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New data on *Myosotella myosotis* (Draparnaud, 1801) (Pulmonata: Basommatophora: Ellobiidae) from Bulgaria

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Abstract: The present paper contains new chorological data on *Myosotella myosotis* from the Bulgarian Black Sea coast, as well as some conchiological (variation in shell size and in the number of apertural folds and denticles), biological, and ecological notes on this ellobiid gastropod from Bulgaria, with brief comments on its conservation status.

Key words: mouse-eared snail, *Myosotella myosotis*, Gastropoda, distribution, conservation, Black Sea coast, Bulgaria.

Introduction

Myosotella myosotis (Draparnaud, 1801), or the mouse-eared snail, is restricted to specific coastal saline habitats (Damyanov & Likharev 1975; Jaeckel 1986; Wiese & Richling 2008; Welter-Schultes 2012). Throughout Europe, this snail occurs along the coasts of Ireland, Scotland, the United Kingdom, Denmark, reaching also the coasts of the Mediterranean countries and the shores of the Black Sea, the Aegean Sea and the Sea of Marmara (Golikov & Starobogatov 1972; Welter-Schultes 2012). The mouse-eared snail has been introduced into North America, Bermuda, Uruguay, Jamaica, the Azores, South Africa, Australia, and New Zealand (Martins 1999; Morton & Britton, 2000; Orensanz *et al.*, 2002; Fofonoff *et al.*, 2003; Scarabino 2004; Cohen 2005; Welter-Schultes 2012). Currently, along the Black Sea coast, this snail species is known from only a few localities (Fig. 1): the shores of Crimea (Fig. 1, locality № 1; see Zernov 1913; Milashevich 1916; Golikov & Starobogatov 1972), Romania (Fig. 1, loc. № 2; see Grossu 1955, 1993; Golikov & Starobogatov 1972; Biodiversitate Dobrogea), and Bulgaria (Fig. 1, loc. № 3-17). Until now *M. myosotis* has not been found along the Turkish Black Sea coast (Öztürk & Çevik 2000; Demir 2003; Öztürk *et al.* 2014).

The first record of the mouse-eared snail from the Bulgarian coast was provided by Grossu & Carausu (1959) (as "*Aplexia* (*Myosotella myosotis*" [sic!]) from the Cape Kaliakra („Caliacra") (Fig. 1, loc. № 4). Later, Kaneva-Abadjieva (1960) confirmed this finding (as *Alexia myosotis*), and while Valkanov & Marinov (1964, as *Alexia myosotis*) were citing the previous work of Kaneva-Abadjieva (1960), they mentioned the species from Kavarna (Fig. 1, loc. № 5), but not from Kaliakra. Further studies carried out by Damyanov & Likharev (1975), Gruev (1981, as *Ovatella mayosotis* [sic!]), Guéorguiev (1982, as *Ovatella myosatis* [sic!]), Kerney *et al.* (1983), Gruev (1988, as *Ovatella mayosotis* [sic!]), Gruev & Kuzmanov (1994, 1999), Wilke (1996), Gruev (2000) and Hubenov (2005, 2007a,b) recorded *M. myosotis* (as *Ovatella myosotis*) from the Bulgarian Black Sea coast but without specifying localities.

The aim of the current study is to 1) supplement the knowledge about the distribution of this snail on the territory of Bulgaria by summarising all available (published and unpublished) data, 2) to add new conchiological, biological and ecological data based on newly-collected material, and 3) to suggest measures for its conservation.

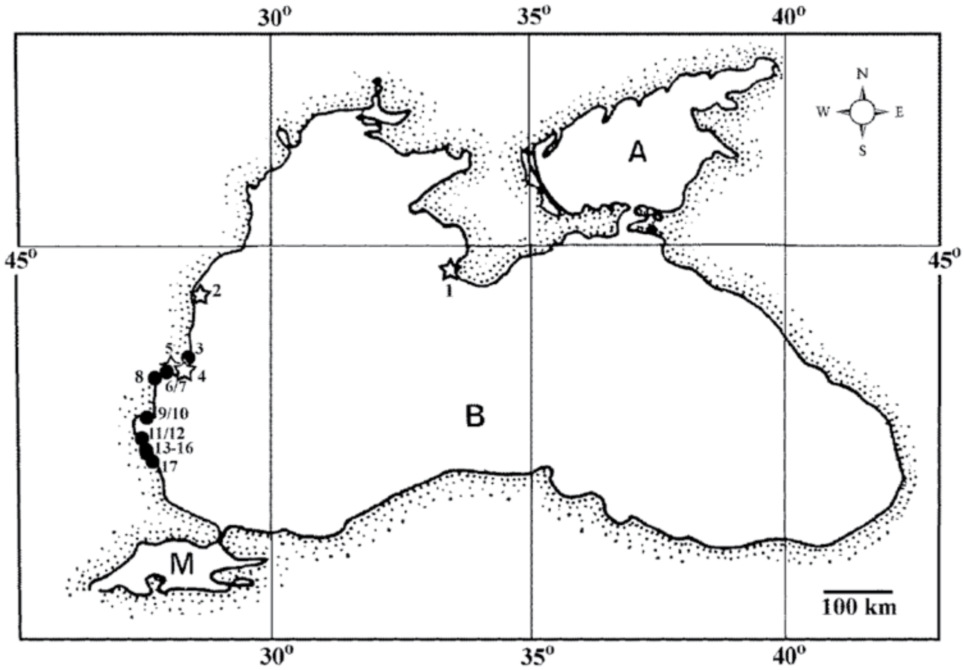

Fig. 1. Distribution map of *Myosotella myosotis* (Draparnaud, 1801) from the Black Sea coast. **A** – Sea of Azov, **B** – Black Sea, **M** – Sea of Marmara; *stars* = literature records; *circles* = new data

Localities: **1. Crimean coast**: Sevastopol: Sevastopolskaya Bay, Pesochnaya Bay, Streletskoy Bay and Fedotov Cape; **2. Romanian coast**: Razelem Lake (Portiţa), Constanţa, Agigea, Eforia Nord; 3-17 **Bulgarian coast**: **3.** Tyulenovo, **4.** cape Kaliakra (= Caliacra), **5.** Kavarna, **6.** Balchik: Balchishka Tuzla, **7.** Baltata Reserve, **8.** Sts. Constantine and Helena Resort, **9.** Nessebar, **10.** Pomorie: Pomorie Lake, **11.** Sozopol: camping Zlatna Ribka, **12.** Sozopol: South beach, **13.** Primorsko: Dyavolska River mouth, **14.** Kiten, **15.** Tsarevo: camping Arapya, **16.** Ahtopol: Stavro (Stavroto) bay, **17.** Rezovska river mouth. (For literature sources concerning localities **1**, **2**, **4**, and **5**, see *Introduction*; for details of localities **3, 6-17** – see Table 1)

Material and Methods

The present work was based on 727 *Myosotella myosotis* specimens, hand-collected by Bulgarian and foreign zoologists along the Bulgarian Black Sea shoreline between 1970 and 2016 (see Table 1). In 2011-2016, the author collected 427 living *M. myositis* specimens (89 mature and 338 juveniles) at locality № 4 (see Table 1). Those were kept in laboratory conditions at temperatures between 15 and 22°C, in glass vessels (20 x 25 x 36 cm, 5 mm glass-strength) filled with a 2 cm layer of sand and stones taken from the collecting locality. After the animals were measured and observed for several months they were returned to the spot where they were initially collected. These specimens were measured with the abapertural surface glued to UHU patafix gluepads (allowing their easy removal after the measurements have been taken); the snails were measured after they were stimulated with a fine, soft brush to withdraw into their shells. The measurements (in milimeters) were conducted as shown on Fig. 3h. Following Wiese & Richling (2008), specimens with HS≥5 mm were assumed to be mature individuals. All the measurements were made under a MBS-9 stereoscopic binocular microscope (JSC Lytkarino Optical Glass Factory, Russia) equipped with an ocular-micrometer. Summary statistics were calculated with PAST (Hammer *et al.* 2001). The shells and abnormal specimens were photographed under an Olympus BX41 SZ61 stereo microscope with an Olympus Color View 1 digital camera. Digital images captured at different focal planes were assembled using the application Combine ZM and edited in Adobe Photoshop.

Water acidity was measured with a pH-meter (model HI 98129, Hanna Instruments, Mauritania), salinity was measured with a Conductivity meter (Cond-330i, WTW – Germany), the substrate salinity was derived from the conductivity (ms/cm) of the soil extract (soil : water ratio = 1:5) measured according to ISO 11265:1994.

Symbols and abbreviations used: AH = aperture length/height; $AH_{\bar{x}}$ = average aperture length/height; AW = aperture width/diameter (= maximal distance between columellar wall and palatal margin of outer lip); $AW_{\bar{x}}$ = average aperture width/diameter; CPM = Malacological Collection of the author;

Table 1. *Myosotella myosotis* – collecting sites and material collected along the Bulgarian Black Sea coast.

	Locality, data, collector, material collected	**Conchiological data**
	Northen Black Sea coast	
№	Dobrich District	
1	Tyulenovo Village, the port, 43° 29' 41.08"N, 28° 35' 07.34"E, seashore, under stones near the water, at sea level, 11.VI.2006, leg. P. Mitov, (CPM). – 5 snails (4 mature, 1 juv.).	mature: SH $\bar{x}$ =5.77±0.25 (5.2-6.2, SD=0.51, CV=0.09), SW $\bar{x}$ =2.9±0.09 (2.7-3.1, SD=0.18, CV=0.06), AH $\bar{x}$ =3.25±0.1 (3.1-3.5, SD=0.2, CV=0.06), AW $\bar{x}$ =1.4±0.04 (1.3-1.5, SD=0.08, CV=0.06) (N=4); 1 juv.: SH=3.6, SW=2.0, AH=2.2, AW=0.9
2	Balchik town, Balchishka Tuzla, 43° 23' 58.18"N, 28° 13' 23.70"E, 17.V.1970, leg. & det. S. Damyanov, (NMNHS: № 4871 (№ 32)). – one bleached empty shell.	1 juv.: SH=4.0, SW=2.2, AH=2.5, AW=0.9
3	Seashore of Baltata Reserve: Albena Resort, sea coast, 43° 21' 8.31"N, 28° 4' 30.36"E, 02.VII.1999, leg. Schtange, det. I. Dedov, (MCD: № 673). – one empty shell; Kranevo village, between Kranevo beach and Baltata beach, 100 m N of the mouth of Batova river, sea coast, 43° 20' 49.2"N 28° 04' 21.4"E, 08.VIII.2016, leg. & det. U. Schneppat, I. Dedov, (MCD: № 1659/9). – one bleached empty shell;	1 mature: SH=8.2, SW=3.3, AH =4.0, AW=1.3 1 mature: SH=7.35, SW=3.3, AH=4.0, AW=1.55
	Varna District	
4	Sts. Constantine and Helena Resort, Complex St. Ellias, breakwater of the yacht haven (Bunata), seashore, under stones, 43° 13' 33.9"N 28° 00' 53.0"E, leg. P. Mitov, (CPM), 06.VIII.1999-09.VIII.2016. – 700 snails (281 mature, 419 juv.: 06.VIII.1999. – 57 snails (36 mature, 21 juv.) (**Fig. 3h**); 20.IV.2001. – 22 snails (19 mature, 3 juv.); 20.-21.VII.2001. – 12 snails (9 mature, 3 juv.) (**Fig. 3a,c**); 02.VII.2002. – 13 snails (12 mature, 1 juv.) (**Fig. 3b, d**); 16.VIII.2003. – 9 snails (5 mature, 4 juv.) (**Fig. 3f**); 05.VII.2006. – 6 snails (2 mature, 4 juv.) (**Fig. 3e**); 01.X.2006. – 12 snails (4 mature, 8 juv.); 18.-25.VII.2008. – 5 snails (4 mature, 1 juv.) (**Fig. 3g**); 07.VIII.2015 – 30 snails (21 mature, 9 juv.); 04.X.2015– 30 snails (24 mature, 6 juv.); 09.I.2016 – 399 snails (52 mature, 347 juv.) (**Fig. 2c**);20.III.2016 – 15 snails (14 mature, 1 juv.); 09.VIII.2016. – 90 snails (79 mature, 11 juv.);	mature: SH $\bar{x}$ =6.66±0.11 (5.0-9.1, SD=1.15, CV=0.17), SW $\bar{x}$ =3.05±0.04 (2.3- 4.0, SD=0.44, CV=0.14), AH $\bar{x}$ =3.57±0.05 (2.7-4.7, SD=0.51, CV=0.14), AW $\bar{x}$ =1.45±0.02 (1.0-2.1, SD=0.26, CV=0.17) (N=105); juv.: SH $\bar{x}$ =3.67±0.12 (1.35-4.9, SD=1.03, CV=0.28), SW $\bar{x}$ =1.94±0.06 (0.4-2.7, SD=0.53, CV=0.27), AH $\bar{x}$ =2.21±0.07 (0.45-3.0, SD=0.62, CV=0.28), AW $\bar{x}$ =0.91±0.03 (0.4-1.3, SD=0.23, CV=0.26) (N=69).
	Southern Black Sea coast	
	Burgas District	
5	1 km NW of Nessebar town, 42° 40' 28.63"N, 27° 42' 43.60"E, on macro-algae on the stony shore, at depth of up to 0.2 meters, 06.V.1996, leg. & det. Thomas Wilke, (MCW). – 1 mature snail. (Wilke, pers. comm.).	1 mature: SH=6.35, SW=2.85, AH=3.0, AW=1.35
6	Pomorie town, close to the south end of Pomorie Lake, 42° 34' 04.31"N, 27° 38' 12.74"E, in marine alluvium/debris (picked out from beach drifts), 08.IX.2006, leg. & det. D. Georgiev, (CPM). – 2 shells.	2 juv.: SH=2.4-4.5, SW=1.4-2.3, AH=1.45-2.8, AW=0.5-0.9;
7	2 km W of Sozopol town, camping Zlatna Ribka, 42° 24' 29.13" N, 27° 40' 24.22"E, in marine alluvium/debris (under seaweed washed ashore), 25.VI.2003, leg. & det. A. Irikov, (MCI). – 1 shell.	1 mature: SH=8.6, SW=3.6, AH=4.5, AW=1.7
8	Sozopol town, South beach, between Harmanite and Rayski beach, 42° 24' 31.82"N, 27° 42' 24.16"E, in marine alluvium/debris (under seaweed washed ashore), 30.VI.2001, leg. & det. A. Irikov, (MCI). – 2 shells.	2 mature: SH=6.3-6.9, SW=2.7-3.0, AH=3.3-3.7, AW=1.4/1.4;

Table 1. Continued

	Locality, data, collector, material collected	Conchiological data
	Southern Black Sea coast	
	Burgas District	
9	Primorsko town, mouth of Dyavolska River, 42° 15’ 54.08”N, 27° 45’ 16.67”E, in marine alluvium/debris (under seaweed washed ashore), 08.VI.2004, leg. & det. A. Irikov, (MCI). – 1 shell.	1 mature: SH=7.5, SW=3.4, AH=4.0, AW=1.5;
10	Kiten town (“Village Kiten”), 42° 14’ 04.40”N, 27° 46’ 42.91”E, 13.V.1970, leg. & det. S. Damyanov: (NMNHS: № 4869 (№ 8)). – 3 (white-beige) shells (1 mature, 2 juv.); (NMNHS: № 4870 (№ 8)). – 3 (white-beige) shells (3 juv.).	1 mature: SH=5.0, SW=2.4, AH=2.8, AW=1.1; 5 juv.: SH $\bar{x}$ =2.37±0.56 (1.70-4.6, SD=1.26, CV=0.53), SW $\bar{x}$ =1.32±0.27 (1.0-2.4, SD=0.61, CV=0.46), AH $\bar{x}$ =1.34±0.27 (1.05-2.4, SD=0.6, CV=0.44), AW $\bar{x}$ =0.61±0.12 (0.45-1.1, SD=0.28, CV=0.45);
11	Tsarevo town, camping Arapya, in marine alluvium/debris (under seaweed washed ashore) at the mouth of a small river flowing into the sea, 42° 11’ 16.18”N, 27° 50’ 16.27”E, 30.VI.2001, leg. & det. A. Irikov, (MCI). – 2 shells. (Irikov, pers. comm.).	
12	north of Ahtopol town, Stavro (Stavroto) bay, at the mouth of a small river, 42° 08’ 05.37”N, 27° 53’ 50.84”E, in marine alluvium/debris, 15.VIII.2000, leg. G. Todorov, det. A. Irikov, (MCI). – 3 shells. (Irikov, pers. comm.).	
13	Rezovo village, “at the estuary Rezvaya” (=Rezovska river), 41° 58’ 58.93”N, 28° 01’ 47.03”E, 23.IV.1972, leg. & det. S. Damyanov, (NMNHS: № 4868 (№ 6)). – 1 (white-beige) shell.	1 juv.: SH=3.0, SW=1.7, AH=1.9, AW=0.7;

CV = coefficient of variation; juv. = juvenile(s); loc. = locality; MCD = Malacological Collection of Dr. Ivaylo Dedov (Sofia, Bulgaria); MCI = Malacological Collection of Dr. Athanas Irikov (Plovdiv, Bulgaria); MCW = Malacological Collection of Professor Thomas Wilke (Giessen, Germany); N = number of individuals; n = number of samples; NMNHS = Malacological Collection of the National Museum of Natural History, Sofia, Bulgaria; SH = shell height; SH $\bar{x}$ = average shell height; SSS = sea surface salinity; SW = shell width/diameter; SW $\bar{x}$ = average shell width/diameter; ± = Standard error of the mean; $\bar{x}$ = mean; SD = Standard deviation.

Results and Discussion

As a result of the present study, and the review of all the available *M. myosotis* materials from museums and private collections, the species has been recorded from 15 localities along the Bulgarian Black Sea coast. Thirteen of these localities are new (Table 1; Fig. 1: loc. 3, 6-17), the northernmost of which is Tyulenovo (less than 30 km from the border with Romania), and the southernmost at the mouth of Rezovska River (in vicinity to the border with Turkey; Fig. 1). These results confirm the literature data (Guéorguiev 1982; Gruev 1981, 1988; Gruev, Kuzmanov 1994, 1999) according to which in Bulgaria this species is restricted to the region of the Black Sea coast.

Morphological notes

Shell variation

According to data from the literature, the shell of *Myosotella myosotis* can reach a length of 12 mm and a width of up to 6 mm (Golikov & Starobogatov 1972), while AH is 5.5 mm (Milashevich 1916). Bulgarian populations of the species have been measured previously (Kaneva-Abadjieva 1960; Damyanov & Likharev 1975): SH=6.3-8.0, SW=2.8-3.5, AH=3.4-4.2, AW=2.0-2.5. Similar measurements have been provided by Grossu (1955) for Romanian populations: SH=6.0-8.0, SW=3.0-3.5. *Myosotella myosotis* is known to be a variable species (Martins 1999), exhibiting local or regional conchiological variations (Wiese & Richling 2008) depending on the salinity of its habitat. That means that the shells are thin-walled and generally smaller (up to 3.2 mm shorter; SH=7.1) in water with lower salinity (e.g., estuaries and the Baltic Sea: SSS of the Baltic Sea = 8-11 ‰; Peychev & Dimitrov 2012, p. 72) while in areas with higher salinity (e.g., brackish waters and the North Sea: SSS of the North Sea = 29.1–35.2 ‰; Peychev & Dimitrov 2012, p. 77) the shells tend to

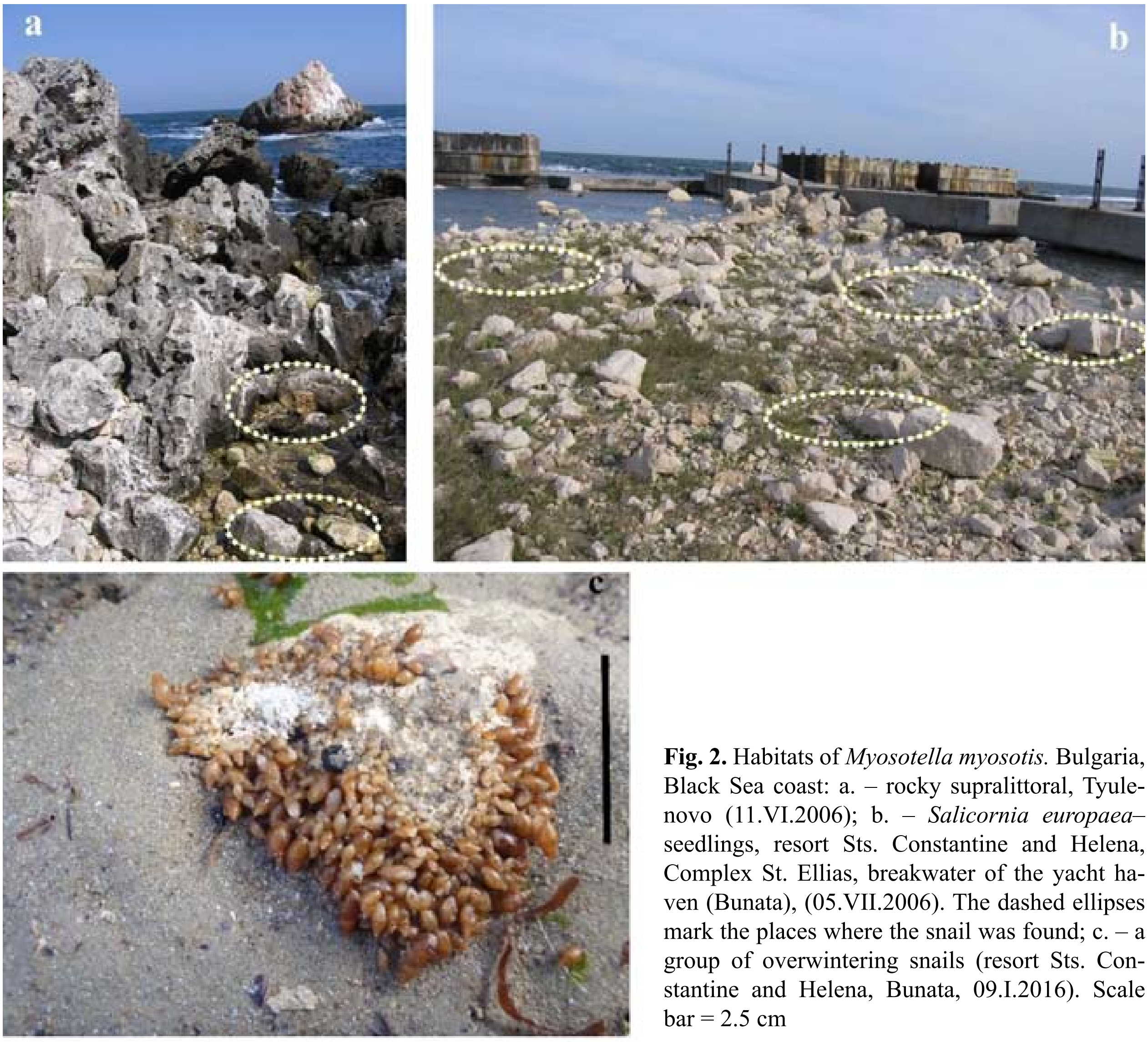

Fig. 2. Habitats of *Myosotella myosotis.* Bulgaria, Black Sea coast: a. – rocky supralittoral, Tyulenovo (11.VI.2006); b. – *Salicornia europaea*– seedlings, resort Sts. Constantine and Helena, Complex St. Ellias, breakwater of the yacht haven (Bunata), (05.VII.2006). The dashed ellipses mark the places where the snail was found; c. – a group of overwintering snails (resort Sts. Constantine and Helena, Bunata, 09.I.2016). Scale bar = 2.5 cm

be thicker, bigger and more elongated (SH=10.3). Such data have been provided by Angelov (1959) for Greek populations of the species (from the Aegean coast: Kavala region and Island Thasos, around the village of Skala Kazaviti). According to his measurements, *Myosotella myosotis* (as *Phytia (Alexia) myosotis*) specimens found under stranded marine algae in coastal marshes on Thasos Island, have bigger shells (SH=8.0; SW=3.5) compared to those, found on the Aegean coast: "Kumburun" (= cape Kum Burnu or Ammodis Akra) among "solonchak" (= salt marsh) (SH=5.5-6.0 and SW=3.0-3.5); the shells of the specimens from the Aegean coast were also more rounded and with shorter spires (salinity of Aegean Sea = 38 ‰; Peychev & Dimitrov 2012, p. 72). For the new (N=194 mature and juv.) *M. myosotis* material originating from Bulgarian populations, the summarised shell-measurements are as follows: SH$_{\bar{x}}$=5.40±0.13 (1.35-9.1, SD=1.88, CV=0.35), SW$_{\bar{x}}$=2.58±0.05 (0.4-4.0, SD=0.74, CV=0.29), AH$_{\bar{x}}$=2.99±0.06 (0.45-4.7, SD=0.89, CV=0.30), AW$_{\bar{x}}$=1.22±0.027 (0.4-2.1, SD=0.37, CV=0.3). Of these, 79 were juvenile specimens with the following measurements: SH$_{\bar{x}}$=3.58±0.12 (1.35-4.9, SD=1.07, CV=0.3), SW$_{\bar{x}}$=1.9±0.06 (0.4-2.7, SD=0.54, CV=0.28), AH$_{\bar{x}}$=2.15±0.07 (0.45-3.0, SD=0.64, CV=0.3), AW$_{\bar{x}}$=0.88±0.03 (0.40-1.3, SD=0.24, CV=0.27). The remaining 115 were mature individuals (i.e., with HS≥5 mm): SH$_{\bar{x}}$=6.65±0.11 (5.0-9.1, SD=1.16, CV=0.17), SW$_{\bar{x}}$=3.05±0.04 (2.3-4.0, SD=0.43, CV=0.14), AH$_{\bar{x}}$=3.57±0.05 (2.7-4.7, SD=0.5, CV=0.14), AW$_{\bar{x}}$=1.45±0.02 (1.0-2.1, SD=0.25, CV=0.17).

Comparative data

The measured range was similar to the previously reported one in the literature for the Bulgarian and Romanian populations of this snail (see above). Only SH had a larger maximal value – up to 9.1

mm, SW – up to 4.0 mm, and AH – up to 4.7 mm. The shells were not as thin-walled as expected, despite the lower salinity of the Black Sea (minimum SSS=13–15‰ in the NW part of the sea, and 18-18.5 ‰ – in the central region; see Peychev & Dimitrov 2012, p. 81). Another possible factor determining the shell thickness of the mouse-eared snail might be also the type of the substrate and the water dynamics in the coastal zone that these snails inhabit.

In mature specimens (N=111) from the investigated Bulgarian populations, some variation in the number of apertural folds and denticles (Fig. 3) was observed. Most common (79 ind., 71.2 %) were specimens with two folds in the ear-shaped aperture (i.e., having one columellar and one parietal fold) and with one single denticle on the parietal wall (Fig. 3a-b). Quite common (21 ind., 18.9 %) were also specimens whose shells have only one columellar and one parietal fold (but with the parietal denticle absent). Less common (six ind., 5.4 %) were snails whose shells bear two folds and one single parietal denticle in combination with one hump on the palatal wall. The most rare individuals were those with two folds and two parietal denticles in combination with one hump on the palatal wall of the shell (two specimens, 1.8 %; see Fig. 3g), those with two folds and two parietal denticles on the shell (one specimen, 0.9 %); one further specimen was with only one (the parietal) fold in addition to a flat apertural hump (Fig. 3f, arrowed) instead of the parietal denticle (one specimen, 0.9 %). It is noteworthy that one of the shells from locality № 4 (see Table 1) appeared similar to *Myosotella denticulata* (Montagu, 1803) with its additional four denticles near the palatal margin of the outer lip of the shell (Fig. 3e). Milashevich (1916: p. 139, as *Alexia myosotis*) also mentions the presence of such tubercles on the outer lip in *M. myosotis*. Some authors treat *M. myosotis* and *M. denticulata* as well-defined species (see comments and notes in Martins 1999; Anderson 2005; Gofas 2015a,b), while others (Martins 1999; Kerney 1999; Welter-Schultes 2012) usually consider *M. denticulata* as an open-coast form of *M. myosotis*. Variation in the number of apertural folds, similar to the above mentioned, have been described in *M. myosotis* also by Martins (1999: p. 66, figs 20-23).

The juvenile shells bear periostracal hairs and show well-developed collumellar and parietal folds (Fig. 3h, see also Martins 1999: p. 66, fig. 24) that are thinner than in the mature specimens (Fig. 3a-g). In rare occasions, some juveniles with shells close to mature size (with SH=4.7-4.8) had one additional, very small, single denticle on the parietal wall of the shell (2 ind. out of 75, 2.7 %), others had that small, single parietal denticle in combination with a hump near the palatal margin of the outer lip (one specimen out of 75 juv., 1.3 %).

Abnormalities

One of the collected *M. myosotis* (Fig. 3b,d; Fig. 1: loc. № 8) had an anomalous (i.e., shorter than usual) columellaris, that is perhaps a result of a traumatic injury from breaking both the shell and the columella resulting in the coarser shell growth-lines which were clearly visible on that specimen (Fig. 3d). Further two *M. myosotis* (SH=7.0 and SH=8.1 mm; loc. № 8; Fig. 1) out of 45 specimens collected on 04.X.2015 and 20.III.2016 had an unusual bifurcating tentacle, i.e., the left tentacle on the inner side, close to the distal end (subapical), bore an additional process (Fig. 4, arrowed). The usual causes for such anomalies is either genetic or an aberrant tissue-regeneration, following a mechanical-traumatic event (Simroth 1908; Miles 1961; Mitov *et al.* 2003; Mitov 2014, and references therein). These cases represent the first teratology records in *M. myosotis*.

Biological and Ecological notes

Habitat preferences

In the Bulgarian literature *M. myosotis* has been mentioned as a typical inhabitant of the rocky supralittoral biocoenoses (Hubenov 2005, 2007a,b). This snail has been characterised also as a stenobathic (stenoepibathic), hydrophilous, supralittoral species. It occurs both under stones outside the water (Kaneva-Abadjieva 1960; Marinov 1990; Hubenov 2005, 2007a,b), as well as among the plant debris on marine alluvium (Damyanov & Likharev 1975; Gruev 2000) where these animals feed by scraping plant particles and diatoms from the surfaces they crawl over (Jaeckel 1986; Cohen 2005; Wiese & Richling 2008). The new observations confirmed the literature data on the habitat and microhabitat preferences of this snail species (Zernov 1913; Milashevich 1916; Băcescu *et al.* 1971; Golikov & Starobogatov 1972; Grossu 1993 as *Ovatella* (*Myosotella*) *myosotis*): *M. myosotis* specimens were consistently collected throughout the Black Sea coastal zone on exposed shores, under partially submerged stones covered with algae (Fig. 2), as well as under stones on sandy beaches (where it was always moist to wet) among *Salicornia europaea* seedlings, about 4-5 m off the waterfront. In the latter microhabitat (Fig. 2b) the stone microphytobenthos included green algae (*Chlorococcum* spp.), blue-green algae (*Oscillatoria* sp.), and diatoms (*Achnanthes* spp., *Cocconeis* sp., *Navicula* spp.). As some of the shells, originating from the southern Black Sea coast, were collected also on seaweed-

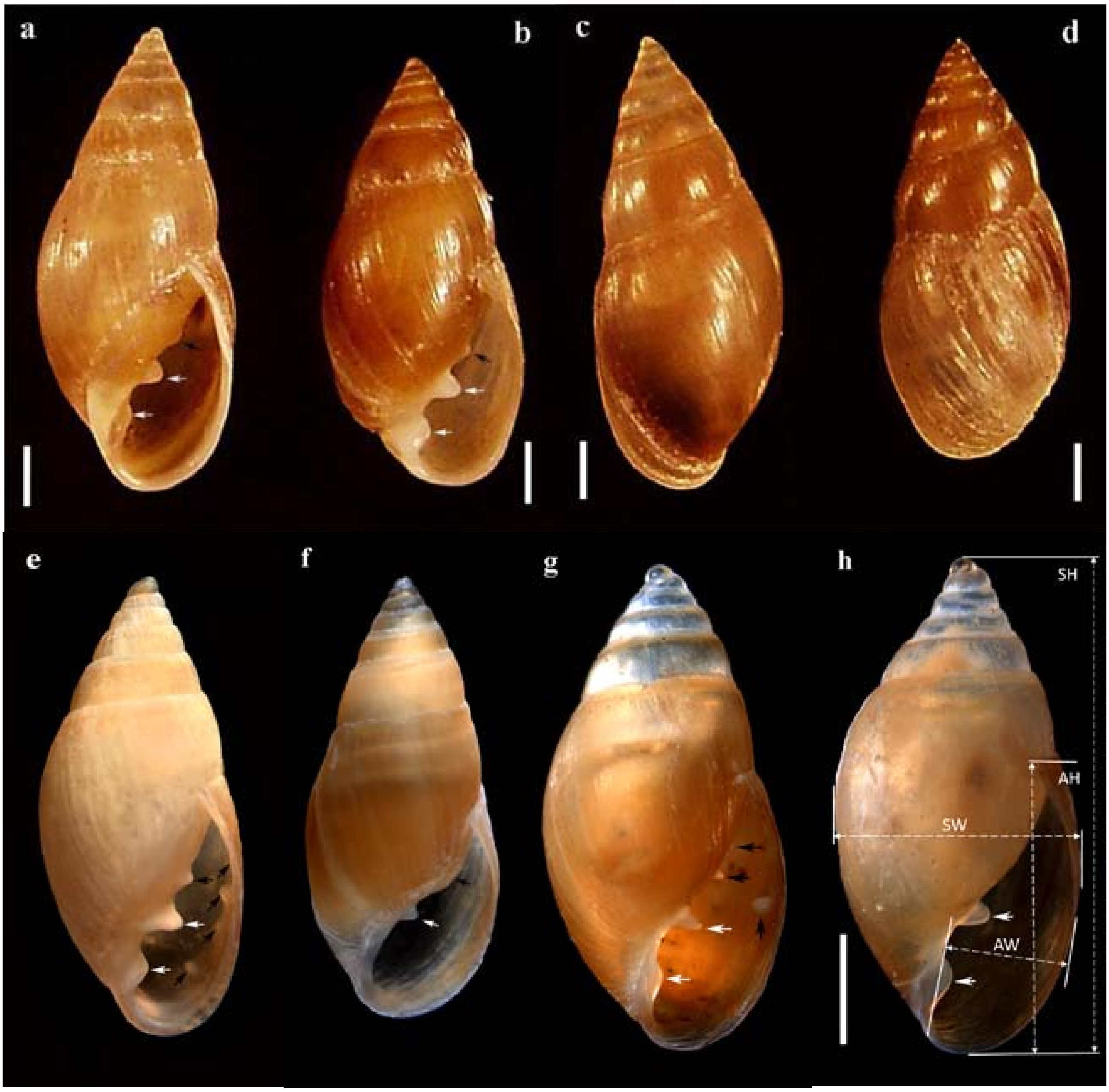

Fig. 3. Shell variation in *Myosotella myosotis* from Bulgarian Black Sea coast (resort Sts. Constantine and Helena, Complex St. Ellias, breakwater of the yacht haven (Bunata)): a.–g.: mature specimens: a., c. – SH=7.9, (20.-21.VII.2001); b., d. – SH=7.4, (02.VII.2002); e. – SH=5.4, (05.VII.2006); f. – SH=7.3, (16.VIII.2003); g. – SH=5.1, (18.-25.VII.2008); h. – juvenile specimen, SH=4.5, (06.VIII.1999), shell measurements. (a, b, e-h. – apertural view; c, d. – abapertural view). The white arrows show the shell folds; the black arrows show apertural denticles and humps; for abbreviations see *Material and methods*. Scale bar = 1 mm

biomass forming rotting piles along the coast, Dr. Atanas Irikov suggested (pers. comm.) that some of those shells might have coasted with the sea-flows from the north (see also the discussion in Irikov & Mollov 2014). Wiese & Richling (2008) noted 1.8 % (18 ‰) as being an optimal salinity value for growth and egg-production in *M. myosotis*. Along the Bulgarian Black Sea coast the sea-surface salinity varies between 12.00 and 18.18 ‰ with a pH of 7.5 to 8.5 (Dineva 2013, 2014, 2015). At the locality along the Bulgarian coastline where the mouse-eared snail was most numerous (Fig. 1: loc. 8; Fig. 2b), the sea-surface pH was 8.0-8.73, and the sea-surface salinity was within the optimal range for *M. myosotis* – 15.4-16.5 ‰ (1.54-1.65 %), while the salinity of the sandy ground under the stones was within the medium range of 0.50-0.51 %.

In nature, the representatives of this species copulate in April/May and August/September, and lay their eggs in May/June (Wiese & Richling 2008,

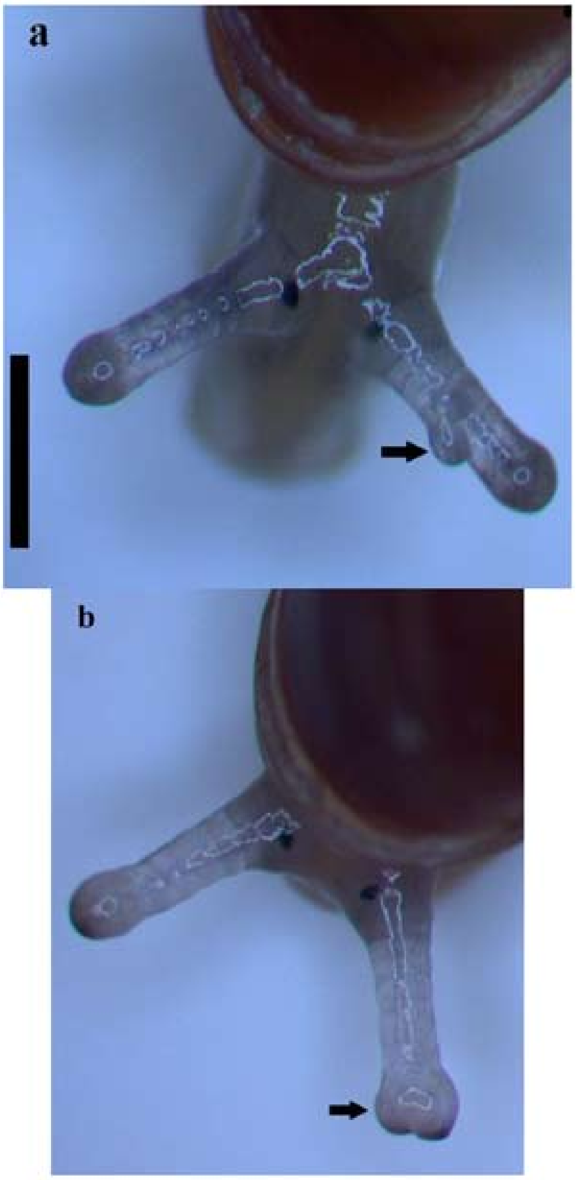

Fig. 4. Two abnormal mature *Myosotella myosotis* from Bulgarian Black Sea coast (resort Sts. Constantine and Helena, Complex St. Ellias, breakwater of the yacht haven (Bunata)): head, dorsal view: abnormal bifurcation of the tentacle; arrows show the abnormal structures. a. – SH=8.1 mm (04.X.2015); b. – SH=7.0 mm (20.III.2016). Scale bar = 1 mm

Welter-Schultes 2012). Living snails collected in April 2001 at locality № 4 (see *Materials and Methods*) and kept in laboratory conditions laid eggs in the second decade of April. The larvae developed completely in the egg and after hatching, the juveniles together with the adults, formed mosaically distributed groups that may be found most frequently on the underside of stones or on the sandy stone-bed. During the winter and early spring these groups, dominated by juvenile snails, were more numerous (35 individuals on average, n=31 groups) and more compact (Fig. 2c). For instance, one such overwintering group (Fig. 2c) consisted of 356 individuals [38 of which were mature with the following shell measurements: SH $_{\bar{x}}$ =6.67±0.42 (5.0-8.7, SD=1.34, CV=0.20), SW $_{\bar{x}}$ =3.0±0.14 (2.3-3.7, SD=0.45, CV=0.15), AH $_{\bar{x}}$ =3.54±0.20 (2.7-4.6, SD=0.65, CV=0.18), AW $_{\bar{x}}$ =1.53±0.01 (1.1-2.1, SD=0.26, CV=0.2) (N=10)]; the juveniles measured as follows: SH $_{\bar{x}}$ =3.29±0.32 (1.45-4.8, SD=1.05, CV=0.32), SW $_{\bar{x}}$ =1.79±0.16 (0.85-2.5, SD=0.52, CV=0.29), AH $_{\bar{x}}$ =2.0±0.19 (0.9-3.0, SD=0.64, CV=0.32), AW $_{\bar{x}}$ =0.89±0.09 (0.45-1.2, SD=0.28, CV=0.32) (N=11). During the summer and autumn the snails usually formed smaller and less dense groups (nine individuals on average, n=21 groups), with juvenile individuals dominating again. Only occasionally, during the summer (09.VIII.2016, in locality № 4, Table 1) several larger groups consisting of 23-33 (up to 90: 79 mature and 11 juv.) individuals were found on the underside of stones near the water; these groups were dominated by adults. A similar aggregating behaviour was observed also in laboratory conditions. According to Wiese & Richling (2008) overwintering *M. myosotis* hide mostly in small groups in hibernation-hollows on the ground. These authors also noted that the snails often crawl down the stems into the roots of the plants, however I failed to observe such a behaviour in the field. A possible explanation for that might be the habitat type (Fig. 2) – a combination of stones, sandy ground and sparse vegetation, as well as the fact that this particular habitat was regularly inundated by the strong waves that formed in winter and early spring.

Conservation status and recommended actions towards the conservation of the species

Myosotella myosotis has been described in the Bulgarian zoological literature as being a rare, relict species of national significance (Dedov 1998: as *Ovatella myosotis,* and Hubenov 2005, 2007a,b). According to Guéorguiev (1982) it is also an indicator species, characteristic for the Bulgarian Black Sea zoogeographical region where the mouse-eared snail inhabits coastal saline habitats, which may be easily disturbed by landslides, backfilling with stones, construction activities, and pollution. Fortunately, part of the habitats of the mouse-eared snail in Bulgaria are protected by law and are included in both the Red Data Book of the Natural habitats and in the European Ecological Network Natura 2000 (Tzonev *et al.* 2008; Kavrakova *et al.* 2009; Tzonev & Gussev 2011). Despite the fact that the snail was newly recorded from 13 localities along the Bulgarian Black Sea coast, living animals were found only at three of them: the region of Tyulenovo (Fig. 1: loc. 3; Fig. 2a), "Sts. Constantine and Helena" resort (Fig. 1: loc. 8; Fig. 2b) and Nessebar (Fig. 1: loc. 9). However, high abundance of *M. myosotis* was found only at the locality near the resort "Sts. Constantine and Helena" where the anthropogenic pressure was considerable, and further building activities in the region could negatively affect the population.

Because of the relatively high vulnerability of the habitats where *M. myosotis* occur, in some European countries this species has been classified either as "Critically Endangered" (e.g., in Germany, see Jungbluth & Knorre 2009) or "Vulnerable" (e.g., in The Netherlands, Byrne *et al.* 2009). In other countries, such as Great Britain and Ireland, this snail is widespread without evidence of decline, and has thus been categorised as being of "Least Concern" (Byrne *et al.* 2009; Seddon *et al.* 2014). In Bulgaria, no conservation measures have been developed for the protection of *M. myosotis* and the presented data could be used for future conservation initiatives and monitoring projects concerning the species. The mosaic occurrence of the species, the conservation significance of its habitats, as well as the restricted distribution of the mouse-eared snail throughout the Black Sea biogeographical region suggest that special measures for the protection and conservation of this snail species might need to be taken also in Bulgaria, perhaps on a regional level.

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