DIET AND TROPHIC NICHE OVERLAP OF THREE TOAD SPECIES (AMPHIBIA, ANURA) FROM POLAND

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ABSTRACT

During our study we identified 53 prey items in the trophic spectrum of Bombina bombina, 124 prey items in the diet of Bufo bufo and 95 prey items in the diet of Epidalea viridis. The average number of prey items per stomach is as follows: Bombina bombina - 7.57, Bufo bufo - 9.0 and Epidalea viridis - 13.57. In all studied species the most important prey category is Coleoptera. Other important prey animals are Hemiptera, Hymenoptera and Dermaptera as well as non-insect invertebrates (Gastropoda and Arachnida) which also play significant role. All toads consume almost only terrestrial prey. The trophic niche breadths for the three species are as follows: Bombina bombina - 5.40, Bufo bufo - 4.47 and Epidalea viridis - 2.42. The estimated trophic niche overlap between the species is moderate (58.82% - 63.72%) and probably there is no or insignificant competition for food resources between them in the places with sympatric distribution. All studied species are polyphagous zoophages, like other amphibian species and they are probably consuming all mobile objects which they come in contact with and can swallow.

Keywords: trophic spectrum, niche overlap, *Bombina bombina*, *Bufo bufo*, *Epidalea viridis*, Poland.

Introduction

Amphibians are important components of ecosystems, because they direct energy from invertebrates, mainly detritivores and phytophages, to higher trophic levels (4). To understand the position of amphibians in the trophic chains it is important to know their food composition (10), studying of which is one of the primary directions in the ecological studies and there are quite a lot of publications in the field.

The Fire-bellied Toad (*Bombina bombina*), the Common Toad (*Bufo bufo*) and the Green Toad (*Epidalea viridis*) are the most common anuran species in Central and Eastern Europe as well as in Poland (1). In most of their range these species have sympatric distribution (8). Because of that studying the potential competition for food between them is an interesting case study. Currently such studies are scares. Studies on the quantitive and qualitative trophic spectrum of these species in Poland are done by several authors (13, 15, 16, 17, 18, 19 and others).

The aim of the current study is to present the trophic spectrum of *Bombina bombina*, *Bufo bufo* and *Epidalea viridis*, their trophic niche breadth and niche overlap from several localities in Poland.

Materials and Methods

For the purposes of the current study we examined a total of 68 stomachs - 37 belonging to the Fire-bellied Toad (*Bombina bombina*), 20 belonging to the Common Toad (*Bufo bufo*), and 11 belonging to the Green Toad (*Epidalea viridis*), preserved in 70% alcohol and kept in the herpetological collection of the Department of Ecology and Environmental Conservation in the Faculty of Biology at the University of Plovdiv, Bulgaria. The material was collected in June 1977 and August 1978 from the following localities (**Fig. 1**): *Bombina bombina* – Miloslaw (Wielkopolskie District), Pyzdry (Konańskie District), Wejherowo (Gdańskie District) and Tczew (Gdańskie District); *Bufo bufo* - Gluche

(Gdańskie District) and Tczew (Gdańskie District) and *Epidalea viridis* - Pyzdry (Konańskie District) and Tczew (Gdańskie District).

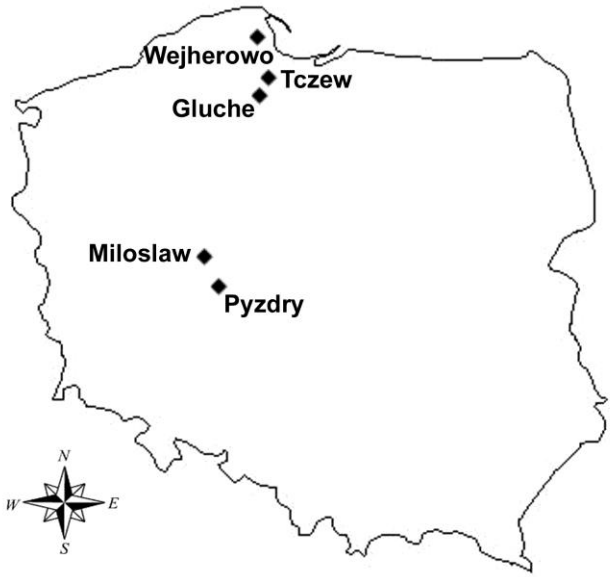

Fig. 1. Localities of the collected material from Poland

The stomachs were dissected in Petri dishes and the stomach contents were analyzed by means of stereomicroscope. The prey taxa were identified to the lowest possible taxon, based on its degree of composition. The systematic of the identified taxa follows Fauna Europaea (6).

For each species are given the number of prey categories, the number of prey items and percentage proportion. Beside the amount of preys (numeric proportion), an important parameter for the study of the trophic spectrum is the frequency with which the preys are consumed. It is important for the determining the value that a certain taxon prey has for the analyzed species, as a consequence to the fact that an individual frog can eat not just different prey taxa but also more individuals of a certain taxon prey. The frequency can be defined as the ratio between the number of stomachs that contain a certain taxon prey and the total of analyzed stomachs, the obtained value being expressed in percentages.

We classified each prey item as either terrestrial or aquatic on the basis of the habitats in which it typically occurs.

Sampling adequacy was determined using Lehner`s formula (11):

$$Q = 1 - \frac{N_1}{I},$$

rising from 0 to 1, where N_1 is the number of the food components occurring only once, and I is the total number of the food components.

The diversity of the diet (niche breadth) was calculated for each season, and the whole period of study, using the reciprocal value of the Simpson's diversity index (2, 21):

$$S = \frac{1}{\sum p_i^2},$$

where: S – trophic niche breadth; P_i – proportion of food component i.

To determine the level of the food specialization we used the index of dominance of Berger-Parker (d), calculated by the following formula (12):

$$d = \frac{n_i \max}{N},$$

where: N – the number of all recorded food components (taxa); $n_i max$ – the number of the specimens form taxon i (the most numerous taxon in the diet). The Berger-Parker index (d) varies between $1/N$ and 1. A value closer to 1 means a higher specialization in the choice of food; a value closer to $1/N$ is typical for a species that is a general feeder (polyphage).

The food niche overlap was calculated by Pianka`s adaptation of Mac Arthur and Levin's formula (21):

$$O_{j,k} = \frac{\sum P_{ij} \cdot P_{ik}}{\sqrt{\sum P_{ij}^2 \cdot \sum P_{ik}^2}},$$

where j and k refer to the two species under comparison, O – niche overlap, P_i – proportion of food component i.

The results were statistically processed using descriptive statistics and t-test for independent samples, to compare the numeric proportion all prey taxa between species in order to detect differences in the use of food resources. Because the data didn't have normal distribution it was normalized using the arcsine transformation (7).

For the statistical processing of the data we used the software package "Statistica 7.0" (25). For the calculations of Simpson's diversity index and the Berger-Parker index we used the computer software "Biodiversity Pro" (14) and for the calculation of the niche overlap we used the computer program "EcoSim 7.0" (9).

Results and Discussion

The analyzed stomach contents - a total 37 stomachs of *Bombina bombina* showed that 23 were empty and 7 contained only digested remains. A total of 7 stomachs contained 53 prey items (**Table 1, Fig. 2**). The average number of prey items per stomach is 7.57 (SD=6.32). The sampling adequacy is considered sufficient - 0.71.

From total of 20 stomachs of *Bufo bufo* - 5 were empty and 1 contained only digested remains. A total of 14 stomachs contained 124 prey items (**Fig. 2, Table 1**). The average number of prey items per stomach is 9.0 (SD=5.94). The sampling adequacy is considered sufficient - 0.84.

From total of 11 stomachs of *Epidalea viridis*, 4 were empty and from 7 stomachs we obtained 95 prey items (Table 1, Fig. 2). The average number of prey items per stomach is 13.57 (SD=9.47). The sampling adequacy is considered sufficient - 0.83.

TABLE 1

Descriptive statistics of the diet of three studied toad species from Poland

Species	Number of stomachs	Number of prey categories	Number of prey items	Mean	Standard Deviation (SD)	Standard Error (SE)
Bombina bombina	7	24	53	2.21	4.40	0.90
Bufo bufo	14		124	5.17	11.22	2.29
Epidalea viridis	7		95	3.96	12.19	2.49

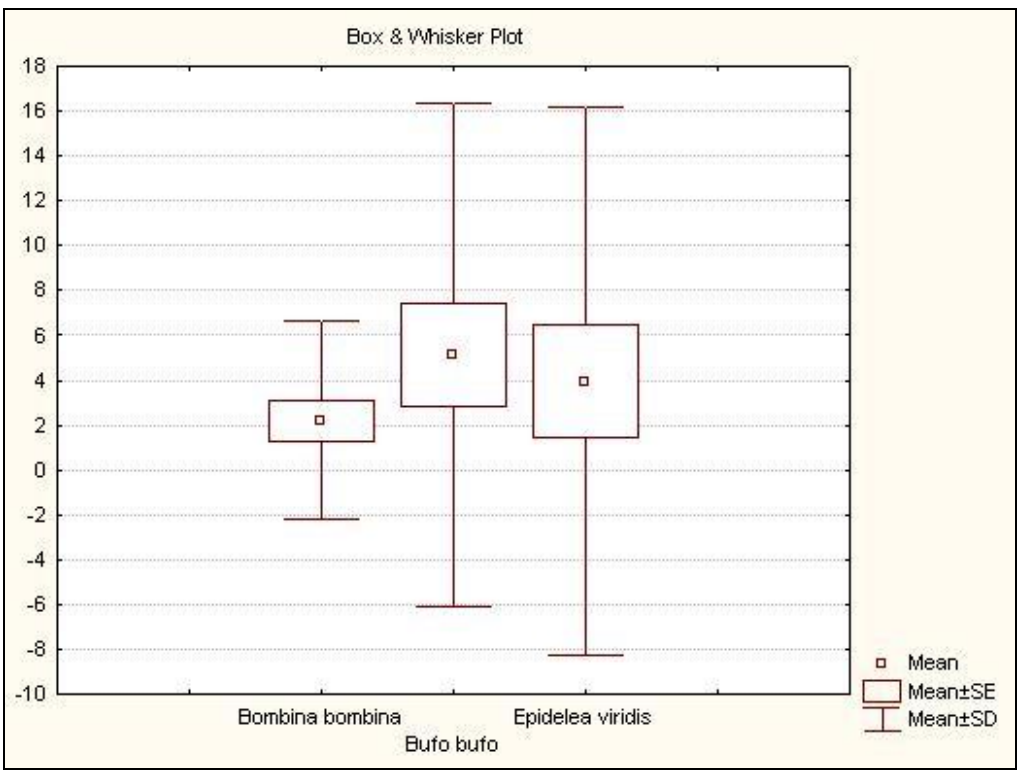

Fig. 2. Box & Whiskers Plots of the trophic spectrum of three studied toad species from Poland

Table 2 presents the qualitative and quantitative proportion and frequency of occurrence of the trophic spectrum of *Bombina bombina*, *Bufo bufo* and *Epidalea viridis*. The predominated food type in the diet of all three toad species is insects (*Bombina bombina* - 60.37%, *Bufo bufo* – 96.77%, *Epidalea viridis* – 93.68%).

The most numerous prey taxon in the diet of the Fire-bellied toad is the Coleoptera order (35.85%), followed by

TABLE 2

Trophic spectrum of the three studied toad species from Poland. Legend: **n** – number of prey items; **n%** - numeric proportion (percentage proportion from the total number of prey items); **f%** - frequency of occurrence (percentage proportion of the frogs that consumed the prey taxon)

Prey taxa	*Bombina bombina*			*Bufo bufo*			*Epidalea viridis*		
	n	**n%**	**f %**	**n**	**n%**	**f %**	**n**	**n%**	**f %**
Arachnida, Aranei	3	5.66	14.29	3	2.42	21.43	2	2.11	14.29
Mollusca, Gastropoda	17	32.08	28.57	—	—	—	4	4.21	14.29
Crustacea, Isopoda	1	1.89	14.29	—	—	—	—	—	—
Insecta									
Trichoptera (larvae)	1	1.89	14.29	—	—	—	—	—	—
Hemiptera – undet.	2	3.77	28.57	—	—	—	1	1.05	14.29
Cicadinea	—	—	—	2	1.61	14.29	6	6.32	42.86
Auchenorrhyncha	—	—	—	11	8.87	28.57	—	—	—
Hymenoptera – undet.	1	1.89	14.29	—	—	—	—	—	—
Formicidae	—	—	—	30	24.19	14.29	—	—	—
Diptera, Brachicera	1	1.89	14.29	2	1.61	14.29	—	—	—
Diptera, Nematocera	1	1.89	14.29	—	—	—	2	2.11	28.57
Diptera (larvae)	3	5.66	14.29	2	1.61	7.14	—	—	—
Coleoptera – undet.	—	—	—	1	0.81	7.14	2	2.11	14.29
Buprestidae	—	—	—	—	—	—	1	1.05	14.29
Carabidae	15	28.30	85.71	49	39.52	64.29	60	63.16	100.00
Coccineliadae	—	—	—	3	2.42	14.29	1	1.05	14.29
Curculionidae	1	1.89	14.29	6	4.84	35.71	5	5.26	42.86
Chrysomelidae	—	—	—	5	4.03	21.43	—	—	—
Ipidae	1	1.89	14.29	—	—	—	—	—	—
Staphylinidae	2	3.77	14.29	2	1.61	14.29	—	—	—
Coleoptera (larvae)	—	—	—	3	2.42	21.43	1	1.05	14.29
Dermaptera	4	7.55	14.29	3	2.42	21.43	10	10.53	28.57
Lepidoptera (larvae)	—	—	—	1	0.81	7.14	—	—	—
pebbles, soil, sand	—	—	—	1	0.81	7.14	—	—	—
Sampling adequacy		**0.71**			**0.84**			**0.83**	
Berger-Parker index[1]		**0.36**			**0.53**			**0.73**	
Niche Breadth		**5.40**			**4.47**			**2.42**	

[1]The Berger-Parker Index of dominance is calculated for the main prey taxa at order level

class Gastropoda (32.08%) and the Dermaptera order (7.55%). The Berger-Parker index showed considerably low value - 0.35 (**Table 2**). Most of the recorded prey taxa are classified as terrestrial (81.13%).

The predominated food type in the diet of the Common Toad is also the Coleoptera order with much higher proportion (53.23%), followed by the Formicidae family (24.19%) and the Hemiptera order (10.48%), especially Auchenorrhyncha. The Berger-Parker index showed a medium value of 0.53 (**Table 2**). The majority of the prey is classified as terrestrial and only 2.82 % of the prey is classified as aquatic.

The predominated food type in the trophic spectrum of the Green Toad again is the Coleoptera order, showing the highest proportion (72.63%) from all of the studied species, followed by the Dermapetra (10.53%) and the Hemiptera orders (7.37%). The Berger-Parker index showed a value of 0.73 (**Table 2**). The majority of the prey is classified as terrestrial (85.71%).

The trophic niche breadth of *Bombina bombina* has the highest value of all three studied species (5.40), followed by *Bufo bufo* (4.47) and *Epidalea viridis* showed the lowest value - 2.42. The estimated trophic niche overlap between the three toad species showed close values and could be considered as "moderate". The comparison between the numeric proportions of the diets (t-test) did not show any statistically significant differences. The trophic niche overlap between *Bombina bombina* and *Bufo bufo* is 60.17% (t-test, t=-0.52, p=0.61), between *Bombina bombina* and *Epidalea viridis* - 58.82% (t-test, t=-0.12, p=0.90) and between *Bufo bufo* and *Epidalea viridis* - 63.72% (t-test, t=0.44, p=0.66). The performed cluster analysis showed higher faunistic similarity between the trophic spectrum of *Bufo bufo* and *Epidalea viridis* (about 60%), compared with *Bombina bombina* (**Fig. 3**).

Unidentified insects in this study usually consisted of a wings, legs, or body segments, which may indicate that either the frog was unable to capture the entire prey item or the remaining portion of the prey item was not detected because it had passed through the digestive system at a different rate.

Because of the fact that the material was collected only in one season it is impossible to analyze the seasonal variations of the trophic spectrum.

The stomach contents of the three studied species of toads underlines the fact that these species are opportunistic predators, having a generalist feeding, generally using the *"sit and wait"* method (20), consuming every animal that reaches their perimeter and has the right size to be captured. All three species do not show a specialization in feeding (except for *Epidalea viridis*, which shows slight preferences to the Coleoptera order), consuming both high and low energetic content preys.

The preys of animal nature are the most important category in the stomach contents, regarding the fact that the adult amphibians are predators (5). The insect larvae are given separately from the imagoes considering that they are different prey categories as mobility and as the environment of their capture. REDFORD & DOREA (22) claimed that adult insects do not vary much as nutrition content but still it is considered that the larvae and pupae of holo–metabolic insects are rich in lipids and thus, more nutritive (3).

The most important prey category for all three species is Coleoptera, being consumed frequently. The beetles are basic food most probably due to the abundance of this food and the wide range of habitats where it could be found. Other important prey animals are Hemiptera, Hymenoptera and Dermaptera as well as non-insect invertebrates (Gastropoda and Arachnida), which also play significant role.

In the stomach contents of the Common Toad we obtained some pebbles. Their presence in the trophic spectrum should be considered as accidental.

The diet of all three studied species is consisted with almost only terrestrial prey. The toads in general tend to drift away from their aquatic habitat outside the breeding season (13). Toads are very well adapted to hunt in terrestrial biotopes and aquatic preys becoming accessible when the puddles dry out or in ponds with an extremely low water level. Aquatic prey consisted of the following taxa: Aranei (*Argyroneta aquatica*), Gastropoda, Isopoda, Trichoptera (larvae) and Diptera (larvae).

Despite the large variety in the diet composition, differences in the numeric proportion of the prey and the trophic niche breadths, there were no statistically significant differences in the diet between the three species. However the niche overlap was moderate, but this parameter should be accepted with caution because it could be affected by sample size (23) and the number of resource categories (24).

In conclusion we could say that all three species of toads have very common feeding behaviour, and they all should be considered as "polyphages", but there are certain differences

in their trophic niches. The niche overlap between the three species is moderate and probably there is no or insignificant competition for food resources between them in the places with sympatric distribution.

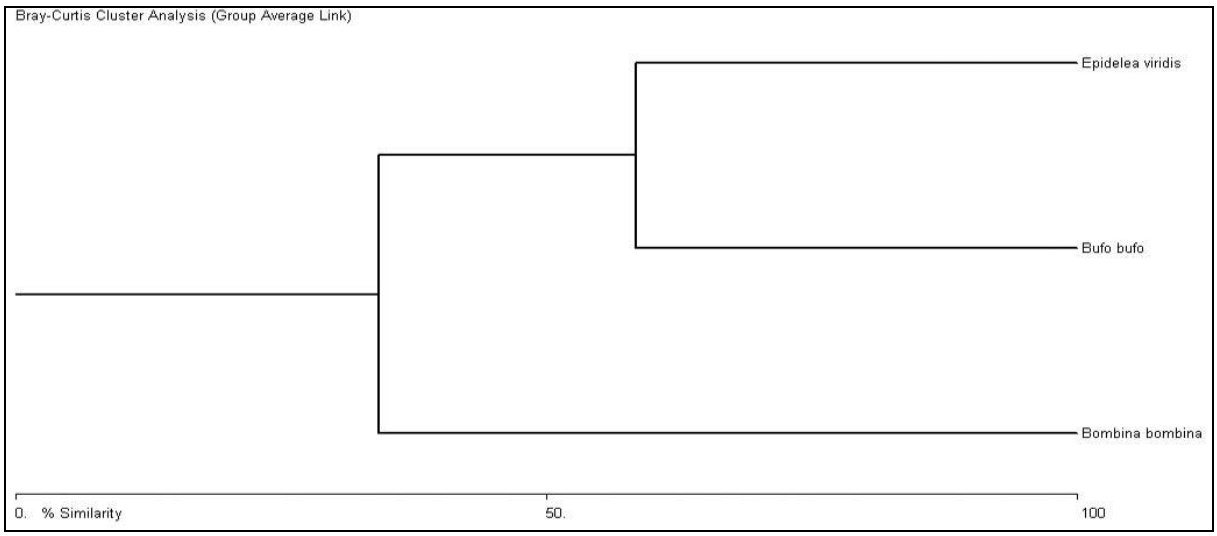

Fig. 3. Similarity of the trophic spectrums of the three studied toad species from Poland (Bray-Curtis index, group average linking)

Conclusions

1. During our study we identified 53 prey items in the trophic spectrum of *Bombina bombina*; 124 prey items in the diet of *Bufo bufo* and 95 prey items in the diet of *Epidalea viridis*. The average number of prey items per stomach is as follows: *Bombina bombina* - 7.57, *Bufo bufo* - 9.0 and *Epidalea viridis* - 13.57.

2. In all studied species the most important prey category is Coleoptera. Other important prey animals are Hemiptera, Hymenoptera and Dermaptera as well as non-insect invertebrates (Gastropoda and Arachnida) which also play significant role.

3. All three species consume almost only terrestrial prey.

4. The trophic niche breadths for the three species are as follows: *Bombina bombina* - 5.40, *Bufo bufo* - 4.47 and *Epidalea viridis* - 2.42.

5. The estimated trophic niche overlap between the species is moderate (58.82% - 63.72%) and probably there is no or insignificant competition for food resources between them in the places with sympatric distribution.

6. All studied species are polyphagous zoophages, like other amphibian species and they are probably consuming all mobile objects which they come in contact with and can swallow.

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