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The variation of some qualitative and quantitative characteristics of shells of *Arianta arbustorum* (LINNAEUS 1758) (Stylommatophora: Helicidae, Ariantinae) from Bosnia and Herzegovina.

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Zusammenfassung

Nach den ersten Funden einzelner Individuen von *Arianta arbustorum* (LINNAEUS 1758) wurde im Gebiet von Bosnien und Herzegowina (KOTROŠAN 2001) die übliche Variation der Art festgestellt, aber nur an einer kleinen Zahl (11 juvenile und 12 adulte Schalen). Deshalb wurde in dieser Arbeit eine etwas präzisere Analyse mit statistischen Methoden durchgeführt. Es wurden auch einzelne morphologische (und statistische) Angaben über die synchronen Veränderungen der ausgewählten morphologischen Charaktere von einigen Populationen aus dem Gebiet der Städte Sarajevo und Visoko (Bosnien und Herzegowina) präsentiert.

Abstract

When *Arianta arbustorum* (LINNAEUS) was first found in Bosnia and Herzegovina (KOTROŠAN 2001), the analyzed specimens displayed a normal variation, although the number of examined individuals was small (11 immature and 12 adult individuals). At this time a detailed study was carried out over a statistically relevant sample. More precise morphological (and statistical) data were presented, relating to the variation of specific morphological characteristics of the above mentioned species, gathered from several populations found in areas of Sarajevo and Visoko (Bosnia and Herzegovina). The results are presented in this article.

Introduction

Arianta arbustorum (LINNAEUS 1758) is a widespread species of land snails, whose shells have highly variable morphological characteristics (shape, color, size - BAMINGER 1997). This species also shows a high degree of adaptation to different life conditions such as type of habitat and altitude. Some of its known habitats include deciduous forests, humid meadows, rocks, and gardens with altitudes of up to 2,700 m above sea level (FECHTER & FALKNER 1990, SCHLESCH 1921).

The species has shown a variation in morphological characteristics of its shell, and numerous subspecies and varieties have been described. For example, according to a list made for Austria (REISCHÜTZ 1998) the following subspecies are known: *Arianta arbustorum arbustorum* (LINNAEUS 1758); *A. a. styriaca* (KOBELT 1876); *A. a. alpicola* (A. FERUSSAC 1821); *A. a. picea* (ROSSMÄSSLER 1837). However, it is necessary to emphasize that there are different arguments regarding the status of the subspecies. This problem became especially obvious after certain combined population and morphological studies (BISENBERGER 1993). The individual subspecies were hence determined according to the statistical analysis of the degree of variation of the selected morphological characteristics.

The available literature offers various data on the distribution of *Arianta arbustorum* (LINNAEUS). However, when comparing these data, it is possible to conclude that the species occurs in central, western and northern Europe (including Iceland) and the Carpathian Mountains (BENTHEM-JUTTING 1933; BAMINGER 1997; LIKHAREV & RAMMELMEYER 1952; PFLEGER 1984; ZILCH 1960). But for a long time literature has also offered conflicting data on the species' distribution in the Balkans. The discovery of the species in Bosnia and Herzegovina resolved this issue and confirmed the distribution of *Arianta arbustorum* (LINNAEUS) in this region (KOTROŠAN 2001; KOTROŠAN & al. 2001).

In Bosnia and Herzegovina this species has been found in several localities at lower altitudes (up to 600 m above sea level) in the towns of Sarajevo and Visoko. Searches at the Igman and Bjelasnica Mountains and the town of Konjic were not successful. Therefore it is not possible to present an exact distribution of *A. arbustorum* in Bosnia and Herzegovina (KOTROŠAN 2001; KOTROŠAN & al. 2001).

In addition the research has also included the appropriate analysis of variation of individual morphological characteristics. This primarily focused on examining the individual shells of *Arianta arbustorum* (LINNAEUS). The obtained data correspond to the already known variation (KOTROŠAN 2001; KOTROŠAN & al. 2001).

Material and methods

In the period between August 1997 and August 2001 97 shells of *Arianta arbustorum* (LINNAEUS 1758) were collected at several localities in central Bosnia and Herzegovina. The analyzed sample included 13 immature and 84 adult shells (tab. 1).

Tab. 1: An overview of the collected individuals of *Arianta arbustorum* (LINNAEUS 1758) at some localities in central Bosnia and Herzegovina.

Locality	Date	Number of collected shells	Legator and determinator
Ilidža	08.1997	11 immature	S. Lelo, M. Mačkić – D. Kotrošan
Buća Potok – Sarajevo	05.1998	6 adults	S. Lelo – D. Kotrošan
Visoko	05.2000	6 adults	S. Lelo – D. Kotrošan
Ilijaš	05.2001	31 adults	S. Lelo
Bojnik, Stup – Sarajevo	04.2001	41 adults	A. Krunić – S. Lelo
Bojnik, Stup – Sarajevo	08.2001	2 immature	A. Krunić – A. Krunić

In order to analyze the variation of adult individuals within the observed population of *Arianta arbustorum* (LINNAEUS) the following quantitative and alternating characteristics of the shells were examined:

Quantitative characteristics:
Shell height – span between the top of the shell and the lowest point of the mouth's lip when the shell is in its basic position;
Shell breadth – maximal breadth of shell between the extreme lateral point of the last whorl and the lateral point of the mouth's lip when the shell is in its basic position;
Mouth height – maximal height of shell's mouth measured between the highest and the lowest point of the mouth's lip;
Mouth breadth – maximal breadth of the shell's mouth measured between two of the most lateral points;
Shell shape – ratio of shell height and shell breadth. A low ratio indicates a flat shell shape and a high ratio indicates a globular shell;
Number of whorls – counted according to KERNEY & CAMERON, 1979; with accuracy up to the eighth part of the whorl.

Qualitative characteristics:
Color of shell – the color shade for each shell was analyzed by direct comparison of the collected material, followed by comparison with available data from literature;
Surface shell drawing – analyzed with direct comparison of the collected material and by comparison with data from literature;
Umbilical form – estimated from open to close;

Shell height and shell breadth as well as the height and breadth of mouth were measured with a vernier calliper to the nearest 0.5 mm. Qualitative characteristics were analyzed with a magnifying glass (magnifying up to 4x).

The applied methods of variation-statistical analysis:
The basic statistic parameters were obtained according to MARINKOVIĆ & al. 1982, and PETZ 1964:

- average (arithmetic mean) (X)

$$X = \frac{\sum x}{N};$$

- variance (s^2)

$$s^2 = \frac{\sum (x_i - x)^2}{N - 1};$$

- standard deviation (S)

$$S = \sqrt{s^2};$$

- standard error of arithmetic mean (SX)

$$SX = \sqrt{\frac{s^2}{N}};$$

- coefficient of variability (V%)

$$V\% = \frac{100 \cdot S}{x},$$

Results and discussion

The analysis of quantitative characteristics of the shells of *Arianta arbustorum* (LINNAEUS) showed a wide span of variation for each of the observed features. The shell height varied from low (11.5 – 14.9 mm), medium (15.0 – 18.4 mm) to high (18.5 – 22.0 mm). It was observed that the medium high shell was the most frequent phenotype variant. The variation span of shell breadth was grouped into two classes: narrow (18.0 – 22.4 mm) and wide (22.5 – 27.0 mm), although the individuals with wide shells dominate the sample. The height and breadth of the mouth were also conditionally split into two phenotypes: low (10.0 – 11.8 mm) and high (11.9 – 13.5 mm); i.e. narrow (11.0 – 13.8 mm) and wide (13.9 – 16.5 mm) mouth. The analysis of shell shape, as the last analyzed quantitative characteristic, showed a quite wide degree of variation. This enabled a clear division of this characteristic into two phenotype variants: flat (24.2 – 39.6 mm) and globular (39.7 – 55.0 mm). The precise count of whorls on the shell showed a variation span from 5.00 to 5.75 whorls (tab. 2).

The shell color in the observed sample varied from light-brown to dark-brown, while the surface shell drawing varied to a greater extent, and as many as six different variants were registered. The variations of this characteristic spanned from strong vertical lines without fleckings and without a visible horizontal band (variant 1) to strong vertical lines with small light-brown fleckings and a visible horizontal band (variant 6). Due to damage or ageing of the material, it was not possible to establish color and surface shell drawing on three shells. The analysis of umbilicus form showed the existence of two phenotype variants: a closed and a partially open umbilicus, where the latter variant was more frequent (tab. 2).

Further, as a precondition to counting the basic statistic parameters of observed characteristics, it was necessary to carry out an increasing numeration, i.e. the quantification of variants of quantitative characteristics, according to the presence of a certain pigment or the development of a certain shape (such as umbilicus form) (tab. 3)

Tab. 2: Analyzed characteristics on the shells of *Arianta arbustorum* (LINNAEUS) with an overview of phenotype variants.

Characteristic		Mark	Phenotype variant
Quantitative	Shell height	Low	11.5 – 14.9 mm
		Medium	15.0 – 18.4 mm
		High	18.5 – 22.0 mm
	Shell breadth	Narrow	18.0 – 22.4 mm
		Wide	22.5 – 27.0 mm
	Mouth height	Low	10.0 – 11.8 mm
		High	11.9 – 13.5 mm
	Mouth breadth	Narrow	11.0 – 13.8 mm
		Wide	13.9 – 16.5 mm
	Number of whorls	-	5.00 – 5.75
	Shell shape	Flat	24.2 – 39.6
		Globular	39.7 – 55.0
Qualitative	Color of a shell	1	Light-brown
		2	Dark-brown
	Surface shell drawing	1	Only vertical lines are present
		2	Vertical lines are present, with small lighter light-brown fleckings, without a horizontal band
		3	Vertical lines are present, with small light-brown fleckings, without a horizontal band
		4	Vertical lines are present, without fleckings, but a horizontal band is visible
		5	Vertical lines are present, with small lighter light-brown fleckings, and a horizontal band is visible
		6	Vertical lines are present, with small light-brown fleckings, and a horizontal band is visible
	Umbilical form	1	A partially opened umbilicus
		2	A closed umbilicus

Tab. 3: An overview of variation of selected qualitative and quantitative characteristics on the shells of *Arianta arbustorum* (LINNAEUS) (n = 84)

Characteristic	Basic statistic parameters				
	Min	Max	X	S_x	V%
Shell height	11.50	22.00	17.80	0.02	15.49
Shell breadth	18.00	27.00	22.62	0.02	13.28
Mouth height	10.00	13.50	11.59	0.01	6.30
Mouth breadth	11.00	16.50	13.53	0.01	8.54
Number of whorls	5.00	5.75	5.25	0.02	3.42
Shell shape	2.42	5.50	4.05	0.07	15.31
Color of shell	1.00	2.00	1.28	0.05	35.08
Surface shell drawing	1.00	6.00	2.78	0.16	51.19
Umbilical form	1.00	2.00	1.39	0.06	30.86

The statistic analysis showed that within the observed characteristics, the surface shell drawing was the most variable characteristic (V% - 51.19), while the number of whorls was the most stable characteristic (V% - 3.42) (tab. 3).

Comparing the obtained data with that from available literature primarily showed that the approach to analyzing specific characteristics of this and other species significantly varies from author to author. For example, in his study, H. BAMINGER determines the shell height and breadth to 0.1mm, while he analyses the openness of the umbilicus by using ten phenotype variants spanning from 10% to 100% (BAMINGER 1997; KOTHBAUER & al. 1991)!? Nevertheless, by comparing the obtained values with the specific values from other studies (KOTROŠAN 2001) one can conclude that the variation spans of shell height (11.5-**17.18**-22.00) and breadth (18.0-**22.62**-27.00) are notably wide, but they do not go beyond the lowest and the highest cited values (10.0-23.0, i.e. 10.0-32.0; PFLEGER 1984; LIKHAREV & RAMMELMEYER 1952; ZILCH 1959 – according to KOTROŠAN 2001). The data available in literature on the height and breadth of mouth are rather poor, so one may only conclude that the values recorded in this study are higher in comparison to those obtained in previous studies: height of mouth, 10.0–**11.59**–13.50, breadth of mouth, 11.0-**13.53**-16.50. In most studies the shell color is described as lighter or darker brown, so it is possible to say that these data (1.00-**1.28**-2.00) also match the data available in literature. The comparison of obtained data of surface shell drawing with data in literature clearly shows a greater variation span of this characteristic: 1.00-**2.78**-6.00. It can be said however, that even in this case it is more of a question of an in-depth analysis of this characteristic rather than a wider variation span, namely, surface shell drawing in the population of this species consists of three possible combined details, which should not be neglected: small vertical lines, dark horizontal band and light brown fleckings. The observed numbers of whorls, i.e. the span of their variation, exactly matches the data available in literature: 5.00-**5.25**-5.75 (KERNEY & CAMERON 1979). The umbilicus form was analyzed in a notably simpler way than was the case in some other studies, but the obtained data were sufficient to conclude that the noted variation span (1.00-**1.39**-2.00) is within the limits of variation present in literature. Data on shell shape were not previously assessed by any authors, therefore the results obtained in this study represent a small contribution to the general description of this species 2.42-**4.05**-5.50.

After a precise analysis of a list of testaceological characteristics of this species one can conclude that the region of Bosnia and Herzegovina is inhabited by the typological subspecies *Arianta arbustorum arbustorum* (LINNAEUS 1758).

Conclusions

- The region of Bosnia and Herzegovina is inhabited by the typological subspecies *Arianta arbustorum arbustorum* (LINNAEUS 1758).

- The analysis of 84 individuals of the metapopulation of *Arianta arbustorum* (LINNAEUS) from the area of Sarajevo and Visoko showed a wide variation span of a list of observed characteristics (somewhat wider in comparison to earlier preliminary studies), but the total description of the metapopulation almost exactly matches the available data on the species in literature. The exception is the variation of the surface shell drawing.

- The analysis of the selected quantitative and qualitative characteristics on the shells of individuals of the species *Arianta arbustorum* (LINNAEUS) showed the following variation span:

shell height: 11.5-**17.18**-22.00
shell breadth: 18.0-**22.62**-27.00
mouth height: 10.0-**11.59**-13.50
mouth breadth: 11.0-**13.53**-16.50
shell shape: 2.42-**4.05**-5.50
number of whorls: 5.00-**5.25**-5.75
color of shell: 1.00-**1.28**-2.00
surface shell drawing: 1.00-**2.78**-6.00
umbilical form: 1.00-**1.39**-2.00

- The statistic analysis also showed that within the observed characteristics the surface shell drawing was the most variable characteristic (V% - 51.19) while the number of whorls was the most stable characteristic (V% - 3.42).

Fig. 1: Selection of *Arianta arbustorum* from Bosnia and Herzegovina (Foto: Drazen Kotrosan)

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