

A note on *Lepidurus apus* Linnaeus, 1758 (Notostraca, Crustacea) from Bosnia and Herzegovina

Tadpole shrimps (order Notostraca) belong to the large branchiopod crustaceans (Class Branchiopoda). The order consists of only one family, Triopsidae, with two recent genera: *Triops* Schrank, 1803, and *Lepidurus* Leach, 1819. They typically live in predator-free standing waters with unpredictable fluctuations in water level, water chemistry, and food resources. Notostracans occur on all continents except Antarctica and inhabit various periodic (astatic) waters (Brtek & Thiéry 1995). Information on the occurrence of the genus *Lepidurus* in the Western Balkans and adjacent regions is rather scattered and incomplete. Populations reported from the region were assigned to *L. apus* Linnaeus, 1758 (Marinček & Petrov 1992, Cvetković-Miličić & Petrov 2001, Kojaković & Gottstein Matočec 2003, Demeter & Stoicescu 2008) and *L. couesii* (Demeter & Stoicescu 2008, Šaganović et al. 2017). *L. apus* was frequently found along the floodplains of the Sava and Danube rivers and in the floodplains and depressions remaining after snowmelt (Petrov & Cvetković 1997, Petrov & Petrov 1997, Kojaković & Gottstein Matočec 2003). Some finds in Central Europe also report the occurrence of *L. apus* at several localities in the middle and lower parts of European river valleys, in riparian forests and meadows, where the species co-occurs with other large branchiopods, mostly in mass populations (Löffler 1993, Zavadil et al. 2013, Schernhammer et al. 2020).

So far, only two finds of *L. apus* from Bosnia and Herzegovina have been published, with no details about the morphology of individuals. The first record of *L. apus* from Bosnia and Herzegovina is from the largest karst field in the Dinaric region – the Livno karst field at ~700 m altitude, characterized by periodic flooding (Tanasijević 1981). The Livno Karst field has been on the List of Wetlands of International Importance since 2008 and has been designated as the Ramsar site Livanjsko Polje (<https://rsis Ramsar.org/>). The second population originated from the Ramsar site Bardača Wetland (Miličić et al. 2022). It was found about 150 km to the north, at a lower elevation of about 90 m a.s.l. and in a completely different habitat type – the alluvial plain along the Sava riverbed.

Since the previous report on *L. apus* from Bosnia and Herzegovina did not include information on the general morphology of the individuals, the present work aims to give a brief overview of the characteristics of *L. apus* from the newly reported population.

Individuals were collected from the alluvial plain of the Sava River near the village of Bajinci (N 45.10883°; E 17.47670°) in northern Bosnia and Herzegovina (Figure 1). This area is part of the Ramsar site Bardača Wetland, where several large branchiopod populations have been found (Miličić et al. 2022). The sample was collected with a hand net, and individuals were placed in flasks filled with 70% ethanol immediately after collection from the field. A unique identification number was assigned to each specimen. Since only one male was present in the sample, it was excluded, and only the ovisac-bearing individuals (females) were included in further analyses (N=101). Specimens were photographed against a ruler (to the nearest 1 mm) using a Canon PowerShot 230HS camera. To describe the main morphological traits of the specimens collected in the field, the following morphometric measures were recorded: carapace length and carapace width (CL and CW, respectively), length of the telson (including lamina) (TL), the average length of cercopods, ACL (only pairs with undamaged tips were considered), and total body length (BL), measured from the anterior edge of the carapace to the end of the cercopods. Caudal lamina length (LL) was measured along the longitudinal axis, from the end of the telson to the top of the lamina. All linear features mentioned above were measured using the ImageJ program (Abràmoff et al. 2004). In addition, two morphometric indices were calculated: the ratio between the length of the caudal lamina and the carapace length and the ratio between the carapace length and the carapace width, respectively.

The sex ratio of the analyzed population favored individuals with ovisacs and can be described as strongly female-dominated. The carapace of individuals is elongated and laterally compressed. In living animals, the dorsal surface of the carapace is mottled greenish brown. The nuchal organ is ellipsoid, and about ¼ of it is cut by a line between the posterior margins of the eyes. The endites of the second thoracic appendage project slightly beyond the carapace margin. The exopodite of the first thoracic appendage is elongated only distally.

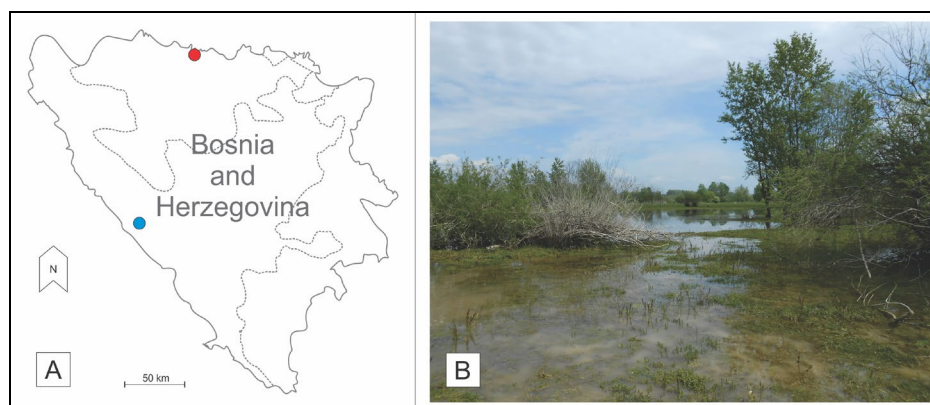


Figure 1. Two known populations of *Lepidurus apus* in Bosnia and Herzegovina: A – Ramsar site Livanjsko Polje (blue dot) and Ramsar site Bardača Wetland (red dot); B – Locality in the village Bajinci during the flooding season in 2016, when a population was discovered in Bardača Wetland.

The total body length of individuals, including cercopods, ranged from 3.19 to 5.50 cm, with an average specimen length of 4.50 cm. The carapace length ranged from 1.71 to 2.68 cm and covered a large portion of the abdomen (the average number of posterior segments not covered by the carapace was 4). The general morphology of the specimens and the main morphological characteristics are shown in Table 1 and Figure 2. The caudal lamina is relatively short in the specimens from Bardača Wetland (average 0.25 cm). The size ratio between the caudal lamina and the carapace length is relatively low, ranging from 0.05 to 0.16.

Although comparison of the length and shape of the caudal lamina with the carapace is often considered a very important taxonomic character for recognizing different species of *Lepidurus* (Rogers 2001), it is very difficult to make relevant comparisons because literature data are quite sparse and inconsistent. Marinček and Petrov (1992) indicated that in *L. apus*, the ratio of the caudal lamina to carapace length ranges from 1:6 to 1:4 (0.17 – 0.25). For comparison, the range of the geographically and ecologically closest species, *L. couesii*, is 0.40 – 0.70 (for large specimens) and 0.10 – 0.30 (for

smaller specimens) (after Rogers 2001, Šaganović et al. 2017). Due to the very elongated carapace covering most of the body, the size ratio between the length of the caudal lamina and the length of the carapace in the population from Bardača Wetland is relatively low. It ranges from 0.05 to 0.16 and is very close to a population reported from northern Croatia, with a ratio of 1:14.54 to 1:10.38 (0.07 – 0.10). This population was found about 130 km north of the Bardača Wetland and was described as "very interesting" for further study (quote from Marinček & Petrov 1992, page 127).

The shape of the exopodite of the first leg is also cited as a very important distinguishing feature and can be used to distinguish some species within the genus. The exopodite of the first thoracic appendage in the Bosnian population was without distinct medial constriction. That is mentioned in literature as characteristic of the species *L. apus* (Brtek et al. 1984). After the comparison with the material from the available collections and based on the literature, the general morphology of studied individuals, the shape and position of the nuchal organ, the shape of exopodite 1, and the size of the caudal lamina, the population from Bardača Wetland is characterized as *L. apus*.

Table 1. Descriptive statistics of analyzed morphometric traits and ratios (sample size N = 101 females).

Morphological traits or ratios	Mean	Min.	Max.	Variance	Standard deviation (SD)	Standard error (SE)
Carapace length – CL (cm)	2.37	1.71	2.68	0.03	0.16	0.02
Carapace width – CW (cm)	1.47	1.03	1.79	0.01	0.12	0.01
Length of telson including lamina – TL (cm)	0.29	0.10	0.42	0.04×10^{-1}	0.06	0.06×10^{-1}
Average length of cercopods – ACL (cm)	1.76	1.09	2.48	0.10	0.31	0.03
Total body length (including cercopods) – BL (cm)	4.50	3.19	5.50	0.18	0.42	0.04
Caudal lamina length – LL (cm)	0.25	0.12	0.39	0.02×10^{-1}	0.05	0.05×10^{-1}
LL/CL	0.11	0.05	0.16	0.04×10^{-2}	0.02	0.02×10^{-1}
CL/CW	1.62	1.43	1.84	0.01	0.10	0.01

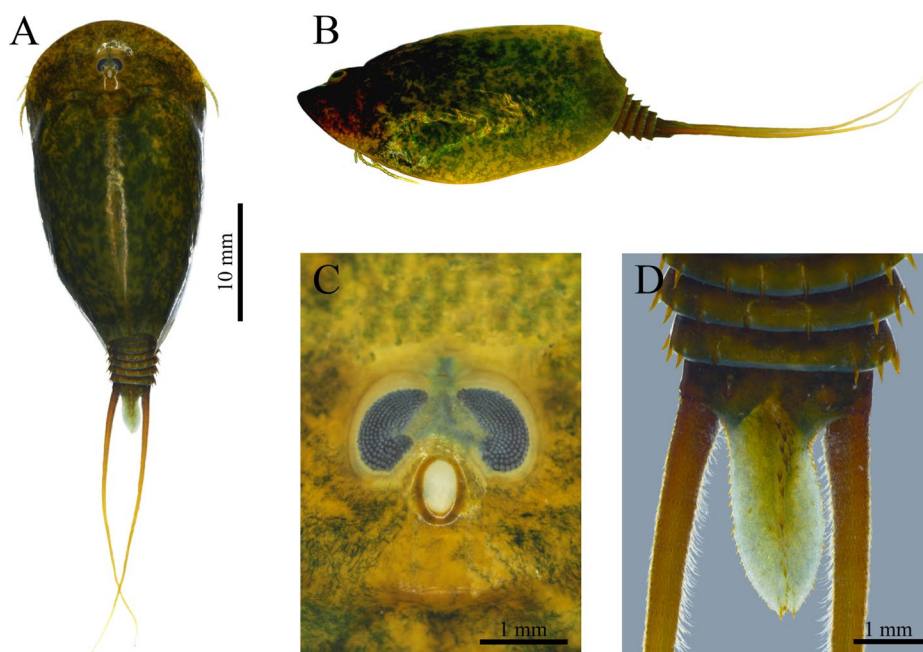


Figure 2. Body morphology (female): A – dorsal view; B – lateral view; C – eyes and nuchal organ; D – telson and caudal lamina.

It is interesting to note that both findings on tadpole shrimps in Bosnia and Herzegovina are limited to two wetlands of international importance: the Livanjsko Polje, designated as a Ramsar site in 2008, and the Bardača Wetland designated as a Ramsar site in 2007 (<https://rsis.ramsar.org/>). These areas' geographic heterogeneity and habitat diversity suggest that *L. apus* can successfully occur in both hilly terrain and low-lying fields. This implies the possibility that new populations may be found in other parts of the country and other parts of the Western Balkans and necessitates further taxonomic and field studies in the future.

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