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SPECIES COMPOSITION OF SHELL MOLLUSKS OF THE BREST FORTRESS (BELARUS)

On the territory of the Brest Fortress 16 species of land mollusks were found. The largest species diversity of the mollusks in the fortress is characterized by the areas with woody vegetation. A high degree of difference is observed between the species composition of sites with meadow and woody vegetation. It was established that the distribution of mollusks throughout the citadel is influenced by such factors as soil cover density, type of soil cover and type of litter.
Key words: *Mollusca, Gastropoda, Species composition, Brest Fortress, Belarus*

Introduction. At present, much attention is paid to the study of the malakofauna of fortresses in Europe. On the one hand, ditches with water and walls around the fortress serve as obstacles when invertebrates species are resettled on its territory. This is the reason for the low species diversity in their territory (Jǔričková&Kučera, 2005) and gives reason to compare the fortresses by the nature of the formation of fauna with the islands (Giller, 1984). On the other hand, a wide range of living conditions can form inside the fortress. It is created due to the presence in the relatively small territory of the fortress of buildings, meadows and tree plantings. Some of these facilities may be abandoned. A large number of stones and bricks near the abandoned buildings leads to the enrichment of the soil with calcium.

The combination of the above factors makes the fortresses an especially interesting object for studying the problems of forming communities of terrestrial mollusks.

Due to the isolation of the fauna, and the variety of living conditions, the territory of the fortress, in our opinion, can serve as a model for the interaction between fauna of ecosystems of various types, for example, wet and mesophilic. Using the example of the fortress, one can also study the process of invertebrate migration between the actively exploited sections of the urban landscape and the wastelands, thickets of trees and bushes in contact with them. Such combination of controlled and uncontrolled territories can occur, for example, on the border between the field and the edge of the forest, between the center of the park and its outskirts, or between the floodplain of the river, in the city and other urban areas adjacent to it.

Materials and methods. The material was collected in the spring of 2016 at 40 points located inside the Citadel of the Brest Fortress and Kobrin fortifications. The collection of mollusks was carried out according to the generally accepted methodology.

The comparison of the degree of species exchange between different territories of the fortress was carried out according to the species lists, using the Chekanovsky–Serensen index:

$$K_{CS} = \frac{2C}{a+b}$$

Where *C* – is the number of common species in the two lists, a and b – are the number of species at each point.

Species diversity was assessed using the Shannon–Weaver diversity index 2:

$$H^{'} = \frac{1}{N}\left[N\ln(N) - \sum n_i \ln(n_i)\right]$$

Where H′ – is Shannon index; N – is the total number of all species; n – is the number of the i–th species.

The classification of the studied points according to the features of the species composition of the mollusks was carried out using the cluster analysis. The points were grouped in Euclidean distance by nearest neighbor method.

To determine the factors affecting the distribution of mollusks on the territory of the Brest Fortress, an ordination analysis was used. The influence of both quantitative and qualitative factors was analyzed. Both ordination and cluster analysis were carried out using the PAST software (Georgiev, 2008).

As quantitative factors were considered, such as:

- The density of the tree cover;
- The density of the ground cover;
- The slope steepness;
- The ratio of deciduous and coniferous species in the forest stand;

The severity of each of these factors was evaluated in percent, on the scale that includes five categories of severity: 0–20%, 20–40%, 40–60%, 60–80%, 80–100%.

As qualitative, factors such as were processed:

- The type of the ground cover: No cover – Mossy – Low grass – High grass – Forbs;
- The type of litter: No litter – Sod – Coniferous – Sod–mossy – Deciduous;
- The presence of branches and windbreak: No branches – Small branches – Pieces of bark – Large branches – Lying logs;

Description of the collection points. On the territory of the fortress, the areas with both moderate and high degree of moisture were investigated. In general, meadow vegetation on the territory of the Brest Fortress is represented by *Poa pratensis* L. and *Lolium spp.*As well as *Calamagrostisepigejos*Roth.*Poa pratensis* and*Lolium spp.* form the vegetation of the grassplots and lawns, and *Calamagrostisepigejos* – plots near the abandoned buildings. In the woody vegetation, *Carpinusbetulus* L., *Acer pseudoplatanus* L., *Acer negundo, Salix spp., Alnusglutinosa*L. prevail.

To classify the studied sites, we used our own previously developed classification, taking into account the type of vegetation and the degree of human exposure (Zemoglyadchuk, 2004).

To determine the area of the vegetation of various types, the satellite images of the territory of the Brest Fortress, obtained from the Google Maps service, were used. The analysis of these images was carried out using QGIS GIS software.

Geobotanical description of the vegetation in the studied areas is given below.

1. **The Areas with a predominance of *Carpinusbetulus*.** They are formed, first of all, on the earthen ramparts of the fortifications. In the tree layer of such sites, *Carpinusbetulus*, *Acer pseudoplatanus*, predominate, and in the grass cover – *Glechomahederacea*, and *Urtica dioica*. Due to the fact that seasonal harvesting of fallen leaves and branches was carried out in the hornbeam thickets, these territories were assigned by us to controlled tree stands (Zemoglyadchuk, 2004). The area of these sites is 7,3% of the investigated area of the Brest Fortress.

2. **The plots with mesophilic meadow vegetation.** Such sites are formed at the foot of the earthen ramparts of the fortifications and on the ruins of the buildings. In the grass cover in such areas *Oenotherabiennis*, *Calamagrostisepigejos*,*Anthriscus sylvestris*, *Taraxacum officinale*, and *Achilleamillefolium* L. predominate on the grass. In addition, there may be a scrub of *Acer negunda* L. We assigned these sites to uncontrolled mesophilic meadows (Zemoglyadchuk, 2004). The meadows of this type are most common in the Brest Fortress. Their area is 19.2% of the area of the investigated territory of the fortress.

3. **The meadows along the river Mukhovets.** In the grass cover of these meadows-*Dactylisglomerata* L. and *Poa pratensis* prevail. We assigned these sites to uncontrolled wet meadows (Zemoglyadchuk, 2004). The area of these meadows is small and amounts to 2.5% of the investigated area of the fortress.

4. **The areas with the predominance of the *Alnusglutinosa*and *Salix spp.*** These type of areas are formed along the banks of the river. Mukhovets. In the grass cover of such sites, *Urtica dioica, Glehomahederacea*, *Arctium lappa* L., and *Geumrivale* prevail. Due to the fact that deciduous leaves and branches are not removed from the territory of these plots, we assigned these territories to uncontrolled tree plantations (Zemoglyadchuk, 2004). The area of these sites is 2.8% of the investigated area of the fortress.

5. **The lawns** were assigned by us to the controlled upland meadows (Zemoglyadchuk, 2004). In the grass cover of the studied lawns *Poa pratensis* and *Loliumspp* prevail. The area of these sites is 4.7%.

Results and discussion.On the territory of the fortress, 16 species of terrestrial mollusks from 12 families and 14 genus were found (table 1).

Table 1.

Species composition and abundance of terrestrial mollusks in the studied types of territories of the citadel of the Brest Fortress

Family	Species	Ecological group	Typeoftheterritory				
			Wetmedows	Drymedows	lawns	Alnusglutinosaforests	Carpinusbetulusforests
Endodontidae	*Punctumpygmaeum* Drap. 1801	m	0	0,86±0,71	0	0,15±0,15	0,03±0,03
Pupillidae	*Pupillamuscorum* L.	m–x	0	1,83±1,55	0	0,26±0,26	0,07±0,07
Vertiginidae	*Vertigosubstriata*Jeffr, 1830	m	0,25±0,25	0,31±0,30	0,20±0,15	0	0
	*Truncatellinacylindrical*Ferussac, 1807	m–x	0	1,23±1,16	0,80±1,31	0	0
Helicidae	*Helixlutescens*-Rossm. 1837	m–x	0	0,38±0,30	0	0,33±0,33	0,17±0,11
Bradybaenidae	*Bradybaenafruticum*	m	0	0,69±0,63	0	2,44±2,40	4,17±3,46
Hygromiidae	*Trichiahispida* L.	m	1,00±1,00	1,08±0,59	0	3,56±3,51	3,33±3,27
Ellobiidae	*Carychiumminimum*	p	1,00±0,82	0	0	0	0
Succineidae	*Succinea putris* L.	p	1,75±1,26	0,23±0,20	0	0,56±0,53	0,33±0,32
Vitrinidae	*Vitrinapellucida*Mull. 1774	m	0	0,62±0,50	0,20±0,15	0,22±0,22	0,33±0,32
Valloniidae	*Valloniapulchella* Mull. 1774	m	0,50±0,50	0,69±0,50	1,00±0,73	0,11±0,11	1,50±1,46
	Valloniacostata Mull. 1774	m	0	5,00±5,00	0	2,22±2,00	0,33±0,33
	*Valloniaenniensis*Gredler, 1856	m	0	2,23±1,83	1,80±1,80	1,78±1,33	0
Cochlicopidae	*Cochlicopalubrica* Pilsbry, 1900	p	2,50±2,38	2,23±2,15	0	6,00±5,58	1,67±1,37
Zonitidae	*Nesovitreahammonis*	m	0	1,23±1,20	0,20±0,20	0	1,33±1,27
	*Zonitoidesnitidus*Mull. 1774	p	1,00±1,00	0,08±0,08	0	2,00±2,00	1,67±1,67

Note: m – mesophilic species; **p** – psychrophilic species; **m–x** –meso– xerophilic species;

It should also be emphasized that a new species of mollusk, *Valloniaenniensis*, was found on the territory of the Brest Fortress.

The largest number of species found on the territory of the Brest Fortress (13 species) are the inhabitants of the litter, among which there are both mesophilic (8 species) and psychrophilic (3 species), and meso– xerophilic (2 species) mollusks.

The largest numbers (3.84–7.25 ind./25cm^2) throughout the Brest Fortress are characterized by such mollusk species as *Trichiahispida, Cochlicopalubrica, Nesovitreahammonis, Valloniacostata, Valloniaenniensis.*

A significant degree of faunistic similarity was found in the species composition of terrestrial mollusks of garbage, black alder and upland meadows (89–92%), which indicates the faunistic unity of these territories (table 2). This is explained by the fact that in the conditions of the fortress there are adjacent small areas with

wood and tall grass meadow vegetation. For example, the width of plantings of black alder and willow along Mukhovets is 40–50 meters, and the width of thickets of American maple on the fortifications is 60–90 meters. The tree plantations are separated from each other by the sections of the meadow 100–200 meters wide.

Table 2.

The degree of faunistic similarity of the studied types of the territories

	fm	hgm	l	anch	hcts
fm	1	0,55	0,31	0,53	0,53
hgm		1	0,57	0,89	0,89
l			1	0,33	0,33
anch				1	0,92
hcts					1

Note: l – lawns; **hgm** – high–grassy meadows; **fm** – floodplain meadows; **hcts** – human–controlled tree stands; **anch** – areas not controlled by humans with woody vegetation.

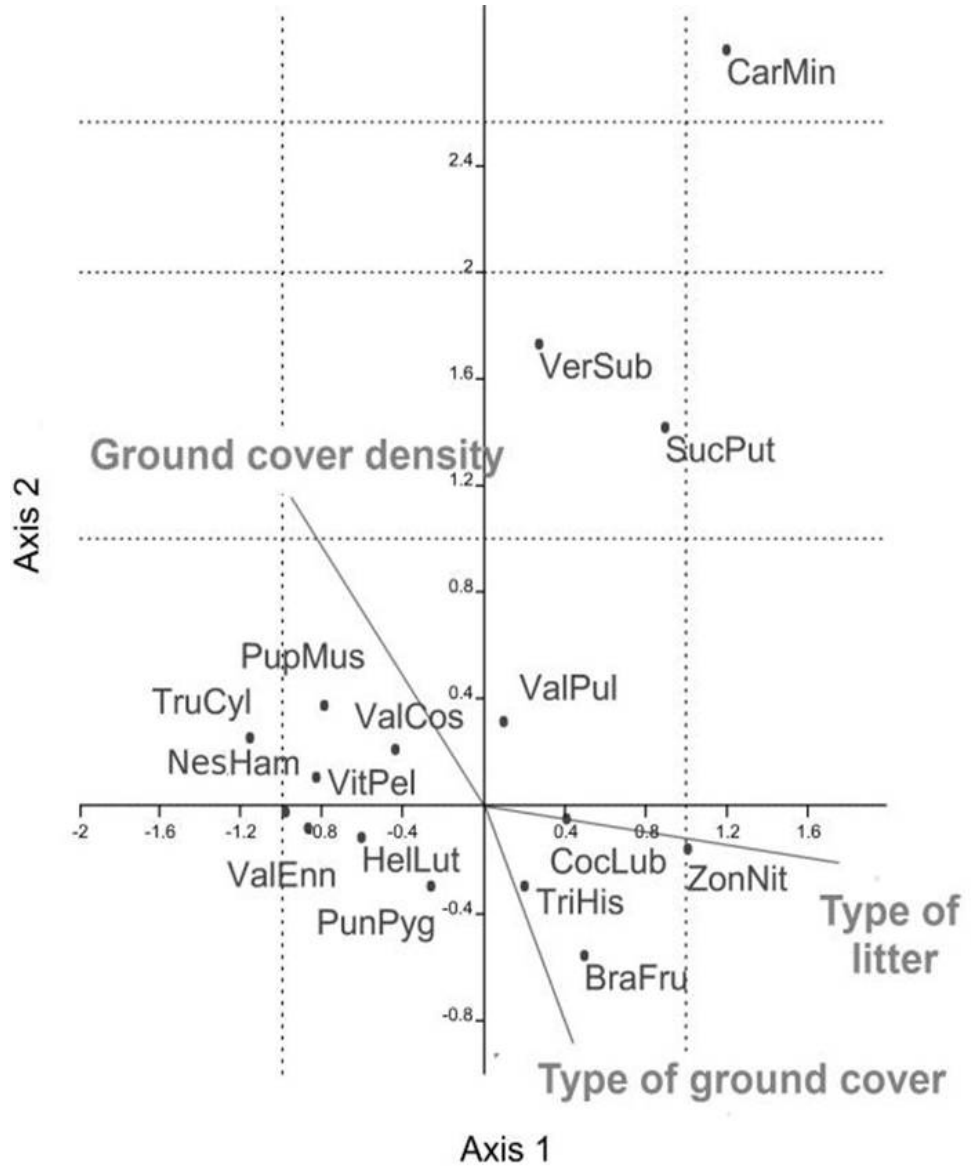

Figure 1. **Distribution of terrestrial mollusks in the gradient of the factors considered**

Note: CarMin – *Carychium minimum*; VertSub – *Vertigo substriata*; SucPut – *Succinea putris*; ValPul – *Valloniaulchella*; ValCos – *Valloniacostata*; ValEnn – *Valloniaenniensis*; PupMus – *Pupillamuscorum*; TruCyl – *Truncatellina cylindrical*; NesHam – *Nesovitreahammonis*; VitPel – *Vitrinapellucida*; HelLut – *Helix lutescens*; PunPyg – *Punctumpygmaeum*; CocLub – *Cochlicopalubrica*; TriHis – *Trichiahispida*; ZonNit – *Zonitoidesnitidus*; BraFru – *Bradybaenafruticum*;

The relatively small area of the sites with the different types of vegetation facilitates the penetration of humid black alder species into the fauna even by such typically meso–xerophilic species as *Pupillamuscorum* and *Helix lutescens* (Figure 1). In turn, the fauna of mesophilic hawks is enriched with such moisture–loving species as *Succinea putris* and *Zonitoidesnitidus.*

The species composition of terrestrial mollusks of the floodplain of the Mukhovets River, on the contrary, is characterized by a relatively low degree of faunal similarity with other territories (31–57%). It is assumed that the reason for such isolation of the sites with moisture–loving vegetation of the floodplain are lawns and footpaths. They separate a narrow strip of floodplain from other territories of the fortress and act as obstacles for the free settlement of mollusks.

The lawns are characterized by the poor fauna of the terrestrial mollusks (6 species) and are inhabited by the small species that can find refuge in conditions where the grass is cut short and practically does not form turf. As a result, among the mollusks inhabiting the lawns, the extinction of species quite common in the meadows, such as *Zonitoidesnitidus, Trichiahispida, and Cochlicopalubrica*, is observed.

Thus, on the territory of the Brest Fortress, one can observe the unity of the species composition of mesophilic and floodplain wood plots and the relative faunal isolation of floodplain meadows.

The ordination analysis showed the presence of three main factors that have the greatest effect on the formation of the mollusk fauna of the Brest Fortress, these are the density of the ground cover, the type of ground cover, and the type of litter (Figure 1). The influence of these factors accounts for about 50% of the observed changes in the species diversity of the studied territories within the Brest Fortress.

The main axes of the ordination plot (Figure 1) can be interpreted as a moisture gradient and a change in the nature of the litter from its complete absence to deciduous litter (Axis 1) and a change in the type of the territory (Axis 2). So, with increasing humidity and changing sod litter to hardwood, xerophilic species of mollusks *Truncatellina cylindrical* and *Pupillamuscorum* are replaced by the psychrophilic species *Zonitoidesnitidus*.

It should be noted the situation on the ordination schedule of *Nesovitreahammonis*. It is known that *Nesovitreahammonis* – is an inhabitant of the mesophilic forests (Лихарев, & Раммельмейер, 1952), however, on the territory of the Brest Fortress, *Nesovitreahammonis* dominates in the dry meadows under xero–mesophilic conditions.

With an increase in the density of the grass cover of the meadows and a further change of meadows with shrubs, and then with tree plantings, a decrease in the number of psychrophilic species such as *Succinea putris, Vertigo substriata,* and *Carychium minimum* is observed.

The ordination schedule demonstrates the possible directions for the separation of ecological niches of mollusks from the genus Vallonia. Since *Valloniaenniensis* predominates in the deciduous litter of tree communities, the habitat of *Valloniapulchella* is confined to the border between the tree and meadow communities in the areas where deciduous litter is present. The habitat of *Valloniacostata* is confined to the sod litter of the upland meadows.

According to the features of the formation of mollusk complexes, the studied points are conditionally divided into three groups:

1. The points where 1–2 species of mollusks are found. It can be different types of mollusks – *Valloniapulchella, Trichiahispida*. The number of mollusks at such points is very low (table 3). This variant of malacocomplexes is characteristic only for the upland meadows of the fortress.

2. The points where 3–4 species of mollusks are found. The number of individuals at these points is relatively low – 8 ind./25cm^2 (table 3). The dominant position at such points is occupied by the species from the genus Vallonia. This type of malacocomplexes is formed in all types of the territories. As mentioned above, the mollusks from the genus Vallonia are confined to the boundary between the tree and meadow communities; therefore, this group of points can be considered as the boundary between the meadows and treeplantations. At the same time, those points where *Valloniacostata*dominates are located closer to the dry meadows, and the points where *Valloniaenniensis* dominates are closer to the treeplantations.

3.The points where 5–8 species of mollusks are found. The number of mollusks at such points can reach 20 ind./25cm^2. Various species can dominate in such points– *Bradybaenafruticum, Cochlicopalubrica, Retinellahammonis* in the areas with woody vegetation, and *Valloniacostata* in the areas with meadow vegetation. In some cases, the abundance of all species at such points is approximately the same (table 3). Such variant of malacocomplexes can be formed in all mesophilic types of the studied territories, except for the lawns in those areas where the conditions characteristic of the woody or meadow ecosystems are more clearly expressed.

Table 3.

Comparison of the faunal characteristics of the points of various types

Typeofarea	hgm	fm	anch	hcts	N	n	H
1	5	3	3	2	3–4	8	0–0,58
2	6	0	1	1	1–2	2,4	0
3	5	1	6	4	5–8	20	0,54–0,78

Note: l – lawns; **hgm** – high–grassy meadows; **fm** – floodplain meadows; **hcts** – human–controlled tree stands; **anch** – areas not controlled by humans with woody vegetation. **N** – number of species; **n** – number of individuals (ind./25cm^2); **H** – species diversity.

Conclusion. On the territory of the Brest Fortress, 16 species of terrestrial mollusks from 12 families and 14 genera were recorded. The areas with woody vegetation, such as hornbeamthicketand black alder forests, are characterized by the greatest species richness. The fauna of the mollusk meadows in the floodplain of the river Mukhovets is quite isolated from the rest of the fortress, while the species are exchanged between the areas with woody and mesophilic meadow vegetation. The distribution of the mollusks throughout the citadel is affected by the density of the soil cover, the type of soil cover, and the type of litter.

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