The dietary habits of Barn Owls (*Tyto alba*) in the spiny bush of southwestern Madagascar

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Abstract

We present an analysis of prey animals recovered from a collection of Barn Owl (*Tyto alba*) pellets found at a roost site in the spiny forest along the Mahafaly Plateau in the Parc National de Tsimanampetsotsa. Among 59 pellets examined, we identify a minimum of 227 individual prey animals, with an estimated combined biomass of slightly more than 7.2 kg. The most frequent class of animals is birds (14 species), which compose nearly 70% of the minimum number of individuals (MNI) and 46% of biomass in the sample. Next most common are mammals (five species), with 24% of the MNI and 51% of biomass. In all cases, the identified species of birds and mammals are known to occur in the general Tsimanampetsotsa region. A few unidentified remains of invertebrates, reptiles, and amphibians were also found in the samples. Based on MNI, the most frequent species are two weavers (Family Ploceidae), Madagascar Fody (*Foudia madagascariensis*) (MNI = 66 or 29.1% of identified prey) and Sakalava Weaver (*Ploceus sakalava*) (MNI = 43 or 18.9% of identified prey). Based on biomass, the most common prey is the introduced black rat (*Rattus rattus*), which accounts for over 40% of the total prey weight. Differences in the diet between Barn Owls living in the spiny forest as compared to gallery forest are discussed.

Key words: prey remains, vertebrates, Mahafaly Plateau, Tsimanampetsotsa, spiny bush

Résumé détaillé

Une analyse des proies récupérées dans une collection de pelotes de chouette effraie (*Tyto alba*) est présentée ici. Ces pelotes ont été trouvées sur un site de la forêt épineuse le long du Plateau Mahafaly, dans le Parc National de Tsimanampetsotsa. Sur les 59 pelotes analysées, un minimum de 227 animaux de proie a été identifié, avec une biomasse combinée estimée à un peu plus de 7,2 kg. Sur la base de la diversité taxonomique, la classe des animaux la plus commune est les oiseaux, avec 14 espèces différentes, suivie des mammifères avec cinq espèces différentes. Dans tous les cas, ces espèces sont connues dans la région de Tsimanampetsotsa. Quelques restes non identifiés d'invertébrés, de reptiles et d'amphibiens ont également été trouvés dans les échantillons.

Basé sur le nombre minimum d'individus (NMI), les oiseaux, qui représentent environ 70 % des restes de proies identifiés, sont le groupe le plus commun dans les échantillons. Parmi les oiseaux, l'espèce la plus commune est le Foudi de Madagascar (*Foudia madagascariensis*) (NMI = 66, soit 29,1 % des proies identifiées) et le Tisserin sakalave (*Ploceus sakalava*) (NMI = 43, soit 18,9 % des proies identifiées). Dans la plupart des cas, les 12 autres taxons d'oiseaux sont représentés par une poignée d'individus (NMI < 10). L'étude de la biomasse a montré que la classe des animaux dominante est les mammifères, qui représentent 50,9 % des proies identifiées, suivie par les oiseaux, qui représentent 45,7 %. En s'appuyant sur cette mesure, la plus grande masse de proies attrapées par les chouettes effraies sur ce site est le rongeur introduit (*Rattus rattus*), en particulier les adultes, qui représentent plus de 40 % de la masse totale des proies.

Mots clés : restes de proies, vertébrés, Plateau Mahafaly, Tsimanampetsotsa, bush épineux

Introduction

The Barn Owl (*Tyto alba*) is a globally-distributed species that inhabits a wide variety of temperate and tropical habitats (Bruce, 1999). In Madagascar, it occurs throughout the island and is often found at the forest edge and in anthropogenic environments. A number of studies have been conducted on the

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food habits of Barn Owls in Madagascar (Goodman *et al.*, 1993; Rasoma & Goodman, 2007; Goodman & Griffiths, 2009) and these reveal that, as is the case in other parts of the range, the local population has a highly varied diet that includes an array of animals of varied body mass. These studies also demonstrate considerable regional variation in the prey taken by Barn Owls. At Andasibe, in eastern Madagascar, for example, Barn Owls took an assortment of frogs, reptiles, birds, bats, and small mammals, with almost 60% of the minimum number of individuals (MNI) and more than 80% of the biomass of prey composed of introduced rodents (Goodman *et al.*, 1993). In this case, average prey body mass varied from 2 to 110 g. In contrast, in the area at the edge of the Manombo forest, south of Farafangana, virtually all of the prey taken was composed of introduced mammals with average body masses from 12 to 110 g. An extreme example is that of the 183 animal remains collected from Barn Owl pellets in a cave near Antonibe, in the central northwest, where, by both MNI and biomass, approximately 80% of the prey was composed of a single bat species, *Rousettus madagascariensis*, the adults of which weigh on average 63 g (Goodman & Griffiths, 2006).

In drier habitats in the west and south of the island, several studies have demonstrated considerable variation in the types of prey taken by Barn Owls inhabiting gallery forests as opposed to spiny bush. In the gallery forests outside of the Réserve Spéciale de Beza Mahafaly, an analysis of over 1000 identified prey remains revealed that frogs, reptiles, birds, and native and introduced mammals are taken, with body mass ranging from 2 to 110 g (Goodman *et al.*, 1993). Here, introduced rodents formed about 35% by MNI and 55% by biomass of the consumed prey. Collections from this site were made on a regular basis and notable seasonal variation was noted. Most important in this regard, frog species that are explosive breeders and form notable concentrations around water pools, made up about one-third of the diet based on MNI during the rainy season. Also at this locality, mouse lemurs (*Microcebus*) composed up nearly 25% by body mass of the animals preyed upon. Another study from gallery forest within spiny bush is that of Rasoma & Goodman (2007) in the Sept Lacs area along the Onilahy River, where 2800 individual prey animals were identified. In general, these results are similar to those from near by Beza Mahafaly, with the following differences: bats were notably more important, representing nearly 20% by MNI of animals taken during the dry season and mouse lemurs were less frequently consumed. The number of introduced rodents taken at this site is similar to that near Beza Mahafaly.

Few studies on the food habits of this owl have been published from spiny bush areas not associated with gallery forest. On the basis of a relatively small collection of pellets obtained in the cave Zohin'Andavaka, in upland spiny bush to the west of Beahitse, a wide assortment of birds was taken, including at least 11 species representing nearly 50% by MNI and 60% by biomass of the total prey (Goodman & Griffiths, 2009). This is notably different from the gallery forest sites mentioned above, where the number of birds taken was less, and in some cases bordering on negligible. Furthermore, at Zohin'Andavaka, introduced rodents were notably less frequent than in the gallery forest sites. Other than this study, little other data on the dietary regime of this owl is available from lowland spiny bush habitat. Goodman & Langrand (1993) published on a small collection of Barn Owl pellets from the spiny bush along the Mahafaly Plateau, near Lac Tsimanampetsotsa at an elevation of about 50 m. Here, mammals made up more than 50% by MNI and 70% by biomass of prey taken, with introduced taxa comprising approximately half of these figures. Hence, important differences appear to exist in the prey taken by Barn Owls in different areas of spiny bush habitat.

In order to examine this variation in finer detail and provide more information on the types of animals taken in lowland spiny bush habitat, we present herein an analysis of a collection of Barn Owl pellets from the Parc National de Tsimanampetsotsa. This zone is one of the most arid and highly seasonal on Madagascar, and these new data provide an interesting window on how adaptable this raptor is concerning the local prey base in an extreme environment.

Materials and methods

Pellet collection site

The Barn Owl pellets analyzed in this study were collected from a cave in the Parc National de Tsimanampetsotsa (ca. S 24°10'36", E 43°46'14"). The site was along the limestone Mahafaly Plateau, the western edge of which forms an abrupt escarpment ranging from 100-200 m in height above the broad coastal plain to the west that includes the Lac Tsimanampetsotsa depression. At a few localities at the base of the plateau, there is exposed water, associated with water percolating to the surface. The Tsimanampetsotsa area has one of the extreme

climates on the island. Mean maximum and minimum temperatures during the dry season were 32.6° and 17.8°C, respectively, and these values during the wet season were 35.5° and 24.0°C (Ratovonamana *et al.*, 2011). The zone tends to have a dry season of approximately 10 months per year, with annual precipitation rarely exceeding 500 mm.

This area at the foot of the plateau forms an important ecological transition zone, with sparse vegetation growing on sandy soils at the base of the escarpment, and on the plateau is found an unusual plant community of spiny, xerophytic vegetation, composed primarily of members of the families Didiereaceae, Euphorbiaceae, Malvaceae, and Fabaceae. Ratovonamana *et al*. (2011) have described the vegetation of this area in detail. This particular zone holds numerous endemic plants and animals, but relatively low levels of species diversity (Goodman *et al.*, 2002).

The collection site was a cave about 30 m deep, and cut horizontally into the escarpment just below the plateau. The cave roof had partially collapsed, creating an open window to the upper surface of the plateau. On 4 January 2011, a single Barn Owl was flushed from a perch just below the cave roof opening and the bird flew upwards and out to the escarpment plateau. The samples were collected within the cave from directly below the owl's perch, where a substantial build up of guano and pellets had accumulated. An inspection of other accessible sections of the cave did not reveal any evidence of nesting or other perch sites with pellet accumulations.

Pellet preparation and identity of contents

Bone remains were removed from pellets (n = 59) after being soaked in water and identified using the comparative osteology collections at the Université d'Antananarivo, Département de Biologie Animale. 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 cheek teeth fully erupted. The MNI per taxon was tallied for mammals and common birds based on cranial-maxillary/mandible counts and the number of unique bilateral elements. In most cases, we report the MNI figure as a percentage of total individuals identified in the sample. The *Microcebus* remains were identified to species using characters outlined by Rasoloarison *et al*. (2000). Invertebrate remains, composed of medium-sized beetles (mostly Scarabeidae) and grasshoppers (Acrididae) were uncommon in the pellets and are not figured in the analysis. Reptile and amphibian remains were also uncommon.

Results

The total MNI of prey items identified from the pellets was 227, for a total vertebrate prey biomass of 7.212 kg. On the basis of the identified remains, Barn Owls at Tsimanampetsotsa prey of an assortment of local land animals including frogs, reptiles, birds, and mammals (Table 1). All of the identified prey species in the pellet sample are known to occur in the Parc National de Tsimanampetsotsa (Goodman *et al.*, 2002). The group with the broadest taxonomic representation in the pellet samples is the Class Aves, with 14 different identified species. These included species with average body mass from 7 to 77 g. Based on MNI and body mass, birds made up 69% and 46%, respectively, of the prey taken. Two species were distinctly the most common: Sakalava Weaver (*Ploceus sakalava*) and Madagascar Fody (*Foudia madagascariensis*). In comparison to all of identified prey remains, these two species represent nearly 50% by MNI and 30% by biomass. When compared to the identified bird remains, they represent by MNI close to 70% of all of the avian prey consumed by the Barn Owl.

The mammal remains were taxonomically less diverse than birds, with five species represented. Mammals identified from the pellets span an average body mass from 12 to 110 g. Amongst the five species, there is one endemic small tenrec of the Family Tenrecidae (*Geogale aurita*), one endemic primate of the Family Cheirogaleidae (*Microcebus griseorufus*), two introduced rodents of the Family Muridae (*Rattus rattus* and *Mus gentilulus*), and one endemic rodent of the Subfamily Nesomyinae (*Macrotarsomys bastardi*). The number of introduced mammals in the sample is disproportionately high in comparison to non-introduced species, with black rats (*Rattus rattus*) making up nearly 45% by biomass of the identified prey. Given that adults of this species are the heaviest prey species in these samples, it is fitting that they make up a distinctly smaller percentage of the total MNI (nearly 15%). Adult rats (n = 24) are more commonly consumed at this locality than subadults (n = 9).

Discussion

These new data enable us to contrast the dietary habits of Barn Owls at two spiny bush sites

Table 1. Prey remains identified from *Tyto alba* pellets collected along the Mahafaly Plateau, Parc National de Tsimanampetsotsa, southwestern Madagascar. Non-native species are identified with an asterisk. Unless otherwise noted all individuals are adult. Mass data for taxa identified from the pellets were obtained from Raselimanana (unpubl.) for amphibians and reptiles, Ravokatra *et al*. (2003) for birds, and Goodman *et al*. (2003) for mammals. Total MNI =107 and calculated biomass for all prey remains was 2780 g.

Taxa	Mass (g)	MNI	% total individuals	% total biomass
AMPHIBIA				
Small unidentified frog	5	2	0.9	0.1
Total AMPHIBIA		**2**	**0.9**	**0.1**
REPTILIA				
Small reptile	est. 7.5	3	1.3	0.3
[1]Medium reptile[1]	est. 20	10	4.4	2.8
Total REPTILIA		**13**	**5.7**	**3.1**
AVES				
Turnicidae				
Turnix nigricollis	61.3	2	0.9	1.7
Columbidae				
Oena capensis	37.7	1	0.4	0.5
Apodidae				
Apus balstoni	35.0	1	0.4	0.7
Meropidae				
Merops superciliosus	41.7	1	0.4	0.6
Upupidae				
Upupa marginata	76.6	3	1.3	3.2
Motacillidae				
Motacilla flaviventris	22.5	1	0.4	0.3
Pycnonotidae				
Hypsipetes madagascariensis	45.1	5	2.2	3.1
Bernieridae				
Thamnornis chloropetoides	14.3	2	0.9	0.2
Turdidae				
Copsychus albospecularis	23.6	10	4.4	3.3
Sylviidae				
Nesillas lantzii	17.5	3	1.3	0.7
Neomixis sp.	27.0[2]	16	7	1.5
Vangidae				
Leptopterus chabert	19.6	3	1.3	0.8
Ploceidae				
Ploceus sakalava	23.8	43	18.9	14.2
Foudia madagascariensis	16.3	66	29.1	14.9
Total AVES		**157**	**68.9**	**45.7**
MAMMALIA				
Tenrecidae				
Geogale aurita	7	9	4	0.9
Cheirogaleidae				
Microcebus griseorufus	63	8	3.5	7
Muridae				
**Mus gentilulus*				
Adult	11.5	3	1.3	0.5
**Rattus rattus*				
Sub-adult	45.4	9	4	5.7
Adult	109.9	24	10.6	36.6
Total		33	14.6	42.3
Nesomyidae				
Macrotarsomys bastardi	24.5	1	0.4	0.3
Total MAMMALIA		**54**	**23.8**	**50.9**

[1]At least one of these animals is referable to *Oplurus cyclurus*.
[2]Body mass presented for *Neomixis tenella*.

(Tsimanampetsotsa [herein] and Zohin'Andavaka [Goodman & Griffiths, 2009]) and two gallery forest sites (near Beza Mahafaly [Goodman *et al.*, 1993] and Sept Lacs [Rasoma & Goodman, 2007]) in southern Madagascar and provide interesting insights in the types of prey taken in these different habitats. Across the four sites, all of identified bird taxa are diurnal and all mammal taxa nocturnal indicating that this nocturnal owl primarily predates roosting birds and active mammals regardless of differences in habitat.

In terms of the proportion of birds and mammals consumed, spiny bush habitats demonstrate notable differences in prey composition and proportional biomass to gallery forests. In spiny bush at Zohin'Andavaka, birds represent between about 50-60% of the animals consumed by both MNI and biomass. In the Tsimanampetsotsa spiny bush, the figures are 70% by MNI and 46% by biomass. For small mammals at Zohin'Andavaka, the MNI is close to 50% and biomass 33%; at Tsimanampetsotsa, these figures are 25% and 50%, respectively. Hence, if these samples are representative of the general diet of Barn Owls at these two sites, there are only slight differences in the proportion of these two classes of prey within spiny bush sites. This is in contrast to comparison to the two gallery forest sites. Near Beza Mahafaly, the MNI and biomass for consumed birds are less than 3%, and for mammals, these figures are 47% and 81%, respectively. At the Sept Lacs site, birds were also relatively rare in the diet, representing between 3-8% of the MNI or biomass consumed, while for mammals, the figures approached or exceeded those from near Beza Mahafaly.

In terms of particular taxa consumed, pronounced differences are apparent between spiny bush and gallery forest sites. In the case of birds, the weavers (*Ploceus* and *Foudia*) are disproportionately represented in the diet of this owl in spiny bush habitat. Sakalava Weavers can be found breeding in closely packed colonies that are notably common in the larger trees at the base of the Mahafaly Plateau and during the non-breeding season, this species and the solitarily nesting Madagascar Fody move in flocks and roost in large numbers at night. We imagine that birds in such aggregations are particularly susceptible during the night to Barn Owl predation.

Amphibians and bats, on the other hand, are much more frequently consumed at gallery forest sites as compared to the spiny bush. At Sept Lacs, amphibians represented 22% of the MNI and 7% of the biomass during the rainy season and 10% of the MNI and 3% of the biomass during the dry season. In the gallery forest near Beza Mahafaly, they represented 48% by MNI and 15% by biomass of the prey. At Tsimanampetsotsa, in contrast, only two individual frogs were identified from the pellet remains and at Zohin'Andavaka they were completely absent. These differences are likely due to the increased density of amphibians in gallery forest sites where water pools can be found most of the year, or at least moist soils, and during the rainy season flowing streams. In the case of bats, four different species of Molossidae were identified at the Sept Lacs gallery forest site and these represented an important proportion of the MNI and biomass taken by Barn Owls. At the spiny bush site of Tsimanampetsotsa, however, no bats were identified in the collection of pellets, and at Zohin'Andavaka, there was only a single individual. Interestingly, at Tsimanampetsotsa and presumably Zohin'Andavaka, bats, including taxa identified in the pellet remains from near Beza and Sept Lacs, are present in considerable numbers, making their day roost sites in caves. Hence, this difference is not simply the presence or absence of these animals at the different sites, but probably associated with bat flight behavior and the local Barn Owl feeding techniques.

For mammals, the MNI in the sample is comparable between Tsimanampetsotsa (24%), Beza Mahafaly (47%), and Zohin'Andavaka (47%), but the biomass is notably lower in the Zohin'Andavaka sample. Most striking in this regard is the importance of introduced mammals in the diet of Barn Owls in southwestern Madagascar. At Sept Lacs, the two non-native genera (*Mus* and *Rattus*) represent 57% by MNI and 70% by biomass during the rainy season and 38% by MNI and 54% by biomass during the dry season of the mammalian prey consumed by Barn Owls. At the site near Beza Mahafaly, they represent 78.0% and 69.3% (by MNI and biomass, respectively). These species are also important at Tsimanampetsotsa, where they correspond to a large proportion of prey, particularly with regards to biomass, but in the Zohin'Andavaka sample, the number of introduced rodents was reduced. These results indicate that introduced rodents are an important prey item for Barn Owls in gallery forest and some spiny bush sites. Whether this is a function of the relative densities of these introduced mammals associated with water availability, human perturbation of the environment or some other factors needs to be further investigated. As is the case with amphibians, water availability may play a role in this variation.

At the base of the Mahafaly Plateau at Tsimanampetsotsa, there are several sites where water percolates to the ground or is exposed in caves, whereas in the region of Zohin'Andavaka exposed water is notably rare. Contrary to expectations, preliminary results of small mammal trapping near Mitoho Cave at Tsimanampetsotsa, which contains a large accessible underground lake, indicate that introduced black rats are distinctly uncommon at the site. Hence, the explanation between the numbers of rats identified from the pellet remains at these two sites might be related to differences in individual Barn Owl hunting techniques (Yom-Tov & Wool, 1997), extreme population cycling in this rodent (Ganzhorn *et al.*, 1996), or annual seasonal differences. Without controlled collections associated with dates a given set of pellets were deposited, it will be difficult to provide definitive answers to these different points.

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