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Synopsis

Feeding Ecology of Anurans (Amphibia: Anura) in Bulgaria - A Review

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Abstract. A contemporary review of the studies on the trophic spectrum and feeding ecology of the Bulgarian frogs and toads is presented. The analysis of the Bulgarian herpetological literature showed that currently, there are 18 specialized studies on the diet of the Bulgarian anuran species. Of all 16 anuran species, occurring in Bulgaria, 9 (56.25%) have been studied in connection with their trophic spectrum. For four species (25.00%), there is very little data, and for 7 (43.75%), such studies have not yet been done. All Bulgarian species of amphibians are zoophagous, mainly insectivorous. All studied species are general feeders (polyphages), except *Bombina variegata*, which shows a slight preference to Coleoptera and *Bufo bufo* and *Bufotes viridis*, which show slight preference to Formicidae and Coleoptera. Cannibalism was recorded only in *Pelophylax ridibundus*. The highest values of the trophic niches breadths are recorded in *P. ridibundus, R. graeca, R. temporaria,* and *R. dalmatina.* The trophic niches breadths of the other anuran species found in Bulgaria have significantly lower values, the lowest being in *Hyla orientalis.*

Key words: Anura, frogs, toads, diet, trophic spectrum, synopsis, Bulgaria.

Introduction

The first step towards understanding the ecology of amphibians (or most animals, for that matter) is to collect information about their feeding ecology (Hódar, 1997). Furthermore, the determination of their feeding habits helps scientists understand how animals use the food resources available in their immediate environment (Bellocq *et al.,* 2000). Therefore their relationship with populations of other species living in the same habitat can be clearly understood by establishing where the species stands within the food chain (Duellman & Trueb, 1986). Feeding ecology is one of the most critical features of a species' natural history, as it affects survival and can provide valuable information to take conservation and management decisions regarding endangered and rare species (Watson et al., 2017). According to Çiçek & Mermer (2007), different studies suggest that food is an essential factor that can explain the structure of anuran communities in different parts of the world.

Amphibians are known to be important components in terrestrial and aquatic ecosystems (Halliday, 2008), represented with a significant number of species. As a major part of this group, anurans can be opportunistic in their feeding behavior and presumably eat any prey they find and can swallow, located in the environment (Caldart et al., 2012).

Most of the studies on the diet of the anurans in Bulgaria were conducted in the 1960s, 1970s, and 1980s. Most of them are researching the trophic spectrum for how much of the caught prey are pests in agriculture, forestry, and fisheries. Some authors analyze the seasonal variation in the trophic spectrum of the studied species, but overall most of the studies just give a qualitative and quantitative description of the diet.

Studies on the trophic niche breadth, niches overlap between the sexes and species, the position of frogs and toads in the food chains in the ecosystems, and using more advanced and contemporary research methods, were made at a much later stage. In 2006, Mollov et al. (2006) published the first country-wide synopsis of all up-to-date research on the diet of all amphibian species in Bulgaria. Three more studies on the diet of anurans in the country were published since then (Mollov, 2008; Mollov & Boyadzhiev, 2009; Mollov et al., 2010).

The current synopsis aims to complement the existing knowledge of the studies on the feeding ecology of the anurans, conducted in Bulgaria and compare and analyze the data concerning the qualitative and quantitive composition of the diet, the food specialization between the species.

Material and Methods

All available literary data on the diet of the Bulgarian frog and toad species were used for the current synopsis. From the available literature, we have summarized the data about the extend of studies on the trophic spectrum of all anuran amphibian species, that occur in Bulgaria (taxonomy of the amphibians follows Speybroeck et al. (2020), the taxonomy of the invertebrates follows Fauna Europaea, de Jong et al. (2014); the number of the studied specimens in each study, period and region of study, as well as the percentage of the three predominant taxa from the trophic spectrum of each species.

Based on the available data, the trophic niche breadth (B) is calculated for each species, using the reciprocal value of the Simpson's diversity index (Magurran, 1988):

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

where:

B – trophic niche breadth;

P_i - proportion of taxa i.

To determine the species' trophic specialization, we used the Berger-Parker dominance index (d) calculated by the following formula (Magurran, 1988):

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

where: d – Berger-Parker dominance index;

N – number of individuals from all taxa;

$n_i max$ – number of individuals from the most-abundant taxon.

The Berger-Parker index (d) ranges from 0 to 1. Values close to 1 indicate a narrow trophic specialization, typical for mono- and oligophages; values close to 0 are typical for species with broad trophic specialization (polyphages).

The results were statistically processed using descriptive statistics (trophic niche breadth) and cluster analysis (Unweighted Paired Group Average Linkage, Jaccard Similarity Index), for determining the similarity of the trophic spectrum of all anurans for which quantitative data is available (Fowler et al., 1998). For the descriptive statistical processing of the data, we used MS Excel. For the cluster analysis, as well as the calculations of Simpson's diversity index and the Berger-Parker index, we used the computer software "PAST" (Hammer et al., 2001).

Results and Discussion

Currently there are 18 specialized studies conducted on the trophic spectrum

of the Bulgarian anurans (Angelov, 1960; Beshkov, 1961; 1970; Hristova, 1962; Bachvarov, 1965; 1967; Angelow & Batchwarow, 1972; Angelov & Batschwarov, 1972; Donev, 1984a; 1984b; 1986; Tomov, 1989; 1990; 1991; Mollov, 2008; Mollov et al., 2006; 2010; Mollov & Boyadzhiev, 2009).

Of all 16 species of frogs found in Bulgaria, 9 (56.25%) have been studied in connection with their trophic spectrum so far. For four species (25.00%), there is very little data, and for 7 (43.75%), such studies have not yet been done.

The summarized results of the conducted studies, arranged by species, are presented in Table 1. The species for which the respective authors have conducted specialized scientific studies are marked with "+"; "?" indicates the species for which there is only partial data and "-" - no studies have been conducted.

The table shows that, of all the representatives of the Bulgarian anuran amphibians, specialized studies on their diet were conducted for only nine species, and by the number of studies they are: *Pelophylax ridibundus* - 11; *Bufotes viridis* - 7; *Bombina variegata* - 6; *Bombina bombina* and *Hyla orientalis* (*H. arborea* is mentioned in the articles, but judging by the places, where these studies were made and the new taxonomy of the species in the genus *Hyla*, it is more likely to refer to *H. orientalis*) - 3; *Bufo bufo* - 2, *Rana temporaria*, *Rana graeca*, and *Rana dalmatina* – 1 each. For the remaining seven species (30.77%) (*Pelophylax bedriagae; Pelophylax* kl. *esculentus*; *Pelobates fuscus; P. syriacus, P. syriacus*), which occur in Bulgaria has only partial data related to their food ecology and trophic spectrum or there are no such studies.

Summary of the studies of the trophic spectrum by species is as follows:

European Fire-bellied Toad (*Bombina bombina*). Data on the diet of this species in Bulgaria are presented in the works of Angelov & Batschwarov (1972); Tomov (1991) and Mollov et al. (2006). The first study conducted in 1962-1965 was based on the stomach contents of 7 individuals from Southern Bulgaria (the surroundings of Plovdiv, Pazardzhik, and Burgas). The authors found that the predominant taxa in the food of the Fire-Bellied Toad are Hymenoptera, Formicidae (84.85%), Coleoptera (9.09%), Gastropoda (0.30%) and Isopoda (0.30%). Tomov (1991) analyzed the stomach contents of 248 individuals from the surroundings of the town of Lom (Northern Bulgaria) and found that it consisted mainly of Coleoptera (26.95%), Hymenoptera, Formicidae (19.43%), Myriapoda (9.14%). Data from the study by Mollov et al. (2006), based on 46 individuals, captured in from Plovdiv District in 1974, show that the most numerous taxa in the diet of the species are Coleoptera (31.0%) and Diptera (31.0%), and Hymenoptera, Formicidae is in third place with 8.3%.

The width of the trophic niche shows significant differences due to the large difference in the number of studied individuals in the three studies - from 1.37 (Angelov & Batschwarov, 1972), 7.54 (Tomov, 1991) to 10.23 (Mollov et al., 2006).

Yellow-bellied Toad (*Bombina variegata*). The trophic spectrum of this species has been very well studied (Angelov, 1960; Bachvarov, 1965; Batchvarov, 1967; Angelov & Batschwarov, 1972; Donev, 1984b; Mollov et al., 2006). The data available at this time indicate that the Yellow-bellied Toad shows some preference for the Coleoptera order, as it is the predominant taxon in all studies except Donev (1984b), which indicates the Diptera order as the most preferred prey. According to the data provided by these authors, the trophic niche of the *Bombina variegata* varies from 2.95 to 7.22.

Common Toad (*Bufo bufo*). The available data on the diet of this species is quite scarce. Angelov & Batschwarov (1972) studied the stomach contents of only six specimens of this species from the surroundings of Plovdiv, Pazardzhik, and Burgas in the period 1962-1965. The data show that the most preferred taxon is Coleoptera (36.36%), Hymenoptera (27.27%), and Arachnida (10.60%). The low food specialization (d=0.36) creates an impression that this species maybe prefers ants, which may be due to the small number of specimens studied,

Species / Author(s)	Angelov (1960)	Beshkov (1961)	Hristova (1962)	Bachvarov (1965)	Batchvarov (1967)	Beschkov (1970)	Angelow & Batchwarow (1972)	Angelov & Batschwarov (1972)	Donev (1984a)	Donev (1984b)	Donev (1986)	Tomov (1989)	Tomov (1990)	Tomov (1991)	Mollov et al. (2006)	Mollov (2008)	Mollov & Boyadzhiev (2009)	Mollov et al. (2010)
Fire-belied Toad *Bombina bombina* (Linnaeus, 1761)	-	?	-	-	-	-	-	+	-	-	-	-	-	+	+	-	-	-
Yellow-belied Toad *Bombina variegata* (Linnaeus, 1758)	+	-	-	+	+	-	-	+	-	+	-	-	-	-	+	-	-	-
Common Spadefoot Toad *Pelobates fuscus* (Laurenti, 1768)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eastern Spadefoot Toad *Pelobates syriacus* Boettger, 1889	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Balkan Spadefoot Toad *Pelobates balkanicus* Karaman, 1928	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Toad *Bufo bufo* (Linnaeus, 1758)	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-
Green Toad *Bufotes viridis* (Laurenti, 1768)	+	+	-	+	+	-	-	+	-	-	-	-	+	-	+	-	-	-
Eastern Tree Frog *Hyla orientalis* Bedriaga, 1890	+	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-
Common Tree Frog *Hyla arborea* (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Frog *Pelophylax ridibundus* (Pallas, 1771)	+	?	+	+	+	-	+	-	+	-	+	+	-	-	+	+	-	+
Edible Frog *Pelophylax kl. esculentus* (Linnaeus,1758)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Levant Green Frog *Pelophylax bedriagae* (Camerano, 1882)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pool Frog *Pelophylax lessonae* (Camerano, 1882)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greek Stream Frog *Rana graeca* Boulenger, 1891	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Common Frog *Rana temporaria* Linnaeus, 1758	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Agile Frog *Rana dalmatina* Fitzinger in Bonaparte, 1838	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-

Table 1. Summary of the conducted studies on the trophic spectrum on the Bulgarian anuran species (explanations are in the text).

but given the high value of the trophic niche breadth (9.13), it is possible that this species is polyphagous. The study of Mollov & Boyadzhiev (2009), based on eight individuals caught in 1967 in the area of the Rowing Canal of Plovdiv City, shows a much lower value for the trophic niche breadth - 1.96 and a very high percentage of Hymenoptera, Formicidae in the diet - 70.20%, which suggests that perhaps depending on the season, there is a certain preference for ants as a food source.

More research is needed over the different seasons to determine variations in diet, trophic specialization of the species, and the trophic niche breadth.

Green Toad (Bufotes viridis). The trophic spectrum of the Green Toad is quite well studied in Bulgaria (Angelov, 1960; Beshkov, 1961; Bachvarov, 1965; Batchvarov, 1967; Angelov & Batschwarov, 1972; Tomov, 1990; Mollov et al., 2006).

The first study of the Green Toad's diet in Bulgaria was conducted by Angelov (1960). The study aims to clarify issues related to the role of frogs as predators of pest insects. The material was collected in 1954 and 1955 from April to September, and 20 individuals were collected from the vicinity of Plovdiv City. The diet consists almost entirely of insects, only 0.8% of the food is non-insect. Predominating taxa consist of the order Hymenoptera, of which the species of the family Formicidae are 95.1%, and only 4.9% are others.

From the study of Beshkov (1961), based on the stomach content of 180 individuals from Sofia City, shows the following composition of food: Hymenoptera, Formicidae (46.89%), Aphidoidea (18.97%), Diptera and Diptera - larvae (11.90%), Coleoptera, Carabidae (4.71%), Arachnida (1.77%), Oligochaeta, Lumbricidae (1.73%), Lepidoptera and Lepidoptera - larvae (1.56%), Hymenoptera (1.25%), Coleoptera Curculionidae (1.11%), Coleoptera, Chrysomelidae (1.03 %), Hemiptera (1%), Gastropoda (0.69%), Arthropoda, Myriapoda (0.66%), Isopoda, Oniscoidea (0.55%). The remaining 6.19% is distributed among the different Coleoptera families - Dermaptera, Orthoptera, etc., as none of the listed groups exceeds 1%.

Bachvarov (1965) studied the food of the Green Toad caught from the Kardzhali Region, as part of a parasitological study. The toads were collected in 1962 and 1964. The stomach contents of 11 specimens were represented by several taxa with a more significant number of Coleoptera, families Carabidae and Cerambycidae, Orthoptera, Gryllidae, Gastropoda, Clausiliidae, and Diptera, without any quantification, given by the author. A similar study by the same author (Batchvarov, 1967) was conducted in May 1965 along the Tundzha River from the towns of Kazanlak to Elhovo. Twenty seven individuals were caught, and their gastric contents show that the most numerous taxa consumed by the Green Toad are Coleoptera, Hymenoptera, Gastropoda (Helicidae, Zonitidae), Oligochaeta, Lumbricidae, Myriapoda, etc.

Angelov & Batschwarov (1972) studied the diet of *B. viridis* in 1962 and 1965 in the regions of Plovdiv, Pazardzhik, and Burgas. The data show that the most numerous taxa in the stomachs are Coleoptera, Carabidae (46.38%), Hymenoptera, Formicidae (18.52%), and Hemiptera (16.91%).

According to Tomov (1990) data on the trophic spectrum of *Bufotes viridis* from the town of Lom for the period 1980-1982, the following results were obtained. The author studied a large sample of 394 individuals, and the material is distributed by seasons as follows: spring - 158 ind. (March - 30, April - 38, May - 90); summer - 151 ind. (June - 13, July - 36, August - 102); autumn 85 ind. (September - 58, October - 31). The diet of the Green Toad in the study area was composed of representatives of 6 classes of invertebrates. The largest are the insects (Insecta); in addition to being the most numerous among the ingested animals - 12,579 preys (96.73%), they were found in the largest number of examined stomachs - in 384 stomachs (97.46%). The second place takes the crustaceans - Crustacea (terrestrial Isopoda only), and in third place, with almost equal

participation, are Oligochaeta (exclusively Lumbricidae), as well as Arachnida (mainly Aranea and single Pseudoscorpiones, Opiliones and Acarina). Third place is taken by the centipedes - Myriapoda (mainly Chiliopada and only a few Diplopoda). The average number of specimens found in one stomach is 33, which shows both the very high trophic activity of the toads and the presence of rich and various prey in the study area.

The seasonal feeding activity of the Green Toad in the study area is well illustrated by the average number of invertebrates found in one stomach, as for spring, this value is 30.61, for summer - 36.56 and in autumn - 31.13. It is visible that the trophic activity of the toads is highest in the summer; the lowest values in the spring are probably due to the breeding season in which the toads do not feed actively. In this regard, it should be noted the presence of empty stomachs only in the spring season, while in summer and autumn, there are none. The most numerous and with the highest percentage of occurrence in the spring are Hymenoptera, Formicidae, Coleoptera, Carabidae, and Diptera. During the summer, Hymenoptera, Formicidae, and Coleoptera take the first and second place, and Heteroptera is in third place, while the number of Lepidoptera - larvae are significantly increasing. In the autumn, ants and carabids are again the most numerous, but significant increase in various species of small Hymenoptera have been observed; the number of Diptera, Isopoda, and Hemiptera also remains relatively large.

According to Mollov et al. (2006), the most numerous taxon in the food spectrum of the Green Toad from Plovdiv City is Coleoptera (52.2%), followed by Hymenoptera, Formicidae (23.9%) and Crustacea (11.0%). According to their data, the trophic niche breadth is 4.98.

The majority of studies on the feeding ecology of *Bufotes viridis* have shown that this species consumes predominantly Hymenoptera, Formicidae, which has the highest value in the data given by Tomov (1990). The second most preferred taxon, which is presented as the first in some studies (Bachvarov, 1965; Batchvarov, 1967; Angelov & Batschwarov, 1972; Mollov et al., 2006) is the order Coleoptera. Based on the available data, the width of the trophic niche of the green toad varies from 1.72 to 8.38.

Marsh Frog (Pelophylax ridibundus). This is the best-studied species in terms of its trophic spectrum in Bulgaria (Angelov, 1960; Beshkov, 1961; Hristova, 1962; Bachvarov, 1965; Batchvarov, 1967; Angelow & Batschwarow, 1972; Donev, 1984a; 1986; Tomov, 1989; Mollov, 2008; Mollov et al., 2006; 2010). The studies conducted in Bulgaria on the food spectrum of *P. ridibundus* can be conditionally divided into two periods. The first period covers all studies conducted in 1954-1985, most of which were conducted in southern Bulgaria (Plovdiv, Pazardzhik, Burgas, Sofia, Kardzhali Region, the Tundzha River Valley and in various places in southwestern Bulgaria). Only one study was conducted in the vicinity of the town of Lom in northern Bulgaria (Tomov, 1989). The second period covers articles published in the period 2006-2010, but they are also based on material collected in 1974-1995 from localities in Plovdiv and Pleven.

The first study on the diet of the Marsh Frog was done by Angelov (1960). The author has researched the diet of some species of frogs, intending to provide some new data on their role in combating pests. From his data, it is clear that the trophic spectrum of the species consists mainly of invertebrates, and insects predominate (Coleoptera – 47,2%; Hymenoptera – 16,8%; Diptera – 13,6 %).

The most extensive and detailed study of the trophic spectrum of *P. ridibundus* was conducted by Hristova (1962), who was the first author to establish that the Marsh frog causes some damage (catches a large number of fish) in fish farms. This is the only study so far on the food spectrum of the larvae in Bulgaria. The author reports that vegetation plays a significant role in the life

of frogs, which largely directly determines the food available in the habitat, as frogs feed mainly on insects, and they are closely dependent on plants. The higher the species richness of the vegetation, the more abundant the insect fauna in this place. Thus, vegetation has indirect and direct importance for the feeding of frogs, as the larvae of *P. ridibundus* are mainly herbivores.

In her research on 162 larvae of the Marsh Frog in the Chelopechene Fish Farm (Sofia Region), Hristova (1962) found that all the larvae ingested plants - 33,1%, animals - 11,1% and detritus – 45,5%, during the study period. Along with these nutrients in the diet are absorbed plant particles 7.7%, as well as sand and silt (8.6%). In the analysis of the change in food depending on the growth of larvae, the author found that until the start of the metamorphosis, they feed almost exclusively on algae and detritus (up to body size of 4.5 cm). In the stage with a single pair of limbs (body size 4.5 to 7.5 cm), plants are also predominant, but tiny invertebrates are also found in the diet. In the stage with two pairs of limbs (over 7.5 cm), more animal food predominates.

According to the same author, the food of the larvae of other species of anurans (*Bufotes viridis, Pelobates fuscus*, and *Hyla orientalis*), which inhabit the fish farms examined by her, does not differ in quality from the diet of the larvae of the Marsh Frog. There are some small differences, expressed in the fact that in some of the pools, a more considerable amount of a particular type of food is found in than in others. In none of these species, can we talk about food selectivity.

Prof. Georgi Bachvarov, in few studies (Bachvarov, 1965; Batchvarov, 1967; 1968), examines the food spectrum of the Marsh Frog from the point of view of possible ways of infecting frogs with helminths. He also found that the three most essential taxa in the diet are Coleoptera, Hymenoptera, Diptera, but did not give any quantitative data (Bachvarov, 1965; Batchvarov, 1967) and that in fish farms, the species also catches a certain amount of fish and specimens of the same species (Bachvarov, 1968), again without any quantitive data. Cannibalism has also been reported in almost every study of the species' food spectrum (Mollov et al., 2010).

It is known from the literature that the feeding of the frogs depends on the temperature of the environment. At low temperatures, frogs stop feeding. This fact was also established in the study of Batchvarov (1968). In late autumn and early spring (immediately after waking from hibernation), only frogs with empty stomachs were caught. In April, as the weather warms and the frequency of insect activity increases, frogs begin to feed and lead an active lifestyle. In the stomachs of the studied frogs from the spring, remains of Coleoptera were found. During the summer months, the food is abundant and consists of remains of Coleoptera, Oligochaeta, larvae of *P. ridibundus*, and even small frogs (Bachvarov, 1965, Batchvarov, 1967).

Donev (1984a, 1986) is the second author to study the Marsh Frog's trophic spectrum in the Plovdiv State Fishery. He also confirmed Hristova's (1962) study that the species can cause severe damage in fish farms. According to the second study from 1986, fish is the third most important food component. In many cases, the author also establishes cannibalism.

Tomov (1989) reports new data regarding the trophic spectrum of *P. ridibundus* from Northern Bulgaria, from where so far, in this respect, there is no data from this part of the country. The study was conducted in the vicinity of the town of Lom, and the author examines both the qualitative and quantitative composition of food and its seasonal dynamics. The author's data show that the diet of the Marsh Frog in the studied area is diverse - it includes representatives of 9 classes of animals (7 classes of invertebrates and 2 classes of vertebrates). Insects are vibrant and constitute an essential component in the food. The seasonal feeding activity of frogs in the study area is highest in summer and significantly lower in autumn and spring.

At a much, later stage in 2006 in a review article by Mollov et al. (2006) published unpublished data on the food of the Marsh Frog and reported that the diet consists predominantly of Coleoptera (36,8%), Diptera (13,0%), and Hymenoptera (12,2%).

Mollov (2008) was the first author in the country to study the sex-based differences in the diet of *P. ridibundus*. According to the author, the trophic niche breadth has a much higher value in males (22.70) than in females (17.45). There is also an overlap of the trophic niches between the sexes, which is 63.8%. Morphology appears to influence the feeding behavior of *Pelophylax ridibundus* significantly, and differences in the diet between sexes can be explained by the fact that males are smaller than females. The author also found that the caught prey was mostly terrestrial, but given the frequency of encounters and the size of aquatic organisms, he concluded that feeding primarily occurs on land, but frogs also hunt in the water. This suggests that the Marsh Frog has an essential position in food chains located in the ecotone area between aquatic and terrestrial ecosystems.

The last article on the Marsh Frog's trophic spectrum was published in 2010 by Mollov et al. (2010). The authors found that in the diet was predominating Coleoptera, Diptera, and Hymenoptera and that the share of aquatic organisms was significantly smaller than terrestrial ones, with the authors again recording a case of cannibalism and the presence of vertebrates in the stomach contents. The variations of the trophic spectrum by seasons are also studied. Feeding is particularly intense in the spring, especially before the breeding season and decreases in the fall with falling air temperatures and changes in climatic conditions.

Most of the publications show Coleoptera as the most numerous taxon in the diet of the Marsh frog and has the highest value in the study of Hristova (1962), which is also confirmed by the results of Mollov et al. (2006; 2010). In the publication of Donev (1986), Collembola is mentioned as the most preferred taxon. Tomov (1989) mentions Hymenoptera as the most numerous taxon, which is confirmed in Mollov's (2008) study. From the above, we can conclude that *P. ridibundus* has no particular preference for certain prey and can undoubtedly be classified as polyphagous. This is confirmed by the high values of the trophic niche breadth, which, based on the data from the above studies, it varies from 3.65 to 19.21. This is the only anuran in our country that exhibits cannibalism.

Greek Stream Frog (Rana graeca). Only one study by Beschkov (1970) was conducted on the diet of this species in Bulgaria. However, since the study is based on a significant number of specimens (n=155) and done in a relatively large area (South-eastern Bulgaria), we can draw some conclusions about the food ecology of this species. The author's data show that the food of the Greek Stream Frog consists of 97% of terrestrial taxa, with Coleoptera (15.73%) predominating, followed by Diptera (13.48%) and Arachnida (9.81%) and showing no preference for a particular taxon (d=0.16) and can, therefore, be classified as a polyphagous. The breadth of the trophic niche, calculated according to the author's data, also has quite high value - 12.85, which confirms this statement.

The author also examines the food of *Rana graeca* by seasons and finds that in the spring, the percentage of empty stomachs is highest, which is the lowest in the fall. In all three seasons, Coleoptera predominates as the most preferred food. In the spring, a large percentage of Plecoptera (imago + larvae) is observed, which shows that the Greek Stream Frog inhabits mainly clean mountain springs and rivers. In summer, in addition to Coleoptera, Araneae and Diptera predominate in the diet, while in autumn, in addition to the beetles, Gastropoda, Homoptera and Collembola predominate. The author also notes that *Rana graeca* does

not search its food underwater, but hunts entirely on land. Also, the Greek Stream Frog feeds both during the day and at night.

Comparing the diet of young and adult frogs, Beschkov (1970) found that characteristic components of the diet of juveniles are Collembola, Aphidodea, Plecoptera, Cicadellidae, Formicidae and some tiny organisms, such as pseudoscorpions, small ticks and leaf fleas, which are absent in the stomachs of the adults. The number of Gastropoda and Orthoptera is very small, which are represented by a much higher percentage in adult individuals. The author also notes that the main food of *Rana graeca* - Coleoptera and Diptera are consumed equally by the juveniles and adults.

Common Frog (Rana temporaria). The trophic spectrum of this species has been studied only by Angelov & Batschwarov (1972). The data given by the two authors, based on a study of 25 individuals from the surroundings of Plovdiv, Pazardzhik, and Burgas, show that the three predominant taxa are Arachnida (14.23%), Hymenoptera, Formicidae (9.61%), Diptera (8.18%). The trophic spectrum of the species to some extend is similar to that of *Rana graeca*, which can be explained by the fact that the two species inhabit similar habitats - mountain springs, streams, and rivers. The Common Frog does not show particular preferences in food (d=0.14) and has high values of the trophic niche breadth - 16.01, which leads us to conclude that it is probably polyphagous.

Agile Frog (Rana dalmatina). Only one study by Angelov & Batschwarov (1972) was conducted for this species. The authors' data based on a small sample (n = 12) show that the Agile Frog feeds mainly on Coleoptera (56%), Gastropoda (16%), Myriapoda (8%) and has a high value of the trophic niche breadth. - 8.11. Further research on the species' diet based on larger samples is needed.

Eastern Tree Frog (Hyla orientalis). So far, three studies have been conducted on the trophic spectrum of this species in Bulgaria (Angelov, 1960; Batchvarov, 1967; Angelov & Batschwarov, 1972). Unfortunately, the three studies were conducted on small samples and give very contradictory results: according to Angelov (1960) the predominant taxa in the diet of *Hyla orientalis* are Coleoptera (67.1%), Hymenoptera (14.6%) and Diptera (7.3%); Batchvarov (1967) mentions only Coleoptera, without any quantification and according to Angelov & Batschwarov (1972), the predominating taxes are: Lepidoptera (larvae) - 30.59%, Arachnida - 23.53%, Diptera (larvae) - 16.47%). Due to this fact, we cannot draw any specific conclusions. *Hyla orientalis* is probably polyphagous, and this is partly confirmed by the values of the width of the niche of the species, which varies from 2.11 to 5.68.

Currently, in Bulgaria, there are no studies on the trophic spectrum of the following species: *Pelobates fuscus, P. syriacus, P. balkanicus, Hyla arborea, Pelophylax* kl. *esculentus, P. bedriagae,* and *P. lessonae*.

Figure 1 presents the average values and the standard deviation of the trophic niche breadths, calculated according to the data from all available studies. The chart shows that the highest values are presented in the trophic niches of the aquatic frogs - *P. ridibundus, R. graeca, R. temporaria, R. dalmatina*. The trophic niches breadths of the other anuran species found in Bulgaria have significantly lower values, the lowest being in *Hyla orientalis*.

From the analysis of the summarized data, we can conclude that all anuran species in Bulgaria are zoophagous, mainly insectophages, because insects occupy a significant part of their trophic spectrum. Summarized data from the Berger-Parker index from all studies show that all species show broad trophic specialization (Table 2) and can be classified as polyphagous, except for *Bombina variegata*, which has narrower limits in the index and shows a preference for the order Coleoptera. Some authors report plant and inorganic components

(pebbles, sand, etc.) in the food spectrum of the studied species, which are considered to be accidentally ingested.

Figure 2 shows a dendrogram showing the similarity between the trophic spectrum of all studied Bulgarian anuran species, calculated based on quantitative data for each species, from the available studies. The figure shows that the studied species in terms of their diet are grouped into three clusters. At 5% similarity, *Rana dalmatina* was isolated in a separate cluster, but this may also be due to the fact that only one study on this species was conducted on a very small sample. The other species are divided into two clusters, the first, which is separated at about 7% similarity, consists of two species - *Bufotes viridis* and *Pelophylax ridibundus*. The reason for the grouping of the two species, in our opinion, is first of all the fact that most of the studies were done on them. On the other hand, the food of the two species is similar, as they hunt mainly on land, and the main taxa they catch are Coleoptera, Hymenoptera, etc. The beetles and ants are basic food most probably due to the abundance of this preys and the wide range of habitats they occupy.

The third cluster is further divided into two sub-clusters. The first one is isolated at about 25% similarity and includes *H. orientalis, R. temporaria*, and *R. graeca*. We have already commented that the trophic spectrum of *R. temporaria* and *R. graeca* is similar mainly because the two species inhabit very similar habitats - clear, mountain streams, rivers, lakes, and rarely swamps. *H. orientalis* appears to show higher similarity to the diet of *R. temporaria* with approximately 43% similarity. The second sub-cluster is separated at about 35% similarity and includes *Bufo bufo, Bombina bombina, B. variegata*, as the last two species have a higher similarity in their trophic spectrum with about 40%.

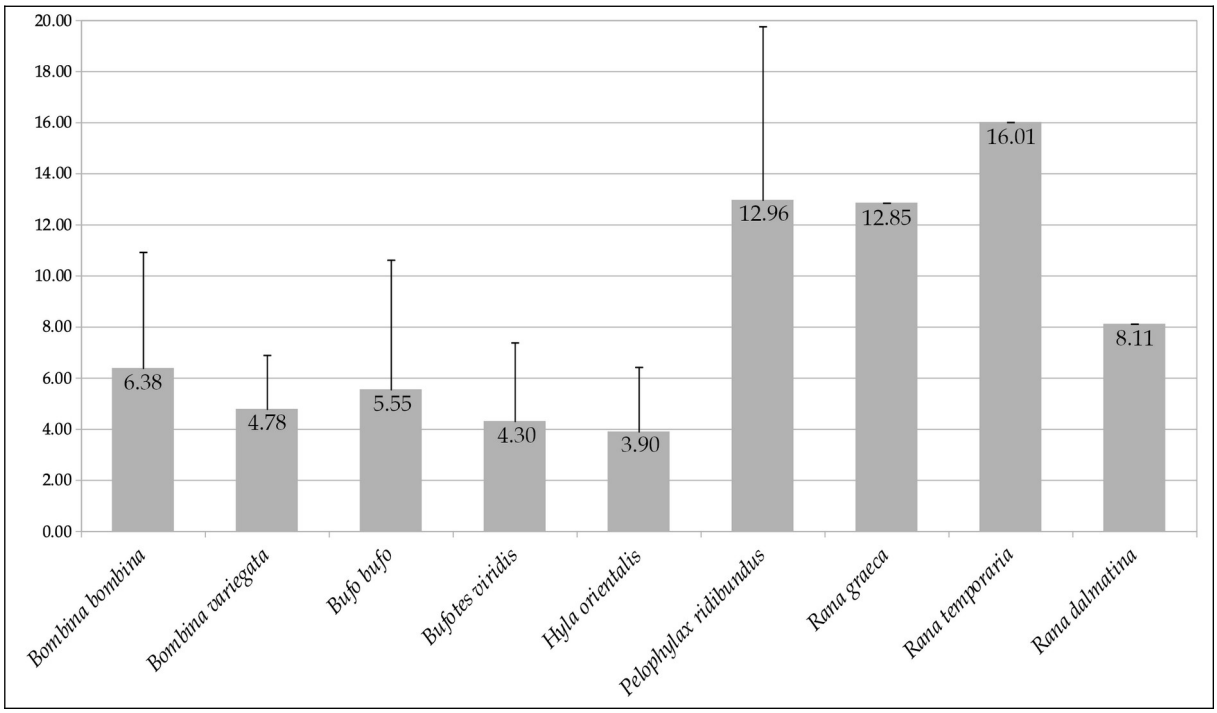

Fig. 1. Average values and standard deviation of the trophic niche breadth of all studied species, calculated based on data from all available studies, conducted in Bulgaria.

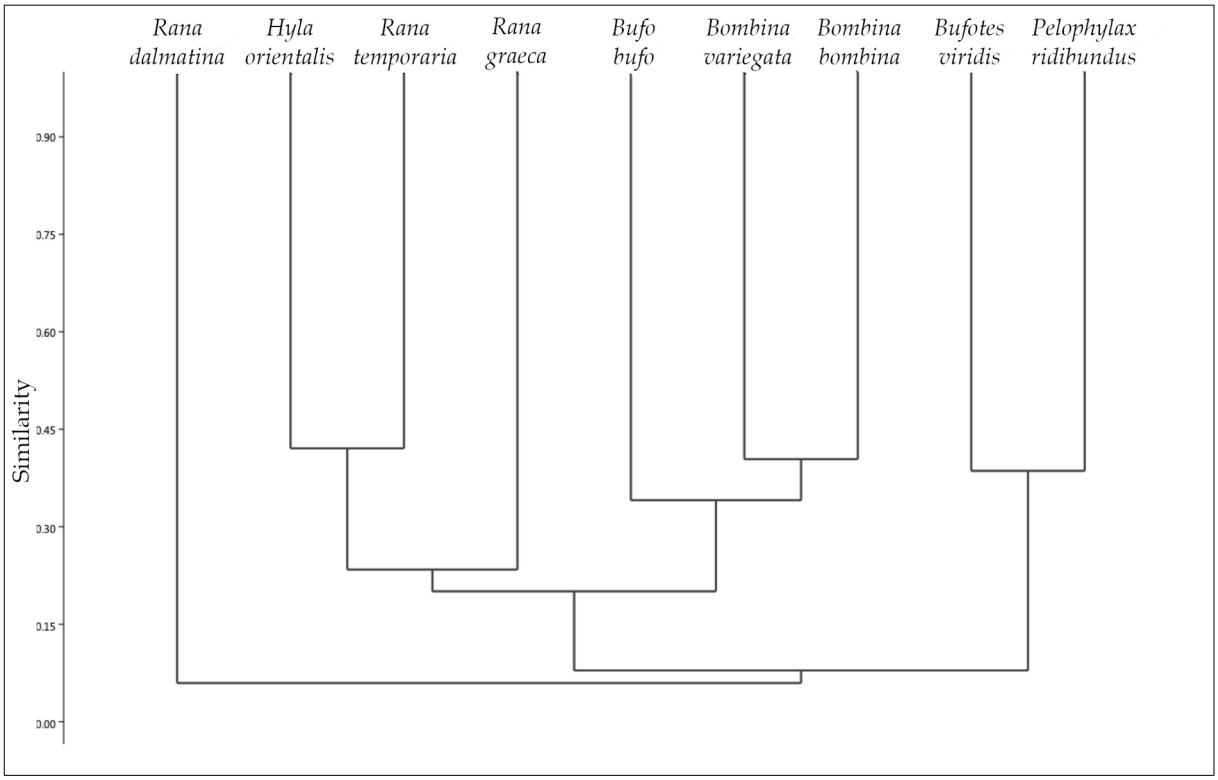

Fig. 2. Similarity of the trophic spectrums of all studied Bulgarian anurans (cluster analysis, Jaccard similarity index, Unweighted Pair Group Average), calculated based on the quantitative data from all available studies, conducted in Bulgaria.

Table 2. Trophic specialization of the Bulgarian anuran species, based on the Berger-Parker index values, calculated from the available studies in Bulgaria.

Species	**Berger-Parker index**	**Trophic specialization**
Fire-belied Toad (*Bombina bombina*)	0.27-0.85	polyphage?
Yellow-belied Toad (*Bombina variegata*)	0.44-0.62	oligophage?
Common Toad (*Bufo bufo*)	0.36-0.70	polyphage?
Green Toad (*Bufotes viridis*)	0.46-0.76	polyphage?
Eastern Tree Frog (*Hyla orientalis*)	0.31-0.67	polyphage
Marsh Frog (*Pelophylax ridibundus*)	0.17-0.58	polyphage
Greek Stream Frog (*Rana graeca*)	0.16	polyphage
Common Frog (*Rana temporaria*)	0.14	polyphage
Agile Frog (*Rana dalmatina*)	0.56	polyphage?

All studies conducted in Bulgaria until 1991 are characterized by research only of the qualitative and quantitative composition of the diet of the Bulgarian anurans and an analysis of what part of the prey are pests in agriculture, forestry, and fisheries. Some authors analyze the seasonal variations in the trophic spectrum of the studied species. Studies on the trophic niche breadth, the overlap of niches between the sexes, and the role of anuran amphibians in food chains in biocenoses are done by Mollov (2008);

Mollov et al. (2006; 2010). There is still no study on the overlap of trophic niches between species that occur together, as well as a studies of the diet regarding its volume.

More studies need to be conducted on the qualitative and quantitative composition of the diet anurans in Bulgaria (especially the species that have not yet been studied in this regard), as well as more detailed studies of their feeding ecology.

Conclusions

Currently, there are 18 specialized studies on the diet of the Bulgarian anuran species. Of all 16 anuran species, occurring in Bulgaria, about half have been studied in connection with their trophic spectrum so far. All Bulgarian species of amphibians are zoophagous, mainly insectivorous, and can be classified as general feeders (polyphages), except *Bombina variegata*, which shows a slight preference to Coleoptera and *Bufo bufo* and *Bufotes viridis*, which show slight preference to Formicidae and Coleoptera. Cannibalism was recorded only in *Pelophylax ridibundus*. *P. ridibundus, R. graeca, R. temporaria,* and *R. dalmatina* has the highest values of the trophic niches breadths. In contrast, the other anuran species found in Bulgaria have significantly lower values, the lowest being in *Hyla orientalis*.

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