

Can Change of Landscape Composition Increase Interspecies Competition Among Amphibians and Thus Decrease the Body Condition of the Endangered *Bombina variegata*?

Peter Mikoláš^{1, 2*}

¹Institute of High Mountain Biology, University of Žilina,
SK - 059 56 Tatranská Javorina 7, Slovak Republic

²Department of Ecology and Environmental Sciences, Faculty of Science, Palacký University,
Šlechtitelů 11 Olomouc, Czech Republic

Received: 18 March 2016

Accepted: 22 April 2016

Abstract

This study investigates the effect of forest cover in close proximity to breeding ponds (N = 29) together with the effect of the presence or absence of other amphibian species on the residual body condition index of *Bombina variegata* (N = 106). PCA and ANOVA analysis showed that body condition index was higher in toads found in breeding ponds with higher forest cover within a radius of 50 m. This observation confirms the results of other authors. Other amphibian species (*Bufo bufo*, *Rana temporaria*, *Triturus montadoni*) occurred together with *Bombina variegata* mostly in ponds surrounded by larger deforested areas. Furthermore, the significantly lower body condition index of *Bombina variegata* was observed mostly in ponds occupied by other amphibian species ($p < 0.001$). Results suggest that *Bombina variegata* is better adapted to shaded environments in comparison to other amphibians and therefore is able to achieve higher body condition in forest ponds not only due to higher nutrient availability and higher moisture but also decreased competition.

Keywords: deforestation, protected areas, land use, body condition index

Introduction

Bombina variegata is frequently described as a species that prefers open unshaded ponds. However, it is known that it can also flourish in cooler environments at higher altitudes [1]. According to Zavadil [2], this species is at present more common in forest environments because there are more permanent ponds and the microclimate

contains more moisture. Scheele [3] measured a higher body condition index of *B. variegata* in forest ponds, indicating adequate conditions in forests. However, at present deforestation is one of the main causes of amphibian decline [4-5].

Deforestation is not only a problem for amphibians in protected areas of Slovakia [6-7] but is also a global issue [8-10]. The main drivers of forest degradation in Slovakia are logging (both legal and illegal) [11] and construction of forest roads [12]. The change of microclimate and reduced

*e-mail: peter.mikolas44@gmail.com

food accessibility are just a few examples of what impacts amphibian physiology [13]. The abundance of predators and pathogens can also be significantly influenced by changes in habitat [14].

How changes in land-use patterns affect the distribution and abundance of organisms is an important question in ecology [15]. There is a great need to focus on individual processes that reflect proximal ecological mechanisms underlying population responses to landscape alterations [16-17]. In general, there are amphibian species that prefer open-canopy ponds and species that are adapted to cooler forest environments [2, 18]. Several studies note a general pattern of increased species richness with increasing forest cover [19-21]. Forest environments provide advantages such as increased moisture and more nutrients.

On the other hand, ecological conditions of closed-canopy ponds may not be suitable for most amphibians. The effect of closed-canopy ponds on the distribution of amphibians was observed, for example, by Werner and Glennemeier [22], who found that either differences in resources or interactions between resources and low dissolved oxygen are largely responsible for the exclusion of some species from closed-canopy ponds. This type of pond was inimical, for example, to *Rana sphenoccephala* and *Anaxyrus americanus*. The advantage of closed-canopy ponds is that they likely provide primarily detritus-based resources – especially bacteria and fungi associated with leaf decomposition [23].

The present study focused on the residual body condition index of *B. variegata* in relation to forest cover in close proximity to ponds and to the presence/absence of other amphibian species. It was hypothesized that the body condition index of *B. variegata* would be lower in populations from ponds with largely deforested surroundings because ecological conditions are in such cases degraded by decreased humidity, decreased food availability, and increased stress due to logging and wood transportation, etc. It was also predicted that the body condition index of *B. variegata* would be lower in ponds colonized by other amphibians due to increased competition for resources. Monitoring the body condition index in amphibians is important for early management before extinction and for ensuring adequate protection of endangered species.

Material and Methods

Study Area

The study area is a part of the Bukovské Mountains, consisting mainly of coarse sandy flysch, greenish-grey and red claystone, and fine sandstone. The area belongs to a moderately warm region, with less than 50 summer days annually on average, and daily maximum air temperature $\geq 25^{\circ}\text{C}$ and a July mean temperature of 16°C .

Vegetation of the studied area is covered mostly by beech forests with such species as coralworts (*Dentaria bulbifera*, *D. glandulosa*), purple rattlesnake root

(*Prenanthes purpurea*), wood barley (*Hordelymus europaeus*), mountain fescue (*Festuca drymeia*), and wood speedwell (*Veronica montana*). Fir (*Abies alba*) occurs at higher locations with increased moisture. Deciduous trees such as Scotch elm (*Ulmus montana*), ash (*Fraxinus excelsior*), sycamore (*Acer pseudoplatanus*), and lime (*Tilia cordata*) can be found on sites with more humus and on talus. In these habitats the herb layer is also different, dominated by perennial honesty (*Lunaria rediviva*), dog's mercury (*Mercurialis perennis*), and white butterbur (*Petasites albus*). Maple-beech forests occur at the highest elevations (1,000-1,190 m.a.s.l.). Mountain brooks are lined by various willows (*Salix aurita*, *S. silesiaca*), butterburs (*Petasites hybridus*, *P. kablikianus*), pendulous sedge (*Carex pendula*), and shiny chervil (*Anthriscus nitida*) in the herb layer [12].

Data Collection

One-hundred and six samples of *B. variegata* from 29 localities were collected (Figs 1-2) in Poloniny National Park (Bukovské Mts.) between April and June 2013. Mass was measured to 0.5 g using PESOLA (50 g) and body length (snout to vent) to 0.02 mm by vernier calliper. Individuals with a snout-vent length greater than 30 mm were considered adults [24]. Environmental data were collected directly in the field: pond depth, elevation, and GPS coordinates (GARMIN Oregon 300 with precision ± 7 m) and the presence/absence of other amphibian species (*Bufo bufo*, *Rana temporaria*, *Triturus montadoni*). After log transformation of weight and body length measurements, the residual body condition index was calculated using STATISTICA 8.0 software (StatSoft, USA) according to Băncilă [25]. To investigate the effects of forest cover in close proximity to the breeding ponds of *B. variegata* on the body condition index, the surface of the deforested area was calculated around each of the locations within the circle with a radius of 50 m. To perform these calculations ARC GIS software (version 10.2) was used with satellite imagery (DIGITAL

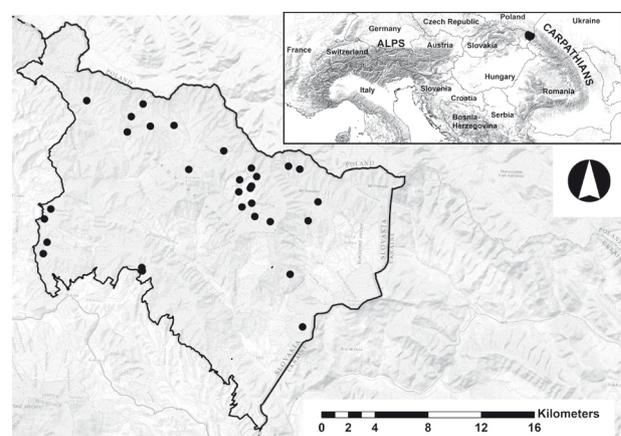


Fig. 1. Studied locations with the presence of *B. variegata* in Poloniny NP (Slovakia, N $49^{\circ}02'07.90''$; E $22^{\circ}19'39.62''$).

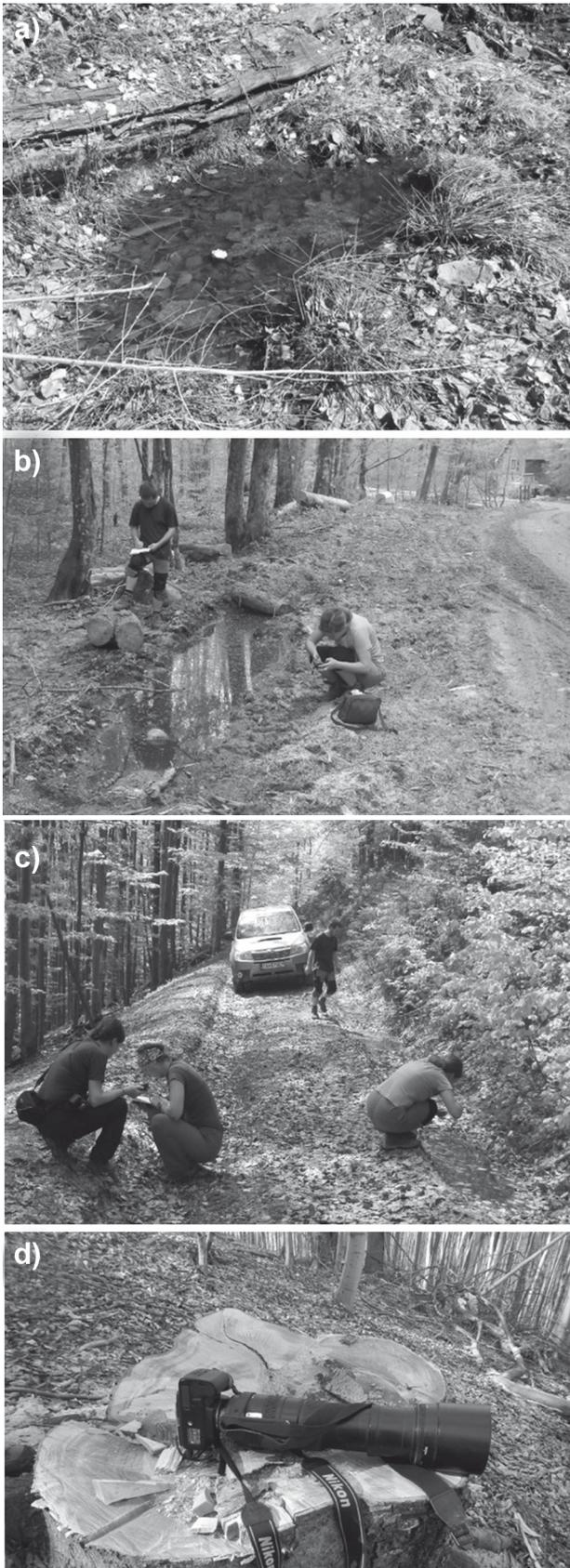


Fig. 2. Field data collection in Poloniny NP. a) Open-canopy pond with presence of *B. variegata* together with egg clutches of *R. temporaria*. b) Closed-canopy pond with presence of only *B. variegata*. c) Breeding pond of *B. variegata* surrounded by deforested area due to forest road. d) Sign of logging activities in protected area near breeding ponds of *B. variegata*.

GLOBE 25.8.2011) of the studied area, captured from Google Earth (Google, Inc. Mountain View, CA, USA) as a base-map.

Statistical Analysis

Statistical analyses were performed using Statistica 8.0 software (StatSoft, USA). Data were previously log-transformed. Principal component analysis (PCA) was used for evaluating the measurements. The variables used in PCA analysis were: residual body condition index, deforested area within 50 m of pond, elevation, pond depth. Principal components with an Eigen value greater than 1.0 were tested with ANOVA to reveal the effect of the presence or absence of other amphibians.

Results and Discussion

PCA results show that *B. variegata* had higher values of residual body condition index in deeper breeding habitats surrounded by larger areas of forest within 50 m and at lower elevations (Table 1). This is in agreement with Scheele [3], who found a higher body condition index among toads from forested landscapes compared to those from pasture ponds. According to Janin [26], body condition can be influenced by short- and long-term environmental stress. Body condition of *Ensatina eschscholtzii* was found to be significantly lower in thinned forests in Northwestern California [27]. Janin [26] detected poorer condition and elevated basal corticosterone levels in common toads found in landscapes characterized by both low forest availability and high forest fragmentation within a 500 m radius of ponds.

On the other hand, the results of the present study are in contrast with studies that describe *B. variegata* as a species preferring open pasture ponds [28-29]. Barandun and Reyer [28] found that *B. variegata* did not use cool or shaded as well as permanent ponds for spawning. Unshaded water bodies are also preferred by *B. variegata pachypus* [30]. So why can *B. variegata* be found in forested landscape with a higher body condition index? Zavadil [2] explained that in recent landscape types in

Table 1. Results of PCA analysis of selected variables.

Variable	PC Body condition index	PC Deforested area	PC Pond depth
Residual body condition index	0.64	-0.29	0.55
Deforested area (r = 50 m)	-0.52	0.65	0.26
Elevation	-0.5	-0.65	-0.33
Pond depth	0.57	0.34	-0.67
Eigenvalue	1.25	1.04	0.92
% Total variance	31.23	26.12	23.07

Europe *B. variegata* has neither adequate aquatic nor terrestrial habitats outside the forest. If there is sufficient habitat outside the forest, toads prefer it.

Results of ANOVA (Fig. 3.) showed that ponds with less forest cover in their surroundings and at lower elevations were inhabited by other amphibians besides *B. variegata*, likely due to increased temperature of breeding habitats. Environmental temperature is positively correlated with rate of growth and metamorphosis [31-32]. Shallow, warm, and productive ponds allow faster larval development and rapid attainment of developmental threshold [33-34]. Other species found in ponds with *B. variegata* were *B. bufo*, *R. temporaria*, and *T. montadoni* – all of which can also be found in forest landscapes [2].

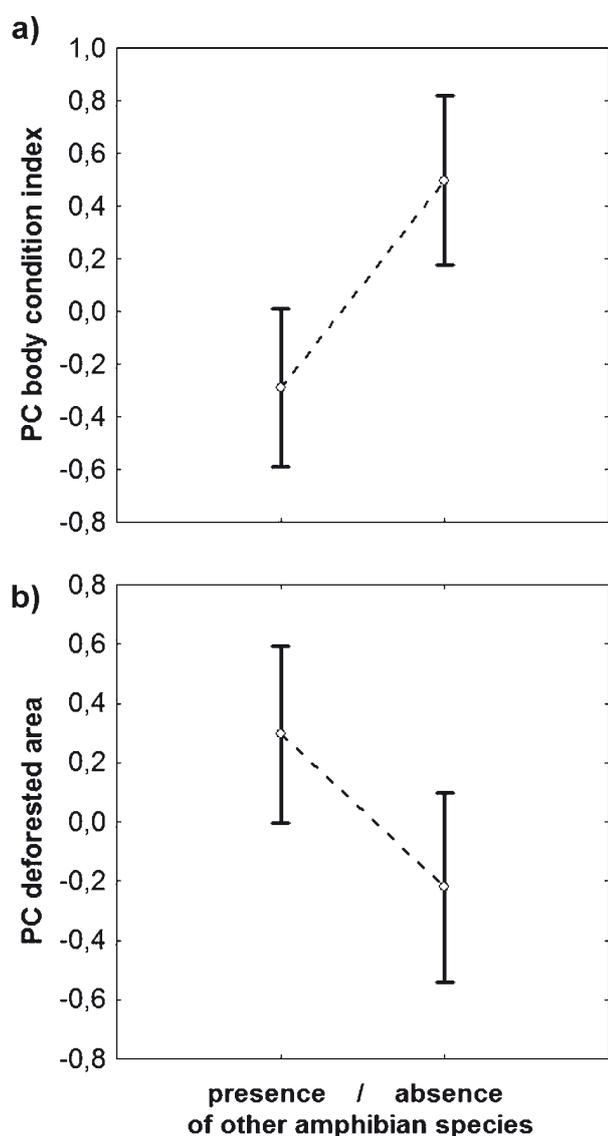


Fig. 3. Comparison of principal components given in Table 1 with Eigen values >1 using ANOVA +/- standard deviation. a) Body condition index of *B. variegata* was significantly lower in ponds with presence of other amphibian species ($F(1, 104) = 12.541, p < 0.001$). b) Deforested area was significantly larger around ponds with presence of other amphibian species including *B. variegata* ($F(1, 104) = 5.48, p < 0.05$).

Hartel [35] observed that ponds preferred by *B. variegata* for reproduction also contained predatory newts (*Triturus vulgaris*, *Triturus cristatus*) and insects (*Odonata*, *Dytiscidae*).

ANOVA analysis (Fig. 3) also shows that *B. variegata* had a higher body condition index in ponds situated in forest and without the presence of other amphibians. It is clear that *B. variegata*, like many other amphibians, prefers warmer ponds outside the forest, but its body condition index can be reduced by competition pressure from other species occupying the same ponds. It is possible that the absence of other amphibians in forest ponds is one of the reasons for a higher body condition index of *B. variegata*, in addition to higher resource availability, more humid micro-climatic conditions, and higher water availability. On the other hand in the case of intraspecific competition Scheele [3] observed no correlation between body condition index and the relative abundance of *B. variegata*. This can be explained by the tendency of toads to frequently move between ponds in a radius of up to 200 m [36]. The more ponds the toad uses, the more resources are available. Therefore, the body condition of adults may not be affected by intraspecific competition if ponds are occupied by *B. variegata* only. However, competition of *B. variegata* conspecifics was observed as a stress factor during their larvae stadium. For example, experimental studies made by Hartel [35] indicated that larval mortality was high in crowded conditions. Jasiński [37] compared the growth and development of sibling and non-sibling *B. variegata* larvae under high-density conditions and found a negative effect of the larger non-sibling tadpoles.

The present study emphasizes that forest is a very important habitat for the internationally endangered *B. variegata* (European Union Habitats Directive Annex II and IV) because it may serve as a refugium with lower competition pressure in contrast to open habitats. The forest also provides better conditions in times of drought [2-3]. Therefore, deforestation may be a serious threat to *B. variegata* in recent and future rural landscapes. While some disturbance of landscape can increase amphibian diversity by creating new breeding habitats [30], on the other hand deforestation can reduce fitness of individuals due to reduction of resources, etc. [3].

There is a need for long-term studies to assess the abundance of all amphibian species occupying the same ponds and to investigate how this affects their body condition index. A long-term study assessing the body condition index of toads would also reveal the trend in their fitness and provide a warning in case of decreasing trends.

Conclusions

This study found that body condition index of *B. variegata* was higher in breeding ponds surrounded by forest landscape in Poloniny National Park (Bukovské Mountains, Slovakia) in comparison to ponds situated in deforested areas. This trend is in agreement with other

investigations conducted in other parts of Europe [3], which emphasizes that forest habitats are important for the protection of internationally endangered amphibian species. Results also showed that amphibian diversity of breeding ponds situated in a deforested landscape is higher (*B. variegata*, *B. bufo*, *R. temporaria*, *T. montadoni*), but the body condition index of *B. variegata* was in these ponds lower in contrast to locations situated in a forest landscape, where the amphibian diversity was smaller and often occupied only by *B. variegata*. These observations suggest that deforestation around amphibian breeding ponds can cause changes in species composition and thus increase interspecies competition, leading to a decrease of amphibian body condition index.

Acknowledgements

This study was partly supported by a project of the Swiss Contribution and State Nature Conservancy of Slovakia [1551/2011], titled "Development of nature protection and protected areas in the Slovakian Carpathians," and partly by Structural Funds of an EU project of the Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic, Bratislava (ITMS No. 26110230078). The Institute of High Mountain Biology was permitted (No. 4797/2008-2.1) to catch and examine protected species in accordance with Act No. 543/2002 on nature and landscape protection. My sincere thanks to Marián Janiga, Zuzana Hrehová, Tomáš Vatycha, Jaroslav Stoklasa, Edita Karaščáková, Monika Pajonková, Ján Graban, and Natália Maximová for their valued assistance in the field. I also thank Robin Rigg of the Slovak Wildlife Society for linguistic assistance.

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