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Reproduction in urban commensal rodents: the case of *Mastomys natalensis* from Niamey, Niger

Abstract: Most wild Sahelian rodents display a seasonal reproduction that is usually related to rainfall, hence resources availability. *Mastomys natalensis* is a well-documented and major pest rodent species. In East Africa where it occurs outdoors, the species is characterized by marked population cycles. In contrast, it is mostly associated with humans in West Africa, and appears to live strictly indoors in the Sahel. Here, we have monitored the proportions of *M. natalensis* juveniles and sexually active adults within the city of Niamey, Niger. Our survey clearly shows that *M. natalensis* reproduces all year long, with no detectable seasonality. Altogether, our data confirm that reproduction may shift from seasonal to continuous when conditions are more favorable. They also suggest that the urban environment may represent an extreme habitat where resources are permanently available. From the perspective of rodent control in Niamey, our results highlight the need for a constant management policy that should be performed by public authorities.

Keywords: commensalism; pest rodents; Sahel; sexual activity.

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Introduction

Some rodent species are major pests, and as such they may heavily influence human agriculture (Leirs 2003) and contribute to the maintenance, spread, and transmission of many human pathogens (Meerburg et al. 2009). As many rodents display cyclic abundance (Krebs et al. 1973), control strategies must rely on well-documented population data to identify the most appropriate period for management (Singleton et al. 1999, Leirs 2003). Thus, a good knowledge of the population biology of rodent pests is critical. In Eastern Africa, rodents are responsible for massive destructions of crops (e.g., Skonhoft et al. 2006). Although quantitative data are rather scarce, the Sahel should be no exception (Granjon and Duplantier 2009), thus rendering this economically poor region even more vulnerable.

Sahelian rodents are semi-arid adapted species the life cycles of which are strongly dependent on water, hence food availability. As a consequence, wild Sahelian rodents usually display marked cyclic population dynamics with a reproductive activity regulated by photoperiod, climatic features, and/or resource availability (e.g., Hubert 1977, Hubert et al. 1978, Poulet 1982, Hubert and Adam 1985, Sicard et al. 1992, 1993, Sicard and Fuminier 1996, Nomao 2001, Granjon et al. 2005, Fichet-Calvet et al. 2007, 2008). However, it has been shown that reproductive patterns in rodents can be strongly influenced by modifications of some parameters such as annual climatic variation (e.g., Hubert 1977, Poulet 1982; see also Menyushina et al. 2012 and references therein), habitat structure and land use (e.g., Granjon et al. 2005, Makundi et al. 2007, Crespin et al. 2008, Dalkvsit et al. 2011, Morris et al. 2011, Mulungu et al. 2013), food availability and/or quality (e.g., Poulet 1982, Singleton et al. 2001, Morris et al. 2011, Mulungu et al. 2013), etc. With this in mind, the drastic ecological modifications associated with urban environment are expected to induce deep changes in many population parameters (e.g., population size, social organization, dispersion, etc.) (Luniak 2004). If true, these changes may have a great impact on public health and storage, as cities are habitats most probably characterized by increased human-rodent interactions. Yet, the effect of such an environment on rodent reproductive cycles remains poorly documented (e.g., Rangoon, Burma: Brooks et al. 1978), and, to our knowledge, no such data exist for the Sahel. Here, we focus on the major pest species *Mastomys natalensis* (Smith, 1834), which is essentially commensal in West Africa while it lives outdoors in East Africa where its populations are clearly seasonal (Leirs 1992, Leirs et al. 1997, Fichet-Calvet et al. 2007, Makundi et al. 2007, Mulungu et al. 2013).

Materials and methods

Recently, a multi-approach program was conducted in Niger with the aim of documenting various aspects of domestic and peri-domestic rodent biology (Garba 2012) as well as monitoring rodent-borne pathogens (e.g., Dobigny et al. 2011, Yama et al. 2012, Mercier et al. 2013). Part of the data accumulated in the city of Niamey (latitudes 13.45–13.60N, and longitudes 2.05–2.20E) is used here to document some aspects of the reproduction in *Mastomys natalensis*. Briefly, a survey of 14,560 trap-nights was conducted between October 2009 and February 2011 in 52 different sites within Niamey (see Garba 2012 for details). Among the 987 rodents that were captured, 614 strictly commensal *M. natalensis* individuals were obtained from 32 different sites that were all located within the city. Note that no non-commensal multimammate rats were found during this survey (Garba 2012). Owing to the possible co-existence of sibling *Mastomys* species in West Africa (Granjon and Duplantier 2009), non-ambiguous species identification was systematically implemented using PCR-RFLP, karyotypes (Garba 2012), and/or genotyping (K. Hima, unpublished).

The sexual status of each individual was categorized as follows:

(i) Juvenile (or potentially very young sub-adults; hereafter referred to as "Juv"), when total weight fell within the juvenile range of the species (<30 g; Granjon and Duplantier 2009), together with a complete absence of any sign of sexual activity (see below).

(ii) Sexually active male ("saM"), when weight fell within the adult range of the species (>30 g; Granjon and Duplantier 2009), together with external testes and developed seminal vesicles.

(iii) Breeding or lactating female ("blF"), when embryos were observed, or when mammae with milk (determined by palpation) were accompanied by visible placental scars.

(iv) Other ("Oth"), when previous criteria were found ambiguous or incomplete; this implies that this category also includes inactive adults as well as sexually active but non-breeding females.

A fifth category, namely the "sexually active adults," corresponded to the pooling of breeding or lactating females and sexually active males (i.e., blF+saM).

Note that the latter categories are very conservative: this was deliberately done to avoid any risk of overestimating the proportion of juveniles or sexually active adults, and thus the reproductive activity, which is the main purpose of the present study.

Although the present survey relies on individuals that originated from the same city but from many different sites, some of the sites are quite distant, i.e., up to ~14 km apart. This raises the question of a possible local asynchrony in the sexual activity of the rodents. However, three distant sites were monitored within the same 2 weeks and showed the same reproductive trends (data not shown). Thus, one can reasonably assume that no differences in reproductive patterns are expected within the city. Consequently, all our records from Niamey were interpreted as one single dataset (n=614 individuals).

Two groups of analyses were performed. First, the data were arranged according to month of capture, which in turn characterizes the season (DCS: dry and cool season, from October to February; DWS: dry and warm season, from March to May; RS; rainy season, from June to September; see Table 1). The differences in the proportions of Juv, saM, blF, or sexually active adults (i.e., saM+blF) between seasons were tested using ANOVAs as well as Student-Newman-Keuls (SNK) pairwise comparisons.

In a second series of tests, the data were arranged by trapping localities for which precise numbers of night-traps were available (n=16 sites and 461 individuals; see Garba 2012 and Table 2). The trapping success for each locality (number of *Mastomys natalensis* captures vs. number of night-traps) was then calculated to perform linear regressions between trapping success (here considered as a proxy for relative abundance as similar field protocols were used in all 16 localities; see Garba 2012) and the proportions of (i) Juv, (ii) saM, (iii) blF, (iv) sexually

Table 1 Number of rodents (n) and percentages of each reproductive category for each month and season.

Season	Month	n	Juv	blF	saM	actA	Oth
DWS	March	59	0.305	0.085	0.169	0.254	0.441
	April	61	0.197	0.311	0.2459	0.557	0.246
	May	75	0.387	0.12	0.333	0.453	0.160
RS	June	32	0.406	0.125	0.125	0.25	0.344
	July	27	0.333	0.148	0.185	0.333	0.333
	August	76	0.132	0.329	0.197	0.526	0.342
	September	21	0.143	0.333	0.286	0.619	0.238
DCS	October	63	0.413	0.222	0.143	0.365	0.222
	November	59	0.356	0.254	0.169	0.428	0.220
	December	65	0.246	0.308	0.215	0.523	0.231
	January	34	0.206	0.176	0.235	0.412	0.382
	February	42	0.5	0.167	0.167	0.333	0.167

DCS, dry and cool season; DWS: dry and warm season; RS, rainy season. "Juv," "blF," "saM," "actA," and "Oth" stand for the category juveniles, breeding or lactating females, sexually active males, active adults, and others, respectively. See text for details about these categories.

Table 2 Number of rodents (n), *Mastomys natalensis* trapping success (TSM), and percentages of each reproductive category in localities for which such data were all available.

Locality	n	TSM	Juv	blF	saM	actA
BAF2	33	0.084	0.242	0.273	0.212	0.485
BOU	47	0.107	0.319	0.234	0.191	0.426
CYA	52	0.122	0.385	0.115	0.308	0.423
DAR	39	0.075	0.103	0.385	0.308	0.692
GAM	23	0.051	0.217	0.261	0.174	0.435
GNA	23	0.068	0.261	0.261	0.261	0.522
KAR	47	0.071	0.340	0.255	0.234	0.489
KOT	10	0.038	0.2	0.1	0.2	0.3
KOU	26	0.069	0.385	0.154	0.115	0.269
LMO	35	0.086	0.171	0.257	0.086	0.343
PKE	39	0.089	0.359	0.231	0.179	0.410
ROF	13	0.041	0.231	0.152	0.231	0.385
TCH	16	0.070	0.438	0.125	0.188	0.313
WAD	11	0.022	0.545	0.273	0.091	0.364
YAB	24	0.060	0.542	0.167	0.125	0.292
YAH	23	0.048	0.217	0.174	0.217	0.391

"Juv," "blF," "saM," and "actA" stand for juveniles, breeding or lactating females, sexually active males, and active adults, respectively.

active adults, as well as (v) all animals that showed recent or current reproductive activity (i.e., Juv+saM+blF), respectively. These analyses were conducted in order to explore possible relative abundance-dependent patterns.

Results

Monthly sample sizes were quite variable; however, it is noteworthy that both juveniles and active adults were found every month (Table 1). Furthermore, Juv, blF, saM, and active adults were always found in relatively important proportions: 13.2–50%, 8.5–33.3%, 12.5–33.3%, and 25–61.9%, respectively (Table 1). This clearly demonstrates that, in Niamey, commensal *Mastomys natalensis* reproduce continuously throughout the year.

The proportion of breeding or lactating females was higher during the rainy season (RS), while that of juveniles was higher during the dry and cool season (DCS). However, these differences were not significant (Juv: p=0.558 and all SNK' p>0.05; blF: p=0.673 and all SNK' p>0.05). In the same manner, no significant seasonal differences were found between proportions of saM (p=0.373; SNK: all p>0.05) and active adults (p=0.973; SNK: all p>0.05). These results indicate that no seasonal variation in reproduction was detected in commensal *Mastomys natalensis* of Niamey. As a supporting observation, one particular

site was investigated twice, in May (n=20 individuals) and December (n=27), and it yielded many juveniles (29% and 40%) and similar proportions of sexually active adults (48.1% and 50%) in both seasons.

Finally, in no instance were significant correlations observed between trapping success and the proportions of any of the reproductive categories (data not shown; 0.002<R²<0.114, all p>0.2). Although our data may be inappropriate to investigate such a point, they tend to suggest that no relationship between relative abundance and reproductive activity was detected at the scale of the whole city.

Discussion

Our study unambiguously demonstrates (i) that *Mastomys natalensis* from the city of Niamey reproduce all along the year and (ii) that no seasonality could be detected. These results clearly confirm that rodent species that display marked seasonal reproduction in wild environments may shift toward continuous reproductive activity under certain circumstances. As *M. natalensis* shows striking seasonal reproduction in East Africa, as do rodent species inhabiting the semi-arid regions of West African Sahel (see references in Introduction), it may then be reasonably assumed that the shift from seasonal to continuous sexual activity observed in the commensal *M. natalensis* of Niamey is related to the urban environment.

Among other features (Luniak 2004), cities obviously provide a permanent food supply. It has been shown that supplemental food may increase transition rates from non-reproductive to reproductive states in some usually seasonal rodent species (e.g., *Sigmodon hispidus* Say and Ord 1825: Morris et al. 2011). As mentioned above, *Mastomys natalensis* displays an essentially seasonal sexual activity. Yet, although still seasonal, reproduction was found to last longer in irrigated rice fields where maximal gestation rates were concomitant with rice maturation (Mulungu et al. 2013). In forest villages in Guinea, fecundity peaks occurred during the rainy season but reproductive activity was maintained throughout the year due to the buffered conditions offered by the commensal habitat (Fichet-Calvet et al. 2008). Commensal populations have also been observed to reproduce all year long in Senegal (Bâ 2002). In villages of the Malagasy highlands, pregnant *Rattus rattus* (Linnaeus, 1758) females were observed outdoors only during the hot and dry season (i.e., 6 months), while they were present indoors every month (Rahelinirina and Duplantier 1997). The prevalence of sexually

active *Mastomys erythroleucus* (Temminck, 1853) has also been reported to be higher in villages than in surrounding natural habitats in the Zakouma NP area, Chad (Granjon et al. 2004).

Altogether, these data strongly suggest that rodents that show seasonal reproduction in habitats characterized by marked temporal variation in resources may extend their sexual activity period when favorable conditions become persistent. Human-maintained environments (such as irrigated perimeters, villages, etc.) represent relevant examples of such improved conditions, with towns being an extreme case where a permanent supply of resources allows reproduction to persist all year long. Our study of commensal *Mastomys natalensis* from Niamey provides a clear illustration of such an adaptive shift in the Sahel.

Niger is one of the economically poorest countries in the world, ranking 186 (out of 187) in the Human Development Index records (UNDP data 2012). In Niamey, where informal settlements are plethoric and sanitary conditions very degraded, houses display very high levels of infestations by rodents (Garba 2012). In such a context, it is not surprising that rodent-associated nuisances are perceived as huge by local people (96% of them complain about domestic rodents; Garba et al. in press). Yet, rodent control is rather rare in Niamey and relies exclusively on isolated efforts by lone individuals using inadequate protocols. Obviously, rodent management in such an urban environment would require wide-scale, intensive, and rigorously organized strategies that can only be conducted by public authorities (see, e.g., Taylor et al. 2008). Our demonstration of a continuous reproduction of a rodent pest in this city further implies that rodent control will have to be permanent as well, thus significantly increasing its cost.

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