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Estimation of *Muscardinus avellanarius* population density by live-trapping

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Abstract. Common dormouse (*Muscardinus avellanarius*) density in Transylvanian Plain is investigated using live-traps. Estimated population size is 39 individuals. Results using non-spatial methods combined with *ad hoc* calculations of the effective trapping area overestimated common dormouse density, both when using the naïve density estimation (27 ind./ha) and also when the "edge-effect" was accounted for by the addition of a boundary strip (16 ind./ha). Compared with published results using the same methods, our results are yet significantly higher. Spatially explicit capture-recapture approach yields lower density, of 13 ind./ha (maximum likelihood estimate), but still one of the highest densities reported for the species. Interspecific competition for traps was negligible at our study site.

Key words: common dormouse, population size, SECR, effective trapping area

Introduction

The common dormouse (*Muscardinus avellanarius* Linnaeus, 1758) is a nocturnal, arboreal and elusive rodent species. With such species, that are difficult to observe and count directly, capture methods are used when there is a reasonable chance of capturing them (Lancia et al. 1994). Population parameters such as size and density of the common dormouse are usually estimated using capture-recapture data collected using regular checks of nestboxes and live-trapping (review in Juškaitis 2014). Nestboxes used as a capture method to estimate the species population size might, in some cases, result in underestimation of the population or it may induce actual population changes. Population size and density may be artificially elevated by providing artificial nest holes (nest boxes), mainly when set in high-density grids (Morris et al. 1990, Juškaitis 2005), thus failing to provide an estimation of the natural density of the species. Live-trapping, although more seldom used, excludes the positive effect of nest boxes on dormouse density (Juškaitis 2014) and can be successfully implemented to estimate population density (Berg & Berg 1999). It also seems that in some cases the nestboxes are not used as shelters by the whole dormouse population, resulting in underestimation of population size compared to live-trapping (Vogel et al. 2012). In areas where several dormouse species coexist, competition may play an essential role in common dormouse use or avoidance of nestboxes (Bakó & Hecker 2006, Sevianu & Filipaş 2008). Competition for traps was also reported with *Apodemus* species (Vogel et al. 2012).

The classical, widely used approach to estimating population density from capture-recapture data is to divide the estimated population size by an estimated (calculated) effective trapping area (e.g. Otis et al. 1978). However, this method has a major deficiency: the estimated population size is not functionally related to the sample area (Royle et al. 2014). This method does not, in fact, estimate the effective trapping area (Shanker 2000), which is usually calculated arbitrary (Royle et al. 2014). The lack of accurate calculation of the sample area may result in severely overestimated densities of the common dormouse (Juškaitis 2014).

A novel approach to estimate population density, based on capture-recapture data, was developed (Efford 2004). The spatially explicit capture-recapture (SECR) method fits a spatial model of the detection process to capture-recapture data that include the locations where each animal was captured and does not need to calculate the effective trapping area (Efford 2004, Borchers & Efford 2008, Royle et al. 2014).

Our study aims to estimate population density of the common dormouse using capture-recapture

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data obtained by live-trapping, thus avoiding any possible influence on natural population density. The main objectives are to estimate common dormouse population density using both non-spatial (classical) methods and the spatially explicit (SECR) methods and to critically analyze the results in an attempt to propose a more accurate method for estimating natural common dormouse density.

Material and Methods

Study area is located in the Transylvanian Plain, Romania, and it is covered by 400 ha of woodland, mainly sessile oak (*Quercus petraea*), hornbeam (*Carpinus betulus*) and Turkey oak (*Quercus cerris*) mixed with poplars and lime trees, and with several compact areas planted with pines. The woodland consists of 24 sections, different in size, age and composition. We captured dormice using live traps that were set close the northern edge of the woodland (46°59′27.40″ N, 24°1′30.00″ E, 310 m a.s.l.), in a young oak stand mixed with hornbeam, with a well-developed shrub layer, consisting mainly of hazel *Corylus avellana*, European cornel *Cornus mas*, spindle *Euonymus europaeus*, elder *Sambucus nigra* and common privet *Ligustrum vulgare*, beyond which (in the North direction) there were pastures and agricultural land. Common dormouse population size and density were investigated using a grid of 49 wooden live-traps (18 × 7.5 × 9 cm), baited with slices of apple, various seeds and jam. The traps were set on tree branches, 2-2.50 m high, 20 m apart from each other, thus resulting a square trapping grid that covered 1.44 ha. Traps were active for three days during May 2013. All captured animals were individually marked by ear tattoo.

Capture data was analyzed using Density 5.0.3 software (Efford 2012) to estimate population parameters in two entirely different ways: classical, non-spatial methods and spatially explicit capture-recapture (SECR) methods.

Non-spatial population size (N-hat) refers to the closed population estimator (Otis et al. 1978). Population size was estimated by fitting the heterogeneity model M_h to our data, using the jackknife procedure. The model selection was performed by calling the program CAPTURE (White et al. 1978) from Density 5.0.3 software. This estimator assumes capture probability to vary by individual animal (Otis et al. 1978). Major sources of heterogeneity in animal populations are the exposure to the trap array and the home range size (Royle et al. 2014). For the classical (non-spatial) method of estimating density we used population size in combination with two assessments of the effective trapping area (N-hat/ETA). First, we used the naïve density estimator, considering that the area covered by traps represents the effective trapping area (1.44 ha), a method widely used in estimating common dormouse density (or at least a boundary strip is not indicated in the description of the method, see review in Juškaitis 2014). Next, we added to the area covered by traps a boundary strip with the width calculated as half of the mean maximum distance moved by dormice between traps (1/2 MMDM) (Wilson & Anderson 1985, Juškaitis 2006, Juškaitis 2014), a standard approach (Royle et al. 2014), to reflect the area beyond the limit of the trapping grid that potentially is contributing individuals to the sampled population (Otis et al. 1978) and to compensate for the “edge effect”: at least some sampled individuals have home ranges that extend beyond the edges of the sampling grid, but they are counted as if they reside only within the trapping grid (Dice 1938).

Spatially explicit capture-recapture (SECR) method incorporates spatial ecological processes into the model and regards the animal probability of being captured in any particular trap as a decreasing function of the distance between the home range center and the position of the trap (Efford 2004). Decline in detection probability with the distance between a trap and a home range center can be inferred from the clumping of locations at which each individual is captured, thus requiring that some individuals are recaptured at different locations (Efford & Fewster 2013). Density is a software developed for fitting SECR models based on simulation and inverse prediction (Efford 2004, Efford et al. 2004) and maximum likelihood (ML) estimation (Borches & Efford 2008) to spatial individual encounter data. We used maximum likelihood estimator which is more flexible than the simulation method (Borches & Efford 2008). The SECR approach allows for estimating population density directly from trapping data, without prior estimating the population size and the effective trapping area (Efford 2004, Borches & Efford 2008, Efford et al. 2009) (for a review of SECR see Royle et al. 2014).

Results

During our study, over the course of 147 trap-nights, 24 common dormice were captured in 32 captures, with eight recaptures. One individual was recaptured two times and six individuals were recaptured only once. All captured individuals were adults, as the trapping was done early in the season. Capture probability was 0.28 (per occasion) and 0.64 (overall). Two other rodent species were captured during our study: forest dormouse (*Dryomys nitedula*) (three captures), and *Apodemus* sp. (two captures). The capture rate was 21.76 captures/100 trap-nights for the common dormouse, 2 captures/100 trap-nights for the forest dormouse and 1.3 captures/100 trap-nights for *Apodemus* species.

The non-spatial estimated size of the common dormouse population (N-hat) was 39 individuals (SE = 5.8, 95 % CI). The mean maximum distance moved (MMDM) by recaptured common dormice was 38 m (SE = 11).

The calculated effective trapping area (ETA) was 1.44 ha when no boundary strip was added to the trapping grid (naïve density) and 2.46 ha when a boundary strip with the width equal to half of the mean maximum distance moved (1/2 MMDM) was added to the area covered by traps (buffering).

Density estimates based on non-spatial methods, using the two different ETAs, and applying spatially explicit methods, yielded different results. Naïve population density estimation gave a result of 27.09 ind./ha (SE = 4.00). Increasing the effective trapping area by adding the 1/2 MMDM boundary strip, the estimated density was 15.81 ind./ha (SE = 3.15). Spatially explicit CR model using maximum likelihood estimator generated the lowest common dormouse density of 12.91 ind./ha (SE = 4.82).

Both non-spatial density estimates (no boundary strip, 1/2 MMDM boundary strip) gave higher densities results than the SECR method.

Discussion

The capture rates of the other two rodent species, compared with the common dormouse, were very low during our research. Other studies showed that traps may be oversaturated by *Apodemus*, up to 100 %, even when set in trees (Vogel et al. 2012), making them useless for trapping dormice. We captured only two *Apodemus* individuals, although they seemed to be abundant in the Transylvanian Plain, and easily trapped on the ground (Sevianu & Coroiu 2005). The low *Apodemus* capture rate could be the result of natural low spring population numbers for both *A. sylvaticus* and *A. flavicollis* (Fernandez et al. 1996, Suchomel & Heroldová 2006). Interspecific competition for traps set on tree branches had a negligible (if any) negative effect on the capture rates of the common dormouse during our study.

The population size parameter is not functionally related to any notion of the sampled area, perhaps unless the trapping array covers the entire study area (Royle et al. 2014). Our estimated common dormouse population size (N) of 39 individuals could not possibly represent the entire population, as the trapping grid covered less than 1 % of the study area. In order to get a sense of the real population size, density should be estimated instead and then extrapolated (Royle et al. 2014). The traditional approach is to convert N to density by dividing it to an independently calculated effective trapping area (ETA), that cannot be estimated by capture-recapture (Efford 2004, Royle et al. 2014). The method used to calculate ETA has a profound effect on the estimated density (Foster & Harmsen 2011) and various authors, acknowledging that, started to report multiple density estimates obtained using different values of ETA (area delimited by traps; addition of a boundary strip of various widths), including studies on common dormouse (Juškaitis 2014). Although this approach in estimating population density is reportedly not robust (Foster & Harmsen 2011, Royle et al. 2014), we applied this method to our capture-recapture data, in order to compare our results with previous published data obtain in a similar manner, and also with our SECR results.

Using the naïve density estimate, our result of 27 ind./ha is likely to be severely overestimated (Dice 1938, Tanaka 1980, Wilson & Anderson 1985, Juškaitis 2006), but compared to published results that also do not account for the “edge effect”, and therefore also possibly severely overestimated, our result is still 1.7 times higher than the highest densities reported: 16 adults/ha in Lithuania (Juškaitis 2006) and 15.6 adults/ha in England (Bright & Morris 1990) (for a review of common dormouse densities, see Juškaitis 2014). Both studies used nestbox checks coupled with live-trapping.

Adding a boundary strip to the area covered by traps gave, as expected, results less positively biased (Wilson & Anderson 1985). The width of the boundary strip is usually determined based on half the home range size or half the distance moved by animals (MMDM), the two parameters being correlated (Mendel & Vieira 2003) and both dependent on population density (Juškaitis 2014). We found that our density estimate was still two times higher than published results based on the same methods of calculating ETA: 7.1 ind./ha (Juškaitis 2006) and 6.7 ind./ha (Berg & Berg 1999).

The traditional non-spatial methods based on translating population size (estimated by capture-recapture) into density does not provide a coherent basis for estimating population density, because it eliminates the space factor from the capture data (Royle et al. 2014), and the *ad hoc* calculations of the width of the boundary strip based on the distance moved between captures are not reliable (Foster & Harmsen 2011). The detected animal movement, on which the calculation of the boundary strip is based, is a function of specific trap spacing and may have an effect on estimating distance moved (Tanaka 1980).

The SECR maximum likelihood density estimate obtained during our study, 13 ind./ha, is lower than both our non-spatial density results (no boundary strip, boundary strip added). The SECR model basically links the capture data of individuals with the notion of space, providing the possibility of estimating density directly, knowing when and where each animal was captured (Royle et al. 2014). The approach excludes the need for arbitrary calculating the area related to the estimated population size (Efford 2004), thus eliminating the uncertainty related to the effective trapping area.

The estimated density of 13 ind./ha from our SECR analysis is still one of the highest density previously reported in literature for the species, regardless of the method used. We used live-trapping, so the effect of nestboxes on density was eliminated, and the results were analyzed applying different methods, but nevertheless, density estimates of our study are situated at the high end of the previously reported values. Such high densities may be the result of trapping in optimal habitat (Juškaitis 2014), so the data might not be applicable to the entire woodland and needs further investigation. The high standard error of our estimated densities indicates a low precision of the results, and that could be improved by aiming for a higher number of recaptures (Efford et al. 2004) being desirable to obtain at least 10 recaptures, preferably 20 (Efford et al. 2009). In our study we had only eight recaptures, so we recommend in further studies to extend the trapping period to five nights and to increase the number of traps to at least 64 (8 × 8 trap grid) in order to try to obtain the suggested number of recaptures.

The non-spatial approach overestimated common dormouse density, even when trying to account for the "edge effect" by adding an *ad hoc* calculated boundary strip to the area covered by the trapping grid. The spatially explicit model provided a lower estimate, but still a very high density for the common dormouse.

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