

Terrestrial “forest-dwelling” endemic small mammals captured outside of natural habitats in the Moramanga District, central eastern Madagascar

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Abstract

The vast majority of Malagasy rodent (Subfamily Nesomyinae) and tenrec (Subfamily Oryzictinae) species living in the eastern humid forest are thought to be strictly forest-dwelling. Small mammals surveys conducted during 2013 and the first portion of 2014 near five villages in the Moramanga District, central eastern Madagascar, revealed the first documented cases of the shrew-tenrecs *Microgale majori* and *M. thomasi* in human-modified habitats and outside of natural forests. Other species of shrew-tenrecs generally occurring in native forest, *M. cowani* and *M. pusilla*, were also found in anthropogenic habitats. Moreover, the rodent *Brachyuromys betsileoensis* was captured in non-natural savanna a considerable distance from native forest. Details on the local habitats where these different small mammals were captured and the distance to the nearest natural forest are given to provide an ecological context for the results presented here. These different small mammal taxa are at least in part able to adapt to habitat perturbation induced by humans.

Key words: *Brachyuromys*, *Microgale*, *savoka*, open habitats, natural forest, adaptation, disturbance

Résumé détaillé

La grande majorité des petits mammifères rongeurs, de la sous-famille des Nesomyinae, et des tenrecs, de la sous-famille des Oryzictinae, qui sont tous endémiques de Madagascar sont considérés comme strictement forestières. Des captures de

petits mammifères, par le biais des trous-pièges et des pièges standards, menées dans cinq villages du District de Moramanga, dans la partie Est-centrale de Madagascar, en 2013 (saison sèche) et en 2014 (saison humide) ont permis d'attraper pour la première fois deux espèces d'Afrosoricida endémiques, *Microgale majori* et *M. thomasi*, dans des habitats anthropogéniques en dehors des forêts naturelles. La première espèce a été répertoriée dans deux sites (Ambalafary et Antsahatsaka) à travers deux types d'habitats principaux : la forêt d'*Eucalyptus* et le *savoka*. Le terme *savoka* désigne des formations végétales secondaires souvent peu pénétrables et correspond à la période de jachère des cultures sur brûlis. Ces habitats de capture sont situés près de 770 m jusqu'à plus de 3 km d'une forêt naturelle. Concernant *M. thomasi*, un spécimen a été capturé dans un *savoka* situé à près d'une centaine de mètres d'une forêt naturelle, dans le site de Besakay. Deux autres espèces d'Afrosoricida répertoriées habituellement dans les formations forestières à savoir *M. cowani* et *M. pusilla* ont été capturées dans un *savoka* et près des rizières. Particulièrement, *M. cowani* a été capturé à Sahavarina où la forêt naturelle la plus proche se trouve entre 240 et près de 580 m du point de capture. Le cas de *M. pusilla* est remarquable car cette espèce est la seule qui a été présente dans les quatre sites cités précédemment faisant varier la distance de son point de capture à près d'une centaine de mètres à plus de 3 km vers la forêt naturelle la plus proche. Outre les Afrosoricida, une espèce de Rodentia endémiques, *Brachyuromys betsileoensis*, a été répertoriée dans une savane dans le site d'Antsirinala qui est distant de plus de 12 km de la formation forestière naturelle la plus proche. Aucun Afrosoricida n'a été recensé dans ce site.

Mots-clés : *Brachyuromys*, *Microgale*, *savoka*, habitats ouverts, forêt naturelle, adaptation, perturbation

Introduction

During the two last decades, research on endemic Malagasy small mammals of the families Tenrecidae (tenrecs), composed of three subfamilies (Tenrecinae,

Geogalinae, and Oryzoricinae), and Nesomyidae (rodents) has progressed significantly. Besides the discovery of new genera and species to science, considerable information has been gathered about the biology, ecology, and biogeography of these animals (Soarimalala & Goodman, 2011; Goodman *et al.*, 2013).

Of the 59 species of endemic small mammals currently recognized from Madagascar (32 Tenrecidae and 27 Nesomyidae), most are thought to be restricted to natural forest, with the exception of spiny tenrecs (Tenrecinae), which occur in natural and human-modified habitats (Soarimalala & Goodman, 2011). For example, the tenrecine *Tenrec ecaudatus* occurs in open habitats, mostly anthropogenic in nature, near villages, plantations, as well as natural forest formations (Ganzhorn *et al.*, 2003). There are a few exceptions amongst endemic oryzoricines, such as the aquatic *Limnogale mergulus*, known to occur outside of forest habitats, including rivers passing through pine plantations (Benstead & Olson, 2003) and *Oryzorictes hova*, in rice fields and open marshy habitats (Goodman, 2003).

Among endemic nesomyine rodents, *Eliurus webbi* has been recorded in degraded littoral forest associated with exotic tree plantations (Rakotondravony *et al.*, 1998; Ramanamanjato & Ganzhorn, 2001); otherwise, members of this genus are considered inhabitants of natural forests (Soarimalala & Goodman, 2011). The other notable exception amongst native rodents is *Brachyuromys betsileoensis*, known to occur in fallow rice fields in close proximity to forest and high mountain ericoid-marshland habitat (Langrand & Goodman, 1997; Jansa & Carleton, 2003).

Effectively, the vast majority of the members of these two endemic families are considered forest dependent and there are few records, excluding the Tenrecinae, of them occurring outside natural habitats. Our recent inventories in human-degraded habitats have revealed evidence of two shrew-tenrecs, *Microgale majori* and *M. thomasi*, in open habitats outside of natural forest formations. Two other members of this genus, *M. cowani* and *M. pusilla*, and one species of rodent, *B. betsileoensis*, were also found in non-forested habitats during this study; all three had been previously documented outside of native forest settings. Herein we present the results for the different endemic taxa captured during recent field inventories outside of intact forest.

Methods

Site and study periods

Studies were carried out in eastern central Madagascar near five villages located in the Alaotra-Mangoro Region and Moramanga District (Figure 1). In many cases, the dominant non-forested habitat in these areas is *savoka*. This term comes from the Malagasy and refers to secondary vegetation, generally of non-native and invasive plants, that grow after deforestation of former natural forest. In many cases, the initial reason for forest clearing is to establish sites for planting agricultural crops, often for only a few seasons (Humbert, 1965). Once the soils are depleted of nutrients, crops cannot be efficiently grown, the site is abandoned, at least temporarily, and dense secondary vegetation takes over. Thus, *savoka* is best defined as fallow areas after slash-and-burn cultivation.

Descriptions of the five different sites are given below (Figure 1):

Besakay - This site is located about 4.7 km direct distance northeast of Andasibe (village). Geographic coordinates are 18°54'4.2"S, 48°27'00.0"E, 985 m asl. Besakay was sampled during the rainy season from 12 to 16 January 2014.

Antsahatsaka - This village is about 3.4 km direct air distance southeast of Moramanga and 6 km by road from Moramanga along the Route National 2 to Toamasina. The camp was established at 18°57'20.6"S, 48°16'47.3"E, 940 m asl and sampling was conducted during the dry season (24 to 29 August 2013) and the rainy season (25 to 29 January 2014).

Antsirinala - This site is located about 900 m direct distance northeast of Antsirinala (village). The camp was based at 18°53'29.1"S, 48°9'10"E, 920 m asl. The field survey took place during the dry season from 13 to 18 September 2013.

Ambalafary - This village is situated 1 km direct distance south of Ambodiriana (village). Geographic coordinates of the site are 19°02'00.4"S, 48°20'20.3"E, 980 m asl. Inventories were carried out during two dry seasons: from 5 to 10 October 2013 and from 12 to 16 April 2014.

Sahavarina - This locality is located 1.5 km direct distance north of Sahavarina (village). The camp was established at 18°51'48.3"S, 48°21'23.9"E, 950 m asl. The sampling took place during the rainy season from 7 to 11 March 2014.

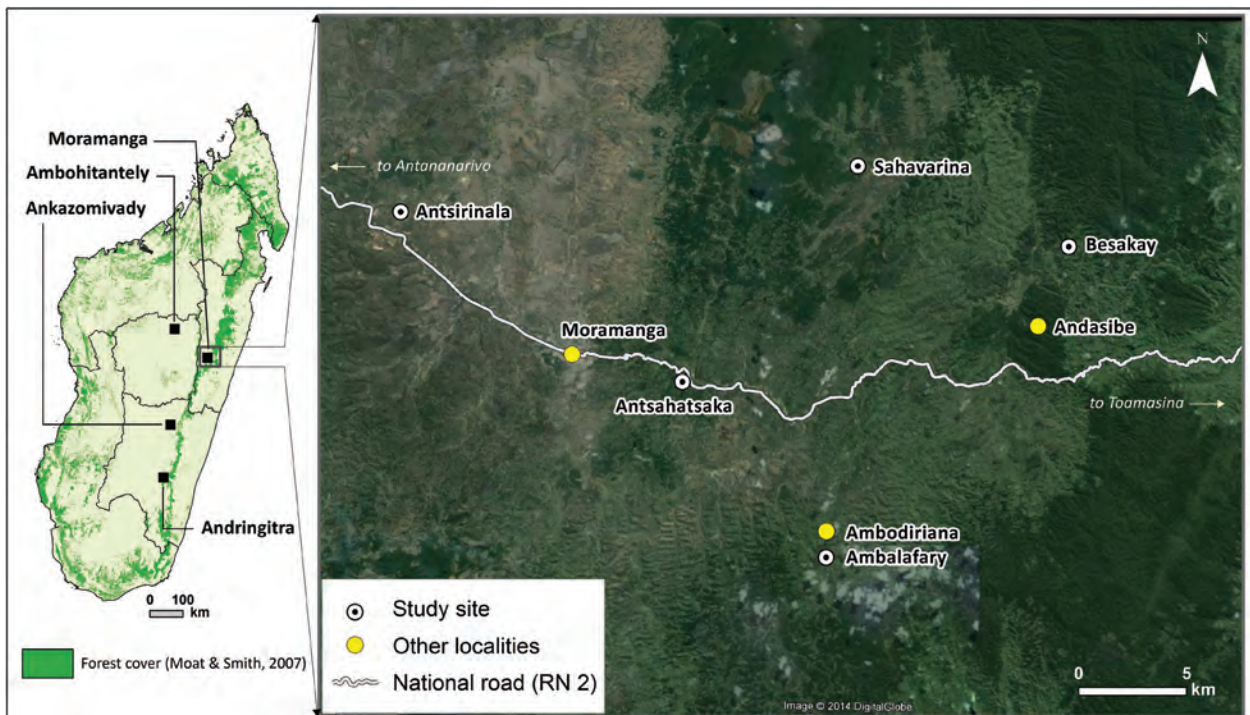


Figure 1. The map to the left is of localities mentioned in the text (Source: Moat & Smith, 2007) and to the right a blow-up of the area around Moramanga showing the five study sites and some other localities. (Source: Image Google Earth, 2014.)

Trapping methods

Trapping techniques commonly used on Madagascar during the past two decades were employed in this study, which include pitfall traps and standard live-capture traps (Soarimalala, 2008). For each site, three pitfall lines (vertical plastic drift fences, each line composed of 11 buckets, and 10 m distant from the nearest bucket), and a total of 120 standard live traps, equally divided between three types (Sherman 22.5 x 8.6 x 7.4 cm, Nationals 39.2 x 12.3 x 12.3 cm, and BTS 30 x 10 x 10 cm), were installed for five to six successive nights.

Specimens

Voucher specimens collected during the field surveys are deposited at the Université d’Antananarivo, Département de Biologie Animale.

Nearest distance to natural forest

In order to assess the distance between a capture site and the nearest natural forest, images were downloaded from Google Earth (consulted on 22 May 2014) and based on the geographic coordinates of the different trapping sites measured during the field



Figure 2. Site of Antsirinala, where the captured animal included: (1) *Brachyuromys betsileoensis* (dry season). (Source: Image Google Earth, 2014.)

inventories, this information were superimposed on a base image. Distances are presented as the minimum direct line from traps to the forest-limit. Based on the Google images it was not always possible to differentiate natural forest, defined as relatively intact natural formations, from degraded

forested habitat with some woody vegetation or from tree plantations. Demarcations presented in Figures 2-6 are based on ground verification. Projections of pitfall lines, all 100 m in length, were not adjusted for slope angle.

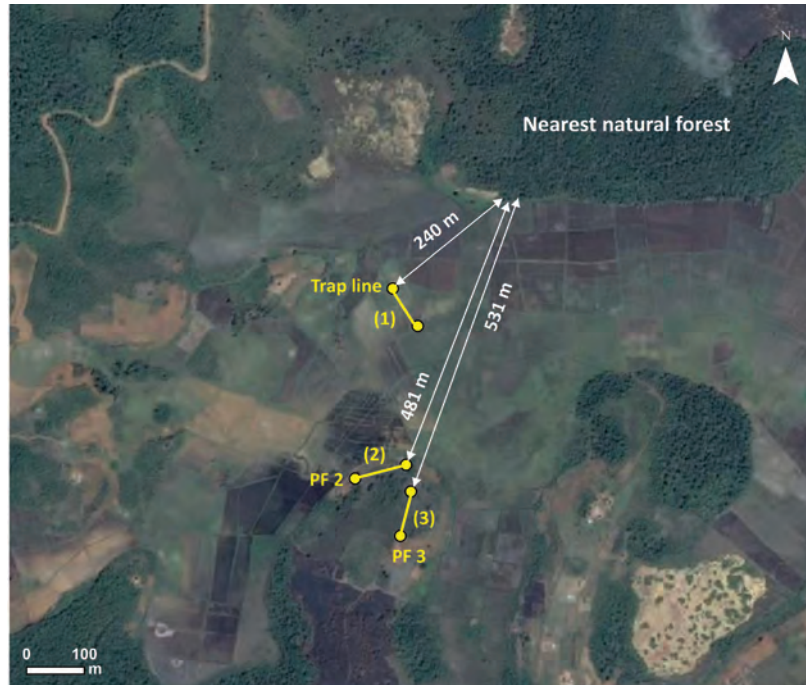


Figure 3. Site of Sahavarina, where animals captured in pitfall lines (PF 1, PF 2) included: (1) & (2) *Microgale cowani* (rainy season) and (3) *M. pusilla* (rainy season). The woody vegetation to the south and east of the trap sites is not natural forest. (Source: Image Google Earth, 2014.)

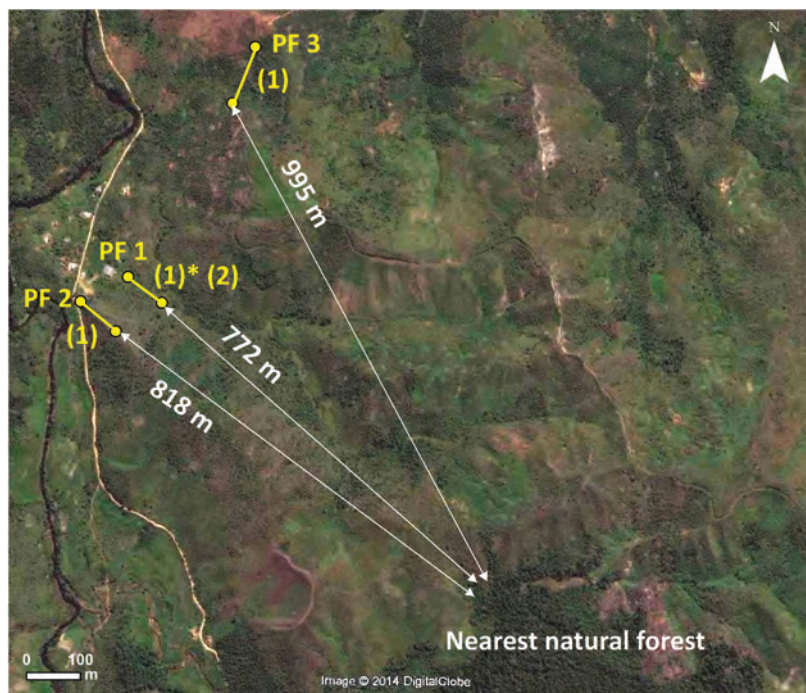


Figure 4. Site of Ambalafary, where animals captured in pitfall lines (PF 1, PF 2, PF 3) included: (1) *Microgale majori* (dry season), (1)* *M. majori* (rainy season), and (2) *M. pusilla* (rainy season). (Source: Image Google Earth, 2014.)

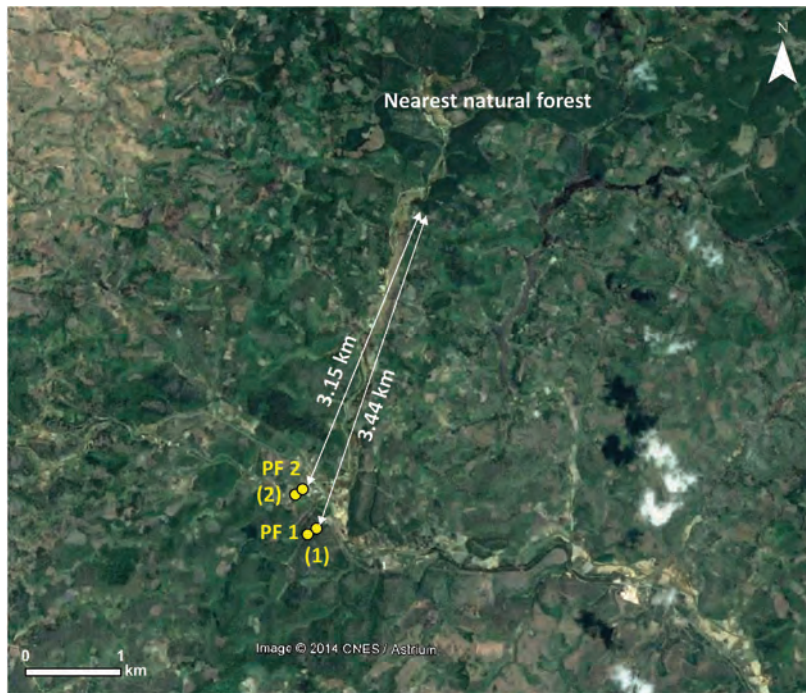


Figure 5. Site of Antsahatsaka, where animals captured in pitfall lines (PF 1 and PF 2) included: (1) *Microgale majori* (dry season) and (2) *M. pusilla* (dry and rainy seasons). (Source: Image Google Earth, 2014.)



Figure 6. Site of Besakay, where animals captured in a pitfall line (PF 2) included: (1) *Microgale thomasi* (rainy season) and (2) *M. pusilla* (rainy season). The woody vegetation to the south of the pitfall is not natural forest. (Source: Image Google Earth, 2014.)

Results

Four species of Oryzoricinae shrew-tenrecs, *Microgale cowani*, *M. majori*, *M. pusilla*, and *M. thomasi*, and one species of Nesomyinae rodent, *Brachyuromys betsileoensis*, were captured outside of natural forest settings. In all cases, these species were trapped within their respective elevational range reported in the literature (Soarimalala & Goodman, 2011; Goodman *et al.*, 2013). The results presented herein for *M. majori* and *M. thomasi* are the first reports of these taxa considerable distances outside natural forest. The information about each endemic small mammal trapped in the context of this study outside of natural forest, the kind of trap, and the habitat are given below and summarized in Table 1.

Brachyuromys betsileoensis

Site: Antsirinala

The habitat where the single individual of this species was captured was at a site with anthropogenic

savanna and a few scattered pine trees (introduced), about 7 m in height. The Sherman trap was set on the ground in a grass tuft and at the base of a pine tree. The trap locality was about 50 m from the nearest rice field, recently harvested, and in close proximity to banana, guava, and peach trees, and sugar cane. A permanent stream occurred at the edge of the rice field. Human habitations were within 400 m of the site and the nearest natural forest block was about 11.5 km in distance (Figure 2).

Microgale cowani

Site: Sahavarina

Two individuals of this species were captured in different habitats. The first was obtained in a pitfall line (PF2, Figure 3) placed in a valley and at a site dominated by sugar cane (about 1.7 m in height) and banana plantations (about 2.5 m in height and not in fruit). The site was next to a rice field with plants without mature seed. Ferns and herbaceous

Table 1. List of small mammals captured outside natural forest formations during the two different sampling seasons. Sex: M = male, F = female. Geographic coordinates for the pitfall lines are given for the start of each line (bucket 1 of 11).

Taxa	Site and season	Method	Number of individuals and sex	Geographic coordinate and elevation	Habitat
RODENTIA					
Nesomyinae					
<i>Brachyuromys betsileoensis</i>	Antsirinala (dry season)	Sherman	1♀	18°53'17.6"S, 48°9'10.2"E, 900 m asl	Savanna
AFROSORICIDA					
Oryzoricinae					
<i>Microgale cowani</i>	Sahavarina (rainy season)	Pitfall	1♂	18°52'01.8"S, 48°21'12.3"E, 925 m asl	Plantation along rice field
	Sahavarina (rainy season)	Sherman	1♂	18°51'54.0"S, 48°21'12.9"E, 925 m asl	Rice field
<i>Microgale majori</i>	Ambalafary village (rainy season)	Pitfall	1♂	19°2'0.917"S, 48°20'22.084"E, 980 m asl	Savoka
	Ambalafary village (dry season)	Pitfall	1♂	19°1'50.4"S, 48°20'2859"E, 985 m asl	<i>Eucalyptus</i> plantation
	Ambalafary village (dry season)	Pitfall	1♂	19°2'2.42"S, 48°20'19.093"E, 985 m asl	Savoka
	Antsahatsaka (dry season)	Pitfall	2♂♂	18°57'22.0"S, 48°16'41.7"E, 950 m asl	<i>Eucalyptus</i> forest
<i>Microgale pusilla</i>	Ambalafary village (rainy season)	Pitfall	1♂	19°2'0.917"S, 48°20'22.084"E, 980 m asl	Savoka
	Antsahatsaka (dry season)	Pitfall	1♀	18°57'10.5"S, 48°16'33.9"E, 940 m asl	Rice field
	Antsahatsaka (rainy season)	Pitfall	2♀♀, 1♂	18°57'10.5"S, 48°16'33.9"E, 940 m asl	Rice field
	Besakay (rainy season)	Pitfall	2♂♂	18°53'59.5"S, 48°26'47.1"E, 1015 m asl	Savoka
	Sahavarina (rainy season)	Pitfall	1♂	18°52'05.8"S, 48°21'12.0"E, 945 m asl	<i>Erica</i> sp.
<i>Microgale thomasi</i>	Besakay (rainy season)	Pitfall	1♂	18°53'59.5"S, 48°26'47.1"E, 1015 m asl	Savoka

plant litter dominated the ground layer along the pitfall. *Harungana* sp. (Family Hypericaceae) and introduced *Lantana camara* (Family Verbenaceae) were also found along the trap line in close proximity to an irrigation canal. The second individual was obtained in a Sherman trap placed on the ground (Figure 3, Trap Line), next to an irrigation canal and tufts of herbaceous vegetation. The site was in a valley with dry soil and situated about 50 m from rice fields without mature seed.

Microgale majori

Site: Ambalafary

Three individuals of this species were captured in different pitfall lines during the two seasons the site was inventoried. The first animal was obtained in PF 1 (Figure 4), which was primarily in *savoka* habitat (see Methods for definition), dominated by two members of the Family Asteraceae, *Psiadia altissima* (about 3 m in height) and *Helichrysum cirrhosum* (about 2 m in height). Herbaceous plants were mixed within relatively short *Lantana camara* vegetation. The line was established in a valley situated about 50 m from a permanent stream. The second animal was in PF 2 (Figure 4), positioned on a slope in *savoka* and the zone dominated by *H. cirrhosum* and a layer of ground growing ferns. The soil was moderately covered by leaf litter. The third individual was captured in PF 3 (Figure 4) installed on a slope in a plantation of introduced *Eucalyptus*, with trees reaching about 3.5 m in height, no herbaceous vegetation, and *Eucalyptus* leaf litter. In close vicinity, there were signs of recent charcoal production. In all cases, these animals were trapped some distance from natural forest, ranging from 770 to 995 m (Figure 4).

Site: Antsahatsaka

Two individuals were captured at this site during the dry season in the same pitfall line. Pitfall line 1 (PF 1, Figure 5) was established in a *Eucalyptus* plantation, trees 2 to 4.5 m in height, with little herbaceous vegetation, and with discontinuous ground litter composed mostly of *Eucalyptus* leaves. Signs of previous charcoal production were present. The distance from the trap site to the nearest natural forest was over 3 km.

Microgale pusilla

Site: Sahavarina

The habitat surrounding the pitfall line that yielded one individual of this species (PF 3, Figure 3) had relatively dense *Erica* bushes (Family Ericaceae), about 1 m tall, and the soil with little leaf litter, but a luxurious growth of lichens. The line was established on a slope and about 50 m from rice fields and an irrigation canal.

Site: Ambalafary

One individual of this species was captured in the Ambalafary pitfall line cited above under *M. majori* (PF 1, Figure 4).

Site: Antsahatsaka

One animal was captured in a pitfall line (PF 2, Figure 5) in an area dominated by herbaceous vegetation at the edge of a recently harvested rice field. Some corn and manioc had also been planted in the immediate vicinity. The pitfall line was set in a valley and a few meters from an irrigation canal.

Site: Besakay

Two individuals were captured in a pitfall line (PF2, Figure 6) installed in an area of *savoka* dominated by ferns about 1.5 m tall and introduced *Psidium cattleianum* (Family Myrtaceae) and *Lantana camara*, *Harungana* sp., and *Psiadia altissima*. The line was located on a hillcrest.

Microgale thomasi

Site: Besakay

This species was captured in the same pitfall line at this site cited above for *M. pusilla* (PF 2, Figure 6).

Discussion

Over the past decades, several hundred small mammal surveys have been conducted at different sites across Madagascar, most using the same trapping techniques employed here. The vast majority have taken place in natural forest formations. The exceptions include surveys in non-forested zones at high mountain sites (above forest line) with natural ericoid vegetation (Langrand & Goodman, 1997), in secondary habitats (Ramanamanjato & Ganzhorn, 2001; Scott *et al.*, 2006), exotic tree plantations (Ramanamanjato & Ganzhorn, 2001), and in marshy areas adjacent to or within natural forest (Soarimalala *et al.*, 2001). Distinctly degraded zones or those with

formations such as *savoka* have generally not been the habitat types included in these small mammal inventories. Hence, based on the results of extensive small mammal trapping across the island, numerous endemic small mammal species, excluding members of the Subfamily Tenrecinae, have been considered largely or strictly restricted to undisturbed or slightly degraded natural forest.

In the context of some recent fieldwork being conducted primarily by the first author in collaboration with the Institut Pasteur de Madagascar and the University of Aberdeen, a series of sites outside natural forest formations were inventoried for small mammals and several endemic species were captured. With the exception of *Microgale majori* and *M. thomasi*, which were formerly considered as forest dependent, the other species of endemic small mammals found during these surveys in human-modified habitats, include *M. cowani*, *M. pusilla*, and *Brachyuromys betsileoensis*. These latter three taxa were previously known from both natural forest and open or degraded forest habitats, in some cases anthropogenic in nature (Soarimalala & Goodman, 2011). Below we review information on each of these five taxa with respect to their occurrence outside natural forest formations.

Brachyuromys betsileoensis

Previous small mammal inventories found this species in non-forested habitats that include herbaceous vegetation, generally in close proximity to marshy areas, ponds, and abandoned rice fields (Jansa & Carleton, 2003). Hence, it is able to adapt at some level to open anthropogenic habitats. In the case of the present study, an individual was captured more than 11 km from the nearest natural forest and close to human habitation (Figure 2). Of probable ecological importance, the capture site was close to a rice paddy and, hence, in an area with humid ground, fitting in part the habitat specificity of this species. The ability of *B. betsileoensis* to adapt to environmental conditions outside native forest is previously mentioned by Langrand & Goodman (1997), who found it in a highland marsh above forest line on the Andringitra Massif, where night minimum temperatures can descend to less than -7°C.

Microgale cowani* and *M. pusilla

In the literature, in addition to intact or disturbed natural forests, these two species are known to occur in fragmented forest habitat with significant

anthropogenic activities (MacPhee, 1987; Goodman *et al.*, 1997; Goodman & Rakotondravony, 2000) and in areas of non-native tree plantations and non-forested habitats (Jenkins, 2003). During our study, *M. cowani* was captured outside of natural forests in areas close to rice fields, often with considerable ground litter; in proximity to water; and in agricultural fields frequently near irrigation canals. Similar results were documented at the Central Highland site of Ankazomivady, where this species was found near marshes surrounded by rice fields and grassy formations, but in close proximity to forest (Goodman *et al.*, 1998).

In the summit zone of the Andringitra Massif, above forest line, *M. cowani* was common in areas along streams or with permanent-temporary marshes, where the vegetation is predominantly grass and sclerophyllous forest (Langrand & Goodman, 1997). In the Réserve Spéciale d'Ambositantely, this species was found in forest parcels varying in size from 1250 to 0.64 ha, which are separated by a matrix of anthropogenic savanna (Goodman & Rakotondravony, 2000); these data indicate that this species almost certainly has the ability to disperse across non-native grassland habitat.

During our current study, *M. cowani* was found up to 450 m from degraded forest, further supporting its capacity to cross or inhabit areas of non-forested habitat. The ecological tolerance of *M. cowani* is considerable, as this species can exploit different habitat types and resist nightly temperatures descending to below -7°C (Langrand & Goodman, 1997).

In the case of *M. pusilla*, a number of studies indicate its presence outside native forest habitat, such as areas with marsh habitat or wet ground (MacPhee, 1987; Goodman *et al.*, 2000; Olson *et al.*, 2004). On the basis of stable isotope analysis, this species fills a trophic niche notably different from other eastern humid forest-dwelling *Microgale* spp. (Dammhahn *et al.*, 2013). *Microgale pusilla* is less sensitive to habitat degradation than other members of the genus (Jenkins, 2003), perhaps with the exception of *M. cowani*. In the context of our current study, *M. pusilla* was captured between a few hundred meters to more than 3 km from natural forest and, in most cases, in open habitats associated with moist ground.

Microgale majori

On the basis of bibliographic information, the records presented herein represent some of the first

indications for this species outside of natural forest. It was captured at Ambalafary and Antsahatsaka in different anthropogenic habitats, including *Eucalyptus* plantations previously exploited for charcoal production and with relatively dense leaf litter of this introduced tree. The distance between capture sites and the nearest natural forest varied from about 770 m to 3.4 km, verifying its capacity to live outside natural forest habitats. Based on a study conducted in the Réserve Spéciale d'Ambohitantely on the impact of forest fragmentation on small mammals, specifically in forest blocks surrounded by a matrix of anthropogenic grassland, this species was found in all fragments ranging in size from 1250 m to 0.64 ha (Goodman & Rakotondravony, 2000; Olson *et al.*, 2004).

Microgale thomasi

On the basis of previous research, this species was considered an inhabitant of intact or relatively pristine eastern humid forests (Soarimalala & Goodman, 2011). In our study, an individual was captured in *savoka* about 90 m from natural forest. Whether the animal was resident at the site of capture or in the process of dispersing is unknown. However, based on this information and some other published details, including the capture of this species in disturbed forest and a plantation introduced pine trees (Goodman *et al.*, 1996), there is evidence that it can live in human-modified habitats.

Conclusion

Fieldwork conducted in the context of this study resulted in the capture of several species of endemic Malagasy small mammals outside of natural forest, including records of *Microgale majori* and *M. thomasi* in non-forest habitats. Further, three other taxa, *M. cowani*, *M. pusilla*, and *Brachyuromys betsileoensis*, are generally considered forest-dwelling but have been previously documented outside natural forest and data presented herein provides further evidence of their ability to adapt to anthropogenic modifications of native forest habitats. In several cases, these animals were captured considerable distances from natural forests. It is important to mention that although these five species are able to live in modified habitats, the vast majority of Malagasy small mammals of the Subfamilies Nesomyinae and Oryzoricinae are still considered to be forest dependant and their future depends on the conservation of these formations.

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