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Spatial density of two sympatric species Yellow-necked Mouse *Apodemus flavicollis* and Bank Vole *Clethrionomys glareolus* in different environment

Ivan Baláž[1*], Imrich Jakab[1], Filip Tulis[1], Michal Ambros[2]

[1]Department of Ecology and Environmental Science, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Trieda A. Hlinku 1, 949 74 Nitra, Slovak Republic
[2]The Protected Landscape Area Ponitrie, Samova 3, State Nature Protection SR, 949 01 Nitra, Slovak Republic

Abstract

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The impact of two different environments (climax forest and glade) on spatial density of Yellow-Necked Mouse and Bank Vole was studied during the years 2011–2013. Species range (95% Kernel) of both species was calculated based on data obtained from live traps placed in trap grids. Eight levels of density probability that surround regions of constant probability density were used to define (i) activity centres of observed species and (ii) areas that tended to be of rather peripheral interest. Results suggest that glade with rich herbal-ground cover represented significantly more suitable habitat, as well as habitat richer in resources for Bank Vole in comparison to climax forest. In contrary, Yellow-necked Mouse had provably the highest spatial density in climax forest habitat where was lack of herbal-grounded cover typical for the glade. In particular, we suggest that different diet specialization may be one of elements in explaining the different spatial density.

Keywords

Bank Vole, climax forest, Glade, spatial activity, Yellow-necked Mouse

Introduction

Distribution of organisms in the landscape is not coincidental and placement pattern of individuals is an important question of ecology (Krebs, 1999). Movement of small mammals in their environment is conditioned by factors as resources obtaining, (Quin et al., 2000; Lin et al., 2004), population density (Tioli et al., 2009), predators avoiding (Norrdahl and Korpimäki, 1998; Yunger, 2004; Fey et al., 2010) and intraspecific or interspecific competition (Myllymäki, 1977; Norrdahl and Korpimäki, 1993), need of social interaction and reproduction (Bujalska, 1973; Madison, 1980), as well as by structure (Diffendorfer et al., 1995; Cartar et al., 1997; Russell et al., 2007) and disturbance of habitat (Jacob and Hempel, 2003; Horváth and Herczeg, 2013).

The common methods for small mammal's investigation used captured-mark-recapture technique (CMR) in live traps grid. This investigation brings data about movement, but mainly about population density estimation. However, to get estimates of population density we need to determine the area occupied by the population members (Krebs, 2011). The kernel density estimation method (KDE) represents techniques where density estimate is derived from the proximity of observation to each evaluation point. Evaluation points may be the observations themselves, or a regular grid laid over the sample (Seaman et al., 1998). KDE is currently the most widely used home range technique, where

*Corresponding author:
e-mail: ibalaz@ukf.sk

observations are represented by sequential locations of individuals (Seaman and Powell, 1996). The next possible usage of KDE is analysis of species range, where observation are single locations of different individual organisms (Seaman et al., 1998). KDE produces two types of contouring. While first one – volume contours connect regions of equal probability density function, the second – density contours surround regions of constant probability density (Roger and Carr, 1998). Density contours thus can be used to determine the area occupied by the population members and offer the possibility to identify high or low density areas.

Two studied rodent species, the Yellow-necked Mouse *Apodemus flavicollis* and Bank Vole *Cletrionomys glareolus* live sympatrically, and can be found in wide spectrum of habitats. From continual forest (Mitchell-Jones et al., 1999; Horváth et al., 2012a; Klimant et al., 2015), through fragmentation habitats (Rajska-Jurgiel, 1992; Stanko et al., 1996) and linear vegetation (Stanko, 1994; Miklós and Žiak, 2002) to open non-forest habitats like arable land (Heroldová et al., 2007). While Yellow-necked Mouse is typical granivore species (Marsh et al., 2001), and preferred different types of forest ecosystems, Bank Vole is considered as species with mixed foraging strategy, granivorous but mainly herbivorous (Hansson, 1983), and preferred wetter habitats with denser undergrowth. Next difference is fact, that *Apodemus flavicollis* is able to utilize space of habitat vertically as well as horizontally (Holišová, 1974; Hlôška, 1999).

The spatial ecology of *Apodemus flavicollis* and *Cletrionomys glareolus* has been well studied throughout its high abundance and large area of distribution (Korn, 1986; Koskela et al., 1997; Stradiotto, 2009; Vukićević-Radić et al., 2006; Bujalska and Grüm, 2013).

This study use untraditional view to spatial density of two sympatric small mammals' species. The aim of this study is to analyze effect of habitat to spatial density of Yellow–necked Mouse and Bank Vole. We assume that (i) Bank Vole prefers higher vegetation level and has higher spatial density in a glade habitat; (ii) Yellow-necked Mouse prefers forest ecosystem and has higher spatial density in an original climax forest.

Material and methods

Study area

Báb forest near Nitra consists mainly of oak and hornbeam trees. According to geobotanical map there are mainly turkey oak forests (*Quercion confertae-cerris*) and Pannonian oak-hornbeam forests (Michalko et al., 1986). Forest community is included in the unit *Carpion betuli* and the association *Primulae veris-Carpinetum*. Forest is located in the southern part of Nitra undulating country on surface area of 66 ha. It is a high productivity area enclave surrounded from each side by cultivated land.

Study of small mammals was realized in two quadrats of Bab forest. First quadrat was situated in original part of forest – climax oak-hornbeam forest, second quadrat was situated in glade habitat in initial successive stage (Fig. 1).

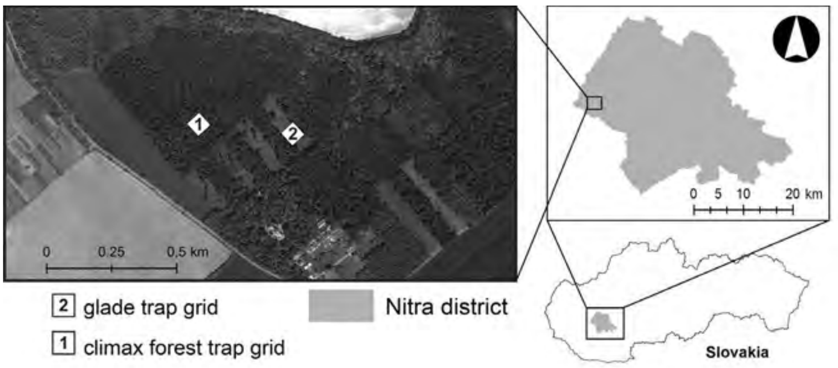

Fig. 1. Localization of two live traps grid.

Rodent research methods

Small mammals were captured simultaneously in two trap grids by CMR – capture-mark-recapture method in course of years 2011–2013. Each trap grid consisted of 49 trapping points placed in 7 rows and 7 columns, 10 m apart from each other. Metal live traps were used with cereals and apple as a lure. 13 three-days trappings were effectuated (3,822 trap/nights). Traps were controlled two times per day. Individuals were marked with numbered ear tags. The age, sex and mass were recorded at each capture.

Density of distribution

The annual summary of trapping data was used to calculate the probability of density occurrence. The kernel density estimation isopleths were generated with Home Range Extension (Rogers et al., 1998), module for ArcView 3.2 from CMR data. Fixed kernel estimation using reference smoothing parameter (Worton, 1995; Seaman et al., 1999) was used to calculate cumulative species range for whole study time. Analyses produce 8 isopleths, which surround regions of constant probability density. Moving inward from the outermost isopleths, which surrounds 1/8× the maximal probability density function value, each successive isopleth surrounds an additional 1/8× the maximal probability density function value. Thus, the innermost contour line encompasses 7/8× the maximal probability density function value (Roger and Carr, 1998). Analyses thus produced 8 isopleths – levels of density occurrence probability (LoDP). Level 8, represents center of species occurrence, with the highest probability of species occurrence and level 1 represents total area of species utilization – species range and patch with the lowest species occurrence within study trapping grid. ArcMap 10.0 was used for density maps visualization.

Statistical analyses

Total density of each trapping quadrat was calculated as average of density over all the years of monitoring, where year density was calculated as an average of all isopleths densities. STATISTICA 8.0 portable software (StatSoft Inc., 2007) was used for graphs and surface plots creation and t-test with the significance level 0.05 was used for total density differences calculations.

Results

Altogether, 711 of small mammal's individuals were caught, formed by 8 species. The Yellow-necked Mouse and Bank Vole represent dominant part of small mammals´ community in both habitats during whole three years. The year proportion of captured adults and also recaptures of individuals varied between years (Fig. 2). The Yellow-necked Mouse was more abundant species in both studied habitats during the years 2011 and 2013. In 2013 the proportion of Bank Vole in small mammals´ community increased and its abundance in both habitat was more similar to the abundance of Yellow-necked Mouse.

Results of species ranges that represent 1. LoDP (Fig. 3), and that are identical with 0.95 isopleths (i.e. 95% kernel) in this case, show that both species utilised whole area of trapping plot in both habitats. An exception was Bank Vole that did not utilise the edge part of glade quadrat. While 1.

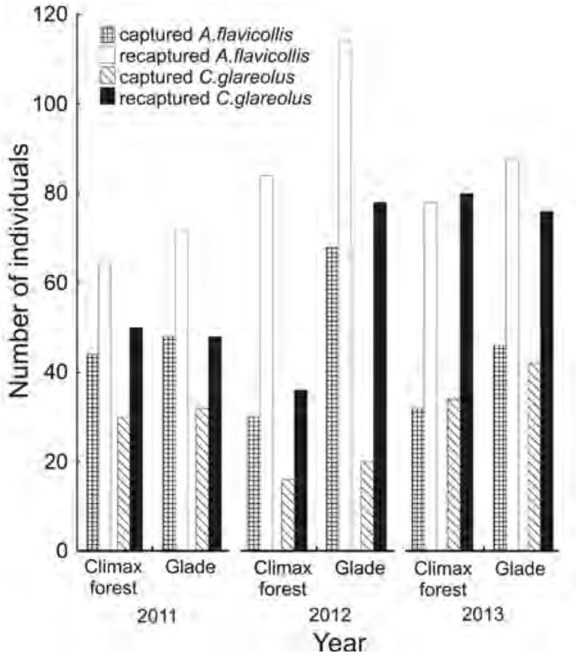

Fig. 2. Proportion of captured and recaptured *Apodemus flavicollis* and *Clethrionomys glareolus* in two habitats during the years 2011–2013.

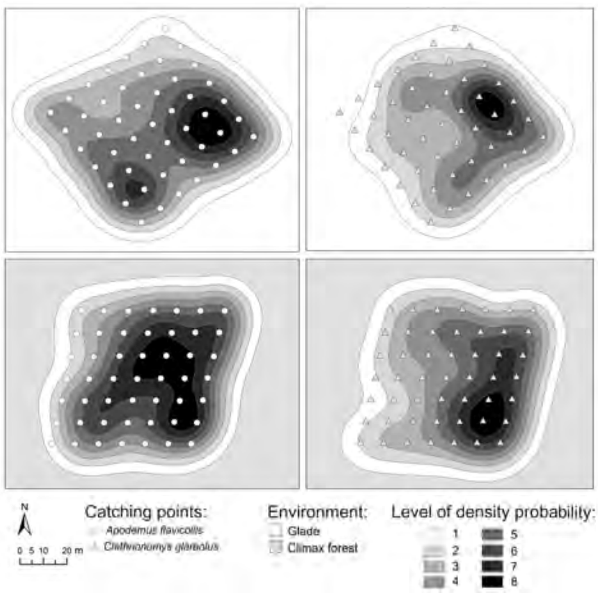

Fig. 3. Occurrence frequency of species *Apodemus flavicollis* and *Clethrionomys glareolus* within a trapping plot in forest cover and in glade.

LoDP of species range suggests identical utilisation of whole monitored quadrats, in other LoDP, which surround regions of constant probability density, we can observe different density of species occurrence in particular parts of traps grid (Fig. 3). This way we can observe activity centres (8. LoDP) of particular species in monitored traps grid, i.e. areas with higher impact on species occurrence, as well as areas that tended to be of rather peripheral interest for them.

As it was expected in both habitats, spatial density of species occurrence of both species decreased with increasing size of area occurrence and changing LoDP.

The highest total values of spatial density of occurrence were observed within bank vole (mean: 3.6-04 ± 2.2E-05 SD in level 8) in glade habitat where it utilised the smallest area 162.8 m^2 ± 24.5 SD (Fig. 4-2). Within this species was also observed the smallest total area utilised (mean: 5,680.6 ± 197.6 SD in level 1) in monitored quadrat. The glade area utilised by bank vole had in all LoDP the highest spatial density utilised (in average 2.0 ± E-04 72.1% ± 2.6SD) (Fig. 5) in comparison to all of the other objects. On average, only 27.9% ± 2.6 SD of utilised glade area had low spatial density (<9.0 E-05).

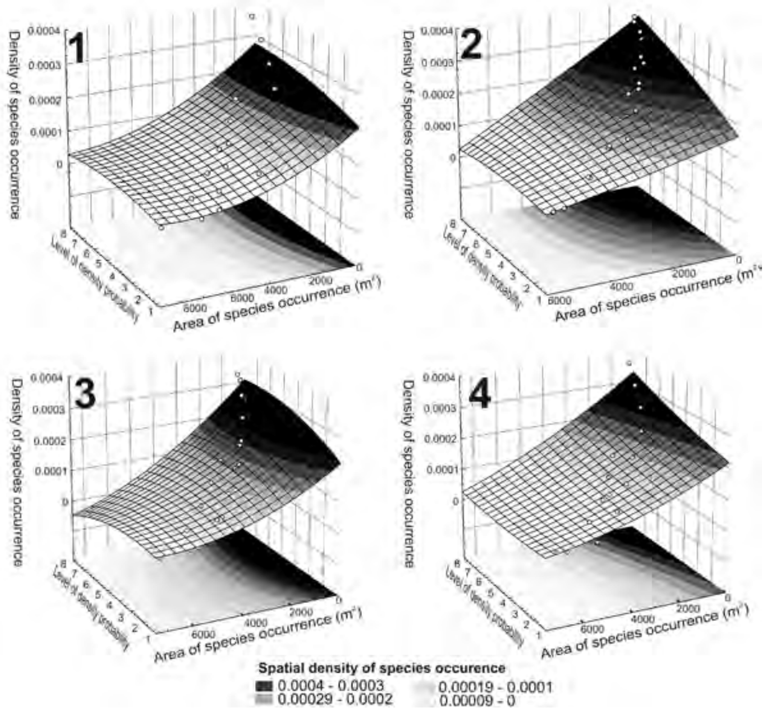

Fig 4. Relationship between spatial density of species occurrence and area of species occurrence size in particular LoDP for each species and habitat (1 – *Apodemus flavicollis* in glade, 2 – *Apodemus flavicollis* in climax forest, 3 – *Clethrionomys glareolus* in glade, 4 – *Clethrionomys glareolus* in climax forest).

In contrary, bank vole in climax forest reached the lowest spatial density (mean: 3.1E-04 ± 5.1E-05 SD in level 8), however, in the area with average surface of 378.5m^2 ± 279.2 SD (Fig. 4-4). The total surface utilised (level 1) by bank vole in forest habitat was higher than in glade (mean: 6,373.1 m^2 ± 847.7 SD), however, its total spatial density was significantly lower (Fig. 5) than the one of bank vole in glade (t-test: t = 3.59, DF = 23, n = 24, P = 0.002). On average, up to 40.4% ± 4.4 SD of utilised forest area had low spatial density of species occurrence (<9.0 E-04).

Spatial density of yellow-necked mouse within activity centre in glade reached the lowest values among all areas and species observed (mean: 2.7 E-04 ± 7.68E-05 SD in level 8). Area of activity centre (level 8) was on average 217 m^2 ± 71.9 SD and during the period of 3 years in cumulated species range was the activity centre divided into two parts (Fig 3). Total surface area utilised in glade (level 1) was 7,463.1 m^2 ± 1,306.5 SD (Fig. 4-1) which represents the largest surface utilised among all of the subjects observed. In contrary, total density of occurrence in glade reached the lowest values (Fig. 5). The area with low spatial density of species (< 9.0 E-04) in this case represented up to 50.7% ± 6.0 SD.

Yellow-necked mouse average spatial density in forest activity centre (level 8) reached 2.9 E-04 ± 4.3 E-0.5SD on surface of 261.7 m^2 ± 66.1 SD (Fig. 4-1). Total forest habitat area utilised by species was 6,415.7 m^2 ± 460.9 SD. Total spatial density of yellow-necked mouse in forest (Fig. 4-2) was partially higher than in glade (t-test: t = –1.94, DF = 23, n = 24, P = 0.06). Area with low occurrence density of species (<9.0 E-04) represented 40.7% ± 2.35 SD of utilised forest area..

Distribution of data (Fig. 4) suggests the lowest annual variability of spatial density and area utilised in particular LoPD of bank vole in glade.

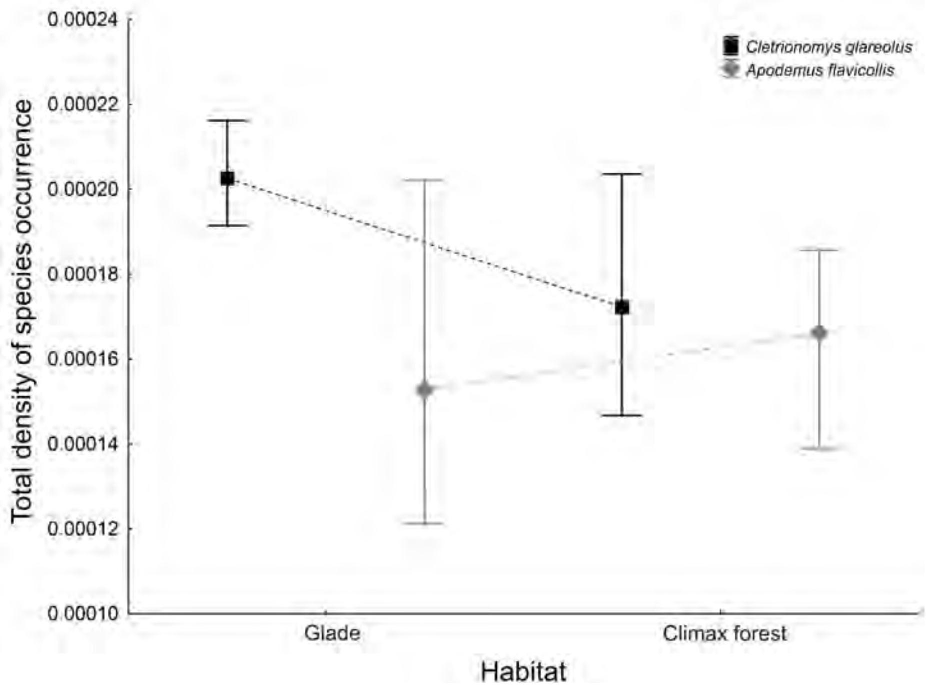

Fig. 5. Differences in total density of species occurrence for each species and habitat (mean ± min-max).

Discussion

Number of both species observed during the years 2011–2013 varied, which is fully in compliance with population ecology of studied species (Oksanen et al., 2000; Horváth et al., 2012a). Demographic deviations in population size of both species are typical during the year (Gliwicz, 1988), as well as in annual comparison (Pucek et al., 1993; Horváth et al., 2012a). Factors stimulating these deviations are changes in food availability (Jensen, 1982), changes of water level (Horváth et al., 2012a), over-wintering survival (Pucek et al., 1993), disturbance of habitats (Horváth et al., 2012b), etc. However, decreasing population density leads to higher spatial activity (Wolff, 1993; Mazurkiewicz and Rajska-Jurgiel, 1998). Spatial density of bank vole and yellow-necked mouse is yet as well conditioned by age, sex, or phase of reproduction activity of individuals (Koskela et al., 1997; Bujalska and Grüm, 2013), by food availability (Tioli et al., 2009; Stradiotto et al., 2009), occurrence of some predators (Jadrzejewski et al., 1993), or by other species of small mammals (Ylönen, 1990).

Structure of habitat has a significant impact on movement and density of small mammals (Diffendorfer et al., 1995; Cartar et al., 1997; Russell et al., 2007). Impact of habitat on spatial density has become noticeably evident in our study within bank vole which had highest total density in glade area and the highest spatial density on the smallest surface in activity centre (level 8). In contrary, it had provably lower total density in forest and lower density in activity centre as well, where it, however, utilised larger surface area.

For bank voles, very dense forest without undergrowth is unsuitable, because it needs a certain level of shading to survive (Wrangel, 1940). The Bank vole is considered as species with mixed foraging strategy – granivorous-florivorous (Hansson, 1983). It is a polyphagous animal that eats seeds, fruits of trees and bushes and plants (Gebczynska, 1983). Bank vole prefers more humid biotopes with more dense undergrowth (Turček, 1953a; Turček, 1953b). All these facts together with our results, and with the fact that if needed bank vole is able to move for more than 1,000 m (Szacki and Liro, 1991) suggested that the glade in successive stage with copious herbal layer is more optimal and preferable habitat for bank vole than climax forest with lack of herbal-ground cover.

Yellow-necked mouse occupied the largest glade surface but its total density was actually the lowest recorded. In contrary, this species occupied smaller area in forest, however, with partially higher total density than in glade. Larger activity centre also shows the higher preference of climax forest with higher average density compared to the glade.

However, spatial activity could be distorted by the fact that yellow-necked mouse uses the area of habitat vertically, as well as horizontally (Balát and Pelikán, 1959; Holišová, 1974; Hlôška, 1999; Puchala, 2004). Borowski (1963) observed movement to treetops up to 6–7 m of height, and rarely more than 20 m. Štěpánková and Vohralík (2009) point out that it is the climbing up the tree of yellow-necked mouse that is an important part of spatial activity and that this fact has to be taken into consideration also in the study of ecology of this species.

Yellow-necked mouse is characterized by greater mobility and is strictly depended on the forest environment (Montgomery and Gurnell, 1985). It is granivore species, is predominantly a seed eater (Droźdź, 1966). The most important components of its food are big seeds of the conifers (Turček, 1957; Montgomery and Gurnell, 1985; Marsh et al., 2001) representing high-calorie and digestible food with the low content of cellulose. These characteristics of species together with our results suggest that climax forest low in herbal-grounded cover is more suitable and more preferred habitat for yellow-necked mouse.

Previous research on small animals (e.g. *Apodemus flavicollis*) has demonstrated that space use varies with resources, with home ranges typically being smaller when food was abundant and population density was high (Falls et al., 2007; Merritt et al., 2001). This confirms a decrease in size of activity centers for both species in preferred habitat types (climax forest for *Apodemus flavicollis*, glade for *Clethrionomys glareolus*) that provide optimal foraging offer.

Based on our results of spatial analysis, and also according to different preferred food, we can conclude that there is no avoiding between the yellow-necked mouse and the bank vole. Yellow-necked mouse and bank vole either utilized different parts of the study area or they shared it in such a way that when there was high abundance of one species, there was an absolute minimum of the other (Rödl, 1974; Bujalska and Grüm, 1989). Horváth and Wagner (2003) studied coexistence of yellow-necked mouse and bank vole in forest habitats and they concluded that bank vole had a limiting effect on the density and spatial distribution of yellow-necked mouse. Horváth et al. (2012a) recorded also the different preference of habitats between bank vole and wood mouse. However, interspecific competition was not the subject of our research. There might be some direct and indirect competitive interactions between the two species (Andrzejewski and Olszewski, 1963; Wójcik and Wolk, 1985), but no quantitative effects of the possible competition on population dynamics of either species have been observed (Pucek et al., 1993). However, detailed study of species range overlapping and interspecific competition could be aim of next study.

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