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TROPHIC ROLE OF THE MARSH FROG *PELOPHYLAX RIDIBUNDUS* (PALLAS, 1771) (AMPHIBIA, ANURA) IN THE AQUATIC ECOSYSTEMS

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Abstract

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During our study we identified 1356 prey items, divided in 64 prey categories in the trophic spectrum of *Pelophylax ridibundus* from the surrounding of Skutare Village (Plovdiv District, South Bulgaria). The average number of prey items per stomach for all studied seasons is as follows: spring 1994 - 11.93 (SD=18.31); autumn 1994 - 9.65 (SD=13.44); spring 1995 - 11.84 (SD=16.34) and totally – 11.49 (SD=38.67). The most important prey category for the whole period of study is Coleoptera (31.93%), followed by Diptera (27.65%) and Hymenoptera (13.42%). A presence of vertebrates (amphibians, reptiles and mammals) in the trophic spectrum was also recorded. The amphibians are presented with tadpoles (0.59 %) and adult specimens of *Pelophylax ridibundus* (0.36%). The reptiles with two subadult specimens (0.15%) of the Balkan Wall lizard (*Podarcis tauricus*) and the mammals with one (0.07%) *Mus sp.*, which evidently were accidental captured in the water. The trophic niche breadths for spring seasons are quite high - spring 1994 (15.04) and spring 1995 (19.52), but for the autumn of 1994 it was 3.14. The trophic niche breadth for the whole period of study is 15.15. The trophic role of the Marsh frog in the aquatic ecosystems in Bulgaria is discussed.

Key words: marsh frog, diet, trophic spectrum, niche breadth, South Bulgaria

Introduction

The amphibians are important component of the ecosystems, because they re-direct energy from invertebrates, mainly detritivores and phytophages, to higher trophic levels (Burton and Likens, 1975). Understanding feeding relationships in the amphibian communities is of fundamental interest to herpetologists and ecologists because of the role that they play in the aquatic ecosystems (Hirai and Matsui, 1999). In order to understand the position of amphibians in the trophic chains it is important to know their food composition, its seasonal distribution and the breadth of the trophic niche and the trophic niche overlap (Gunzburger, 1999).

The Marsh frog (*Pelophylax ridibundus*) is one of the largest frogs native to Europe (Balint et al., 2008) and the most common amphibian species in

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Bulgaria (Beshkov and Nanev, 2002). In the scientific literature there are many studies regarding this species's trophic spectrum, published abroad (Torok and Csorgo, 1992; Simic et al., 1992; Covaciu-Marcov et al., 2005; Cicek and Mermer, 2006; 2007; Balint et al., 2008; Ferenti et al., 2009) and in Bulgaria (Angelov, 1960; Angelow and Batchwarow, 1972; Batchvarov, 1965; 1967; 1968; Beshkov, 1961; Donev, 1984, 1986; Hristova, 1962; Kovachev, 1979; Tomov, 1989; Mollov et al., 2006 and Mollov, 2008). Despite the extensive research on the trophic spectrum of this species in Bulgaria so far there is still some unknown aspects of its trophic niche and its role in the trophic networks.

The aim of the current study is to contribute to the knowledge of the trophic spectrum of *Pelophylax ridibundus* in Bulgaria and its seasonal variation with the viewpoint of the trophic niche of this species and its role in the aquatic ecosystems.

Material and Methods

We examined 118 preserved in 70% alcohol stomachs of adult specimens of the Marsh frog (*Pelophylax ridibundus*), kept in the herpetological collection of the Department of Zoology at the University of Plovdiv, Bulgaria. The material was collected between April 1994 and May 1995 from water basins and Maritsa River from the surroundings of Skutare Village (UTM LG26-LG27), Plovdiv District (South Bulgaria).

The stomachs were dissected in Petri dishes and the stomach contents were analyzed by means of binocular microscope. 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 (2009), except for the Homoptera suborder, used by us for convenience, which combines Cicadomorpha, Fulgoromorpha and Sternorrhyncha.

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 (Lehner, 1996):

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

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 (Pianka, 1973; Begon et al., 1986):

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

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 (Magurran, 1988):

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

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 results were statistically processed using descriptive statistics. The Wilcoxon's Sign test was used to compare the numeric proportion all prey taxa between seasons in order to detect differences in the use of food resources, when the data were not normally distributed (Fowler et al., 1998). Cluster analysis was used to categorize the studied seasons based on the similarity of the trophic niche.

For the statistical processing of the data we used the software package "Statistica v.7.0" (StatSoft Inc., 2004). For the calculations of Simpson's diversity index and the Berger-Parker index we used the computer software "Biodiversity Pro" (McAleece et al., 1997).

Results

The analyzed stomach contents of total 118 stomachs contained 1356 prey items, divided in 64 prey categories (Table 1). The average number of prey items per stomach for all studied seasons is as follows: spring 1994 - 11.93 (SD=18.31); autumn 1994 - 9.65 (SD=13.44); spring 1995 - 11.84 (SD=16.34) and totally – 11.49 (SD=38.67) (Figure 1). The sampling adequacy is considered sufficient for all studied seasons (Spring 1994 - 0.78; Autumn 1994 - 0.73; Spring 1995 – 0.89) as well as for the whole period of study – 0.86.

Table 2 presents the qualitative and quantitive proportion, as well as the season variation of the trophic spectrum of the Marsh frog for the whole period of study. The predominated food type in the diet of the Marsh frog is insects (88.52 %). The most important prey category is Coleoptera (31.93%), followed by Diptera (27.65%) and Hymenoptera (13.42%). The Berger-Parker index showed considerably low value - 0.32 (Table 2). Unidentified insects in this study usually consisted of a wing, leg, or body segment, 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.

Besides invertebrates three vertebrate groups were identified from the stomach contents (Amphibia, Reptilia and Mammalia). The amphibians are presented with tadpoles (0.59 %) and adult specimens of *Pelophylax ridibundus* (body length 2.5 cm) (0.36%). The reptiles with two subadult specimens (0.15%) of the Balkan Wall lizard (*Podarcis tauricus*) and the mammals with one specimen (0.07%) *Mus sp.* (Table 2).

Plant material found in the stomach contents included seeds and small leaves, including a branch with seeds from Poaceae (5 cm long), seeds from *Capsella bursa-pastoris*, and was most likely ingested accidentally during foraging.

Aquatic prey consisted of the following taxa: Aranei (*Argyroneta aquatica*), Amphipoda (*Gammarus sp.*), Isopoda, Gastropoda, Hemiptera (*Ilyocoris cimicoides*), Odonata, Diptera (larvae) – mainly from the Syrphidae family, Coleoptera (Hydrophilidae, Haliplidae, Dytiscidae) and Amphibia (*Pelophylax ridibundus* – adults and larvae). The numeric proportion of the aquatic prey is 5.68 %.

The Wilcoxon's Sign test showed statistically significant differences between both spring seasons and the autumn season (Z=5.39, $p<0.05$; Z=5.76, $p<0.05$) and not statistically significant difference between the two spring seasons (Z=1.19, p=0.19). Clus-

Table 1
Descriptive statistics of the diet of *Pelophylax ridibundus* for all studied seasons

Season	Number of stomachs	Number of prey categories	Number of prey items	Mean	Standard deviation (SD)	Standard error (SE)
Spring 1994	41	64	489	9.22	18.31	1.77
Autumn 1994	20		193	3.01	13.44	1.68
Spring 1995	57		674	10.53	16.34	2.04
Total	118		1356	21.22	38.67	4.83

Table 2

Trophic spectrum of *Pelophylax ridibundus* for all studied seasons

***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	Spring 1994			Autumn 1994			Spring 1995			Total		
	n	n%	f %	n	n%	f %	n	n%	f %	n	n%	f%
Annelida, Oligochaeta	3	0.61	7.32	1	0.52	5	3	0.45	5.26	7	0.52	5.93
Arachnida – undet.	4	0.82	2.44	—	—	—	6	0.89	1.75	10	0.74	1.69
Aranei	17	3.48	26.83	5	2.59	10	26	3.86	28.07	48	3.54	24.58
Acari	1	0.2	2.44	—	—	—	—	—	—	1	0.07	0.85
Mollusca, Gastropoda	4	0.82	9.76	2	1.04	10	5	0.74	8.77	11	0.81	9.32
Myriapoda												
Diplopoda	1	0.2	2.44	3	1.55	10	—	—	—	4	0.29	2.54
Chilopoda	—	—	—	—	—	—	1	0.15	1.75	1	0.07	0.85
Crustacea												
Amphipoda	7	1.43	4.88	—	—	—	—	—	—	7	0.52	1.69
Isopoda	12	2.45	9.76	—	—	—	21	3.12	15.79	33	2.43	11.02
Insecta – undet.	—	—	—	1	0.52	5	3	0.45	5.26	4	0.29	3.39
Insecta (larvae) – undet.	13	2.66	9.76	1	0.52	5	3	0.45	5.26	17	1.25	6.78
Rhaphidioptera	—	—	—	—	—	—	1	0.15	1.75	1	0.07	0.85
Hemiptera – undet.	6	1.23	9.76	2	1.04	10	16	2.37	12.28	24	1.77	11.02
Heteroptera	12	2.45	24.39	2	1.04	5	10	1.48	15.79	24	1.77	16.95
Homoptera	1	0.2	2.44	—	—	—	2	0.3	3.51	3	0.22	2.54
Hymenoptera – undet.	11	2.25	14.63	5	2.59	10	10	1.48	12.28	26	1.92	12.71
Apidae	6	1.23	9.76	—	—	—	4	0.59	5.26	10	0.74	5.93
Chrysididae	—	—	—	1	0.52	5	2	0.3	3.51	3	0.22	2.54
Formicidae	28	5.73	41.46	10	5.18	35	76	11.28	40.35	114	8.41	39.83
Ichneumonidae	2	0.41	4.88	—	—	—	—	—	—	2	0.15	1.69
Vespoidea	2	0.41	4.88	1	0.52	5	11	1.63	10.53	14	1.03	7.63
Vespidae	5	1.02	7.32	2	1.04	5	9	1.34	14.04	16	1.18	10.17
Odonata – undet.	1	0.2	2.44	1	0.52	5	7	1.04	10.53	9	0.66	6.78
Anizoptera	—	—	—	—	—	—	7	1.04	7.02	7	0.52	3.39
Zygoptera	2	0.41	2.44	1	0.52	5	21	3.12	17.54	24	1.77	10.17
Odonata (larvae)	1	0.2	2.44	—	—	—	—	—	—	1	0.07	0.85
Diptera – undet.	1	0.2	2.44	—	—	—	1	0.15	1.75	2	0.15	1.69
Culicidae	68	13.91	7.32	107	55.44	30	70	10.39	21.05	245	18.07	17.8
Brachicera	6	1.23	9.76	3	1.55	10	35	5.19	8.77	44	3.24	9.32
Muscidae	4	0.82	9.76	1	0.52	5	9	1.34	5.26	14	1.03	6.78
Nematocera	9	1.84	14.63	—	—	—	24	3.56	14.04	35	2.58	11.86
Tipulidae	4	0.82	9.76	—	—	—	26	3.86	19.3	30	2.21	12.71
Syrphidae	5	1.02	4.88	—	—	—	—	—	—	5	0.37	1.69
Diptera (larvae)	16	3.27	7.32	—	—	—	1	0.15	1.75	17	1.25	3.39
Coleoptera – undet.	6	1.23	12.2	3	1.55	10	6	0.89	10.53	15	1.11	11.02
Anthicidae	—	—	—	1	0.52	5	—	—	—	1	0.07	0.85

Table 2 (continued)

Buprestidae	1	0.2	2.44	—	—	—	3	0.45	5.26	4	0.29	3.39
Cantharidae	3	0.61	7.32	1	0.52	5	24	3.56	21.05	28	2.06	13.56
Carabidae	83	16.97	53.66	16	8.29	40	64	9.5	49.12	163	12.02	49.15
Cerambicidae	—	—	—	2	1.04	5	42	6.23	38.6	44	3.24	19.49
Coccineliadae	2	0.41	4.88	—	—	—	7	1.04	8.77	9	0.66	5.93
Curculionidae	12	2.45	19.51	4	2.06	20	11	1.63	17.54	27	1.99	20.34
Chrysomelidae	33	6.75	39.02	1	0.52	5	26	3.86	28.07	60	4.42	27.97
Dytiscidae	1	0.2	2.44	—	—	—	7	1.04	12.28	8	0.59	6.78
Elateridae	3	0.61	4.88	1	0.52	5	3	0.45	5.26	7	0.52	5.08
Haliplidae	1	0.2	2.44	—	—	—	—	—	—	1	0.07	0.85
Histeridae	1	0.2	2.44	—	—	—	3	0.45	5.26	4	0.29	3.39
Hydrophilidae	—	—	—	1	0.52	5	1	0.15	1.75	2	0.15	1.69
Malachiidae	—	—	—	—	—	—	2	0.3	3.51	2	0.15	1.69
Meloidae	1	0.2	2.44	—	—	—	—	—	—	1	0.07	0.85
Scarabeidae	24	4.91	26.83	1	0.52	5	25	3.71	24.56	50	3.69	22.03
Staphylinidae	1	0.2	2.44	1	0.52	5	5	0.74	5.26	7	0.52	4.24
Coleoptera (larvae)	5	1.02	7.32	—	—	—	8	1.19	12.28	13	0.96	8.47
Dermaptera	7	1.43	17.07	—	—	—	—	—	—	7	0.52	5.93
Orthoptera	8	1.64	9.76	4	2.06	20	2	0.3	3.51	14	1.03	8.47
Lepidoptera	10	2.04	17.07	4	2.06	20	6	0.89	8.77	20	1.47	13.56
Lepidoptera (larvae)	18	3.68	14.63	2	1.04	5	4	0.59	5.26	24	1.77	8.47
Amphibia, Anura – undet.	1	0.2	2.44	—	—	—	—	—	—	1	0.07	0.85
Pelophylax ridibundus	1	0.2	2.44	—	—	—	3	0.45	1.75	4	0.29	1.69
Pelophylax ridibundus (larvae)	—	—	—	—	—	—	8	1.19	1.75	8	0.59	0.85
Reptilia, Podarcis tauricus	1	0.2	2.44	1	0.52	5	—	—	—	2	0.15	1.69
Mammalia, Mus sp.	—	—	—	—	—	—	1	0.15	1.75	1	0.07	0.85
plant remains	4	0.82	7.32	1	0.52	5	1	0.15	1.75	6	0.44	4.24
pebbles, soil, sand	10	2.04	17.07	—	—	—	2	0.3	1.75	12	0.88	6.78
Sampling adequacy		0.78			0.73			0.89			0.86	
Berger-Parker index[1]		0.35			0.58			0.34			0.32	
Niche Breadth (1/Simpson)		15.04			3.14			19.52			15.15	

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

ter analysis also grouped the two spring seasons in one group with high percentage of similarity, apart from the autumn season (Figure 2).

The Berger-Parker index showed relatively low value in the spring, but its value in the autumn is moderate (d=0.58), when there appears to be a slight preference to Diptera (Table 2).

The trophic niche breadths for the spring seasons have close values and are quite high - spring 1994 (15.04) and spring 1995 (19.52), but for the autumn of 1994 it was 3.14. The trophic niche breadth for the whole period of study is 15.15 (Table 2).

Discussion

The current study confirmed that the adult Marsh frogs (*Pelophylax ridibundus*) consume a wide variety of invertebrates (mainly insects) and even vertebrates. It is noteworthy the high proportion of the Coleoptera order as well as the Diptera and the Hy-

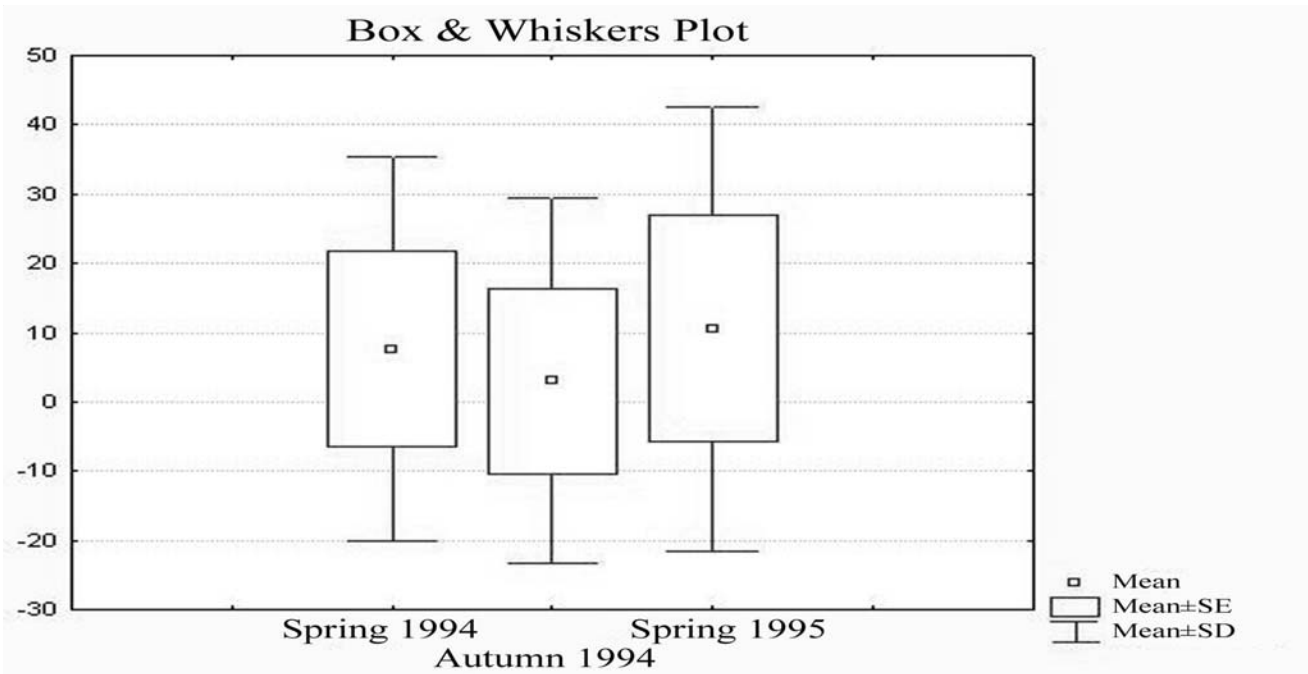

Fig. 1. Box & Whiskers Plots of the trophic spectrum of *Pelophylax ridibundus* for the three studied seasons

menoptera orders. The beetles and ants are basic food most probably due to the abundance of this preys and the wide range of habitats where they can be found. This type of prey being frequently consumed could be also explained with the fact that these frogs hunt at the groundmark and at the low vegetation level (Kovacs and Torok, 1995).

The Marsh frog does not show a strong specialization in feeding, consuming both high and low energetic content preys. The appearance of larger preys (Coleoptera), together with the smaller ones (Formicidae) suggests an opportunistic feeding behaviour. The feeding of these frogs not being selective shows that the green frogs would capture all the

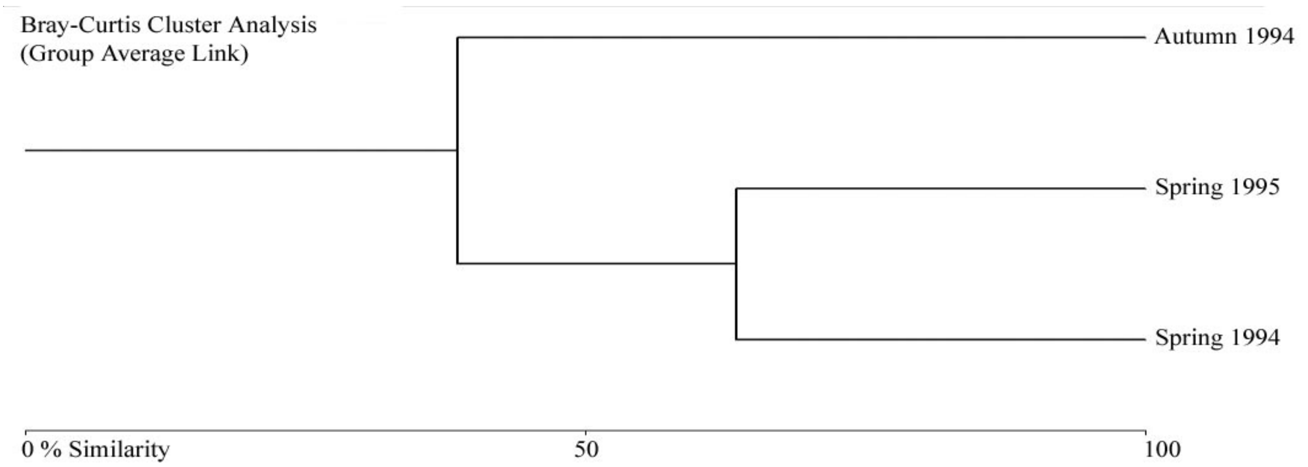

Fig. 2. Cluster analysis of the seasonal distribution of the trophic spectrum of *Pelophylax ridibundus*

moving preys which have a suitable size for consumption (Torok and Csorgo, 1992; Mollov et al., 2006).

The vertebrate animals recovered from the stomach contents showed that the Marsh frogs did not limit their diet to invertebrates, but that they could consume vertebrate prey as well. Cicek and Mermer (2006) established that morphology had a significant effect on the feeding behaviour of *Pelophylax ridibundus* in Turkey. The larger an individual is, the wider range of food it has. The Marsh frog being the largest frog species in Bulgaria (Beshkov and Nanev, 2002) could easily capture and consume some small vertebrate species like fishes (Donev, 1984; 1986; Hristova, 1962), frogs (Angelow and Batchwarow, 1972; Batchvarov, 1965; 1967; 1968; Beshkov, 1961; Kovachev, 1979; Tomov, 1989 and others), rodents (Hristova, 1962) and in the case of our study even small lizards.

Cannibalism is reported in almost all scientific studies on the diet of the Marsh frog, conducted in Bulgaria so far (Mollov et al., 2006) and seems to be a pretty common case for this species. Stebbins and Cohen (1995) suggested that cannibalism could be observed in certain species of frogs, especially where the number of juveniles in the population is excessively high. If changes in the ecological conditions in the habitat occur or the population outgrows the area it inhabits in time, this could force individuals towards cannibalism. If the amount of food in the environment starts to decrease, cannibalism emerges as a mechanism of increasing the survival rate of the individuals (Crump, 1992).

The presence of cannibalism, as well as the capture of other vertebrate preys (fish, lizards and rodents) perhaps happening accidentally (usually in the water), proves that *Pelophylax ridibundus* have an opportunistic feeding behaviour.

Despite the fact that *Pelophylax ridibundus* is considered to be an aquatic animal, leaving the water very rarely (Basoglu and Ozeti, 1973), the majority of the consumed preys have terrestrial origin. Capturing the terrestrial preys is probably done on land, but not necessarily, because these animals could be accessible from the water plants or even from the surface of the water (Ferenþ i et al., 2009). This fact suggests that the Marsh frog forages mainly in the ecotone area in the border of aquatic and terrestrial habitats.

There is a strong seasonal variation of the feeding of the frogs caused by the climate modifications throughout the year. The feeding is strongly influenced by these fluctuations which actually determine the trophic offer. The variation of the environments' factors can induce changes in the food composition depending on the period of the year (Dodd, 1994). The rate of the frogs' feeding is drastically reduced in the cold season, which is a result of the entrance of the majority of terrestrial preys in a state of inactivity due to the low temperatures of the air.

In conclusion the Marsh frog (*Pelophylax ridibundus*) can be categorized as a zoophagous polyphage. Like other anuran species in Bulgaria and it is consuming all the mobile objects which it comes in contact with, that it can swallow. The Marsh frog plays very important position in the trophic network situated in the ecotone area in the border of aquatic and terrestrial ecosystems.

Conclusions

This study showed that the adult Marsh frogs (*Pelophylax ridibundus*) consume a wide variety of invertebrates (mostly insects) and even vertebrates. In our opinion, this species is an opportunistic predator, polyphage and it consumes any animal that is in its perimeter and is with suitable size. The Marsh frog does not show a specialization in the feeding and consume prey with high and low energy levels. Prey is mainly terrestrial, but there is a certain amount of aquatic prey, suggesting that feeding largely occurs on the land, but the frogs hunt in the water as well. The feeding is extremely intense in the spring, especially before breeding and declining in the autumn with the fall of the air temperature and the change of the weather conditions. In conclusion it may be noted that the Marsh frog has an important position in the trophic network, located in ecotone area on the border of aquatic and terrestrial ecosystems.

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