

A faunistic study of the family Elateridae in Bačka, Serbia

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SUMMARY

A faunistic study of the family Elateridae was carried out in Bačka, the north-western district of Vojvodina Province in Serbia, focusing on their preferred habitats and soil types. The survey included four locations with a total of 1059 ha, in which 35 species, belonging to 15 genera of Elateridae, were observed. The frequency of larval and adult forms was 58.94% and 67.40%, respectively, proving that wireworms are regular residents of the area. Regarding habitat preferences, it was shown that a majority of Elateridae species prefer open biotopes and wheat crop, while marsh soil, chernozem and alluvium were the preferred soil types of wireworms.

Keywords: Wireworms; Faunistics; Habitats; Serbia

INTRODUCTION

Click beetles, and their larval form known as wireworms, belong to the family Elateridae, which includes important soil-dwelling pests that cause severe damage and yield losses to many cultivated crops. Wireworms are one of the most widespread agricultural pests worldwide and are considered as major pests of a variety of crops (Anon, 1983; Parker & Howard, 2001). Living underground

and feeding by tunneling through lower stem parts and crop roots they cause significant damage. Their polyphagous preferences and ability to inhabit different types of habitats, such as arable land, woodland, woodland margins, including pastures as well, demonstrate their economic importance. Infestation level and damage caused by wireworms depend on many factors, including insect species composition and population density, as well as the infested plant species, its growth stage, vigor shown under

attack and plant density (Anon, 1983). The necessity of pest control and/or use of insecticides implies a need for better understanding the insect's life cycle, adult and wireworm incidence and its presence and ecology.

Population density and species composition of Elateridae family in particular areas depend on a variety of ecological factors, and the most important factors are climatic and micro-climatic conditions existing in certain habitats (Lawrence et al., 2007; Platia, 2011), temperatures and soil specifications. This is particularly evident in natural habitats where resources are intact and mostly unaffected by human influence (Platia & Gudenzi, 2005).

In previous decades, especially during the second half of the 20th century, faunistic-ecological investigation of the family Elateridae in Serbia was focused mainly on arable land, and certainly on the most threatened crops, while natural habitats remained unexplored (Štrbac, 1981; Čamprag, 1997). A comparison with reported species composition in neighboring countries, Central and Southeast Europe and Turkey (Martin, 1989; Laibner, 2000; Mertlik, 2005; Platia & Gudenzi, 2005; Csorba et al., 2006; Kesdek et al., 2006; Mertlik & Dušánek, 2006; Recalde & Sánchez-Ruiz, 2006; Landl et al., 2010; Platia, 2010; Sert & Kabalak, 2011; Jarzabek-Müller, 2013) revealed that some species of click beetles are not on the list of Elateridae species found in Serbia, while the scientific hypothesis of the present paper was that some of those species would also inhabit this area. Species composition and population densities of Elateridae specimens should serve as an additional element in assessing the state of the studied arable land and for forecasting, which is required before any protective measures are applied in different cultivated crops.

The purpose of the present study was to fill up the missing data on species composition of Elateridae family present in this region of Europe. For that purpose, a three-year comprehensive faunistic investigation was conducted, including the sampling of both adult and larval forms of click beetles, morphometric analysis enabling species identification, along with studies of ecological parameters, such as population density, relative abundance, dominance, constancy, similarity indices and habitat preferences in relation to crop and soil characteristics.

MATERIALS AND METHODS

Surveillance was conducted for three years, from 2010 to 2012, and both larval and adult specimens were collected. The sampled larval specimens belonging to the family Elateridae were stored in 70% ethyl alcohol, while click beetle adults were preserved and pinned.

Their species were identified in the laboratory, according to relevant keys for identification. The specimens separated by sampling location and year of collection, were identified according to their morphological characteristics, by a number of keys published in literature (Peterson, 1951; Giliarov, 1953; Dolin, 1960a,b; Dolin, 1964; Cherepanov, 1965; Dolin, 1967; Dolin, 1975; Dolin, 1978; Klausnitzer, 1978; Becker, 1991).

Sampling was conducted in four locations in the north-western part of Vojvodina Province, i.e. the villages Žabalj, Bačka Topola, Apatin and Bajmok in Bačka region. Coordinates of the investigated locations were determined by the global positioning system GPS Garmin 100-SRVY: Žabalj N 45° 40' 16.0" E 20° 07' 81.22", 79 m a.s.l.; Bačka Topola N 45° 79' 17.33" E 19° 63' 71.70", 98 m a.s.l.; Apatin N 45° 66' 75.55" E 19° 06' 38.38", 82 m a.s.l.; Bajmok N 45° 98' 83.20" E 19° 38' 53.82", 116 m a.s.l. The locations are all situated in the Pannonian plain, on arable land with different soil types suitable for agriculture: chernozem, brown soil known as "smonitsa", brown soil classified as cambisol, parapodzol, red soil, black (or marsh) soil, saline soil, alluvium and sand. Vegetation overgrowing the sampled soil included wheat, row crops, fodder crops, vegetables and meadows (as a type of open biotope).

Preimaginal specimens, i.e. wireworms, were sampled during the autumn period from late August to mid-November of each year. The procedure for larval sampling was as follows: a) entomological soil probes according to standard square method (50 x 50 cm, to the depth of the parent layer of approximately 40 cm) and b) inspection of the rotting plant debris. In total, 380 samples were taken, covering an area of 1059 ha from which wireworms were collected. Adult specimens were sampled: 1) from the soil surface and young crops, 2) over the vegetation season using the sweep net (10 strokes in dense crops on five spots of the same plot) and 3) with plant surface baits, set prior to sowing or after the harvest. A total number of 270 adult specimens were sampled using these three methods.

While processing the collected material, the following terms were used as quantitative indicators for wireworm fauna: relative abundance, density, dominance (D) and constancy (C). Relative abundance was used for calculation of population density, i.e. the number of individuals per square meter. Dominance was calculated as the percentage of specimens of a given species according to formula: $D_i = (n_i/N) \times 100\%$, where D_i is dominance of certain species i , n_i – number of specimens of certain species, while N – is the total number of sampled specimens in a locality/crop. Tischler's scale for species dominance (Tischler, 1949) was used for data interpretation: eudominant: $10\% \leq D_i \leq 100\%$; dominant: $5\% \leq D_i < 10\%$; subdominant: $2\% \leq D_i < 5\%$; recedent: $1\% \leq D_i < 2\%$ and subrecedent:

$0\% < D_i < 1\%$. Constancy or frequency of certain species in the sampling pool was calculated according to a formula given by Balogh (1958): $C = (u/U) \times 100\%$, where C – is constancy (or frequency) of certain species, u – number of samples which contain a certain species and U – total number of samples in one location/crop. According to Tischler (1949) there are four constancy classes, and they were used in this survey: euconstant species – having 75.1-100% constancy; constant species – having 50.1-75% constancy; accessory species – having 25.1-50% constancy; and accidental species – having up to 25% constancy.

Ecological parameters, as the Shannon-Wiener diversity index, Sørensen's similarity index and Renkonen index were calculated by the statistical software ComEcolPaC (Drozd, 2010). The formula for calculating Sørensen's similarity index (S_s) was:

$$s = \frac{2c}{a + b},$$

where a is the number of species in sample/ecosystem 1, b is the number of species in sample/ecosystem 2, c is the number of species in common between 1 and 2. Renkonen index (Re) was calculated according to formula:

$$Re = \sum_{i=1}^s \min p_i^j p_i^k,$$

where p_i is the frequency of certain species in samples.

In analyzing the species composition of click beetle adults, only dominance was calculated based on the species found in the total sample of adults, due to their mobility and impossibility to determine whether they had come from one crop or another. Therefore, relative abundance of adults was calculated for each sampling point.

RESULTS

The results of the larval stage investigation showed that there were 555 wireworm specimens in 224 samples out of 380 samples in total that were collected in the region of Bačka over the period 2010-2012. A total of 571 adult

specimens were captured from 270 samples taken on the locations (Table 1). Species identification revealed the presence of 34 species from 14 genera, which were found in different larval stages of development. On the other side, samples collected from soil surface revealed 35 species belonging to 15 genera of the Elateridae family at the adult stage of life cycle (Table 2).

Wireworm sampling results revealed a dominance of *Agriotes ustulatus* (Schall.), which was the most abundant species in total, comprising 31.7% of sample pool. This species was eudominant in four out of five observed crops: wheat, row crops, vegetables and meadows, while it was subdominant in fodder crops. The second most abundant, and also eudominant species, was *A. sputator* (L.) (comprising 10.6% of the sample), which was eudominant in row crops and meadows, dominant in wheat and vegetables, while in fodder crops it was not detected at all. Beside the eudominant, four dominant species were also recorded: *Adrastus rachifer* (Geoffr.), dominant in wheat and meadows and subdominant in row crops; *Agriotes lineatus* (L.), eudominant in vegetables, dominant in wheat and meadows, while in row and fodder crops this species was subdominant; *Adrastus limbatus* (F.) was eudominant in row crops, dominant in wheat and vegetables and subdominant in meadows, while *Agriotes obscurus* (L.) was eudominant in row crops, dominant in wheat, vegetables and fodder crops, and subdominant in meadows. Other species comprised singularly less than 5% of the sample, and are therefore not mentioned separately.

Considering the crops, one eudominant, five dominant, two subdominant, three recedent and eight subrecedent wireworm species were found in soil under wheat crops. In soil samples taken under row crops, four eudominant species, two dominant, nine subdominant and five recedent species were found. On the other side, each of 13 wireworms species found in the soil samples collected from vegetable crops were highly abundant, i.e. five were eudominant and eight dominant species.

Table 1. Average number of Elateridae larvae (L) and adults (A) per m² in samples of arable soil on investigated locations in Bačka region in 2010-2012

Location	Plot (ha)	Average number of larvae			Average number of adults		
		No. of samples	No. of larvae	Larvae/m ²	No. of samples	No. of adults	Adults/m ²
Žabalj	284	100	162	6.5	70	94	1.3
Bačka Topola	217	100	118	4.7	50	185	3.7
Apatin	262	93	147	6.3	65	125	1.9
Bajmok	296	87	128	5.9	85	167	1.9
Total	1059	380	555	5.8	270	571	2.1

Table 2. List of species in the family Elateridae found in 2010-2012.

Species	Larvae					Adults				
	Year of sampling			Total	%	Year of sampling			Total	%
	2010	2011	2012			2010	2011	2012		
<i>Adrastus limbatus</i> (F.) *	14	9	10	33	5.6	13	8	20	41	7.2
<i>Adrastus rachifer</i> (Geoffr.) *	17	15	10	42	7.6	14	12	7	33	5.8
ADRASTUS	31	24	20	75	13.5	27	20	27	74	13.0
<i>Agriotes brevis</i> Cand. #	4	5	5	14	2.5	2	2	2	6	1.0
<i>Agriotes gurgistanus</i> (Fald.) #	2	4	4	10	1.8	4	1	4	9	1.6
<i>Agriotes lineatus</i> (L.) *	16	14	11	41	7.4	9	3	12	24	4.2
<i>Agriotes medvedevi</i> Dolin *	2	5	9	16	2.9	2	4	6	12	2.1
<i>Agriotes obscurus</i> (L.) *	12	11	10	33	6.0	15	3	15	33	5.8
<i>Agriotes pilosulus</i> (Panz.) #	3	5	5	13	2.3	4	4	2	10	1.7
<i>Agriotes ponticus</i> Stepanov #	3	2	3	8	1.4	4	3	6	13	2.3
<i>Agriotes rufipalpis</i> Brullé *	10	5	7	22	4.0	5	2	5	12	2.1
<i>Agriotes sputator</i> (L.) #	19	12	28	59	10.6	21	12	26	59	10.3
<i>Agriotes ustulatus</i> (Schall.) *	57	66	53	176	31.7	80	67	81	228	39.9
AGRIOTES	128	129	135	392	70.6	146	101	159	406	71.0
<i>Betarmon bisbimaculatus</i> (Fabr.) ◇	0	0	1	1	0.2	0	0	1	1	0.2
BETARMON	0	0	1	1	0.2	0	0	1	1	0.2
<i>Dalopius marginatus</i> (L.) ◇	0	1	0	1	0.2	0	1	0	1	0.2
DALOPIUS	0	1	0	1	0.2	0	1	0	1	0.2
<i>Idolus picipennis</i> (Bach)							1	0	0	1
IDOLUS							1	0	0	1
<i>Agrypnus murinus</i> (L.) ◇	0	1	0	1	0.2	0	1	0	1	0.2
AGRYPNUS	0	1	0	1	0.2	0	1	0	1	0.2
<i>Ampedus pomorum</i> (Herbst) ◇	0	1	0	1	0.2	0	1	0	1	0.2
AMPEDUS	0	1	0	1	0.2	0	1	0	1	0.2
<i>Athous bicolor</i> (Goeze) ◇	1	0	1	2	0.4	1	0	1	2	0.3
<i>Hemicrepidius hirtus</i> (Herbst) ◇	1	0	1	2	0.4	0	1	0	1	0.2
<i>Hemicrepidius niger</i> (L.) ◇	1	0	0	1	0.2	1	0	1	2	0.3
<i>Athous subfuscus</i> (Mull.) ◇	1	1	0	2	0.4	1	0	0	1	0.2
ATHOUS	4	1	2	7	1.4	3	1	2	6	1.0
<i>Cidnopus aeruginosus</i> (Ol.) ◇	1	0	0	1	0.2	1	0	0	1	0.2
<i>Nothodes parvulus</i> (Panz.) ◇	1	0	0	1	0.2	1	0	0	1	0.2
<i>Cidnopus pilosus</i> (Leske) ◇	1	0	0	1	0.2	1	0	0	1	0.2
CIDNOPUS	3	0	0	3	0.6	3	0	0	3	0.6
<i>Dicronychus cinereus</i> (Herbst) □	2	1	1	4	0.7	2	0	1	3	0.5
CARDIOPHORUS	2	1	1	4	0.7	2	0	1	3	0.5
<i>Actenicerus siaelandicus</i> (Müll.) ◇	0	1	0	1	0.2	1	0	0	1	0.2
ACTENICERUS	0	1	0	1	0.2	1	0	0	1	0.2
<i>Ctenicera cuprea</i> (F.) ◇	1	0	1	2	0.4	0	0	2	2	0.3
CTENICERA	1	0	1	2	0.4	0	0	2	2	0.3
<i>Prosternon tessellatum</i> (L.) ◇	1	0	0	1	0.2	1	0	0	1	0.2
PROSTERNON	1	0	0	1	0.2	1	0	0	1	0.2
<i>Selatosomus aeneus</i> (L.) #	3	5	1	9	1.6	6	2	1	9	1.6
<i>Parapothistus impressus</i> (F.) #	6	4	1	11	2.0	3	4	3	10	1.7
<i>Selatosomus latus</i> (F.) □	3	3	2	8	1.4	5	2	2	9	1.6
SELATOSOMUS	12	12	4	28	5.0	14	8	6	28	4.9
<i>Melanotus brunniipes</i> (Germ.) #	3	5	3	11	2.0	7	3	2	12	2.1
<i>Melanotus crassicolis</i> (Er.) *	4	6	3	13	2.3	5	3	7	15	2.6
<i>Melanotus villosus</i> (Herbst) #	3	2	4	9	1.6	2	1	3	6	1.0
<i>Melanotus tenebrosus</i> (Er.) □	2	3	0	5	0.9	3	2	4	9	1.6
MELANOTUS	12	16	10	38	6.8	17	9	16	42	7.3
Total	194	187	174	555	100.00	215	142	214	571	100.00

Larvae and adults occurring in each year of sampling and percentage share in total sample. Marks next to species name show constancy:

* - euconstant, # - constant, □ - accessory and ◇ - accidental species

Under fodder crops, there were three eudominant species, three dominant and 10 subdominant species recorded, while the samples taken from meadows comprised two eudominant, five dominant, six subdominant, five recedent and six subrecedent species. Constancy, which was calculated for species recorded at the larval stage of Elateridae development, revealed eight euconstant species, nine constant, three accessory and 14 accidental species in soil samples in total (Table 2).

The species composition list which was made for Elateridae adults (Table 2) showed that the most abundant specimens in the sample pool were click beetles belonging to the genus *Agriotes* (71%), followed by the genera *Adrastus* (13%) and *Melanotus* (7.3%). There were two eudominant Elateridae species which were recorded at adult stage: *A. ustulaus* and *A. sputator*, together with three dominant species: *Ad. limbatus*, *Ad. rachifer* and *A. obscurus*. In the adult click beetle sample pool there were also six subdominant, eight recedent and 18 subrecedent species. Click beetle adults were most abundant on the location Bačka Topola, where their average number was 3.7 adults/m², while the lowest number of adult specimens was found on the location Žabalj, where only 1.3 adults/m² were sampled (Table 1).

The calculated Shannon-Wiener diversity index showed that the most diverse wireworm fauna was recorded in

meadows (H' 3.93), followed by row crops (H' 3.89), fodder crop (H' 3.79) and vegetables (H' 3.57), while the smallest range of Elateridae species detected at the larval stage of development was recorded in wheat fields (H' 2.79). Sørensen's similarity index calculated for the five vegetation types, showed the most similarity in species composition between wireworm fauna in wheat and row crops (S_o 0.87), while the smallest similarity, or rather the highest species diversity, was recorded between species sampled in vegetables and fodder crops (S_o 0.48) (Table 3), according to larval catch. Renkonen index, which shows both qualitative and quantitative similarity in the observed crops, according to relative abundance of the recorded species at the larval stage of development, showed that the highest similarity in numbers and species composition was found in meadows and row crops (Re 0.66), while the most divergent wireworm species composition was recorded in wheat and fodder crops (Re 0.24).

Soil type as a medium for development was also considered as a factor in the present study, and the surveillance showed that the most appropriate soil type for wireworms was black, or marsh soil, in which sampled larvae were the most abundant per square meter. Conversely, the most inappropriate soil type for development of wireworms was red soil, in which only a few Elateridae larvae were found (Table 4), considering the total sample pool.

Table 3. Similarity indices for wireworms sampled in different crops

Sørensen's index	Row crops	Vegetables	Fodder crops	Open biotopes
Wheat	0.87	0.63	0.63	0.70
Row crops	-	0.67	0.61	0.68
Vegetables	-	-	0.48	0.54
Fodder crops	-	-	-	0.50
Renkonen index	Row crops	Vegetables	Fodder crops	Open biotopes
Wheat	0.53	0.39	0.24	0.59
Row crops	-	0.49	0.38	0.66
Vegetables	-	-	0.35	0.53
Fodder crops	-	-	-	0.31

Table 4. Average number of Elateridae larvae per m² in relation to soil type in Bačka region over the period 2010-2012

Soil type	Area (ha)	No. of samples	No. of larvae	larvae/m ²
Chernozem	263	84	136	6.5
Brown soil (smonitsa)	92	20	16	3.2
Brown soil (cambisol)	84	22	19	3.4
Parapodzol	61	26	14	2.1
Red soil	26	14	3	0.9
Black soil (marsh soil)	310	111	286	10.3
Saline soil	14	11	6	2.2
Alluvium	89	41	50	4.9
Sand	120	51	25	1.9
Total	1059	380	555	5.8

Generally speaking, the most abundant genus of the family Elateridae in this survey was *Agriotes*, which comprised 70.9% of the samples in total, counting in both larval and adult stages of development (Table 2). It was followed by the genus *Adrastus*, which accounted for 13.2% of the entire sample pool, and *Melanotus*, whose adult and larval specimens were present in 7.1% of the samples in total. Species belonging to the remaining 12 genera of the family Elateridae comprised singularly less than 5% of the sample. The most abundant species was *A. ustulatus*, followed by *A. sputator*, and they were most abundant at both stages of development, i.e. larval and adult. Also abundant, and with relatively high population density, were several other species of the same genus: *A. lineatus* and *A. obscurus*, together with both species recorded from the genus *Adrastus*: *Ad. limbatus* and *Ad. rachifer*. These six species may be considered the most important species of click beetles, family Elateridae, in the five types of observed crops. Being present in almost each sample collected from the north-western part of Vojvodina Province during the three-year period, these six species might be of great economic importance for agricultural production in the surveilled region and crops.

DISCUSSION

Based on the frequency of occurrence of two different stages of life cycle of the family Elateridae, larval and adult, detected over the three-year investigation period, click beetles have been named and noted as regular residents in the region of Bačka, the NW part of Vojvodina Province. *Agriotes* was the most frequent genus in the total sampling pool, and followed by the genera *Adrastus*, *Melanotus*, *Selatosomus* and *Athous*. Domination of the tribe Agrotinae and genus *Agriotes* had also been reported in neighboring Romania under similar geographical conditions (Manole et al., 1999), where the most common and economically important Elateridae species was *A. obscurus*.

Out of the total number of specimens belonging to the family Elateridae that were captured at the larval stage of development, the largest number (in relation to covered area and number of samples) was collected from open biotopes, such as meadows, which coincides with previous reports (Parker & Howard, 2001). The next most numerous wireworm species were collected in areas under wheat crops. This finding confirms that wheat, as well as other small grains, especially those grown in monoculture, offer favorable ecological conditions and suitable diet for click beetles larvae, and at the same time indicates that wireworms do not prefer frequent tillage and application of herbicides (Manole et al., 1999). In the present study,

less click beetles were found in plots with fodder crops (mainly alfalfa), which is conspicuously at odds with some previous data (Štrbac, 1981) in which the population density of wireworms in fodder crops was higher. The highest number of click beetle larvae was found in marsh soil, and in varieties of black soil, chernozem and alluvium. Wireworm soil type preferences depend primarily on soil moisture, humidity and temperature, which directly affect their vertical movement in the soil profile. The most important factor in wireworm activity seems to be humidity, which affects larvae by increasing their activity in dry substrate and decreasing it in very moist environments, probably due to muscular inhibition, while regarding temperature, wireworms show a much wider ecological amplitude (Campbell, 1937; Lees, 1943a, b; Čamprag, 1997; Cate, 2007) and temperature has less importance for the dynamic of their life cycle.

The identified Elateridae species have different requirements in relation to environmental conditions, which affect their distribution and population density, and often give non-straightforward relationship between aboveground adult and belowground wireworm distribution (Benfer, 2011). The majority of species prefer habitats with moderate humidity and open biotopes. For click beetle reproduction, species composition, diet and plot size with a crop play important roles. Larvae have periodical and seasonal type of diet, so that they feed intensively between coating periods and poorly during coating. In the spring, larvae feed on plant residues, newly emerged plant parts, and spontaneous floristic specimens, and then they begin to attack spring cereals. During the summer, they leave old and coarse plants and turn to newly sprouted weeds. In the autumn, wireworms feed on winter crops, mainly wheat. Larval distribution differs among species, which is likely caused by a variety of environmental and species-specific factors. Precise assessment of click beetles distribution is difficult because of their aboveground and belowground stages of life cycle, the latter of which is the pest phase (Benfer, 2011).

Meadows, pastures and uncultivated plots contain natural pools of click beetles. Those areas are under permanent vegetation cover where microclimatic conditions are favorable for egg lodging, embryonic development and the highest percentage of surviving newly hatched larvae (Parker & Howard, 2001). Considering cultivated fields, the most favorable conditions are found in alfalfa, clover and perennial grasses (forage plants), followed by small grains. Areas in which row and shallow tillage are practiced without an extensive usage of pesticides, and consequently weedy, and the crops are regularly irrigated, may be favorable

to a degree. Conversely, crops managed with intensive technology and frequent deep processing of soil do not provide a favorable environment for click beetle larvae. Some authors have shown a positive correlation between wireworm distribution and grass duration (Miles, 1942), soil bulk density (Parker & Seeny, 1997) and weeding (Parker & Howard, 2001).

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Faunistička studija familije Elateridae u regionu Bačke, Srbija

REZIME

Faunističko-ekološka studija familije Elateridae u regionu Bačke je sprovedena tokom trogodišnjeg istraživanja prisutnosti predstavnika ove familije na različitim staništima u pogledu dominantne vegetacije i tipa zemljišta. U istraživanju koje je obavljeno na tri lokaliteta, na ukupnoj površini od 1059 hektara, zabeleženo je prisustvo 35 vrsta skočibuba, svrstanih u 15 rodova. Frekvencija prisustva larvenih formi je bila 58,94%, a adultnih formi 67,40%, što je potvrdilo da su predstavnici skočibuba uobičajeni stanovnici na ispitivanom području. Analizom prisustva predstavnika skočibuba na različitim staništima je utvrđeno da većina vrsta preferira otvorene biotope i pšenicu, a u odnosu na tip zemljišta, najveći broj vrsta je prisutan na močvarnom zemljištu, černozeu i aluvijumu.

Ključne reči: Skočibube; Faunistika; Staništa; Srbija