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Presence-absence-based modelling and estimations in the population and community-level investigation of small mammals

PhD Thesis

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I. Introduction and aims

All over the world, including Hungary, fragmentation and habitat loss of natural and semi-natural areas pose a great challenge for conservation biology and practical nature protection as well (Wilcove et al. 1986, Báldi 1996, Buchmann et al. 2013). Fragmentation has great impact on wetlands, which areas have been dramatically decreasing in the past decadesmaking them very sensitive to little changes in the climatic conditions. Nevertheless, we can find diverse communities in these wetlands (Gibbs 2000, Mitsch & Gosselink 2000, Balcombe et al. 2005), which are important habitats for water tolerant small mammals (Krištofík 2001, Michelat & Giraudoux 2006, Scott et al. 2008). Over the past decades, the vulnerability of forested areas was rapidly growing not only in Europe but also all over the planet. Therefore, the protection and conservation of these diverse biotopes are the most pressing concern of nature protection (Terborgh 1992, Myers 1996). Small mammals, as prey species, play an important role in forest ecosystems, and as granivores they have great influences in the ecological processes (Hsia & Farncl 2009, Bricker et al. 2010, Wróbel & Zwolak 2013).

It is an important factor in the examination of small mammals that non-detection of the target species does not mean they are truly absent (Takekawa et al. 2003). MacKenzie et al. (2002, 2003) developed a framework, which is based on detection/non-detection data and easily applicable to assess the occupancy dynamics and migratory events, when the probability of detection is less than one. Although, site occupancy is not a population parameter. It provides information about the status of a given population in a long-term monitoring context.

Site occupancy is also in focus of different ecological investigations such as community ecology. Therefore, it is often used as state variable or incidence function (i.e. Levins 1969, 1970; Lande 1987, 1988; Hanski 1992, 1994, 1997; Moilanen 1999, Almeida-Neto et al. 2007). One of the most important aims of community ecology is to describe the community structure (Gee & Giller 1987, Southwood 1996, Weiher & Keddy 1999), to evaluate the co-occurrence pattern (Gotelli 2000, Gotelli & MacCabe 2002, Lehsten & Harmand 2006) and to formulate testable null hypotheses (Gilpin & Diamond 1982, Gotelli & Graves 1996, Gotelli

2000, Moore & Swihart 2007). The nested pattern has been given considerable attention by community ecology from both theoretical and empirical perspectives (Báldi 2003, Higgins et al. 2006, Bloch et al. 2007, Ulrich et al. 2009). Only a few studies were published in connection with temporal nestedness (Gonzalez & Oliva 2006, Bloch et al. 2007, Azeria & Kolasa 2008, Florencio et al. 2011, Herczeg & Horváth 2015). The investigation of temporal nestedness can be particularly important from conservation aspect because we can observe the effect of perturbations occuring at different time points. Based on this we can develop appropriate habitat management.

The primary goal of the dissertation was to use methods that do not require individual marking and to evaluate them from population and community-level view. Furthermore, to use these methods for modelling, which aea based only on detection/non-detection data. Thus, we formulated the following main aims:

- How the various disturbances affect occupancy dynamics of the detected species (*Sorex araneus*, *Apodemus agrarius*, *Microtus oeconomus mehelyi*) from Kis-Balaton, representing three different taxa.
- In case of Kőszegi-forrás Erdőrezervátum, we examined the differences between the detected species (*Apodemus flavicollis*, *Apodemus sylvaticus*, *Myodes glareolus*) based on their site occupancy and detection probabilities.
- Furthermore, we wanted to test and evaluate if the Royle N-mixture method can be applied for population dynamics examinations of small mammals
- In community-level, we examined how the community ecological parameters and the temporal nestedness vary due to the different disturbances.

II. Materials and methods

Trapping was conducted on two different areas, namely Kis-Balaton and Kőszegi-forrás Erdőrezervátumban in Mecsek hills. In Kis-Balaton, we were trapping in two marshlands, where 36-36 sampling points were used. Each sampling point consisted more traps (3-4 pieces). There were 4–5 sampling occasions annually between 2007 and 2012 with five trapping-night periods. In case of Kőszegi-forrás Erdőrezervátum, 6×6 trapping grids with a total of 36 traps were used. The plastic box-type live-traps (75×95×180 mm) were placed 5 m from each other on both examined areas, thus the trap densities were the same. In the Erdőrezervátum, the trappings were carried out from April to September between 2010 and 2012. In 2010 and 2011 10 while in 2012 13 trapping grid were used.

The aim of site occupancy modelling is to estimate the probability with which at least one individual is presence on the examined area (MacKenzie et al. 2002). For this, we need the encounter histories of the sampling points. Encounter histories can be expressed by "1" and "0", indicating detection and non-detection of a given individual, respectively. The multiple-season occupancy model was used in the dissertation, which is based on Pollock’s robust design (Pollock 1982). This model has two more parameters **ε[t]** and **γ[t]** (MacKenzie et al. 2003). These two parameters are the local extinction (**ε[t]**) and the local colonization (**γ[t]**) between **t** and **t+1**. For instance, the probability of the 101 000 detection history can be calculated as:

$$\psi \times p_{1,1}(1-p_{1,2})p_{1,3} \times \{(1-\varepsilon_1)(1-p_{2,1})(1-p_{2,2})(1-p_{2,3})+\varepsilon_1\},$$

where there were no detection after the first period. **1-** $\boldsymbol{\varepsilon_1}$ means that the species was not detected. The multiple season model estimates the probability of site occupancy only for the first primary period. Based on the local extinction, colonization, and the detection probabilities the model calculates the site occupancy for subsequent periods as derived probabilities.

In case of Kis-Balaton, we used background variables such as natural and anthropogenic disturbances to take account their effects on site occupancy (Table 1.). We took into account the main effects of variables and their interaction as well.

Table 1. The backgrounds variables and their definitions.

Variable	Definition
Year (year)	of a given year
Season (season)	of a given season
Mowing (mowing)	0 = no mowing 1 = mowing
Water cover (water)	0 = no water cover 1 = water cover

Royle's N-mixture model was used to estimate the abundance of species (Royle 2004). The sampling design is similar as in case of occupancy model. The only difference is that the number of the captured individuals is recorded in the matrix. Let $\mathbf{n}_{it}$ the number of individuals in a given sampling point **i** and in a given sampling time **t**. In the matrix, the rows represent the sampling points while the columns represent the sampling times:

$$matrix_{n_{it}} = \begin{matrix} 0 & 2 & 5 \\ 0 & 0 & 2 \\ 1 & 4 & 3 \end{matrix}$$

For instance, the value of 5 in the top right corner means that we captured 5 individuals in the third sampling occasion in the first sampling point. This method assumes that the spatial distribution of the individuals is following Poisson distribution (Royle 2004). It also assumes that the detection of the individuals can described by Binomial distribution. Thus, we can model the abundance and the detection probabilities with the combined use of these two distributions (based on Royle (2004) lambda is equal with theta):

$$L(p,\Theta \mid \{n_{i,t}\}) = \prod_{i=1}^{R} \left\{ \sum_{N_i=\max_t n_{it}}^{\infty} \left(\prod_{t=1}^{T} Bin(n_{it}; N_i, p) \right) f(N_i;\Theta) \right\}.$$

For the site occupancy modelling RMark (Laake 2013) were used, which is a package for R (R Core Team 2013) and constructs model for program MARK (White & Burnham 1999). Models were ranked by Akaike's information criterion (Akaike 1973). For the estimation of abundance Presence software was used (Hines 2006). Nestedness Temperature Calculator

(NTC) (Atmar & Patterson 1993, 1995) and BINMATNEST (Rodriguez-Girones & Santamaria 2006) were used to examine the existence of nestedness pattern on community-level investigation of small mammals.

III. Results and discussion

At Kis-Balaton, the estimated occupancy probabilities were different between the examined three species. Similarely, differences were observed in the occupancy probabilities between the species in case of the two marshlands (Balatoni-, Keleti-berek) as well. These differences were greatly affected by natural and anthropogenic disturbances. Mowing not necessarily cause direct mortality in case of small mammals rather it eliminates the vegetation cover (Lin & Batzli 2001). The negative effect of mowing was the lowest in case of *A. agrarius* which can explain with the euriok and/or habitat generalist features of this species (Niethammer 1976). Mowing had greater effect on occupancy dynamics in case of root vole (*M. oeconomus mehelyi*) and common shrew (*S. araneus*). The site occupancy probabilities decreased for both species, while the strictly protected *M. oeconomus mehelyi* went locally extinct.

The occupancy dynamics were not different in case of the examined species of Kőszegi-forrás Erdőrezervátum. The highest occupancy value belonged to yellow-necked mouse (*A. flavicollis*) (~ 90%) while the other two species' probabilities were slightly lower (~ 75-80%). These high probabilities showed that this area provides optimal habitat for each species of this study. The estimated detection probabilities were not different. The average detection probability of yellow-necked mouse (*A. flavicollis*) was approximately 35% while this value was lower in case of bank vole (*M. glareolus*) (28%). The lowest value belonged to wood mouse (*A. sylvaticus*) (20%).

The estimated abundances of the three species were different. Based on our results, *A. flavicollis* was dominant, while the other two small mammals appeared as subdominant species. These results confirmed previous findings (i.e. Pucek 1983, Flowerdew 1985, Kalmár & Horváth 2002, Trubenová & Miklós 2007, Suchomel et al. 2009).

Based on the monthly data of the entire study period, the NTC and the BINMATNEST showed nested pattern. After the mowing, small mammals went locally extinct then they recolonized from the rescue patches. Therefore, the events of colonization-extinction created a regular sequence, which led to nestedness (Atmar & Patterson 1993). Different disturbances (mowing, flood) were acting on both areas during the studied six years. These changed the species composition through the structuring of small mammals assemblages.

Based on our results, the applied methods (occupancy models under MLE and the Royle's estimator), which are based on only detection/non-detection data, have great importance and are appropriate for various studies in population and community level as well. They have several advantages; only detection/non-detection data are necessary (no need to mark the individuals which is important in conservation aspect, too), they have fewer assumptions than the CMR method, do not require large effort, and numerous different sampling methods can be used and analysed together even if the data are collected in direct and/or indirect way.

IV. Conservation assessment

Mortelliti et al. (2010) emphasize that the current knowledge about loss and fragmentation of habitats in respect of European mammals is negligible. Therefore, there is a lack of information for the decision-making processes. They noted that the 67% of the examined studies (n = 73) were related to rodents, while only 4 papers were examined the effect of loss and fragmentation in case of shrews. Báldi et al. (1995) noted that there are only spatial data regarding to mammals of Hungary and for conservation of these species these information are not sufficient. The long-term conservation of species (and/or communities) is also important from nature protection aspect. This is especially true for those species (i.e. shrews) which occur only in such habitats (wetlands, grasslands) where the habitat fragmentation and/or degradation take place more rapidly. The applied methods, which are based on detection/non-detection data, have great importance allowing numerous different sampling methods to be used and analysed together (i.e. live trapping, hair tubes, and pellet analysis, etc.).

Kis-Balaton, as one of the largest wetland in Hungary, is considered as priority research and monitoring area (Petróczi & Magyari 2007). Based on the recent years field research and results, mowing and climatic conditions (rainy or drier weather period) became the two largest ecological constrains. Within the Balaton Uplands National Park, mowing as habitat management methods can properly design in space and time, therefore, we can take into account the ecological needs of the species. In contrast, it is hard to manage the mowing on the privately owned areas, where the strictly protected root vole (*Microtus oeconomus mehelyi*) also occur (i.e. Balatoni-berek). In spite of that, if not the entire area will be mown then the remained (0.5-1.5 hectare) can provide rescue patches for small mammals decreasing the probability of extinction.

In Hungary, population and community-level studies of small mammals have been primarily conducted to examine the response of these species to the different forest types. However, there are no investigations, which examine the small mammals as seed predators or granivores. From conservation aspect, these kinds of investigations can be important because granivores have a dual role: as consumers, they greatly reduce the amount of seed in a given year, in contrast, they distribute a large amount of seed, which are not consumed later. Thus affecting the ecological processes, which are taking place in forest ecosystems (Zwolak & Crone 2012).

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Publications

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