Mammal Research
https://doi.org/10.1007/s13364-019-00443-4

ORIGINAL PAPER

Winter activity rhythms of a rodent pest species in agricultural habitats

Filippo Dell'Agnello[1] • Matilde Martini[2] • Emiliano Mori[3] • Giuseppe Mazza[1,4] • Valeria Mazza[1,5] • Marco Zaccaroni[1]

Received: 14 April 2019 / Accepted: 27 June 2019

Abstract
Predation risk is the main factor affecting movements of mammal prey species. Here we assessed the activity patterns of a nearly endemic fossorial rodent, the Savi's pine vole *Microtus savii*, in two agroecosystems in central Italy. Direct captures were carried out in cold months (December–March) with live-traps; sex and age were recorded for each captured individual following standard methods. Savi's pine voles were mostly active during daytime in both study sites, with no differences between sexes or age classes. Night-time movements were mainly registered during waning moon nights and were severely restricted in bright moonlight. The activity pattern of Savi's pine voles seems to support the hypothesis of predation avoidance. The most common predators of these small rodents are mainly active during bright nights, when visibility is highest, forcing voles to be more active aboveground during daylight hours as well as in the darkest nights. Efficient monitoring and trapping programmes should therefore take place in daylight hours to increase capture success and to reduce stress levels of the captured animals.

Keywords Agroecosystems · *Microtus savii* · Savi's pine vole · Predation risk · Moonlight avoidance

Introduction

Small mammals (i.e. Rodentia, Soricomorpha and Erinaceomorpha) play pivotal roles in food chains and are very reliable environmental bio-indicators (e.g. Avenant 2011; Umhang et al. 2013; Bertolino et al. 2015a). At the same time, some species, mainly among rodents, contribute to the spread of diseases and have a deleterious impact on human economy, including agriculture and forestry. Consequently, small mammal species are often neglected in conservation biology, and for most of them, information on natural history and ecology are lacking, thus negatively influencing the success of control methods (e.g. Holmes et al. 2015). As to Southern Europe, management strategies of small mammals are inadequate, and impacts of these species are still partly unknown (cf. Bertolino et al. 2015a).

The Savi's pine vole *Microtus savii* (Rodentia: Cricetidae) is the most widespread vole species of Italy, being recorded from the Alps to Southern Latium and Abruzzi (Ranchelli et al. 2016). In Southern regions (Molise, Campania, Apulia, Basilicata and Calabria), the similar Calabrian pine vole *M. brachycercus* is present; the Sicilian vole *M. nebrodensis*, formerly subspecies of *M. savii*, occurs in Sicily (Amori and Castiglia 2018). Despite its wide distribution range, knowledge on ecology and behaviour of the Savi's pine vole is scanty (Ranchelli et al. 2016). The habitat of the species included mostly ecotonal areas, fallows, croplands and orchards, from the sea level to 2800 m (Osella and Montolli 1986; Patriarca

Filippo Dell'Agnello and Matilde Martini contributed equally to this work.

Communicated by: Joanna Stojak

✉ Marco Zaccaroni
marco.zaccaroni@unifi.it

1 Department of Biology, University of Florence, Via Madonna del Piano, 6, Sesto Fiorentino, 50019 Florence, Italy

2 Department of Biology, University of Pisa, Via Alessandro Volta, 4, 56126 Pisa, Italy

3 Department of Life Sciences, University of Siena, Via P.A. Mattioli 4, 53100 Siena, Italy

4 CREA Research Centre for Plant Protection and Certification, Via di Lanciola 12/A, Cascine del Riccio, 50125 Florence, Italy

5 Department of Animal Ecology, University of Potsdam, Maulbeerallee 1, 14469 Potsdam, Germany

and Debernardi 1997). Savi's pine vole is a fossorial rodent species, inhabiting systems of shallow underground burrows, and feeds mostly on herbaceous plants (Dell'Agnello et al. 2018a). Savi's pine voles are considered to be responsible for extensive debarking on roots and stems (Ranchelli et al. 2016), often leading to plant death; thus, they are considered agricultural pests (Capizzi et al. 2014; Bertolino et al. 2015b). For this species, the 'pest' effects are more remarkable in cold months than in warm ones. In winter, when the grass cover is strongly reduced or covered by snow, Savi's pine voles exploit alternative food sources: accordingly, in this season, the species provokes debarking of trunks and roots just above and below the ground level (Rapisarda et al. 1998; Capizzi and Santini 2007). Moreover, in winter, populations are reported to be more stabilised and the least active, as probably outside the reproduction period, which occurs in early spring (Amori et al. 2008). Studies on pest species' activity rhythms are important (e.g. Fanini et al. 2014) to improve control success and reduce potential damages (e.g. Somogyi and Horvàth 2018). Activity rhythms of small rodents are known to vary locally according to day-length, local food availability and seasonal hormone secretions, suggesting that general conclusions may be hard to be derived (Miller and Elton 1955; Lehmann 1976; Daan and Slopsema 1978; Rowsemitt 1986). Most studies on vole ranging periods outside burrows have been carried out without direct captures, but only by measuring the rate of re-opened burrows over wide study areas (Liro 1974; Lisická et al. 2007; Somogyi and Horvàth 2018). Conversely, capture success with repeated daily controls may be used as a more accurate surrogate for epigeal activity rhythms and may provide researchers and wildlife managers with a useful tool to improve control or removal of pest species. Most *Microtus* voles show polyphasic epigeal activity rhythms, with peaks both during the day and the night (e.g. *M. arvalis*, *M. liechtensteini*, *M. multiplex* and *M. subterraneus*: Amori et al. 2008); each of the 12–14 daily activity periods lasts for 30–35 min, with at least 80 min of resting (Salvioni 1988a, 1988b). In the mountain habitats of Switzerland, Savi's pine voles seem to be mostly nocturnal during winter months (October–March) and mostly diurnal in summer ones (April–September) (Salvioni 1988a; Amori et al. 2008). In Italy, despite being known as an agricultural pest, 'round the clock' information on epigeal activity of the Savi's pine vole is lacking (cf. Amori et al. 2008). In our work, we aimed at defining the activity rhythms of the Savi's pine vole during winter (Dell'Agnello et al. 2018a; Dell'Agnello et al. 2018b), when the highest amount of damage to cultivations occurred (Caltran 2002). Crop managers also suggested that winter was the best season to effectively control this rodent (Osella and Montolli 1986; Caltran 2002), since rain increases vole activity.

Materials and methods

Study areas

This study was conducted in two peach orchards of 2 ha each, located in two regions of central Italy, i.e. Emilia-Romagna and Tuscany (Fig. 1), where the highest densities of this species seem to occur (Amori et al. 2008).

The study site in Emilia-Romagna was located in Imola (44° 21′ N, 11° 42′ E; province of Bologna; 39–57 m a.s.l., hereafter site A). This intensely farmed landscape is highly fragmented and has average annual rainfalls of 750 mm and mean annual temperatures between + 2.6 °C and + 23.7 °C.

The study site in Tuscany is located near Foiano della Chiana (43° 15′ N, 11° 48′ E; province of Arezzo; 250–266 m a.s.l., hereafter site B), about 1 km away from human settlements. The average annual rainfall was 700 mm and mean annual temperatures ranged between + 5.4 °C and + 23.0 °C. The only vole species to be found in this area was the Savi's pine vole, whereas the common vole *Microtus arvalis* was observed in site A, although it was a rare occurrence (about < 1% of the total captures). Both areas were covered by similarly managed peach orchards, with trees ageing from 5 to 15 years, and cultivated through traditional farming methods, periodically treated with pesticides but not with rodenticides.

Trapping and handling

Sampling was conducted on both study sites once a month, from December 2014 to March 2015. Each sampling session lasted 8 days, with traps kept active 24 h for 6 trapping nights, for a total of 144 h of sampling. Multiple-capture live-traps ($N = 183$ Ugglan Special Traps, ©Grahnab AB, Hillerstorp, Sweden) were used. Traps were baited with apples and provided with cotton to protect voles from hypothermia and to lower their stress response by providing nesting material.

At the beginning of each trapping session, we identified 'active' holes, i.e. holes belonging to currently used tunnels. The study area was walked through in all its width, and all tunnel holes were closed (Bertolino et al. 2015b). Ugglan traps were placed only in front of re-opened (i.e. active) holes detected after 24 h to improve capture success. Traps were placed horizontally in front of the entrance hole, so that no light passed through; voles would then enter the traps on their way out of the tunnels, as a continuation of their burrow (Dell'Agnello et al. 2018b). Traps were checked five times a day: C1, midnight; C2, 04:00; C3, 08:00; C4, 13:00; C5, 19:00. Each trap-check lasted for about 1 h. Therefore, individuals captured at C2 (04:00–05:00) may have entered the trap between the end of C1 (01:00) and the end of C2 (05:00). According to this last consideration, 5 periods of potential

Fig. 1 Location of the study sites. Site A, Imola; site B, Foiano della Chiana. Grey area, distribution of Savi's pine vole in Italy (cf. Amori et al. 2008)

vole activity were identified: P1, 20:00–01:00; P2, 01:00–05:00; P3, 05:00–09:00; P4, 09:00–14:00; P5, 14:00–20:00. Since Savi's pine voles tunnel systems are also used by other species (e.g. common voles *Microtus arvalis*, white-toothed shrews *Crocidura* spp. and European moles *Talpa europaea*), we avoided using passage counters to analyse active burrows (cf. Halle and Lehmann 1987), as it was impossible to assess whether passing individuals belonged to our target species or to others. At first capture, each vole was marked with a pit tag, using a syringe-injected, 1.4 mm × 9 mm ISO FDX-B glass transponder (© Planet ID GmbH, Essen, Germany). Animals weighting less than 10 g were marked by fur clipping. Sex and age class of each animal were assessed. Age classes were defined according to body mass (juveniles ≤ 15 g, adults > 15 g: cf. Amori et al. 2008). Data were recorded on the transponder reader at every capture, to allow individual recognition (Nichols 1992). Thus, handling occurred just once for each individual, which was immediately set free at each recapture event. We are confident that frequent trap controls would have limited forced resting period of voles in traps, thus not affecting their activity bouts.

Animal trapping and handling procedures took place in compliance with the European Council Directives 92/43EEC and 86/609/EEC and the national regulations for animal research (D. Lgs 157/92 and D. Lgs 116/92).

Data analysis

Circular statistics tests were used to assess activity peaks among identified periods of the day standardised per number of hours. The time at which voles were found within the traps (i.e. P1–P5) was used as a predictor of activity bouts by the Savi's pine vole. We performed a Rayleigh test for uniformity (on single-capture events) to assess whether activity bouts differed from a unimodal distribution and activity peaks occurred throughout the 'round the clock' cycle.

Then, the same test was used to verify if a nocturnal activity peak occurred also throughout the 29.5 days of lunar cycle (day 0, new moon; day 15, full moon: Mori et al. 2014a; Carnevali et al. 2016). In particular, the night was defined as the period included between 1.5 h after the sunset and 1.5 h before the sunrise (Carnevali et al. 2016). The Watson-Wheeler test for homogeneity was carried out to show differences in activity rhythms between sexes, age classes and study sites (Lioy et al. 2016).

Statistical analyses were performed through the R package *circular* (Agostinelli and Lund 2013). The function *as.-circular* was used to coerce an object (the hours in the format hh:mm, or the days of the lunar cycle) to a circular distribution (Agostinelli and Lund 2013).

Results

A total of 45 individuals (28 males, 17 females; 36 adults, 9 juveniles) were trapped in site A, 48 (24 males, 24 females; 32 adults, 16 juveniles) in site B. A total of 540 capture events occurred in site A, 665 in site B. Savi's pine voles were active throughout the 24-h cycle, with most ranging movements occurring in daylight hours (65.57–67.26% of total captures: Fig. 2).

The Rayleigh test showed that the activity of Savi's pine vole was not uniform at both study sites, with a peak occurring at P4 (Rayleigh test: site A, mean direction, 11:44 ± 00:25, $Z = 133.12$, $r = 0.750$, $P = 0.041$; site B, mean direction, 11:17 ± 00:31, $Z = 138.17$, $r = 0.780$, $P = 0.036$).

No difference was observed between sexes (Watson-Wheeler U^2 test = 83.11, $P = 0.43$), age classes (Watson-Wheeler U^2 test = 53.19, $P = 0.13$), and study sites (Watson-Wheeler U^2 test = 40.02, $P = 0.11$). As to nocturnal hours, captures were mainly concentrated at lunar day 27 ± 1.33 (Rayleigh test, $Z = 17.12$, $r = 0.43$, $P = 0.027$), during the waning moon.

Discussion

According to our data, Savi's pine voles were active throughout the day, confirming the polyphasic activity observed in other *Microtus* voles, triggered by the fast metabolic rate of small rodents, which implies constant food consumption (Grodzinski 1962; Daan and Slopsema 1978; Nagy 1987; Speakman 1999; Amori et al. 2008). Most of epigeal activity was detected during the day, which is in contrast with the results by Salvioni (1988b), who reported that, in winter, Savi's pine voles were mostly active during the night, in mountain prairies. Other *Microtus* voles were also reported to be mostly nocturnal in natural environments (e.g. Calhoun 1945; Erkinaro 1961; Amori et al. 2008). Predation pressure has been suggested to be the main driving force activity rhythms of voles: Daan and Slopsema (1978) reported the kestrel *Falco tinnunculus* as the main predator of the common vole *Microtus arvalis*, whose presence reduce the voles' daytime foraging/activity bouts/movements as an antipredator response. This is in line with the data reported by Salvioni (1988b), who claimed that *Microtus* voles in Swiss mountain habitats are mostly nocturnal, possibly to avoid diurnal predators such as the golden eagle *Aquila chrysaetos*, the stoat

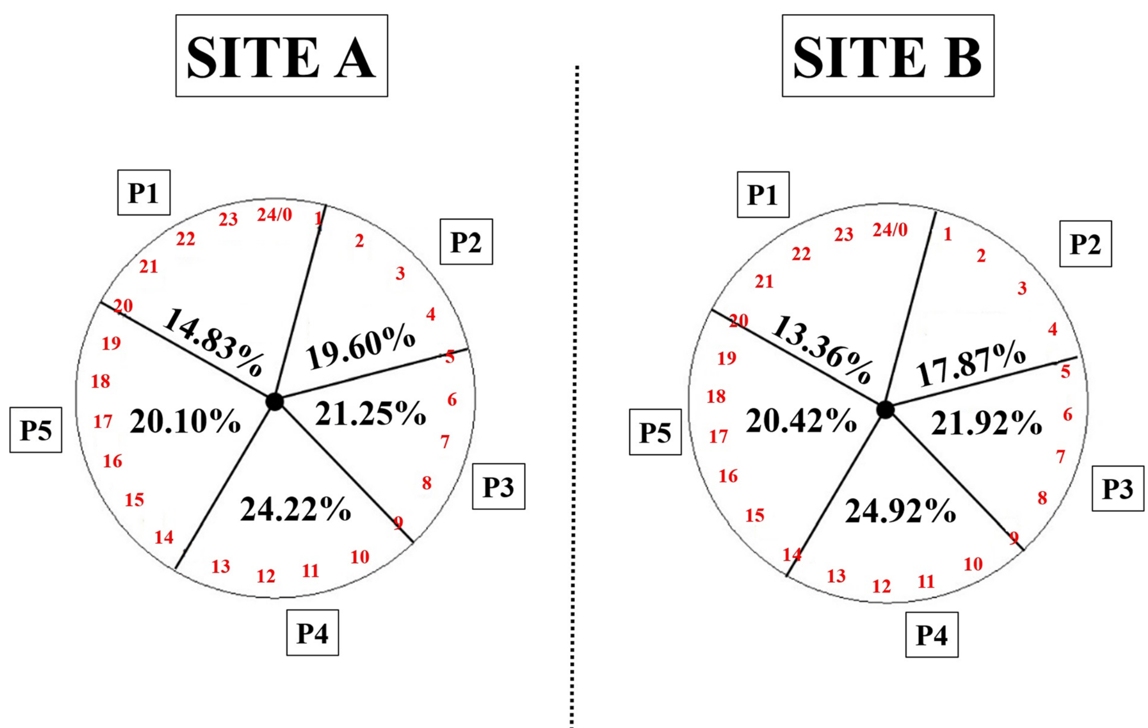

Fig. 2 Activity bouts of the Savi's pine vole captured at both study sites on the 24-h cycle

Mustela erminea and the least weasel *Mustela nivalis* (Amori et al. 2008; Ranchelli et al. 2016).

The winter diurnal habits of Savi's pine vole in suburban croplands may be due to the fact that the main predators of this rodent in central Italy are the barn owl *Tyto alba*, the tawny owl *Strix aluco*, the long-eared owl *Asio otus* and the red fox *Vulpes vulpes* (Mori et al. 2014b; Ranchelli et al. 2016; Soe et al. 2017; Dell'Agnello et al. 2018b) which are all active mostly at night (Jaksić 1982; Cavallini and Lovari 1994), when human disturbance is lowest. This may explain why we observed differences in activity rhythms of the Savi's pine vole between day and moon phases (cf. Penteriani et al. 2010; Mori and Menchetti 2019, for activity of predators). The constant and clumped food distribution (Cavallini and Lovari 1991) in croplands and orchards may drive animals to range outside underground burrows when the predation risk is lowest, i.e. when natural predators are less active (i.e. daytime in anthropised habitats: Grinder and Krausman 2001; Marks and Bloomfield 2006), suggesting a trade-off between costs and benefits of a lower predation risk. The lack of difference between study sites, sexes and age classes supports the hypothesis that Savi's pine voles modulate the timing of ranging behaviours to reduce predation risk.

Furthermore, our results indicate remarkable moonlight avoidance by Savi's pine voles, whose nocturnal movements mainly occurred in waning moon nights. This brings further support to the antipredator adaptation hypothesis (cf. Monterroso et al. 2013; Mori et al. 2014a; Prugh and Golden 2014), since the voles' main predators, i.e. raptors and red foxes, are active mostly during moonlight nights, when the success of hunting is highest (Abramsky et al. 1996; Molsher et al. 2000; Penteriani et al. 2010; Lourenço et al. 2011; Mori and Menchetti 2019, but see Mukherjee et al. 2009).

From conservation and management perspectives, we suggest carrying out capture sessions not only during night hours but also during the daylight, and also in the cold months, particularly when concerning this species in suburban agroecosystems. Our findings support the suggestion that cold months are best suited to conduct numerical control of this pest species, when the pest effect is suggested to be highest (cf. Rapisarda et al. 1998) and the diurnal activity of this species peaks. In conservation studies, this trapping protocol would also reduce rodent mortality at night, when environmental temperatures are lowest (Decoursey et al. 1998). Trap-checks should be intensified during daylight hours, to increase the capture success in the unit of time and to reduce mortality. We are aware that the fluctuating population size among years may be an important driver of temporal activity (e.g. Clotfelter et al. 2007). However, although we did not perform a spatial replication, we studied two populations during the same study period, but in similar environments, obtaining comparable results. We have no reason to think that some difference would have occurred in successive years.

Our study provided new finding on the activity pattern of the Savi's pine vole. These aspects, in a pest management context, can contribute to build a more efficient pest control programme. Farmers may concentrate captures, also using snap traps, during a specific and short period (daylight and cold months) to obtain highly cost-effective results.

Acknowledgements We thank Raimund Grau, Ralf Barfknecht, Jörg Hahne and Emmanuelle Bonneris for their support.

Funding information The study was funded by Bayer CropScience.

Compliance with ethical standards

Animal trapping and handling procedures took place in compliance with the European Council Directives 92/43EEC and 86/609/EEC and the national regulations for animal research (D. Lgs 157/92 and D. Lgs 116/92).

References

Abramsky Z, Strauss E, Subach A, Riechman A, Kotler BP (1996) The effect of barn owls (*Tyto alba*) on the activity and microhabitat selection of *Gerbillus allenbyi* and *G. pyramidum*. Oecologia 105:313–319

Agostinelli C, Lund U (2013) R package "circular": circular statistics (version 0.4-7). http:// r-forge.r-project.org/projects/circular/. Accessed on 24th July 2017

Amori G, Castiglia R (2018) Mammal endemism in Italy: a review. Biogeographia 33:19–31. https://doi.org/10.21426/B633035335

Amori G, Contoli L, Nappi A (2008) Mammalia II: Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia. Edizioni Calderini de Il Sole 24 Ore, Milano

Avenant N (2011) The potential utility of rodents and other small mammals as indicators of ecosystem 'integrity' of South African grasslands. Wildl Res 38:626–639

Bertolino S, Colangelo P, Mori E, Capizzi D (2015a) Good for management, not for conservation: an overview of research, conservation and management of Italian small mammals. Hystrix 26:25–35

Bertolino S, Asteggiano L, Saladini MA, Giordani L, Vittone G, Alma A (2015b) Environmental factors and agronomic practices associated with Savi's pine vole abundance in Italian apple orchards. J Pest Sci 88:135–142

Calhoun JB (1945) Diel activity of the rodents, *Microtus ochrogaster* and *Sigmodon hispidus hispidus*. Ecology 26:251–273

Caltran S (2002) I roditori dannosi alle colture erbacee ed arboree si combattono durante l'inverno. Vita di Campagna 10:29–32

Carnevali L, Lovari S, Monaco A, Mori E (2016) Nocturnal activity of a diurnal species, the northern chamois, in a predator-free Alpine area. Behav Proc 126:101–107

Cavallini P, Lovari S (1991) Environmental factors influencing the use of habitat in the red fox, *Vulpes vulpes*. J Zool (Lond) 223:323–339

Cavallini P, Lovari S (1994) Home range, habitat selection and activity of the red fox in a Mediterranean coastal ecotone. Acta Theriol 39:279–287

Clotfelter ED, Pedersen AB, Cranford JA, Ram N, Snajdr EA, Nolan V, Ketterson ED (2007) Acorn mast drives long-term dynamics of rodent and songbird populations. Oecologia 154:493–503

Daan S, Slopsema S (1978) Short-term rhythms in foraging behaviour of the common vole, *Microtus arvalis*. J Comp Physiol 127:215–227

Decoursey PJ, Pius S, Sandlin C, Wethey D, Schull J (1998) Relationship of circadian temperature and activity rhythms in two rodent species. Physiol Behav 65:457–463

Dell'Agnello F, Mazza V, Martini M, Bertolino S, Capizzi D, Riga F, Zaccaroni M (2018a) Trap type and positioning: how to trap Savi's pine vole using the tunnel system. Mammalia 84:350–354

Dell'Agnello F, Barfknecht R, Bertolino S, Capizzi D, Martini M, Mazza V, Riga F, Zaccaroni M (2018b) Consistent demographic trends in Savi's pine vole between two distant areas in Central Italy. Folia Zool 67:35–42

Erkinaro E (1961) The seasonal change of the activity of *Microtus agrestis*. Oikos 12:157–163

Fanini L, Longo S, Cervo R, Roversi PF, Mazza G (2014) Daily activity and non-random occurrence of captures in the Asian palm weevils. Ethol Ecol Evol 26:195–203

Grinder MI, Krausman PR (2001) Home range, habitat use, and nocturnal activity of coyotes in an urban environment. J Wildl Manag 4:887–898

Grodzinski W (1962) Influence of food upon the diurnal activity of small rodents. Symp Theriol Praha 1:134–140

Halle S, Lehmann U (1987) Circadian activity patterns, photoperiodic responses and population cycles in voles. Oecologia 71:568–572

Holmes ND, Griffiths R, Pott M, Alifano A, Will D, Wegmann AS, Russell JC (2015) Factors associated with rodent eradication failure. Biol Conserv 185:8–16

Jaksić FM (1982) Inadequacy of activity time as a niche difference: the case of diurnal and nocturnal raptors. Oecologia 52:171–175

Lehmann U (1976) Short-term and circadian rhythms in the behaviour of the vole, *Microtus agrestis* (L.). Oecologia 23:185–199

Lioy S, Mori E, Wauters LA, Bertolino S (2016) Weight operated see-saw feeding hoppers are not selective for red squirrels when greys are present. Mammal Biol 81:365–371

Liro A (1974) Renewal of burrows by the common vole as the indicator of its numbers. Acta Theriol 19:259–272

Lisická L, Losík J, Zejda J, Heroldová M, Nesvadbová J, Tkadlec E (2007) Measurement error in a burrow index to monitor relative population size in the common vole. Folia Zool 56:169–176

Lourenço R, Penteriani V, del Mar DM, Marchi-Bartolozzi M, Rabaça JE (2011) Kill before being killed: an experimental approach supports the predator-removal hypothesis as a determinant of intraguild predation in top predators. Behav Ecol Socibiol 65:1709–1714

Marks CA, Bloomfield TE (2006) Home-range size and selection of natal den and diurnal shelter sites by urban red foxes (*Vulpes vulpes*) in Melbourne. Wildl Res 33:339–347

Miller RS, Elton C (1955) Activity rhythms in the wood mouse, *Apodemus sylvaticus* and the bank vole, *Clethrionomys glareolus*. Proc Zool Soc London 125:505–519

Molsher RL, Gifford EJ, McIlroy JC (2000) Temporal, spatial and individual variation in the diet of red foxes (*Vulpes vulpes*) in Central New South Wales. Wildl Res 27:593–601

Monterroso P, Alves PC, Ferreras P (2013) Catch me if you can: diel activity patterns of mammalian prey and predators. Ethol 119: 1044–1056

Mori E, Nourisson DH, Lovari S, Romeo G, Sforzi A (2014a) Self-defence may not be enough: moonlight avoidance in a large, spiny rodent. J Zool (Lond) 294:31–40

Mori E, Menchetti M, Dartora F (2014b) Evidence of carrion consumption behaviour in the long-eared owl *Asio otus* (Linnaeus, 1758) (Aves: Strigiformes: Strigidae). Ital J Zool 81:471–475

Mori E, Menchetti M (2019) Living with roommates in a shared den: spatial and temporal segregation among semifossorial mammals. Behav Proc 164:48–53

Mukherjee S, Zelcer M, Kotler BP (2009) Patch use in time and space for a meso-predator in a risky world. Oecologia 159:661–668

Nagy KA (1987) Field metabolic rate and food requirement scaling in mammals and birds. Ecol Monogr 57:111–128

Nichols JD (1992) Capture-recapture models. BioScience 42:94–102

Osella G, Montolli A (1986) La micromammalofauna di una stazione planiziaria piemontese. Hystrix 1:119–136

Patriarca E, Debernardi P (1997) Insectivora, Chiroptera, Lagomorpha, Rodentia and Carnivora of the Gran Paradiso National Park: checklist and preliminary ecological characterization Ibex. J Mount Ecol 4:17–32

Penteriani V, del Mar DM, Campioni L, Lourenço R (2010) Moonlight makes owls more chatty. PLoS One 5:e8696

Prugh LR, Golden CD (2014) Does moonlight increase predation risk? Meta-analysis reveals divergent responses of nocturnal mammals to lunar cycles. J Anim Ecol 83:504–514

Ranchelli E, Barfknecht R, Capizzi D, Riga F, Mazza V, Dell'Agnello F, Zaccaroni M (2016) From biology to management of Savi's pine vole (*Microtus savii*). Pest Manag Sci 72:857–863

Rowsemitt CN (1986) Seasonal variations in activity rhythms of male voles: mediation by gonadal hormones. Physiol Behav 37:797–803

Salvioni M (1988a) Rhythmes d'activitè de trios espèces de *Pitymys*: *Pitymys multiplex*, *P. savii* and *P. subterraneus* (Mammalia, Rodentia). Mammalia 52:483–496

Salvioni M (1988b) Home range and social behaviour of three species of European *Pitymys* (Mammalia, Rodentia). Behav Ecol Sociobiol 22: 203–210

Soe E, Davison J, Süld K, Saarma U (2017) Europe-wide biogeographical patternsin the diet of an ecologically and epidemiologically important mesopredator, the red fox *Vulpes vulpes*: a quantitative review. Mammal Rev 47:198–211

Somogyi BA, Horvàth GF (2018) Seasonal activity of common vole (*Microtus arvalis*) in alfalfa fields in southern Hungary. Biologia 74:91–96. https://doi.org/10.2478/s11756-018-0149-8

Speakman JR (1999) The cost of living: field metabolic rates of small mammals. Adv Ecol Res 30:177–297

Umhang G, Richomme C, Boucher JM, Guedon G, Boué F (2013) Nutrias and muskrats as bioindicators for the presence of *Echinococcus multilocularis* in new endemic areas. Vet Parasit 197:283–287

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.