ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 60 (3), 2008: 277-284

Sex Based Differences in the Trophic Niche of *Pelophylax ridibundus* (Pallas, 1771) (Amphibia: Anura) from Bulgaria

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Abstract: During our study we identified 182 prey items in the trophic spectrum of *Pelophylax ridibundus* (110 in males and 72 in females) with average number of prey items per stomach as follows: ♂ – 2.05 (SD=2.18); ♀ – 2.00 (SD=2.00). For both sexes the most important prey category is Hymenoptera (♂ – 20.91% and ♀ – 31.95%), followed by Coleoptera (♂ – 19.09% and ♀ – 22.23%) and Diptera (♂ – 17.29% and ♀ – 15.28%). A presence of vertebrates (fish and amphibians) in the trophic spectrum was also recorded for both sexes. The fish (*Carassius gibelio*) is taking 1.82% from the diet of the males and 2.78 % from the diet of the females. The amphibians are presented with tadpoles (♂ – 3.65 % and ♀ – 1.39 %) and adult specimens of *Pelophylax ridibundus,* recovered only form the female stomachs. The trophic niche breadths for both sexes are quite high (♂ – 22.70, ♀ – 17.45). The estimated trophic niche overlap between the sexes is moderate (63.8%), but the numeric proportion of all prey taxa occurring in the stomachs did not differ significantly between the sexes.

Key words: marsh frog, diet, trophic spectrum, niche overlap

Introduction

Understanding feeding relationships in amphibian communities is of fundamental interest to herpetologists and ecologists because of the pivot role that amphibians play in aquatic ecosystems (Hirai, Matsui 1999). Adult amphibians are consumers of second or further degree and studying their position in the trophic network is extremely important (Ruchin, Ryizhov 2003). A variety of studies describing the diet of amphibians has been conducted in Europe, but the studies dealing with their trophic niche and niche overlap are quite scarce.

The Marsh frog (*Pelophylax ridibundus*) is the most common amphibian species in Bulgaria (Beshkov, Nanev 2002), which diet is studied the most. Studies on the trophic spectrum of Marsh frog in Bulgaria are conducted by Angelov (1960); Angelow, Batchwarow (1972); Batchvarov (1965, 1967, 1968); Beshkov (1961); Donev (1984, 1986); Hristova (1962); Kovachev (1979) and Tomov (1989). Despite the extensive research on the trophic spectrum of this species in Bulgaria so far there is only one study concerning its trophic niche (Mollov *et al.* 2006-in press).

The aim of the current study is to analyze the trophic spectrum of *Pelophylax ridibundus* from Bulgaria with the viewpoint of the trophic niche of this species and the intraspecific niche overlap between the two sexes.

Material and Methods

We examined 375 (196 ♂ and 179 ♀) preserved in 70% alcohol stomachs of adult specimens of Marsh frog (*Pelophylax ridibundus*), kept in the herpetological collection of the Department of Ecology and Environmental Conservation at the University of Plovdiv, Bulgaria. The material was collected on 20.XI.1971 from water basins from the surroundings of Saedinenie Town and Pravishte Village (UTM KG98), Plovdiv District (South Bulgaria) – 355 (185 ♂ and 170 ♀) specimens, and 20 (11 ♂ and 9 ♀) specimens collected on 19.X.1984 from Zlatna Panega River near Lukovit Town (UTM KH78) and Cherven Bryag Town (UTM KH69), Pleven District (North 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 invertebrate taxa follows Fauna Europaea (2007), the fish – Karapetkova, Zhivkov (2000) and the amphibians – Biserkov *et al.* (2007).

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 base 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 sex, 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 food specialization of each sex 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 food niche overlap was calculated by Pianka`s adaptation of Mac Arthur and Levin's formula (Pianka 1973):

$$O_{j,k} = \frac{\sum P_j . P_k}{\sqrt{\sum P_j^{\,2} . \sum P_k^{\,2}}},$$

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

The results were statistically processed using descriptive statistics and the Mann-Whitney U-test was used to compare the numeric proportion all prey taxa between sexes in order to detect intraspecific differences in the use of food resources, when the data were not normally distributed (Fowler *et al.* 1998).

For the statistical processing of the data we used the software package 'Statistica 7.0' (StatSoft

Inc. 2004). For the calculations of Simpson's diversity index and the Berger-Parker index we used the computer software 'Bio-DAP' (Thomas, Clay 2000) and for the calculation of the niche overlap we used the computer program 'EcoSim 7.0' (Gotelli, Entsminger 2001).

Results

The analyzed stomach contents of total 375 stomachs (196 ♂ and 179 ♀) from both localities showed that 111 (52 ♂ and 59 ♀) were empty and 174 (90 ♂ and 84 ♀) contained only digested remains. A total of 90 stomachs (54 ♂ and 36 ♀) contained 182 prey items (110 in the males and 72 in the females) (Fig. 1, Table 1). The average number of prey items per stomach is as follows: ♂ – 2.05 (SD=2.18); ♀ – 2.00 (SD=2.00). The sampling adequacy is considered sufficient for both sexes (♂ – 0.78; ♀ – 0.67).

Table 2 presents the qualitative and quantitive proportion of the trophic spectrum of Marsh frog. The numeric percentage of the main prey taxa is presented for both sexes in Fig. 2. The predominated food type in the diet of Marsh frog is insects (♂ – 85.42% and ♀ – 80.54%). The most numerous prey taxa in both sexes is Hymenoptera (♂ – 20.91% and ♀ – 31.95%), followed by Coleoptera (♂ – 19.09% and ♀ – 22.23%) and Diptera (♂ – 17.29% and ♀ – 15.28%). The Berger-Parker index showed considerably low value (♂ – 0.21 and ♀ – 0.32) for both sexes (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.

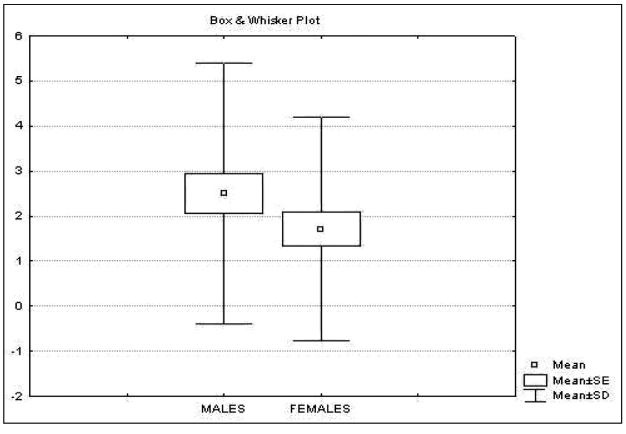

Fig. 1. Box and Whisker Plot of the trophic spectrum of both sexes of Marsh frog.

Besides invertebrates, two vertebrate groups were recovered from the stomachs (Pisces and Amphibia). The fish is presented only with the Prussian crap (*Carassius gibelio*), taking 1.82% from the diet of the males and 2.78% from the diet of the females. The size of the fish digested by the frogs varied between 30.0 and 43.0 mm. The amphibians are presented with tadpoles (♂ – 3.65% and ♀ – 1.39%) and adult specimens of *Pelophylax ridibundus,* as well as bone fragments from unidentified amphibian species. The adult Marsh frogs (L = 33.7-55.0 mm) and bones were recovered only form the female stomachs (Table 2).

Plant material found in the stomach contents included seeds and small leaves and was most likely ingested accidentally during foraging.

Aquatic preys were as follows: Aranei (*Argyroneta aquatica*), Collembola, Trichoptera, Hemiptera (Nepidae), Odonata, Diptera (larvae), Coleoptera (Dytiscidae and Gyrinidae), Pisces (*Carassius gibelio*) and Amphibia (*Pelophylax ridibundus*). The numeric proportion of the aquatic prey for the males is 17.30% and for the females – 20.85%.

The trophic niche breadth is rather higher in the males (22.70) than the females (17.45). The trophic niche overlap between sexes was 63.8%, but the numeric proportion of all prey taxa occurring in the stomachs did not differ significantly between the

Table 1. Descriptive statistics of the studied diet of both sexes of Marsh frog.

Sex	Number of prey categories	Number of prey items	Mean	Standard Deviation (SD)
Males (♂)	44	110	2.50	2.90
Females (♀)		72	1.70	2.48

Table 2. Results from the food niche study of the diet of both sexes of Marsh frog. 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	Males (♂)			Females (♀)		
	n	n %	f %	n	n %	f %
Arachnida, Aranei	2	1.82	3.70	3	4.17	8.33
Collembola	3	2.74	1.85	-	-	-
Insecta – undet.	7	6.36	11.11	1	1.39	2.78
Insecta (larvae) – undet.	2	1.82	3.70	-	-	-
Trichoptera	2	1.82	1.85	-	-	-
Hemiptera – undet.	5	4.56	5.55	-	-	-
Aphidoidea	1	0.90	1.85	1	1.39	2.78
Psylloidea	1	0.90	1.85	-	-	-
Cicadellidae	1	0.90	1.85	2	2.78	5.56
Cicadellidae (larvae)	1	0.90	1.85	-	-	-
Nepidae	4	3.65	3.70	-	-	-
Notorectidae	2	1.82	1.85	1	1.39	2.78
Pentatomidae	-	-	-	1	1.39	2.78
Hymenoptera – undet	2	1.82	1.85	-	-	-
Formicidae	9	8.18	16.67	4	5.56	5.56
Ichneumonidae	1	0.90	1.85	-	-	-
Vespoidea	7	6.36	9.26	12	16.67	11.11
Vespidae	4	3.65	3.70	7	9.72	11.11
Odonata – undet.	1	0.90	1.85	-	-	-
Anizoptera	-	-	-	1	1.39	2.78
Zygoptera	1	0.90	1.85	-	-	-
Diptera – undet.	3	2.74	5.55	-	-	-
Culicidae	2	1.82	1.85	-	-	-
Brachycera	12	10.91	9.26	7	9.72	13.89
Nematocera	2	1.82	3.70	-	-	-
Trachinidae	-	-	-	1	1.39	2.78
Syrphidae	-	-	-	1	1.39	2.78
Muscidae	-	-	-	1	1.39	2.78
Diptera (larvae)	-	-	-	1	1.39	2.78
Coleoptera – undet.	8	7.27	14.81	8	11.11	11.11
Curculionidae	9	8.18	16.67	2	2.78	5.56
Carabidae	1	0.90	1.85	1	1.39	2.78
Chrysomelidae	-	-	-	2	2.78	5.56
Dytiscidae	-	-	-	1	1.39	2.78
Gyrinidae	-	-	-	1	1.39	2.78
Staphylinidae	3	2.74	3.70	1	1.39	2.78

Table 2. Continued.

Prey taxa	Males (♂)			Females (♀)		
	2n2	n %	f %	n	n %	f %
Dermatoptera	1	0.90	1.85	-	-	-
Orthoptera	-	-	-	1	1.39	2.78
Lepidoptera (larvae)	2	1.82	3.70	3	4.17	5.56
Pisces, *Carassius gibelio*	2	1.82	3.70	2	2.78	5.56
Amphibia, Anura – undet.	-	-	-	2	2.78	5.56
Pelophylax ridibundus	-	-	-	3	4.17	8.33
Pelophylax ridibundus (larvae)	4	3.65	7.41	1	1.39	2.78
plant remains	5	4.55	7.41	3	4.17	8.33
Sampling adequacy	**0.80**			**0.66**		
Berger-Parker index	**0.21**			**0.32**		
1/Simpson	**22.70**			**17.45**		
Niche overlap	**63.8 %**					

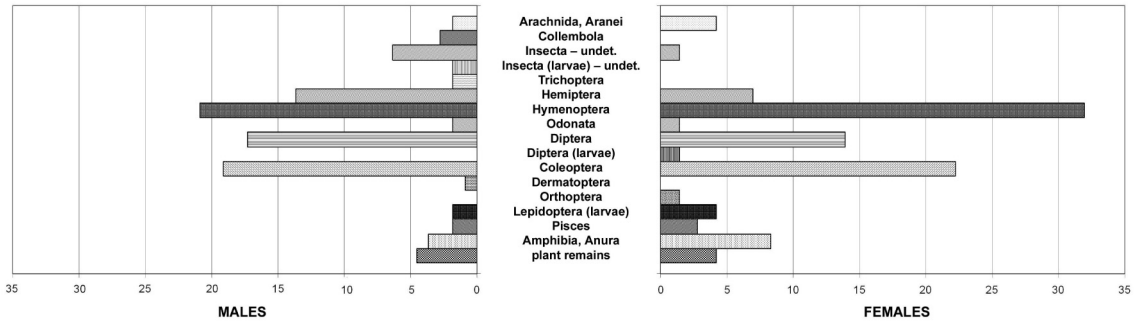

Fig. 2. Numeric proportion of the main prey taxa in the trophic spectrum of both sexes of Marsh frog.

sexes (U-test, U=28.5, Z=0.15, P=0.88, P>0.05 for all prey taxa).

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.

Discussion

The present study revealed that adult Marsh frogs (*Pelophylax ridibundus*) consume a wide variety of invertebrates (mainly insects) and even vertebrates. The prey is mainly terrestrial, but there is considerable amount of aquatic prey as well, which shows that the feeding largely occurs on land, but the frogs hunt in the water as well. This suggests that Marsh frog has an important position in the trophic network situated in the ecotone area in the border of aquatic and terrestrial ecosystems.

The preys of animal nature are the most important category in the stomach contents, regarding the fact that the adult amphibians are predators (Cogălniceanu *et al.* 2000). The larvae forms of the insects are given separately from the imago considering that they are different prey categories as mobility and as the environment of their capture. Redford & Dorea (1984) claimed that adult insects do not vary much as nutrition content but still it is considered that the larvae and pupae elements of homometabolic insects are rich in lipids and thus, more nutritive (Brooks *et al.* 1996). The presence of plant remains in the stomach contents of both sexes of the Marsh frog should be considered accidental.

The most important prey categories are Hymenoptera, Coleoptera and Diptera being consumed frequently by both sexes. 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 species does not show a specialization in feeding, consuming both high and low energetic content preys.

Fish and frogs recovered from the stomach contents showed that Marsh frogs did not limit their diet to invertebrates, but that they could easily consume different larger vertebrate prey groups as well. Çiçek, 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. This could explain why males, being smaller than females, consumed only tadpoles, which are close in size with small fish also found in their diet. In contrast, in the diet of the females there were fully developed froglets along with small fish and tadpoles. Stebbins, Cohen (1995) reported 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). A number of researchers have also reported cannibalism in *Pelophylax ridibundus* in their studies (Angelow, Batchwarow 1972; Batchvarov 1965, 1967, 1968; Beshkov 1961; Covaciu-Marcov *et al.* 2005; Donev 1984, 1986; Hristova 1962; Kovachev 1979; Tomov 1989 and others).

Sexual size dimorphism, with larger females than males, is generally seen in anurans (Shine 1979). As far as feeding is concerned, no significant difference was found between females and males examined in the present study. A medium degree of overlap exists between the trophic niche of the males and the females (males having a slightly broader tropic niche), suggesting that the different size classes exploit different segments of the trophic resource (Cogălniceanu *et al.* 2000). The cause of the niche overlap is probably associated with the fact that females and males use the same area for foraging. Studies conducted on this and other species also revealed no significant difference between females and males with respect to feeding (Çiçek, Mermer 2006, 2007; Guidali *et al.* 1999; Measey 1998; Parker, Goldstein 2004).

Conclusions

During our study we identified 182 prey items in the trophic spectrum of *Pelophylax ridibundus* (110 in males and 72 in females) with average number of prey items per stomach as follows: ♂ – 2.05 (SD=2.18); ♀ – 2.00 (SD=2.00).

For both sexes the most important prey category is Hymenoptera (♂ – 20.91% and ♀ – 31.95%), followed by Coleoptera (♂ – 19.09% and ♀ – 22.23%) and Diptera (♂ – 17.29% and ♀ – 15.28%).

Presence of vertebrates (fish and amphibians) in the trophic spectrum was also recorded for both sexes. The fish is presented only with the Prussian crap (*Carassius gibelio*), taking 1.82% from the diet of the males and 2.78 % from the diet of the females. The amphibians are presented with tadpoles (♂ – 3.65 % and ♀ – 1.39 %) and adult specimens of *Pelophylax ridibundus,* recovered only form the female stomachs.

The trophic niche breadths for both sexes are quite high (♂ – 22.70, ♀ – 17.45). The estimated trophic niche overlap between the sexes is moderate (63.8%), but the numeric proportion of all prey taxa occurring in the stomachs did not differ significantly between the sexes (U-test, U=28.5, Z=0.15, P=0.88, P>0.05 for all prey taxa).

The Marsh frog (*Pelophylax ridibundus*) is zoophagous polyphage, like other amphibian species and it is consuming all the mobile objects which it come in contact with and can swallow. It plays an important position in the trophic network situated in the ecotone area in the border of aquatic and terrestrial ecosystems.

Acknowledgements: The author would like to express his sincerest gratitude to Prof. Georgi Batchvarov and Assoc. Prof. Dr. Atanas Donev (University of Plovdiv, Faculty of Biology, Department of Zoology) for the given collection of stomachs used in the current study. I would like to thank Dr. Petar Boyadzhiev (University of Plovdiv, Faculty of Biology, Department of Zoology) and Mr. Dilian Georgiev (University of Plovdiv, Faculty of Biology, Department of Ecology and Environmental Conservation) for their help in the determination of part of the material and Mrs. Iskra Banova for her help during the laboratory work.

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Received: 12.09.2008
Accepted: 27.10.2008

Полови различия в трофичната ниша на *Pelophylax ridibundus* (Pallas, 1771) (Amphibia: Anura) от България

И. Моллов

(Резюме)

В настоящото проучване установихме 182 компонента в хранителния спектър на голямата водна жаба (*Pelophylax ridibundus*) (110 при мъжките и 72 при женските), като средният им брой за стомах е както следва: ♂ – 2.05 (SD=2.18); ♀ – 2.00 (SD=2.00). И за двата пола най-важният хранителен компонент е Hymenoptera (♂ – 20.91% и ♀ – 31.95%), следван от Coleoptera (♂ – 19.09% и ♀ – 22.23%) и Diptera (♂ – 17.29% и ♀ – 15.28%). Наличие на гръбначни животни (риби и земноводни) бе отчетено в хранителния спектър и на двата пола. Рибата (*Carassius gibelio*) заема 1.82% от храната на мъжките и 2.78 % от храната на женските. Земноводните са представени с попови лъжички (♂ – 3.65 % и ♀ – 1.39 %) и метаморфозирали екземпляри *Pelophylax ridibundus,* установени само в женските стомаси. Ширината на хранителните ниши и за двата пола е голяма (♂ – 22.70, ♀ – 17.45). Установеното припокриване на хранителните ниши между двата пола е средно 63.8%, но в числената пропорция на всички таксони в хранителния спектър между двата пола няма достоверна разлика.