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HERPETOLOGICAL SURVEYS OF FOREST FRAGMENTS BETWEEN MONTAGNE D'AMBRE NATIONAL PARK AND ANKARANA SPECIAL RESERVE, NORTHERN MADAGASCAR

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***Abstract.*—Despite Madagascar being well known for its unique biodiversity and high levels of endemism, its herpetofauna remains understudied, especially outside protected areas. Here, we surveyed the herpetofauna within the fragmented dry deciduous forests of the Tsarakibany area, between Montagne d'Ambre National Park and Ankarana Special Reserve in northern Madagascar. We recorded 15 amphibian and 34 reptile species via active searching, pitfall trapping and opportunistic collection. Twenty of these species are considered regional endemics, six species are listed as Vulnerable or Near Threatened according to the IUCN Red List, and nine species are listed on the CITES appendices. This is the first study to inventory the herpetofauna of the unprotected landscape located between Montagne d'Ambre and Ankarana, and reports new localities for the little-known snake species *Pararhadinaea melanogaster* and *Liophidium therezieni*.**

Key Words.—amphibians; Ankarana; conservation; Madagascar; Montagne d'Ambre; reptiles.

INTRODUCTION

Madagascar is recognised as a global biodiversity hotspot due to its high levels of endemism (Myers et al. 2000; Ganzhorn 2001). More than 90% of Madagascar's endemic animal species are found exclusively in forests (Dufils 2003), making the island's tropical forests one of the world's highest priorities for biodiversity conservation. However, it has been estimated that continued habitat destruction has led to the disappearance of 90% of the original vegetation cover (Harper et al. 2007).

Although the past two decades have seen an increase in research effort focused on Madagascar's biodiversity and conservation, baseline information regarding the distribution and abundance of species and the size and condition of remaining forest is far from complete, particularly for unprotected areas (D'Cruze et al. 2009). Fieldwork conducted in northern Madagascar has revealed an area of extraordinary biodiversity and endemism (Raxworthy and Nussbaum 1994; D'Cruze et al. 2006, 2007, 2008; Megson et al. 2009). A network of five protected areas currently conserves representative ecosystems in far northern Madagascar. Now separated by deforested savannah and agricultural lands, it has been suggested that the protected areas were once connected by continuous lowland corridors of dry or transitional forest (Ramanamanjato et al. 1999; D'Cruze et al. 2006, 2007, 2008).

Montagne d'Ambre National Park and Ankarana Special Reserve each incorporate dominant geological features of northern Madagascar's landscape. Montagne d'Ambre is a mountain range that is volcanic in origin; its highest peak reaches 1,475 m, with the foot of the mountain range at 200–300 m (Raxworthy and Nussbaum 1994). Its elevation gives it a distinctive microclimate; the annual precipitation (e.g., Station Rousettes, mean = 2,378 mm) is much higher than that received by the surrounding region (e.g., Antsiranana, mean = 980 mm; Nicoll and Langrand 1989). Thus, the massif typically supports montane rainforest above 800 m and lowland rainforests below 800 m, although the forests at 0–300 m are transitional in form between lowland rainforest and the surrounding much drier deciduous forests. Raxworthy and Nussbaum (1994) point out that a substantial proportion of the massif's biodiversity is found only in lower altitude forests; therefore, these peripheries warrant a high conservation priority for current and future park managers and regional forest authorities.

Ankarana is a limestone massif; the highest point of the plateau is around 500 m (Cardiff and Befourouack 2003). Characteristic of Ankarana are its pinnacle karst formations known as 'tsingy', and an extensive network of caves, underground rivers, and sunken forests. Ankarana receives around 1890 mm of precipitation annually (Hawkins et al. 1990), more than other areas in Madagascar's dry western zone due its proximity to Montagne d'Ambre (Bloxam and Barlow 1987). Ankarana's varied geological history and conditions and relatively moist climate for its geographic position have led to the evolution of a unique set of habitats and community of endemic organisms.

The different environmental conditions present in Montagne d'Ambre and Ankarana have given rise to some locally endemic reptile, amphibian, and bird species (Morris and Hawkins 1998; Glaw and Vences 2007). However, it is not known whether populations of other species are continuous between the two protected areas. This area presumably represents the last vestiges of forest habitat that once linked these

FIGURE 1. Map of the study area in northern Madagascar.

two protected areas and consists of transitional deciduous forest fragments. These patches of forest receive a relatively low amount of annual rainfall compared to that of Montagne d'Ambre National Park and have a lower average canopy height, but they are more similar in structure and in rainfall received than to the dry deciduous forests of Ankarana. Anthropogenic disturbance is present in the forests themselves and abundant in the surrounding area. This report outlines the findings of 15 months of herpetological surveys aimed at collecting baseline data on distribution and abundance in three remnant forest patches between Montagne dÁmbre National Park and Ankarana Special Reserve, near the Tsarakibany settlement.

MATERIALS AND METHODS

Study sites.—Montagne d'Ambre National Park and Ankarana Special Reserve are separated by a distance of approximately 10 km (Fig. 1 and 2); the intervening landscape has largely been converted for zebu grazing and rice cultivation, and there are several villages and farm settlements. The foothills of the Montagne d'Ambre range extend southwards outside of the park boundary, descending near the village of Tsarakibany into basalt plains, which extend south to the rising karst plateau of Ankarana. There are many streams, usually supporting linear riparian corridors of introduced mango, and several small remnant forest patches, which are largely secondary in nature.

We surveyed three forest fragments between the southern boundary of Montagne d'Ambre National Park and the northern boundary of Ankarana Special Reserve for herpetofaunal diversity and abundance (Fig. 2, Table 1). Forest A was the smallest fragment surveyed and also the site of the research team's base camp, at 12º 46'25.24"S, 49º 10'26.85"E. Banana is grown within the forest fragment by local farmers,

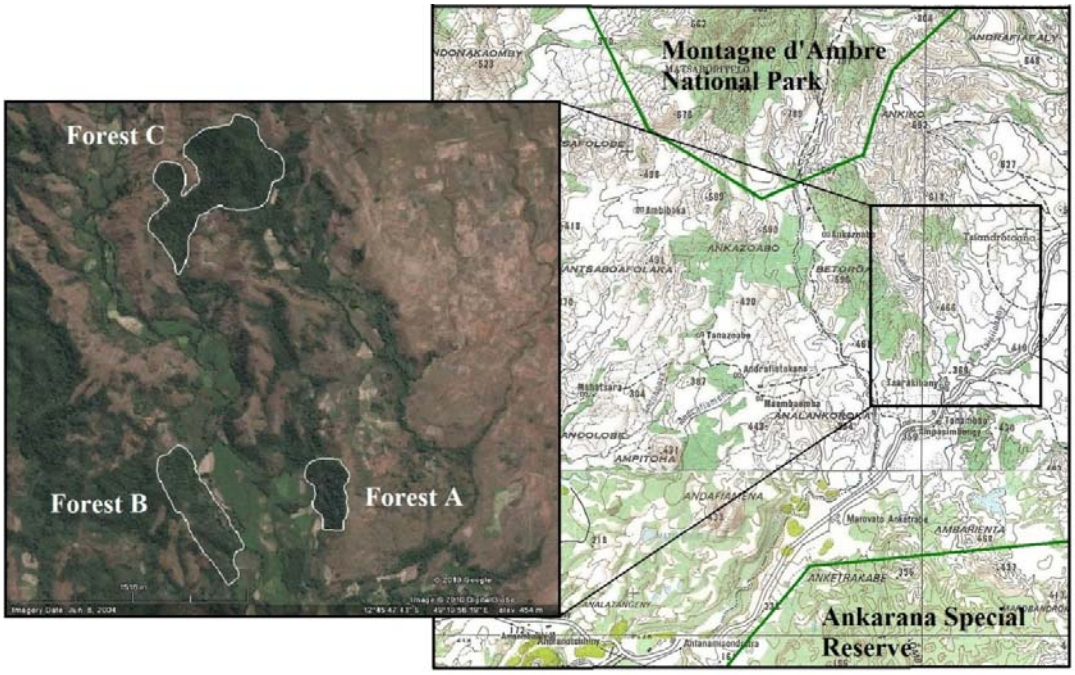

FIGURE 2. Topographic map of study area showing boundaries of Montagne d'Ambre National Park to the north and Ankarana Special Reserve to the south. Inset: GoogleEarth satellite image showing the surveyed forest fragments A, B and C (accessed 6 October 2010).

TABLE 1. Data for the three forest fragments surveyed for amphibians and reptiles in the Tsarakibany area between Montagne d'Ambre National Park and Ankarana Special Reserve, northern Madagascar.

Fragment name	Coordinates	Elevation (m a.s.l.)	Size (ha)
Forest A	12º46'19.60"S, 49º10'03.48"E	379–435	9.1
Forest B	12º46'14.21"S, 49º09'54.47"E	373–470	19.2
Forest C	12º45'04.89"S, 49º10'03.48"E	395–563	29.8

although some large trees remain to provide canopy cover. Forest B, located closest to Tsarakibany village, was the most structurally degraded of the three fragments studied, with a discontinuous or absent canopy, and evidence of fire damage in recent years, isolating it from forest patches to the northwest by regenerating scrub. Forest C was the largest and also the most isolated fragment surveyed, with relatively intact forest structure. However, as with the other fragments, secondary regeneration in Forest C was evident as a result of sustained timber extraction. All three fragments were subjected to selective timber extraction for fuel wood and construction, as well as slash-and-burn agriculture. The region is characterized by a reliable wet season from November to March during which the majority of rainfall occurs. This period is followed by a pronounced dry season during which rainfall is infrequent.

A team of researchers and volunteers carried out fieldwork over five survey periods conducted during both wet and dry seasons from January 2008 to March 2009 (*c.* 15 months). Surveys were approximately nine weeks in length and can be summarized as follows: Survey 1: 9 January to 14 March 2008; Survey 2: 9 April to 13 June 2008; Survey 3: 9 July to 12 September 2008; Survey 4: 8 October to 12 December 2008; Survey 5: 7 January to 13 March 2009. We conducted fieldwork throughout the full altitudinal range (373–563 m a.s.l.) within all habitat types. Although we surveyed all three forest fragments during each period, survey effort varied across fragments for each survey period.

Methodologies.—We employed a wide range of sampling methods in a variety of habitats, targeting the forest fragments but also anthropogenically disturbed areas (grasslands, paddy fields, village roadsides). The main techniques used were pitfall trapping with drift fences, active searching, and refuge examination. We also collected data on an opportunistic basis to inventory those species rarely recorded using other methods (e.g., terrapins, burrowing skinks, burrowing snakes, and boas. We followed the methodologies of Emmett et al. (2003). We classified species following a system similar to that used by Wilson and McCranie (2004): abundant (species encountered in large numbers regularly all year round), common (encountered on a regular basis all year round), infrequent (unpredictable and few individuals encountered), and rare (rarely encountered). This classification is based on data collected using all survey techniques and refers to the total number of individuals encountered for each species. We recorded the following information for each observation: date, latitude, longitude, habitat, microhabitat, altitude, and descriptive notes. Unfortunately, due to our lack of the necessary permits, we did not collect any specimens during the course of this survey. We identified species using Glaw and Vences (2007), photographic documentation, and collection of morphological data (Table 2).

Pitfall trapping.—Pitfall traplines consisted of 11 buckets (270 mm deep, 290 mm top internal diameter, 220 mm bottom internal diameter) sunk into the ground at 10 m intervals. We constructed three parallel traplines at a time, each 100 m in length, within forest fragments across a variety of microhabitats. We removed bucket handles and each bucket had small holes (2 mm diameter) punched in the bottom for drainage. Drift fences consisted of plastic sheeting (50 cm high) attached to thin wooden stakes, with the bottom buried in leaf litter to prevent animals from slipping underneath. We positioned the three fences to run over the center of each line of buckets. We checked the traplines each morning and afternoon; once identified, we uniquely marked and released all specimens at the point of capture. Each trapline was in place for 6–12 days. We conducted 18 traplines in the three target forest fragments during this survey.

Active searching and refuge examination.—We carried out both diurnal and nocturnal active searches across the full range of available altitudes and habitats. Searches lasted between 30 minutes and three hours and focused mainly on streams and associated riparian vegetation for amphibians, and forest interior near paths and trails for cryptic reptile species and arboreal frogs. Refuge examination constituted an important part of active searches, as many species are known to retreat to refuges when inactive (Raxworthy 1988). Researchers searched amongst leaf litter, dead wood, under stones, on tree trunks, and in the leaf axils of palms and banana plants.

Opportunistic observations.—We made general observations at all times for amphibians and reptiles found outside of normal survey activities. This method ensured inclusion in the species list any cryptic or particularly rare species that may not have been recorded from other standardized methodologies.

TABLE 2. Measurements and morphological characters of amphibians and reptiles recorded in the Tsarakibany area between Montagne d'Ambre National Park and Ankarana Special Reserve, northern Madagascar.

	Frogs	Snakes	Chameleons	Geckos	Skinks
Weight		X	X	X	X
Snout to vent length	X	X	X	X	X
Total length	X	X	X	X	X
Tail length		X	X	X	X
Head width	X				
Hind limb length	X				
Eye diameter	X				
Tympanum diameter	X				
Eye to nostril length	X				
Nostril to snout tip length	X				
Terminal disc shape	X				
Tibiotarsal articulation reach (eye, between eye and nostril, snout tip, beyond snout tip)	X				
Tympanum distinct/indistinct	X				
Metatarsal tubercles present/absent	X				
Femoral glands present/absent	X				
Tubercles present/absent	X		X		
Coloration, any distinct markings	X	X	X	X	X
Iris pattern and color	X				
Webbing formula (interior side of fourth toe)	X				
Number of ventral scales		X			
Number of subcaudal scales		X			
Number of mid-body dorsal scale rows		X			
Number of loreal scales		X			
Subcaudal scales divided/undivided		X			
Anal scale divided/undivided		X			
Conical scales present/absent and location			X		
Spines present/absent and location			X		
Occipital lobe present/absent			X		
Rostral appendage present/absent			X		
Dorsal crest present/absent			X		
Gular crest present/absent			X		

These observations included any individual captured by hand by a member of the research team, such as opportunistic discoveries of snakes, chameleons, or geckos.

RESULTS

We recorded 15 amphibian and 34 reptile species from the Tsarakibany area, giving a total herpetofaunal diversity of 49 species, 94% of which are endemic to Madagascar. Of the amphibians we found, including *Boophis roseipalmatus* and *Boophis cf. entingae* (Fig. 3), there were eight genera and four families, and all but one of these species is endemic to Madagascar. For reptiles, including *Liophidium therezieni*, *Leioheterodon modestus*, and *Thamnosophis stumpffi* (Fig. 3), we recorded 25 genera and eight families, only two of which are not endemic to Madagascar. By far the most successful means of herpetofauna collection was active searching. We found few individuals in pitfall traps.

Abundance and rarely encountered species.—We classified four species (8%) as abundant, 11 species (22%) as common, 12 species (24%) as infrequent, and 22 species (45%) as rare (Table 3). Amphibian captures were dominated by *Mantidactylus bellyi*, with 47% of the total amphibian records. The following species were only encountered once during the 15 month survey: a juvenile Plated Lizard, *Zonosaurus* cf. *boettgeri*, was found at basecamp in October 2008; the frog *Gephyromantis ambohitra* was found in Forest C in April 2008; a fossorial blind snake (*Typhlops* sp.) was found at base camp during rain in November 2008; the tree snake *Phisalixella inopinae* was recorded in Forest C in July 2008; and the cryptic *Pararhadinaea melanogaster* was captured using pitfall traps in Forest B in July 2008. Species which we did not encounter in target forest patches, but which we found opportunistically throughout the Tsarakibany region included: a *Thamnosophis stumpffi* hatchling found in a clearing while on an expedition to Ankazoabo (*ca.* 2 km from the southern border of Montagne d'Ambre National Park, Fig. 2); *Allaudina bellyi* found at night in a stream while on the same expedition to Ankazoabo in February 2009; and a *Langaha madagascariensis* hatchling found on the road near the village of Morovato in February 2009.

Occurrence within available habitats and microhabitats.—We found five species (10%) only in anthropogenically disturbed non-forest habitat, 28 species (57%) solely within the forest fragments, and 16 species (33%) both in disturbed and relatively

TABLE 3. Distribution and relative abundance of all amphibian and reptile species found in the Tsarakibany area during this survey. Abbreviations: Relative Abundance: A = abundant, C = common, I = infrequent, R = rare; Ecological Distribution: AB = arboreal, T = terrestrial, S = semi-aquatic; Habitat: F = forest, A = anthropogenically disturbed habitat; Endemicity: E = endemic to Madagascar, RE = endemic to the north of Madagascar (regional endemic), N = not endemic to Madagascar. * = species encountered in Tsarakibany area but not within the surveyed forest fragments. + = population assumed to be intermediate between *Z. madagascariensis* and *Z. haraldmeieri* (Frank Glaw, pers. comm.).

Species	Forest A	Forest B	Forest C	Relative abundance	Ecological distribution	Habitat	Endemic
Amphibia: Ptychadenidae							
Ptychadena mascareniensis	x			C	T,S	F,A	N
Hyperoliidae							
Heterixalus cf. *carbonei*	x			R	T,AB	A	E
Microhylidae							
Stumpffia cf. *gimmeli*	x		x	I	T,S	F	RE
Mantellidae							
Blommersia wittei	x			R	T,S	F	E
Boophis tephraeomystax	x			I	T,AB,S	F,A	E
Boophis blommersae	x		x	R	T,AB,S	F	RE
Boophis brachychir	x	x		I	T,AB	F	RE
Boophis cf. *entingae*			x	I	T,AB,S	F	RE
Boophis roseipalmatus	x		x	I	T,AB,S	F	RE
Boophis septentrionalis	x		x	I	T,AB,S	F	RE
Aglyptodactylus madagascariensis	x	x		R	T,S	F	E
Gephyromantis cf. *ambohitra*			x	R	T,S	F	RE
Gephyromantis pseudoasper			x	R	T,S	F	RE
Mantidactylus bellyi	x	x	x	A	T,S	F	RE
Mantidactylus ambreensis			x	I	T,S	F	RE
Reptilia: Chamaeleonidae							
Brookesia stumpffi	x	x	x	I	T,AB	F	E
Furcifer oustaleti	x	x	x	C	T,AB	F,A	E
Furcifer pardalis	x	x	x	A	T,AB	F,A	E
Furcifer petteri	x		x	C	T,AB	F	RE
Gekkonidae							
Blaesodactylus boivini	x		x	I	T,AB	F,A	RE
Ebenavia inunguis	x			R	AB	F	E
Geckolepis cf. *maculata*	x		x	R	T,AB	F,A	E
Phelsuma grandis	x	x	x	A	AB	F,A	E
Phelsuma cf. *abbotti*	x			R	AB	F	RE
Uroplatus sp. aff. *henkeli*	x		x	C	AB	F	E
Uroplatus sikorae	x			I	AB	F	E
Gerrhosauridae							
Zonosaurus cf. *boettgeri*	x			R	T	A	RE
Zonosaurus madagascariensis /haraldmeiri+	x	x	x	C	T	F,A	E
Scincidae							
Madascincus polleni	x	x	x	I	T	F	E
Trachylepis elegans	x	x		I	T	F,A	E
Boidae							
Acrantophis madagascariensis	x			R	T,AB	F,A	E
Sanzinia madagascariensis volontany	x			R	T,AB	F	E
Colubridae							
*Alluaudina bellyi**				R	T,S	F	E
Dromicodryas quadrilineatus	x	x	x	C	T	F,A	E
Ithycyphus miniatus	x			C	T,AB	F	E
*Langaha madagascariensis**				R	T	A	E
Leioheterodon madagascariensis	x	x	x	A	T	F,A	N
Leioheterodon modestus	x			C	T	F,A	E
Liophidium therezieni	x			R	T	F,A	RE
Liophidium torquatum	x			R	T	F	E
Madagascarophis colubrinus	x		x	C	T,S	F,A	E
Mimophis mahfalensis	x	x	x	C	T	F,A	E
Pararhadinaea melanogaster		x		R	T	F	RE
Phisalixella granuliceps			x	R	AB	F	RE
Phisalixella inopinae			x	R	AB	F	RE
Thamnosophis lateralis	x	x	x	C	T	F	E
*Thamnosophis stumpffi**				R	T	F	RE
Typhlopidae							
Typhlops sp.	x			R	T	A	RE
Pelomedusidae							
Pelusios castanoides	x			R	S	A	N

undisturbed habitat (Table 3). Of the available microhabitats, 15 species (31%) were solely observed in terrestrial environments, seven species (14%) were solely observed in arboreal environments, and 11 species (22%) were recorded in both microhabitats. Ten species (20%) occurred in both terrestrial and semi-aquatic environments, one species (2%) occurred exclusively in semi-aquatic areas, and five species (10%) occurred in all three microhabitats (terrestrial, arboreal, and semi-aquatic). Of the species recorded from the area, 20 (41%) are regional endemics restricted to only a few places in northern Madagascar.

Species occurrence comparisons across Tsarakibany and adjacent protected areas.—We found only four amphibian species and eight reptile species across all of Tsarakibany, Ankarana, and Montagne d'Ambre (Appendix). Of the nine amphibian species known to occur in Ankarana, four (44%) were recorded at Tsarakibany, and of the 20 amphibian species known from Montagne d'Ambre, 14 (70%) were recorded at Tsarakibany. Indeed, all of

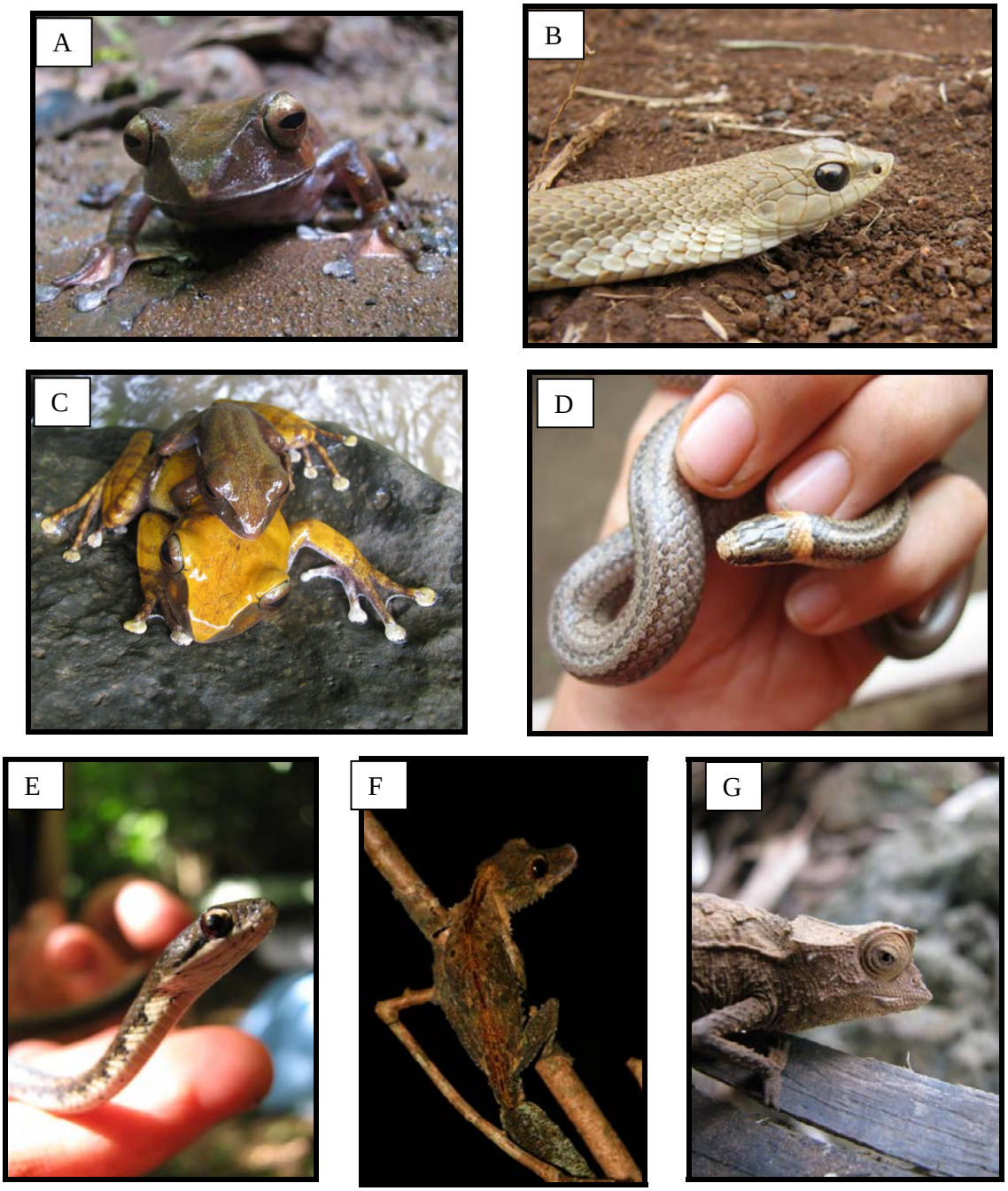

FIGURE 3. Photographic documentation of some of the species found in the Tsarakibany area. Plate A: *Boophis roseipalmatus*. Plate B: *Leioheterodon modestus*. Plate C: *Boophis cf. entingae*. Plate D: *Liophidium therezieni*. Plate E: *Thamnosophis stumpffi* at Ankazoabo. Plate F: *Uroplatus* sp. aff. *henkeli*. Plate G: *Brookesia stumpffi*. (Photographed by: A, C, E, F - Dante Wasmuht, D - Frontier Staff, B - Robbie Labanowski, G - Duncan Parker).

the amphibian species found at Tsarakibany were also recorded in Montagne d'Ambre. Of the 32 reptile species known from Ankarana, 19 (59%) were recorded at Tsarakibany, and of the 51 reptile species known from Montagne d'Ambre, 16 (31%) were recorded at Tsarakibany. Four of the colubrid snakes and one typhlopid snake recorded at Tsarakibany were so far unrecorded in both Ankarana and Montagne d'Ambre. The Appendix also incorporates the inventory list of herpetofauna compiled by Köhler et al. (2010) and D'Cruze et al. (2008) from Forêt d'Ambre Special Reserve, at the north of the Montagne d'Ambre massif and of comparable elevation to Tsarakibany. Percentage ratios of similarity in this herpetofauna to that of Tsarakibany have not been calculated, as several species from Forêt d'Ambre and Tsarakibany reported as potentially distinct in the Appendix (e.g., *Madascincus pollen* and *M. cf. polleni*) may in fact be conspecific.

DISCUSSION

We encountered 49 different reptile and amphibian species during this survey. Almost all of these are endemic to Madagascar (94%), with only two, *Ptychadena mascareniensis* and *Leioheterodon madagascariensis*, occurring on other Indian Ocean islands and one, *Pelusios castanoides*, occurring on the African mainland.

New records and relevance to patterns of biodiversity in northern Madagascar.—Because this was the first survey to focus on this area, all of the species found were new records for these specific localities. In addition, several species encountered during this study require special mention as their occurrence in the Tsarakibany forests significantly contributes to the current information regarding their distribution in Madagascar. A single specimen of the little known species *Pararhadinaea melanogaster* was captured in a bucket pitfall trap in Forest B in July 2008. We recorded the following data for this snake: snout-vent length 180 mm, tail length 35 mm (total length 215 mm), 17 dorsals, 140 ventrals, and 14 subcaudal pairs. This species was not recorded from either Forest A or Forest C, despite bucket pitfall trapping in these fragments. Since this survey was completed, however, Labanowski and Lowin (2011) captured three individuals of *P. melanogaster* in pitfall traps approximately 1 km to the northwest of Forest B.

The presence of *Liophidium therezieni* (Fig. 3) is noteworthy, as prior to this survey, this terrestrial snake was only reported from four locations: Montagne des Français, Anatelo, Ampombofofo, and Forêt d'Orangea (D'Cruze et al. 2007; Franzen et al. 2009; Megson et al. 2009). Its presence at Tsarakibany indicates that it is not restricted solely to limestone and coastal habitat (Franzen et al. 2009). Two individuals were found opportunistically throughout the 15 month survey: the first in leaf litter of Forest A in January 2008, and the second on bare ground also in Forest A in August 2008.

Both *Uroplatus sikorae* and *U.* sp. aff. *henkeli* occur in the Tsarakibany forests, a sympatry previously reported by D'Cruze et al. (2008) following their survey of Forêt d'Ambre Special Reserve. At Tsarakibany, *U.* sp. aff. *henkeli* was encountered more frequently than *U. sikorae* (100% more captures), suggesting *U.* sp aff. *henkeli* is the dominant *Uroplatus* species at lower elevations of Montagne d'Ambre.

Amphibians of conservation concern.—Three frog species recorded during our surveys are listed on the IUCN Red List (2010): *Boophis blommersae* and *Gephyromantis ambohitra* are considered to be Vulnerable, and *Heterixalus carbonei* is listed as Near Threatened on account of its habitat specificity and restricted range. *Heterixalus carbonei* was recorded six times in January and February 2008 from paddy fields, on the periphery of Forest A. Although this frog has only ever been recorded from forests (Raxworthy et al. 2008), it is possible that the captured individuals were using the seasonally abundant water sources available in paddy fields on the forest edge for breeding purposes. *Boophis blommersae* is listed as Vulnerable on account of being known from fewer than 10 locations and a continuing decline in the extent and quality of its habitat (Nussbaum et al. 2008). This frog was recorded four times in April, May and August 2008 along streams in Forests A and C. *Gephyromantis ambohitra* is also listed as Vulnerable due to its restricted range and extremely fragmented distribution (Raxworthy and Vences 2008). One individual of this species was recorded from Forest C in April 2008. Two additional species that we encountered during our surveys, the recently described *Boophis roseipalmatus* and *Boophis entingae* are also considered by Glaw et al. (2010) to be eligible for Vulnerable status, on account of their restricted range in forest patches of northern Madagascar and the continuing decline of extent and quality of their habitat.

Local distribution of herpetofauna.—Over half of the total herpetofaunal species recorded were found only in the remnant forests, despite extensive active searching in disturbed areas such as paddy fields and grasslands. It is therefore likely that these fragmented forest habitats act as refuges for much of the remaining local biodiversity, and that these species could not persist should these forests disappear from the landscape. Several studies have shown herpetofaunal diversity to decrease with decreasing forest fragment size (Ramanamanjato 2000; Vallan 2000). In western dry forests similar to the Tsarakibany habitat, Penner (2005) reported no reduction in species richness but significant changes in community structure with decreasing fragment size; common reptile species in original forest (e.g. *Brookesia* spp.) were entirely

absent in fragments. A similar effect may be acting on the herpetofaunal communities of Tsarakibany's fragmented forests. Indeed, species recorded from the larger, less degraded forests of Ankazoabo several kilometres to the west (e.g. *Allaudina bellyi, Thamnosophis stumpffi*) were not recorded from our three target forest fragments. The two *Phisalixella* species recorded during this survey were found only in Forest C, the largest and least degraded fragment. This fragment is also the most isolated, severely restricting the ability of *Phisalixella* species, which are arboreal specialists, to disperse to other fragments. Edge effects and microhabitat influences may also become important factors with decreasing fragment size (Vallan 2000), although these were not a focus of this study. The isolation of the Tsarakibany forest fragments has created habitat islands in which relict populations of species are persisting, although their long term survival is threatened by the ongoing slash-and-burn practices that continue to diminish fragment sizes.

In addition, this survey recorded the presence of four colubrid snakes and one typhlopid snake that to our knowledge have not been recorded from either of the adjacent protected areas. This suggests either that inventories for the two reserves are incomplete, or that the matrix of habitats available in the Tsarakibany area between the reserves is used by snake species that are not represented in either reserve. The discovery of these regionally endemic and rare species therefore highlights the need to protect these remaining forest fragments in order to preserve habitat islands in the Tsarakibany landscape and ensure the long term survival of species at risk.

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LITERATURE CITED

Bloxam, Q.M.C., and S.C. Barlow. 1987. A summary of the reptile field survey in the Ankarana massif, Madagascar. Dodo 24:61–67.

Cardiff, S., and J. Befourouack. 2003. The Reserve Speciale d'Ankarana. Pp. 1501–1507 *In* The Natural History of Madagascar. Goodman, S.M., and J.P. Benstead (Eds.). University of Chicago Press, Chicago, Illinois, USA.

D'Cruze, N.C., K.E. Green, J.E. Robinson, and C.J. Gardner. 2006. A rapid assessment of the amphibians and reptiles of an unprotected area of dry deciduous forest in north Madagascar. Herpetological Bulletin 96:17–25.

D'Cruze, N., D. Henson, A. Olssen, and D. Emmett. 2009. The importance of herpetological survey work in conserving Malagasy biodiversity: Are we doing enough? Herpetological Review 40:19–25.

D'Cruze, N., J. Köhler, M. Franzen, and F. Glaw. 2008. A conservation assessment of the amphibians and reptiles of Forêt d'Ambre Special Reserve, north Madagascar. Madagascar Conservation and Development 3:44–54.

D'Cruze, N., J. Sabel, K. Green, J. Dawson, C. Gardner, J. Robinson, G. Starkie, M. Vences, and F. Glaw. 2007. The first comprehensive survey of amphibians and reptiles from Montagne des Français, Madagascar. Herpetological Conservation and Biology 2:87–99.

Dufils, J.M. 2003. Remaining forest cover. Pp. 88–96 *In* The Natural History of Madagascar. Goodman, S.M., and J.P. Benstead (Eds.). University of Chicago Press, Chicago, Illinois, USA.

Emmett, D.A., E. Fanning, and A. Olsson. (Eds.). 2003. Forest Research Methodology Training Manual. Frontier-Madagascar Environmental Research Report 8. Society for Environmental Exploration, UK and University of Toliara, Institute of Marine Sciences, Toliara, Madagascar.

Franzen, M., J. Jones, A.P. Raselimanana, Z.T. Nagy, N. D'Cruze, F. Glaw, and M. Vences. 2009. A new black-bellied snake (Pseudoxyrhophiinae: *Liophidium*) from western Madagascar, with notes on the genus *Pararhadinaea*. Amphibia-Reptilia 30:173–183.

Ganzhorn, J.U., P.P. Lowry II, G.E. Schatz, and S. Sommer. 2001. The biodiversity of Madagascar: One of the world's hottest hotspots on its way out. Oryx 35:346–348.

Glaw, F., J. Köhler, I. De la Riva, D. Vieites, and M. Vences. 2010. Integrative taxonomy of Malagasy treefrogs: Combination of molecular genetics, bioacoustics and comparative morphology reveals twelve additional species of *Boophis*. Zootaxa 2383:1–82.

Glaw, F., and M. Vences. 2007. A Field Guide to the Amphibians and Reptiles of Madagascar. 3rd Edition. Vences and Glaw Verlag, Köln, Germany.

Harper, G.J., M.K. Steininger, C.J. Tucker, D. Juhn, and F. Hawkins. 2007. Fifty years of deforestation and forest fragmentation in Madagascar. Environmental Conservation 34:325–333.

Hawkins, A.F.A., P. Chapman, J.U. Ganzhorn, Q.M.C. Bloxam, S.C. Barlow, and S.J. Tonge. 1990. Vertebrate conservation in Ankarana Special Reserve, northern Madagascar. Biological Conservation 54:83–110.

IUCN 2010. IUCN Red List of Threatened Species. Version 2010.3. www.iucnredlist.org. Accessed on 25 August 2010.

Köhler, J., M. Vences, N. D'Cruze, and F. Glaw. 2010. Giant dwarfs: discovery of a radiation of large-

bodied ‘stump-toed frogs’ from karstic cave environments of northern Madagascar. Journal of Zoology 282:21–38.

Labanowski, R.J., and A.J. Lowin. 2011. A reptile survey in a dry deciduous forest fragment in northern Madagascar showing new records for the little-known snake *Pararhadinaea melanogaster* and a range extension for the skink *Amphiglossus tanysoma*. Herpetology Notes 4:113-121.

Megson, S., P. Mitchell, J. Köhler, C. Marsh, M. Franzen, F. Glaw, and N. D’Cruze. 2009. A comprehensive survey of amphibians and reptiles in the extreme north of Madagascar. Herpetology Notes 2:31–44.

Morris, P., and F. Hawkins. 1998. Birds of Madagascar: A Photographic Guide. Yale University Press, New Haven, Connecticut, USA.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

Nicoll, M.E., and O. Langrand. 1989. Madagascar: Revue de la conservation et des aires protegees. World Wildlife Fund, Gland, Switzerland.

Nussbaum, R., C. Raxworthy, and F. Glaw. 2008. *Boophis blommersae*. *In* IUCN 2010. IUCN Red List of Threatened Species. Version 2010.2. www.iucnredlist.org. Accessed 25 August 2010.

Penner, J., 2005. Reptile Communities in the Kirindy Dry Forest (Western Madagascar) – What is the Pattern? Ph.D. Dissertation, University of Würzburg, Würzburg, Germany. 107 p.

Ramanamanjato, J.B. 2000. Fragmentation effects on reptile and amphibian diversity in the littoral forest Isolated of southeastern Madagascar. Pp. 297–308 *In* Vertebrate Communities in the Tropics. Rheinwald, G. (Ed.). Bonner Zoologische Monographien 46. Zoologisches Forschungsinstitut und Museum A. Koenig, Bonn, Germany.

Ramanamanjato, J.B., R.A. Nussbaum, and C.J. Raxworthy. 1999. A new species of *Mabuya* Fitzinger (Squamata: Scincidae: Lygosominae) from northern Madagascar. Occasional Papers of the Museum of Zoology, University of Michigan 728:1–22.

Raxworthy, C.J. 1988. Reptiles, rainforest and conservation in Madagascar. Biological Conservation 43:181–211.

Raxworthy, C.J., and R.A. Nussbaum. 1994. A rainforest survey of amphibians, reptiles and small mammals at Montagne d’Ambre, Madagascar. Biological Conservation 69:65–73.

Raxworthy, C.J., and M. Vences. 2008. *Gephyromantis ambohitra*. *In* IUCN 2010. IUCN Red List of Threatened Species. Version 2010.2. www.iucnredlist.org. Accessed 25 August 2010.

Raxworthy, C.J., M. Vences, and F. Glaw. 2008. *Heterixalus carbonei*. *In* IUCN 2010. IUCN Red List of Threatened Species. Version 2010.2. www.iucnredlist.org. Accessed 25 August 2010.

Vallan, D. 2000. Influence of forest fragmentation on amphibian diversity in the nature reserve of Ambohitantely, highland Madagascar. Biological Conservation 96:31–43.

Wilson, L.D., and J.R. McCranie. 2004. The herpetofauna of Parque Nacional El Cusuco, Honduras (Reptilia, Amphibia). Herpetological Bulletin 87:13–24.

LOUISE DURKIN is a Conservation Biologist and ecologist with a background in surveying and monitoring of threatened species populations in Central America, Madagascar, and Indochina. Experienced in leading biodiversity assessments and delivering training in wildlife survey techniques, her main interests are herpetology, forest ecology, and applied conservation research. Since completing field work for this study, Louise has coordinated Frontier's operations in Cambodia and will soon be undertaking a MRes in Conservation Biology focusing on freshwater turtle ecology. (Photographed by Lindsay Patterson).

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Appendix. Inventory list of herpetofauna found in Ankarana Special Reserve, the Tsarakibany area, Montagne d'Ambre National Park, and Forêt d'Ambre Special Reserve (Glaw and Vences 2007; D'Cruze et al. 2008; Köhler et al. 2010). x = present. Notes: [a]: species endemic to Ankarana, [m]: species endemic to Montagne d'Ambre. [f]: species endemic to Forêt d'Ambre. * = species encountered in Tsarakibany area but not within the surveyed forest fragments.

Species	Ankarana	Tsarakibany	Mt. d'Ambre	Forêt d'Ambre
Amphibia: Dicroglossidae				
Hoplobatrachus tigerinus	x			
Ptychadenidae				
Ptychadena mascareniensis	x	x	x	x
Hyperoliidae				
Heterixalus carbonei		x	x	
Microhylidae				
Cophyla aff. *phyllodactyla*			x	
Cophyla sp. nov.				x
Platypelis grandis			x	x
Rhombophryne laevipes			x	
Rhombophryne sp. nov.				x
Stumpffia be	x			
Stumpffia gimmeli			x	
Stumpffia cf. gimmeli		x		x
Stumpffia madagascariensis			x	
Mantellidae				
Aglyptodactylus madagascariensis		x	x	x
Aglyptodactylus securifer	x			x
Blommersia wittei		x	x	x
Boophis baetkei[f]				x
Boophis blommersae		x	x	
Boophis brachychir		x		x
Boophis entingae		x	x	
Boophis sp. nov. aff. *brachychir*				x
Boophis roseipalmatus		x	x	x
Boophis septentrionalis		x	x	x
Boophis tephraeomystax	x	x	x	x
Guibemantis liber			x	
Gephyromantis ambohitra		x	x	
Gephyromantis granulatus			x	x
Gephyromantis horridus			x	
Gephyromantis pseudoasper	x	x	x	x
Laliostoma labrosum	x			
Mantella sp. aff. *viridis* 'Ankarana'[a]	x			
Mantella viridis				x
Mantidactylus ambreensis		x	x	x
Mantidactylus bellyi	x	x	x	x
Mantidactylus aff. betsileanus				x
Tsingymantis antitra[a]	x			
Reptilia: Chamaeleonidae				
Brookesia ambreensis[m]			x	
Brookesia antakarana[m]			x	
Brookesia ebenaui			x	x
Brookesia stumpffi		x	x	x
Brookesia sp. 'Mt. D' Français'	x			
Brookesia sp. nov.				x
Brookesia tuberculata[m]			x	

Calumma amber[m]			x	
Calumma ambreense			x	
Calumma boettgeri			x	
Calumma nasutum			x	
Furcifer oustaleti	x	x		x
Furcifer pardalis	x	x	x	x
Furcifer petteri	x	x	x	x
Furcifer timoni[m]			x	
Gekkonidae				
Blaesodactylus boivini	x	x		x
Ebenavia inunguis		x	x	
Geckolepis cf. maculata	x	x	x	x
Hemidactylus frenatus				x
Lygodactylus expectatus[a]	x			
Lygodactylus heterurus	x			x
Lygodactylus madagascariensis			x	
Lygodactylus rarus	x			
Paroedura gracilis			x	
Paroedura homalorhina	x			
Paroedura karstophila	x			
Paroedura oviceps			x	x
Paroedura stumpfii			x	x
Phelsuma abbotti		x		
Phelsuma abbotti checkei				x
Phelsuma lineata dorsivittata			x	x
Phelsuma grandis	x	x	x	x
Uroplatus alluaudi			x	x
Uroplatus ebenaui			x	
Uroplatus sp. nov. *ebenaui*				x
Uroplatus giganteus			x	x
Uroplatus sp. aff. *henkeli*	x	x		x
Uroplatus sikorae		x	x	x
Gerrhosauridae				
Zonosaurus boettgeri	x	x		
Zonosaurus madagascariensis/haraldmeieri	x	x	x	x
Zonosaurus tsingy	x			
Scincidae				
Amphiglossus allaudi	x			
Amphiglossus mandokava			x	
Amphiglossus melanurus			x	
Amphiglossus sp. 'Ankarana'[a]	x			
Madascincus melanopleura			x	
Madascincus minutus			x	
Madascincus mouroundavae			x	
Madascincus polleni		x	x	
Madascincus cf. *polleni*				x
Paracontias brocchii[m]			x	
Paracontias hildebrandti			x	
Trachylepis elegans		x	x	x
Trachylepis tavaratra	x		x	x
Boidae				
Acrantophis madagascariensis	x	x		
Sanzinia madagascariensis volontany	x	x		x

Colubridae				
*Alluaudina bellyi**		x	x	x
Alluaudina mocquardi[a]	x			
Compsophis albiventris[m]			x	
Compsophis infralineatus			x	
Dromicodryas quadrilineatus	x	x		x
Exallodontophis albignaci			x	
Heteroliodon lava	x			
Ithycyphus miniatus		x		x
*Langaha madagascariensis**		x		
Leioheterodon madagascariensis	x	x	x	x
Leioheterodon modestus		x		x
Liophidium rhodogaster			x	
Liophidium therezieni		x		
Liophidium torquartum	x	x	x	x
Liopholidophis dimorphus[m]			x	
Madagascarophis colubrinus	x	x		
Mimophis mahfalensis	x	x	x	x
Pararhadinaea melanogaster	x	x		
Pseudoxyrhopus ambreensis[m]			x	
Pseudoxyrhopus microps			x	x
Pseudoxyrhopus cf. *quinquelineatus*				x
Phisalixella arctifasciatus			x	
Phisalixella granuliceps	x	x		x
Phisalixella inopinae	x	x		x
Phisalixella variabilis	x			
Phisalixella cf. *variabilis*				x
Thamnosophis lateralis		x	x	x
Thamnosophis martae				x
*Thamnosophis stumpffi**		x	x	
Typhlopidae				
Typhlops microcephalus			x	
Typhlops mucronatus			x	
Typhlops sp.		x		
Pelomedusidae				
Pelusios castanoides		x		