al. 2003). The elevations surveyed at these sites ranged from sea level to 2300 m. As expected, the majority of species shared between these sites are low and mid-elevation species. Twenty-six of the 61 (42.6%) species we encountered receive protection within Lokobe Strict Nature Reserve, 22 (36.1%) species have been previously recorded from Montagne d'Ambre National Park, 19 (31.1%) species have been previously recorded from Ankarana Special Reserve and 15 (24.6%) species have been recorded from Marojejy National Park. Therefore, according to the current literature 19 species (31.1%) are in immediate danger from a conservation perspective as they are not protected within the system of protected areas in the north of Madagascar. A significant number of these species are probably endemic to Montagne des Français: *Amphiglossus* sp. nov., *Brookesia* sp. nov., *Heteroliodon fohy, Liophidium* cf. *therezieni, Bibilava martae, Madagascarophis* sp. nov., *Paroedura sp. and Paroedura lohatsara*. These eight taxa make up 13.1% of the massif's herpetofauna, a degree of site endemism greater than other sites, such as Marojejy National Park (12%; Raselimanana et al. 2000).

Relevance to patterns of biodiversity in northern Madagascar.—Initial comparison with other protected sites indicates that Montagne des Français shares the closest biogeographic relationship with the humid forest of the Sambirano Domain. The validity of this similarity is brought into question however, as the current inventories for these localities are incomplete. We strongly suspect that additional survey work focused on the protected areas surrounding the massif will show that Montagne des Français shares a closer biogeographic relationship with the dry deciduous forest found within Ankarana Special Reserve.

It has been suggested that prior to human invasion continuous lowland corridors of dry or transitional forest linked the lower slopes of the six major massifs of Analamera, Ankarana, Daraina, Montagne d'Ambre and Montagne des Français located in the extreme north of Madagascar (Ramanamanjato et al. 1999; D'Cruze et al. 2006). The current distribution of the skink *Trachylepis tavaratra* at all of these locations has been used as evidence to support this hypothesis (Ramanamanjato et al. 1999). The results of this survey also support this assumption as 19.7% of the species found in Montagne des Français are found in both Montagne d'Ambre and Ankarana Special Reserve. These former corridors help to explain how these species were able to cross the distance (ca. 50 km) between these sites. We strongly suspect that further detailed surveys, and associated genetic analyses, focused on the remaining two massifs will result in patterns of distribution similar to that of *T. tavaratra* for a significant number of other robust species and will add further weight to this hypothesis.

Once isolated from the other major areas of forest located in the extreme north of Madagascar, Montagne des Français may have preserved relict populations of species that disappeared from other regions of the forest or it may have facilitated speciation through geographical isolation (Glaw et al. 2005a,b). This isolation in conjunction with acquired morphological adaptation to the calcareous formations found within the massif would greatly help to explain the relatively high level of endemism displayed by the herpetofauna of this massif. It is clear that to better understand speciation mechanisms in Malagasy reptiles and the historical changes of climate and vegetation cover in the north of Madagascar, more data regarding their exact distribution, phylogenetic relationships, and phylogeographic structure must be gathered (Vences et al. 2004; Boumans et al. 2007).

Other Species of Conservation Importance.—Although it is not the major focus of this paper, we would like to further emphasize the conservation importance of this massif by documenting the presence (photographic records held by the first author) of four species of lemur that have not previously been recorded from Montagne des Français: *Daubentonia madagascariensis* (Vulnerable), *Eulemur coronatus* (Vulnerable), *Lepilemur septentrionalis* (Critically Endangered) and *Microcebus tavaratra* (Endangered) [Conservation status according to Mittermeier et al. (2006)]. We would also like to reinforce the view of this northern-most Malagasy limestone massif as an important biological center of endemism by highlighting recent field work conducted by other researchers. Recent research has resulted in the discovery and description of a new and potentially locally endemic species of *Heteroscorpion* (Lourenço and Goodman 2006); as well as, a plethora of regionally endemic botanical taxa including several succulents (*Pachypodium windsorii, Aloe suarezensis and Euphorbia leuconeura*) and one species of Baobab (*Adansonia suarezensis*) (Grubenmann, pers. comm.). We strongly suspect that surveys focused on the other taxonomic groups found within the massif will equally result in the discovery of additional undescribed and locally endemic taxa.

Conservation issues for Montagne des Français.—As a result of its close proximity to the administrative capital of Antsiranana province (ca. 12 km), the unique biodiversity of this massif is under immediate threat from numerous anthropogenic pressures. The major threats to the integrity of the herpetofauna of this area are: (1) agricultural clearance for maize and rice cultivation; (2) charcoal production (Fig. 4); (3) timber production; and (4) zebu grazing (during which sites are either selectively logged or cleared of all trees). All of these threats have resulted in

the degradation or clearance of large areas of forest. Continued forest clearance will lead to the eventual fragmentation of the remaining areas of forest (with strong consequences for the herpetofauna, e.g., Vallan 2000, 2003). This will be followed by local extirpation, and possibly extinctions, that will in turn place increased pressure on the existing system of protected areas in the north of Madagascar.

Conclusion.—The data collected in this study contributes to our current understanding regarding patterns of biodiversity of Malagasy herpetofauna by fully documenting the species composition of an unsurveyed site that has already been identified as a threatened area of high biodiversity requiring full protection (ANGAP 2003; Glaw et al. 2005a,b; Ministère de l'Environment, des Eaux et Forets 2006; Robinson et al. 2006). The extremely high level of endemicity seen in the herpetofauna, at both the regional and national level, immediately emphasizes the importance of Montagne des Français as a biological refuge. Furthermore, many of the species encountered during this study appear to be dependent on forest habitat, and do not appear to thrive in degraded or more open habitats. Only by conserving this area of forest will we be able to safeguard against future herpetological extinctions at this location. Moreover, we would like to reiterate the extraordinary conservation importance of this northern-most Malagasy limestone massif by bringing attention to the other taxonomic groups for which comprehensive inventories do not exist. We hope that the data contained within this paper will ensure that this massif is fully included in the system of protected areas in north Madagascar and will help to facilitate informed and effective conservation decision-making.

FIGURE 4. The result of charcoal production in *Montagne des Français.*

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APPENDIX

Voucher specimens from Montagne des Français.

1. Between "Kings Lodge" and French Fort: *Aglyptodactylus securifer* (ZSM 922-923/2003); *Amphiglossus* sp. nov. (ZSM 246/2004); *Blaesodactylus boivini* (ZSM 534/2000, 999/2003, 263/2004); *Brookesia ebenaui* (ZSM 515-517/2000, 248/2004, UADBA 24475); *Brookesia* sp. nov. (ZSM 354/2004, 357/2004); *Ebenavia inunguis* (ZSM 533/2000); *Furcifer petteri* (ZSM 521/2000); *Geckolepis maculata* (ZSM 523/2000, 998/2003); *Geckolepis sp*. (ZSM 522/2000, 527/2000, 912/2003); *Hemidactylus frenatus* (ZSM 539/2000, 541/2000); *Hemidactylus mercatorius* (ZSM 542/2000, 536/2000); *Heteroliodon fohy* (ZSM 548/2000); *Laliostoma labrosum* (ZSM 500-501/2000, 35/2001); *Bibilava martae* (ZSM 253/2004); *Lygodactylus heterurus trilineigularis* (ZSM 915/2003); *Madagascarophis colubrinus* (ZSM 549/2000); *Madagascarophis* sp. nov. (ZMA 19622); *Madascincus intermedius* (ZSM 242/2004, 245/2004, UADBA 24476); *Mantella viridis* (ZSM 502/2000); *Mimophis mahfalensis* (ZSM 634/2000, 310/2004); *Paroedura sp.* (ZSM 531-532/2000, 337-342/2004, 352-353/2004); *Paroedura lohatsara* (ZSM 529-530/2000, 807/2001, 981/2001, 291-293/2002); *Paroedura stumpffi* (ZSM 635/2000); *Phelsuma abbotti chekei* (ZSM 528/2000); *Phelsuma madagascariensis grandis* (ZSM 524/2000); *Ptychadena mascareniensis* (ZSM 506/2000); *Stenophis granuliceps* (ZSM 550/2000, 553/2000); *Stenophis inopinae* (ZSM 551-552/2000); *Trachylepis elegans* (ZSM 543/2000); *Trachylepis tavaratra* (ZSM 213/2003, 266/2004); *Uroplatus sp*. (ZSM 525/2000, 526/2000, 1000/2003); *Zonosaurus tsingy* (ZSM 545-547/2000).

2. Andavakoera: *Aglyptodactylus securifer* (UADBA 24080, 24756, ZSM 298-299/2004); *Furcifer petteri* (ZSM 315/2004); *Lygodactylus heterurus trilineigularis* (ZSM 308/2004); *Mantella viridis* (UADBA 24762, 24776, 24792, 24803, 24808, ZSM 296-297/2004); *Mantidactylus bellyi* (UADBA 24174, 24176, 24089, 24090-24092, 24104, 24111, ZSM 291-295/2004); *Stumpffia sp*. (UADBA 24163, 24741, 24765, 24786, ZSM 300-303/2004).

NEIL D'CRUZE is a conservation biologist possessing an MSc in Taxonomy, Biodiversity and Conservation from Imperial College London and the Natural History Museum (London). He has successfully led volunteer based biodiversity research projects throughout Africa and Central America. With a particular passion for herpetology and chiropteran ecology, the majority of his research to date has been dedicated to developing standardized survey protocols which can be used to generate baseline data and contribute to longer term monitoring programs. With a concurrent interest in wild animal welfare (principally human-wildlife conflict resolution), Neil currently works as a Wildlife Projects Officer for The World Society for the Protection of Animals (WSPA) in Central London. He also holds the position of Reviews Editor for the Herpetological Bulletin which is published by the British Herpetological Society.

JEREMY SABEL MSC, AIEEM is an ecologist and member of the British Ecological Society (BES). Jeremy has a broad range of research interests and currently works for ecosulis ltd, an environmental consultancy, carrying out protected species surveys, botanicals surveys and advising on mitigation strategies and development plans in the UK.

KATHLEEN GREEN attained a First Class Honours MBiolSci/Zoology degree at The University of Sheffield in 2005, with animal behaviour and conservation being her main fields of research. She then spent one year working with the Frontier Madagascar Forest Research Programme in Montagne des Français and took over as Research Coordinator in December 2005. Since returning to the UK in June 2006 Kathleen has been completing a MRes degree in Ecological Conservation at Cranfield University. Her research project is mapping UK BAP Priority Habitats using remote sensing, image processing, and GIS technology. In December 2007 Kathleen is returning to Madagascar with Azafady to work on both GIS application and project management of a reforestation project in the Anosy region.

JEFF DAWSON is a conservation biologist with a broad knowledge of biology, ecology and evolution. He has successfully led and worked on biodiversity research projects overseas and as an ecologist in the UK; working on Environmental Impact Assessments and implementing UK and European biodiversity and conservation legislation. He has a keen interest in zoological field work as well as community-based conservation work and has actively contributed to a number of scientific peer reviewed papers and conservation related publications. Jeff is currently working as Project Science Officer for Coral Cay Conservation on The Waria Valley Community Conservation and Sustainable Livelihoods Programme (WVCP) in Papua New Guinea. The main aims of which are conducting biodiversity research; implementing community based sustainable livelihood programmes and providing environmental education and awareness. This is a 3-year multi partner research project funded, in part, by the Darwin Initiative.

MIGUEL VENCES is Professor for Evolutionary Biology at the Technical University of Braunschweig, Germany. He is a systematist by training, having received his diploma and doctoral degrees at the Zoological Research Museum A. Koenig in Bonn. Since his times as undergraduate, 15 years ago, he has been working on the taxonomy, biogeography, evolution, and natural history of the amphibians and reptiles of Madagascar. His research, carried out in close collaboration with Frank Glaw and other researchers, has led to the research of numerous new species of amphibians and reptiles in Madagascar, and to the elucidation of their molecular phylogenetic relationships. In the past 5 years, he has also included aspects of conservation genetics in his research.

GEORGINA STARKIE is a conservation biologist and ecologist with experience of guiding independent research in Madagascar, Greece and the UK. Recent presentations include the Madagascar Symposium at the University of East Anglia and in late 2007 she will be presenting work at the International Bear Association Conference in Mexico. Currently employed as an ecologist by Michael Woods Associates Ecological Consultants, she is responsible for coordinating reptile, amphibian and other protected species surveys across the UK.

DR. FRANK GLAW is curator of the section herpetology at the Zoologische Staatssammlung München, Germany. Since 1987 he has carried out field work in Madagascar and has specialized on the systematics, bioacoustics and biogeography of the Malagasy herpetofauna.

CHARLIE GARDNER has an MSc in conservation biology from the Durrell Institute of Conservation and Ecology, and a wide range of experience in endangered species recovery programmes, biodiversity inventorying and evaluation, and protected areas management in the United Kingdom, East Africa, and Madagascar and the Western Indian Ocean Islands. With a background in avian ecology and herpetology, his current research interests focus primarily on the economics and sustainable financing of conservation and sustainable land management, including payments for ecosystem services and other market-based approaches to conservation, and exploring the synergies between conservation and the private sector.

JANINE ROBINSON graduated with a BSc (hons) in Biology from Leeds University in 2004 and has spent the majority of the last two and a half years working on wildlife monitoring and surveying projects within Africa. Her main areas of interest are conservation and community development. Her current role is Chief Scientist for Greenforce Tanzania where she has been responsible for initiating a project in collaboration with The African Wildlife Foundation. Presently she is leading a volunteer based research program in Manyara Ranch, an important and understudied wildlife migration corridor between the Tarangire –Manyara national parks ecosystem of Northern Tanzania.