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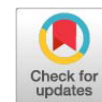
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# Seasonal Reproduction Shift among Three Murine Rodents in a Mediterranean Area of North-Western Africa

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## ABSTRACT

Reproduction of wild rodents in the temperate regions is adaptively timed with the season under the influence of photoperiod, temperature and food availability. The aim of this study was to investigate the responses of three small-sized murine species to the same physical and ecological conditions in a locality of Great Kabylia (Algeria). *Apodemus sylvaticus*, and *Mus spretus* synchronized their reproduction in winter and spring, *Lemniscomys barbarus* in spring and summer. Photoperiod and temperature cannot explain this reproduction shift that might be linked to the feeding ecology of the species.

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## Authors' Contributions

NKEH and SA conceived the project. SM and LA collected data. SM and NKEH collated and analysed the data. All authors wrote the manuscript.

## Key words

Seasonal reproduction, Murine rodents, *Apodemus sylvaticus*, *Mus spretus*, *Lemniscomys barbarus*.

## INTRODUCTION

All latitudes find some mammals reproducing seasonally, even in the deep tropics (Bronson, 2009). In the temperate regions the reproductive process of wild rodents is adaptively timed with the season contrary to synanthropic species which can have litters along the year (Bronson and Perrigo, 1987). Winter is a period of high energetic demand and many rodents show a break in reproductive activity (Gockel and Ruf, 2001), under the main influence of poorer foraging conditions and shorter photoperiod. Ovulation more than spermatogenesis is commonly sensitive to both low temperature and food restriction in small mammals (Bronson, 2009). Hence the end of winter usually initiates the reproductive period in response to lengthening of days, rising of temperature and vegetation growth (e.g. Martinet and Spitz, 1971). Within the reproductive period extending from spring to the beginning of autumn many species show a peak of reproductive activity depending mostly on their feeding ecology, herbivores being earlier than granivores, as they face an enormous energetic drain during lactation

(Bronson and Perrigo, 1987). However, this reproductive pattern can be softened by winter reproduction for some members of the population (e.g. Gockel and Ruf, 2001) or even be inverted for the whole population. So, for example, populations of wood mouse (*Apodemus sylvaticus*) breed from March to November in Brittany (north-western France), and from November to April in Doñana (southern Spain), Pyrénées-Orientales (southern France) and Corsica (Moreno and Kufner, 1988; Fons and Saint Giron, 1993).

In North Africa, rodent females usually give birth during winter and spring, after autumn rainfalls, either in Dipodidae, Gerbillinae, Murinae or Ctenodactylidae (Bernard, 1969; Osborn and Helmy, 1980). For some species, the reproductive period may vary geographically, according to the wet season in the most arid zones, to the temperature in mountains. So, for the lesser Egyptian gerbil (*Gerbillus gerbillus*), it extends from January to May in Egypt (Osborn and Helmy, 1980) and from July to September in Mauritania (Klein et al., 1975). Pregnant wood mouse females have been recorded from September to February or April in Tunisia, Algeria and Moroccan lowlands (Bernard, 1969; Kowalski, 1985; Harich and Benazzou, 1990; Khidas, 1993; Hamdine and Poitevin, 1994), while the reproductive period extends to May in Moroccan high mountains where there is also a winter break (Saint Giron, 1972). The Algerian mouse (*Mus spretus*) exhibits a similar last pattern with an approximately three-month winter rest period (Bernard, 1969; Palomo et al., 1985; Kowalski and Rzebi-Kowalska, 1991), like in southern Spain (Vargas et al., 1984, 1991; Antuñez et al., 1990). However, Orsini et al. (1982) reported an

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absence of reproduction in summer in southern France. The Barbary striped grass mouse (*Lemniscomys barbarus*) is the third non-commensal murine species widely distributed in north-western Africa (Happold, 2013). Zaime (1985) trapped juveniles mainly during winter and spring periods in central Morocco, suggesting births from September–October or December–January depending on the year. However, pregnant females were reported in May, June and September in Tunisia (Bernard, 1969), in spring/summer months in northern Morocco (Lahmam *et al.*, 2008).

Investigating such variations was the starting point of a study in a Mediterranean area where the three small-sized murine species live sympatrically. We aimed to identify the specific responses to the same physical and ecological conditions in the wild. We hypothesized that all three species may adapt similarly to photoperiod and temperature variations for adjusting their reproductive activity to vegetation growth.

## MATERIALS AND METHODS

### Study site

The study site is located at Boudjima (36°48'50"N, 4°09'32"E, 429 m), 21 km north-west of Tizi-Ouzou (Great Kabylia, northern Algeria). According to Daget (1977), the climate is sub-humid and winter is cool. The mean monthly temperatures vary from 9.9°C in January to 29.7°C in July. Rainfalls extends irregularly from November to April, with a peak in January with 130.6 mm; summer is usually dry, July is the driest month. Vegetation is relatively dense including the trees and shrubs *Olea europea*, *O. oleaster*, *Ficus carica*, *Pistacia lentiscus*, *Calycotome spinosa*, *Rubus ulmifolius*, *Rosa canina*. Grasses and forbs include mainly *Phragmites* sp., *Centaurea napifolia*, *Malva sylvestris*, *Apiaceae* sp., *Emex spinosa*, *Poaceae* sp., *Hedysarum* sp., *Borago officinallis* and *Galactite tomentosa*. Human activity is restricted around some sparse buildings.

### Study plan

Rodents were trapped along a 150 m linear transect, a low disturbing but efficient method for sampling rodent populations in the temperate zone (Spitz *et al.*, 1974). Three-day captures were conducted each month from January to December 2017. Baited traps with bread and pilchard were 3-meter spaced, giving a total of 1620 night-trappings. Animals were euthanized, sexed, aged, measured and any sexual activity was recorded. According to Kowalski (1985), males were considered sexually active when the diameter of testes was over 10 mm and seminal vesicles were developed. For females, reproductive state

was estimated by appearance of open vagina, developed mammary glands and uterus (including embryos). They were considered sexually active when gestating and/or lactating (Birkan, 1968).

Age classes were identified according to upper molar wear after cleaning the skulls by boiling heads and then soaking them in bleaching water during 5–10 min. For *Apodemus sylvaticus*, we followed Saint-Girons (1972) who considered three age classes: juveniles, sub-adults and adults. For *Mus spretus*, we identified the same three age classes according to Palomo *et al.* (1983). For *Lemniscomys barbarus*, we adapted the table published by Van der Straeten (1980) for *L. linulus* to our trapped specimens for identifying the same three age classes.

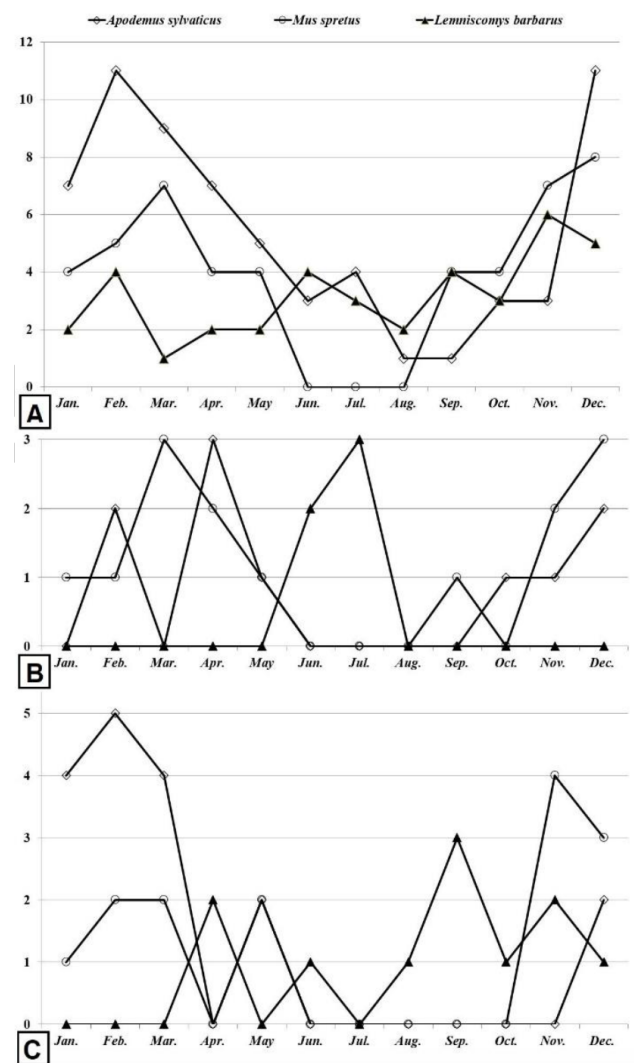


Fig. 1. Monthly captures of adults (A), juveniles (B) and sub-adults (C) of three wild murine species at Boudjima (Great Kabylia, Algeria).

## RESULTS

The 1620 night-trappings provided the capture of 165 small mammals, including 150 murine species: 65 *Apodemus sylvaticus* (43.3%), 47 *Mus spretus* (31.3%) and 38 *Lemniscomys barbarus* (25.3%). Trapping result varied along the year with larger numbers in winter (December to February) and lower numbers in summer (June to September) for *A. sylvaticus* and *M. spretus*, which no specimen was trapped in June, July and August (Fig. 1A). The monthly low number of *L. barbarus* (maximum 6 specimens in November) was quite similar along the year. The gross sex-ratio was balanced for *A. sylvaticus* (33:32) and in favour of males for *M. spretus* (32:15) and *L. barbarus* (28:10), including deep monthly variations for the two first species and not for the third one, males being always more numerous than females (Fig. 2). No female of *L. barbarus* was trapped from March to May, in August and October.

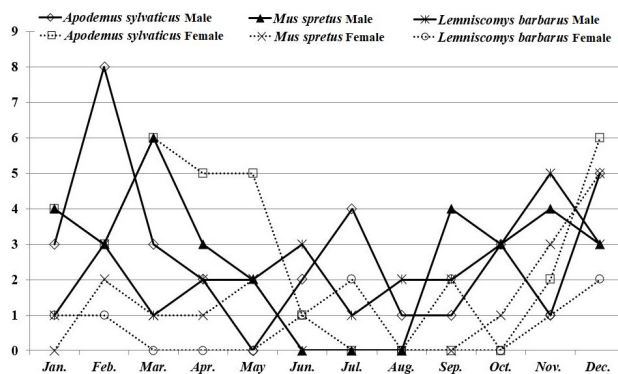


Fig. 2. Monthly captures of males and females of three wild murine species at Boudjima (Great Kabylia, Algeria).



Fig. 3. Nests of *Lemniscomys barbarus* (Mekla, Great Kabylia, Algeria, June 2017).

Few juveniles were trapped for any species except for *M. spretus* with 11 juveniles over 26 specimens. Juveniles of *L. barbarus* were trapped in June and July (Fig. 1B) and sub-adults mainly from August to December (Fig. 1C), suggesting a winter break of reproduction. At the opposite, juveniles of *M. spretus* were trapped from

September to May, and sub-adults from November to May. A quite similar pattern was observed for *A. sylvaticus* with juveniles from October to May and sub-adults from December to March. None of sub-adults was sexually active as well as none adult male of *A. sylvaticus* trapped from June to September, the first gestating female being recorded in December. Adult males of *L. barbarus* were sexually active from April to October.

Two nests of *L. barbarus* with litters of 6 pups were found in June at Mekla (36°41'16"N, 4°16'05"E), a locality 33 km from our study site (Fig. 3).

## DISCUSSION

The vegetation of our study site is relatively dense, so it is not surprising that *Apodemus sylvaticus* was the most trapped species among small mammals. This species which prefers forest or forest edges is found in a wide variety of habitats (Denys, 2017a), including mountain grasslands, shrubs and undergrowth cover (lower woody vegetation) in Kabylia (Hamdine and Poitevin, 1994; Khidas *et al.*, 2002). *Mus spretus* is associated with Mediterranean scrub, bush, grasslands and cultivated fields (Denys, 2017b), and was found syntopic with wood mouse where high woody vegetation is sparse (Khidas *et al.*, 2002) despite some competition for food (Fons *et al.*, 1988). *Lemniscomys barbarus* prefers bushes and grasses habitats with dense ground cover (Happold, 2013) whereas *M. spretus* includes a high percentage of bare ground in its home range in Kabylia (Khidas *et al.*, 2002). Such occurrence of the three murine species has been rarely reported, for example in cultivated fields of Esperada (Morocco), among 17 sampled sites, and Lansarine region (Tunisia) with a low number of *A. sylvaticus* each time (Denys *et al.*, 2015; Ben Ibrahim *et al.*, 2019). In Kabylia, these three species were previously trapped in four sites: Bouberek (Khidas, 1993), Azazga (Khammes, 1998), Cap Djinet and Boukhalfa (Amrouche-Larabi *et al.*, 2015), with a lower number of *L. barbarus* each time, like in our study site.

Sex-ratio was balanced for *A. sylvaticus*, contrary to Hamdine and Poitevin (1994) who reported a larger percentage of males, as we recorded for *M. spretus* and *L. barbarus*. An unbalanced sex-ratio is most often observed in trapped small murine species, particularly during the breeding period for *A. sylvaticus* (Butet and Paillat, 1997) and after the breeding period for *M. spretus* (Vargas *et al.*, 1984; Cassaing and Croset, 1985). In *L. barbarus* males are more often trapped than females after the age of five months when the later become more sedentary (Zaime, 1985). Juvenile dispersal and exploratory behaviour are widely reported in small mammals to explain sex ratios



skewed in favour of males in trapping sessions (Stenseth and Lidicker, 1992).

Despite the small sample size our results clearly suggest a different reproductive period for *A. sylvaticus* and *M. spretus* with a summer break (June to August), and *L. barbarus* with a winter break (November to January). In the Mediterranean region, the reproductive period of *A. sylvaticus* was linked to the availability of food, usually reduced in summer as a consequence of drought, and abundant in autumn (fruits and berries) and winter after vegetation growth following autumn rainfalls (Soriguer and Amat, 1979; Torre *et al.*, 2002; Díaz and Alonso, 2003; Rosário and Mathias, 2004). Similarly, the reproductive period of *M. spretus* is linked to water availability and vegetation growth, mainly mast production and grass seeds in southern France (Orsini *et al.*, 1982).

Similarly, according to Zaime (1985) food availability synchronized the reproductive period of *L. barbarus* and the two syntopic gerbilline species *Meriones grandis* and *Gerbillus campestris*. But this period is spread over winter and spring in this sub-arid study site of central Morocco, before the spring and summer period estimated from our data which are supported by previous studies in Tunisia (Bernard, 1969) and northern Morocco (Lahmam *et al.*, 2008), where the climate is sub-humid. These results confirm that, in the Mediterranean area, small mammals are irresponsive to variation in photoperiod (Bronson, 2009). For a species which reproduces along the whole year in captivity (Lenkiewicz and Saint-Girons, 1964), the reproduction shift agrees with the hypothesis of an adjustment of the breeding activity to vegetation growth. Moreover, Lenkiewicz and Saint-Girons (1964) showed that activity declined in cold weather, which can contribute to delay the reproductive period to hotter days in some parts of its range.

The influence of temperature on the shift of reproductive period among the three murine species is hardly supported by our data. First, the mean January temperature is lower in central Morocco (Zaime, 1985) than in Boudjima. Second, *L. barbarus*, a diurnal species, should be less affected by winter cold nights than *A. sylvaticus* and *M. spretus*, which are mainly nocturnal. Then, feeding ecology remains the main likely cause of this seasonal reproduction shift. *A. sylvaticus* is omnivorous, but predominant food is seeds and acorns, and *M. spretus* eats mainly fruits, seeds and green parts of plants (Denys, 2017b). In Kabylia, both species are primarily granivorous (Khammes, 1998; Khammes and Aulagnier, 2007). *L. barbarus* is “probably herbivorous” (Happold, 2013), like most *Lemniscomys* species (Taylor, 2017) and its reproductive activity seems to respond to herbaceous vegetation growth starting at the end of winter, whereas

the two granivorous species get an energetic source from seed and acorn production in autumn and winter.

## CONCLUSION

The occurrence of the three small-sized non commensal murine species in one area is a quite rare event that is worth to be reported, mainly when populations seem to be almost balanced, contrary to previous trapping sites reported in the literature. As some competition between *Apodemus sylvaticus* and *Mus spretus* was recorded by Fons and Saint Girons, (1988), our study site provides a good opportunity for investigating their interactions with a third phylogenetically related species that could influence their population dynamics.

Our main result is the seasonal reproduction shift between *A. sylvaticus* and *M. spretus* on one side, and *Lemniscomys barbarus* on the other. Roughly, the summer break of the formers stands in opposition to the winter break of the later. This pattern cannot be related to physical factors widely reported to influence reproductive period, such as photoperiod or temperature. Ecological factors are also poorly relevant since, even if they exhibit different daily activity pattern, the three species are living in syntopy. However, a more comprehensive study could reveal some different use of the study area. More likely, the reproduction shift among the three species is linked to their feeding ecology that should be investigated, our study site becoming a higher research spot.

## Statement of conflict of interest

Authors have declared no conflict of interest.

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