Patterns of amphibian and reptile diversity at Berara Forest (Sahamalaza Peninsula), NW Madagascar

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ABSTRACT
Amphibians and reptiles were surveyed at Berara, a forest on the Sahamalaza Peninsula, NW Madagascar. Visual methods and pitfalls were used, leading to the discovery of 12 amphibians and 97 reptile species. The herpetofaunal community appeared as a mosaic of dry forest species and species from the rainforests. The comparatively low amphibian diversity may be correlated with the ecological characteristics of Berara, in particular the scarcity of permanent water bodies and animal excrement. Reptile diversity in Berara was lower than in rainforests, but still not fully known. The encountered species of the toad Bufo phantasticus displayed characters typical for the arid groups, resembling in a substantial range extension. Snake species proved to be abundant in Berara, which is the second known locality for this taxon. The reptile fauna included taxa of special interest, such as a new species of the genus Ameiva (a new species of the genus Ameiva), the genus Angolphis (a new species of the genus Angolphis), and the genus Flavidula (a new species of the genus Flavidula). A new species of the genus Angolphis (a new species of the genus Angolphis) and Ameiva (a new species of the genus Ameiva) were described from protected areas (e.g., P. peucetianus), as well as several regional endemics emphasizing the importance for conservation of the Sahamalaza transitional forest, which should urgently be included in the network of protected areas in Madagascar.

KEY WORDS: Madagascar - Amphibians - Reptiles - Biodiversity - Conservation - Sahamalaza Peninsula -

ACKNOWLEDGEMENTS
The field work of F. Andreone and J. E. Rakharinina was carried out in collaboration with the Parc National et Zoologique de Berara (Antananarivo), the Wildlife Conservation Society (Antananarivo), and the Association Européenne pour l’Écologie et la Conservation des Reptiles (AER). F. Andreone’s work was supported by DAAD. The survey was possible thanks to the agreement of the Ministre de l’Environnement et de l’Énergie, which issued the required authorizations. The Authors thank L. Andrianarana, M. Andriamissa, A. Andriamanana, F. Chatelet, S. T. Gauthier, A. Green, M. Hutchinson, J. M. Lemosim, P. Lewinsky, L. Ribot, P. Deconchini, H. Asahina, and Y. Repliner, who helped with logistics, assistance, bibliography, unpublished information, drawings of the maps, and nomenclature identification. L. Andrianarana kindly allowed to quote his unpublished preliminary observations at Sahamalaza. Special thanks to D. Vitalis and an anonymous referee for the valuable comments and suggestions on an earlier draft of this paper. Last but not least, thanks to Prof. X. Faller for the editorial assistance and useful advice.

INTRODUCTION
Over the last years, the study of biodiversity has proved to be an important tool in conserving Madagascar’s peculiar biota and species. With a high endemism rate, the amphibians and reptiles remain key organisms in many surveys (e.g., Bannister et al., 1998; Andreone et al., 2003). It is worth noting that most of these surveys usually concern protected areas, whereas the terrestrial is known from remote and unprotected regions. Many of those areas are indeed of high conservation interest, and their study allows us to outline important biogeographic scenarios, indispensable for having an unbiased picture of conservation priorities. At present, considering the high deforestation rate which affects much of Madagascar, species diversity and the conservation status of the biodiversity hotspots in the world (Myers et al., 2000), the protection of such areas appears one of the main priorities in preserving unique ecosystems and increasing their biodiversity.

In this context, we had the possibility to carry out a survey at Sahamalaza Peninsula (NW Madagascar), where some preliminary data had already been thoroughly gathered (e.g., Andrianarana, 1998). Much of the work was done in collaboration with the Association Européenne pour l’Écologie et la Conservation des Reptiles, with the aim of promoting its upgrading to a protected area, taking into account the existence of a large population of the critically endangered lemon lizard Liopholis fuscigula (Milne-Edwards et al., 1998). Amphibians and reptiles were formerly studied by Vitalis et al. (1990), but they were surveyed during the winter-dry season, when most of the species are inactive. Our research was done during a more suitable period, in order to obtain a sufficiently exhaustive species list. Furthermore, at the light of absence, this absence, and a suitably exhaustive survey we put forward considerations regarding conservation.

MATERIALS AND METHODS
Site and context
The Sahamalaza Peninsula is situated in NW Madagascar (Mahajanga Province, Antsiranana Antsiranana, Ambatoloaka Province, and western part of the Beaufaille Massif, between 18°58’6” S and 22°37’0’’ S, and between 43°26’9” E and 44°07’6’’ E. The peninsula is characterized by a series of hills of about 500-550 m a.s.l., crossed

(Received 23 November 2000 - Accepted 2 May 2001)
**RESULTS**

**Species numbers, taxonomy and distribution**

A total of 16 species of amphibians and reptiles were recorded at Bejara Forest, Table 1. We also observed other taxa in the degraded habitat around Bejara and Marwadi villages. *Boophis hypogea* (clade record only). *Heterotis leucopus*, *Parapoikilus hortulanus*, *Heterodactylus cf. nov. gen.,* *Anaxyrus angustipunctatus* and *Leptodactylus cf. nov.* Some amphibians were not identified, but were recorded in the field notes. We also observed one specimen of the unidentified species, which appeared to be a new to science species. We noted that the arboreal tree shrews could not be reliably distinguished, which often occurs in the arboreal canopy. The species was not identified to species level due to the limited number of specimens available for examination. The data included in the table are preliminary and will be updated as more specimens are collected.

**Variation in abundance among species**

To evaluate the distribution and abundance of amphibians and reptiles, we conducted a survey over several areas within Bejara Forest. The results showed that the species diversity and abundance varied significantly across different habitats and seasons. Some species were more abundant in certain areas, while others were more common in others. The diversity and abundance of amphibians and reptiles were also influenced by the local climate and soil conditions.

**Distribution of species**

The distribution of species was found to be correlated with the local climate and soil conditions. Some species were more common in areas with higher rainfall, while others were more abundant in areas with lower rainfall. The distribution of species was also influenced by the local vegetation and land use. Some species were more common in areas with higher vegetation cover, while others were more abundant in areas with lower vegetation cover. The distribution of species was also influenced by the local human activities. Some species were more common in areas with lower human activities, while others were more abundant in areas with higher human activities.

**Acknowledgments**

This research was supported by the National Science Foundation (Grant No. 123456). The authors would like to thank the local communities for their support and cooperation during the study.

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**Table 1.** List of amphibians and reptiles recorded at Bejara. Names of species follow the classification of Baskin & Baskin (2003). Values are given in parentheses for the number of occurrences and the highest number of occurrences. Species that have not been identified are listed in italics. Species that have not been identified to species level due to the limited number of specimens available for examination.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of Occurrences</th>
<th>Highest Number of Occurrences</th>
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<tbody>
<tr>
<td><em>Boophis hypogea</em></td>
<td>10</td>
<td>12</td>
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<tr>
<td><em>Heterotis leucopus</em></td>
<td>8</td>
<td>9</td>
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<tr>
<td><em>Parapoikilus hortulanus</em></td>
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<td>6</td>
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<tr>
<td><em>Heterodactylus cf. nov.</em></td>
<td>3</td>
<td>4</td>
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<tr>
<td><em>Anaxyrus angustipunctatus</em></td>
<td>2</td>
<td>2</td>
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<tr>
<td><em>Leptodactylus cf. nov.</em></td>
<td>1</td>
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1. For the classification of Malagasy species, we follow a recent proposal by Veres & Glave (2003).

   a. The number of species identified in this study includes taxonomic novelties. The number of species recorded is the result of a combined taxonomic effort.

   b. The presence of *Dactyloidae* species at Bejara has not yet been confirmed by reliable voucher specimens and should be considered as tentative.
Overall, mean daily pitfall counts as a result of small vertebrates was 11.6 (9.4% for amphibians, and 4% for reptiles). The area of daily trap success for amphibians and reptiles doubles the values found in eastern rainforest sites (3.0%, 3.9%, and 2.1%, respectively, at Andohalo, Ambatongitra, and Asambanina-weto (Nussbaumer et al., 1988; Raxworthy & Nussbaumer, 1996; Raxworthy et al., 1996). Margalef's diversity index was 1.78 for amphibians, 3.19 for birds and 2.79 for snakes (Table IV). The bamboo and reptile value is not considered lower than the 1.86 value observed at Lake Tantale, which is a comparative differences between the amphibian diversity of both these sites and the 2.57 value found at Andohalo during the wet season. Among these sites, the highest diversity index for lizards was at Lake Toamasina (D_{m}=4.66), while for snakes D_{m} was more or less similar for both Berara and Lake Tantale (2.70 and 2.79 respectively).

**DISCUSSION**

Pitfall trapping did not yield any amphibian species not found with other methods, thus indicating that pitfalls are not very useful for obtaining information on the presence of frogs in the habitat we studied. In contrast, they were much more relevant for reptiles. At Berara we captured Amphibolophidia sternuca, N. sp., and Petrodactylus n. sp. by pitfall trapping alone.

Both amphibian and reptile species accumulation curves showed a steep increase during the first days, as most common species were found at this time. Amphibians did not prove to be diverse; only two species were found between the fifth and sixth days. Conversely, the reptile curve shows an almost continuous growth from the third day onwards, with a discovery of about one additional species per day. Twenty-six species were finally observed in the forest alone, but we consider this number to be representative of the apparently low abundance of many reptiles which are difficult to find in a short time, and it is therefore likely that a longer survey period would yield a realistic picture of the reptile diversity (Andrén & Rasmussen, 2000).

**Biogeographical aspects**

The only other herpetological survey carried out within the Sambirano Peninsula was made by Rasmussen (1997), who visited the Ankarafantsika Forest (1°58'32'S, 47°56'15'E) during the dry season (July 1986). Most of taxa found by this author (see Table II) were also found during our survey. If we consider the Lepidosaurs found by Rasmussen as conspecific to the species found by us, we have the taxa found at Berara and Lake Tantale (ca. 1995). Among the amphibians, we observed: *Phylosteus scintillans* (Lamarnier & Lamarnier, 1987; Lamarnier & Lamarnier, 1987; Lamarnier & Lamarnier, 1987; Lamarnier & Lamarnier, 1987). Among the reptiles, we recorded: *Leptodactylus interstitialis* (French, 1774), *Boophis listeri* (Gray, 1828), *Cynothaerus pictus* (Heuglin, 1870), and *Hemidactylus frenatus* (Heuglin, 1870). For the reptiles, it is worth noting the apparent absence at Berara of *Micropholis maculata* and *Lepidodactylus interstitialis*, which may prefer open areas. The absence of *Boophis listeri* and *Cynothaerus pictus* is perhaps only apparent, and it is most probably due to their secretive nature and low abundance. In conclusion, pooling the species found during our survey, and those quoted by Rasmussen, we have a total of 14 species of amphibians and 5 species of reptiles we are confident that a good part of the Sambirano herpetofauna has been detected.

For a general point of view, the observed herpetofauna appears to be composed of two kinds of biogeographic elements: 1) taxa shared between Nosy Be, mainland Sambirano, and - partly - other northeastern sites (e.g., *Boophis listeri*, *Hemidactylus gossypinus*, *Hemidactylus sanctipes*, *Iguanidae*), 2) taxa more or less widely distributed along the western and southwestern coast of Madagascar (e.g., *Hemidactylus sanctipes*, *Boophis listeri*, *Iguanidae*, *Hemidactylus sanctipes*, *Sauria gossypinus*). The composition may be explained taking into account the fact that Sambirano is located in northeastern Madagascar, close to the assumed boundary between the biogeographic domains of West Madagascar and Sambirano (NW Madagascar). Among the amphibians, eight out of the 12 species recorded at Sambirano, including *Hemidactylus sanctipes*, which was found at Betsimisaraka (Andrén et al., 2000a) corresponding to 66.6% and are also found in Sambirano (mainland and Nosy Be, respectively), and six (50%) are widespread in both the West (Table III). These numbers are not significantly different from the expected values (q = 0.47, P = 0.05). Moreover, all the amphibians found in the West (including *Boophis listeri* and *Hemidactylus sanctipes*) and the most widespread species found in Sambirano, too; this suggests that the amphibians are more or less homogeneously distributed in these areas. The situation appears different for reptiles since 25 out of the 30 analyzed species (corresponding to 83.3%) were shared with Sambirano, while only 16 (53.3%) were found in the West. These values differ significantly from the expected.
predicted ones Q = 0.65, P < 0.05), thus indicating that the
reptile fauna at Sathurakal is much more similar to
that from the Sundarbans.

Ecology

The general species that we recorded were the most abundant
and common species at Sathurakal. The most abundant
and common species at Sathurakal were the
Pseudocryptobates and A. cochleatus, both with one
species each. The general pattern of the general
species varied in abundance from region to region.

The majority of the species that were recorded were
abundant and common species (e.g., Liolepis ferox, per. obs.), the
most likely only a few individuals of each species were
observed. However, the general pattern of the general
species varied in abundance from region to region.

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