Critical elements for biologically based management plans for amphibians in the middle section of the Târnava Mare basin[1]

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Abstract

Habitat loss and fragmentation are the main causes of amphibian decline in Western Europe. Its negative impact may be stopped or even reversed through management interventions. To make efficient proposals in this direction, the critical habitats for each species should be identified. The main objective of our studies in the Târnava Mare basin is to understand the habitat use of the amphibian communities in this area. Eleven amphibian species and a species complex were found in this area. The most important ponds amphibians in the Târnava Mare basin are represented by the permanent ponds that do not contain predatory fish and have a large amount of emergent vegetation cover. These ponds are closely situated to the forests and connected with them with green corridors. Moreover, areas with high density of ponds, ranging from permanent to temporary ones and connected to each other harbor species rich amphibian communities and large populations. Factors negatively affecting amphibian populations in this area are the introduction of the predatory fish, loss of habitats (ponds), the terrestrial habitat loss due to the fragmentation of the landscape by roads and increasing urbanization. No evidence was found regarding the effect of the pond acidification on amphibians. Further studies should be conducted to assess the importance of different landscape elements in the dispersal and connectivity between the populations and the source populations in

1. The title of this paper was inspired from an essay of Semlitsch (2002) entitled: "Critical elements for biologically based recovery plans of aquatic – breeding amphibians" (see reference list for a complete citation).

this area. Moreover, we stress the importance of involving land owners and land users in amphibian conservation and communicating the results of such activities. This aspect, probably considered as “social domain” by most herpetologists and conservationists is actually ignored by many researches; although increased human expansion should be between the most important aspects of biodiversity conservation.

Key words: decline of amphibians, management, cultural landscapes, Târnava.

Introduction

The problem of the „declining amphibian populations” was first presented as a serious global concern in 1989 (First Congress of Herpetology, England) and later in 1990 in Irvine, California (National Research Council Board on Biology symposium on Declining Amphibian Populations) (i.e. Barinaga 1990, Phillips 1990, Wake & Morowitz 1991, Wyman 1990). In those two symposia the major findings on the causes of amphibians decline were presented and also the urgency of future research in this topic was emphasized. Moreover, the major gaps in understanding the role of amphibians in ecosystems and their potential role as indicators of “ecosystem health” were also highlighted.

According to the recent report of the Global Amphibian Assessment (GAA-IUCN), 32.5% of the 5743 species are globally threatened, at least 43.2% are experiencing decreasing population trends, whereas only 0.5% are increasing and 27.2% show no trend. 29.1% of amphibian species are still unknown (Stuart *et al.* 2004). The intensive field and experimental studies demonstrate that the causes of amphibian decline are multiple, ranging from habitat loss and fragmentation (with its various forms, including road constructions, intensive agriculture, extension of urban areas etc.), introduced species (especially fishes), chemical pollutants emerging infectious diseases, perhaps tied to climate change to UV-β radiation and the complex interaction of these factors (reviewed by Dodd & Smith 2003, Collins & Storfer 2003, Storfer 2003, Kats & Ferrer 2003, Beebee 2005, Beebee & Griffiths 2005, Cushman 2005, Puky 2006, Arajuo *et al.* 2006). Long term population studies on amphibians show that their size may largely fluctuate; long decreasing trends may be followed by population increases (Alford & Richards 1999). These fluctuations may have both natural and anthropogenic causes, their separation being often difficult (Pechmann *et al*. 1991).

The most obvious and serious cause of amphibian decline in Europe is the loss of the habitats (Stuart *et al*. 2004). Habitat loss has many gradations from the dissapearance of one or more critical habitats, the loss of connectivity between them, to their quality loss through the introduction of nonnative fish (Dodd & Smith 2003, Cushman 2005). It was also recognised that the negative impact of habitat loss can be ameliorated through adequate management plans. In order to propose efficient management plans, local studies should be conducted regarding the ecological needs of amphibians and the factors threatening them. Moreover, species specific informations are needed to emphasize the interspecific differences in the preference for different habitat / landscape elements.

To our knowledge, the habitat based studies on amphibians are largely absent from Romania, the faunistical studies being conducted mainly considering territorial administrative units (many authors). Habitat based studies were conducted (and are still on-going) in the Hațeg Geoparc, Retezat National Parc (Cogălniceanu *et al*. 2006), Ciuc basin (Demeter *et al*. 2006, Hartel *et al*. 2006) and the Târnava Mare basin (Hartel *et al*. 2005, 2006, 2007 a,b,c, Hartel, *unpubl. results*). These studies aim to explain the distribution of amphibians using a series of pond and landscape parameters and multiple surveys on aquatic habitats.

In this paper we review our preliminary results regarding the factors affecting the habitat use of amphibians in the Târnava Mare basin, we will give an estimation on their severity in short, middle and long term and emphasize on the aspects that we consider critical for the management. The major justification of the habitat association studies on amphibians in Romania is the high level of biodiversity that still can be found in these cultural landscapes. The traditional land use during the centuries, maintained until the recent past, resulted in a patchy landscape with high spatial heterogenity in the middle section of the Târnava Mare basin. Due to this recognition, an area of 85,374 ha was recently declared as Natura 2000 Site of Community Importance (Government Order 776/2007).

The life cycle and the habitat requirements of amphibians

Pond breeding amphibians use aquatic habitats for reproduction while the postreproductive period is spent in terrestrial habitats for the majority of species. Thus, the year round life of pond breeding amphibians consists of periodical migrations between the aquatic and terrestrial habitats. The importance of both is presented below.

The quality of the aquatic habitats is an important determinant of the reproductive success of amphibian populations and may represent overwintering habitats for some species (and individuals). There are two major constrains related to aquatic habitats, both are connected to the pond hydroperiod (Schneider & Frost 1996, Wellborn *et al.* 1996): the threat of crowding and catastrophic mortality caused by the pond drying at one extreme, and the predation (by fish and insects) when the ponds have long hydroperiod. Amphibians are adapted to survive in both circumstances. Fig. 1 presents the adaptations of amphibians to the two hydroperiod extremes.

In the temporary ponds, where the predation risk is generally low (Sheffer et al. 2005), intra- and interspecific larval competition interacting with other abiotic and biotic conditions strongly influences growth rate, larval period, body size at metamorphosis and survival (Wilbur 1997). Crowding may affect tadpoles through a combination of a series of factors such as: increased amount of waste elements, increased CO_2 and decreased O_2 concentrations, food depletion, thermal effects, reduced swimming volume, increased physical interaction among larvae, intraspecific competition (see for example Semlitsch & Caldwell 1982, Denver 1997, Loman 1999). There is a carry over effect of the larval environment on the adult fitness: if the pond quality is low, the energy intake will be low and this will slower the growth and developement, the larval mortality will increase, the adult stage will be attained later and at low body size (Scott 1990, 1994). Since there is a positive relationship between the body size and fecundity in amphibians (Semlitsch *et al.* 1998, Scott 1994), females originating from stressed larval environments will lay fewer eggs. Amphibians adapted for successful reproduction in temporary ponds are selected for rapid colonization of the available ponds, multiple breeding through the year, rapid larval growth rates and flexible larval development (fig. 1) (Barandun & Reyer 1998, Laurila & Kujasalo 1999, Loman 1999, Merila *et al.* 2000).

Temporary ponds with intermediate duration are assumed to be more preferred by amphibians than the ephemeral or permanent ponds (Semlitsh 2000, 2002) because the periodical desiccation creates a disturbance that eliminates predators (or keeps them at low density) but allows amphibian larvae to successfully reach the size at which the metamorphosis can begin.

The permanent ponds do not present the risk of drying but frequently hold predatory fish. To coexist with predators, special adaptations are required such as behavioural avoidance using chemical cues, toxic compounds and phenotypic changes in the body (fig. 1). These adaptations are efficient only if the aquatic habitat is complex enough to allow amphibians using them as refugia (see Hartel et al. 2007b and the references cited here). Massive fish introductions, often associated with the reduction of the habi-

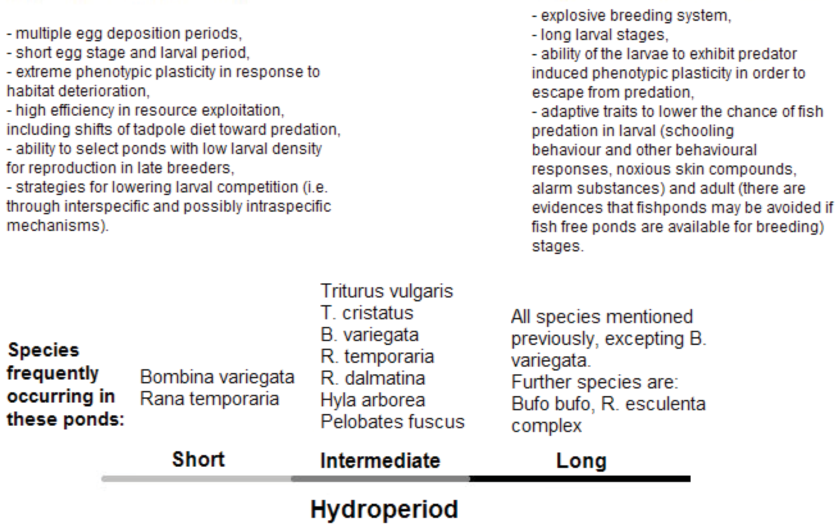

Figure 1. Schematic representation of the pond hydroperiod gradients and the adaptive strategies used by amphibians. The amphibian species, which occurr frequently in the short, intermediate and long duration ponds in the Târnava Mare basin are also shown. Note that the habitat / microhabitat features are always important determinants of the efficiency of these adaptations and strategies (see text).

1. ábra: *A tavak vizes időtartam-gradiensének vázlatos ábrázolása valamint a kétéltűek alkalmazkodási stratégiái. A rövid-, közép- és hosszú időtartamú tavakban gyakran előforduló kétéltű fajokat is bemutatjuk. Megjegyzés: az élőhely / mikroélőhely sajátosságai mindig fontos meghatározói ezen alkalmazkodások és stratégiák hatékonyságának (lásd a szöveget).*

tat complexity may reduce or completely eliminate amphibians throughout predation, competition and even pathogen transfer (reviewed by Kats & Ferrer 2003, for a local study see Hartel *et al.* 2007b).

An important management implication with respect of the hydroperiod of the aquatic habitats (also suggested by Semlitsch 2000, 2002) is to maintain, if possible, a large variety of ponds from ephemeral to long duration (permanent) ponds. Thus, different amphibian species from the same community will be able to select the ponds for reproduction according to the eco-physiological needs of their larvae. In this way, the intensity of competition and predation by other groups would be diminished and the risk for reproductive failures lowered.

The large part of the active season of the postreproductive explosive breeder amphibians is spent in terrestrial habitats around the ponds. Moreover, the terrestrial habitats are important dispersion culoars for juveniles (important for the regional maintenance of amphibian species and communities) and overwintering habitats for some species. The distances of the terrestrial habitats from the ponds at which the postreproductive adults are distributed were reviewed and calculated by a number of authors using published reports (i.e. Semlitsch 1998, Lemkert 2004, Hartel 2005, Rittenhouse & Semlitsch 2007). The overall results of these reviews suggest that the year round life of adult postreproductive amphibians is spent on a distance of up to 1000 m from the ponds, the distance being shorter for urodeles (usually within 400 m) than that for anurans.

It is increasingly recognized that landscape scale studies are of crucial importance for the understanding of spatial distribution of organisms and biodiversity conservation (two recent reviews in this respect were done by Fischer et al. 2007, Lindenmayer et al. 2007). Since the recognition that the „ponds as patches" approach has several limitations (Marsh and Trenham 2001), the „landscape approach" becomes more and more popular in amphibian studies. These studies assume that adult amphibians are not uniformly distributed around the ponds, those areas with high terrestrial habitat quality being more preferred. In these studies the land use patterns (i.e. forests, pastures, arable lands, built areas, roads etc.) are used as explanatory variables for the presence of different species in the ponds. In these studies, different land use types are defined at various distances from the ponds (usually between 100–3000m) in radius circles. These studies present clear evidences on the importance of the landscape elements (terrestrial habitats) in determining the aquatic habitat use of amphibians (e.g. Scribner *et al.* 2001, Mazerolle et al. 2005, Van Buskirk 2005, Gagne & Fahrig, 2007, Hartel *et al.* 2006, 2007b see below). Due to the life cycle characteristics and the spatial heterogenity of the habitats required to complete it, amphibians are especially sensitive to the habitat loss and fragmentation (possible scenarios are presented in fig. 2). Those landscape elements that are not used as habitats but may play a major role in determining the success of movements, such are migrations in the case of adult amphibians, represent the *matrix* (Kindlmann *et al.* 2005). A matrix with *high permeability* assures good movement conditions, these are high quality and safe areas/corridors. A matrix with *low permeability* increases the rate of mortality for individuals that pass them (Hein *et al.* 2004). Human made structures such as roads, urban areas, intensively treated agricultural lands etc. may cause severe mortality of the amphibians crossing them and for many

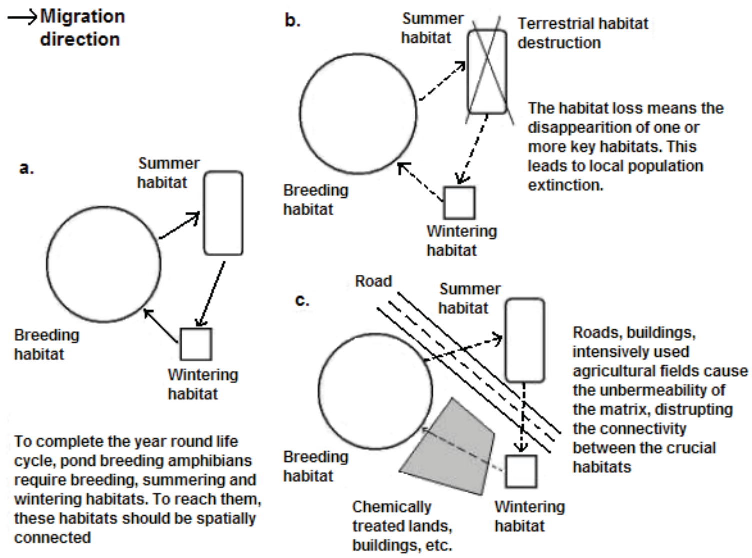

Figure 2. Amphibian populations are negatively affected by both habitat loss and landscape fragmentation. a. the year round periodical migrations of amphibians, b. the effect of habitat loss on amphibian populations, c. the impact of landscape fragmentation.
2. ábra: *A kétéltű populációkra negatívan hat mind az élőhely pusztítása mind a táj feldarabolódása. A. a kétéltűek éves periodikus vándorlása, b. az élőhelypusztítás hatása a kétéltű populációkra, c. a táj-feldarabolódás hatása.*

species represent an *impermeable matrix* (fig. 2). Amphibian populations may enter in decline because of (i) the loss of critical habitats (these may be the reproduction, summer and/or owervintering habitats) and / or (ii) the loss of connectivity between the critical habitats (fig. 2).

A glimpse to the Saxon cultural landscapes of the middle Târnava Mare basin

The study area is situated in the middle section of the Târnava Mare Basin (fig. 3). Here we studied an area of approximately 4000 km^2. The central section of the basin is dominated by hills ranging in elevation from maximum 600–800 m in the west to maximum 750–800 m in the east (Pop 2001). The traditional land use during the centuries, maintained until today, resulted in a patchy landscape with high spatial heterogeneity in the middle section of the Târnava Mare basin (Pop 2001, Mountford & Akeroyd 2005). Due to this recognition, an area of 85,374 ha was recently declared as Natura 2000 site (Government Order 776/2007). The deciduous forests have a large percentage cover in the landscape (30%), the meadows and pastures represent 35%, the arable land 15.57% and the urbanized areas cover 5% (Pop 2001, CORINE landcover map, European Environmental Agency 2006). The geomorphologic properties of these landscapes (narrow flooded areas along the springs) do not allow the formation of large marshy areas (but see the Șaeș valley) (Pop 2001). Some of these permanent ponds were formed naturally, while most of them were created during the regularization of the Târnava Mare river or, in the case of its tributaries, the damming upstream parts of the springs.

Currently there are two large roads and one railway that cross the valley.

The studies were carried out between 2000 and 2007. We inventoried 96 permanent and 305 temporary ponds and 11 springs (totally 30 up to 1000 m length transects) in this period in an area of around 4000 km^2 area. Long term studies (1997 – present) were conducted on an amphibian community reproducing in a permanent seminatural pond and a number of temporary ponds in its surroundings (at 800 to 1 200 m distance in the forest) near the town of Sighișoara (Sercheș-Vila Franka area) (Hartel 2003, 2004, Hartel et al. 2007c). Two temporary pond networks were monitored

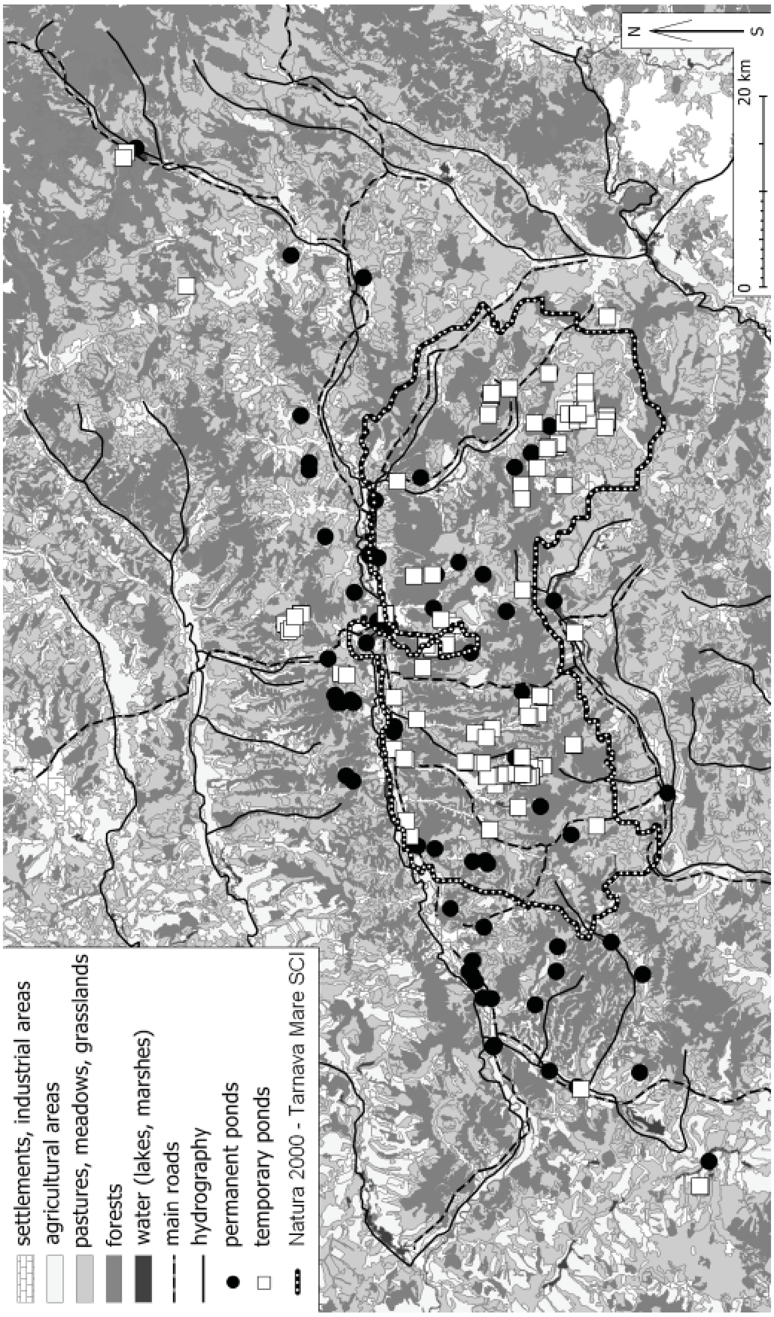

Figure 3. The research area with the studied permanent and temporary ponds. The NATURA 2000 area is also shown with dotted line.
3. ábra: *A kutatási terület az állandó és időszakos tavakkal. A natura 2000 terület pontozott vonallal van körüljelölve.*

beginning with 2002 (Hartel *et al.* 2007c) and 2003 (Hartel *et al.* 2005) to find how the pond use and the reproductive success of the different species is related to pond duration. The relationship between the pond and landscape features on the pond occupancy of amphibians were analysed using a number of habitat parameters described in Hartel *et al.* (2006, 2007a, b, *unpubl.*). The „landscape" is defined by us as the land use patterns in a 800 m area surrounding the ponds. 800 m was selected because it encompasses the migration distance of anurans and newts (Hartel 2007a, see above). Eleven amphibian species and a species complex were found as breeding in this area. These species and their status is presented in *Table 1*.

Table 1. The amphibian species and their protective status.
1. táblázat: *A kétéltű fajok és védettségi státusuk.*

	Bern Convention	Habitat Directive 92/43/EEC	Law 462/2001	Ordinance 1198/2005
Salamandra salamandra	III			IIIB
Triturus cristatus	II	II, IV	III, IV	II, IIIA
Triturus vulgaris ampelensis	III		III	II, IIIA
Bufo bufo	III		III	IIIB
Bufo viridis	II	IV	IV	IIIA
Bombina variegata	II	II, IV	III, IV	II, IIIA
Pelobates fuscus	II	IV	III,IV	II, IIIA
Rana arvalis	II	IV	IV	IIIA
Rana dalmatina	II	IV	V	IIIA
Rana temporaria	III	V	V	IIIB, IV
Hyla arborea	II	IV	III, IV	IIIA
Rana esculenta complex	III	V	V	IV

Legend: *Habitat directive 92/43/EEC:* II = conservation through establishment of protected areas, IV=strictly protected, V=exploitation requires management plans. ***Bern Convention:*** II=strictly protected, III=protected. *Law 462/2001:* III=species of which protection requires the establishment of special protected areas and special protected avifaunistical areas, IV=species that require strict protection, V= exploitation requires management plans. *Ordinance 1198/2005:* II=species of which protection requires the establishment of special protected areas and special protected avifaunistical areas, 3A= species that require strict protection, 3B=species of National interests that require strict protection.

The permanent pond occupancy of three species (*R. dalmatina, B. bufo, H. arborea*) and the *R. esculenta* complex is between 70 and 90%, three species are present 50 to 60 % of the permanent ponds (*R. temporaria, T. cristatus, B. variegata*).

The most common species in temporary ponds are *R. temporaria* (58%) and *B. variegata* (82%). *Rana dalmatina* is present in 49% of the temporary ponds and *T. vulgaris* in 37% of these ponds. The temporary pond occupancy of the *R. esculenta* complex, *P. fuscus*, *B. viridis* and *R. arvalis* is below 10%. *Salamandra salamandra* was identified only in one spring in the Nadeş tableland.

The descriptive statistics of the permanent ponds studied and the terrestrial areas in a 800 radius circle around the pond are presented in table 2. The average altitude at which these ponds were situated is 407.62 m. The average area of the permanent ponds is 5.4 ha. The majority of ponds have no fish at all (30%) or contain no predatory fish (41.17%) whereas 29% of the ponds contain predatory fish (Table 2, Hartel *et al*. 2007b).

The most frequent predatory fish species identified by us are *Perca fluviatilis* (56% of predatory fish ponds), *Pseudorasbora parva* (56%) and *Silurus glanis* (48%) (Table 2, Hartel *et al*. 2007b). 36% of the ponds were situated near high volume traffic roads (average number of cars / five minutes during the breeding migration of anurans being up to 25) whereas in 43% of the cases the ponds were situated away from the roads. 76% of the ponds were connected to a forest patch by green corridors (meadows, pastures, small brooks and hedgerows that are situated between the pond and forest) (Table 2).

The main factors identified by us as negatively affecting amphibian populations are connected to the loss of the habitats and landscape fragmentation and the introduced predatory fish. The most important habitat variables influencing the pond use of amphibians were the presence of the predatory fish (negatively affecting four species and the species richness), the emergent macrophyte vegetation cover (positive effect on six species and the species richness), the forest adjacency (five species), urban area cover (four species) the presence of green corridors between the ponds and the forest patches (species richness), and the high traffic road (five species and the species richness) (Hartel *et al.* 2006, 2007b, *unpubl.*). The destruction of the aquatic microhabitats, the reduction of the macrophyte vegetation cover and the predatory fish introductions become more intensified and common as the ponds become privately owned. Species such are *T. cristatus*, *T. vulgaris*, *H. arborea*, *P. fuscus* and *R. temporaria* are especially sensitive to massive predatory fish introductions especially because of their nektonic larvae (*T. cristatus*, *H. arborea*, *P. fuscus*) and the lack of effective defense against predatory fish. We found no significant difference between the species richness of amphibians in fish free ponds and the ponds lacking predatory fish (Hartel *et al.* 2007b).

Table 2. The descriptive statistics of the (permanent) pond and landscape related variables in Târnava Mare basin
2. táblázat: *A tó- (állandó) és tájváltozók deszkriptív statisztikája a Nagy-Küküllő medencében*

	Average	Minimum	Maximum
Pond variables			
Size (ha)	5.4	0.003	150
pH (median value)	7.88	6.18	8.94
Conductivity (μS/cm)	655.1	66.2	1828
Shallow water cover (depth ≤ 50cm) (%)	37.06	1	100
Emergent macrophyte vegetation cover (%)	36.65	0	100
No fish (%)	30		
No predatory fish (%)	41.17		
Predatory fish (%)	29		
Landscape variables			
Altitude (m)	407.62	257.00	626.0
Distance from the forest (m)	265.51	0.00	1500.0
Green corridor (%)	76	-	-
No road (%)	43	-	-
Low traffic road (%)	21	-	-
High traffic road (%)	36	-	-
Urban areas (% cover)	7.62	0.00	67.9
Pasture (% cover)	40.32	20	100
Forest (% cover)	28.00	0.00	85.9
Wet areas (% cover)	3.27	0.00	43.6

Fish species considered by us as being non predatory (such are *Carassius auratus*, *Cyprinus carpio*) were found to negatively affect the pond use of *Triturus carnifex*, *Hyla arborea*, *Bombina variegata*, *Salamandra salamandra*, *Bufo viridis* (complete elimination), *Rana dalmatina* and *T. vulgaris* (reduced population effectives) in the ponds where these fish were introduced near Trieste (Italy). The reason may be the lack of vegetation or scarce vegetation in these carstic ponds and/or their small size (Nicola Bressi, *pers. comm.*).

The drainage ditches may shorter the hydroperiod of the temporary ponds and this may eliminate those amphibians that have long larval period. Our studies show that species such as *T. cristatus*, *B. bufo, H. arborea* and *P. fuscus* have a larval period ranging from 90 to 120 days (Öllerer and Hartel, *unpubl.*). These species have low reproductive success in a hydrologically modified landscape near Sighişoara (*Breite Reservation*) with complete reproductive failures in some years (Hartel *et al.* 2005, Hartel unpubl.). Other species such are *B. variegata*, *R. temporaria*, *R. dalmatina* and *T. vulgaris* have shorter larval period (from 30 to 70 days) and larger reproductive success. Studies carried out in this area in 2007 (an exceptionally dry year) shows that species that are well adapted to temporary ponds such are *B. variegata* and *R. temporaria* may also suffer significant reproductive failures due to pond drying (Hartel *unpubl.*). These observations suggest that the human impact (draining ditches) may increase the effect of the extremely dry years and call for management interventions that aim to stop water loss.

The critical landscape elements for amphibians identified by us are linked to the landscape connectivity (pond – forest connection) and forest adjacency. The proximity of nearby forests positively affects many amphibian populations by ensuring that conditions for feeding, moisture, shelter and hibernation are available for all terrestrial life stages. Considering that the majority of ponds are situated close to forests, forests play an important role in maintaining a high species number in the central Târnava Mare basin. Joly *et al.* (2001) found that the size of an uncultivated section between a pond and a nearby forest is an important predictor of newt abundance.

The high volume traffic roads negatively affect five species of amphibians and also the species richness: *Triturus vulgaris, Hyla arborea, Rana dalmatina, R. temporaria* and *Bufo bufo* (Hartel *et al.* 2006, 2007a, Öllerer *et al. unpubl.*). Roads have a huge impact on environment, being a significant

Table 3. The factors threatening amphibians in this area according to our present estimations and the global tendencies. The factors with "short term" impact are estimated to represent serious threats in the next 5 years, the middle term impacts are estimated for 6–10 years and the long term impacts for >10 years.
3. táblázat: *A kétéltűeket veszélyeztető tényezők ezen a területen, jelenlegi tudásunk alapján. A rövidtávon ható tényezők becsléseink szerint a következő öt even belül jelentenek veszélyt, a középtávon ható tényezők 6–10 éven belül, míg a hosszú távon ható tényezők 10 évnél hosszabb periódusban éreztetik hatásukat.*

Threat	**Forms identified by us**	**Estimated impact at a landscape scale**	**Amphibians affected**	**Management urgency**	**Reference**
Habitat loss and fragmentation	Loss of wetlands due to drainage. Reduction of the reed cover. Loss of landscape connectivity due to road constructions and urban development. Deforestation. Loss of habitats due to intensive agriculture.	Middle (wetland loss) to long term (changes in the landscape)	Species richness B. bufo P. fuscus T. cristatus H. arborea R. temporaria R. dalmatina B. variegata	Middle to high	Hartel et al. 2005. Hartel et al. 2006. 2007 a.b. Hartel unpubl.
Introduced species	Predatory fish introductions.	Short term	Species richness, T. vulgaris, T. cristatus, H. arborea, R. temporaria	High	Hartel et al. 2007a

Climate changes (precipitation regime)	Especially affecting amphibian communities breeding in temporary ponds. Potential negative effect on population sizes if it shifts toward dry and warm springs.	Short term in temporary pond communities; Long term in permanent pond communities	Species richness, T. cristatus, B. bufo, H. arborea, P. fuscus, R. dalmatina	High, especially in temporary pond communities isolated from permanent ponds	Hartel et al. 2005, Hartel, 2003
UV – B radiation	Not studied.	Potential in long term			
Infectious disease	Not observed.	Potential in middle-long term			
Acid rain	No threat.	Long term		Low	Hartel, unpubl.
Pollution	Extremely high values of water conductivity were measured in the ponds from Copșa Mică. No reproductive success recorded.	Middle to long term		Low	Hartel, unpubl..

Table 4. Habitat and landscape elements and other interventions proposed for management for amphibians in the Târnava Mare basin.
4. táblázat: *Az élőhely- és tájelemek valamint a javasolt beavatkozások a kétéltűek managementjének érdekében a Nagy Küküllő medencéjében.*

Targets for management and interventions	Description and justification
Restricting fish introductions to non predatory fish. Maintaining ponds that do not contain fish at all.	Allow safe development of the eggs and larvae and good feeding habitat for adults. The presence of ponds without fish increases gamma diversity.
Maintenance of a high diversity of wetlands (from temporary ponds to permanent ones) at a landscape scale.	Will allow different species to use the wetlands according to their ecological needs. Finally will lead to species rich amphibian communities at a landscape scale.
Maintaining large emergent vegetation cover, especially in those parts of the pond that are on the side of the forest.	May buffer against predatory and non-predatory fish. Assures safe feeding and breeding conditions for all aquatic life stages.
Stopping water loss through enclosing the drainage ditches.	Allow increased hydroperiod of the ponds. Potentially may buffer against extreme changes in the precipitation range. A management implication based on the habitat use of amphibians will be soon made in a hydrologically modified landscape near Sighişoara (in the Breite Reserve).
Maintaining green corridors between the ponds and the forests.	Allow safe migrations between the critical (breeding, feeding and summering) habitats.
Maintaining forest cover close to ponds.	Assures that the high quality terrestrial habitats can be reached easily. Clear cutting forest edges and forest patches will increase the effective distance between the ponds and the forests and will drastically change the microclimatic conditions.

Roads	Placing indicators on those parts that are intensively used by amphibians (low costs, may work if drivers "collaborate"). Tunnel construction in the places where migration corridors intersect roads (high financial costs and may not work efficiently).
Road and urban planning	Should consider the connectivity between the populations at regional level. Although the gene flow is crucial for local populations, this task is extremely difficult to realize because it implies many economical and political aspects.
Community involvement	Involving landowners (pond and terrestrial areas) for the protection of amphibians through explaining them the benefits of maintaining the key elements for amphibians (i.e. tourism, fish).

factor causing the loss of biodiversity. Their multipple effects are reviewed by many authors (see for example Trombulak & Frissel 2000). Amphibians are especially exposed to road traffic, due to their life cicle characteristics (see above). The impact of road traffic on amphibians was recently reviewed by Puky (2006). He summarized the road effects as follows: influence on the distribution, sex ratio, genetic isolation (leading to low heterozigocy), decreased population densities near the roads with high traffic, population declines and local extinctions. Our recent surveys on a 83.3 km length road transect (Hartel and Moga *unpubl.*) in the breeding migration of amphibians (12 nights between 15th of February – 3rd of April, 2007) have shown that a large number of *B. bufo* (883 individuals) and *R. dalmatina* (1437 individuals) may be killed in this area by roads. We located with the Global Positioning System (GPS) those 11 road transects with intensive migrations for *B. bufo* and 16 for *R. dalmatina*. Around half (685) of the killed *R. dalmatina* individuals were found migrating individually (i.e. not in the identified major routes), whereas only 163 individuals of *B. bufo* were found outside the migration culoars. This suggests that amphibian tunnels placed in the migration routes may not be effective for *R. dalmatina* since a large number of individuals migrate isolated. The factors identified as negatively affecting amphibians in this area, their estimated regional impact and the urgency for management are represented in *Table 3*. Based on our results in this area (see above), we propose a number of habitat and landscape elements that should be targeted in management plans for amphibians and their habitats in this area (Table 4).

Further thoughts

The general approach to study the relationship between the landscape elements and the pond use by amphibians is to describe land use patterns around the ponds (see above). This approach is helpful to identify the most important landscape elements that explain the use of ponds by individual species at local scale, and to assess the spatial scale of the sensitivity of different species. However, being "scale limited", these studies may capture only the habitats within the movement range of breeding adults (that regularly show high site fidelity) and miss some important factors acting beyond the scale considered, that may hamper gene flow and the colonization of the newly created ponds. This may reduce the effective population size and expose amphibian populations to environmental stressors even if the "landscape" (i.e. the terrestrial areas around the pond in a defined distance) and the pond are suitable for the formation of large reproductive aggregates. Since the juvenile amphibians may disperse to large distances (up to 10 kilometers in some species) (Smith & Green 2005) studies need to be conducted to understand the effect of isolation (by distance and matrix quality) from other breeding aggregates on the breeding habitat use (metapopulation perspective). Comparative studies need to be conducted to find how different other groups (i.e. reptiles, birds) are reacting on a particular modification in the landscape. These kind of studies are already going on in this area.

Since the lands tend to be privately owned, the conservation of amphibians in this area can be realized only by involving land owners and land users and communicating the results of such activities for the herpetologists. This aspect, probably considered as "social domain" by most herpetologists and conservationists is actually ignored by many researches; although increased human expansion should be between the most important aspects of biodiversity conservation.

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Érvelés a Nagy-Küküllő medencéjében élő kétéltűek számára kidolgozandó biológiai alapú kezelési terv érdekében[2]

Kivonat

Az élőhelyek eltűnése és fragmentációja jelenti a kétéltűek hanyatlásának legfőbb okát Nyugat-Európában. Ezek negatív hatása megállítható vagy akár vissza is fordítható megfelelő környezetgazdálkodási közbelépés által. Annak érdekében, hogy valóban hatékony ajánlatokat tehessünk ezirányban, szükség van az egyes fajok kulcsfontosságú élőhelyeinek beazonosítására. A Nagy-Küküllő medencéjében, ahol 11 kétéltű fajt és egy fajkomplexumot sikerült beazonosítani, azzal a céllal végezzük kutatásainkat, hogy megértsük a kétéltű-közösségek élőhelyhasználatát. A Nagy-Küküllő medencéjében élő kétéltűek számára fontos élőhelyi sajátosságoknak bizonyultak a következők: a ragadozó halakat nem tartalmazó állandó tavak jelenléte, melyeknek felszínén számottevő arányban van vegetáció, az erdők közelsége, valamint a tavak és az erdők között található zöldfolyosók. Az itteni kétéltű populációkra negatív hatással van a ragadozó halak betelepítése, az élőhelyek (tavak) eltűnése, és a táj fragmentációja az utak vagy a fokozott városiasodás miatt. Jelen pillanatig nem sikerült kimutatni, hogy a tavak savasságának növekedése káros hatást gyakorol-e az itt élő kétéltűekre. További tanulmányokat igényel a különböző tájelemek fontosságának felbecsülése a kétéltű populációk diszperziójában, az ezek közötti kapcsolatok létesítésében, fenntartásában, valamint a forrás-populációk beazonosításában ezen a területen. Mindemelett kiemeljük annak fontosságát, hogy a természetvédelmi beavatkozások és ezirányú kutatások a telektulajdonosok, a különböző területek használói és a helyi közösségek bevonásával történjenek. Ez a nézőpont, melyet sok herpetológus és természetvédelmi szakember inkább „szociális szakterületnek" tart, és emiatt közömbösen kezel, még a fokozott emberi térhódítás korszakában is, a biológiai sokféleség megőrzésének egyik legfontosabb eleme kell, hogy legyen.

2. A dolgozat címét Semlitsch (2002) "Critical elements for biologically based recovery plans of aquatic-breeding amphibians" cikke ihlette (lásd az irodalomjegyzéket).