Reptile mark-recapture trials using rainforest plots at Montagne d'Ambre, Madagascar

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Abstract: Three plots (50 x 100 m) established in primary rainforest (650 -1150 m elevation) were intensively searched on two or three nights for chameleons, geckos, and snakes at Montagne d'Ambre, in northern Madagascar. A total of 486 captures were made for eight geckos, eight chameleons, and three snakes belonging to the following genera: Gekkonidae- *Geckolepis, Lygodactylus, Phelsuma, Paroedura, Uroplatus*; Chamaeleonidae- *Brookesia, Calumma, Furcifer*; Colubridae- *Alluaudina, Geodipsas, Lycodryas*. Nightly capture success ranged from 47-79 individuals, indicating that plot searches of this scale may have applications for long term monitoring. Chameleon movements recorded during the study showed that plot populations cannot be considered closed, and recapture success was too low to allow population size to be measured for most species. Obvious differences in species composition of *Brookesia* and *Paroedura* were found on opposite banks of a small river (one to five metres wide), suggesting that rivers of relatively small size can affect dispersal in these groups.

Key words: Chamaeleonidae, Colubridae, Gekkonidae, methods, reptile

Introduction

The endemic fauna and flora of Madagascar is considered a global priority for conservation due to the 'megadiversity' of the island and the ongoing loss of natural habitats (Myers *et al.* 2000). Aerial photographs and satellite images taken between 1950 and 1985 reveal that 50% of the remaining rainforest was destroyed during this period (Green and Sussman 1990). Half the Malagasy endemic vertebrates are rainforest amphibians or reptiles, and virtually all these species are restricted to native forest. As the rainforests become increasingly fragmented, isolated herpetological populations will decrease in size until eventually some populations will no longer be viable. The commercial collecting of some Malagasy reptiles such as geckos (*Phelsuma, Uroplatus*) and chameleons (*Brookesia, Calumma, Furcifer*) may also have a negative impact on some populations. However, to date, no detailed population studies have been reported for any rainforest amphibians and reptiles in Madagascar, and field techniques for calculating densities remain largely untested (the one exception being distance sampling with *Calumma* chameleons, see Brady & Griffiths 1999).

We here examine the potential of using nocturnal searches of rainforest plots, to determine population data for reptiles. Sampling at night has the advantage that diurnal geckos and chameleons can be found roosting, while nocturnal geckos and snakes are active and typically obvious. This study was made at Montagne d'Ambre during a herpetological survey of the region (Raxworthy & Nussbaum 1996).

Study area

Montagne d'Ambre, centered at 12°32'S, 49°10'E, is a mountain range with a north-south orientation at the extreme northern tip of Madagascar (Fig. 1). This mountain range is also referred to as Ambohitra on modern Madagascan maps and as Amber Mountain on English maps of the last century, but both these names are rarely used. The highest peak is at 1475 m elevation, with the base 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 rainforest above and lowland rainforest below 800 m elevation (vegetation types of White 1983). The forest below 800 m appears to be transitional in form to the surrounding much drier deciduous forests that are at 0-300 m in elevation. The first National Park in Madagascar was created at Montagne d'Ambre in 1958, with a surface area of 18,200 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.

Two camps were used during this study, with the survey plots established in close proximity. The first camp, Antomboka River, was centered at 12°32.22'S, 49°10.05'E, 1150 m elevation in montane forest, and was occupied from 15 November 1991 to 15 December 1991. The second camp, Antomboka River Fitsahana, centered at 12°29.33'S, 49°10.28'E, 650 m elevation in lowland rainforest, was occupied from 21 December 1991 to 20 January 1992. This period represents the start of the rainy season for Montagne d'Ambre.

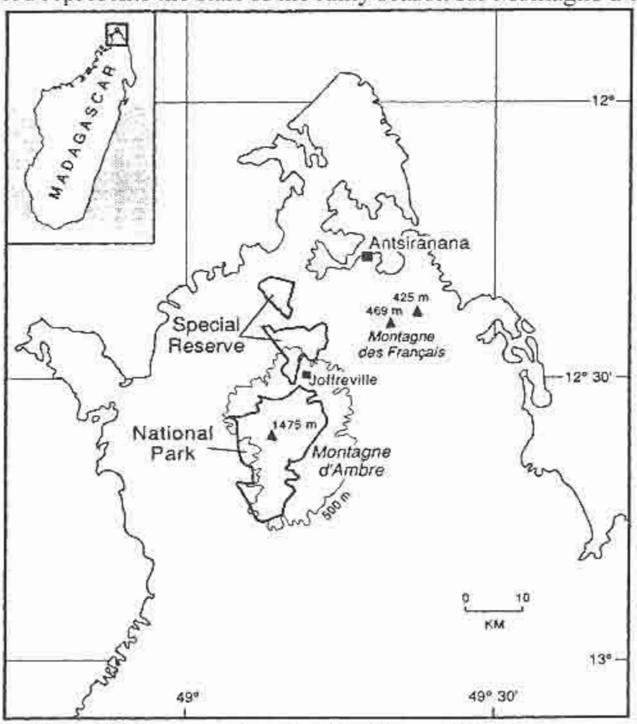

Fig. 1. Map of northern Madagascar showing Montagne d'Ambre.

Methods

The horizontal plots measured 50 x 100 m and were located in valley bottom/slope primary rainforest undisturbed by previous collecting or surveying. Plots were chosen without prior knowledge of the reptile species present. Each plot was divided into 10 x 10 m cells. Brightly colored flagging on tree branches was used to mark the plot boundaries and the center of each cell. Searches for reptiles were made at night between 2000-0100 h using headlamps. Between nine and 13 workers searched the entire plot by slowly walking and scanning for a period of two to three hours. The forest floor and understory vegetation up to six meters high was searched. Chameleons and diurnal geckos were found in their night time roosting positions (Parcher 1974; Raxworthy 1991). Nocturnal geckos *(Geckolepis, Uroplatus, Paroedura)* and snakes were sampled by scanning tree trunks, exposed foliage, and the forest floor. Geckos and chameleons were captured and uniquely marked with white correction fluid. A spot code was used to give a unique number to each capture, by ventrally marking the limbs, tail, and, body with one or two spots. The marked geckos and chameleons were released at the point of capture. The sex and closest plot cell coordinate were recorded for each capture and recapture. Two or three searches were made on each plot, with time intervals of two to seven days between searches.

Results

The coordinates, search dates, and number of searchers for each of the three plots were: Plot 1 centered at 12°32.30'S, 49°10.23'E, 7 December 1991 and 11 December 1991, 9-10 searchers; Plot 2 centered at 12°29.23'S, 49°10.47'E, 29 December 1991, 3 January 1992 and 10 January 1991, 13-15 searchers; Plot 3 centered at 12°29.48'S, 49°10.30'E, 13 January 1992, 16 January 1992, 18 January 1992, 11-13 searchers.

A total of 376 individual reptiles were found on the plots representing eight gecko, eight chameleon, and three snake species. Some of the most frequently encountered species of gecko and chameleon are shown in Fig. 2. Nightly capture success and mean capture success per plot is given for each species in Table 1. A total of 486 captures (including 110 recaptures) were made on the plots, with a mean nightly plot success of 60.8 (range 47-79).

Recaptures were too few for most species to estimate population sizes by mark-recapture techniques. To increase the number of recaptures on Plot 2 and 3, we pooled the data from the second and third search (Seber 1982). Because all individuals were given unique marks, animals sampled twice during the second and third searches could be identified. The mark-recapture results for the chameleons *Calumma boettgeri* (Plot 1) and *Brookesia stumpffi* (Plot 2 and 3) are summarized in Table 2. These two species accounted for more than half (57) of the entire survey recaptures (110). Symbols are as used by Seber (1982) and the population estimate is Chapman's (1951) modified Petersen estimate that gives less bias for small samples.

A 2 x 2 contingency table Chi Square test of equal catchability (Blower *et al.* 1981) at first recapture and second recapture was performed on the data for Plots 2 and 3. At first recapture individuals were handled and marked, but at second recapture animals were handled or inspected only. For *Brookesia stumpffi*: Plot 2, $X^2 = 0.484$, 1 df, $P > 0.25$, NS; and Plot 3, $X^2 = 0.002$, 1 df, $P > 0.95$, NS. The process of marking did not significantly effect the probability of recapture compared to animals that were just handled.

Table 1. Reptile captures for each plot search.

Species	Specimen capture numbers							
	Plot 1		Plot 2			Plot 3		
Dates	**7.12**	**11.12**	**29.12**	**3.1**	**10.1**	**13.1**	**16.1**	**18.1**
Gekkonidae								
Geckolepis maculata	-	-	1	0	0	0	0	1
Lygodactylus madagascariensis	-	-	2	2	2	3	3	4
Phelsuma lineata	-	-	-	-	-	0	0	1
Paroedura oviceps	-	-	3	10	3	3	0	1
Paroedura stumpffi	-	-	-	-	-	3	8	4
Uroplatus ebenaui	9	7	3	5	1	1	2	3
Uroplatus fimbriatus	-	-	1	0	0	0	1	1
Uroplatus sikorae	-	-	0	1	1	3	7	4
Chamaeleonidae								
Brookesia ebenaui	-	-	1	0	0	-	-	-
Brookesia stumpffi	-	-	25	27	23	45	50	54
Brookesia antakarana	-	-	10	9	11	-	-	-
Brookesia ambreensis	-	-	7	7	5	-	-	-
Calumma boettgeri	35	40	0	0	1	-	-	-
Calumma brevicornis	5	4	-	-	-	-	-	-
Calumma oshaughnessyi	3	4	-	-	-	-	-	-
Furcifer petteri	-	-	2	1	0	3	2	3
Colubridae								
Alluaudina bellyi	-	-	1	0	0	0	0	2
Geodipsas infralineata	-	-	1	0	0	-	-	-
Lycodryas arctifasciatus	-	-	-	-	-	0	0	1
Total captures	**52**	**55**	**57**	**62**	**47**	**61**	**73**	**79**

For *Calumma boettgeri* and *Brookesia stumpffi*, there were sufficient recaptures to measure the degree of individual movement between the first and last plot searches. Approximate individual movement was calculated as the straight-line distance between the centers of the cells in which the individual was captured. *Calumma boettgeri*, a highly arboreal species (found roosting and active at two to at least six metres height), moved 10-70 m (n=13, median=30 m) over a period of four days. *Brookesia stumpffi*, typically found on the forest floor (roosting 0.3 - 2.0 m above ground), moved 0-40 m (n=15, median=10 m) over a period of five days and 0-77 m (n=10, median=10 m) over a period of 12 days.

Discussion

The number of recaptures was too low for most species to calculate population estimates by mark-recapture methods. In the cases of *Paroedura*, *Geckolepis*, and *Uroplatus*, this may be due to the difficulty in sampling these highly arboreal geckos, with most of the population always too high in the canopy to observe. The low numbers of the two diurnal geckos *Phelsuma lineata* and *Lygodactylus madagascariensis* probably underestimate their true densities (based on numbers of active individuals seen during the day). The roosting habits of these diurnal geckos, clinging to the tops or undersides of leaf blades at two to at least four meters above the ground, make them difficult to sample. The single *Brookesia ebenaui* found on Plot 2 suggests that this species occurs at much lower densities than the other three *Brookesia* species. *Brookesia ebenaui* had a similar low capture rate at Manongarivo, with just two found over 44 days compared to 102 *B. stumpffi* (Raxworthy 1991). Because the roosting behaviour of *Brookesia ebenaui* appears similar to other *Brookesia*, it does not seem likely that this species was under-sampled. The typical chameleons, *Calumma* and *Furcifer*, were more difficult to find than the *Brookesia* dwarf chameleons because their roosting sites were typically much higher up in the canopy (two to at least six meters). We suspect a significant proportion of typical chameleon populations are roosting above six meters and thus were missed during the plot surveys.

Both *Calumma boettgeri* and *Brookesia stumpffi* will move up to 70 m horizontally over 4-12 days, although the median distance moved during the plot surveys was 30 m for *C. boettgeri* and 10 m for *B. stumpffi*. It is clear that both these small species are capable of moving significant distances over a short period of time, suggesting that individuals are not necessarily fixed to a small territory. For larger African species (*Chamaeleo jacksoni*, *C. hoehnelii*, *C. bitaeniatus*, and *C. dilepis*) Toxopeus *et al.* (1988) reported average daily movements of 1-12 m. However these authors found a significant decrease in daily movement for chameleons found together in pairs, with average movement in all four species being less than one metre. None of the Montagne d'Ambre animals were found roosting in pairs, although we have occasionally observed this behaviour at other sites in Madagascar.

The mark-recapture population estimates for the plots are probably overestimates, based on the significant movements we recorded in this study, and the open nature of the plots. In particular, immigration of unmarked animals into the plot would have had the effect of reducing the proportion of marked animals captured. Another source of error may be due to loss of marks as a result of skin sloughing, during the sampling period (4-12 days). To reduce both these sources of errors, we suggest future studies reduce time between sampling to a minimum- ideally successive nights, for roosting species sampled at night.

The differences in species composition found between Plot 1 (1150 m elevation) and Plots 2-3 (650 m elevation) are largely due to the elevational distribution limits found at Montagne d'Ambre (Raxworthy & Nussbaum 1994). The majority (61%) of amphibians, reptiles, and small mammals at Montagne d'Ambre have distributions restricted to forest either above or below 900 m elevation, reflecting the transition between lowland and montane rainforest in Madagascar. Only two species, *Uroplatus ebenaui* and *Calumma boettgeri*, were found on both the montane and lowland rainforest plots, and in both cases their densities were much higher in montane forest (especially so for *Calumma boettgeri*).

The most unexpected result was the very different species composition of *Brookesia* and *Paroedura* found between Plot 2 and Plot 3. These plots were separated by the Antomboka River, which is 1-5 m wide at this point, with Plot 2 east and Plot 3 west of the river. The plots were at the same elevation and within 300 m of each other. *Paroedura stumpffi* was found only on Plot 3 and *Brookesia ambreensis* and *Brookesia antakarana* only on Plot 2. All three species were common on the plot where they occurred. These plot distributions were completely consistent with distribution information obtained from other observations and collections made locally on both sides of the river.

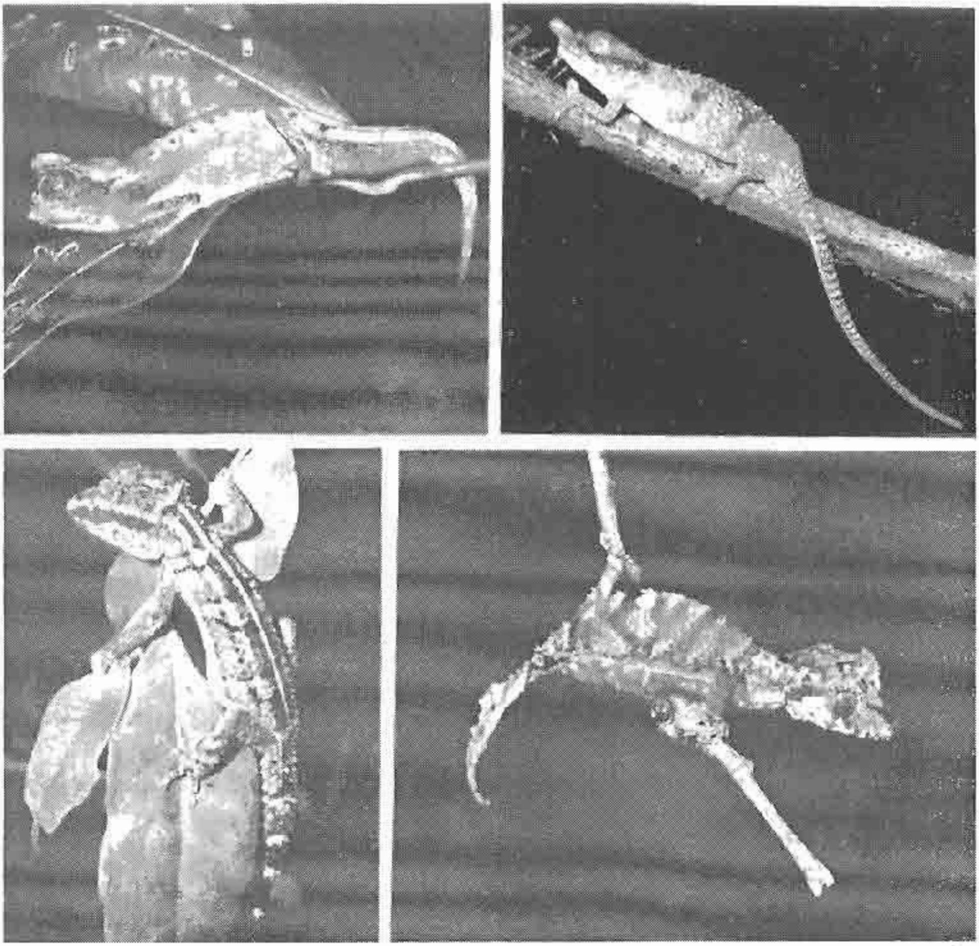

Fig. 2. *Brookesia stumpffi* (top left), *Calumma boettgeri* (top right), *Paroedura stumpffi* (lower left), *Uroplatus ebenaui* (lower right).

Table 2. Chameleon mark-recapture data. n1 = number of individuals marked in first search, n2 = number of individuals caught in subsequent search, m2 = number of marked individuals in subsequent search, N* = Chapman's (1951) modified Petersen estimate of population size, V* = approximate variance.

Species	**Plot**	**n1**	**n2**	**m2**	**N***	**±1.96√V* approx. 95% confidence limits**	**V***
Calumma boettgeri	1	35	40	13	104.4	±33.9	298.2
Brookesia stumpffi	2	25	42	18	57.8	±10.0	26.0
Brookesia stumpffi	3	45	78	26	133.6	±26.0	175.9

We suspect that the Antomboka River, even though modest in size, is an effective local barrier to dispersal for these dwarf chameleons and geckos. Along this stretch of the river the understory canopy is completely broken, and the overstory canopy largely broken. We never saw *Paroedura* or *Brookesia* above four meters in height, and species of these genera probably do not climb into the overstory canopy. Because these groups appear to be restricted to forest understory, rivers that cause a break in the understory canopy may be effective barriers to local dispersal.

Where *Paroedura oviceps* is sympatric with *P. stumpffi* (Plot 3), the number of *P. oviceps* sampled is much lower than where it is found alone (Plot 2). Similarly, where *Brookesia stumpffi* is sympatric with *Brookesia ambreensis* and *Brookesia antakarana* (Plot 2), the number of *B. stumpffi* observed is much lower than where it occurs singly (Plot 3). These preliminary observations suggest the possibility of competition between these species in microsympatry.

Conclusions

Detailed nocturnal searches of the 100 x 50 m plots rainforest plots, with teams of nine or more people, can yield consistently more than 45 reptile captures a night at Montagne d'Ambre. During the rainy season. This type of sampling therefore offers potential for the long term monitoring of populations, provided that sampling team effort can be standardized (for example using the same team members). However, the numbers of recaptures that we recorded in this study, and the substantial movement observed for the most commonly recaptured chameleons, do not suggest that mark-recapture studies can be used to effectively estimate population size for the plots. The variation in species sampled across the three plots further highlights the importance of elevation, and the potential influence of local landscape features (in this case, possibly a small river disrupting dispersal), on reptile community structure at Montagne d'Ambre.

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