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Original scientific paper

Testing the validity of "dark data" on the Late Miocene freshwater cockles housed in the CNHM

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Abstract

Late Miocene freshwater cockles from the Croatian Natural History Museum (CNHM) were studied in order to recognize the size patterns within the population and reveal the possible subjective approach to the collecting process (size or preservation quality preferences). The most abundant taxa, *Tauricardium baraci* (Brusina, 1884), *Lymnocardium diprosopum* (Brusina, 1884), *L. inflatum* (Gorjanović–Kramberger, 1889), *L. majeri* (M. Hörnes, 1862), *L. riegeli* (M. Hörnes, 1862), *L. rogenhoferi* (Brusina, 1884), *Prosodacnomya vutskitsi* (Brusina, 1902) and *Pseudocatillus simplex* (Fuchs, 1870), from the localities: Okrugljak (SW Medvednica), Glogovnica (S Kalnik), Glogovac (Bilogora) and Kindrovo, were chosen for comparative studies. Relations between the length (L) and height (H) (=surface) and length (L)/height (H)/width (W) (=volume) values were calculated for each taxon and compared within a single species and within the cockle populations from the same locality. Calculations yielded the following results: (1) Volume (L/H/W) compared to surface (L/H) studies proved to be the better choice in population analyses; (2) size distribution values group independently of species dimensions, but can be well correlated within the finding-sites; (3) cockles from Bilogora-Kalnik area show normal value distribution, while all taxa from Okrugljak locality present a similar slight asymmetry of size distribution; (4) such distribution probably points to the different taphonomical processes in these two depositional basins. This research has proved that the CNHM Late Miocene cockle collections can be successfully studied from all paleontological aspects, even when field outcrops are no more available, because fossils were collected objectively, taking all available specimens from the site, regardless of their size or preservation quality.

Keywords: Lymnocardiinae; CNHM collection; biometry; Late Miocene; Croatia

1. Introduction

From the seventies to the present, paleoecology has gained more importance and more attention is given to the sampling methods and criterion, which effect diversity, or recording geographic and stratigraphic data. As a result, many older museum collections lack information that is valuable for modern paleobiological research (e.g., **Lawrence, 1971; Allmon, 2005**). The problem of museum collections has recently emerged and there are not many available studies that could resolve it, but can give a new perspective on the museum „dark data“ (**Marshall, 2018**). Because every collection is a case for itself, there is a need to carefully choose which data we want and can get from the chosen collections (e.g., **Dominici et al., 2020**).

Upper Miocene – Panonnian deposits are widely distributed in Northern Croatia (**Figure 1**) and comprise rich findings of freshwater Lymnocardiinae, also known as cockles (e.g. **Basch, 1990; Vrsaljko, 1999; Kovačić et al., 2004; Vrsaljko et al., 2005; Sebe et al., 2020; Magyar, 2021**). Majority of these cockle fossils are today housed in the Croatian Natural History Museum (CNHM). Considering the fact that the original outcrops are no longer available, we numerically analyzed the relations between the surface and volume measured values of the cockle shells housed in the CNHM, in order to study the best promising tool for the population analysis based on the museum collections. We tested the possible size sampling bias during the collecting work, wandering if the museum collection has stored only the biggest and best looking samples or does it include versatility. These results may affect further research and our ability to include the museum samples in the paleobiological studies.

Specimens for this research were chosen from three localities in Northern Croatia (**Figure 1**), which yielded so far the richest collections of cockle species housed in the CNHM. Analysis of these cockles is a part of the test model for A. Jarić Matanović PhD dissertation, where part of the Upper Miocene cockles from northern Croatia will be studied.

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Analyzed Lymnocardiinae were collected from the Upper Miocene – Pannonian – *Rhomboidea* beds at the Okrugljak locality, Bilogora and Kalnik area (**Figure 1**). Okrugljak locality is situated near Zagreb, the capital of Croatia, but outcrops are no longer available, due to the expansion of buildings and tram rails. Fossil cockles were mostly collected by **Brusina** (**1874, 1897, 1902**) and **Kiseljak** (**1889**). After exploring the Okrugljak area, I. Kiseljak in agreement and advised by S. Brusina, set out to explore the Glogovnica locality (Kalnik Mt.), which is the second analyzed locality in this paper (**Figure 1; Kochansky-Devidé, 1982**), described in **Poljak and Šuklje** (**1934**), with the age of fossils belonging to the Pannonian (after **Šimunić et al., 1990**). Third locality is Glogovac locality (Bilogora Mt.) (**Figure 1**), where **Šuklje** (**1933**) processed the coal mine macrofauna of fossil mollusks and concluded that their age is the upper Pannonian *Rhomboidea* beds. The latest revision on Lymnocardiinae from the CHNM collections was made by **Basch** (**1990**) and the results are included in this analysis.

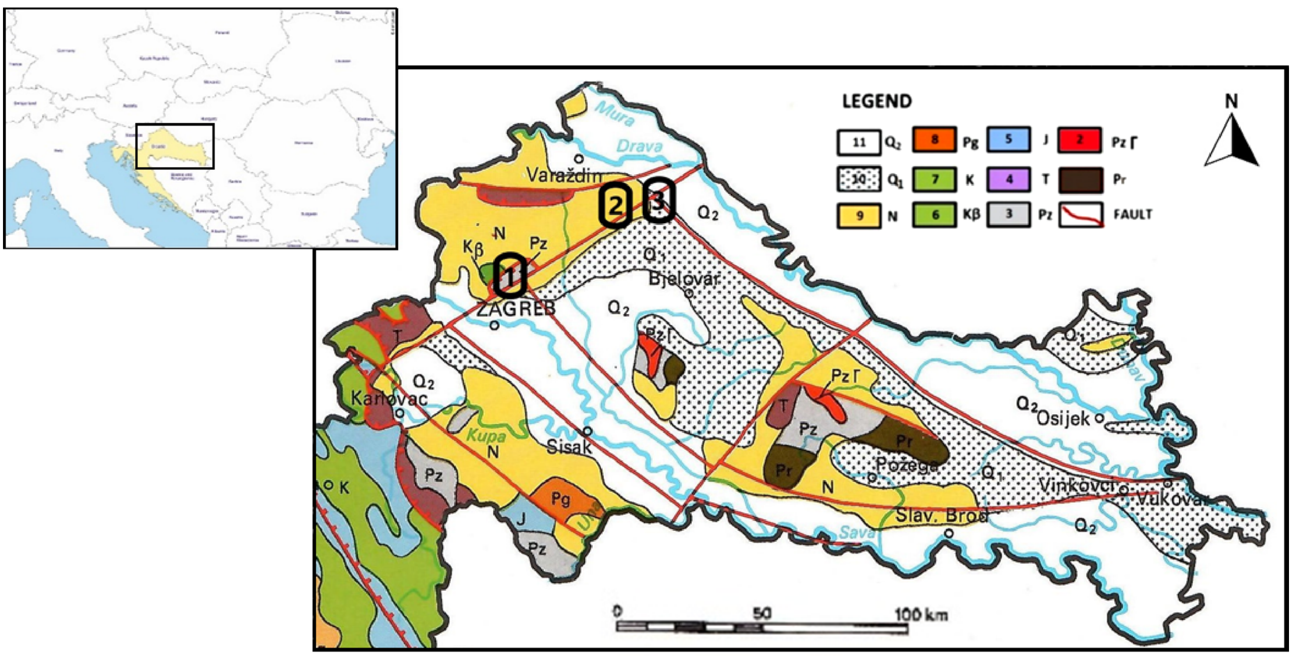

Figure 1: Geographic position of studied localities in Northern Croatia (modified after **Velić and Velić 1995**; https://d-maps.com/carte.php?num_car=2242&lang=en: 1. Okrugljak locality; 2. Glogovnica (Kalnik Mt.); 3. Glogovac Bilogora Mt.). Legend (after **Sremac et al., 2022**): 1. Precambrian metamorphic rocks; 2. Paleozoic granites; 3. Paleozoic sedimentary rocks; 4. Triassic carbonates, sporadically clastites; 5. Jurassic carbonates with scarce volcanoclastites; 6. Cretaceous dominantly carbonate rocks; 7. Cretaceous basalts; 8. Paleogene limestones; 9. Neogene clastic and carbonate rocks; 10. Pleistocene, dominantly unconsolidated clastites; 11. Holocene unconsolidated clastites.

2. Materials and methods

For the here presented numerical analysis, 402 fossil cockles from the CNHM collection were measured. Analyzed specimens include four species from Okrugljak locality, two species from Glogovnica locality, one species from Glogovac locality and one species from Kindrovo locality (**Table 1, Figure 1**). Specimens of *Pseudocatillus simplex* from Kindrovo were too fragile so they were excluded from the further analysis, although the number of specimens was sufficient. Species *Lymnocardium majeri* is also excluded from the numerical analysis, because most of the smaller specimens were stored in sealed tubes. For this occasion, these small specimens were not available for measurement, and the authors did not include this species further because the lack of smaller measurements would affect the analysis results.

CNHM Inventory number	Species	Number of specimens	Locality
83., 84., 85., 86., 87., 811., 813.	*Lymnocardium rogenhoferi* (Brusina, 1884)	34	Okrugljak
73., 74., 75., 76., 77., 78., 79., 80.	*Lymnocardium majeri* (M. Hörnes, 1862)	69	Okrugljak
63., 64., 65., 66., 67., 68., 69., 70., 71.	*Lymnocardium riegeli* (M. Hörnes, 1862)	145	Okrugljak
88., 89., 90., 816., 817.	*Tauricardium baraci* (Brusina, 1884)	52	Okrugljak
715., 716.	*Lymnocardium inflatum* (Gorjanović-Kramberger, 1899)	13	Glogovnica
748.	*Lymnocardium diprosopum* (Brusina, 1884)	25	Glogovnica
682., 683.	*Prosodacnomya vutskitsi* (Brusina, 1902)	41	Glogovac
1168., 1169., 1170.	*Pseudocatillus simplex* (Fuchs, 1870)	23	Kindrovo

Table 1: List of the analyzed Late Miocene cockles from the CNHM collection. Grey shaded rows show specimens which were not included in the analysis.

All cockle shells were measured for their length (L), height (H) and width (W) using a digital caliper (**Figure 2**). Each shell was categorized according to its state of preservation, ranging from (1) best preserved (all shell elements are visible and in good condition allowing the determination), (2) partly preserved cockles (part of the valve missing, but still allowing measuring), and (3) poorly preserved cockles (could not be measured or determined because of the incomplete preservation of the shell). There are grades in between numbers, for example 1 to 2 if there is a small piece missing, but all of the essential parts for determination are present; or 2 to 3 for cockles that are filled with sediment and the inner side of the shell is not visible. The measurements were made on samples belonging to categories 1 and 2.

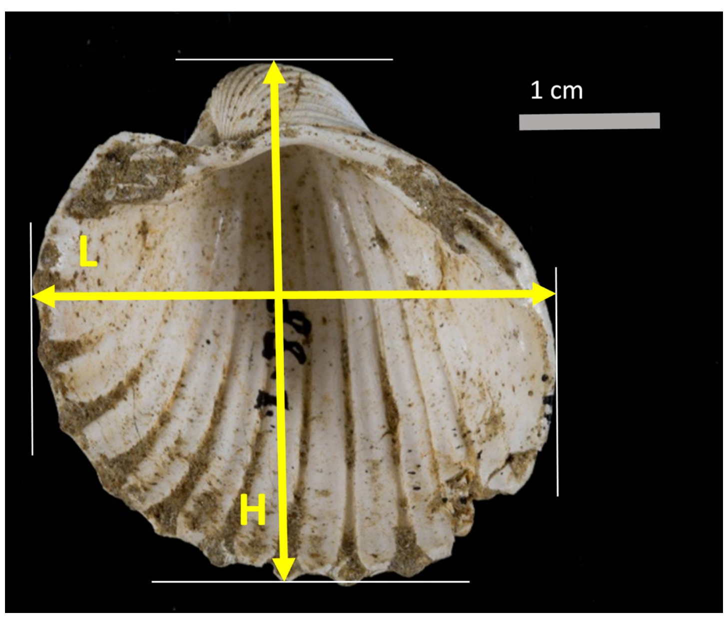

Figure 2: Measured elements on the analyzed cockles. L = shell length; H = shell height

From the measurements of shells, volume (V) was calculated by **Equation 1** and converted to dm^3 for better result visibility.

$$V = \frac{L * H * W}{1000} \tag{1}$$

Where are:
V = shell volume (dm^3),
L = shell length (mm),
H = shell height (mm),
W = shell width (mm).

From all measured shell volumes, average and standard deviation were calculated using the standard formulas in the Microsoft Office Excel. The Normal distribution is calculated by (**Equation 2**).

=NORM.DIST(Ax,Cx,Dx,FALSE) (2),

Where are:
NORM.DIST. – normal distribution,
A, C, and D columns included in the equation,
x – row number in wich the calculation is performed.

The result is shown in the form of a Bell Curve which was constructed on the resulting calculations of the Volume and Normal distribution in Microsoft Office Excel. Shell surface was calculated in order to portray the situations where samples could not be measured by hand, but only from photographs without the lateral view and therefore width could not be measured. These calculations were made using the **Equation 3**, and the results are divided by 100 so they would be in in the same range as the volume.

$$S = \frac{L * H}{100} \tag{3}$$

Where are:
S = shell surface (cm^2),
L = shell length (mm),
H = shell height (mm).

3. Results

The derived normal distribution of the shell volume and surface curves for measured cockles (**Table 1**) are shown in **Figures 3 and 4**. As it can be seen in **Figure 3**, shell volume bell curves have peaks in the middle or near the middle of the curve and a proper layout of the curve. This characteristic of the shell volume curve is present in species from all studied localities.

Looking at the normal distribution shell surface curve (**Figure 4**), there is a shift to the left in the bell curve of *Prosodacnomya vutskitsi*, and the species *Lymnocardium riegeli* is showing the better shaped bell curve than in the case of the shell volume curve (**Figure 3**). Other species are showing more or less similar shape of the shell surface curves (**Figure 4**), except the species *Tauricardium baraci* which is still shifted to the left.

Comparing the sampling locations by shell surface and volume curves, they cannot be linked (**Figures 1, 3 and 4**). In the Kalnik – Bilogora specimens these are slightly shifted to the right, but the curve itself has the same pattern of appearance. Specimens of *Lymnocardium diprosopum* and *Prosodacnomya vutskitsi* display a shift to the right, but *L. diprosopum* still kept the standard normal distribution curve appearance. Specimens of *L. inflatum* are similar to *L. rogenhoferi* resulting with a more prominent peak in the surface measurements. Okrugljak specimens have more diverse results than the Kalnik – Bilogora ones. Specimens of *Tauricardium baraci* are showing shell surface curve very similar to the volume, and for this purpose it can be considered as the same. Comparing shell surface results to volume, the Okrugljak samples of *Lymnocardium rogenhoferi* show a more prominent peak in the surface measurements, and *L. riegeli* shell surface has centered normal distribution curve (**Figures 3 and 4**).

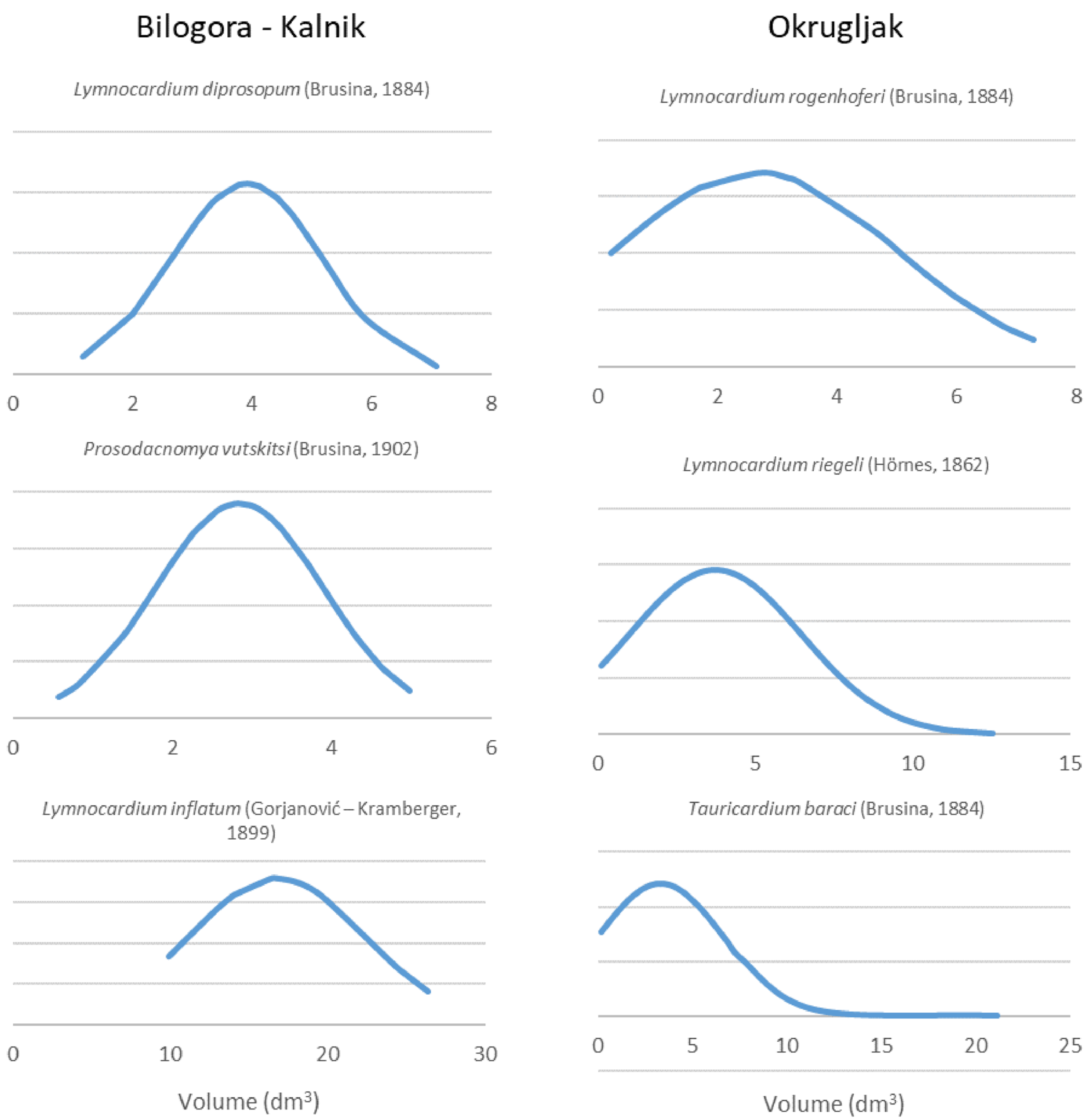

Figure 3: Normal distribution shell volume curves of Lymnocardiinae after **Table 1**

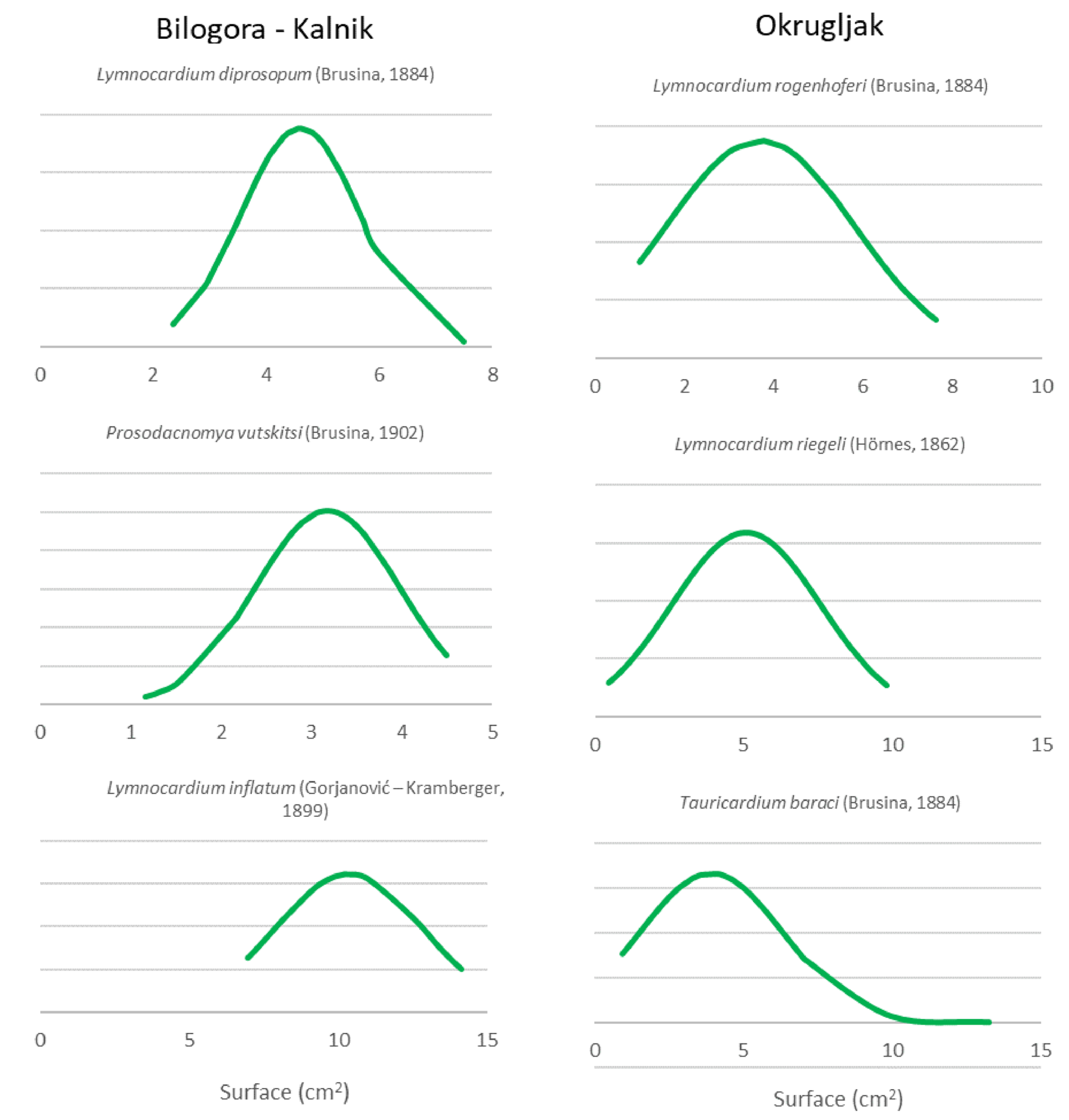

Figure 4: Normal distribution shell surface curves of Lymnocardiinae after **Table 1**

4. Discussion and conclusions

Lymnocardiinae bivalves belong to the Cardiidae family, named for rounded shells that are bilaterally symmetrical, and shaped like a heart when viewed laterally. There are numerous records of their findings in the Upper Miocene deposits (e.g. **Basch, 1990; Magyar et al., 1999; Müller et al., 2007; Sebe et al., 2020**). The Upper Miocene in the Croatian part of the Pannonian Basin is characterized by the isolation from the marine areas and by the formation of the long-lived brackish Lake Pannon (e.g., **Magyar et al., 1999; Pavelić and Kovačić, 2018**). The progradation of deltas from the north was the main force that was reducing the area of the Lake Pannon (e.g., **Magyar et al., 1999**). The youngest sediments deposited in the Lake Pannon are *Rhomboidea* beds, which can be found on elevated areas along the mountain massifs of Northern Croatia (**Figure 5**), that emerged from the Lake Pannon during one or more time intervals (e.g., **Basch, 2009; Sebe et al., 2020**). *Rhomboidea beds* covered a great part of Northern Croatia and include the here analyzed Okrugljak and Bilogora-Kalnik localities (Glogovnica and Glogovac) which belonged to the margins of the Lake Pannon (**Figures 1** and **5**).

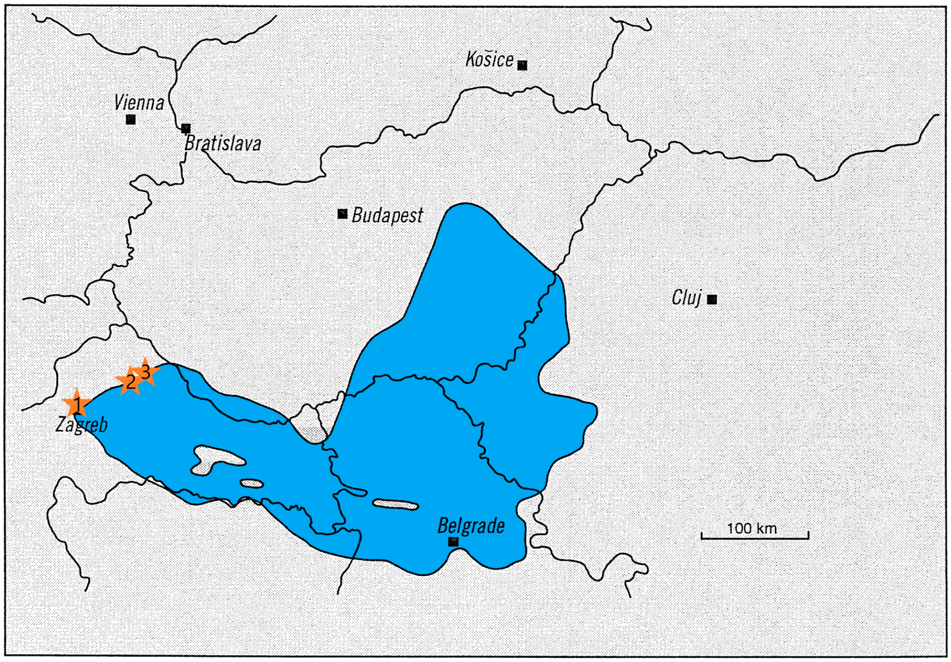

Figure 5: Distribution of the Lake Pannon deposits during the Upper Miocene – Rhomboidea beds, with marked localities presented in this paper (modifed after **Magyar et al., 1999**). Legend: 1 – Okrugljak locality; 2 - Glogovnica (Kalnik Mt.); 3 - Glogovac Bilogora Mt.).

In previous papers, Upper Miocene deposits of Northern Croatia were stratigraphically divided in the Pannonian and Pontian stages (**Figure 6**). After the study of **Mandic et al.** (**2015**), part of the Croatian geologists accepted the proposal to exclude the two-partite division (into the Pannonian and Pontian) and equalize the North Croatian Upper Miocene deposits with the single, Pannonian stage, keeping the division into the four fossiliferous horizons, including the here studied, youngest, *Rhomboidea* beds (e.g., **Mandic et al., 2015; Pavelić and Kovačić, 2018** and references therein), as shown in **Figure 6**.

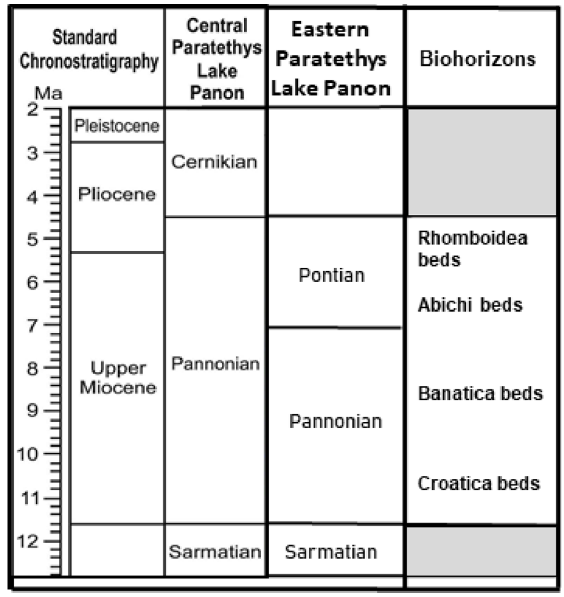

Figure 6: Chronostratigraphic divison of the Upper Miocene deposits in Northern Croatia (modified after **Pavelić and Kovačić, 2018; Sebe et al., 2020**)

At the end of the Pannonian (**Figure 6**), frequent regressions took place in some parts of the basin (**Šimunić et al., 1990**). Shallowing caused the formation of wetlands, with accelerated vegetation growth under the favorable climatic conditions. After the repeated terrain sinking and the deposition of new layers of clay and sand, lignite was formed from plants and other organic material (**Šimunić et al., 1990**). Unlike Okrugljak locality, Bilogora-Kalnik samples are located in the area where coal layers occur (**Šuklje, 1933**). **Burdon et al.** (**2014**) recognized a number of reasons for cockle mortality. Oxygen depletion and organic loadings could be one of the reasons for mass mortalities in cockles. This can be also suggested to the environmental conditions on the Bilogora – Kalnik coast (**Figure 5**). Frequent and sudden changes in the environment of Bilogora – Kalnik area are possibly the reason for the normal distribution shell volume and surface curves to be positioned in the center of the population (**Figures 3 and 4**). The lack of young individuals could be explained through, e.g., (1) oxygen depletion and organic loadings that could possibly have a greater impact on smaller individuals, which caused their mortality, and (2) of predators. Okrugljak specimens have Bell curves that are leaning to the left (**Figures 3 and 4**), which indicates a larger number of younger members of the community. That would suggest a lack of predators (**Burdon et al., 2014**) that did not impact the young population of cockles and generally favorable conditions that prevailed during the late Pannonian for freshwater cockles. Answer to the question of the lack of young individuals requires further research.

In order to get a complete picture of the appearance of the Lymnocardiinae, it would be advisable to measure their shell length (L), height (H) and width (W). Based on the here presented analysis, samples that include L, H and W in shell volume have normal distribution curves showing two distinct groups matching two different sampling localities (**Figure 3**). The Okrugljak samples show a shift to the left on the distribution curve, while Bilogora – Kalnik samples have a centered normal distribution curve. Surface measurements are practical for situations when there is no possibility to measure specimens by hand, but only from the photographs. Sometimes there are available photographs with all necessary views for complete measurement (anterior, posterior and lateral view), but there can also be photographs showing only the anterior and posterior views, without the lateral view disabling the width measurement. Further research is needed to understand what caused the population differences in the studied locations, which were rather closely situated at the western coast of the Lake Pannon.

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Sažetak

Testiranje valjanosti muzejskih podataka o gornjomiocenskim slatkovodnim srčankama iz fundusa HPM-a

Gornjomiocenske slatkovodne srčanke koje se čuvaju u fundusu Hrvatskoga prirodoslovnog muzeja (HPM) proučavane su kako bi se prepoznali uzorci veličine unutar populacije i otkrili mogući subjektivni pristupi procesu sakupljanja fosilnog materijala na terenu (preference veličine ili kvalitete očuvanja). Najbrojnije vrste, *Tauricardium baraci* (Brusina, 1884), *Lymnocardium diprosopum* (Brusina, 1884), *L. inflatum* (Gorjanović–Kramberger, 1889), *L. majeri* (M. Hörnes, 1862), *L. riegeli* (M. Hörnes, 1862), *L. rogenhoferi* (Brusina, 1884), *Prosodacnomya vutskitsi* (Brusina, 1902) i *Pseudocatillus simplex* (Fuchs, 1870), s lokaliteta: Okrugljak (JZ Medvednica), Glogovnica (J Kalnik), Glogovac (Bilogora) i Kindrovo, odabrani su za komparativnu analizu. Odnosi između vrijednosti duljine (L) i visine (H) (= površina) i duljine (L)/visine (H)/širine (W) (= volumen) izračunati su za svaku vrstu i uspoređeni unutar jedne vrste i unutar populacije srčanki s istog lokaliteta. Proračuni su dali sljedeće rezultate: (1) Volumen (D/H/W) u usporedbi s površinom (D/H) se pokazao kao bolji izbor u populacijskim analizama; (2) vrijednosti raspodjele veličine grupiraju se neovisno o dimenzijama vrste, ali mogu biti dobro povezane unutar nalazišta; (3) srčanke s Bilogorsko-Kalničkog područja pokazuju normalnu raspodjelu vrijednosti, dok sve vrste s lokaliteta Okrugljak imaju sličnu blagu asimetriju distribucije veličine; (4) takva raspodjela vjerojatno ukazuje na različite tafonomske procese u ova dva taložna bazena. Ovo istraživanje je pokazalo da se gornjomiocenske srčanke iz muzejskih zbirki mogu uspješno proučavati sa svih paleontoloških aspekata, čak i kada terenski izdanci više nisu dostupni, jer su fosili prikupljeni objektivno, uzimajući sve raspoložive primjerke s lokaliteta, bez obzira na njihovu veličinu ili kvalitetu očuvanosti.

Ključne riječi: Lymnocardiinae, zbirka HPM-a, biometrija, gornji miocen, Hrvatska

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Author’s contribution

Anja Jarić Matanović (PhD student) provided the shell measurements, suggested the first concept of the paper and prepared the manuscript and presentation of the results. **Marija Bošnjak (Dr.sc., senior curator, geology, paleontology, geomathematics)** prepared and provided the Lymnocardiinae specimens for measurement, contributed in conceptualization and participated in writing, reviewing and editing of manuscript. **Jasenka Sremac (Dr.sc., Full Professor, retired, geology, paleontology, paleoenvironment)** provided the conceptualization and methodology of the paper and participated in writing, reviewing and editing of manuscript.