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Local turnover and factors influencing the persistence of amphibians in permanent ponds from the Saxon landscapes of Transylvania

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Abstract. There is an increasing interest among ecologists and conservation managers in exploring the factors that influence the distribution and persistence of natural populations. In order to correctly assess the conservation status of a species, both local and landscape level studies are needed. Moreover, the temporal change in the habitat occupancy should be explored. In this paper we examine the turnover rate and explore the factors affecting the persistence of six amphibian species in 21 permanent (focal) ponds in the rural landscapes of Southern Transylvania (central Romania) over six years. The "patch model" approach was used, meaning that amphibians, if present in the focal ponds were considered as local populations. The number of temporary ponds in the landscape positively influenced both the persistence of permanent pond populations (individual species) and the number of species that persisted continuously during the six years. Four species that were absent from the focal permanent ponds were present in ponds from the surrounding landscape. Roads and settlement cover were the most important variables negatively influencing the persistence of permanent pond populations. The regression models regarding the persistence of pond populations had a better fit if the population sizes were included in the model. The results of this study indicate that a high variability of interconnected ponds would increase the persistence of amphibian populations. We suggest that creating and maintaining a number of ponds without fish in the surroundings of permanent ponds will allow their use as refuges by amphibian species sensitive to fish predation, and therefore increase the persistence of local populations.

Key words: amphibians; population turnover; patchy populations; landscape; Romania

Introduction

An important challenge for conservation biologists today is to understand which environmental factors are responsible for the distribution and persistence of organisms in habitats and landscapes. Much information that comes from population and metapopulation ecology (e.g. Harrison 1991, Hanski 1998) and landscape ecology (reviewed by Wiens 1997) indicates that both local and regional approaches should be adopted for a more complete view on this issue.

According to the metapopulation theory, species persist at regional scale because of the recolonization of the vacant habitats via dispersal, although there may be a considerable rate of local population turnover (Hanski and Simberloff 1997, Hanski 1998). Large, self-sustainable populations represent "hotspots" in the landscape, producing emigrants that may rescue smaller populations from extinction and recolonize hospitable habitats (Gill 1978, Hanski and Simberloff 1997). The results of landscape ecological studies showed that population and metapopulation characteristics and processes such as size of (local) populations, their long term persistence, their extinction and (re)colonization capacity, their distribution, the routes and costs of the movements in the matrix and/or habitats are influenced by the quality and localization of the various patches and corridors (Wiens 1997, Hartel et al. 2008a). The role of landscape elements is crucial also in the patchy population approach (Harrison 1991). In these cases, habitat patches are emptied temporarily or permanently due to shifts in habitat patch use (Harrison 1991, Alford and Richards 1999, Petranka and Holbrook 2006). Such shifts may occur because of increased competition and/or predation within patch, and/or changes in habitat quality (Harrison and Fahrig 1995).

Pond-breeding amphibians represent important focal groups for such studies. They have complex life cycles (Wilbur 1980) and are in decline worldwide (Stuart et al. 2004). Evidence suggests that pond-breeding amphibians are able to assess the quality of the breeding habitat and cease their use when it becomes inhospitable due to natural and/or anthropogenic factors (Sjögren-Gulve 1994, Marsh and Trenham 2001, Petranka et al., 2006). Studies that explore the persistence and turnover of amphibian populations are still relatively scarce (Gill 1978, Sjögren-Gulve 1994, Edenhamn 1996, Hecnar and M`Closkey 1996, 1997, Vos et al. 2000, Sinsch et al. 2003, Petranka et al. 2004, 2006, Schmidt and Pellet 2005, reviewed by Marsh and Trenham 2001), although these are also important for developing conservation strategies for amphibians (Vos et al. 2000, Marsh and Trenham 2001, Petranka and Holbrook 2006, Petranka et al. 2006). To the best of our knowledge such studies are lacking from Central and Eastern Europe, including Romania. These studies are of major importance for this region, with overall conservation theory and practice implications, especially in a period when many landscapes are being seriously altered in the short term, mostly due to shifts from traditionally managed lands to intensive agriculture.

In this paper, we quantified the persistence and turnover of pond-breeding amphibian populations using 21 permanent ponds in the Saxon landscapes of Transylvania from 2003 to 2008. As a large part of the study area is within a recently designated Natura 2000 SCI Site, the information presented here will be useful for developing conservation strategies for amphibians in this area. The objectives of this study are:

(i) To estimate the colonization and extinction rate of six amphibian species in permanent ponds using presence/absence data,

(ii) To identify the most important pond and landscape metrics affecting the persistence of amphibian populations in the permanent ponds.

Materials and Methods

Surveys and variables used

We regularly surveyed 21 permanent man-made ponds from 2003 to 2008, which we hereafter refer to as focal ponds. Focal ponds were all located within a

700 km² study area that was near the town of Sighisoara (lat. 46.2178, long. 24.7896), Romania, and representative for local landscape composition and configuration. We initially selected permanent ponds for this study because the large scale pond inventory focused at the beginning on the permanent ponds. Later, temporary ponds were also inventoried and monitored (at small scale). The techniques used for finding amphibians included dipnetting (this worked in the permanent pond especially for newts and amphibian larvae), egg counts (used to detect individuals of all species, including newts) and the call of adults (in anurans). The surveys were repeated for 3-4 times each year in the period of late February – late May. At least one night survey was carried out in each year for each pond. The night survey was carried out from the second period of April to the first half of May, when the probability to detect all the species was at its peak. We consider that the detection of all species was possible with the survey design used by us. We estimated the detection probability only in some species for 2007 and 2008. In *Triturus cristatus* the detection probability was more than 0.60 whereas in anurans such are *Hyla arborea*, *Bufo bufo*, *Rana dalmatina*, *R. temporaria* the detection probability in permanent ponds ranged from 0.70 to 1 (Hartel *unpublished results*). All the permanent and temporary ponds were searched for amphibians in a 800 m circle surrounding the focal pond. These landscape surveys (surrounding the permanent focal ponds) were repeated out from three to six years. The landscape was considered within 800 m diameter around focal ponds because this encompasses the migratory distance and territory size of the majority of amphibians (Smith and Green 2005, Hartel et al. 2008b).

We used the ”patch model” approach (Hanski and Simberloff 1997) in our study, patches being represented by permanent ponds and the amphibians present in the focal ponds were considered as pond (local) populations. This model is frequently used in classical metapopulation studies. It ignores local population sizes and considers only the presence/absence of the individuals in a certain habitat patch (see Hanski and Simberloff 1997 for a general presentation; Marsh and Trenham 2001 for a review of amphibian studies). Thus, we considered ponds as occupied by a species when any of the life stages (egg, larvae, adult) were identified in the focal ponds, otherwise we considered the species absent (Hecnar and M`Closkey 1996, 1997). In cases when a species was not detected in a focal pond after a previous year in which it was detected we considered that a local extinction event had occurred. In the case when a species was detected after a year with non-detection, we considered that a local colonization had occurred (Hecnar and M`Closkey 1996, 1997).

We have used ”pond population size” estimations for five anurans. In the case of *Bufo bufo*, the population size was estimated by counting the number of active individuals in the focal ponds (Hartel *et al.* 2008b). The populations of two species (*Rana dalmatina* and *R. temporaria*) were estimated using the number of egg masses. The calling index (Gagne and Fahrig 2007) was used to estimate the population size of *Hyla arborea* and *Pelobates fuscus*.

Two pond and eight landscape variables were used to characterize the focal ponds and the surrounding landscape (Hartel et al. 2008 b, c). These variables were (i) the pond area (ha), (ii) percentage of emergent macrophyte vegetation (*Typha* sp., *Phragmites* sp.) in the ponds, (iii) the distance of the pond from the closest permanent pond, potential breeding site (in meters), (iv) the closest distance to the forests (m); within the 800 m radius we measured (v) the number of permanent ponds, and (vi) the number of temporary ponds in the landscape surrounding the focal pond, (vii) the settlement cover (%), (viii) the agricultural land cover (%), (ix) pasture and the grassland cover (%), (x) and wet area cover (%). Moreover, data on the presence of predatory fish (fish absent, ponds without predatory fish, ponds with predatory fish) and roads with high traffic densities, was used from previous studies (Hartel et al. 2006, 2007). The land cover within 800 m radius circles around each pond was calculated using GIS software Manifold 7x, based on CORINE Land Cover 2000 for Romania (European Environment Agency 2005), completed and adjusted with visual estimations.

Data analysis

We estimated the following aspects of pond use by amphibians: (i) amphibians present in the focal pond (the permanent pond continuously monitored through six years) but absent in ponds surrounding the landscape, (ii) amphibians absent from the focal pond but present in the surrounding landscape, (iii) amphibians present in both the focal pond and ponds in the surrounding landscape and finally (iv) amphibians absent both from the focal pond and ponds from the landscape.

We calculated the annual extinction and colonization rate of the focal pond populations using the methodology described in Hecnar and M`Closkey (1997). The extinction rate was calculated as the number of ponds where losses were registered divided by the total number of ponds occupied in the previous year. The rate of colonization was calculated by dividing the number of ponds with gains with the total number of ponds occupied in the previous year. Further, we calculated the overall rate of extinction and colonization for each species by dividing the sum of the yearly extinction and colonization rates with the overall number of years (i.e. five).

The relationship between the number of focal ponds where the different species persisted during the five years and the logarithm value of the maximum dispersal distance recorded personally (unpublished) and in literature (Smith and Green 2005) was tested with linear regression. The relationship between variables was analysed with multiple regression (forward stepwise procedure). The dependent variables in this analysis were the sum of years in which the pond populations of different amphibian species were detected (hereafter called "sum of overall presence", SOP) in the focal ponds. The independent variables were the pond- and landscape variables and the maximum pond population sizes (egg masses, active individuals and call scores, see above). The values of dependent variables in this analysis varied between 0 (not present during the six years of study) and 6 (continuous presence, the species being detected every year). As a species can only be present (and detected) if abundance is greater than zero, the use of the above presented abundance index to model SOP may suggest a circularity. Our hypothesis is that the pond populations persist for a longer time (i.e. the values of SOP are larger) if they are larger. The multiple regression analysis in the five anuran species, where population size data were available, was carried out in two steps: only with pond and landscape variables (without using the population size data as predictors) and with habitat and population size data together. This was done to test if adding the population size data would increase the model fit.

The mean differences in the SOP and the number of species with continuous presence in the landscapes with and without high traffic roads were compared using Mann-Whitney U test. The differences in the SOP regarding the presence and absence of non-predatory and predatory fish was tested using Kruskal-Wallis ANOVA. Population size estimations were not possible every year for each focal pond, because we missed the peak activity in some years (thus, it is possible to underestimate the pond populations). In the case on which ponds were surveyed for multiple years for population size estimations, the largest estimation of the population was used for the statistical analysis. The SOP *Rana esculenta* complex was not modelled by regression because of its persistence.

Results

Extinctions and colonization dynamics in the focal ponds

There were a number of focal ponds where the different species were continuously detected during the six years (Figure 1). In this respect, *R. esculenta* complex, *R. dalmatina* and *B. bufo* had the most, whereas *T. cristatus* and *P. fuscus* had the least stable pond populations (Figure 1). Generally the species were identified both in the focal ponds and the ponds from the surrounding landscape (Figure 2). However, there are a number of cases when *T. vulgaris*, *T. cristatus*, *H. arborea* and *P. fuscus* were present in the ponds surrounding the focal ponds but not in the focal ponds themselves (Figure 2). In the majority of cases these ponds were temporary (data not showed here). Focal pond population turnover was recorded in all species (Table 1).

The relationship between the *log* transformed dispersal distance (m) recorded personally and in the literature (Smith and Green 2005) and the number of focal ponds where the species persisted through the whole study period was positive and close to a significant level (linear regression, R^2 = 0.49, $F_{[1,6]}$ = 5.85, P = 0.052) (Figure 3).

Through the study period, two focal ponds were impacted by human activity: one pond was almost totally filled with waste elements in late 2006 and the other one had been almost totally desiccated in 2005, and then refilled in the autumn of 2007. We know about five new permanent ponds created in the years 2005 and 2006 and in the autumn of 2007 in the study area. These ponds were colonized by *T. cristatus*, *T. vulgaris*, *B. bufo*, *R. dalmatina*, *R. esculenta* complex and *H. arborea*.

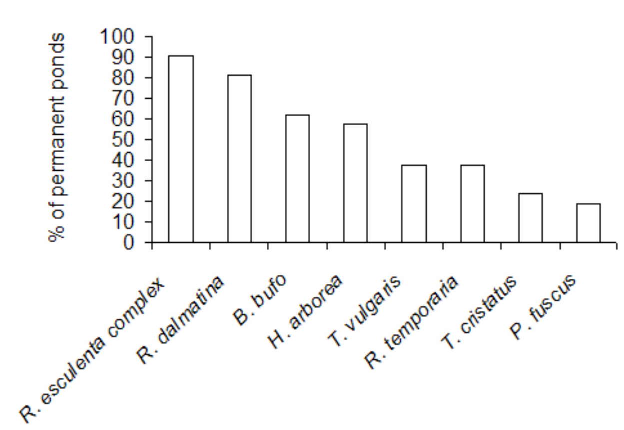

Figure 1. The percentage of ponds where the different species were continuously detected during the five years

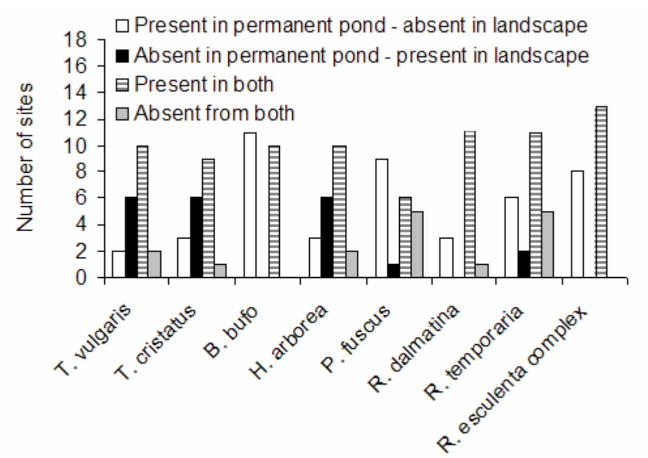

Figure 2. The presence of amphibians in the studied focal ponds and the ponds in the surrounding landscape

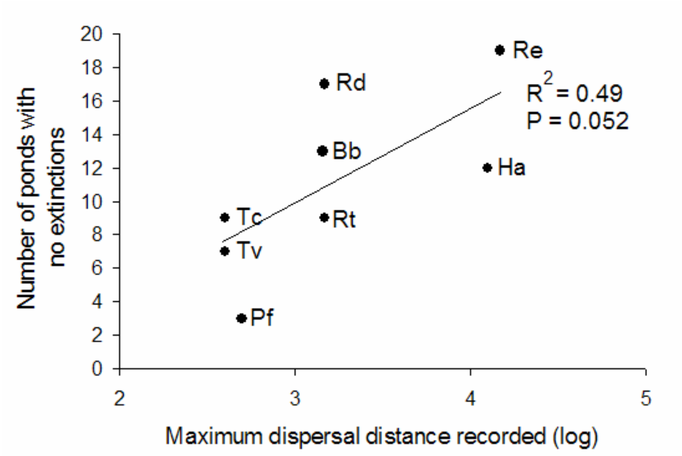

Figure 3. The relationship between the *log* transformed maximum dispersal distances recorded in the literature and the number of ponds with no losses during 2003-2007. The maximum dispersal distances (m) recorded from the literature (reviewed by Smith and Green 2005) and personally (for *R. dalmatina* and *R. tremporaria*) (Hartel *personal observations*). Pf = *Pelobates fuscus*, Tv = *Triturus vulgaris*, Tc = *T. cristatus*, Rt = *Rana temporaria*, Rd = *R. dalmatina*, Bb = *Bufo bufo*, Ha = *Hyla arborea*, Re = *R. esculenta complex*

Factors affecting the persistence of amphibians in permanent ponds

The multiple regression models without adding population size data revealed that the number of the temporary ponds in the landscape positively influenced the SOP of three species (*B. bufo*, *H. arborea* and *P. fuscus*) and the number of species with continuous presence in the focal ponds (Table 2). The variables related to the forest (distance and cover) were important for five species. The SOP of *T. vulgaris*, *R. dalmatina* and *H. arborea* was negatively related to the forest distance (Table 2). The SOP of *T. cristatus* and *R. temporaria* was positively related to the forest cover in the landscape (Table 2). Other variables that were significant predictors for the species SOP in the ponds were the settlement cover (negative effect on the SOP of *B. bufo*) and the agricultural land cover (negative effect on the SOP of *R. temporaria*). The SOP of *R. temporaria* was negatively related to the number of permanent ponds in the landscape (Table 2). The percentage of variation in the SOP of individual species explained by the used pond and landscape variables was highest in *R. temporaria* (R^2 = 0.68) and *B. bufo* (R^2 = 0.57) and the lowest in *T. cristatus* (0.23) and *T. vulgaris* (0.21) (Table 2).

The regression models constructed by using both environmental (pond and landscape) and demographic (population size) data resulted in a better model fit in the case of *R. temporaria* (an increase of R^2 from 0.68 to 0.82 and the adjusted R^2 from 0.63 to 0.79). In this case, the negative effect of the agricultural land cover and the number of permanent ponds in the landscape remained significant but a strong positive effect of the population size also was evident (β [±SE] = 0.56 [0.11], t = 4.90, P < 0.0001). In the case of *H. arborea*, after introducing the calling index (as a variable denoting population size), the calling index was the only predictor that positively affected the SOP (β [±SE] = 0.92 [0.08], t = 10.68, P < 0.0001), the environmental variables being not significant. The model fit was also better (R^2 = 0.85, adjusted R^2 = 0.84). In *P. fuscus* also, the calling index was the only predictor that positively affected the SOP of the pond populations (β [±SE] = 0.80 [0.13], t = 5.86, P < 0.0001), the percentage of variation being large (R^2 = 0.64, adjusted R^2 = 0.62).

The number of species that were continuously present in the landscape was negatively influenced by the extent of settlement cover and the arable land cover (Table 2). The differences in the mean values of SOP regarding the presence/ absence of fish were significant only in two species. *Rana temporaria* had significantly smaller SOP in the ponds with predatory fish (mean = 0.66, SD = 1.65) than those without fish (mean = 3.75, SD = 2.50) and the ponds without predatory fish (mean = 3.50, SD = 2.26) (Kruskal-Wallis ANOVA, P < 0.05). *Bufo bufo* had the largest mean SOP (= 5, SD = 0) in the ponds without predatory fish whereas the lowest (= 3, SD = 1.63) in the ponds without fish. The mean SOP of this species was intermediate in the ponds with predatory fish (= 3.77, SD = 1.39) (Kruskal-Wallis ANOVA, P < 0.05).

The pairwise comparisons made with the Mann-Whitney U test evidenced that the SOP of *R. temporaria* and the number of species with continuous presence were significantly larger in the landscapes without high traffic road than in the landscapes with road (P < 0.05 in both cases).

Table 1. The species specific colonization and extinction rate in the focal permanent ponds. The calculations of the colonization and extinction rates are described in the Materials and Methods section

	Colonization rate	Extinction rate
T. vulgaris	0	0.12
T. cristatus	0.10	0.17
B. bufo	0.07	0.09
H. arborea	0.03	0.03
P. fuscus	0.22	0.28
R. dalmatina	0.05	0.05
R. temporaria	0.02	0.05
R. esculenta complex	0	0.02

Discussion

The values of the colonization/extinction rate found in this study (Table 1) are close to those recorded in other amphibian studies from Europe. Thus, Sjögren-Gulve (1994) found an extinction rate of 0.021 and a colonization rate of 0.023 for *R. lessonae*, Edenhamn (1996) reported an extinction rate of 0.07 and a colonization rate of 0.04 for *H. arborea*. Other studies carried out in North America reported extinction rates between 0 and 0.30 and colonization rates between 0 and 0.46 (Hecnar and M`Closkey 1996, 1997; reviewed by Marsh and Trenham 2001).

Table 2. The multiple regression analysis of the relationship between the sum of overall presence (SOP) of the individual species and the number of species with continuous presence in the focal ponds and the considered variables.

	β (±SE)	*t*	*P*	R^2	R^2 adjusted
T. vulgaris					
Forest distance	-0.46 (0.20)	-2.27	0.03	0.21	0.17
$F_{(1, 19)} = 5.19$, $P < 0.03$					
T. cristatus					
Forest cover	0.48 (0.20)	2.39	0.02	0.23	0.19
$F_{(1, 19)} = 5.74$ $P < 0.02$					
R. temporaria					
Forest cover	0.34 (0.15)	2.40	0.01	0.68	0.63
Agricultural land cover	-0.40 (0.14)	-2.81	0.01		
Number of permanent ponds	-0.33 (0.15)	-2.25	0.03		
$F_{(3,17)} = 12.44$, $P < 0.001$					
R. dalmatina					
Forest distance	-0.47 (0.19)	-2.44	0.02	0.56	0.51
$F_{(1,19)} = 11.47$, $P < 0.006$					
B. bufo					
Settlement cover	-0.66 (0.15)	-4.32	0.004	0.57	0.53
Number of temporary ponds	0.42 (0.15)	2.78	0.01		
$F_{(2,18)} = 12.30$, $P < 0.001$					
H. arborea					
Forest distance	-0.43 (0.18)	-2.35	0.02	0.44	0.38
Number of temporary ponds	0.39 (0.18)	2.17	0.04	0.51	0.39
$F_{(1,18)} = 7.36$, $P < 0.01$					
P. fuscus					
Number of temporary ponds	0.45 (0.20)	2.22	0.03	0.20	0.16
$F_{(1,18)} = 4.97$, $P < 0.03$					
Number of species with continuous persistence					
Settlement cover	-0.57 (0.17)	-3.35	0.003	0.46	0.41
Arable land cover	-0.39 (0.17)	-2.31	0.03		
$F_{(2, 18)} = 7.95$, $P < 0.003$					

Previous studies have documented a number of instances where amphibians have shifted breeding habitats when sites have become inhospitable, such as the introduction of predatory fish (Hopey and Petranka 1994, Petranka *et al.* 2006, but see Laurila and Aho 1997 for *R. temporaria*). The avoidance of permanent ponds is likely to be the reason for the recorded „extinction" events in newts, *H. arborea*, *P. fuscus* and *R. temporaria* from some focal ponds in our area. Even if this study cannot directly control for such interpond movements (and thus misestimate the extinctions from permanent ponds), the results, together with those previously found in this area (see below) highlight some deterministic factors that cause the unsuitability of the permanent ponds for amphibians.

Our analysis showed that the persistence of populations of three anurans (*R. temporaria*, *H. arborea* and *P. fuscus*) were better predicted if data regarding population sizes were incorporated in the regression model, rather than the use of habitat variable data alone. Similarly, the importance of population sizes in the persistence of amphibian populations was found by Hecnar and M`Closkey (1997) for *R. clamitans* in Canada. The call for including population demographic data in the modeling of the distribution of organisms was also highlighted by Schmidt and Pellet (2005), who found that the population sizes were more important predictors of the distribution of *B. calamita* and *H. arborea* than the environmental and metapopulation variables. Their explanation was that the dynamics of amphibian populations is largely governed by stochastic processes, and habitat features remained constant over short time periods. A long term study on *R. dalmatina* carried out in a landscape in this area also showed that the fluctuations in population sizes were influenced both by stochastic (weather) conditions (R^2=0.41), but also, that the population growth rate was influenced by density (R^2=0.42) (Hartel 2008b). The small populations may be more prone to extinction due to stochastic events than larger ones (Schmidt and Pellet 2005).

The positive relationship of amphibian pond use and the extent / number of wetlands in the landscape was reported by many studies in Europe (see Laan and Verboom 1990, Ficetola and De Bernardi 2004). Our study showed that only the temporary ponds are important (positively affecting the SOP of *B. bufo* and *H. arborea*, a near significant effect being also found for *P. fuscus*) whereas the permanent ponds have little effect (negative on *R. temporaria*). The temporary ponds surrounding the focal ponds may represent sources of individuals, stepping stones for dispersing individuals, reducing the effective isolation distance between neighbouring populations (Semlitsch 2001), or may allow the use of them as refuges when the permanent ponds are inhospitable e.g. due to the presence of predatory fish (Hartel et al. 2007). The temporary ponds with longer duration are both productive, complex to allow the coexistence of different species (being vegetated), lack predatory fish and keep the invertebrate predators at low density (due to their temporary character) (Hartel *et al.* 2005, Öllerer 2007, Hartel 2008a). A good example of such a pond system is in the Saes valley. The temporary ponds and springs are important even after they dry out because they may allow the terrestrial stages to find patches with high soil-humidity, and thus increase survival (Hartel et al. 2008a). The persistence of *Rana temporaria* is negatively affected by the number of permanent ponds in the landscape. The reasons may be both the fish introductions (Hartel et al. 2007) and the preference of this species for temporary ponds.

The variables related to the forest (forest distance, forest cover) were the most important landscape predictors of the SOP of species in this area. The negative relationship of amphibians with landscape metrics related to the lack of availability of forests in the landscape was reported by nearly all studies that considered these as explanatory variables (European studies: Joly et al. 2001, Scribner et al. 2001, Van Buskirk 2005, Denoël and Lehmann 2006, Denoël and Ficetola 2007, for this study area: Hartel et al. 2008b,c; North American studies: Hecnar and M`Closkey 1998, Lehtinen et al. 1999, Guerry and Hunter 2002, Houlahan and Findlay 2003, Hermann et al. 2005, Babbitt et al. 2006). The percentage of variation in SOP explained by the variables related to forest was small in the newts and *H. arborea* (Table 2). We suspect that the traditionally used meadows and pastures may lower the importance of forested habitats in the case of these species. These landscape elements have large spatial heterogeneity (bushes, reed patches, mesophylic grasslands) with large potential of being used by amphibians. The SOP of *R. temporaria* and the number of amphibian species with continuously persistent populations were smaller near the ponds with high traffic roads. Moreover, the settlement cover and the arable land cover negatively affected the amphibians (*R. temporaria* and the number of species with continuous persistence). The previous studies on the relationship between the habitat variables and population size in two species (*B. bufo* and *R. dalmatina*) did not highlight any effect of arable lands on the population size in a larger number of ponds (Hartel et al. 2008 b, c).

The importance of the ability for long distance dispersal in the persistence of species in the permanent ponds is also suggested by the near-significant positive relationship between the maximum movement distance recorded and the number of permanent ponds with no extinctions (Figure 3). This suggests that increased (interconnected) pond density should be ensured for species with short dispersal distances (such as the newts), whilst landscape level connectivity is also crucial for the species with long dispersal distances (*H. arborea*, *R. esculenta*). Vos *et al.* (2000) showed that *H. arborea* is able to disperse several kilometres to select already occupied ponds for reproduction, avoiding ponds that are at close distance and are not occupied. They suggest that the conspecific attraction may be important determinant of the direction of movement in this species. We did not control for such conspecific attraction in our study, but this possibility is worth considering and testing in the future. Our observations suggest that the newly created ponds may be colonized by *H. arborea* and other species relatively quickly (i.e. within one-two years).

The data showing only the presence-absence of individuals of species may lead to the underestimation of the importance of different variables in causing population declines in amphibians. Although recorded as continuously present, a population may undergo decline in its size or may show no trend. For example, Meyer et al. (1998) showed that a *R. temporaria* population entered into decline after fish (*Carassius auratus*) introductions. Similar results were found for *H. arborea*, *T. vulgaris* and *T. cristatus* in this area, in a long term study (Hartel and Moga 2007, Hartel *unpublished*), probably due to the introduction of the fish *Silurus glanis*.

The present tendency in the study area is for permanent ponds to go into private ownership. Owners will try to make the ponds financially profitable, and a way to do this, in our study area, is to populate them with large densities of fish for recreational fishing purposes. This will negatively affect those species sensitive to fish predation (*T. cristatus*, *T. vulgaris*, *H. arborea*, *R. temporaria* [Hartel et al. 2007]). The results of the present study show that the temporary pond clusters increase the persistence of some amphibians in permanent ponds. We suggest that if a number of ponds without fish are created and maintained surrounding permanent ponds, amphibian species sensitive to fish predation will be able to use these as refuges by, and so increase the persistence of local populations. In line with previous findings and suggestions, we recommend interconnected pond clusters for the monitoring of amphibian populations rather than single ponds. An on-going long time research in three landscapes with large temporary pond numbers will help a better understanding of the use of temporary ponds by amphibian communities in this area.

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References

Alford, R.A., Richards, S.J. (1999): Global amphibian declines: a problem in applied ecology. Annual Review of Ecology and Systematics 30: 133-156.

Babbitt, K.J., Baber, M.J., Brandt, L.A. (2006): The effect of woodland proximity and wetland characteristics on larval anuran assemblages in an agricultural landscape. Canadian Journal of Zoology 84: 510-519.

Denoël, M., Ficetola, G.F. (2007): Conservation of newt guilds in an agricultural landscape of Belgium: the importance of aquatic and terrestrial habitats. Aquatic Conservation: Marine and Freshwater Ecosystems DOI: 10.1002/aqc.853.

Denoël, M., Lehmann, A. (2006): Multi-scale effect of landscape processes and habitat quality on newt abundance: implications for conservation. Biological Conservation 130: 495-504.

Edenhamn, P. (1996): Spatial dynamics of the European tree frog Hyla arborea L. in a heterogeneous landscape. PhD Dissertation, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Ficetola, G.F., De Bernardi, F. (2004): Amphibians in a human dominated landscape: the community structure is related to habitat features and isolation. Biological Conservation 119: 219-230.

Gagne, S. A., and. Fahrig, L. (2007): Effect of landscape context on anuran communities in breeding ponds in the National Capital Region, Canada. Landscape Ecology 22: 205-215.

Gill, D.E. (1978): The metapopulation ecology of the red spotted newt, *Notophtalmus viridescens* Rafinesque. Ecological Monographs 48: 145-166.

Guerry, A.D., Hunter, M.L. (2002): Amphibian distribution in a landscape of forest and agriculture: an examinantion of landscape composition and configuration. Conservation Biology 16: 745-754.

Hanski, I. (1998): Metapopulation dynamics. Nature 396: 41-49.

Hanski, I., Simberloff, D. (1997): The metapopulation approach, its history, conceptual domain and application to conservation. pp. 5-26, In: I. Hanski & M. Gilpin (eds.): Metapopulation Biology: Ecology, Genetics and Evolution. Academic Press.

Harrison, S. (1991): Local extinction in metapopulation context: an empirical evaluation. Biological Journal of Linnean Society 42: 73-88.

Harrison, S., Fahrig, L. (1995): Landscape pattern and population conservation. pp. 294-307, In: L. Hansson, L. Fahrig & G. Merriam (eds.): Mosaic Landscapes and Ecological Processes. Chapman & Hall, London.

Hartel, T. (2008a): Studiul ecologic si faunistic al amfibienilor din bazinul Tarnavei Mari. PhD Dissertation, Ovidius University, Constanta, Romania.

Hartel, T. (2008b): Weather conditions, breeding date and population fluctuation in *Rana dalmatina* from Central Romania. Herpetological Journal 18: 40-44.

Hartel, T., Demeter, L., Cogălniceanu, D., Tulbure, M. (2006): The influence of habitat characteristics on amphibian species richness in two river basins of Romania. Herpetologia Bonnensis 2: 31-34.

Hartel, T., Moga, C. I. (2007): Population fluctuations and the spatial habitat use by amphibians in a human modified landscape. Studia Universitatis Babes – Bolyai, Biologia 2: 19-32.

Hartel, T, Moga. C.I., Nemes, Sz. (2005): Use of temporary ponds by amphibians in a wood pasture, Romania. Biota 5: 21-28.

Hartel, T., Moga, C.I., Öllerer, K., Sas, I., Demeter, L., Rusti, D., Balog, A. (2008a): A proposal towards the incorporation of spatial heterogeneity into animal distribution studies in Romanian landscapes. North-Western Journal of Zoology 4: 173-188.

Hartel, T., Nemes, Sz., Cogălniceanu, D., Öllerer, K., Schweiger, O., Moga, C. I., Demeter L. (2007): The effect of fish and habitat complexity on amphibians. Hydrobiologia 583: 173-182.

Hartel, T., Nemes, Sz., Demeter, L., Öllerer, K. (2008b): Pond and landscape characteristics: which is more important for the common toad? A case study from central Romania. Applied Herpetology 5: 1-12.

Hartel, T., Nemes, Sz., Cogalniceanu, D., Öllerer, K., Moga, C. I., D. Lesbarreres, L. Demeter (2008c): Pond and landscape determinants of *Rana dalmatina* population sizes in a Romanian rural landscape. Acta Oecologica 2008: Accepted (in press).

Hecnar, S.J., M`Closkey, R.T. (1996): Regional dynamics and the status of amphibians. Ecology 77: 2091-2097.

Hecnar, S.J., M'Closkey, R.T. (1997): Spatial scale and determination of species status of the green frog *Rana calamitans melanota*. Conservation Biology 11: 670-682.

Hecnar, S.J., M'Closkey, R.T. (1998): Species richness patterns of amphibians in southwestern Ontario ponds. Journal of Biogeography 25: 763-772.

Hermann, H.L., Babbitt, K.J., Baber, M.J., Congalton R.G. (2005): Effects of landscape characteristics on amphibian distribution in a forest dominated landscape. Biological Conservation 123: 139-149.

Hopey, M.E., Petranka, J.W. (1994): Restriction of wood frogs to fish-free habitats: How important is adult choice? Copeia 1023-1025.

Houlahan, J.E., Findlay, C.S. (2003): The effects of adjacent land use on wetland amphibian species richness and community composition. Canadian Journal of Fisheries and Aquatic Sciences 60: 1078-1094.

Joly, P, Miaud, C., Lehmann, A., Grolet, O. (2001): Habitat matrix effect on pond occupancy in newts. Conservation Biology 15: 239-248.

Laan, R., Verboom, B. (1990): Effects of pool size and isolation on amphibian communities. Biological Conservation 54: 251-262.

Laurila, A., Aho, T. (1997): Do female common frogs choose their breeding habitat to avoid predation on tadpoles? Oikos 78: 585-591.

Lehtinen, R.M., Galatowitsch, S.M., Tester, J.R. (1999): Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19: 1-12.

Marsh, D.M. Trenham, P.C. (2001): Metapopulation dynamics and amphibian conservation. Conservation Biology 15: 40-49.

Meyer, A.H., Schmidt, B.R., Grossenbacher, K. (1998): Analysis of three amphibian populations with quarter-century long time-series. Proceedings of the Royal Society London 265: 523-528.

Öllerer, K. (2007): Local and landscape determinants of breeding pond use by amphibians in central Târnava Mare Valley, Romania. Master Thesis, Swedish Biodiversity Centre, Uppsala, Sweden.

Pechmann, J.H.K., Scott, D.E., Semlitsch, R.D., Caldwell, J.P., Vitt, L.J., Gibbons, J.W. (1991): Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253: 892-895.

Petranka, J.W., Smith, C.K., Scott, A.F. (2004): Identifying the minimal demographic unit for monitoring pond-breeding amphibians. Ecological Applications 14: 1065-1078.

Petranka, J.W, Holbrook, C.T. (2006): Wetland restoration for amphibians: should local sites be designed to support metapopulations or patchy populations? Restoration Ecology 14: 404-411.

Schmidt, B.R., Pellet, J. (2005): Relative importance of population processes and habitat characteristics in determining site occupancy of two anurans. Journal of Wildlife Management 69: 884-893.

Scribner, K.T., Arntzen, J.W., Burke, T., Cruddace, N., Oldham, R.S. (2001): Environmental correlates of toad abundance and population genetic diversity. Biological Conservation 98: 201-210.

Semlitsch, R.D. (2001): Critical elements for biologically based recovery plans of aquatic-breeding amphibians. Conservation Biology 16: 619-629.

Sinsch, U., Lang, V., Wiemer, R., Wirtz, S. (2003): Dynamik einer Kammmolch-Metapopulation (*Triturus cristatus*) auf militärischem Übungsgelände (Schmittenhöhe, Koblenz): 1. Phänologie, Wettereinfluss und Ortstreue. Zeitschrift für Feldherpetologie 10: 193-210.

Sjögren-Gulve, P. (1994). Distribution and extinction patterns within a northern metapopulation of the pool frog, *Rana lessonae*. Ecology 75: 357–1367.

Smith, M.A, Green, D.M. (2005): Dispersal and the metapopulation paradigm in amphibian ecology and conservation: are all amphibian populations metapopulations? Ecography 38: 110-128.

Stuart, S.N, Chanson, I.S., Cox, N.A., Young, B.E., Rodrigues, A.S.L., Fishman, D.L., Waller, R.W. (2004): Status and trends of amphibian declines and extinctions worldwide. Science 3: 1783-1785.

Van Buskirk, J. (2005): Local and landscape influence on amphibian occurrence and abundance. Ecology 86: 1936-1947.

Vos, C.C., Ter Braak, C.J.E., Nieuwenhuizen, W. (2000): Incidence function modelling and conservation of the tree frog *Hyla arborea* in the Netherlands. Ecological Bulletins Copenhagen 48: 165-180.

Wiens, J.A.. (1997): Metapopulation dynamics and landscape ecology. pp. 43-60, In: I. Hanski and M. Gilpin (Eds.): Metapopulation Biology: Ecology, Genetics and Evolution. Academic Press.

Wilbur, H.M. (1980): Complex life cycles. Annual Review of Ecology and Systematics 11: 67-93.

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