Acta Biol. Univ. Daugavp. 14 (1) 2014
ISSN 1407 - 8953

HABITAT REQUIREMENTS FOR *BOMBINA BOMBINA* (LINNAEUS, 1761) AND *TRITURUS CRISTATUS* (LAURENTI, 1768) IN NORTH EUROPEAN LOWLANDS: RECOMMENDATIONS FOR POND RESTORATION

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Reshetylo O., Briggs L. 2014. Habitat requirements for *Bombina bombina* (Linnaeus, 1761) and *Triturus cristatus* (Laurenti, 1768) in North European lowlands: recommendations for pond restoration. *Acta Biol. Univ. Daugavp., 14 (1): 75 – 84.*

Documented population decline of *Bombina bombina* (Linnaeus, 1761) and *Triturus cristatus* (Laurenti, 1768) on the northern range of their species areas, as well as Habitat Directive status, and their vulnerability as ones of the most ecologically demanding species of amphibians in Europe are the main reasons for research of their habitat requirements in North European lowlands.

Data were collected from 274 ponds of different types within the investigated area in Poland, Lithuania and Germany during 2007-2010. Ponds were checked for variety characteristics as follows: physical parameters of ponds (type, size, maximum depth, slope inclination, shallow water area), water quality (sediment, water clarity and color), surrounding habitats (buffer zone around the pond, grazing, terrestrial habitat type around, distances to the closest forest and other ponds), biotic factors (shade provided by trees, presence of fish and water birds).

The results of *B.bombina* and *T.cristatus* habitat requirements research let us make recommendations for pond creation and restoration in North European lowlands. First of all it is very important to have pond clusters with different pond size and characteristics. Distances between ponds in pond cluster should be 100 m for *T.cristatus* and 200 m for *B.bombina*. In each pond cluster there should be ponds of less than 500 sq m for *T.cristatus* and larger than 2000 sq m for *B.bombina*. It is most optimal to create 0,5-1,0 m deep ponds with clear water and shallow water zone in order to secure breeding both of the species. It is important to have forest no more than 200 m far from the species' breeding ponds, which need a wide uncultivated buffer zone around (over 50 m) to be effective. It is better to avoid fish and water birds in the ponds to benefit *T.cristatus* and *B.bombina* breeding success.

Key words: Fire-Bellied Toad, Great Crested Newt, habitat, restoration, pond cluster, creation, Northern Europe.

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INTRODUCTION

An ongoing decline of the Fire-bellied toad *Bombina bombina* (Linnaeus, 1761) is now documented throughout the North European lowlands (Krone & Kühnel 1996, Fog 1997, Pupina & Pupins 2007). Additionally, the decline of the Great crested newt *Triturus cristatus* (Laurenti, 1768) is recognized in Estonia, Finland, Germany and Denmark, and is suspected in Poland and Lithuania as well (Talvi 1992, Fog 1995, Griffiths 2001, Krone 2001, Edgar & Bird 2006, Rassi et al. 2010).

Based on population genetics theories, each population of these species has to have at least 500 adults to survive in changing environmental conditions (Shaffer 1981). However, today very few populations meet this criterion as most of them are below this value. One of the ways to reach the goal is to restore, improve or even create the habitats of this annex II amphibian species, especially within intensively-used landscapes on the northern edge of their species' areas.

During successfully implemented *B.bombina* projects (Consolidation of *B.bombina* in Denmark LIFE99NAT/DK/006454, Management of *B.bombina* in the Baltic region, LIFE04NAT/DE/000028) and *T.cristatus* project (Protection of *T.cristatus* in the eastern Baltic region, LIFE04NAT/EE/000070), considerable knowledge has accumulated on the design and improvement of high quality pond habitats for amphibians. With basic experience on the projects results, there is a solid foundation for the implementation of protective measures on herpetological sites of European interest and to develop a concept of active protection of sites of high herpetological diversity in the North European lowlands. The active protection of aquatic habitats of *B.bombina* and *T.cristatus* will also often support a number of annex IV amphibian species on the same sites, e.g. *Rana arvalis* (Nilsson, 1842), *Rana lessonae* (Camerano, 1882), *Pelobates fuscus* (Laurenti, 1768) and *Hyla arborea* (Linnaeus, 1758) depending on the region in North European lowlands.

Fig. 1. *Bombina bombina* adult pond of large size (over 2000 sq m) and over 1 m deep in Northeast Poland. The pond has got fish and is unsuitable for larvae of *B.bombina* and *T.cristatus.*

The main threats to the targeted species generally are habitat fragmentation and migration barriers, loss of ponds, overgrowth of ponds, lack of hibernation sites, loss of terrestrial habitats, intensive agriculture, fish introduction, lack of public environmental awareness, etc. (Halliday 1997, Houlahan et al. 2000, Kiesecker et al. 2001).

The main objective of the investigation is to find out optimal aquatic habitat characteristics for the species to ensure the possibility of creating and restoring enough cluster ponds of good quality for the populations of *T.cristatus* and *B.bombina* in the North European lowlands.

The habitat improvement is expected to increase population sizes which are necessary for the structure of viable populations of *B.bombina* and *T.cristatus* and the successful preservation of them in the investigated region.

MATERIAL AND METHODS

Data were collected from 274 ponds within the investigated area of North European lowlands in 2007-2010. For adult *T.cristatus* we used visual observations, traps and dip-nets; *T.cristatus* larvae were checked only by dip-nets. For adult *B.bombina*: sound and visual observations; *B. bombina* larvae: dip-nets (Heyer et al. 1994). There were investigated 104 ponds in Poland, 47 in Lithuania and 123 in Germany. The species were searched during the breeding period from May to July.

Ponds were checked for variety characteristics as follows: physical parameters of ponds (type, size, maximum depth, slopes, shallow zones), geology and water quality (sediment, water clarity and color), surrounding habitats (buffer zone, grazing, terrestrial habitat within a 50 m around, terrestrial habitat within 50-500 m around, distance to the forest, distance to the other ponds), biotic factors (shade provided by trees, fish, water birds). Parameters that could be quantified were quantified and noted down. For example, ponds were classified into the size categories of 0-100 sq m, 101-500 sq m, 501-2000 sq m, 2001-10000 sq m and over 10000 sq m.

Data analysis covering the North European lowlands is presented in the results section below. The results are presented in tables where the percentage of occupancy of each species within each habitat category is shown for *Bombina bombina* and *Triturus cristatus*. The attention is drawn to the statistically significant results and most interesting trends to be used in decisions on practical implementation of habitat improvements.

For analyzing the significance of obtained results we used just a simple Chi-square test based on the null hypothesis theory. In some cases we applied Yates correction factor (Chi-square$_{0,5}$) (Brown 2004). With this simple statistics we could look individually on each parameter, e.g. pond size, amount of shade on the water surface, fish presence, etc.

The conclusion part below presents suggestions how to use the results in pond restoration practice.

RESULTS AND DISCUSSION

The results provide habitat characteristics of Fire-Bellied toad and Great Crested newt in the North European lowlands. The strength of this study is that it combines data collected in a broad area covering three countries: Southern Lithuania, Northeast and Northwest Poland, and Northeast Germany. Statistical analysis and the percentage of species occupancy in each habitat category are presented below.

Pond size

Some tendency to prefer smaller ponds (less than 500 sq m) can be noticed in *T.cristatus* larvae occupancy (36-42%). Big ponds (more than 2000 sq m) were found out to be preferable for adult *B.bombina* (57-59% occurrence) with considerable significance (Chi-square = 17.489, p = 0.0016) (Table 1, Fig. 1).

Table 1. Relation between size of the ponds and occurrence of Great crested newt and Fire-bellied toad in them

Pond size category, sq m	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
100 and less	26	42	28	20	22
101-500	58	36	17	17	27
501-2000	73	29	22	29	40
2001-10000	78	25	26	29	59
over 10000	39	0	0	20	57

Table 2. Relation between depth of the ponds and occurrence of Great crested newt and Fire-bellied toad in them

Pond depth category, m	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
less 0,5	59	25	3	0	21
0,5-1,0	107	46	10	30	45
over 1,0	108	16	24	13	49

Table 3. Relation between slope inclination of the ponds and occurrence of Great crested newt and Fire-bellied toad in them

Pond slope inclination category, grad	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
10 and less	94	35	13	26	58
11-25	109	27	16	33	48
over 25	71	32	16	0	37

Table 4. Relation between shallow water area of the ponds and occurrence of Great crested newt and Fire-bellied toad in them (0-30 cm)

Shallow water area category, %	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
10 and less	45	25	10	0	55
11-25	63	24	14	25	56
over 25	166	33	16	40	73

Table 5. Relation between water clarity of the ponds and occurrence of Great crested newt and Fire-bellied toad in them

Water clarity type	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
Brown	70	30	24	23	25
Clear	124	38	11	32	55
Muddy	80	27	14	11	47

Table 6. Relation between the buffer zone width around the ponds and occurrence of Great crested newt and Fire-bellied toad in them (area of any type of habitat except cultivated land)

Buffer zone width category, m	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
less 10	62	0	6	0	58
10-49	86	31	17	15	42
50 and more	126	37	14	34	39

Pond depth

The analysis shows significant preferences for 0,5-1 m pond depth for *T.cristatus* larvae (46% occurrence) and more than 1 m depth for adults (24%). *B.bombina* is mostly found where the water depth is at least 0,5 m (45-49% adult occurrence) (Table 2, Fig. 1).

Pond slope inclination

Analysis of the pond slope inclination doesn't show any significant dispersal for *T.cristatus*. The frequency trend of pond slope inclination shows higher adult *B.bombina* occurrence on flatter slopes (Table 3).

Shallow water area

No significant differences between *T.cristatus* preferences for shallow water areas were noticed. For *B.bombina* adults (73% occurrence) and larvae (40%) conditions seem to be more optimal if the shallow water area exceeds 25% of the pond size (Table 4).

Water clarity

The highest frequency of *T.cristatus* larvae was found in clear water ponds (38%) while the highest occupancy of adults was recorded in brown waters (24%). The preferred water clarity for *B.bombina* larvae (32%) and adults (55%) is clear water (Table 5).

Buffer zone of uncultivated land around the pond

T.cristatus occupancy was rather low in case of narrow buffer zone (0-9 m) (up to 7% occurrence) compare to the wider zone, especially on larval stage (31-37%). Only larvae of *B.bombina* show extremely significant positive relation between the width of buffer zone and their occurrence (34% in case of more than 50 m wide buffer zone) (Table 6, Fig. 2).

Distance from pond to forest

The data show that *T.cristatus* is found only in the ponds with a maximum distance to the forest of 200 m. *B. bombina* has the highest occurrence when forest is more than 50 m away: larvae in 35% and adults in 55% of the ponds (Table 7).

Distance from the investigated pond to the closest other one

Both *T.cristatus* larvae (47%) and adults (17%) have the highest occupancy in the ponds where

Table 7. Relation between pond-forest distances and occurrence of Great crested newt and Fire-bellied toad in the ponds

Distance between pond and forest, m	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
less 10	75	33	18	7	31
10-49	51	23	17	29	43
50-200	108	36	17	35	55
over 200	40	0	0	0	55

Table 8. Relation between pond-pond distances and occurrence of Great crested newt and Fire-bellied toad in the ponds

Distance between pond and pond, m	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
100 and less	71 (32*)	47	17	8	46
101-200	65 (24)	27	13	9	73
201-500	74 (30)	17	13	7	53
over 500	64 (18)	31	13	0	0

*Number of investigated ponds in case of *B.bombina*

Fig. 2. Narrow buffer zone around *T.cristatus* pond in Northern Germany.

Table 9. Relation between grazing of the ponds and occurrence of Great crested newt and Fire-bellied toad in them

Grazing of pond	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
Absent	164	38	14	7	28
Present	110	27	15	27	55

Table 10. Relation between shade provided by trees over the ponds and occurrence of Great crested newt and Fire-bellied toad in them

Shaded portion of the pond surface, %	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B bombina* larv, %	Presence of *B.bombina* ad, %
0	96	28	14	29	50
25	79	35	19	17	45
50	41	50	19	0	39
75	39	33	6	0	27
100	19	50	0	0	0

Fig. 3. *B.bombina* and *T.cristatus* moderately grazed pond in Northeast Poland.

Table 11. Relation between fish presence in the ponds and occurrence of Great crested newt and Fire-bellied toad in them

Fish presence	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
Absent	188	39	12	9	36
Present	86	13	24	0	49

Table 12. Relation between water birds presence in the ponds and occurrence of Great crested newt and Fire-bellied toad in them

Water birds presence	Number of investigated ponds	Presence of *T.cristatus* larv, %	Presence of *T.cristatus* ad, %	Presence of *B.bombina* larv, %	Presence of *B.bombina* ad, %
Absent	193	27	14	7	27
Present	81	12	0	0	38

the distance to the closest other pond is less than 100 m (Chi-square = 11.414, p = 0.0097 for larvae). The highest occupancy of *B.bombina* adults (73%) was recorded in the ponds with neighboring ponds within 100-200 m (Chi-square = 9.889, p= 0.0195) (data obtained in Poland only) (Reshetylo & Briggs 2014) (Table 8).

Grazing of pond

Pond grazing seems to have a slightly negative influence on the occurrence of *T.cristatus* larvae, however it is not proven to be statistically significant. Clear assumption can be made in case of *B.bombina*: both larvae and adults are much more frequent in grazed ponds but the results are considered to be not statistically significant (Table 9, Fig. 3).

Characteristics of habitats around the pond

Analysis of surrounding terrestrial habitats showed that *T.cristatus* larvae and adults have the highest presence when in the vicinity of the pond there is dead wood (39% for larvae, 18% for adults), meadow/fen (41% for larvae, 20% for adults), or common dry grassland (46% for larvae, 25% for adults). High occurrence of *B.bombina* larvae was recorded in cases where the surrounding habitat was presented by meadow/fen, shrub, deciduous forest or common dry grass (24-29%). *B.bombina* adults were found mostly in the ponds where field and shrub occur around the pond (56-57%). It may be that adults are found in many pond types with different surroundings, but larvae are found mainly where surroundings consist of more natural habitats. In the landscapes with intensive agriculture, where *B.bombina* populations are declining, adults may still occur and even call, but breeding success is reduced or limited by agricultural pollution of the ponds (Briggs & Damm 2004).

Amount of shade on the pond surface

Optimal shade over the pond for *T.cristatus* is 25-75% according to our results. The conclusion is considered to be statistically significant for larvae of *T.cristatus* (33-50% occupancy). The less shade (0%) the better conditions for *B.bombina* larvae and adults (29% and 50% correspondingly), what is also statistically significant (Chi-square$_{0,5}$ = 5.786, p = 0.0173 and Chi-square = 33.830, p = 0.0001) (Table 10).

Influence of fish

Analysis of the influence of fish presence in the ponds showed that *T.cristatus* larvae have much higher occurrence in fishless ponds (39%) compared to those with fish (13%). *B.bombina* larvae were found only in the ponds without fish (9%),

whereas adults inhabit both pond types (36% and 49%) (Table 11).

Influence of water birds

There is statistically significant lower occurrence for *T.cristatus* larvae with water birds presence in the pond (Chi-square$_{0,5}$ = 11.253, p = 0.0008) but not for adults (Chi-square$_{0,5}$ = 2.250, p = 0.1673). Results of analysis of the given parameter (mostly foraging of water birds) for larvae and adults of *B.bombina* are considered to be not statistically significant (Table 12).

CONCLUSIONS

Based on the results of our research and on the experience of mentioned LIFE projects focused on *B.bombina* and *T.cristatus* we can make recommendations for pond creation and restoration. The following criteria and parameters for pond restoration in North European lowlands are important for both of the investigated species.

Generally it is very important to have pond clusters with different pond size and rich in the biological structures needed for each species. Some biological structures like plant communities or dead wood develop in time and can't be managed at once, but during the restoration and creation process it is possible to influence on physical parameters of the ponds, water color and quality, distance to other habitats, fish presence, grazing, etc.

So, we suggest that increasing pond density will benefit for the species: distances between ponds in pond cluster should preferably be 100 m for *Triturus cristatus* and 200 m for *Bombina bombina*. In each pond cluster it seems to be better to have some ponds of less than 500 sq m for *Triturus cristatus* and some larger than 2000 sq m for *Bombina bombina.*

It is most optimal to create 0,5-1,0 m deep ponds for *Triturus cristatus* and deeper than 0,5 m for *Bombina bombina*. Pond slope inclination and shallow water area have no real influence on *Triturus cristatus*, while *Bombina bombina* prefers ponds with flat slopes and shallow zone more than 25% cover. So it is recommended to create ponds with a variation in slopes and always with shallow water zone in order to benefit both of the species.

It is better to have clear water in the ponds both for *Triturus cristatus* and *Bombina bombina*, especially in case of larvae, but adults can also live in brown or muddy water. It is recommended to have several ponds with clear water in each cluster to secure breeding of *Triturus cristatus* and *Bombina bombina.*

The composition of terrestrial habitat is of high importance for the species as preferable distance from the breeding ponds to the nearest forest for *Triturus cristatus* and *Bombina bombina* is no more than 200 m, better less for *T.cristatus*. Moreover, breeding ponds to be effective need a wide uncultivated buffer zone around (over 50 m). One of the best ways to maintain it in optimal condition is moderate grazing, which has shown its positive effect in case of *Bombina bombina*. In support of this, the occurrence of permanent grasslands close to *Triturus cristatus* and *Bombina bombina* aquatic habitats (within 50 m around) was found to be important as well.

It is better to make moderate shaded ponds for *Triturus cristatus*, and the less shade the better for *Bombina bombina*. It is important to create/restore fishless breeding ponds for the species as their larvae can't normally survive together with fish, while some exceptions can be in the case of a large fluctuating shallow zone. At the same time adults can live also in ponds with fish. Presence of water birds in the pond might be harmful for the species, especially ducks for the larvae of *Triturus cristatus* and *Bombina bombina*, while the birds do not harm adults according to this study. So, it is not needed to avoid water birds in the pond cluster but it is important not to attract them by feeding or other actions.

ACKNOWLEDGEMENT

The research was carried out in the frames of LIFE-projects "Management of *B.bombina* in the Baltic region" (LIFE04NAT/DE/000028) and "Protection of *Emys orbicularis* and amphibians in the North European lowlands" (LIFE05NAT/LT/000094). Authors are grateful to all the collegues involved in the research for their help, comments and cooperation.

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Received: 15.09.2014.
Accepted: 25.09.2014.