Synecology of the European common spadefoot toad, *Pelobates fuscus* (Laurenti, 1768) (Amphibia: Anura: Pelobatidae), in agroecosystems of Bosnia and Herzegovina

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Abstract: The European common spadefoot toad (*Pelobates fuscus*) is a lowland, semi-fossorial and secretive anuran species with a narrow ecological niche. The southernmost border of its habitat reaches the northern parts of Bosnia and Herzegovina (Posavina region), where the species has lost the vast majority of its natural habitat, resulting in it being restricted to agroecosystems close to aquatic habitats. This paper describes the ecology of *P. fuscus* in such habitats – and generally in Bosnia and Herzegovina – for the first time. Two types of independent research were performed: (1) assessment of population density and microhabitat preferences along with habitat quality analysis (performed in three localities) and (2) a food preferences study and morphometry in one locality (Čardak, Modriča), where the largest known population of *Pelobates fuscus* in Bosnia and Herzegovina resides.

Key Words: fossorial, Posavina, agriculture, ecology, population, density, microhabitat, morphometry, sex ratio, diet

INTRODUCTION

The European common spadefoot toad – *Pelobates fuscus* (Laurenti, 1768), is a semi-fossorial and nocturnal anuran species, which inhabits lowlands areas and hilly regions of the central, eastern and south-eastern parts of Europe. The vertical distribution of the species goes from 0 to 800 m AMSL (Speybroeck et al., 2016). Typical natural habitats of *P. fuscus* are dunes, open forests, heathlands, river valleys and steppes (Rot-Nikčević et al., 2001; Speybroeck et al., 2016). However, they can be found in anthropogenic habitats (such as agricultural areas) in low population densities (Bosman, 2005; Bosman & van den Munckhof, 2006). Due to their secretive behaviour and low abundance, the knowledge on the species's ecology is scarce. It is a highly specialized toad, and occupies a narrow ecological niche (Džukić et al., 2008; Cogălniceanu et al., 2013), mostly confined to flat and open areas with loose soil (Speybroeck et al., 2016). *Pelobates fuscus* selects breeding habitats based on characteristics of the terrestrial and aquatic environment (Rannap et al., 2011). Aquatic habitats are used only during the mating period; however, individuals always live very close to water, and they appear to be poor migrants (Eggert, 2002). *Pelobates fuscus* is an opportunistic predator, feeding on the most abundant trophic resources available in their environment (Juszczyk, 1974; Medvedev, 1974; Sczerbak & Sczerban, 1980; Kuzmin, 1995; Cogălniceanu et al., 1998, Tarkhnishvili & Gokhelashvili, 1999; Covaciu-Marcov et al., 2010; Alekseev & Korzikov, 2013).

The southernmost border of the spadefoot toad's distribution is the area of the northern Balkan Peninsula. More precisely, the floodplains of the Sava River [natural border between Bosnia and Herzegovina (hereinafter: B&H) and Croatia], known as the Posavina region, represent the south-western border of the species's distribution (Agasyan et al., 2009; Ćurić et al., 2018; Dufresnes et al., 2019a,b). In the Balkans, *P. fuscus* is quite rare, and its populations are fragmented due to the presence of mountain ranges (Dinarides, Carpathians, Balkan), which represent natural barriers (Džukić et al., 2005; Ćurić et al., 2018; Dufresnes et al., 2019a,b). Within the species range, populations are further fragmented due to intensive agricultural activities (Ćurić et al., 2018). According to IUCN (International Union for Conservation of Nature) criteria, *P. fuscus* is considered Data Deficient in Serbia (Ljubisavljević & Džukić, 2015) and Croatia (Jelić et al., 2012) and Not Evaluated in B&H, due to its recent discovery (Ćurić et al., 2018).

The aim of this study is to provide basic information on the biology and ecology of these populations in B&H: population density, habitat and microhabitat preferences, sex ratio, sexual size dimorphism and food preferences.

MATERIAL AND METHODS

Study area. The study was carried out from 7 to 14 May 2016 in Posavina region (Pannonian part) of Bosnia and Herzegovina. We selected three different agricultural sites (monocultures of corn, wheat and sunflower) close to three different types of aquatic habitats: (1) eutrophicated pond in Čardak, Modriča (44.956271° 18.404087°; 96 m AMSL), (2) hypereutrophicated pond in Okanovići, Gradačac (44.930588° 18.405854°; 98 m AMSL) and (3) flood forest (vegetation communities: *Salicetum cinereae, Alnetum glutiosae, Alno-Quercion roboris*) in Gromiželj, Bijeljina (44.866651° 19.309240°; 80 m AMSL) (Fig. 1). All aquatic habitats belong to the vegetation of *Caricetum ripariae*, while Gromiželj has additional *Alnetum glutiosae* and *Alno-Quercion roboris*. Farmers change the type of monoculture on these agricultural sites every year (mainly corn and wheat).

Each field research was conducted during the evening and night from 21:00 to 01:00. Only adult individuals (body length >33mm) were taken into consideration for the purposes of this study. Two types of independent research were done: (1) assessment of population density and microhabitat preferences along with habitat quality analysis (performed in all three localities); and (2) study of food preferences and morphometry (performed in only one locality: Čardak) (Fig. 1).

Population density assessment. We used linear transects, counting the number of individuals found along transects. For each individual/cluster of animals, we estimated its perpendicular distance from the transect line (in cm). The cluster size was annotated along the transects. A total of 50 randomly selected transects (each 25 m length, with an overview of 10 metres both to the right and left) were carried out independently for each of the three sites: Čardak (number of transects (n) = 15; 375 m), Okanovići (n = 20; 500 m) and Gromiželj (n = 15; 375 m). We pooled the data within each locality as if it were one continuous transect, according to the instructions provided by Sutherland (2006) and the DISTANCE 6.0 manual. In this way, the analysis increased the possibility of recording an individual in any part of transect without any impact on the accuracy of the overall assessment. Population density analyses were performed using the Distance software (version 6). We used the suggested *Model 1*, the classic "*single observer*" option and "*cluster data*" without multiplication coefficient.

Additionally, we chose a 1km^2 area that had a body of water within it for each locality, and divided it into small squares, size 25x25m using the software QGIS 2.12.3. We searched a total of 97 randomly chosen squares (26 in Čardak, 29 in Okanovići and 42 in Gromiželj), in which we counted *P. fuscus* and other anuran species, logging the localities using a Garmin GPSMAP 64s. We calculated mean values of

Figure 1. Positions of investigated localities: (1) Čardak, (2) Okanovići and (3) Gromiželj; approximate distribution border of ***Pelobates fuscus*** is given according to: Ćurić et al. (2018)

individuals for each anuran species, to determine the most abundant species in the arable ecosystems (Fig. 2).

quality of the aquatic habitat. The state of the aquatic habitat suitable for the reproduction of *P. fuscus* was assessed using eight parameters (modified from Rannap et al., 2011). Lower values of the parameters indicate minor threat, while higher values indicate a higher threat or risk. The parameters that were used were: (1) number of fish species (sp.): (0 – no sp., 1 – one sp., 2 – two sp. and 3 – three or more sp.), (2) water body origin (0 – natural or 1 – artificial), (3) oxygen level (0 – high, 1 – medium, 2 – low, 3 – very low), (4) size (volume) of aquatic habitat (0 – big, 1 – small, 2 – very small), (5) depth of littoral zone (0 – shallow or 1 – deep), (6) forest presence around water bodies (0 – no forest, 1 – forest leftovers, 2 – large forest areas and 3 – huge forest areas), (7) the presence of open landscapes around water bodies (0 – yes, 1 – no) and (8) amphibian diversity in water bodies (number of other breeding species: 0 – five or more sp., 1 – four or three sp., 2 – two or fewer sp.) Scores for each parameter were estimated on the basis of personal experience. The overall index of habitat quality for each locality was determined as the sum of the scores of all variables divided by the total number of variables (mean). The lower the index, the higher the quality of the habitat.

Microhabitat preferences. At the start of each field research, we recorded air temperature and relative humidity 5 cm above the ground using a hand-held data logger (Kestrel 4000 Weather Meter). Soil temperature was recorded using a PCE-IR 100 thermometer (Figs. 3-5). For every individual found we recorded the microhabitat at its exact location: arable land (bare, overgrown (10-30 cm) or densely overgrown (>30 cm), meadow (<5 cm or densely overgrown), road, macadam, gravel, forest edge and other (Fig. 6).

Morphometry. This study was conducted at the Čardak locality. We collected the following data from each captured toad: (1) sex (detecting presence or absence of oval glands on upper front limbs), (2) snout-to-vent length (hereinafter: SVL) and (3) head width at the ends of the mouth (hereinafter: HW) with a digital calliper and (4) body weight (hereinafter: W) with electronic pocket scale (model: Camry EHA901 with 0.01g precision). Sexual dimorphism was tested by means of a t-test or the Wilcoxon test if the distribution of the data was not normal. Morphometric measurements were carried out on a sample of 121 individuals (63 females and 58 males) (Tab. 3). To eliminate the possibility of measurements being taken from the same individual in subsequent field visits, each toad was photographed from the dorsal side, with these photographs being examined later. A study of the photographs indicated that no individual was measured on two occasions.

ANALYSIS OF FOOD PREFERENCES. We flushed the stomachs of 124 individuals from the Čardak locality, following the instructions provided by Solé et al. (2005). The animals were released afterwards. Stomach flushes were stored in 1.5ml tubes with 10% formaldehyde and studied in the laboratory using a binocular magnifier according to Clessin (1877), Chinery (1986) and Stresemann (2011).

RESULTS

Population densities. We recorded 102 individuals along a total length of 1225m of linear transects. The total area analysed across all three localities was 6000 m^2 (0.6ha). For each locality, we obtained the following population densities: (1) 703 individuals per hectare of habitat in Čardak (95% confidence interval: min. 491 – max. 1006), (2) 191 individuals per hectare of habitat in Okanovići (min. 111 – max. 326) and (3) 309 individuals per hectare of habitat in Gromiželj (min. 194 – max. 491) (Tab. 1).

Registered anuran species for each locality were: *Bombina bombina, Hyla arborea, Rana dalmatina* and *Pelophylax* complex species (most likely *ridibundus-esculentus* system). Čardak additionally includes the anuran species *Bufo bufo*, and Gromiželj *Bufotes viridis*. On all three localities *P. fuscus* was the most numerous amphibian species along the transect (Fig. 2).

Habitat quality. Parameters for estimation of habitat quality showed that the Čardak locality possesses a habitat that is in excellent condition, and significantly better than the other two (with an index of 0.5 compared to values of 0.7 and 0.9) (Tab. 2).

Microhabitat preferences. In a sample of 137 individuals, we recorded the highest number of the individuals at an air temperature between 15°C and 18°C (Fig. 3) and at a humidity ranging from 60% to 80% (Fig. 4). From a sample of 111 individuals, most were caught at soil temperatures between 11°C and 13°C (Fig. 5). The majority of *P. fuscus* individuals were found in open areas, such as bare arable land and meadows (Fig. 6).

Sex ratio and morphometry. The sex ratio at the Čardak locality was 1:1. The first sample (from 1 to 5 May 2017), consisting of 121 individuals, had 58 males (48%) and 63 females (52%). The second sample (from 10 to 14 May 2017) consisted of 72 individuals, of which35 were males (49%) and 37 were females (51%).

Table 1. Population densities in the three localities: **P** – total area, **nt** – number of transects, **Td** – total length of transects, **N** – estimated number of individuals per total area (min – max: 95% confidence interval), **G** – density of individual per m^2, **p** – the probability of finding one individual along 25m of transect

Locality	P (m^2)	n_t	Td (m)	N (individual/P)	N (min - max)	G (individual/m^2)	p (%)
1. Čardak	1500	20	500	5	4 - 8	0.0703	0.55525
2. Okanovići	2250	15	375	3	2 - 5	0.0191	0.27692
3. Gromiželj	2250	15	375	5	3 - 7	0.0309	0.49966

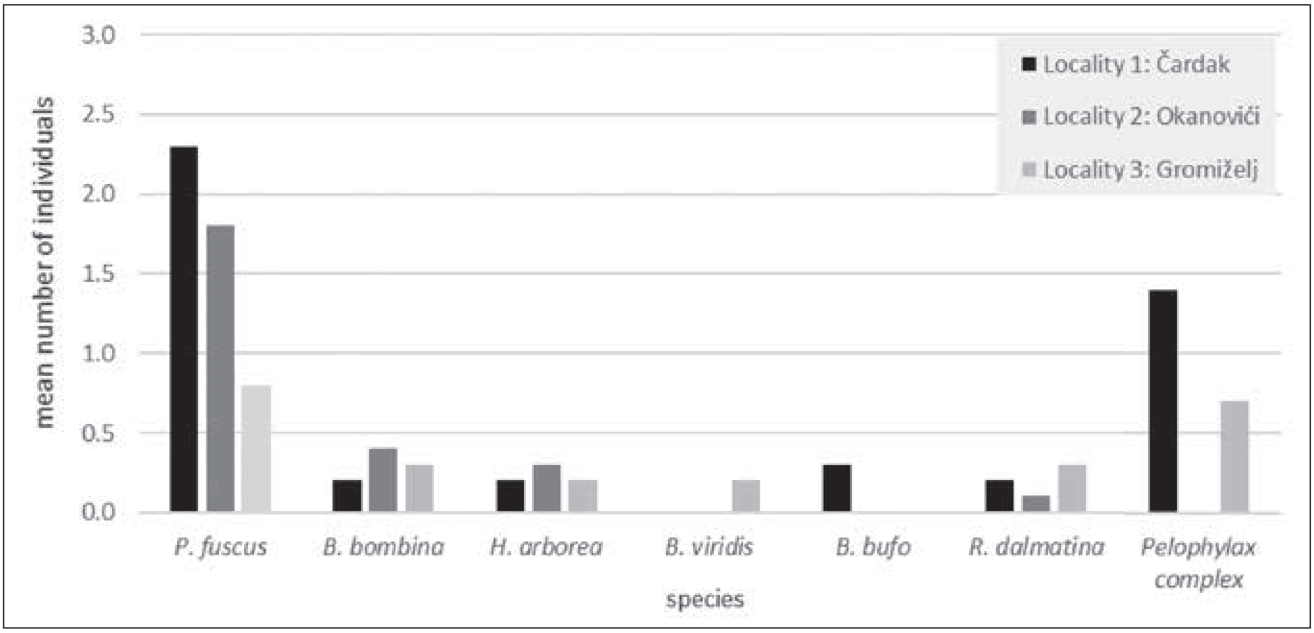
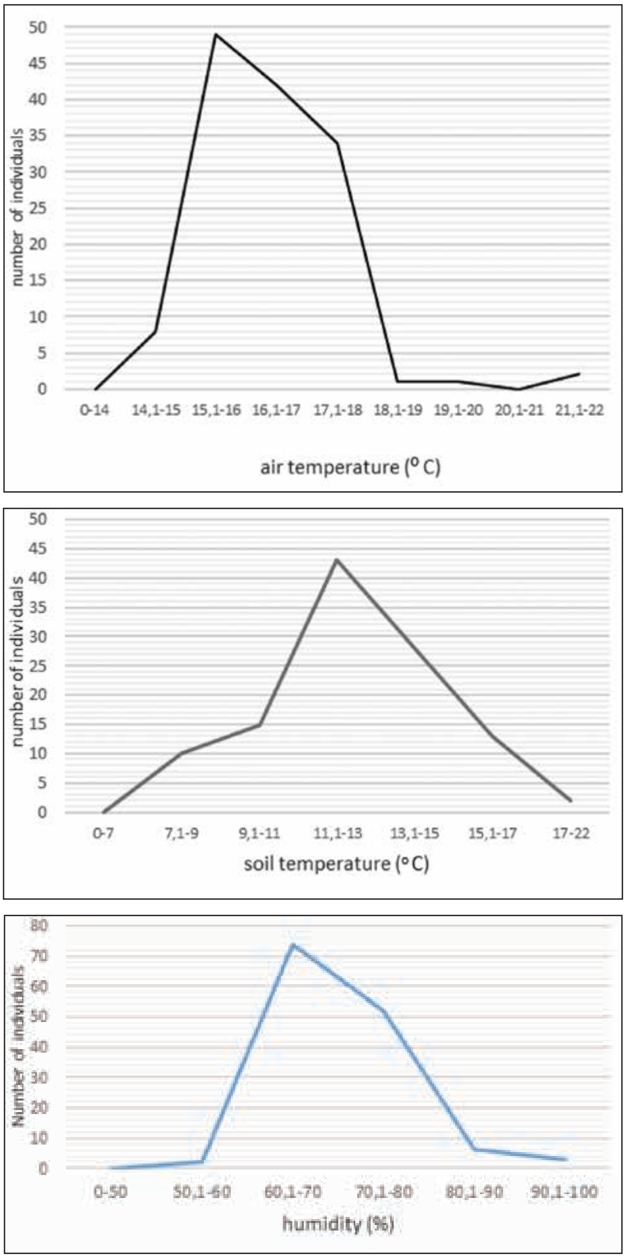


Figure 2. Mean values of individuals in 25x25m quadrat samples at three sites for each anuran species

Table 2. Characteristics of aquatic habitats of *P. fuscus* at the observed localities

Characteristics of aquatic habitats		1. Čardak	2. Okanovići	3. Gromiželj
1.	Presence of fish	0	0	3
2.	Water quality/presence of wastewater	2	3	0
3.	Water body permanence	0	0	0
4.	Size of the water body/eutrophication level	0	3	0
5.	Depth of littoral zone	0	0	1
6.	Presence of woodland	0	1	2
7.	Presence of roads/traffic	3	0	0
8.	Presence of open land	0	0	0
9.	Number of other breeding species	0	1	0
Habitat quality index:		0.5	0.9	0.7



Figures 3-5. Activity of *P. fuscus* individuals based on the abiotic parameters of: air temperature (3), soil temperature (4), and relative humidity (5)

The body weight and length differed significantly between males and females, in contrast to head width of measured individuals (Tab. 3).

Food composition. From the sample of 124 individuals, 64 (51%) had empty stomachs or non-animal content inside. Non-biological material found inside the stomach compromised: stones and soil in 16 individuals (17%), and vegetation remains in 22 individuals (20%). Regarding the plant material, in two samples we found the remains of *Fraxinus* sp. seed, while one sample had algae, from the following taxa: *Oedogonium* sp., *Epithemia adnate*, *Rhopalodia* sp., *Euastrum* sp. and *Scenedesmus* sp. present. A total of 60 individuals (49%) had faunal remains within their stomach contents.

All of the prey items were invertebrates. Representatives of three phyla were identified: (1) Arthropoda with 164 individuals, representing 80% of the sample, (2) Mollusca with 29 individuals, or 14%, and (3) Annelida with 9 individuals, or 5% of the sample. Only 1% of the materials remained unidentified. The most numerous taxa within the phylum Arthropoda were members of the class Insecta (47% of total) and Diplopoda (46% of total).

DISCUSSION

According to the transect method, the number of individuals of *P. fuscus* is highest in the Čardak locality (703 individuals), followed by Gromiželj (309 individuals) and lowest at Okanovići (191 individuals). These results are predominantly related to the condition of the aquatic habitat, with Čardak having the best habitat quality, followed by Gromiželj and then Okanovići. The habitat at Okanovići is hyper-eutrophic with desiccation most likely occuring during the early summer. Gromiželj differs significantly, because it has a naturally clean water source, while the water quality at the other two localities (Čardak and Okanovići) is very low, mainly due to

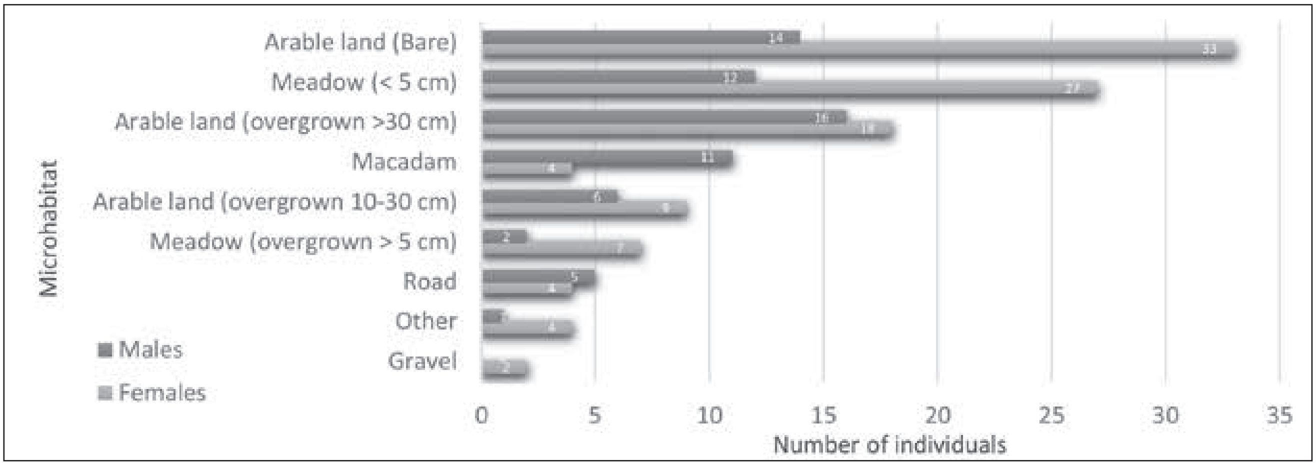


Figure 6. Microhabitat preferences of *P. fuscus* summarized for three sites in Bosnia and Herzegovina

Table 3. Comparative analysis of morphological traits of *P. fuscus* (**t** – t value, **w** – Wilcoxon value, **p** – p value); Number of individuals: 58 ♂ and 63 ♀; **t** – t test, (**w**) – Wilcoxon test; *bootstrap value 9999x

Morphometric Characteristic					t (w)	p
SVL (mm)						
MIN-MAX		MEDIAN	MEAN	CONFIDENCE INTERVAL (95%)	3.20	0.001
♂	34.85-56.45	45.48	45.59	44.38-46.8		
♀	38.43-56.45	45.48	45.59	47.18-49.7		
*HW (mm)					(1289)	0.042
♂	10.39-27.05	17.16	17.34	16.87-17.86		
♀	10.60-21.51	18.02	18.04	17.61-18.65		
W (g)					3.39	0.001
♂	6.68-20.32	11.08	12.04	10.70-12.46		
♀	6.24-34.28	13.72	15.39	12.74-15.74		

the direct impact of wastewater. Gromiželj is also a habitat for at least two fish species: the northern pike (*Esox lucius* Linnaeus, 1758) and the European mudminnow (*Umbra krameri* Walbaum, 1792). True forest habitats were present around the water ecosystem in Gromiželj, while the other two sites have open landscapes surrounding the aquatic habitats. However, the Čardak locality has a road running along one side of the habitat, where a lot of dead on road (DOR) individuals were found (Tab. 4).

The registered population of Čardak is somewhat larger than expected, considering that this is a population inhabiting an agroecosystem; population densities in such habitats are expected to be lower, as evidenced by the studies of Bosman (2005) and Bosman & van den Munckhof (2006). In these studies, a very low number of common spadefoot toads (88 specimens in their reproductive phase at two sites) was found during intensive field research in an agricultural area called "Groot Soerel", Netherlands. The same authors suggest that stable populations of *P. fuscus* would arguably be twice as large. Rannap et al. (2012) suggest that an effective population size must have at least 500 adult individuals. Population densities of *P. fuscus* can be very high in suitable habitats, where the population density can reach 4-5 specimens per square metre (AmphibiaWeb, 2008). Spadefoot toad populations are known to suffer strong fluctuations in population size, mainly due to interannual variation of the number of metamorphs (Eggert & Guyetant, 2002 and references therein).

Table 4. Stomach contents and taxonomic composition of the diet of *P. fuscus*, showing total numbers and percentages of different taxa that were found in the stomach; **A** – Percentage abundance; **f** - Frequency of occurrence is given by both the sum of empty and full stomach contents (124 individuals), and only full stomach contents (60 individuals)

Prey taxa	**Stomach content**			**A (%)**	**f (%) from 60 stomach**	**f (%) from 124 stomach**
	♂	♀	**Total**			
Annelida/Lumbricidae	5	4	9	4.3	15	7.2
Gastropoda (slugs)	13	14	27	12.8	45	21.8
Gastropoda (snails)	1	1	2	0.9	3.3	1.6
Araneae/Trachelidae	-	1	1	0.5	1.6	0.8
Araneae undet.	4	3	7	3.3	11.6	5.6
Lithobiomopha/Lithobiidae	-	1	1	0.5	1.6	0.8
Diplopoda total	**53**	**22**	**75**	**35.5**	**124.9**	**60.5**
Diplopoda/Julida	48	17	65	30.9	108.3	52.4
Diplopoda/Glomerida	4	4	8	3.8	13.3	6.5
Diplopoda/Polydesmida	1	1	2	0.9	3.3	1.6
Lepidoptera, [i]	-	2	2	0.9	3.3	1.6
Lepidoptera, [l]	1	3	4	1.9	6.6	3.2
Coleoptera total	**21**	**28**	**55**	**26.1**	**91.6**	**44.3**
Coleoptera/Elateridae [i]	8	13	21	9.9	35	16.9
Coleoptera/Carabidae [i]	6	5	15	7.1	25	12.1
Coleoptera/Curculionidae [i]	-	1	1	0.5	1.6	0.8
Coleoptera/Dytiscidae [l,a]	-	1	1	0.5	1.6	0.8
Coleoptera undet. [i]	6	7	15	7.1	25	12.1
Coleoptera undet. [l]	1	1	2	0.9	3.3	1.6
Blattoidea	-	3	3	1.4	5	2.4
Hymenoptera/Formicidae [i]	2	8	10	4.7	16.6	8.1
Heteroptera/Cydnidae [i]	1	-	1	0.5	1.6	0.8
Heteroptera undet. [i]	-	1	1	0.5	1.6	0.8
Diptera/Tipulidae [i,f]	-	1	1	0.5	1.6	0.8
Diptera undet. [l]	-	1	1	0.5	1.6	0.8
Orhtoptera/Gryllidae	1	7	8	3.8	13.3	6.4
Hemiptera/Aphididae	-	1	1	0.5	1.6	0.8
Animalia undet.	1	1	2	0.9	3.3	1.6
Total of prey individuals	**103**	**102**	**211**			

l – larvae, i – imago, a – aquatic taxon, f – flying taxon

The results of this study clearly show that *P. fuscus* prefers arable lands, with a majority of individuals being found on bare cultivable surfaces during spring. Although the presence of individuals on densely covered cultivated surfaces is probably high, the finding of individuals in such a habitat type is hindered by visual limitations. Arable land allows easy digging, providing hiding places; additionally, monoculture plant species that are grown upon such land (wheat, corn and sunflower) represent good shelter from predators.

The optimal sex ratio at the Čardak locality corresponds to the maximum effective population size (close to total population size) and suggests a minimal impact of genetic drift and inbreeding effects (Cavalli-Sforza & Bodmer, 1971). The sex ratio can vary significantly between *P. fuscus* populations, ranging from 1:1 to 3:1 in favour of males (Jehle et al., 1995; Eggert & Guyétant 2003). Females occasionally refrain from mating in some years, while males routinely come to reproductive habitats to attempt to mate (Jehle et al., 1995).

The results indicate that the weight and SVL measures are significant characteristics for explaining sexual dimorphism, while the head width does not differ significantly between males and females (Tab. 3). These results were to be expected, due to the fact that other studies also emphasize that females of *P. fuscus* are significantly larger than males (e.g. Rot-Nikčević et al., 2001). A larger female body size is applicable to 90% of anuran species, and is believed that this is due to the effects of the fecundity advantage hypothesis (Shine, 1979), whereby larger females produce more offspring and have greater energy storage for reproduction (Ha & Fu, 2013 and references therein).

The presence of stones, soil and vegetation in the diet suggests that *P. fuscus* often fails to catch prey, and/or these materials are accidentally ingested together with the prey that they eat. Non-biological components and vegetation residuals are common in the diet of amphibians (e.g. Garcia-R et al., 2013). The dietary analysis confirms that *P. fuscus* is a generalist, and shows very little specialization in prey choice. Published data on the diet of *P. fuscus* supports the given hypothesis: the diet varies significantly between observed populations (Juszczyk, 1974; Medvedev, 1974; Sczerbak & Sczerban, 1980; Kuzmin, 1995; Cogălniceanu et al., 1998; Tarkhnishvili & Gokhelashvili, 1999; Covaciu-Marcov et al., 2010; Alekseev & Korzikov, 2013). However, the dietary analysis of the populations studied here is of interest for two reasons: Abundance and frequency of prey species belonging to the class Diplopoda are highest (Tab. 4), which is unusual as it is known that they secrete toxic compounds such as alkaloids, phenols, hydrogen cyanide, terpenoids and benzoquinone (Blum & Woodring, 1962; Kuwahara et al., 2002). The second most frequent are representatives of the families Cydnidae (Heteroptera) and Elateridae (Coleoptera), known to be serious agricultural pests (King & Saunders, 1984; Parker & Howard, 2001; Vernon et al., 2008), which are difficult to combat/control, even with insecticides (Doane et al., 1975; van Herk & Vernon, 2007; van Herk et al., 2008). Since Elateridae (Coleoptera) seems to have no natural predators (Berry, 1997), *P. fuscus* may prove to be a very effective predator that can be used in integrated pest management (IPM) programs through the introduction and development of small aquatic ecosystems for *P. fuscus* in places where it is needed.

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SAŽETAK

Žaba češnjarka (***Pelobates fuscus***) predstavlja tajnovitu vrstu sa uskom ekološkom nišom koja naseljava nizijska područja te većinu svog vremena provodi ukopana u tlo. Najjužnija granica ukupnog areala vrste doseže sjeverne dijelove Bosne i Hercegovine (regija Posavine), gdje je vrsta uglavnom izgubila svoja prirodna staništa uslijed intenzivnih poljoprivrednih aktivnosti, te je njen areal ograničen na poljoprivredna područja u blizini odgovarajućih vodenih staništa. Provedene su dvije vrste neovisnih istraživanja: (1) procjena veličine populacije i preferencija mikrostaništa zajedno s analizom kvalitete akvatičnih staništa (izvedena na tri lokaliteta: Čardak, Okanovići i Gromiželj), te (2) preferencije u ishrani i morfometrija na jednom lokalitetu (Čardak). Na osnovu (1) broja pronađenih jedinki, (2) uticaja ribljih vrsta, (3) prisustva muljevitog dna, (4) prisustva široke zone plitke vode, (4) nepostojanja šume i (5) prisustva otvorenih pejzaža (obradivih površina) oko vodenog tijela, stanište na lokalitetu Čardak spada u najbolje stanište za vrstu ***Pelobates fuscus*** u Bosni i Hercegovini, u odnosu na ostala dva istraživana lokaliteta. Najveću aktivnost (optimum ekoloških faktora) žabe češnjarke su pokazale na: temperaturi između 15 °C i 18 °C, s vlažnošću od 60% do 80%, i temperaturi tla između 11 °C i 13 °C. Analize mikrostanišnih preferencija ukazale su na to da češnjarke najviše preferiraju obradive površine (zbog fosorijalnog načina života), nakon čega slijede fragmenti livadskih ekosistema koji su vrlo rijetki na području Bosanske Posavine. Češnjarka je prema literaturnim podacima i poznatom rasprostranjenju najrjeđa vrsta bezrepatih vodozemaca u Bosni i Hercegovini, ali gotovo najčešća vrsta na mjestima u kojima obitava. Iako dijeli stanište sa polovinom ukupnog broja vodozemaca u Bosni i Hercegovini, zastupljena je sa relativnom zastupljenošću od 23% do 68% u zavisnosti od posmatranih lokaliteta. Odnos spolova u populacijama je 1:1, što slijedi biološke zakonitosti matematičke raspodjele za ostvarenje totalne populacione veličine i minimalno ispoljavanje genetičkog drifta i efekata inbridinga. Mužjaci i ženke vrste u populacijama imaju jasno prepoznatljiv spolni dimorfizam. Ženke imaju generalno duže tijelo i veću težinu u odnosu na mužjake, dok se širina glave ne razlikuje unutar populacija.

Kada je u pitanju ishrana, može se jasno zaključiti da češnjarke ne pokazuju specijalizaciju, odnosno da se radi o životinjama sa širokom trofičkom nišom i vrlo aktivnim predatorima. U posmatranim populacijama češnjarke se najviše hrane pripadnicima klase Insecta (unutar kojih se najviše izdvaja red Coleoptera) i Diplopoda (unutar kojih se najviše izdvaja red Julida), s tim da mužjaci preferiraju više toksičnu ishranu u odnosu na ženke.

Ključne riječi: fosorijalno, Posavina, agrokultura, ekologija, populacija, gustina, mikrostanište, morfometrija, odnos polova, ishrana