

***Vellaria solenta* (Monothalamea: Allogromiidae) — new species of soft-walled foraminifera from Sivash Bay (the Sea of Azov)**

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ABSTRACT: We describe *Vellaria solenta* sp.n., a new species of soft-walled, monothalamous foraminifera based on 16 individuals found in the hypersaline Sivash Bay (Sea of Azov). The distinctive morphological features of the species are the presence of protoplasm completely filling the entire space of the test and the interior of the apertural neck, and the short, thin processes that extend beyond the aperture in most individuals. Other representatives of the genus *Vellaria*, namely *V. pellucida* Gooday et Fernando, 1992 and *V. sacculus* Gooday et Fernando, 1992, were found in the south-western of the Sea of Azov (Sergeeva, 2016), where the salinity did not exceed 14‰, compared to 74‰ in Sivash in the case of *Vellaria solenta* sp.n.

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KEY WORDS: Soft-walled foraminifera, Sivash, the Sea of Azov, *Vellaria solenta*.

***Vellaria solenta* (Monothalamea: Allogromiidae) — новый вид мягкораковинных фораминифер из залива Сиваш (Азовское море)**

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РЕЗЮМЕ: Описан новый вид мягкораковинных фораминифер *Vellaria solenta* sp.n., основываясь на изучении 16 особей, обнаруженных в гиперсолёном заливе Сиваш (Азовское море). Отличительными морфологическими признаками вида являются полностью заполненное протоплазмой пространство клетки и апертурной шейки, а также ветвистые, короткие, тонкие отростки, выходящие за пределы апертурной у большинства особей. Ранее в юго-западной части Азовского моря были обнаружены и другие представители рода *Vellaria* — *V. pellucida* Gooday et Fernando, 1992 и *V. sacculus* Gooday et Fernando, 1992 (Сергеева, 2016), однако солёность в местах их обитания не превышала 14‰, в то время как солёность в Сиваше, при которой обнаружен вид *Vellaria solenta*, составляет 74‰.

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КЛЮЧЕВЫЕ СЛОВА: Мягкораковинные фораминиферы, Сиваш, Азовское море, *Vellaria solenta*.

Introduction

Sivash Bay, or Rotten Sea, is a shallow lagoon-type bay in the western part of the Sea of Azov, separating the Crimean Peninsula from the mainland. It is shallow along its whole extent, 0.6–1.5 m on average but reaching a depth of 3 m in a few places. In summer, the water temperature varies from 20 to 32 °C and this heating leads to strong evaporation and high mineralization.

The bay extends for 115 km from north to south, and 160 km from west to east. In the eastern part, it is separated from the Sea of Azov by a long narrow sand-and-shell spit, Arabatskaya strelka (length 115 km, width from 270 m to 7.5 km). Sivash also connected with the Sea of Azov through two narrow straits, 150–200 m wide, near Genichesk (Genichesky Bay), while the narrow (8–12 km) Perekop Isthmus separates Sivash from the Black Sea in the west. The area of the bay amounts to about 2,560 km², of which about 100 km² are occupied by islands and 560 km² are covered by water intermittently only (Report of the Collegium No. 2, 2015).

Sivash Bay is a unique ecosystem that doesn't have an analogue anywhere in the world. The salinity varies from the north to south, within the range 22.0 to 87.0‰. The bottom of is covered with a layer of silt with a mass of rotting algae and a strong hydrogen sulfide smell.

Sivash Bay is the most anthropogenically and technogenically impacted area of the coastal zone off Crimea and is characterized by specific hydrodynamic and hydrochemical processes (Sovga *et al.*, 2018a, b). From the first half of the 20th century to the present, it has been subjected to serious anthropogenic impacts twice. The bay was a hypersaline lagoon before

1963 (average salinity of 141.0‰). At this time, the North Crimean Canal was built to improve water supply to the Crimean Peninsula by diverting the waters of the Dnieper River. The subsequent development of irrigated agriculture resulted in effluent waters from the fields draining into Sivash Bay and the salinity therefore began to decrease. In 1997 it had dropped to 17.0‰. These events caused a reorganization of the entire ecosystem due to drastic changes in salinity, transforming a hypersaline basin into a brackish-water one. A fundamentally new brackish water ecosystem gradually formed in Sivash Bay. In April 2014, Ukraine made a political decision to stop supplying Dnieper water via the North Crimean Canal. Discharge of fresh water to the bay almost ceased. Salinity began to increase, and the Sivash ecosystem underwent another transformation (Shadrin *et al.*, 2018). At present, Sivash is acquiring hypersaline properties again. Studies of thermaline conditions in the bay have shown that the salinity has recently increased to 60.0–80.0‰, i.e., almost 3- to 4-fold since 1997 (Shchurova *et al.*, 2016).

Recent studies have shown how benthic communities in Sivash Bay have responded to these environmental shifts. The taxonomic structure of the community has changed. The diversity of major macro- and meiobenthic taxa has decreased slightly, with some groups disappearing completely. However, the species diversity of some meiobenthic taxa, such as Harpacticoida, has increased (Shadrin *et al.*, 2016) and organisms that were previously unknown in this region have been discovered (Sergeeva, 2016; Shadrin *et al.*, 2016, 2018, 2019; Sergeeva *et al.*, 2019, 2020).

In this paper we describe *Vellaria solenta* sp.n., a hitherto unrecorded representative of

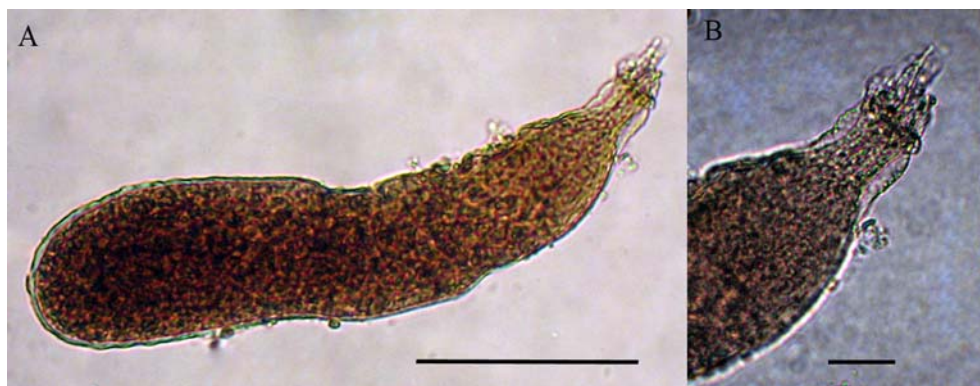


Fig. 1. *Vellaria solenta*, the holotype: A — general view of the specimen; B — aperture part. Scale bars: A — 100 μm ; B — 20 μm .

Рис. 1. *Vellaria solenta*, голотип: А — общий вид экземпляра, В — апертурная часть. Масштаб: А — 100 мкм, В — 20 мкм.

the fauna of soft-walled monothalamous foraminifera (Protozoa) in the hypersaline Sivash Bay.

Material and methods

This work is based on a collection of soft-walled foraminifers found in samples of bottom sediments obtained on July 17, 2020, during a study of the bottom fauna of Sivash Bay. The sediments were sampled using a plastic beaker with a volume of 23.75 cm³ and fixed with 4% formalin solution.

In the IBSS laboratory, the sample was carefully washed with water through sieves with a mesh size of 1 and 0.63 mm, and the residue concentrated on the lower sieve was stained with Bengal Rose. The stained sample was placed in a Bogorov chamber and meiofaunal organisms picked out under a MBS-9 binocular microscope. Specimens were sorted into major meiofaunal taxa and counted. Foraminiferal specimens were studied further using Canon and Mikmed-6 microscopes and photographed using a Canon A620 digital camera.

The holotype and three paratypes of *Vellaria solenta* are deposited in the collection of soft-walled foraminifera of the A.O. Kovalevsky Institute of Biology of the Southern Seas, Russian Academy of Sciences.

In this work, we follow the classification of soft-walled foraminifera according to the WoRMS (Hayward *et al.*, 2021).

Results

Supergroup Rhizaria Cavalier-Smith, 2002
 Phylum Foraminifera d'Orbigny, 1826
 Class Monothalamaea Haeckel, 1862 (sensu Pawlowski *et al.*, 2013)
 Order Allogromiida Loeblich et Tappan, 1961
 Family Allogromiidae Rhumbler, 1904
 Genus *Vellaria* Gooday et Fernando, 1992

Vellaria solenta sp.n.

Figs 1–3.

ETYMOLOGY: Latin “solent” meaning hypersaline.

MATERIAL. The holotype (Meib. 71 Al. h.) (Fig. 1), three paratypes (Meib. 72 Al. p.1, Meib. 73 Al. p.2 and Meib. 74 Al. p.3) (Fig. 2) and other studied specimens (Fig. 3) were collected in July 2020 in the Sivash Bay of the Sea of Azov (45°52'38.8"N; 34°44'33.3"E), at a depth of 5 to 10 cm, in muddy sediment with a hydrogen sulfide smell. All specimens are preserved on the glass slides in gelatin-glycerine. Table 1 contains the quantitative parameters of all studied specimens of *Vellaria solenta*.



Fig. 2. *Vellaria solenta*, the paratypes: A, C, E — general view of the paratypes 1, 2 and 3; B, D and F — apertural part of paratypes 1, 2 and 3. Scale bars: A, C — 100 μm ; E — 50 μm ; B, D, F — 20 μm .

Рис. 2. *Vellaria solenta*, паратипы: А, С, Е — общий вид паратипов 1, 2 и 3; В, D и F — апертурная часть паратипов 1, 2 и 3. Масштаб: А, С — 100 мкм, Е — 50 мкм, В, D, F — 20 мкм.

DESCRIPTION: The test is elongated, organic, with a thin, flexible wall. It measures 240–435 μm long and 50–90 μm wide. The protoplasm is homogeneous, fine-grained and contains diatom frustules in some individuals. The nucleus is located in the distal part of the cell; it has a diameter of about 15–28 μm , but is not visible in some specimens. The only aperture is located at the end of the elongated neck, situated at the narrower end of the test. The form of the apertural neck varies from funnel-shaped with a slightly ragged edge, as in typical representatives of the genus *Vellaria*, to cylindrical, sometimes becoming narrower at the end. A characteristic feature of the species is that the dense protoplasm completely fills the body space and the apertural neck, adhering tightly to the test wall with no intervening space. In many individuals, the neck has short, thin processes that extend beyond the aperture. The diameter

of the aperture in the studied specimens ranges from 18 to 26 μm . The proximal end of the test is smoothly rounded in most specimens. The coefficient C (length/width ratio) varies from 3.4 to 7; on average it is about 5.

HABITAT. The new species was found in the Sivash Bay of the Sea of Azov at a depth of 5 to 10 cm, in muddy sediment with a hydrogen sulphide smell. The density was 67 specimens/10 cm^2 . The salinity was 74‰. It can be assumed that they actively feed on filamentous, mat-creating algae. In some individuals, the filaments of blue-green algae occupied the entire length of the aperture neck and penetrated deeper into the cell.

DIFFERENTIAL DIAGNOSIS: Three valid species belonging to the genus *Vellaria* are currently known: *V. pellucida* Gooday et Fernando, 1992, *V. sacculus* Gooday et Fernando, 1992 and *V. zuchellii* Sabbatini, Pawlowski,



Fig. 3. Other investigated specimens of *Vellaria solenta*. Scale bars: 100 μm .

Рис. 3. Другие исследованные экземпляры *Vellaria solenta*. Масштаб: 100 мкм.

Gooday et Bowser, 2004. The first two species, first described from the Vellar estuary in SW India (Gooday, Fernando, 1992), occur in both the Black Sea (Sergeeva, Anikeeva, 2004; Anikeeva, 2007; Gooday *et al.*, 2011; Anikeeva, Gooday, 2016) and the Sea of Azov (Sergeeva, 2016) quite frequently. The morphological similarity between the new species and the two Indian species is in the structure of the apertural neck and test wall. The test of *V. solenta* is slightly more elongated than that of *V. pellucida* and *V. sacculus*. A distinctive feature of the new species is that the entire space of the test and apertural neck is completely filled with protoplasm. Also, the short, thin filaments that extend beyond the aperture in most individuals have not been observed in other species of the genus.

Vellaria solenta resembles the Antarctic species *V. zuchellii* (Sabbatini *et al.*, 2004) in the elongated shape of the test but new species differs in body size, apertural structure and distribution of protoplasm within the test.

Discussion

Over 50 zoobenthic species, including accidental introductions, have been recorded during

more than a century of research in Sivash Bay. However, most studies have been limited to assessing benthic organisms as a food source for fish and birds (Dovgal, 2005). Soft-walled foraminifera have not been previously recorded in the bay.

Allogromiids were first discovered in 2013 and 2015 in areas of Sivash characterized by different salinities (Sergeeva, 2016; Sergeeva, Anikeeva, 2018). According to our current data, published in part, *Bellarium rotundum* Anikeeva, Sergeeva et Gooday, 2013, Allogromiid sp. 40, Allogromiid sp. 42 (Sergeeva, Anikeeva, 2018), Allogromiid sp. X, Allogromiid sp. W and Allogromiid sp. Z (unpublished data) inhabit Sivash. *Bellarium rotundum* and Allogromiid sp. 42 have been found in the Sea of Azov and Sivash Bay at a salinity of no more than 10‰, Allogromiid sp. 40 has only been recorded in Sivash at a salinity of up to 40‰ but other monothalamid species appear to be resistant to the high salinity of Sivash.

Vellaria pellucida and *V. sacculus* were previously recorded in the Sea of Azov in habitats with a salinity of 14‰ (Sergeeva, 2016), but these species have not been found in Sivash. The new species *Vellaria solenta* inhabits Sivash Bay at salinity of up to 74‰. How this species

Table 1. Morphological parameters of the holotype (in μm), the three paratypes and other examined specimens of *Vellaria solenta*.

Таблица 1. Морфологические параметры голотипа (в $\mu\text{м}$), трёх паратипов и других исследованных особей *Vellaria solenta*.

Specimen	Test length	Test width	Diameter of apertural neck	Nucleus	Coefficient C
Holotype	310	70	25	18	4.4
Paratype 1	330	75	26	18	4.4
Paratype 2	365	75	25	15	4.8
Paratype 3	350	50	20	—	7
Specimen No. 1	365	80	23	—	4.5
Specimen No. 2	320	90	18	—	3.5
Specimen No. 3	410	70	26	21	5.8
Specimen No. 4	350	65	20	28	5.4
Specimen No. 6	300	50	18	—	6
Specimen No. 8	380	70	20	—	5
Specimen No. 9	435	70	10	20	6.2
Specimen No. 10	300	70	20	—	4.3
Specimen No. 11	240	70	20	—	3.4
Specimen No. 13	240	50	18	15	4.8
Specimen No. 14	270	60	13	16	4.5
Specimen No. 16	350	60	26	—	5.8

“—” = not visible.

penetrated into these hypersaline conditions is unknown. We assume that it has long inhabited the harsh environment of Sivash, but since soft-walled foraminifers have never been investigated in this area, we cannot say for sure. It is unlikely that they come from the adjacent, brackish waters of the Sea of Azov.

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