

HOW MANY POPULATIONS ARE THERE? ON THE NEED FOR DELIMITING AMPHIBIAN POPULATIONS

Introduction

“...no longer makes sense to consider population dynamics as a particular way to view ecology – it’s the only way. Population dynamics becomes synonymous with ecological dynamics, with the variables of ecological change being numbers, biomass or energy contained within the constituent populations.” (Alan Berryman)¹

The concept of “population” started to fascinate ecologists a long time ago. The population is the unit that locally represents the species, the population is the main “arena” where the local adaptations occur. The species will go extinct when the last population disappears. At a theoretical level, a population is a group of organisms belonging to the same species that share the same area/place and contribute to the formation of a genetic pool.² The term “place” is very frequently present in population definitions, yet there is large debate around the size and limits of this area.³

Berryman⁴ and Camus & Lima⁵ in their notes present some definitions and uses of this concept:

- Andrewartha & Birch (1984) defined “natural populations” as the totality of interbreeding local populations. These local populations are interconnected by dispersing individuals. In this definition, the “natural population” is close to the definition of metapopulation. The limits of the natural populations, according to Andrewartha & Birch are the geographical barriers that hamper dispersal.
- Huffaker et alii (1999) consider as the area of a population the area which allows populations to persist for more generations and also permit natural movement behaviours (dispersal and migration).
- Yablokov (1986) defines populations through evolutionary perspective. According to his view, the area where a population lives should be large

enough to allow the formation of self-sustainable populations and isolated enough to allow the formation of a proper gene pool in evolutionary time.

- Camus & Lima (2002) write about *population area* to include those areas that serve as migration corridors but are not used as habitats.

It is worth mentioning that the metapopulation theory and landscape ecology of populations are based on a theoretical definition of populations. For example Hanski & Gilpin⁶ enumerate four conditions for defining metapopulations: (i) the existence of habitat patches and local populations, (ii) local populations should have a certain probability of being extinct, (iii) local populations should be connected by dispersing individuals, but the interpopulational movements should not be too frequent to synchronize the populations dynamics and therefore (iv) the probability of all populations for being extinct simultaneously is low. All these conditions have at their base the population concept as “operational unit”. A recent paper on amphibian metapopulations clearly demonstrated that the term is often “misused” and only a few studies use the term “metapopulation” correctly for their studied systems.⁷ We think that the same is true for the populations also.

A survey of the Romanian literature on amphibians showed that population studies are largely absent on this group. The distribution of different species is presented through lists of localities (administrative units – the most frequent case) or UTM quadrates (in a lesser extent). Moreover, there are a few studies that use the habitat as the main basis of presenting distribution or present the spatial and temporal dynamic of breeding assemblages what they call “population”.⁸ However, the term population, if used, was still ambiguous. The situation seems to be the same at international level also. As Camus

¹ BERRYMAN, A. A. 2002.

² CAMUS, P. A. – LIMA, M. 2002; BERRYMAN, A. A. 2002; RIDLEY, M. 2004.

³ CAMUS, P. A. – LIMA, M. 2002; BERRYMAN, A. A. 2002.

⁴ BERRYMAN, A. A. 2002.

⁵ CAMUS, P. A. – LIMA, M. 2002.

⁶ HANSKI, I. – GILPIN, M. E. 1997.

⁷ SMITH, M. A. – GREEN, D. M. 2005.

⁸ HARTEL, T. – MOGA, C. I. 2007.

& Lima⁹ mentioned “*It is strange that early ecologists opted for the view of closed populations dominated by local factors, but even stranger is that, after a century of population studies, ecologists continue to operate with population abstractions, lacking a proper definition or a general agreement*”.

Amphibians are in the focus of conservation efforts because there are in global decline.¹⁰ The need for population delimitations is, thus, even more urgent. Therefore we consider that this concept should be recalled and attempts should be made for its application in real situations. To our knowledge, this study is the first attempt to address the problems associated with the delimitation of amphibian populations.

The specific aims of this paper are:

- i) To present the variety of meanings of the term “population” in amphibians.
- ii) To present the aquatic habitat use of amphibians in ponds (permanent and temporary) and streams in the Târnava Mare basin.
- iii) To present some important aspects that should be considered when the amphibian populations are to be identified. Moreover, distribution maps are presented for the *Rana esculenta* complex and for *Hyla arborea* together with an attempt for delimiting *Hyla arborea* populations in the Târnava Mare basin.

The idea of this paper comes from two papers published simultaneously in *Oikos* by Berryman¹¹ and Camus & Lima¹².

Amphibian populations: how are they used in the scientific literature?

Temperate amphibians have complex life cycles and life histories. They have three developmental stages (egg, larvae and adults) and multiple habitat requirements. Their terrestrial stages are less active, mainly nocturnal. Thus, studies on amphibians' terrestrial habitat use are still generally lacking.

Considering these difficulties, researchers used different terms to delimit populations:

- i) *Breeding assemblages, breeding populations, adult populations.* These are represented by the totality of adult, reproducing individuals of a species that can be found in a pond or breeding habitat. Adults can be counted (counts of active individuals in the breeding habitat), dipnetted or, more rarely, trapped after the ponds were enclosed with a drift fence.

- ii) *Female populations.* In this approach the target of the studies are the breeding females. This is especially attractive in the case of frogs from the *Rana* genus (*R. dalmatina*, *R. arvalis*, *R. temporaria*, *R. esculenta* complex). The assumption is that females lay only one egg mass in a year and counting the egg masses will reflect the number of breeding females.¹³
- iii) *Calling index.* This refers to the intensity of male vocalization, thus the primary target here is the “male population”.
- iv) *Larval populations.* These studies target primarily the larval communities. Larvae are caught using dipnets and the sampling effort is generally described (i. e. the number of dipnet sweeps per time unit, the dipnet size etc.).¹⁴

As it can be seen, in all these approaches amphibians are studied during their aquatic stages or phases (ponds as patches approach). By focusing on the aquatic stages, the population area can be easily delimited: the pond. Ponds can be measured, numbered and monitored. The terrestrial juveniles and/or adults are not considered in these studies. A recent paper¹⁵ highlighted some important problems associated with the pond-population approach. Studies that are primarily pond-based will “skew” the results toward the ponds. Most of the life of the majority of pond breeding amphibians is spent in terrestrial habitats. These habitats serve as overwintering habitats and feeding habitats, moreover, amphibians should find proper microhabitats in the case of extreme weather conditions (i. e. drought) during their aquatic stage. We can state that a very important “input” to the reproductive potential and success is made by the terrestrial habitats. Moreover, these habitats are those through which the migration and dispersal occur. Thus, what a researcher can find in a pond may be in a very large part the result of what happened in the surrounding terrestrial areas. Amphibians may go extinct locally even if the ponds have good quality but the terrestrial habitats are destroyed. All these suggest that a pond based approach in population ecology studies on amphibians, without considering the terrestrial habitats, may be misleading. Only a few population studies consider the birth rate, dispersal, immigration, mortality (i. e. both aquatic and terrestrial stages and lives).¹⁶ The ponds as patches approach was recently criticized mainly because it offers a too simplistic view of the factors influencing amphibian populations.

⁹ CAMUS, P. A. – LIMA, M. 2002.

¹⁰ HARTEL, T. 2003.

¹¹ BERRYMAN, A. A. 2002.

¹² CAMUS, P. A. – LIMA, M. 2002.

¹³ MEYER, A. H. et alii 1998; HARTEL, T. – ÖLLERER, K. et alii 2008.

¹⁴ BABER, M. J. – BABBITT, K. J. – TARR, T. L. 2003.

¹⁵ MARSH, D. M. – TRENHAM, P. C. 2001.

¹⁶ KUHN, J. 1994.

Study case: the amphibians from the Târnava Mare basin

1. Study area and methods

In 2000 a project was started with the aim to inventory and monitor the aquatic habitats in the Târnava Mare basin. From that period, yearly, searches were made to find new ponds and resurveys were made in selected subgroups of ponds. Till 2007, 96 permanent ponds, 305 temporary ponds and 30 stream sectors were inventoried along the tributaries of the Târnava Mare river. The stream transects have around 300m and were selected in 8 streams (average 3.75 transects per stream, SD = 1.38). The stream sectors were chosen in a way to include more natural sectors, i. e. with flooding areas, because these are likely to be good spawning sites for amphibians. The permanent ponds have anthropogenic origins, and were created mostly in the last 40 years as a result of river regulations and dam building in the upper part of the Târnava Mare and its tributaries. The characterization of the ponds was already made¹⁷ therefore we will not detail these here.

We will present the aquatic habitat use of *Hyla arborea* and the *R. esculenta* complex using maps. These species were surveyed at a large scale and were selected because they are easily identified using call surveys. A larger scale survey on the tributaries of the Târnava Mare river and the river itself (central section) was made in 2006, resurveys being made in 2006 and 2007.

The characterization of the tributaries of the Târnava Mare river was made recently by Bănăduc & Bănăduc.¹⁸ According to their study, the streams of this area are of relatively short length and have a small gradient, their course is meandering and the sedimentary substrate dominates. They are relatively shallow, with a maximum depth of around 1 m. The streams are bordered by forested areas, hay meadows, and traditionally used arable lands. The invertebrate communities of different stream sectors were found to be differentiated according to the water flow and substrate. The fish are important determinants of the habitat use of amphibians. The upper part of the streams harbour less fish species than the middle and lower part.¹⁹ Thus, the upper streams are characterized by the presence of *Orthrias barbatulus* and *Gobio obtusirostris*,²⁰ both being inoffensive for amphibians. The species that may be a threat for amphibians are present in the lower part of the

streams, at the confluence with the Târnava Mare river (*Squalius cephalus*).²¹

Below, we will first compare the site occupancy and species richness in the three aquatic habitat types (permanent ponds, temporary ponds and streams). After this, we will present the distribution of *H. arborea* and *Rana esculenta* in ponds and streams (the river Târnava Mare and its tributaries).

The surveys were made in May-June after sunset. The surveys along the stream and river were made by stopping in every around 500 m distances, because calling males can be identified within this distance. We recorded with handheld GPS the points along streams and all the ponds where at least one calling male was heard (in 2007 only the presences were recorded). In this study we use pooled presence-absence data for the 2000–2008 period.

2. Results and discussions: habitat use and species richness of amphibians in the three aquatic habitat types

The species richness was significantly larger in the individual permanent ponds (average 5.46, SD = 2.30) than in the individual temporary ones (1.97, SD = 0.98) or stream sectors (2.10, SD = 2.86), whereas no significant difference was found between the streams and temporary ponds (ANOVA $F_{[2, 428]} = 107.08$, $P < 0.001$, Tukey HSD post hoc for unequal N: $P > 0.05$). We also should mention that there are temporary pond clusters (such are those from Angofa – Saes valley) and streams (the majority of the tributaries of Târnava) that harbour all the amphibian species found in Târnava Mare basin. The higher amphibian species richness in the individual permanent ponds was interpreted through the higher complexity of these habitats.²² Having a more abundant and diverse vegetation, these ponds provide a larger offer of habitat diversity for amphibians.

Newer results suggest that the pond clusters may be even more important predictors of species rich communities than the individual ponds.²³ The population turnover of many amphibian species (i.e. those susceptible to fish predation and the temporary pond breeders) may be higher in permanent ponds with predatory fish.²⁴

Figure 1 presents the site occupancy of the individual species in the three aquatic habitat types. Some species (*Rana dalmatina*, *B. bufo*, *R. esculenta* complex, *H. arborea*) are more common in the

¹⁷ HARTEL, T. – DEMETER, L. et alii 2006; HARTEL, T. – NEMES, Sz. et alii 2007; HARTEL, T. – ÖLLERER, K. – NEMES, Sz. 2007; HARTEL, T. – ÖLLERER, K. et alii 2008; HARTEL, T. – MOGA, C. I. et alii 2008.

¹⁸ BĂNĂDUC, A. C. – BĂNĂDUC, D. 2007.

¹⁹ BĂNĂDUC, A. C. – BĂNĂDUC, D. 2007.

²⁰ BĂNĂDUC, A. C. – BĂNĂDUC, D. 2007.

²¹ HARTEL, T. – NEMES, Sz. et alii 2007.

²² HARTEL, T. – ÖLLERER, K. et alii 2008.

²³ HARTEL, T. – MOGA, C. I. 2007.

²⁴ HARTEL, T. unpublished data.

permanent ponds than in other types of aquatic habitats whereas others (such are *R. temporaria*, *Bombina variegata*) tend to be more common in temporary ponds and streams. A recent study showed that the introduction of predatory fishes in ponds pose serious threats for amphibians (*T. cristatus*, *T. vulgaris*, *H. arborea*, *R. dalmatina*).²⁵ The various adaptations of amphibians to the selective forces linked to hydroperiod gradient were presented in Hartel et alii²⁶ Amphibians use for reproduction the small flooded areas (Figure 8 and 9), mainly the middle – upper parts of the streams, although calling males were observed sometimes along the entire stream, see below. These sectors are safer because the absence of predatory fish and have more natural flooding areas.²⁷

Most of amphibians disperse at juvenile stage.²⁸ It can be assumed that the longer the dispersal ability, more likely for a species to colonize new habitats. Any “deviation” from this assumption may be caused by (i) the quality of the matrix where the dispersal occurs. In a permeable matrix the costs associated with dispersal are low. The movements are risky in inhospitable landscapes. (ii) the quality of the aquatic habitats. There are species that prefer permanent ponds (some being able to coexist with fish whereas some species not), while others prefer temporary ponds. The presence of predators and competitors (often linked to pond hydroperiod) is an important determinant of the aquatic habitat selection in amphibians in this area.²⁹

The maximum dispersal distances reported for different species were taken from the literature.³⁰ We analysed the relationship between the site occupancy and the dispersal distance using linear regression. For this, the dispersal distances were *log* transformed.

There was a significant positive overall relationship between the dispersal distance and the number of permanent ponds used (Figure 2). No such relationships were found in the case of temporary ponds and springs (Figure 2, 3). We think that the major limiting factor of the use of temporary ponds and streams is the low quality of these habitats (i. e. they are ephemeral, lack sectors with flooded areas or contain predatory fish) while landscape fragmentation is influencing only in a lesser extent. Amphibians, in theory, can disperse safely along the streams also due to the seminatural state of the stream margins and slopes.³¹ Considering the reported dispersal

distances (than may be serious underestimations) and the probability of finding stepping stones that would increase the dispersal distances in this area (see the maps below), from the above written it can be concluded that in theory amphibians should be “everywhere” in these landscapes, but do not reproduce in all wetlands. Indeed, our observations suggest that the newly created permanent ponds may be colonized by different species (newts, Tree Frog, Common – and Agile Frog, Common Toad, Green Toad) (i. e. within one-two years). There are two major roads that represent fragmentation but many of the studied sites are far from roads (this being especially true for those being in the southern part of the Târnava Mare river).³²

The results of the calling surveys from 2005 on *H. arborea* are presented in Figure 4. The Tree Frog is present in all the streams surveyed, although in some of them it was not frequent. Observations made in 2006–2007 show that the calling sites of this species are dynamic, suggesting that the adults move along the stream to find proper breeding sites. A large scale recapture study carried out in Sweden³³ suggests that *H. arborea* is able to disperse several kilometres (up to 11) to select already occupied ponds for reproduction, avoiding sites 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. Good breeding habitats for this species in streams were found along Stejăreni valley, Criș valley and Valchid valley. The larger streams such are Târnava Mare and Hârtibaci were not used by the Tree Frog, most probably due to lack of suitable habitats and the presence of fish.

The *R. esculenta* complex has a different distribution in this area (Figure 5). It is generally lacking from the streams that are far from the main water courses (Târnava Mare and Hârtibaci). Moreover, it is absent from the large majority of temporary ponds (Figure 1 and Figure 5). According to the previous studies in this area³⁴ this species is common in the permanent ponds and it is not sensitive to predatory fish. The overall picture about this species is that it requires larger and more constant waters. The streams may be used as migration corridors, but we have repeatedly observed vocalizing territorial males along different transects of the Târnava Mare river, suggesting that ponds suitable for breeding occur even in this area.

²⁵ HARTEL, T. – NEMES, Sz. et alii 2007 ; HARTEL, T. – ÖLLERER, K. – NEMES, Sz. 2007.

²⁶ HARTEL, T. – ÖLLERER, K. – NEMES, Sz. 2007.

²⁷ BĂNĂDUC, A. C. – BĂNĂDUC, D. 2007.

²⁸ SEMLITSCH, R. D. 2007.

²⁹ HARTEL, T. – ÖLLERER, K. – NEMES, Sz. 2007.

³⁰ MARSH, D. M. – TRENHAM, P. C. 2001; SMITH, M. A. – GREEN, D. M. 2005.

³¹ BĂNĂDUC, A. C. – BĂNĂDUC, D. 2007.

³² HARTEL, T. – ÖLLERER, K. – NEMES, Sz. 2007.

³³ VOS, C. C. et alii 2000.

³⁴ HARTEL, T. – NEMES, Sz. et alii 2007.

What should be considered when delimiting amphibian populations?

The data presented above lead to the question: how many amphibian populations are in this area? A potentially useful way to estimate the number of populations would be to estimate the area where the adult amphibians move during their life, assuming amphibians' pond fidelity (see below). We suggest that when defining populations as demographic units in amphibians the following two aspects need to be considered: (i) the landscape characteristics (ii) and some behavioural traits of amphibians related to migration, dispersal and site fidelity.

i *The origin of the breeding habitats and the life cycle of amphibians.* The permanent ponds were all created by dam construction (tributaries of Târnava Mare) or regulation. Thus, initially, all amphibians in this area reproduced (and their populations probably persisted) in running waters. There are only few studies available regarding the use of streams by amphibians in Europe. These studies show that streams can be efficiently used for reproduction, providing that safe, flooded areas are available.³⁵ Moreover, some species (*R. temporaria*) use the streams as migration corridors.³⁶ All the species identified as breeding in ponds, were also identified in springs, even in those streams without man-made ponds along them (such as those from the Nadeș plateau, Stejăreni valley etc.). A very important aspect of these habitats (till a certain point in common with temporary ponds) is that they are extremely dynamic. Thus the proper habitats for reproduction are not necessarily stable in space and time. This spatio-temporal variability of the breeding site quality and location may have at least three consequences for amphibians: (i) it does not allow the formation of large "local" populations because of variable reproductive success. (ii) the amphibians may be selected for intensive movements along the streams in order to "monitor" the quality of the habitat. Finally (iii) the habitat quality variable may select for the short larval period and large phenotypic plasticity. Petranka³⁷ was the first who "tied" the evolution of amphibian's complex life cycle to metapopulation dynamic and persistence. According to Petranka³⁸ the selection for the short larval period increases the potential of amphibians

to use temporary ponds in the landscape, and this may have positive consequences on the spatial organisation and persistence of amphibian populations. If the larval period increases (i.e. due to adaptations for breeding in permanent ponds), amphibians will lose their ability to reproduce in temporary ponds and this will increase the effective distance between breeding habitats (because the ponds with longer hydroperiod may be in smaller density than the temporary ponds). With increased interpond distance, the risk of metapopulation extinction also increases. By creating permanent ponds along the streams, that were free from predatory fish for long time, the conditions were created for the formation of large "population hotspots" for species that prefer vegetated permanent ponds (*B. bufo*, *R. dalmatina*, *H. arborea*, *T. cristatus*, *P. fuscus*, *R. esculenta* complex). Moreover, conditions were created for occasional reproduction of temporary pond breeders (*B. viridis*, *B. variegata*, *R. temporaria*, *T. vulgaris*) in these ponds.

ii *Amphibian movements, the general pattern being that adults show periodical migrations between habitats and juveniles are the dispersal stage.*³⁹ The dispersal distance of juveniles may vary from tens to thousands of meters.⁴⁰ Considering the overall good conditions that are present along the tributaries of the Târnava Mare river, we believe that the conditions for the efficient dispersal are mostly assured (see above). Moreover, good evidences exist for the dispersal of juveniles along humidity gradients;⁴¹ it is very possible that juveniles disperse mainly along the stream due to the increased soil humidity. Juvenile amphibians are especially sensitive to desiccation. The adults tend to show breeding site (or breeding area – referring to a number of potential breeding sites) fidelity. Studies show that amphibians are able to learn, to "monitor" a certain area for old and new breeding sites and choose those sites that are of the best quality at that moment.⁴² The small "excursions" along certain sectors of the streams are therefore very likely. The long dispersal ability and the site fidelity make possible the quick finding of newly created habitats (confirmed by our studies as well, see above). The stable habitats will allow a quick increase in the birth rate within the permanent ponds, thus a large production of

³⁵ PINTAR, M. – SPOWLIND, R. 1998.

³⁶ DEMETER, L. – MARA, Gy. 2006.

³⁷ PETRANKA, J. P. 2007.

³⁸ PETRANKA, J. P. 2007.

³⁹ GILL, D. E. 1978; SINSCH, U. 1990, 1991; SEMLITSCH, R. D. 2008.

⁴⁰ SINSCH, U. 1990; 1991; MARSH, D. M. – TRENHAM, P. C. 2001; SMITH, M. A. – GREEN, D. M. 2005.

⁴¹ HARTEL, T. – MOGA, C. I. et alii 2008.

⁴² SINSCH, U. 1990; 1991; HARTEL, T. 2008c.

dispersing juveniles in some species. For many species, the permanent ponds will act as source habitats⁴³ that will, in theory, produce much more juveniles than that sector of the stream where the pond was created, or probably the whole stream itself. The role of these ponds as source habitats for many species become more evident if/when the streams will be regularized (such modifications were already seen in different Saxon villages) and/or the terrains along them will be converted into intensive arable lands. This will lead to decrease of the general quality of the stream and increase the importance of permanent ponds. However, as Petránka⁴⁴ noted, stable habitats will select for the loss of ability for extreme phenotypic plasticity of amphibian larvae. Moreover, the permanent ponds in this area tend to be populated with predatory fish (our personal observations) suggesting that their quality will decrease in the near future. These possibilities and trends should be considered in our wish to conserve amphibian populations in this area.

As a final remark, Semlitsch⁴⁵ demonstrated that many of the studies regarding the spatial movements of amphibians do not make clear difference between the dispersal and migration. Migration is probably the movement type suitable for delimiting populations, because dispersal represents movements of emigration from the population.

A potentially useful way to estimate the number of populations would be to estimate the area where the adult amphibians move during their life, assuming amphibians' pond fidelity (see below). According to the suggestion of Berryman⁴⁶ "*the area (of a population) must be large enough for the emigration and immigration rates to be negligible or, at least, roughly balanced. If you can imagine such an area for a particular species, then you can grasp the spatial identity of that species' population*". We agree with this and present such an approach in delimiting *H. arborea* populations.

First, we realized a map where every pond was encircled in 1 km distance. We used this distance because there are evidences regarding the spatial scale of the landscape effects of 1000 m in *H. arborea*.⁴⁷ This distance was considered by us the area where the majority of adults live and move after reproduction. When two such populations overlapped (i.e. the

circles overlapped), they were unified because of the possibility to represent one single demographic unit. Around 1 km distance (1070 m) was found to be associated with statistically significant genetic differences between populations in *R. sylvatica*.⁴⁸ A local study, conducted on *R. dalmatina* breeding in a permanent pond and a temporary pond cluster at 800–1300 m distance from this⁴⁹ also show that in this distance (around 1 km) the spatial dynamic and fluctuations of the two populations are not correlated, suggesting demographic independence.

Secondly, we delimited *H. arborea* populations using 11 km distances around the ponds (the largest movement distance recorded in this species, Vos et alii⁵⁰). The same methodology was applied with the overlapping populations as written above. Here the major roads and the river Târnava Mare river were considered barriers of dispersal, thus, populations situated in the two sides (although close to each other) were considered to be isolated.

To express the potential limitations of our model we present the following assumptions: (i) the quality of used aquatic habitats is equal. Considering the source-sink character of many habitats⁵¹ this assumption is unlikely to be met, however. In this study we were not able to quantify what habitats are sources and what are sinks. (ii) All ponds were inventoried. This may be true for the central part of the area but unlikely in the periphery. (iii) The quality of the landscape that would assure the dispersal (juveniles) and migration (adults) is good. We mention these assumptions because we believe that the quantification of source-sink systems and also the exact knowledge of the habitats are critical for every attempt of constructing population area "models". Further similar studies made in a smaller scale will account for these aspects also.

Overall 158 presence data for *H. arborea* were shown in the maps presented in Figures 6 and 7. These would represent the "pond populations" if a "naïve" ponds as patches approach is adopted. These points were grouped in 59 populations, considering the area of a population as being 1 km radius circle around the ponds. Moreover, if we consider 11 km distance, the number of populations becomes seven. The first level grouping (using 1 km radiuses) seems for us reliable since evidences exist regarding the movement of this species within this area (Hartel *personal observations*). According to this spatial level approach, the area of a population may be roughly a valley.

⁴³ PULLIAM, H. R. 1988; RUNGE, J. P. et alii 2006.

⁴⁴ PETRANKA, J. P. 2007.

⁴⁵ SEMLITSCH, R. D. 2008.

⁴⁶ BERRYMAN, A. A. 2002.

⁴⁷ PELLET, J. – GUIAN, A. – PERRIN, N. 2004.

⁴⁸ SQUIRE, T. – NEWMAN, R. A. 2002.

⁴⁹ HARTEL, T. 2008b; HARTEL, T. unpublished.

⁵⁰ VOS, C. C. et alii 2000.

⁵¹ PULLIAM, H. R. 1988.

A study carried out in France on two newt species (*T. cristatus* and *T. marmoratus*) showed that the number of pond populations (21 in both species) is larger than the number of populations identified at genetic level (seven in *T. cristatus* and three in *T. marmoratus*)⁵². In most of cases, ponds situated in less than 2 km geographical distance were pooled as one population.

The second level grouping however that stands the existence of seven populations is likely to be a misestimation. It is very probable that at this level the *H. arborea* populations are organized in a metapopulation. But in order to test this, the four conditions for defining a metapopulation⁵³ should be tested. It is very likely that movements of 10 km distance are not very common in the case of the Tree Frog.

A real difficulty in tracing population boundaries in amphibians in this area is the large number of wetlands in a relatively unfragmented landscape. These wetlands may act as reproductive sites, stepping stones or refuges. The temporary ponds and occasionally flooded areas deserve important attention in this respect. Their hydroperiod is strictly dependent on precipitation and temperature. Some of them may act as “source” habitats in rainy years but as “sinks” in others.⁵⁴ They may significantly decrease the effective distances between the neighbouring breeding areas, occasionally (i.e. in rainy years) allowing a larger gene flow between them.

The continuum conceptual model approach

The continuum model approach was recently emphasized as a tool for a better understanding the distribution of animals in the landscape⁵⁵. This model links the spatial distribution of organisms to the four key resources: (i) food, (ii) shelter, (iii) space and (iv) climate. These resources are not uniformly distributed in space, therefore the organism's distribution would show gradual changes in the landscape. Particularly in amphibians, their distribution in the landscape may be presented using distance from the breeding ponds and humidity gradients. The estimation of the density in different points of the landscape may be done using traps and/or direct observations coupled with mark-recaptures. The population boundaries in this case would be those areas from the landscape that show the lowest density of individuals. The distribution of the population in the landscape can be presented using contour maps (e. g. the highest densities of individuals are presented with dark colors and the lower densities with lighter colors⁵⁶).

⁵² JEHLE, R. et alii 2005.

⁵³ SMITH, M. A. – GREEN, D. M. 2005.

⁵⁴ HARTEL, T. 2008c.

⁵⁵ FISCHER, J. – LINDENMAYER, D. 2006; HARTEL, T.

Concluding remarks

Why is important to try to delimit populations? We witness the massive extinction of species, the most invoked cause being habitat loss and fragmentation. The fields of biology that aim to make conservation proposals for biodiversity (*conservation biology, restoration ecology* etc.) put more and more emphasis on populations. The targets of biodiversity management and conservation measures are the populations. How we intend to protect natural populations if we don't know their spatial extent?

Populations are much more than groups of interbreeding individuals that belong to one species. Natural populations are the result of evolution, selective forces act upon them (and their different parts) maintaining them genetically viable (and heterogenous) and able to adapt to changes in their environment. The gene pool of a population receives genes from other ones through dispersal (immigration). The “rescue” effect is also the result of dispersal. Any management intervention should consider these aspects. Populations may be genetically depleted whereas the ecological population size may be large. If the effective (genetic) population size is low, this may expose natural populations to different stochastic effects (diseases, extreme climatic events, changes in habitat quality) more, even if the management strategies of local habitat are “the best”.

Although the Târnava Mare basin is well covered regarding amphibian studies, and we have an overall image on the distribution and habitat- and landscape determinants of amphibians' distribution, the main questions still remain. More intensive studies should be carried out to quantify the habitat distribution, variability, to construct maps regarding the “permeability” of different landscape elements and collect information regarding the spatial and temporal extent of amphibian population dynamic. We suggest that researchers working on understanding the spatial extent on population (and community) dynamic should move beyond individual ponds. Rather, considering groups of (interconnected) ponds at different spatial scales, would be more useful tool for understanding population dynamics and developing conservation strategies for amphibians (this being also suggested by Griffiths⁵⁷). This approach was applied at a smaller scale in this area when the management interventions were planned for the restoration of the wetlands in the *Breite Natural Reserve* near Sighișoara, the target being the maintenance of a large diversity of

– MOGA, C. I. et alii 2008.

⁵⁶ HARTEL, T. – MOGA, C. I. et alii 2008.

⁵⁷ GRIFFITHS, R. A. 1997.

reproductive habitats for amphibians. Furthermore, we suggest more intensive studies regarding the use of streams by amphibians. By mapping the flooded areas along them, their potential can be evaluated and management recommendations can be made to maintain them “active”.

To find out the movement range of amphibians, the recapture studies are the most accessible ones⁵⁸. If done with caution (to reduce the chances for infections), these kind of studies would provide important data regarding the movement of adults (migration) and juvenile dispersal distances. Even if they probably underestimate the distances that lead to genetic differences between populations, recapture

studies are more accessible than the expensive genetic studies. The recapture studies should go parallel with the landscape ecological studies, because the movement efficiency is directly influenced by the landscape elements (e. g. two breeding sites that are closely situated physically may be isolated by an impermeable matrix).

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⁵⁸ See HARTEL, T. 2008c.

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Hány populáció? A kétéltű-populációk körülhatárolásának szükségességéről (Kivonat)

Jelen dolgozatunkban a *populáció* fogalom alkalmazásának fontosságát emeljük ki. A dolgozat első felében pár – populációkra vonatkozó – definíció bemutatása után kitérünk a populáció fogalom alkalmazását bemutató különböző kétéltű-kutatásokra. A második részben egy esettanulmányt mutatunk be a kétéltűek elterjedéséről a Nagy-Küküllő-medencében. A kutatások „vizes élőhely” központúak, olyan értelemben, hogy a valós vagy potenciális szaporodóhelyek leltározásán alapulnak. Ebben a megközelítésben elterjedési térképeket mutatunk be a *Hyla arborea* és a *R. esculenta* fajkomplexum esetében. Két potenciális migrációs távolság figyelembevételével megpróbáljuk körülhatárolni a levelibéka (*H. arborea*) populációkat. Különböző migrációs elméletekre alapozva az egyik megközelítés 1 km-es migrációs távolságot, míg a második 11 km-es távolságot vesz figyelembe. A természetes populációk körülhatárolásának fontossága abban rejlik, hogy ez a módszer jobb rálátást biztosít a populációkra ható szelekciós nyomásokra, ezáltal alapozva meg a különböző természetvédelmi stratégiákat.

Câte populații? Despre necesitatea delimitării populațiilor de amfibieni (Rezumat)

Pornind de la trecerea în revistă a câtorva din definițiile utilizate pentru descrierea conceptului de populație în lucrarea de față argumentăm privind necesitatea delimitării populațiilor naturale. Pe baza acestor definiții, prezentăm modul în care conceptul de populație este aplicat în cazul amfibienilor. În a doua parte a lucrării prezentăm un studiu de caz asupra distribuției amfibienilor în trei tipuri de habitate acvatice: bălți permanente, bălți temporare, ape curgătoare din bazinul Târnavei Mari. Se prezintă distribuția la *H. arborea* și a complexului *R. esculenta* în cele trei tipuri de habitate acvatice din bazin. În a doua parte a lucrării vom prezenta două propuneri de delimitare a populațiilor de *Hyla arborea*, folosind posibile distanțe de migrare a adulților (1, respectiv 11 km). Considerăm că delimitarea la scara mică oglindește limitele populaționale pe când delimitarea la scara mare foarte probabil că include o metapopulație. Delimitarea populațiilor oferă informații specifice despre varietatea forțelor selective, care afectează acestea, reprezentând un pas important în dezvoltarea strategiilor de conservare.

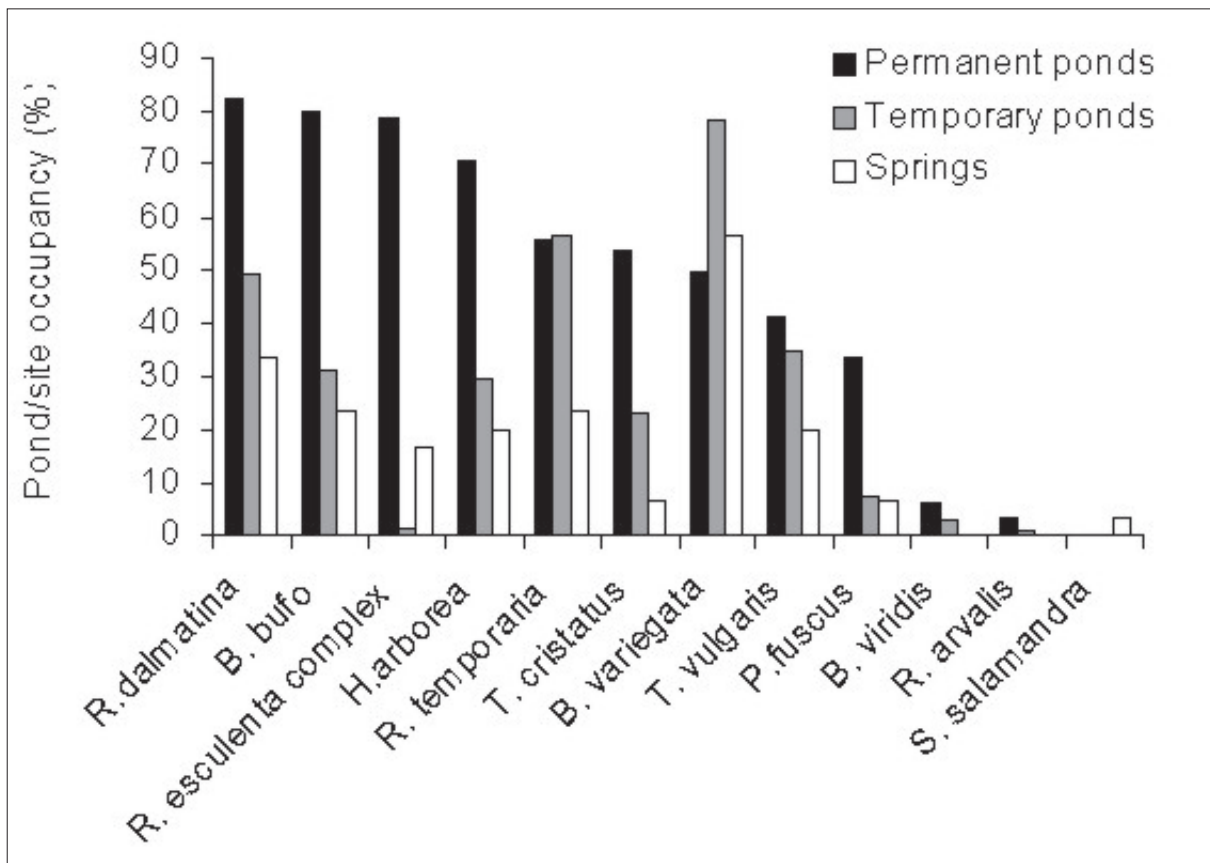


Figure 1. The site occupancy of the individual species in the three aquatic habitats studied. The data regarding ponds are from HARTEL, T. – ÖLLERER, K. et alii 2008. The figure was made by pooling the overall presence of individual species during 2000–2007. By doing so, the permanent pond occupancy of *Bombina variegata* was overestimated. This species is present in permanent ponds only in rainy years when the pond floods small terrestrial areas around it. HARTEL, T. – MOGA, C. I. 2007.

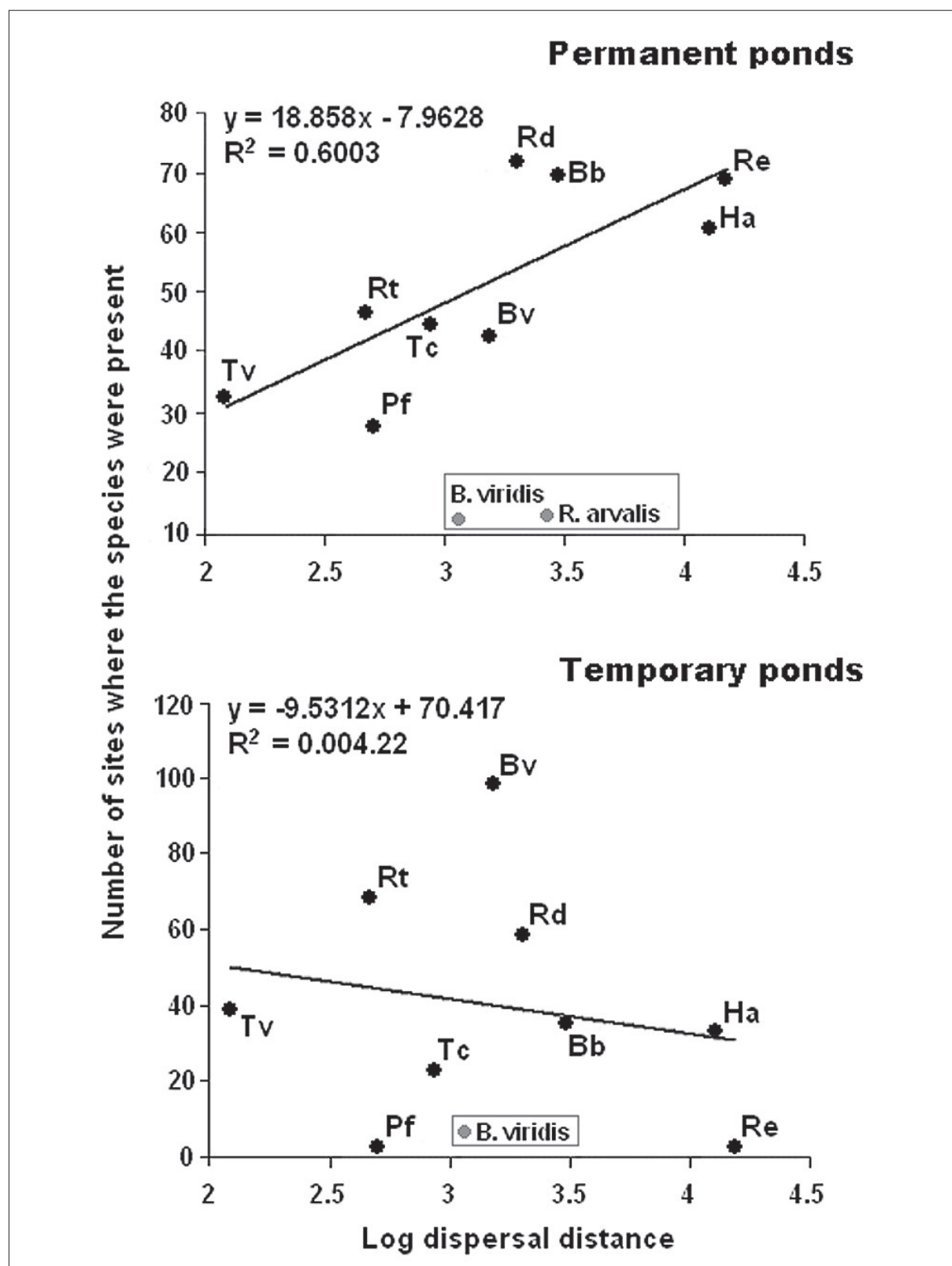


Figure 2. The dispersal distance (logarithmic) and the number of aquatic habitats used by amphibians. The species *Bufo viridis* and *Rana arvalis* were highlighted because, although their high ability to disperse, their habitat use is low. These two species were not included in the regression analysis. Abbreviations: Tc = *T. cristatus*, Tv = *T. vulgaris*, Bb = *B. bufo*, Bv = *B. variegata*, Ha = *H. arborea*, Pf = *P. fuscus*, Rd = *R. dalmatina*, Rt = *R. temporaria*. The species highlighted with grey square are long dispersers but still occupy a low number of habitats. These species were not included in the regression analysis.

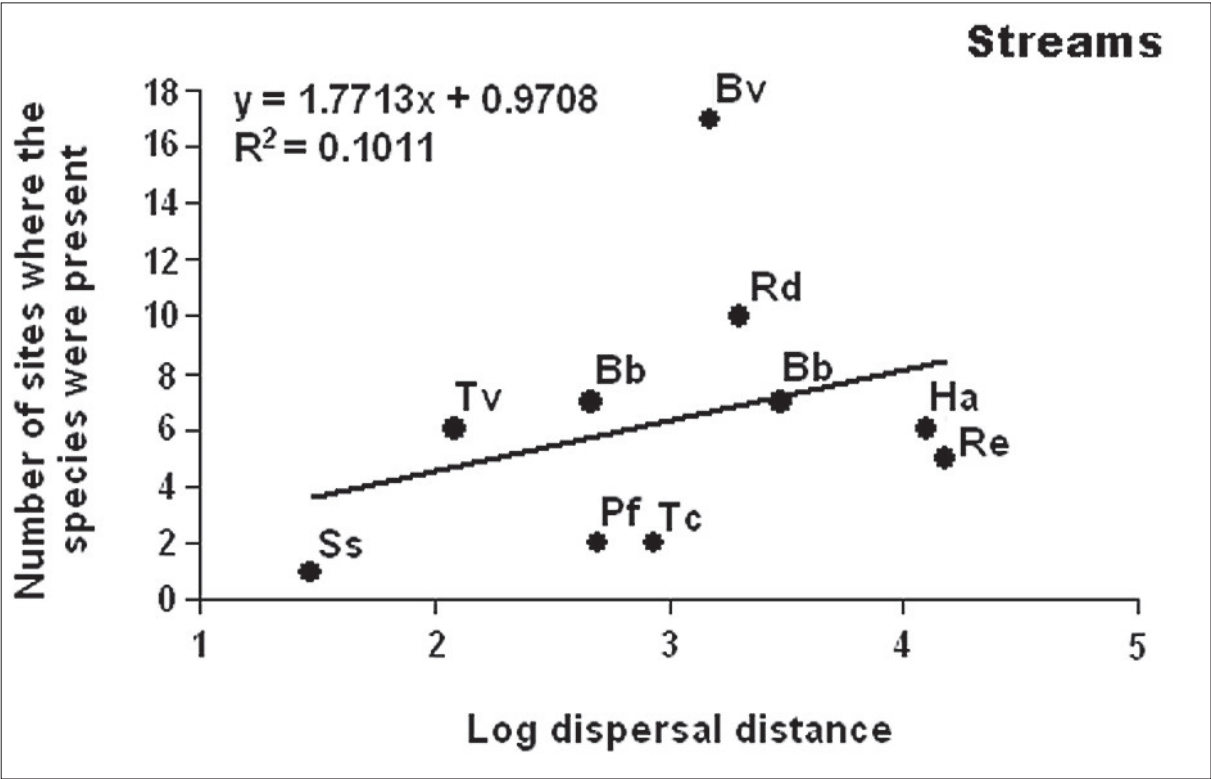


Figure 3. The dispersal distance (logarithmic) and the number of aquatic habitats used by amphibians. Ss = *S. salamandra*. For other abbreviations see Figure 2.

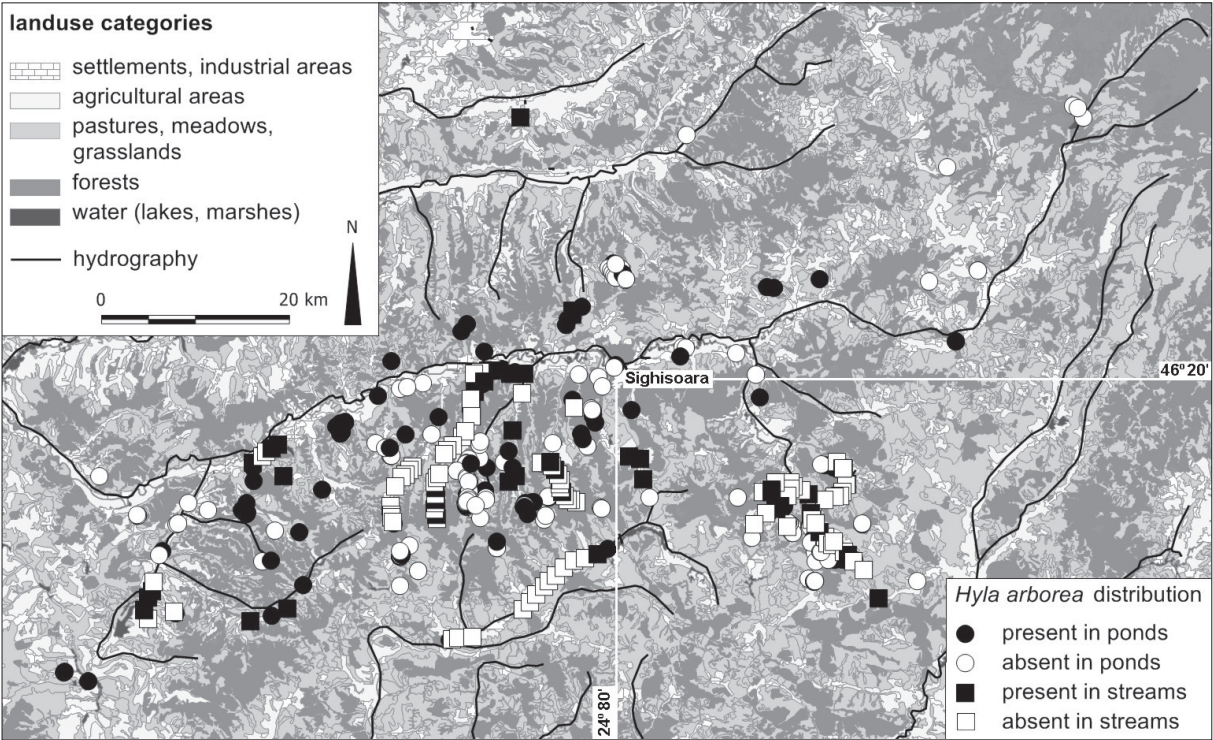


Figure 4. The map of the sites surveyed for *H. arborea* showing the presence and absence of this species in ponds and streams.

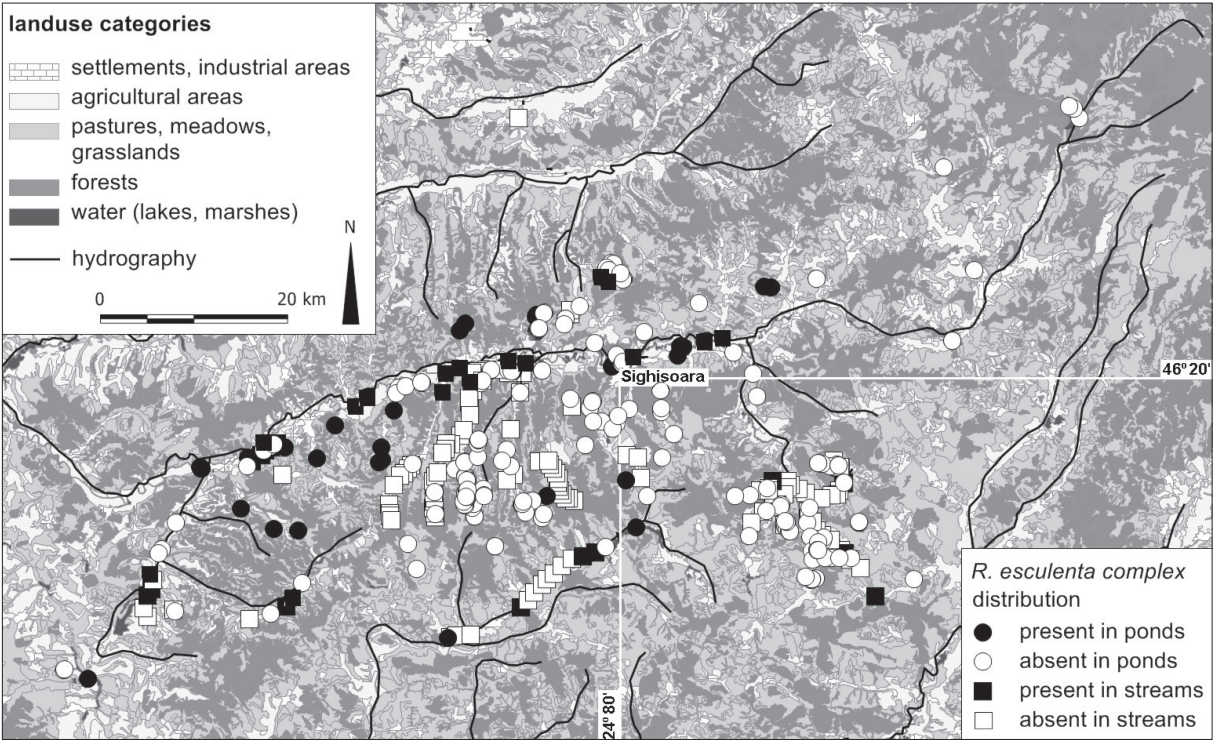


Figure 5. The distribution of the *R. esculenta* complex in ponds and streams.

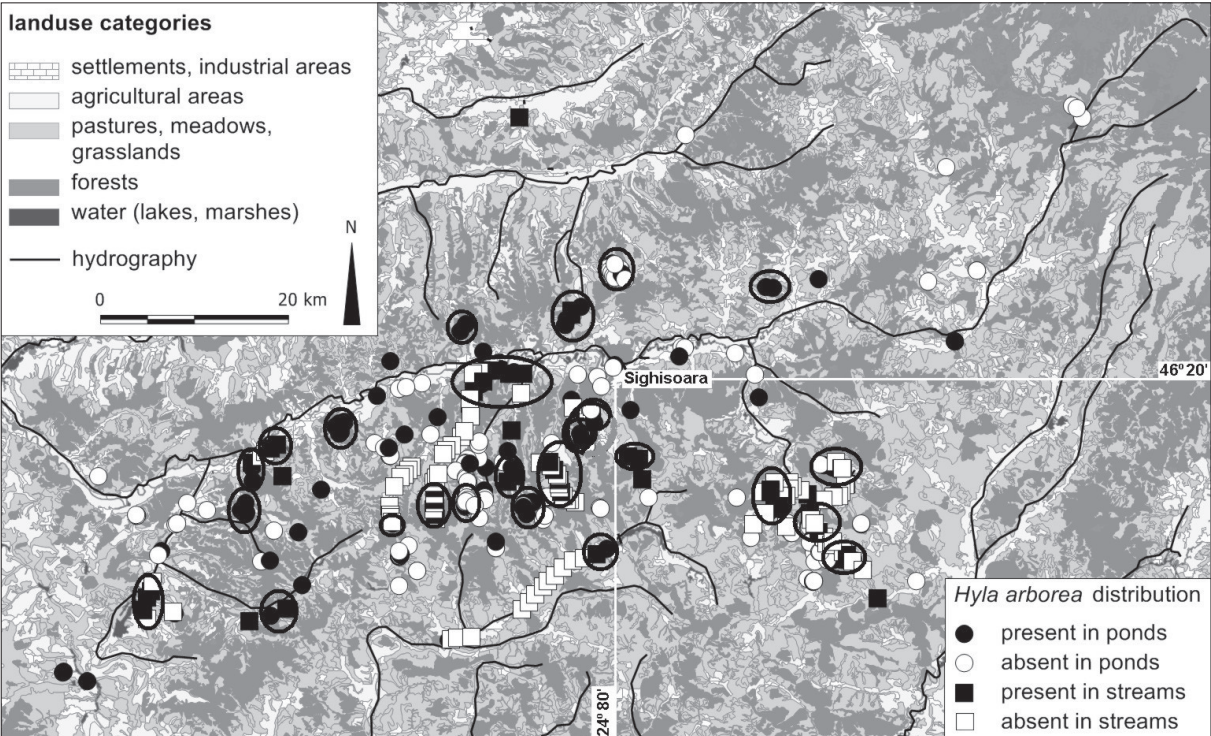


Figure 6. The *H. arborea* populations delimited with 1 km circles around each occupied breeding habitat. The overlapping “populations” were unified under one circle. Note that not all habitats occupied by this species are equal in their quality. Moreover, the map and presentation oversimplifies the potential spatial extent of population dynamics (some habitats of good quality may not be used every year).

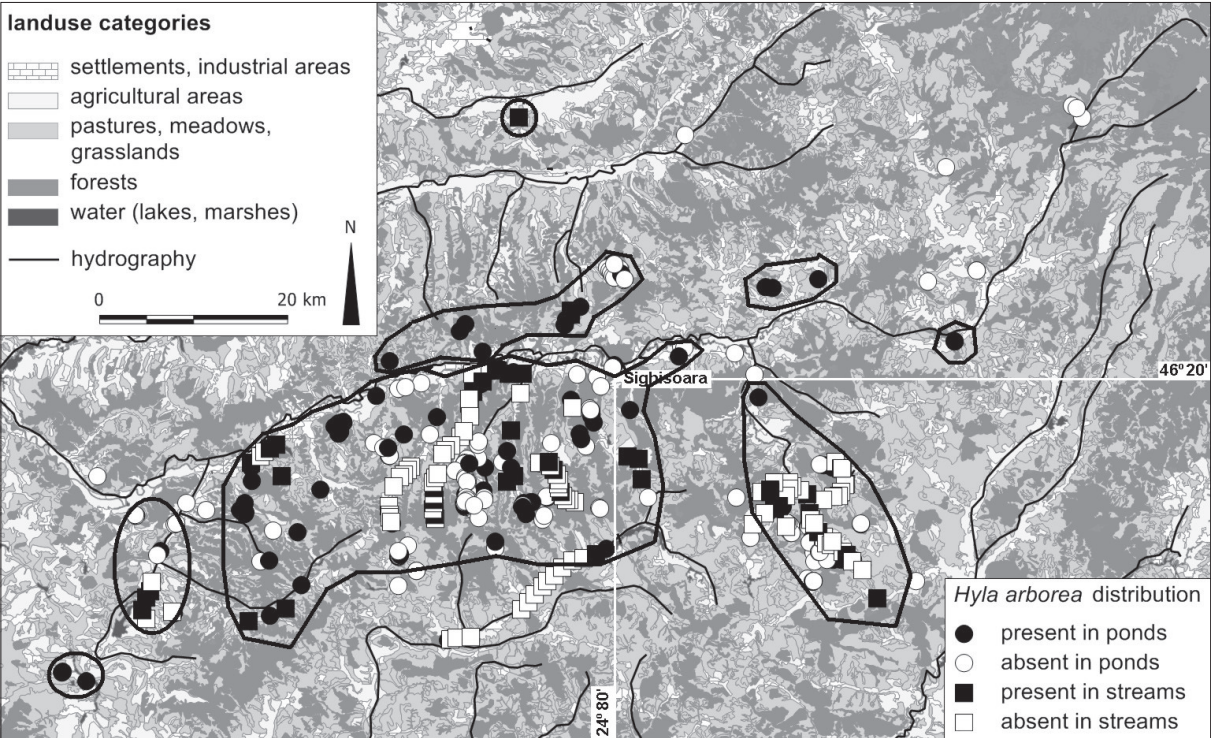


Figure 7. The *H. arborea* populations delimited using 11 km circles. See Figure 6 for other specifications.



Figure 8. Small flooded area along the Valchid stream (upper part). It was present till the middle part of June (2005, 2006). Here the tadpoles of *B. bufo*, *R. dalmatina* and *R. temporaria* and adults of *H. arborea* and *B. variegata* were identified.



Figure 9. A small sector of stream along Daia valley, with *B. bufo* tadpoles. Five similar sites were identified in an approximately 1500 m total stream length in 2007.