Use of temporary ponds by amphibians in a wooded pasture, Romania

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Abstract
In this paper we describe the breeding habitat use of amphibians in a wooded pasture between the years 2003 and 2005. The temporary ponds are described using a number of pond variables: area (m^2), maximum depth (cm), presence/absence of aquatic invertebrate predators, aquatic macrophyte vegetation, pH and water conductivity (µS). Three temporary pond categories were identified considering their hydroperiod: ephemeral, transient and constant ponds. Eight amphibian species were identified in the area. Three species, *Triturus cristatus*, *Hyla aborea* and *Pelobates fuscus,* breed in the ponds, but not all three breed each year. The number of species breeding in a specific pond is influenced mostly by the type of pond. A switch from ephemeral to transient and finally to constant character leads to an increase in species richness. Neither biotic (vegetation, predators) or abiotic factors other than pond type has a significant effect on the number of breeding amphibian species. Historical data shows that the area was marshy in the past. Maintenance of larger, more stable populations on the Breite plateau could be realized by creating and maintaining a higher diversity of aquatic habitats, regarding both their sizes and hydroperiod.

Key words: temporary ponds, amphibian communities, breeding pond use.

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INTRODUCTION

Temporary ponds provide a rich environment for aquatic organisms that inhabit them (Williams 1987) and make a significant contribution to the increase of biodiversity both on a local and regional level (Semlitsch 2000). However, temporary ponds are uncertain habitats. Organisms with complex life cycles (individuals undergo metamorphosis) such as pond breeding amphibians frequently use temporary ponds as breeding habitats. Reproductive success in habitats whose quality is highly variable over time depends on various adaptations of both breeding adults and larvae. A common example of adaptation in adults which breed in temporary ponds is the synchronization of breeding with pond filling (Barandun & Reyer 1997 a,b,1998). Late breeding in temporary ponds could be disadvantageous for the newly hatched larvae that encounter older, larger and competitively superior larvae (Morin 1987, Morin et al. 1990). The response of larvae to changes in habitat quality is usually acceleration of developmental rate (phenotypic plasticity) (i.e. Newman 1992). There are many factors that influence larval growth and developmental rate and therefore their adaptive plastic response to environmental conditions. For instance, biotic factors that influence amphibian development include food availability (Newman 1994), predation (Skelly & Werner 1990, Petranka et al. 1998) or density (Scott 1990, 1994, Semlitsch & Caldwell 1982). With highly variable reproductive success, including complete reproductive failures for long periods of time, long term persistence of amphibian populations and communities that use temporary ponds for breeding also depends on the recolonization rate from autosustainable populations (Gill 1978).

We studied the use of temporary aquatic habitats and the reproductive success of an amphibian community in a number of ponds in a wooded pasture in the central part of the Târnava Mare Valley, near the town of Sighişoara.

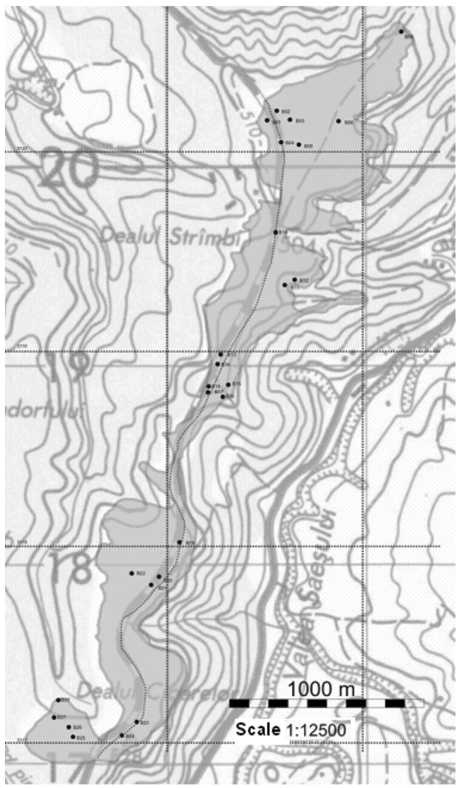
The Breite Reservation is a 70 ha area encompassed in a large plateau of 132 ha area, which is protected under Romanian Law 5/2000 (Annex A).

Our objectives during this study were: (i) to determine amphibian breeding pond occupancy and reproductive success, and (ii) to identify which habitat parameters are most important in determining species richness in these temporary ponds.

MATERIAL AND METHODS

The Breite plateau is situated in the middle section of the Târnava Mare Valley, near the town of Sighişoara, at about 515 m elevation (Figure 1). It is a wooded pasture, a culturally modified forest type (Makkai 2003). The wetlands on the site are heavily influenced by the ditches that drain the landscape. Ditching in the past several decades has resulted in an almost complete disappearance of the marsh system that characterized the area in the past (A. Goţa, personal observations). Today only temporary ponds are available to amphibians for breeding in this area.

Figure 1. A map of the study area. The black spots represent the ponds.



The studies were carried out during three years: 2003-2005. Considering the fact that most of the amphibian species in Romania reproduce explosively (*sensu* Wells 1977) with a relatively short peak activity (when most of the breeding adults are in the water), we increased the probability of finding breeding adults in the water by searching every breeding habitat at least three times, including night observation searches. Adults, eggs and/or larvae were sampled either by dipnetting, by using torch counts, or by identifying calling male anurans. Dipnetting was carried out for 15 to 30 minutes, depending on the size of the site.

We used nine aquatic habitat variables to describe the temporary ponds (n = 29): area (m^2), maximum depth (cm), presence or absence of invertebrate predator insect larvae, the presence of aquatic vegetation, pH, and water conductivity (µS). Also, the ponds were classified in one of the following three categories, considering their hydroperiod: ephemeral (those that dry up within a few days after filling [2-3 weeks]), transient (those that usually dry up once or twice per season) and constant (those that regularly hold water through a whole year).

Logistical conditions do not allow us to estimate reproductive success using the number of freshly metamorphosed juveniles. Therefore, we used the number of ponds where we observed metamorphosed juveniles as the estimator of reproductive success.

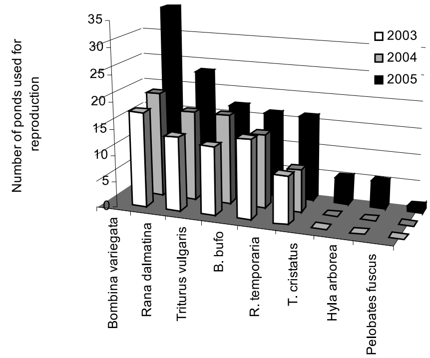
Linear regression, GLM analysis and Reclassification Analysis were used to analyze the data. The level on which the analyses were considered statistically significant (P value) is ≤0.05.

RESULTS

Eight amphibian species were identified on the Breite plateau: *Triturus cristatus*, *T. vulgaris*, *Bombina variegata*, *Bufo bufo*, *Hyla arborea*, *Pelobates fuscus*, *Rana dalmatina* and *R. temporaria*. The reproductive success of most of the species is low. Some species are not present every year in the breeding ponds, such as *T. cristatus* and *P. fuscus,* and *H. arborea* appeared only in 2005 (Figure 2). The most common species is *B. variegata*,

Figure 2. Temporary pond use (a) and the number of ponds in which metamorphosis occurs (b) between the years 2003-2005.

a



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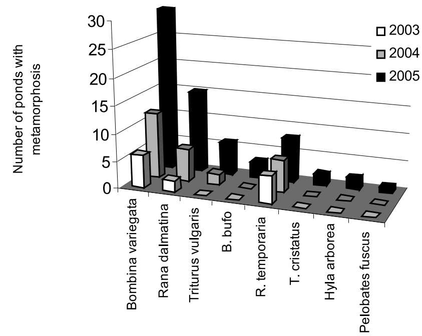


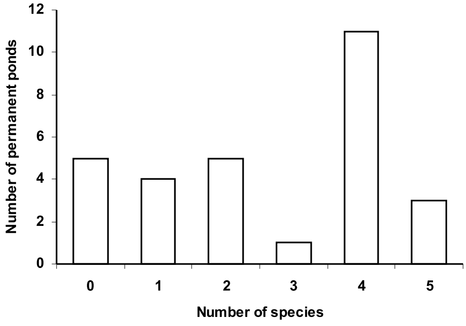
represented by a large population (up to 500 individuals) (Hartel unpublished data). The larvae of this species metamorphose from the largest number of ponds every year in our study area (Figure 2). *Rana dalmatina* and *R. temporaria* also reproduce successfully in a larger number of ponds, compared to other species (Figure 2). *B. bufo* is the only species that constantly uses the ephemeral ponds for breeding (Table 1). The short hydroperiod did not allow the metamorphosis of *B. bufo* larvae in 2003 and 2004 (Figure 2). The rarest species on the plateau are *T. cristatus*, *H. arborea* and *P. fuscus* (Figure. 2). All these species appeared in only a few ponds in 2005 and their larvae metamorphosed in only some of them (Figure 2). Ponds used for reproduction by four amphibian species are most common in the study area, although there are some ponds with five reproducing amphibian species (Figure 3).

The number of species breeding in a specific pond is mostly influenced by the type of the

Table 1. Descriptive statistics of the variables describing the temporary ponds on the Breite plateau. The habitat parameters of the ponds used by five species are also shown. SD= Standard deviation.

	Total ponds	*T. vulgaris*	*B. variegata*	*B. bufo*	*R. dalmatina*	*R. temporaria*
Area	35.01 (3-225) SD=49.61	42.0 (3-225) SD=53.14	45.38 (3-225) SD=55.28	42.39 (3-225) SD=57.59	47.91 (3-225) SD=58	28.19 (3-28) SD=14.01
Maximum depth	26.52 (4-40) SD=9.02	30 (20-40) SD=6.84	30.25 (20-40) SD=6.38	27.5 (10-40) SD=7.56	30.6 (25-40) SD=6.34	27 (25-40) SD=5.3
pH	6.3 (5.97-6.48) SD=0.16	6.3 (5.97-6.48) SD=0.19	6.3 (5.97-6.58) SD=0.18	6.29 (5.97-6.48) SD=0.16	6.26 (5.97-6.48) SD=0.17	6.21 (6.14-6.27) SD=0.05
Conductivity (μS)	248.41 (74-534) SD=128.47	257.7 (74-534) SD=129.23	250.92 (74-534) SD=127.29	270.8 (74-534) SD=147.29	240.31 (74-471) SD=117.27	201.13 (74-263) SD=77.54
Average species richness	2.62 (0-5) SD=1.75	3.82 (2-5) SD=0.95	3.6 (2-5) SD=1.04	3.5 (1-5) SD=1.45	3.88 (2-5) SD=0.85	4 (1-5) SD=1.3
Vegetation (no. ponds)	12	9	12	7	10	1
Invertebrate predators (no. ponds)	15	11	14	8	1	6
Ephemeral (no. ponds)	7	0	0	3	0	0
Transient (no. ponds)	17	13	16	8	13	7
Constant (no. ponds)	4	4	4	3	4	1

Figure 3. The distribution of the ponds regarding the number of amphibian species that use them for reproduction.



pond. A switch from ephemeral to transient and finally to constant character leads to an increase by 2.05 (±0.34 1SE) ($F_{[1, 28]}$ =35.4, P<0.001) in species richness, although pond character explains only 55.2% of species richness variation. Neither biotic (vegetation, predators) or abiotic factors other than pond type has a significant effect on the number of breeding amphibian species (Table 2) although the three pond types are distinguishable based on biotic or abiotic factors with a high precision (Table 3) .

Table 2. Results of GLM analysis with Surface, Deepness and Conductivity as stochastic continuous variables, Pond Type, Vegetation, Predators as level factors.

Source	**DF**	**F**	**P**
Pond Type	2	13.41	0.000
Surface	1	0.62	0.438
Vegetation	1	3.05	0.096
Deepness	1	0.28	0.605
Predators	1	0.51	0.484
Conductivity	1	0.06	0.805
Error	21	–	–
S = 1.04082 R^2 = 73.18%			

Table 3. Results of Reclassification analysis of the three types of ponds based on biotic and abiotic factors.

	True Group		
	Constant	Ephemeral	Transient
Constant	4	1	0
Ephemeral	0	7	3
Transient	0	0	14
Total N	4	8	17
Correct N	4	7	14
Proportion	1	0.875	0.824
N = 29; N Correct = 25; Proportion Correct = 0.862			
	Squared distance		
	Constant	Ephemeral	Transient
Constant	–	16.501	9.972
Ephemeral		–	8.003
Transient			–

DISCUSSION

Our results show that the species richness of the Breite plateau is high, compared to the Târnava Mare valley (12 species, Hartel et al. unpublished data) and Romania in general (19 species, Cogălniceanu et al. 2000). Other species such as *B. viridis* and *R. arvalis* that were not found by us on the Breite plateau are rare in the middle section of the Târnava Mare valley (Hartel 2001, 2004). However, another species not found by us on the Breite plateau, the *R. esculenta* complex, is very common in the permanent ponds along the valley. Long term studies show that individuals from this frog complex could colonize temporary ponds not previously used, if the temporary ponds are close to a large source population (<1000 m distance, Hartel unpublished data). The closest autosustainable population of this species complex is within 5 km of the plateau, and the lack of fragmentation, in theory, allows the dispersion of juveniles/subadults throughout this area. Further studies are needed to identify this species in this area.

To maximize their reproductive success, amphibians must choose breeding ponds in such a way that the growth and development of the larvae can be assured before the end of metamorphosis. Pond desiccation frequently causes catastrophic mortality of amphibian larvae, and this affects the spatio-temporal dynamic of the populations (Pechmann et al.1991, Semlitsch et al. 1996). As was expected, reproductive success in temporary ponds is variable between years, and is influenced principally by the hydroperiod of the ponds, which depends in turn on precipitation. The species successfully reproducing in most of the ponds, and also represented by the largest population (up to 500 individuals) (Hartel unpublished results) is *B. variegata*. This species is adapted to temporary ponds by a short larval period and the synchronization of the breeding period with the rains that fill the temporary ponds (Barandun & Reyer 1997 a, b). In the middle section of the Târnava Mare Valley this species has 2-3 breeding periods during the year (Hartel, unpublished results), compared with one breeding period for the other species (in spring). The phenotypic plasticity of the larvae (i.e. the acceleration of larval development in response to pond drying) also increases the survival probabilities of the larvae of some species (i.e. *R. temporaria*) and thus their reproductive success in the temporary ponds (Newman 1992, Laurila and Kujasalo 1999, Loman 1999). Even if the larvae of some species show phenotypic plasticity, often the accelerated pond desiccation rate does not allow metamorphosis: in 2003 most of the ponds dried up by the first

part of May, and the consequence of this was high reproductive failure in some ponds (see Figure 2). *Bufo bufo* is the single species that uses ephemeral ponds constantly (Table 2). There were no ponds from which the larvae of this species metamorphosed in 2003 and 2004 and only a few ponds in 2005 (Figure 2). Experimental studies conducted in small rock ponds shows that *B. bufo* has a low survival rate in the small pools (Laurila 2000). The reason could be lower food ability or physical factors associated with small pools, rather than intraspecific competition (Laurila 2000).
In a long term study, Petranka et al. (2004) found that if ponds are present in adequate density, amphibians can choose their breeding sites opportunistically and shift from one site to another depending on disturbance history. Areas with a high variability of ponds in an adequate density may occur only rarely in a region. Thus, amphibians are often faced with no possibility of choosing an adequate breeding site. The amphibians in our study area faced this situation. As Figure 2 shows, *B. bufo, T. cristatus* and *P. fuscus* prefer larger permanent ponds for reproduction (Laurila 1998, Babik & Rafinski 2001, Cogălniceanu et al. 2000); when breeding in temporary ponds they have low reproductive success. Because of their highly variable reproductive success, the long term maintenance of amphibian populations depends both on the maintenance of the temporary ponds until metamorphosis (the climatic factor), and recolonization events from potential larger, autosustainable populations (the demographic factor). There is only one permanent pond in the surrounding forest, situated at a distance of about 1500 m, which is used by 4 amphibian species (*T. vulgaris*, *B. variegata*, *B. bufo* and *R. dalmatina*) in small populations because of the fact that the water is cold and deep (up to 2 m) (Hartel, personal observations). If we consider a high dispersion rate of amphibians in the juvenile stage (i.e. several kilometers observed in *Bufo calamita*, Sinsch 1990, 1991) that allows recolonization from more distant ponds, and their longevity, we speculate that the maintenance of the populations in these small temporary ponds is the result of both recolonization and natality.

IMPLICATIONS FOR MANAGEMENT AND CONSERVATION

According to Semlitsch (2000) there are three critical factors that must be considered in all management plans for amphibians: (i) local population dynamics – the number and density of individuals dispersing from wetlands, (ii) diversity of wetlands – the availability of the breeding habitat primarily regarding wetland hydroperiod and (iii) metapopulation dynamics – the probability of dispersal among adjacent wetlands or the rescue and recolonization of local populations.
As we showed above, the aquatic habitat diversity available for amphibian reproduction on the Breite plateau is low. Being situated in open, sunny places, these temporary ponds are subject to drying through lack of precipitation. The breeding pond "offert" in the Breite plateau favors those species with short larval periods and a high capacity for phenotypic plasticity (*Bombina variegata, Rana temporaria*).
Maintaining larger, auto sustainable populations in this area could be assured through creation and maintenance of a higher diversity of aquatic habitats. Considering the surface area of the plateau (132 ha) and the approximate movement distances of the postreproductive adults (approximately 800 m for some anurans, e.g. *B. bufo* and *R. temporaria* [Reading et al. 1991, Baker & Halliday 1999] and approximately 400 m for urodeles [Baker & Halliday 1999, Joly et al. 2001) we consider that the creation of 5 permanent ponds would significantly increase the possibilities for formation of larger, auto sustainable populations. For example, in Denmark, after the creation and modification of permanent ponds, the populations of *Triturus alpestris*, *Hyla arborea* and *Rana dalmatina* increased (doubled) over the next five years (Fog 1997). An increased use of ponds by breeding natterjack toads (*Bufo calamita*) after management was observed in a small area in Scotland (Phillips et al. 2002). In western North Carolina artificially constructed ponds supported significantly more species than reference ponds (Petranka et al. 2003). Data and personal observations (Goța A.) show that the plateau was marshy in the past; the wetlands disappeared during

the last several decades because of human activities. The creation of permanent aquatic habitats would also contribute to the overall increase of biodiversity on the Breite plateau. Careful planning is needed, since increasing the number of permanent water bodies might negatively affect other species as the overall water balance of the plateau will be changed. This goal could be met by a strong collaboration of scientists working in different fields of ecology.

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