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Assessment of terrestrial small mammals and a record of the critically endangered shrew *Crocidura wimmeri* in Banco National Park (Côte d'Ivoire)

Abstract: This study investigated the small mammal community of the periurban Banco National Park (34 km^2), Abidjan, Côte d'Ivoire, using identical numbers of Sherman and Longworth traps. We aimed to determine the diversity and distribution of rodents and shrews in three different habitats: primary forest, secondary forest and swamp. Using 5014 trap-nights, 91 individuals were captured that comprised seven rodent and four shrew species. The trapping success was significantly different for each species, i.e., the Longworth traps captured more soricids (31/36 shrews), whereas the Sherman traps captured more murids (37/55 mice). The most frequent species was *Praomys cf. rostratus*, followed by *Crocidura buettikoferi*, *Hybomys trivirgatus* and *Crocidura jouvenetae*. Indices of species richness (S) and diversity (H′) were greatest in primary forest, followed by secondary forest and swamp. Several expected species, such as *Crocidura obscurior*, were not found, whereas we captured four specimens of the critically endangered (IUCN 2012) Wimmer's shrew *Crocidura wimmeri*, a species that has vanished from its type locality, Adiopodoumé. Therefore, Banco National Park represents an important sanctuary, not only for plants, birds and primates, but also for other small forest vertebrates.

Keywords: diversity index; Muridae; small mammal community; Soricidae; threatened species.

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Introduction

In Côte d'Ivoire, over 80% of the primary forest has disappeared because of agriculture and logging (Chatelain et al. 1996). Most of the relics of primary forest are found only in protected areas such as national parks and forest reserves (forêts classées). These fragmented zones represent the last sanctuaries for the protection and conservation of biodiversity (Gonedelé Bi et al. 2006). With the exception of the Taí and Comoé National Parks (southwest and northeast Côte d'Ivoire, respectively), the biodiversity of these protected areas remains poorly documented (Kouadio 2009). This is particularly true for terrestrial small mammals, such as rodents and shrews (Dosso 1983, Churchfield et al. 2004).

Among eight national parks and five natural reserves in the country, Banco National Park (BNP) encompasses an area of 34 km^2, situated partially within the metropolis Abidjan. Set up in 1953 by the colonial administration, it is a priceless floristic sample of wet, dense evergreen forest in the south of the country, an isolated part of the Upper Guinea forest of West Africa (Bakarr et al. 2001, Assemian et al. 2006).

Previous studies conducted in BNP were mostly related to botanical censuses (Aké-Assi et al. 1974, De Koning 1983). Very few studies have been concerned with the fauna. An ecological and biological program managed by the Wild Chimp Foundation (WCF) and observations by one of the authors (BK) have confirmed the survival of primate populations, particularly chimpanzees. However, small mammals have only been surveyed in two studies that focused on rodents (Bellier and Gautun 1968, Adam 1977). Thus, a detailed survey of the small mammal community in BNP is still needed. Scientists at the former French scientific station (ORSTOM) in the Adiopodoumé forest (AF), a site 15 km from BNP, identified several new species, making Adiopodoumé the type locality for Doucet's musk shrew *Crocidura douceti* Heim de Balsac, 1958 and Baer's wood mouse, *Hylomyscus baeri* Heim de Balsac and Aellen, 1965. The most enigmatic, and highly endemic species, from that type locality is Wimmer's shrew *C. wimmeri* Heim de Balsac and Aellen, 1958. Today, AF is strongly degraded and partially lost due to the combined effects of logging and farming, the lack of protection status and urban pressure from the expanding city of Abidjan.

Our study focussed on the small mammal community of the BNP, especially families Muridae and Soricidae, to determine their associations with primary forests and secondary forests and swamp and to determine whether any of the rare species recorded at AF have survived in this sanctuary. Drift fences combined with pitfalls appear to be the best technique in rainforest habitats (Goodman et al. 2001, Barrière et al. 2005, Nicolas and Colyn 2006, Gambalemoke et al. 2008a,b), but this method has been prohibited to avoid any disturbance of the wild chimpanzee population in this small park. Therefore, we used two types of live traps to facilitate a more exhaustive sampling of the terrestrial small mammal community.

Material and methods

Study area

BNP (5°21′–5°25′ N; 4°01′–4°05′ W) contains about 34 km^2 of remnant rainforest (Mangenot 1955, Aké-Assi et al. 1974), and it is located in Abidjan, where it is surrounded by urban areas. Only the northwestern limit is adjacent to open landscape (Figure 1). The climate is tropical, and it is characterized by four seasons, with an average annual rainfall of about 2000 mm, and an annual average temperature of 26.4°C. The dry season lasts from December to March and is followed by the period of highest precipitation (main rainy season) from March to July. A minor rainy season lasts from October to November.

Trapping design

Our field survey was conducted between November 2007 and January 2008 with a total of 5014 trap-nights. Small mammals were sampled using two types of live traps: (i) Sherman traps (type SFA, H.B. Sherman Traps, Inc., Tallahassee, FL, USA), with entrance dimensions of 5.5×7 cm, and (ii) Longworth traps (Penlon Ltd., Oxford, UK), with entrance dimensions of 4.5×4.5 cm and a nest chamber that can be filled with hay.

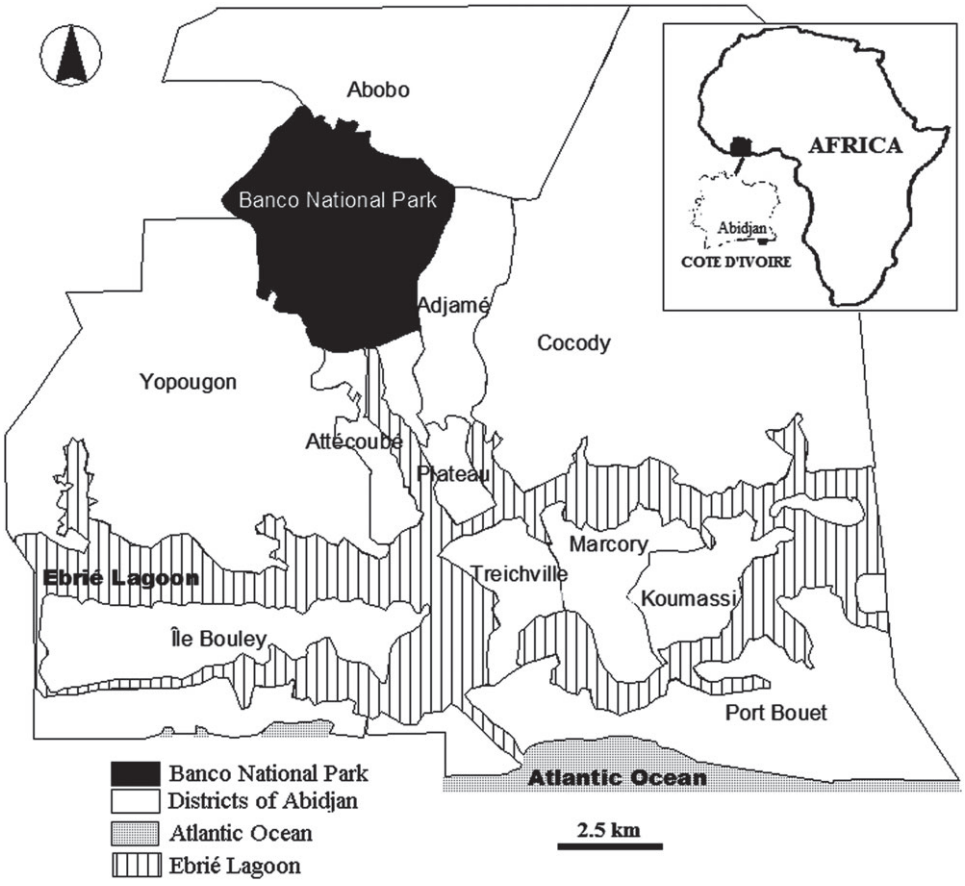

Figure 1 Map of Abidjan district with Banco National Park in the north.

Twelve plots, each with an area of 5 ha, were selected and sampled randomly in primary forest, secondary forest and swamp.

The traps were baited with fresh palm nut shavings (*Elaeis guinneensis*) and smoked fish. Each transect or trap line contained 25 Sherman and 25 Longworth traps per station that were spaced 5–10 m apart and, where possible, placed close to structural complexities, e.g., at the base of a tree, along a fallen trunk or sometimes on a thick branch. Trapping was performed over 4 consecutive days, and the traps were checked daily and rebaited as necessary.

The captured animals were identified, sexed and standard measures were recorded. Animals that were not identifiable in the field were autopsied and kept as voucher specimens. Tissue samples were saved from all of those specimens, which were preserved in ethanol (90%) and deposited at the Laboratory of Zoology at University of Cocody-Abidjan (Côte d'Ivoire). The fieldwork was initiated by PV and conducted by BK and RYK. The rodents were identified by BK and PV based on morpho-anatomical data and a comparative specimen collection.

Taxonomy followed Happold (1977), Wilson and Reeder (2005), with modifications for *Hylomyscus* and *Praomys* following Quérouil et al. (2001) and Nicolas et al. (2005, 2006, 2008, 2010b), and for *Mastomys* and *Mus* following Denys et al. (2005) and Kouassi Kan et al. (2010). This taxonomy is challenging due to a lot of sibling species (Taylor 2000). All of the shrews were identified by molecular analyses performed by VV and SD.

Data and statistical analyses

To standardize data for all sites sampled, the trapping success (T) was calculated as the number of captured individuals/100 trap nights: T={n/E}×100, where n is the number of small mammals trapped, and E is the number of traps checked. To describe the overall characteristics of the small mammal communities, we used the Shannon-Wiener index (H′), Simpson's diversity index (1-D), evenness and equitability indexes and the Chao2 estimator based on the presence or absence of data (Colwell 2000). For both live trap models, we compared the number and identity of species captured. Chi-square tests (χ^2) were used for trap success comparisons. The weight distribution of mammals was compared using Wilcoxon's rank sum test to test for any possible selectivity with both trap types. All statistical analyses were performed using XLSTAT 7.1 and the "R" Statistical package version 2.5.1. (http://www.r-project.org).

Results

Species composition

During 11 weeks, 5014 trap nights were conducted in the three habitats, and 91 terrestrial mammals were captured (Table 1). Captured mammals belonged to two families in two orders: 36 soricids (Soricomorpha: Soricidae), represented by five species, and 55 murids (Rodentia: Muridae), represented by seven species. The four most frequent species comprised 72.2% of the captures: *Praomys cf. rostratus* Miller, 1900 was the most abundant rodent species, followed by *Hybomys trivirgatus* Temminck, 1853. *Crocidura buettikoferi* Jentink, 1888 was the most abundant shrew, followed by *Crocidura jouvenetae* Heim de Balsac, 1958. The remaining species (27.8%) each represented less than 10% of the mammals captured, i.e., the murids *Malacomys edwardsi* Rochebrune, 1885, *Hylomyscus alleni* (Waterhouse, 1838), *Dephomys defua* (Miller, 1900), *Mastomys natalensis* (Smith, 1834), *Lophuromys sikapusi* (Temminck, 1853) and the shrews *Crocidura olivieri* (Lesson, 1827) and *Crocidura wimmeri*. The capture of four Wimmer's shrews was the most important result in this study.

Habitat preference and species distribution

The diversity indexes (Table 1) showed that the small mammal community in the primary forest had the highest species richness (S=13) and the highest diversity index (H′=2.048; Chao2=42.75), followed by the secondary forest (S=8, H′=1.873; Chao2=11.12) and the swamp (S=6, H′=1.445; Chao2=11.84). The Mann-Whitney test (with Bonferroni's correction) detected a significant difference in the diversities of the three habitats (H_c=6.925, p=0.036). The equitability was lower in the primary forest (0.85) than the secondary forest and swamp (both 0.90).

In the primary forest, the small mammal community was dominated by *Praomys cf. rostratus* (35.5% of all captures, n=16, T=0.67%). Among the rare species, *Dephomys defua* and *Crocidura wimmeri* (with three captures) were associated with this habitat. In the secondary forest, *Hybomys trivirgatus* and *Crocidura buettikoferi* (both n=8, T=0.49%) were the most abundant species. They were followed by *Crocidura jouvenetae*, which had a capture rate three times higher in secondary forest than the other habitats (T=0.37%). In the swamp, the community was dominated by *P.* cf. *rostratus* (T=0.41%) and *C. buettikoferi* (T=0.41%). *Malacomys edwardsi* had a higher capture rate in swamp (T=0.20%) than in the other habitats.

Table 1 Diversity and relative abundance of Murids and Soricids trapped in Banco National Park during three months from November 2007 to January 2008 (5014 trap nights).

	Primary forest	T (%)	Sec. forest	T (%)	Swamp	T (%)	Total	Rel. abundance (%)
Trap-nights	**2393**		**1631**		**985**		**5014**	
Soricidae								
Crocidura buettikoferi	7	0.29	8	0.49	4	0.41	19	20.80
Crocidura jouvenetae	3	0.13	6	0.37	1	0.10	10	10.99
Crocidura wimmeri	3	0.13	1	0.06	0	0.00	4	4.40
Crocidura olivieri	3	0.13	0	0.00	0	0.00	3	3.30
Total Soricidae	16	0.67	15	0.92	5	0.51	36	39.56
Muridae								
Praomys cf *rostratus*	16	0.67	5	0.31	4	0.41	25	27.47
Hybomys trivirgatus	3	0.13	8	0.49	0	0.00	11	12.09
Malacomys edwardsi	3	0.13	2	0.12	2	0.20	7	7.69
Hylomyscus alleni	2	0.08	2	0.12	1	0.10	5	5.49
Dephomys defua	3	0.13	0	0.00	0	0.00	3	3.30
Mastomys natalensis	1	0.04	2	0.12	0	0.00	3	3.30
Lophuromys sikapusi	1	0.04	0	0.00	0	0.00	1	1.10
Total Muridae	29	1.21	19	1.16	7	0.71	55	60.44
Number of species (S)	11		8		5			
Total T		1.88		2.08		1.22		
Diversity indexes								
Shannon-Wiener	2.05		1.87		1.45			
Simpson	0.82		0.83		0.74			
Evenness	0.70		0.81		0.85			
Equitability J	0.85		0.90		0.90			
Chao2 (S*2)	42.75		11.12		11.84			

T, trap success.

Comparative trap success

Only 91 terrestrial mammals were captured during 5014 trap nights (Table 1), a trapping success of 1.81%. The overall capture success was similar for the two trapping systems (Longworth: 49 captures, T=1.95%; Sherman: 42 captures, T=1.68%). However, the trapping efficiency for shrews was significantly higher with the Longworth traps (31 individuals with Longworth *versus* 5 with the Sherman traps, χ^2=13.86, df=1, p<0.001). For murids, the trapping efficiency was higher with the Sherman traps (37 individuals *versus* 18 with the Longworth traps, χ^2=4.65, df=1, p<0.05). The body weight distribution (Figure 2) was significantly different in the two trap types (Wilcoxon rank sum test, W=346.5, p<0.001). The Longworth traps appear to have a higher trapping success for species with low body masses, such as shrews, whereas the Sherman traps appear to be more suitable for heavier species (e.g., mice and rats).

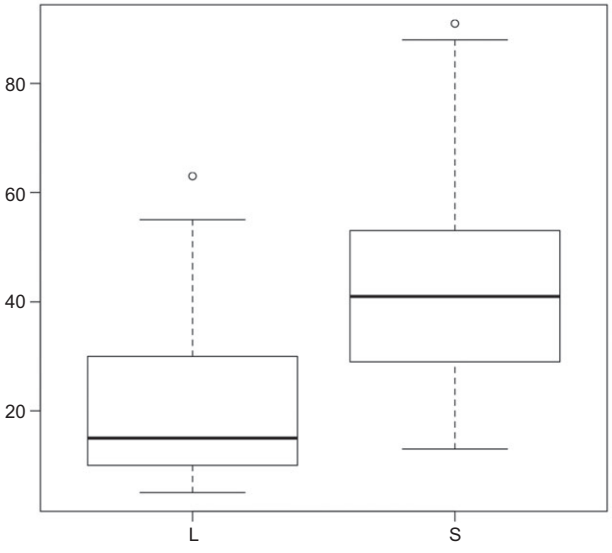

Figure 2 Box plot of the weight [g] of the small mammals captured by Longworth (L) and by Sherman (S) traps.

Discussion

Shrew species in BNP

The most important species captured was Wimmer's shrew *Crocidura wimmeri*. Previously, this species was known only from Adiopodoumé forest (Heim de Balsac and Aellen 1958, Vogel 1976, Vogel et al. 1981, Meylan and Vogel 1982), and several attempts to find new specimens for a genetic study failed (PV, personal observation). This highly endemic shrew is listed as a critically endangered species in category B1ab (iii), which concerns species with distribution areas that are probably less than 100 km^2 (IUCN 2012). It is among the 794 most threatened species in the world and the 10 most threatened vertebrates in Côte d'Ivoire (Alliance for Zero Extinction 2012). Habitat deterioration at the former ORSTOM station (now the Centre National de Recherche Agronomique) due to woodcutting may explain this shrew's extinction at the type locality.

The most frequent species was *Crocidura buettikoferi*, a common shrew that also lives in agricultural habitats in the region of Abidjan. *Crocidura jouvenetae* was also a ubiquitous species, although it was clearly associated with secondary forest. *Crocidura olivieri* was only found in primary forest, although this is usually the most frequent species in villages and the agricultural landscape, where it is often present at a high density (Kadjo et al. 1996, Lim and Van de Groot Coeverden 1997, Decher et al. 2005, Nicolas et al. 2009). It is widespread throughout much of Africa, where it is characterized by many genetic lineages (Dubey et al. 2007).

Unexpectedly, *Crocidura douceti* and *Crocidura muricauda* (Miller, 1900) were not captured, although both are known from AF. Another species that we did not find in BNP was *Crocidura obscurior*, which is well known from AF (Meylan 1971, Hunkeler 1973, Vogel et al. 1981) and also found 125 km west in Azagny National Park (Kang et al. 2011). However, the traps used in this study were probably not suitable for capturing this small shrew species (Vogel 2012) because previous successful captures used pitfall traps (Vogel et al. 1981). Our study also failed to capture *Crocidura theresae* Heim de Balsac 1968, which is trapped frequently 40 km to the west near Dabou (Meylan 1971), or the rare *Sylvisorex megalura* (Jentink 1888). According to Vogel (1974) and Meylan (1975), these species may be limited to the coastal savannah. Other forest species known from Taí forest and Nimba Mountain in Côte d'Ivoire that were also absent in the Abidjan region or AF were *Crocidura nimbae* Heim de Balsac, 1956, *Crocidura grandiceps* Hutterer, 1983 and *Crocidura lamottei* Heim de Balsac, 1968.

Murid species in BNP

Both of the trap types used in this study limited rodent captures to the smaller Muridae, excluding adult *Rattus rattus*. Cricetomyidae, Sciuridae and arboreal dormice (Gliridae) were not captured.

Previously, the most frequent murid in BNP was considered to be *Praomys tullbergi*, but due to the discovery of *Praomys rostratus* as a more common sympatric sibling species in this region (Akpatou et al. 2007, Nicolas et al. 2008, 2010a), we prefer to use the name *Praomys cf. rostratus* for captured individuals. *Praomys* specimens cannot be determined easily without genetic analysis. The next most common species, *Hybomys trivirgatus*, was most frequent in secondary forest and also frequent in AF (Hunkeler 1973). *Malacomys edwardsi* was trapped in all three habitats, although most frequently in swamp. *Dephomys defua* is a primary forest species (Rosevear 1969). By contrast, *Mastomys natalensis* and *Lophuromys sikapusi* are present at the intersections between agricultural land and secondary forests, and they have been trapped regularly in Adiopodoumé. In Côte d'Ivoire, *Mastomys erythroleucus* has been sampled at low frequencies in forest zones (Kouassi Kan 2010). Lecompte et al. (2006) trapped ten times more *M. natalensis* than *M. erythroleucus* in Guinea.

Also absent were *Mus* (*Nannomys*) *setulosus* Peters, 1876 and *Mus* (*Nannomys*) *minutoides* (Smith, 1834); both prefer rather open landscapes (agricultural land near Adiopodoumé and Dabou). Surprisingly, the forest species *Hylomyscus baeri* Heim de Balsac, 1965, *Hylomyscus alleni* (Waterhouse, 1838) and *Grammomys poensis* Eisentraut, 1965 were absent. However, these partly arboreal species were probably not sampled because all of the traps were set at ground level (Dosso 1988). Moreover, *Malacomys cansdalei* Ansell, 1958, which was trapped in BNP by Bellier and Gautun (1968), was not observed. The species accumulation curve for all three habitats (not shown) indicated that other species might still be found.

Species richness and diversity

In the three different habitats, our results confirmed the classical view of decreasing species richness in primary forest through secondary forest to swamp (Turner and Corlett 1996, Gardner et al. 2007). This was confirmed by Shannon's index of diversity (H′). The trapping success was also significantly lower in swamp, which indicates a

lower population density that might be explained by the limited potential for population growth due to flooding.

The classical diversity indices are rarely useful for comparing different regions due to different sampling techniques. Therefore, a simple comparison of species richness (S) can be used. At BNP, S=4 for soricids, and S=7 for murids. Compared with other parks in Côte d'Ivoire, this species richness was very low. In Taí National Park, the value for soricids is S=10, whereas that for murids is S=19. At Mount Nimba Reserve, the values are 11 and 15, respectively (Dosso 1975, 1988, Churchfield et al. 2004, Decher et al. 2005). Perhaps the coastal forest of which BNP is part is rather species poor. Moreover, its surface is small (34 km^2) compared with the Mount Nimba Reserve (50 km^2) or the Taí National Park (3300 km^2). The diversity of habitats is higher in both of these protected areas due to the presence of several river systems and their more complex geomorphology.

Conclusion

This study updates the terrestrial small mammal list for BNP and confirms its important function as a sanctuary in this increasingly urbanized West African region. The vertebrates of concern include small mammals and amphibians as well as primates, especially chimpanzees. Endemic species are particular important, such as the newly discovered frog genus (*Astylosternus*) reported by Assemian et al. (2006) and the rediscovered endemic Wimmer's shrew *Crocidura wimmeri*, which are both highly threatened by ongoing urbanization (Mcdonald et al. 2008). These issues are important arguments for keeping BNP under strict protection to maintain its role as a vertebrate sanctuary for future generations. The persistence of human-induced disturbance is a major challenge for most of the protected areas in Africa (Nicolas et al. 2010c).

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