

VARIABILITY OF SHELL IN GASTROPODS OF THE GENUS *BORYSTHENIA* LINDHOLM, 1914: TESTING THE STATISTICAL APPROACH IN SEARCH OF TRAITS FOR THE RECENT AND FOSSIL SPECIES DELIMITATION**МІНЛИВІСТЬ ЧЕРЕПАШКИ ЧЕРЕВОНОГИХ МОЛЮСКІВ РОДУ *BORYSTHENIA* LINDHOLM, 1914: ТЕСТУВАННЯ СТАТИСТИЧНОГО ПІДХОДУ В ПОШУКАХ ОЗНАК ДЛЯ РОЗМЕЖУВАННЯ СУЧАСНИХ ТА ВИКОПНИХ ВИДІВ****Diana S. Osipova^{1,2}, Olga Yu. Anistratenko^{2,3}, Vitaliy V. Anistratenko²
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The gastropod mollusc genus *Borysthenia* Lindholm, 1914 comprises many species throughout Europe, Asia, North Africa and North America but species delimitation, based mainly on shell morphology (only possible concerning the fossil records) is often disputable. Statistical methods used to test if the shell measurements are reliable traits in delimitation of recent and fossil species in gastropod molluscs of the genus *Borysthenia*. Our analyses based on quantitative study of over 100 specimens of the *Borysthenia* species both modern and fossil. It is concluded that the dimensional characteristics of their shell are suitable for the differentiation of both recent and fossil (at least of Pontian age) species through the statistical processing of quantitative data. Through the morphological study of type material, taxonomic status of *B. jalpuchense* Gozhik, 2002 and *B. vinogradovkaense* Gozhik, 2002 described from the middle-pontian deposits of Ukraine revised. It is suggested that these taxa are considered two distinct though close relative extinct species. Stratigraphic range of *B. jalpuchense* is expanded up to the Lower Pontian. All the modern individuals of *Borysthenia* involved are attributed to *B. menkeana* (Jelski, 1863) due to their exact correspondence to the lectotype of this species.

Keywords: Valvatidae, *Borysthenia*, fossil and modern species, shell morphology, taxonomy, south Ukraine

Рід червоногих моллюсків *Borysthenia* Lindholm, 1914 включає багато видів з усієї Європи, Азії, Північної Африки та Північної Америки, але визначення границь видів, що базується, головним чином, на морфології черепашки (єдине можливе для викопних знахідок), часто є дискусійним. Нами використано статистичні методи обробки промірів черепашки гастропод роду *Borysthenia* для перевірки, чи є параметри черепашки надійною ознакою розмежування сучасних та викопних видів. Наш аналіз побудований на кількісному вивченні понад 100 екземплярів *Borysthenia*, як сучасних, так і викопних. Зроблено висновок про те, що розмірні характеристики черепашки є придатними для диференціації як сучасних, так і викопних (принаймні, понтичного віку) видів шляхом статистичної обробки кількісних даних. Вивчення типового матеріалу дозволило уточнити таксономічний статус *B. jalpuchense* Gozhik, 2002 та *B. vinogradovkaense* Gozhik, 2002, що були описані з середньо-понтичних відкладів України. Запропоновано вважати ці таксони двома окремими, хоча й близько спорідненими вимерлими видами. Стратиграфічний діапазон *B. jalpuchense* розширено до нижнього понту. Все сучасні особини *Borysthenia* віднесено до *B. menkeana* (Jelski, 1863), оскільки вони точно відповідають лектотипові цього виду.

Ключові слова: Valvatidae, *Borysthenia*, викопні та сучасні види, морфологія черепашки, таксономія, південна Україна.

INTRODUCTION

The gastropod mollusc family Valvatidae Gray, 1840 represents a small group of freshwater snails known from Jurassic. It is distributed throughout

the Europe, the North part and the mountainous parts of Asia, North Africa and North America (Starobogatov, 1970). Being ovoviviparous and possessing very slender (vs. broad) marginal

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radular teeth the valvatid genus *Borysthenia* Lindholm, 1914 (type species *Valvata jelskii* Crosse, 1863) makes a clearly distinct branch within the family having a rank of subfamily Borystheniinae Starobogatov in Sitnikova, 1983 (Sitnikova, 1983). The rest of valvatid species are egg-lying molluscs.

Modern distribution of *Borysthenia* is limited to the waters of South Baltic, Danube, Dniester and Dnieper river basins (Sitnikova et al., 1986; Glöer, 2002, 2019; Welter-Schultes, 2012). In fresh waters of the Ukraine the genus is represented by four nominal species: *B. naticina* (Menke, 1846), *B. menkeana* (Jelski, 1863), *B. naticina* var. *alligans* (Lindholm, 1927), and *B. jelskii* (Crosse, 1863) (Sitnikova et al., 1986; Anistratenko, Anistratenko, 2001; Anistratenko et al., 2010). However, many authors consider these taxa as a same species (Falkner et al., 2001; Vinarski, Kantor, 2016).

Fossil representatives of the genus were more widely distributed and occurred in the Miocene deposits of Europe and Kazakhstan (Starobogatov, 1970; Gozhik, 2002; Gozhik, Datsenko, 2007; Anistratenko et al., 2010; Haszprunar, 2014). This also concerns to Ukraine: for instance, two new species of *Borysthenia* were described by Peter Gozhik (Gozhik, 2002; Gozhik, Datsenko, 2007) from the Pontian deposits of South Ukraine and Moldova, namely *B. jalpuchense* Gozhik, 2002 and *B. vinogradovkaense* Gozhik, 2002.

The protoconch traits of the valvatid snails are well known (e.g. Anistratenko et al., 2010; Hawe et al., 2013), however teleoconch variability of both recent and fossil *Borysthenia* is not well studied. This makes it nearly impossible to assess accurately the conchological features in the taxonomy of the group for reliable differentiation of species (Osipova, Anistratenko, 2018; Osipova et al., 2019).



Fig. 1. The geographic positions and views of the localities of material studied. Details for each sampling point are given in Table 1.

Рис. 1. Географічне положення та вигляд місць збору вивченого матеріалу. Деталі щодо кожної з точок збору надано у Таблиці 1.

Table 1. List of the examined material
The numbers of localities refer to the text and figures

Таблиця 1. Перелік дослідженого матеріалу
Номери локалітетів відповідають таким у тексті та рисунках

No	Lot# IZAN	Locality	Date	N	E	Collect by	n
1	479	Yalpug Lake, Vinogradovka village, Bolgrad district, Odessa region, N ₁ P ₁	06.1987	45° 39' 29"	28° 35' 08"	V. V. Anistratenko	40
2	478	Dnieper-Bug liman, near Rybalche settlement, Kherson region	1987	46° 29' 03"	32° 14' 04"	not stated	39
3	390	Dnieper River in Kherson City near Kherson Hydrobiological station of NAN Ukraine, depth 1,5–7,5 m	18.05.2016	46° 35' 55"	32° 34' 51"	V. V. Anistratenko	26
		Total					105

The present study aims to define the ranges of variability in features of the shell measurements in molluscs of the genus *Borysthenia* and to assess reliability of these features in delimitation of recent and fossil species.

MATERIAL AND METHODS

Recent samples of *Borysthenia* were collected in the Dnieper-Bug estuary. Molluscs were hand-picked from aquatic vegetation and using a hydrobiological net or Petersen dragger at depths of 0.5–7.5 m. The fossil specimens came from the Lower Pontian deposits of the Lake Yalpug near Vinogradovka village, Odessa region, Ukraine (age is determined by V. A. Prisyazhnyuk) (Fig. 1).

Altogether 105 specimens were studied and measured (Table 1). Apart from these the holotypes of two *Borysthenia* species were also studied: *B. jalpuchense* Gozhik, 2002 and *B. vinogradovkaense* Gozhik, 2002 described from the Middle Pontian (N₁P₂) near Vinogradovka village (ind.#3162 and #3163 accordingly, after Gozhik, 2002). Images of the specimens were taken with a Leica M165C stereomicroscope equipped with digital camera. Before photographing shells were cleaned by ultrasound in a water bath. Measurements (Fig. 2) were made using MBS-9 stereoscopic microscope with an ocular-micrometer of 0,1 mm precision.

RESULTS AND DISCUSSION

It was found that the shell growth geometry (detected through the shell shape comparison) of recent and fossil *Borysthenia* are significantly

different (Wilk’s lambda: 0,5385, F=5,864 with significance level p=0,01). The difference is mainly expressed in relative height of shell spire but with the same whorls number (Fig. 3). Besides, the whorls of spire in fossil shells are less inflated, separated with shallower suture and therefore an outline of entirely shell looks more trochoid in comparison to recent ones.

In fact the studied samples have statistically different main shell indexes (ratio HSh/WSh and HSh/WA), although a significant overlap in some of their shell measurements also exists (Fig. 4).

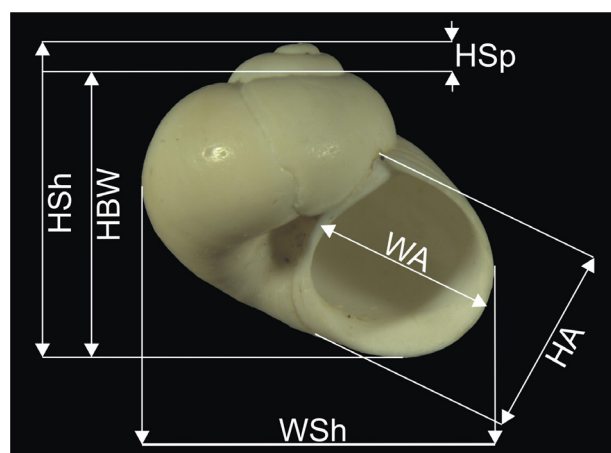


Fig. 2. Measuring of the shell parameters: HSh – height of shell, HBW – height of body whorl, WSh – width of shell, HSp – height of spire, HA – height of aperture, WA – width of aperture.

Рис. 2. Виміри параметрів черепашки: HSh – висота черепашки, HBW – висота останнього звою, WSh – ширина черепашки, HSp – висота завитка, HA – висота устя, WA – ширина устя.

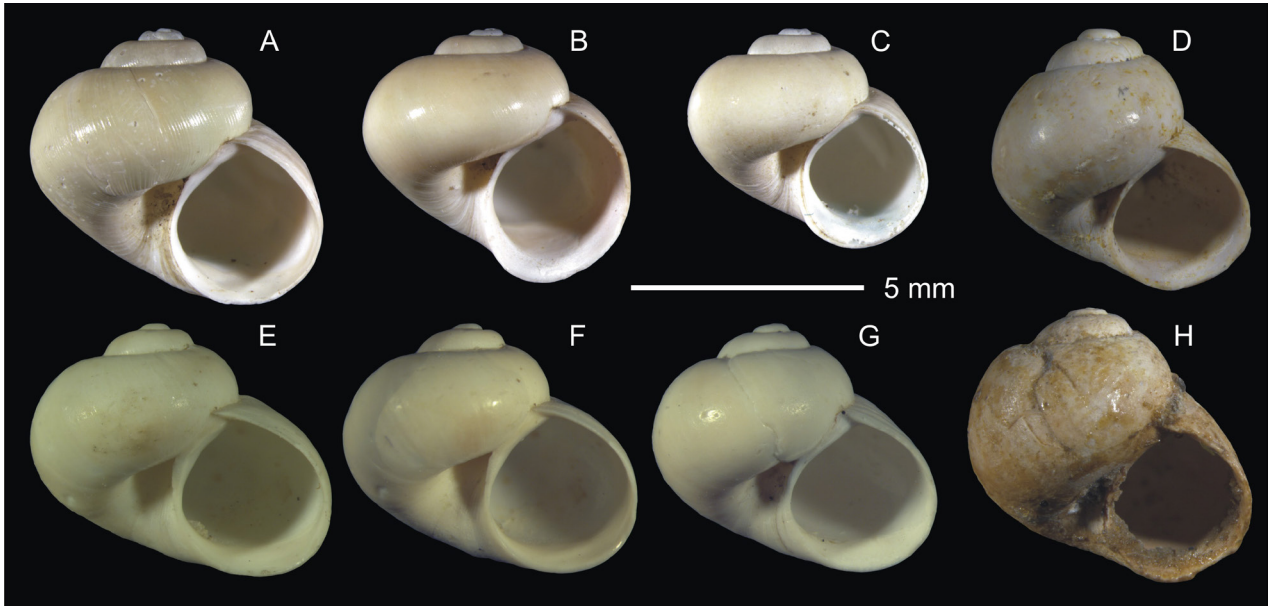


Fig. 3. Shells of examined *Borysthenia* species:

A–C – *B. menkeana* (Jelski, 1863) (locality 2 and 3); D – *B. vinogradovkaense* Gozhik, 2002 (holotype, N_1P_2); E–G – *B. jalpuchense* Gozhik, 2002 (locality 1, N_1P_1); H – *B. jalpuchense* Gozhik, 2002 (holotype, N_1P_2).

Рис. 3. Черепашки вивчених видів *Borysthenia*:

A–C – *B. menkeana* (Jelski, 1863) (місцезнаходження 2 та 3); D – *B. vinogradovkaense* Gozhik, 2002 (голотип, N_1P_2); E–G – *B. jalpuchense* Gozhik, 2002 (місцезнаходження 1, N_1P_1); H – *B. jalpuchense* Gozhik, 2002 (голотип, N_1P_2).

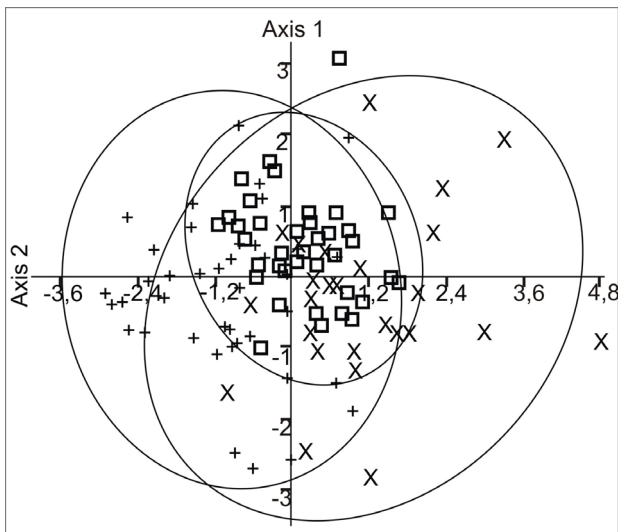


Fig. 4. Graphic distribution for shell measurements from 105 specimens of *Borysthenia*: 'X' – *B. menkeana* (locality 3); '□' – *B. menkeana* (locality 2); '+' – Early Pontian *B. jalpuchense* (locality 1, N_1P_1).

Рис. 4. Графічний розподіл промірів черепашки 105 зразків *Borysthenia*: 'X' – *B. menkeana* (locality 3); '□' – *B. menkeana* (locality 2); '+' – Early Pontian *B. jalpuchense* (locality 1, N_1P_1).

We consider the differences observed as sufficient to refer to the fossil (locality 1) and recent specimens of *Borysthenia* (localities 2, 3) as the two morphologically distinct species.

Since the holotype of *B. jalpuchense* (Fig. 3, H) matches well to the main shell features of the specimens from the Lower Pontian deposits (sample # 479) (Fig. 3, E–G) they may be considered conspecific. Thus, the stratigraphic range of *B. jalpuchense* in the Miocene was significantly expanded up to the Lower Pontian deposits.

Differences between the shell morphology of *B. jalpuchense* and *B. vinogradovkaense* (still known only by type series from the Middle Pontian) allow us to consider them as two distinct taxa on the species or the subspecies level (Fig. 3, D). The holotypes of *B. jalpuchense* and *B. vinogradovkaense* are slightly differentiating from each other. Shell whorls in *B. vinogradovkaense* comparatively inflated, increase regularly while in *B. jalpuchense* the whorls are flattened and increasing faster make more slender shell. Studied specimens from the Lower Pontian are characterizing with less inflated whorls, shallower suture and relatively shorter spire. All the specimens of *Borysthenia* came from the Lower

Pontian deposits represent a highly monomorphic sample with a narrow range of individual variability.

The studied modern mollusc individuals of *Borysthenia* (Fig. 3, A–C) we attribute to *B. menkeana* due to their exact correspondence to the lectotype of this species, illustrated by Sitnikova et al. (1986). The overall similarity of *B. menkeana* and *B. jalpuchense* (Fig. 4) suggests that both species are closely related; given the age, *B. jalpuchense* might be a phylogenetic predecessor of *B. menkeana*.

Based on the obtained data we suggest that the representative taxa of the Pontian and recent *Borysthenia* should be interpreted as distinct but morphologically similar (and most likely related) species or varieties of one polymorphic species. Observed conchological differences can be explained by the influence of environmental conditions.

CONCLUSION

Analysis of the data obtained confirms that the dimensional characteristics of the *Borysthenia* shell are suitable for the differentiation of

both recent and fossil (at least of Pontian age) species through the statistical processing of quantitative data. Morphological study of the type specimens (holotypes) of *B. jalpuchense* and *B. vinogradovkaense* supports their taxonomic status as two distinct though close relative extinct species. Stratigraphic distribution of *B. jalpuchense* apparently covers the lower- and middle-pontian deposits. All modern shells of *Borysthenia* involved in this study are attributed to *B. menkeana* since their shell morphology fairly corresponds to the lectotype of this species.

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**ИЗМЕНЧИВОСТЬ РАКОВИНЫ БРЮХОНОГИХ МОЛЛЮСКОВ
РОДА *BORYSTHENIA* LINDHOLM, 1914: ТЕСТИРОВАНИЕ СТАТИСТИЧЕСКОГО ПОДХОДА
В ПОИСКАХ ПРИЗНАКОВ ДЛЯ РАЗГРАНИЧЕНИЯ СОВРЕМЕННЫХ И ИСКОПАЕМЫХ ВИДОВ**

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Род брюхоногих моллюсков *Borysthenia* Lindholm, 1914 включает множество видов по всей Европе, Азии, Северной Африке и Северной Америке, но определение границ видов, основанное, главным образом, на морфологии раковины (единственно возможное для ископаемых находок), часто является спорным. Нами использованы статистические методы обработки промеров раковины гастропод рода *Borysthenia* для проверки, являются ли параметры раковины надежным признаком разграничения современных и ископаемых видов. Наш анализ основан на количественном изучении более 100 экземпляров *Borysthenia*, как современных, так и ископаемых. Сделан вывод о том, что размерные характеристики раковины пригодны для дифференциации как современных, так и ископаемых (по крайней мере, понтического возраста) видов путем статистической обработки количественных данных. Изучение типового материала позволило уточнить таксономический статус *B. jalpuchense* Gozhik, 2002 и *B. vinogradovkaense* Gozhik, 2002, описанных из средне-понтических отложений Украины. Предлагается считать эти таксоны двумя отдельными, хотя и близкородственными вымершими видами. Стратиграфический диапазон *B. jalpuchense* расширен до нижнего понта. Все современные особи *Borysthenia* отнесены к *B. menkeana* (Jelski, 1863), поскольку они точно соответствуют лектотипу этого вида.

Ключевые слова: Valvatidae, *Borysthenia*, ископаемые и современные виды, морфология раковины, таксономия, южная Украина.