Overdorff, D. J. 1993. Similarities, differences, and seasonal patterns in the diets of *Eulemur rubriventer* and *Eulemur fulvus rufus* in the Ranomafana National Park, Madagascar. *International Journal of Primatology*, 14(5): 721-753.

Picot, M., Jenkins, R. K. B., Ramilijaona, O., Racey, P. A. & Carrière, S. 2007. The feeding ecology of *Eidolon dupreanum* (Pteropodidae) in eastern Madagascar. *African Journal of Ecology*, 45: 645-660.

Prum, R. O. 1993. Phylogeny, biogeography and evolution of the broadbills (Eurylaimidae) and asities (Philepittidae) based on morphology. *Auk*, 110: 304-324.

Prum, R. O. & Razafindratsita, V. R. 1997. Lek behavior and natural history of the Velvet Asity (*Philepitta castanea*: Eurylaimidae). *Wilson Bulletin*, 109: 371-392.

Prum, R. O. & Razafindratsita, V. R. 2003. Philepittinae, asities and sunbird-asities. In *The natural history of Madagascar*, eds. S. M. Goodman & J. P. Benstead, pp. 1123-1130. The University of Chicago Press, Chicago.

Prum, R. O., Morrison, R. L. & Ten Eyck, G. R. 1994. Structural color production by constructive reflection from ordered collagen arrays in a bird (*Philepitta castanea*: Eurylaimidae). *Journal of Morphology*, 222: 61-72.

Raherilalao, M. J., Gautier, F. & Goodman, S. M. 2002. Les oiseaux de la Réserve Spéciale de Manongarivo, Madagascar. In Inventaire floristique et faunistique de la Réserve Spéciale de Manongarivo (NW Madagascar), eds. L. Gautier & S. M. Goodman. *Boissiera*, 59: 359-381.

Rakotomanana, H., Hino, T., Kanzaki M. & Morioka H. 2003. The role of Velvet Asity *Philepitta castanea* in regeneration of understory shrubs in Madagascan rainforest. *Ornithological Science*, 2: 49-58.

Razafindratsita, V. R. 1995. *Etude biologique et écologique de* Philepitta castanea *(Muller 1776): son rôle dans la régénération du sous-bois forestier du Parc National de Ranomafana*. Diplôme d'Etudes Approfondies, Université d'Antananarivo, Antananarivo.

Schatz, G. E. & Malcomber, S. T. 1993. Botanical research at Ranomafana National Park: baseline data for long-term ecological monitoring. MBG, St. Louis.

Turk, D. 1995. *A guide to trees of Ranomafana National Park and central eastern Madagascar*. U.S. Agency for International Development, Washington, D. C.

Wheelwright, N. T., Haber, W. A., Murray, K. G. & Guindon, C. 1984. T ropical fruit-eating birds and their food plant: A survey of a Costa Rican lower montane forest. *Biotropica*, 16(3): 173-192.

White, F. J., Overdorff, D. J., Balko, E. A. & Wright, P. C. 1995. Distribution of ruffed lemur (*Varecia variegata variegata*) in Ranomafana National Park, Madagascar. *Folia Pimatologica*, 64: 124-131.

Zar, J. H. 1984. *Biostatistical analysis*. 2nd Edition. Prentice Hall Inc., Englewood Cliffs, New Jersey.

The diet of the endemic bat *Myzopoda aurita* (Myzopodidae) based on fecal analysis

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Abstract

Fieldwork was undertaken in the station forestière d'Ivoloina, eastern Madagascar, north of Toamasina, during four months between April 2007 and May 2008 to study aspects of the natural history of *Myzopoda aurita*, including its dietary regime. Fecal samples from 11 adults were analyzed and three orders of insects (Lepidoptera, Coleoptera, and Blattaria) and one order of Arachnida (Araneae) were identified. There are differences in the importance of each insect order in the diet of *M. aurita*; Lepidoptera have the highest mean percentage volume and were identified in all samples. The mean percentage volume of Coleoptera and Blattaria were largely equal. There is similarity in the diet of *M. aurita* and *M. schliemanni* (occurring along the western portion of the island), with Lepidoptera being the dominant prey type. Fecal pellet analysis was found to be a good method to assess the diet of *M. aurita* and is applicable to dietary studies of Malagasy bats in general.

Key words: diet, *Myzopoda aurita*, scats, station forestière d'Ivoloina, eastern Madagascar

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Résumé détaillé

La présente étude a été entreprise dans la station forestière d'Ivoloina pendant quatre mois, entre avril 2007 et mai 2008 afin d'étudier l'histoire naturelle de *Myzopoda aurita,* incluant son régime alimentaire. La station forestière d'Ivoloina est située à 12 km au nord-est de Toamasina (18°02'-18°04'S, 49°20'-49°21' E). Avec une superficie de 282 ha environ, le site est dominé par des zones marécageuses partiellement converties en rizières; des formations secondaires constituées majoritairement par *Ravenala madagascariensis* (Strelitziaceae) et *Typhonodorum lindleyanum* (Araceae) et d'une petite partie de formation quasi-naturelle de 1 ha environ. Cette station est largement dominée par une plantation d'arbres exotiques comme *Eucalyptus* spp. (Myrtaceae) et *Pinus* spp. (Pinaceae). Les chauves-souris, capturées à l'aide des filets de 12 m, sont laissées au moins 2 heures dans des pochons en tissu afin d'obtenir les matières fécales. Ces dernières sont conservées dans des tubes contenant de l'alcool à 75° avant les études entreprises au laboratoire. Des matières fécales venant de 11 individus adultes ont été analysées. Trois ordres d'insectes : Lepidoptera, Coleoptera et Blattaria et des restes des Araneae ont été recensés. Il y a une différence significative entre le pourcentage du volume de chaque ordre, les Lepidoptera étant plus représentés, tous les échantillons en contiennent. Le volume moyen de Coleoptera et de Blattaria ne montre pas une différence significative. Lepidoptera constitue la principale source de nourriture de *M. aurita* et la raison de ce choix mérite une étude plus poussée. Ces analyses permettent de reconnaître une certaine ressemblance entre le régime alimentaire de *M. aurita* et de *M. schliemanni*. L'analyse des matières fécales permet une meilleure appréciation de l'habitude alimentaire de *M. aurita*. Cette méthode peut être appliquée pour l'étude du régime alimentaire des chauves-souris insectivores Malgaches.

Introduction

Until about a decade ago, bats were largely neglected by mammalogists working on the Madagascar fauna. Recent inventories conducted on the island's Chiroptera have filled considerable voids in distributional information, systematics, and some aspects of their natural history. However, only a few studies have examined the dietary regime of these animals based on stomach contents (Razakarivony *et al*., 2005) or scat analysis (Göpfert & Wasserthal, 1995; Andrianaivoarivelo *et al*., 2006; Rajemison & Goodman, 2007; Rakotoarivelo *et al*., 2007). Little dietary information is available on members of the genus *Myzopoda*, which comprise a family, the Myzopodidae, endemic to Madagascar. The genus is composed of an eastern species, *M. aurita,* and a recently named and morphologically similar to western species, *M. schliemanni* (Goodman *et al.,* 2007). Members of this genus have sucker-like organs on their wrists and ankles, which aid them in moving on upright surfaces associated with roosting (Racey *et al.,* in press). Published dietary information on *M. aurita* is based on a single individual studied by Göpfert & Wasserthal (1995), while *M. schliemanni*, has been the subject of a more detailed study (Rajemison & Goodman, 2007). In this paper, we describe the

Table 1. Information on the adult individuals of *Myzopoda aurita* captured during the two principal seasons at the station forestière d'Ivoloina, eastern Madagascar, and used in the dietary analysis. Presence and absence information on the different invertebrates identified from each sample are presented.

Date of capture	Season	Field number	Sex	Lepidoptera	Coleoptera	Blattaria	Araneae
25 April 2007	Relatively low rainfall	SMG 15946	♂	+	-	-	+
27 April 2007	Relatively low rainfall	SMG 15950	♂	+	+	-	-
27 April 2007	Relatively low rainfall	SMG 15951	♂	+	-	-	-
19 November 2007	Relatively high rainfall	RB 07	♀	+	+	-	-
19 November 2007	Relatively high rainfall	RB 08	♂	+	+	+	-
19 November 2007	Relatively high rainfall	RB 09	♂	+	+	+	-
19 November 2007	Relatively high rainfall	RB 10	♂	+	-	-	-
5 December 2007	Relatively high rainfall	RB 11	♀	+	+	+	-
16 January 2008	Relatively high rainfall	RB 16	♂	+	+	+	-
14 May 2008	Relatively low rainfall	RB 23	♂	+	-	+	-
22 May 2008	Relatively low rainfall	RB 24	♂	+	-	+	-

diet of *M*. *aurita* at a site in central lowland eastern Madagascar based on scat analysis.

Materials and Methods

Fieldwork was conducted over the course of four months between April 2007 and May 2008 in the station forestière d'Ivoloina, 12 km northeast of Toamasina (18°02'-18°04'S, 49°20'-49°21' E). This 282 ha site is dominated by marsh systems partially converted to rice paddy, secondary formations with *Ravenala madagascariensis* (Strelitziaceae), *Typhonodorum lindleyanum* (Araceae), and one patch of disturbed natural forest (approximately 1 ha). Numerous portions of the station have exotic *Eucalyptus* spp. (Myrtaceae) and *Pinus* spp. (Pinaceae) tree plantations.

Bats were captured using 12 m mist nets (36 mm mesh), functioning from sunset to about 21:30 and then from 3:00 to sunrise; nets were checked every 15 minutes for captured animals. On the basis of different details associated with their capture, all of the *Myzopoda* captured in this study are different individuals. Each netted bat was placed in a clean cloth bag for at least two hours; the deposited fecal pellets were preserved in vials with 75° ethanol and marked with an associated field collection number. Information on the captured individuals is presented in Table 1.

In the laboratory, the pellets from a given individual were removed from the vial and placed in a shallow dish with ethanol. Pellets were allowed to soften, then were slowly agitated to tease them apart, and the contents were separated under a binocular microscope (Whitaker, 1988). In certain previous published papers on the dietary regime of Malagasy insectivorous bats, 5 to 10 fecal pellets were used as the sample unit (e.g., Andrianaivoarivelo *et al*., 2006; Rakotoarivelo *et al*., 2007), but in this current study, all fecal pellets from a given individual were analyzed to maximize information on the prey types consumed.

Insect remains were identified using different keys (Borror & White, 1970; Whitaker, 1988; Borror *et al*., 1989; Shiel *et al*., 1997) and in some cases using insect reference collections in the California Academy of Sciences collection, Tsimbazaza, Antananarivo. The analysis reported herein is based on identifiable remains of invertebrates. Data are expressed as percentage volume calculated from identifiable fragments (number of each invertebrate order in a given sample, divided by total number of remnants, and multiplied by 100) and percentage frequency (number of samples containing a given invertebrate order, divided by total number of samples analyzed, and multiplied by 100). We tested differences in the importance of each insect order using Kruskal-Wallis H and Mann-Whitney U statistical procedures with arcsine transformed data.

Results

Fifty-eight nights of capture were undertaken at the station forestière d'Ivoloina. In total, 13 adult *Myzopoda aurita* were netted, from which fecal pellets were obtained from 11 individuals. These 11 samples were analyzed separately and retained as separate data points (Table 1). The number of fecal pellets per individual sample varied from one to 36. Three orders of Arthropoda were identified from the scats (Table 2): 1) Lepidoptera (moths), at least some of which are of the family Saturniidae; 2) Coleoptera (beetles), a portion of which are Scarabeidae; and 3) Blattaria (cockroaches). Moreover, spider legs (order Araneae, class Arachnida) were found in one sample. Lepidoptera have the highest mean percentage volume and percentage frequency. Remains of Lepidoptera occurred in all 11 samples, Coleoptera and Blattaria were found in six samples and Araneae in one sample (Table 1).

Table 2. Percentage frequency and percentage volume of each invertebrate order consumed by 11 different individuals of *Myzopoda aurita* in the station forestière d'Ivoloina. Data are mean percent volume ± standard error.

Order	Percentage frequency (%)	Percentage volume (%)
Lepidoptera	100	60.4 ± 9.54
Coleoptera	54.5	19.4 ± 8.44
Blattaria	54.5	19.0 ± 6.32
Araneae	9.1	1.2 ± 1.21

As only one fecal sample contained spider remains, this order was excluded from statistical tests. There is a significant difference between the percentage volume of each prey type consumed by *M*. *aurita*, with Lepidoptera being the most important ($H = 10.97$, $df = 2$, $P = 0.004$). No difference was found between the percentage volume of Coleoptera and Blattaria ($U = 58.5$, $P = 0.90$).

Discussion

The first published information on the diet of *Myzopoda aurita* was by Göpfert & Wasserthal (1995) based on fecal pellets collected from a single individual captured north of Tolagnaro, in the extreme

southeast. They identified Lepidoptera from the sample, specifically "Microlepidoptera", which is now considered paraphyletic (Powell, 1980) and, hence, this taxonomic designation is not utilized herein. Lepidoptera are easily identified by the presence of scales in the fecal pellets (Whitaker, 1988).

Scats from the station forestière d'Ivoloina contained three orders of Insecta (Lepidoptera, Coleoptera, and Blattaria) and one order of Arachnida (Araneae). The percentage volume of each prey type differed significantly, with Lepidoptera being ubiquitous to all samples and constituting the principal food source of this bat in the station forestière d'Ivoloina. Based on the single sample from near Tolagnaro (Göpfert & Wasserthal, 1995) and the data presented here, Lepidoptera is the most commonly taken prey across the geographical range of *Myzopoda aurita*. Also using fecal analysis from 18 different individuals of *M. schliemanni*, Rajemison & Goodman (2007) identified four orders of insects in the diet of animals captured in central western lowland Madagascar (percentage frequency across the 18 samples in parentheses): Lepidoptera (89%), Coleoptera (28%), Blattaria (78%), and Hymenoptera (17%).

These different analyses indicate certain parallels in the diets of *Myzopoda aurita* and *M. schliemanni*, dominated by Lepidoptera that are presumed to be taken in flight. In contrast, Araneae do not have wings, and the presence of this group in the scats of *M. aurita* at Ivoloina, indicates that this bat can glean prey, presumably from vegetation, an ability shared with *M. schliemanni* in western Madagascar (Rajemison & Goodman, 2007). It is important to point out that the Blattaria identified in these samples possess wings. Although we have no clear field evidence to support this point, it is conceivable that while moving on leaf surfaces with their wrist and ankle suckers, *Myzopoda* are able to feed on invertebrate prey. If this indeed were the case, these organs would not simply aid with maintaining roosting positions, but may actively be used in foraging.

Although, the new dietary data for *Myzopoda aurita* presented here from the station forestière d'Ivoloina are based on 58 nights of capture during four months of fieldwork across a 13-month period, it is not possible to extrapolate seasonal variation in its diet, in part because of the limited number of samples available in any given season (Table 1). More long-term research at the site, combined with scat collections from other localities, will provide the needed information to examine seasonal, intra-specific, and inter-specific variation in the diet of *Myzopoda* spp. This information should augment knowledge on the natural history of this endemic and extraordinary group of bats.

Conclusion

On the basis of scat remains from 11 different individuals of *Myzopoda aurita* captured in the station forestière d'Ivoloina, aspects of this species' diet can be quantified and the principal groups of Insecta they consume (in order of importance) are Lepidoptera, Coleoptera, and Blattaria. Remains of flightless Araneae were found in one sample, indicating that this bat has the ability to glean prey. These data provide further insight into the dietary regime of *M. aurita*, but because of sampling limitations, little inference can be made on seasonal variation. The two members of this genus, *M. aurita* in the east and *M. schliemanni* in the west, have similar external morphological structure and even given differences in the habitat and climatic regimes of these two portions of the island, show considerable parallels in aspects of their diets at the ordinal level. As shown by this current study, as well as others, information on aspects of the dietary regime of these taxa is relatively straightforward to study based on fecal analysis. The station forestière d'Ivoloina does not contain any natural forest of importance, indicating that *M. aurita* is not a strict forest-dwelling species and is able to adapt to anthropogenic habitats.

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References

Andrianaivoarivelo, A. R., Ranaivoson, N., Racey, P. A. & Jenkins, R. K. B. 2006. The diet of three synanthropic bats (Chiroptera: Molossidae) from eastern Madagascar. *Acta Chiropterologica*, 8: 439-444.

Borror, D. J. & White, R. E. 1970. *A field guide to insects. America north of Mexico*. Houghton Mifflin, Boston.

Borror, D. J., Triplehorn, C. A. & Johnson, N. F. 1989. *An introduction to the study of insects*, 6th edition. Hartcourt Brace College, Orlando.

Goodman, S. M., Rakotondraparany, F. & Kofoky, A. F. 2007. The description of a new species of *Myzopoda* (Myzopodidae: Chiroptera) from western Madagascar. *Mammalian Biology*, 72: 65-81.

Göpfert, M. C. & Wasserthal, L. T. 1995. Notes on echolocation calls, food and roosting behaviour of the Old World sucker-footed bat *Myzopoda aurita* (Chiroptera, Myzopodidae). *Zeitschrift für Säugetierkunde*, 60: 1-8.

Powell, J. A. 1980. Evolution of larval food preferences in Microlepidoptera. *Annual Review of Entomology*, 25:133-159.

Racey, P. A., Goodman, S. M. & Jenkins, R. K. B. In press. The ecology and conservation of Malagasy bats. In: *Island bats*, eds. T. H. Fleming & P. A. Racey. The University of Chicago Press, Chicago.

Rajemison, B. & Goodman, S. M. 2007. The diet of *Myzopoda schliemanni*, a recently described Malagasy endemic, based on scat analysis. *Acta Chiropterologica*, 9: 311-313.

Rakotoarivelo, A. A., Ranaivoson, N., Ramilijaona, O. R., Kofoky, A. F., Racey, P. A. & Jenkins, R. K. B. 2007. Seasonal food habits of five sympatric forest microchiropterans in western Madagascar. *Journal of Mammalogy*, 88: 959-966.

Razakarivony, V., Rajemison, B. & Goodman, S. M. 2005. The diet of Malagasy Microchiroptera based on stomach contents. *Mammalian Biology*, 70: 312-316.

Shiel, C., McAney, C., Sullivan, C. & Fairley, J. 1997. *Identification of arthropod fragments in bat droppings*. The Mammal Society, London.

Whitaker, J. O. 1988. Food habits analysis of insectivorous bats. In: *Ecological and behavioral methods for the study of bats*, ed. T. H. Kunz, pp. 171-189. Smithsonian Institution Press, Washington, D.C.

Notes on the diet of the Barn Owl (Aves: Tytonidae: *Tyto alba*) from Zohin'Andavaka, Beahitse, extreme southwestern Madagascar

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Introduction

A number of papers have been published on the diet of Barn Owls (*Tyto alba*) on Madagascar based on the analysis of regurgitated pellets. Samples for these studies were obtained in different ecosystems on the island, including gallery forest in spiny bush (Goodman & Langrand, 1993; Goodman *et al*., 1993; Rasoma & Goodman, 2007), edge of limestone plateau in spiny bush (Goodman & Langrand, 1993), limestone area of dry deciduous forest (Goodman & Owens, 2006), open habitats adjacent to areas of eastern humid forest (Goodman & Langrand, 1993; Goodman *et al*., 1993; Goodman & Thorstom, 1998), and near urban areas in the Central Highlands (Goodman & Langrand, 1993). However, no quantified information has been available on the food habits of this raptor from southwestern inland areas of the spiny bush away from riverine habitats; herein we present such an analysis from a site near Beahitse. Further, this is a region that little data is available on local small mammal communities and the food remains provide interesting insights in this regard.

Materials and Methods

The Barn Owl roost site was located near the entrance of a cave known as Zohin'Andavaka, southwest of the village of Beombe (=Beomby), to the west of Beahitse, 24º20.155'S, 44º6.739'E, approximately 400 m above sea-level. The habitat surrounding the site was noted as dry with degraded euphorb forest and scattered tall baobabs growing on limestone with thin red top soils. The pellets were collected on 14 November 2007.

The bone remains were removed from pellets and identified using the comparative osteology collections at the Field Museum of Natural History, Chicago. Age classes for mammals are based on the ossification of the basisphenoid suture and molar eruption patterns: juveniles – suture non-fused and distal molars non-erupted and adults – suture fused and

Goodman, S. M. & Griffiths, O. 2009. Notes on the diet of the Barn Owl (Aves: Tytonidae: *Tyto alba*) from Zohin'Andavaka, Beahitse, extreme southwestern Madagascar. *Malagasy Nature*, 2 : 163-166.