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CHRONOLOGY OF MICROMAMMAL ASSEMBLAGES ON THE TERRITORY OF BELARUS IN THE LATE GLACIAL AND HOLOCENE

CHRONOLOGIA ZESPOŁÓW MIKROSSAKÓW NA TERYTORIUM BIAŁORUSI W PÓŹNYM GLACJALE I HOLOCENIE

***Abstract*:** Complex geological and paleontological study of new locations of the Late Glacial and Holocene micromammals on the territory of Belarus and their resources allowed communities to establish 9 fauna formation phase. The phases are characterized by qualitative (appearance-disappearance of individual marker species and groups) and quantitative (number of species, the ratio of species and proportion of ecological groups) changes, which are reflected in the history of the formation small mammals region. The dynamics of species composition and community structure of small mammals considered for each chronointervals. Background characteristic and small mammal marker species are given in article. The dynamics of species composition and community structure of microtheriofauna considered for each chronointervals. Background characteristic and small mammal marker species are given in article.

***Key words*:** micromammalian fauna (small mammals), Late Glacial, Holocene, the dynamics of species composition, faunal associations
***Słowa kluczowe*:** drobne ssaki, późny glacjał, holocen, dynamika składu gatunkowego, zespoły faunistyczne

Introduction

Late Glacial and Holocene is the relatively short period of geological history of the Quaternary. The final formation of the natural appearance of modern zoning, animal and phytocenoses happened during this period. The study of the events, which took place during the Late Holocene and allows a better understanding of the processes of transition from one of the main phases of the climatic cycle to another, that is, from the glacial to interglacial.

The radical transformation of the landscape has led to relatively short-term climate variability and significant amplitude. The study of the transition interval of the Late Glacial-Holocene allows for quantitative estimates of the rates, frequency and amplitude characteristic of the climatic oscillations of such a rank, as well as the corresponding changes of landscape systems. Such estimates are necessary for an understanding of current environmental changes, both natural and caused by human activities.

The problem is also interesting from a practical point of view in connection with the study of the history of the development of ecosystems, biocenoses and other basic structural units of natural systems, the rationale and development strategies, principles, methods, and programs aimed at the long-term conservation of biodiversity, as well as activities for the enrichment modern theriofauna.

The field of study

Specific targeted research Quaternary fossil micromammalia Belarus began only in the early 70s of the XX century. There are more than 40 small mammals fossil locations of Late Glacial and Holocene in Belarus. The greatest number of locations are characteristic of the Holocene period. According to the concentration and degree of knowledge of the locations of Late Glacial and Holocene micromammalian fauna are three grounds: the Dnieper basin with Gomel and its tributaries (of the Dnieper River valley from the border with Russia to Orsha), basin Western Dvina from the border with Russia to the Beshenkovichi and Neman almost all its duration within the country (Fig. 1). Not all are equal in the location information with respect. The most presentable is only 29, which is confirmed by a statistically and a large number of fossils (Table 1).

Conducting chronological reconstructions and periodization of natural events by Holocene micromammalian has a certain specificity in comparison with earlier stages of the Quaternary. Holocene is not sufficiently long length of time and the fundamental evolutionary changes of genus or species rank cannot arise and be reflected in the morphology of the molars and the skeleton. Holocene location differ in lack of averaging of material. This allows tracking the ratio of environmental groups (faunal associations) and species of animals in the general structure of micromammalian communities that vary not only in time at each stage of the Holocene, but in space, depending on the environmental conditions of habitats in which they exist. We are widely used evolutionary and paleontological fossils and signs of structural and ecological features of microtheriocomplex: typical environmental groups and associations small mammals at each time slice, their species composition and individual marker species; indicators of species similarities and species diversity of the micromammalian communities in chronointervals at geological correlations and periodization of the events in the development of the Late Glacial and Holocene micromammaly (Ivanov 2008c, 2011).

Table 1

The species belonging fossils Late Glacial-Holocene, Belarus (Ivanov 2008c)

Tabela 1

Gatunki późnoglacjalnych i holoceńskich okazów drobnych ssaków Białoruś (Ivanov 2008c)

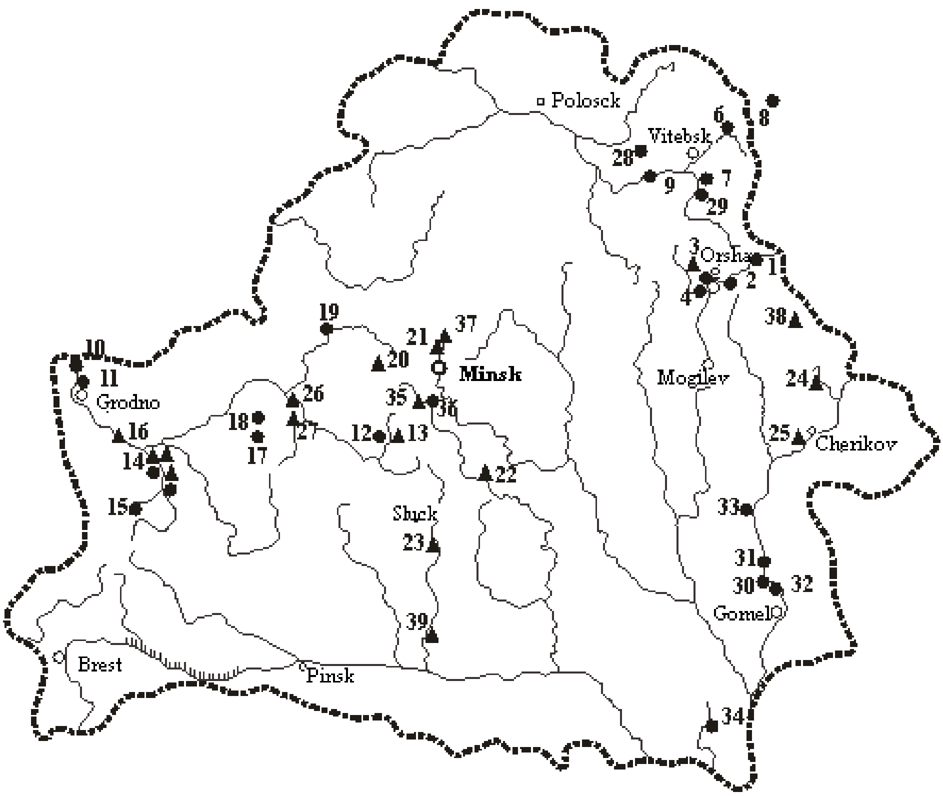
Fossils localities	Pashino	Gozha-2	Volosovo	Plaskovcy	Buroe	Lopatino	Peski-4	Peski-5	Zabolot'e	Cherikov	Peski-2	Brod	Sl. Dvinskaja	Drozdy	Kyharovka	Lunno	Sinjavskaja Sloboda	Pionerskii-2	Peski-1	Peski-3	Luzinovka	Zel'va	Semenovichi-2	Kirovo	Pionerskii (горизонт 1)	Voroncha	Zarech'e	Semenovichi-1	Nov. Rutkovochi
Species	**Late Glacial**			**Preboreal (PB-1)**		**Preboreal (PB - 2)**					**Boreal (BO-1)**								**Boreal (BO-2)**					**Atlantic (AT)**				**Subboreal (SB)**	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Insectivora																													
Erinaceus sp.					+																								
Erinaceus aff. europaeus L.																						+				+			
Talpa europaea L.						+		+					+	+			+									+		+	+
Desmana moschata L.					+												+									+			
Sorex coecutiens Laxm.																							+		+	+	+	+	
S. minutus L.	+				+					+									+		+	+	+			+	+		+
S. isodon Tur.					+	+															+			+					
S. araneus L.	+				+		+		+	+	+	+		+			+	+			+	+	+	+	+	+	+	+	+
Neomys fodiens Pen.						+								+	+		+				+		+		+		+		+
Neomys cf. anomalus Cabr.					+																		+			+			
Crocidura suaveolens Pall.																										+			
Chiroptera																													
Plecotus auritus L.																										+			
Lagomorfa																													
Ochotona cf. pusilla Pall.					+																								
Ochotona cf. hyperborea Pall.	+																												
Rodentia																													
Sciurus vulgaris L.																						+							
Castor fiber L.						+		+																					

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Spermopfilux ex gr. superceliosus Kaur.					+																								
Glis glis L.																										+			
Muscardinus sp.																										+			
Dyromys cf. mitedula Pall.																										+			
Sicista betulina Pall.					+																					+	+		
Mus musculus L.							+																		+				+
Apodemus agrarius Pall.						+			+																		+		
A. silvaticus L.				+	+					+				+	+			+			+		+			+	+		
A. flavicollis Melch.						+	+	+		+		+	+	+		+	+		+	+	+	+	+		+	+	+	+	+
Rattus norvegicus Ber.						+																							
Cricetus cricetus L.	+				+																								
Arvicola terrestris L.	+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
***Microtinae – Muridae gen*.**	+				+	+	+	+	+	+	+			+	+	+	+	+	+		+	+	+	+	+	+	+		+
Microtus sp.			+																										
M. oeconomus Pall.	+			+	+	+	+	+		+	+	+		+	+	+	+		+	+	+		+		+	+	+	+	+
M. agrestis L.	+			+	+	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+		+	+	+	+	+
M. arvalis Pall.					+	+	+		+	+	+			+			+	+	+	+	+		+	+	+		+	+	+
M. gregalis Pall.	+	+			+		+	+		+				+							+								
M. subterraneus Sel.-Long																			+	+	+	+	+	+	+	+	+		+
Clethrionomys glareolus Schreb.	+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Lemmus sp.		+																											
Lemmus sibiricus Kerr.	+		+		+	+	+					+					+				+*								
Dicrostonyx sp.				+	+				+			+		+	+	+													
D. cf. gulielmi Sanf	+																+*												
D. cf. torquatus Pall.		+					+											+											
Lagurus lagurus Pall.		+																											
Mimomys ex gr. pusillus Meh.																	+*												
Mimomys sp.																	+*												
Total:	**150**	**12**	**13**	**29**	**1282**	**175**	**84**	**93**	**41**	**72**	**127**	**174**	**41**	**141**	**21**	**32**	**154**	**49**	**183**	**30**	**171**	**585**	**209**	**34**	**136**	**1833**	**218**	**152**	**288**

* Fossils, by outward appearances (color, degree of preservation and the rounding), are redeposited

Material and methods

Fossil material from 29 locations micromammalian Late Glacial-Holocene was analyzing in the study (Fig. 1). Fossil cover different time slices Late Glacial--Holocene. Most of the locations has alluvial origin. The total number of determinate species and analyzed fossils exceeded 6000 units. According to the 42 species of mammals it has been determined (Table 1) (Ivanov 2008c, Motuzko, Ivanov 1996). Total statistical number was about 9,000 specimens of modern animals.



1. Buroe, 2. Pashino, 3. Zabolot'e, 4. Adrov, 5. Berestenevo, 6. Sloboda Dvinskaja, 7. Volosovo, 8. Belousovo, 9. Barvin Perevoz, 10. Plaskovcy, 11. Gozha, 12. Semenovichi-1, 13. Semenovichi--2, 14. Peski 1-5, 15. Zel'va, 16. Lunno, 17. Voroncha, 18. Novye Rutkovochi, 19. Brod, 20. Rakov, 21. Drozdy, 22. Kyharovka, 23. Kirovo, 24. Lopatino, 25. Cherikov, 26. Sinjavskaja Sloboda, 27. Luzinovka, 28. Urovo, 29. Mjaklovo, 30. Prisno, 31. Odnopol'e, 32. Raduga, 33. Voznesenskii, 34. Yastrebka, 35. Ptich', 36. Zakruzka, 37. Pionerskii 1-2, 38. Zarech'e, 39. Sluch' 1-2

● – data of different authors
▲ – the location, identified by the author

Fig. 1. Sites of the Late Glacial and Holocene fossil micromammals on the territory of Belarus
Ryc. 1. Stanowiska późnoglacjalnych i holoceńskich mikrossaków (drobnych ssaków) na obszarze Białorusi

Table 2

The study of fossil micromammalian localities Late Glacial-Holocene by geological and paleogeographic methods

Tabela 2

Stanowiska badań kopalnych drobnych ssaków okresu późnego glacjału i holocenu za pomocą metod geologicznych i paleogeograficznych

Fossils localities (radiocarbon dating)	**Methods of study**							
	Geological and geomorphological	Radiocarbon	Microteriological	Palinological	Carpological	Malakofaunal	Herpeto-batracho faunal	Entomological
Yastrebka	■		■					
Novye Rutkovochi 4200±60 (Vib-48)	■	■	■	■			■	■
Semenovichi-1 5780±70 (Mir-24)**	■	■	■		■		■	
Zarech'e 5150±120 (IGSB-1169)	■	■	■	■		■	■	
Voroncha	■		■			■	■	■
Kirovo	■		■			■	■	
Pionerskii (hor. 1, 2)	■	■	■	■		■	■	
Zel'va	■		■					
Semenovichi-2	■		■	■			■	
Peski-3	■		■	■			■	
Luzinovka	■		■				■	
Peski-1	■		■	■	■		■	■
Peski-2	■		■	■	■		■	■
Sloboda Dvinskaja 5050±70 (Tln-308)*	■	■	■		■		■	■
Drozdy	■		■	■		■	■	
Kyharovka	■		■					
Zabolot'e	■		■					
Peski-4	■		■	■			■	
Peski-5	■		■	■	■			
Lopatino	■		■			■	■	
Cherikov	■		■					
Brod	■		■	■	■		■	■
Sinjavskaja Sloboda	■		■	■			■	
Buroe 10170±170, 9640±160 (Гін – 2309, Гін – 2308) и 9430±85 (Міг – 28)	■	■	■	■		■	■	
Plaskovcy	■		■		■	■	■	
Gozha-2 11020± 90 (Mir – 25)	■	■	■	■		■		
Volosovo 10650 +160 (Tln – 325)	■	■	■	■	■	■		
Pashino	■		■			■		

* Radiocarbon dating made to the overlying stratigraphy layers

** Radiocarbon dating made to the underlying stratigraphy layers

Table 3

Distribution of micromammals during Late Glacial and Holocene by environmental groups

Tabela 3

Dystrybucja mikrossaków (drobnych ssaków) podczas późnego glacjału i holocenu według grup środowiskowych

Species (Taxons)	**Environmental groups**							
	Tundrasteppe complex species		Intrazonal (aquatic and wetland) species	Forest complex species	Forest complex groups (associations)			
	Steppe species	Tundra species			*Taiga and deciduous forests*	*Southtaiga and deciduous forests*	*Deciduous forests*	*Open forest-meadow habitats*
1	2	3	4	5	6	7	8	9
Erinaceus sp.				■		■		
Erinaceus aff. *europaeus* L.				■		■		
Talpa europaea L.				■		■		
Desmana moschata L.			■					
Sorex sp.				■				
S. coecutiens Laxm.				■	■			
S. minutus L.				■		■		
S. isodon Tur.				■	■			
S. araneus L.				■		■		
Neomys fodiens Pen.			■					
Neomys cf. *anomalus* Cabr.			■					
Crocidura suaveolens Pall.				■			■	
Plecotus auritus L.				■				
Ochotona cf. *hyperborea* Pall.		■						
Ochotona cf. *pusilla* Pall.	■							
Sciurus vulgaris L.				■	■			
Castor fiber L.			■					
Spermopfilux ex gr. superceliosus Kaur.	■							
Glis glis L.				■			■	
Muscardinus avellanarius L.				■			■	
Eliomis sp.				■			■	
Dyromys cf. *mitedula* Pall.				** ■			■	
Sicista sp.				■	■			
Sicista betulina Pall.				■	■			
Mus musculus L.				* ■	■			
Apodemus agrarius Pall.				** ■				■
A. silvaticus L.				■		■		

1	2	3	4	5	6	7	8	9
A. flavicollis Melch.				**				
Rattus norvegicus Ber.			*					
Cricetus cricetus L.								
Arvicola terrestris L.								
Microtus minutus Pall.								
M. oeconomus Pall.								
M. agrestis L.								
M. arvalis Pall.				**				
M. gregalis Pall.								
M. subterraneus Sel.-Long.								
Clethrionomys glareolus Schreb.				**				
Lemmus sp.								
Lemmus sibiricus Kerr.								
Dicrostonyx sp.								
D. cf. *gulielmi* Sanf								
D. cf. *torquatus* Pall.								
Lagurus lagurus Pall.								

* Currently are eucommensal species (Motuzko, Ivanov 2007)
** Currently are gemicommensal species

Analysis of the material were carried out by studying the fossils and paleocommunities based on the modular system of integrated empirical analysis (Ivanov 2011). Almost all location of small mammals were studied by complex geological-paleogeographic and paleontological methods (Table 2). This was allowed to compare and adjust the results. Using complex analysis significantly was increased the accuracy of determining the age and stratigraphic confinement of fossils. We first used an index of similarity of species composition micromammalia (Serensen index) (Ivanov 2005, 2008b) in determining of relative age of paleocommunities. Paleoassemblages of small mammals from different locations that are value of similarity index of composition species at least 0.6 in the presence of common marker species can be considered as one-age.

Species definitions of fossils was carried out on molars of M_1 and M^3 and only in some cases (when determining *Mus musculus* L.) were used cutters. For definition of separate morphologically similar species (*Microtus* ex gr. *arvalis* Pall. and *Microtus agrestis* L.) we used an original technique of identification of these species among fossils (Ivanov 2007, 2008a, 2008d). The quantitative composition and the percentage of species in the location was calculated using index of “conditional number of fossils” (Ivanov, Kasach 2003).

The study of structure of microtheriocomplex was based: throughout the Holocene on the territory of the country is dominated by forest type of vegetation and animals of forest habitats with very similar species composition, in the structure of micromammalia is not happened a sharp contrast qualitative changes, prevailed slow quantitative changes that reflect of successional dynamics of forest formations and the evolution of forest landscapes.

For understand the ecological status of small mammals of region is of great importance in the composition ratio of the proportion of community representatives tundrasteppe and forestry systems and intrazonal group of species for consideration the length of time and the study of the forest complex micromammaly (as complex structure).

Faunal associations have been allocated within the forest complex (Table 3). Human impact on the environment is becoming increasingly important in the Holocene time. “Commensal” species – extra environmental group has been selected. This group includes species of small mammals whose way of life is closely related to human habitation.

Structure of modern micromammal assemblages of territory of Belarus were considered by the example of communities of different habitats of the republic: Polesie Radiation Ecological Reserve, the “Pripyat” National Park, the north-western regions of the Grodno region, wetlands of valley of the Vitebsk region and Pripyat river valley in the Luninets district.

Results and discussion

Holocene micromammalian fauna of Belarus were formed during the Quaternary. Studies of Quaternary fauna of Belarus and the correlation with the stages of development of the fauna of neighboring territories were possible to identify in the evolution of the Quaternary fauna Belarusian region a number of temporary faunal zones (Motuzko et al. 2002, Nadakhovskiy et al. 2003). The youngest faunistic area (I) covers Muravian interglacial. The Poozersky stage and the Holocene belongs to faunistic complex of the upper paleolith. Formation of all modern species ended by this time except *Arvicola terrestris* (L.) and line *Dicrostonyx gulielmi – Dicrostonyx torquatus* (evolution took place during the Late Pleistocene). Modern species of evolutionarily were presented Late Glacial and Holocene mikroteriofauna region. Evolutionary changes largely were concerned the dynamics of its species composition and ecological structure of mikroteriocomplex. They are reflected in the gradual replacement of periglacial complex by forest species and associated change of *faunal associations.*

The study of the composition and structure of the Late Glacial and Holocene micromammalian complexes were conducted by chronointervals. In which manifest quantitative (number of species, the ratio of species and ecological groups) and quality (appearance-disappearance of individual indicator species and groups) changes in micromammaly communities. The Late Glacial micromammalian complexes of Poozerie were viewed in two time intervals: 1 – interstadial Allerød oscillation [AL]; 2 – stadial Late Dryas cooling [DR-3]. Seven time intervals allocated to the Holocene: 1 – the first half Preboreal [PB-1]; 2 – the second half Preboreal [PB-2]; 3 – the first half of the Boreal Period [BO-1]; 4 – the second half of the Boreal Period [BO-2]; 5 – Atlantic Period [AT]; 6 – Subboreal [SB]; 7 – Subatlantic [SA] – modernity.

Interstadial Allerød oscillation **[AL].** *Tundraforest with steppe elements association of periglacial fauna.* Fossils location of Pashino. The numerous of animals of

Horizon, subhorizon	Period, zone (Zernitskaya et al. 2005)		Faunal assemblages (Association)	Lagurus lagurus Pall.	Ochotona cf. pusilla Pall.	Lemmus sibiricus Kerr.	M. gregalis Pall.	Dicrostonyx gulielmi (torquatus) Sanf	M. arvalis Pall.*	M. oeconomus Pall.	M. agrestis L.	Arvicola terrestris L.	Cl. glareolus Schreb.	S. isodon Tur.	S. araneus L.	A. silvaticus L.	A. flavicollis Melch.	Glis glis L.	Dyromys cf. mitedula Pall.	Muscardinus sp.	M. subterraneus Sel-Long	Background and characteristic indicator species	Fossils localities (radiocarbon dating)
S y d o b o l's k y	(SA) sd Y	sd Y-3 sd Y-2 sd Y-1	F o r e s t c o m p l e x: Medium taiga and forest-meadow habitats with elements of deciduous forests																			**Clethrionomys glareolus Schreb., Microtus arvalis Pall., Sorex araneus L., Arvicola terrestris L., Apodemus flavicollis Melch., (**Microtus agrestis L., M. oeconomus Pall.**),** Apodemus agrarius Pall., Apodemus silvaticus L., Mus musculus L.	Recentny fauna; Yastrebka
	(SB) sd IY	sd IY-3 sd IY-2 sd IY-1	South taiga with elements of deciduous forests																			**Clethrionomys glareolus Schreb., Microtus arvalis Pall., Arvicola terrestris L., (M. agrestis L., M. oeconomus Pall.), Sorex araneus L., Sorex coecutiens Laxm.,** M. subterraneus Sel.-Long., Apodemus flavicollis Melch., Apodemus silvaticus L., Sorex minutus L.	Nov. Rutkovochi – 4200+60 (Vib-48); Semenovichi-1 – 5780+70 (Миг-24)[2]
	(AT) sd III	sd III-3 sd III-2 sd III-1	Deciduous forests																			**M. subterraneus Sel.-Long., Cl. glareolus Schreb., A. flavicollis Melch., Arvicola terrestris L., (M. agrestis L., M. oeconomus Pall.), Sorex araneus L., S. coecutiens Laxm.,** M. arvalis Pall., S. minutus L. Sicista betulina Pall. Glis glis L., Muscardinus sp., Dyromys cf. mitedula Pall.	Voroncha; Zarech'e – 5150±120 (IGSB-1169); Kirovo; Pionerskii (hor 1)
	(BO) sd II	sd II-2	South taiga with elements of deciduous forests																			**Clethrionomys glareolus Schreb., Arvicola terrestris L., (Microtus agrestis L., Microtus oeconomus Pall.), A. flavicollis Melch.,** Microtus subterraneus Sel-Long., Microtus arvalis Pall.., Sorex araneus L., Sorex minutus L.	Zel'va; Semenovichi-2; Peski-3; Luzinovka; Peski-1 (clean. 5)
		sd II-1	Medium taiga with elements of deciduous forests																			**Arvicola terrestris L., Clethrionomys glareolus Schreb., Microtus oeconomus Pall., (Microtus arvalis Pall., Microtus agrestis L.),** Apodemus flavicollis Melch., Sorex araneus L., Apodemus silvaticus L., *Microtus subterraneus Sel.-Long., Sorex isodon Tur.*	Sl. Dvinskaja – 5050+70 (Tln-308)[1]; Brod; Peski-2 (clean.11); Lunno; Drozdy; Kyharovka; Sinjavskaja Sloboda and ect..
	(PB) sd I	sd I-2	North-medium taiga forests																			**Arvicola terrestris L., Clethrionomys glareolus Schreb., Microtus agrestis L., (M. arvalis Pall., M. oeconomus Pall.),** Sorex araneus L., Sorex isodon Tur., Apodemus silvaticus L., A. flavicollis Melch., *Microtus gregalis Pall., Lemmus sibiricus Kerr., Dicrostonyx torquatus Sanf.*	Peski-4; Peski-5; lopatino; Cherikov; Zabolot'e
		sd I-1	Forest with elements of tundra and steppe																			**Microtus oeconomus Pall., (M. agrestis L., M. arvalis Pall.), Arvicola terrestris L., Cl. glareolus Schreb. +** Sorex araneus L., S. isodon Tur., Apodemus silvaticus L., M. gregalis Pall., Lemmus sibiricus Kerr., Dicrostonyx torquatus Sanf., Cricetus cricetus L., Ochotona cf. pusilla Pall.	Buroe – 10170+170, 9640+160 (GIN – 2309, GIN – 2308) and 9430+85 (MIG – 28); Plaskovcy
Narochansky	DR-1, DR-2, DR-3 (pz-n1, pz-n3, pz-n5)		Tundra with steppe elements						?	?	?	?										**Dicrostonyx gulielmi (torquatus) Sanf., Lemmus sibiricus Kerr., Microtus gregalis Pall., Lagurus lagurus Pall. Ochotona cf. pusilla Pall.** Arvicola terrestris L.?, (Microtus. oeconomus Pall., Microtus agrestis L.)?	Gozha-2 – 11020 +90 (MIG-25) -; 10650 +160 Volosovo – (Tln-325)
	BL, AL (pz-n2, pz-n4)		Tundraforest with steppe elements																			**Dicrostonyx gulielmi (torguatus) Sanf., Lemmus sibiricus Kerr., Clethrionomys glareolus Schreb., Microtus gregalis Pall., Arvicola terrestris L., (M. oeconomus Pall., M. agrestis L.),** Cricetus cricetus L., Ochoto,na cf. pusilla Pall.	Pashino

Legend to figure 4

Lemmus sibiricus Kerr. – indicating dominant and dominant species
Apodemus silvaticus L. – conventional species indicator
M. subterraneus Sel –Long. – indicator rare and very rare species
**** M. arvalis Pall.*** – in natural forest biocenoses biocenoses and river valleys only it reaches the level of the ordinary kind, but transformed "treeless" landscapes it is sodominantnym a dominant view;

(grey bar) – the estimated weight (due to lack of materials or taphonomic features of accumulation));
? – remnants of data phases, according to the available materials, are not available, but may be subsequently identified
(dashed line) – rare and very rare species, the remains of which were found in all localities or area where intermittent (for retsentnyh communities);
1 – radiocarbon dating carried out for the overlying layers;
2 – for lower-lying layer
.

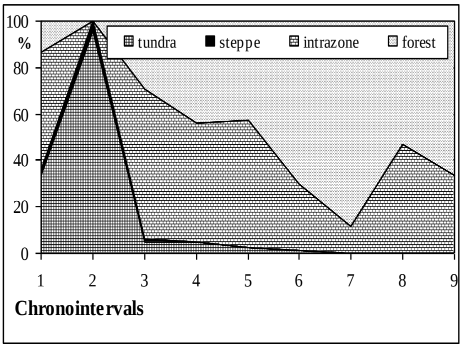
Digital gradation and alphabetic indexes classes ratings dominance and abundance of species

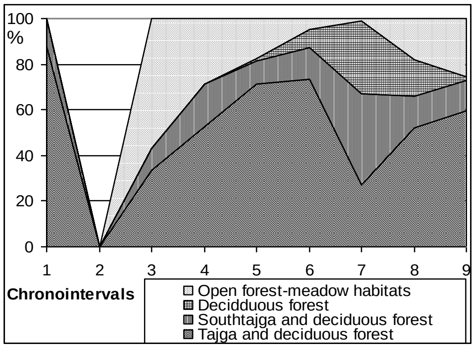
Domination		Amount (Verbal evaluation)	Classes dominance and the quantity	
%	Verbal evaluation			
< 0,5	***Tertiary***	***Very rare***	Д	
0,6 – 1,5	***Secondary***	***Rare***	Г	
1,6 – 9,9	***Subdominant***	***Normal***	В	
10,0 – 29,9	***Codominant***	***Numerous***	Б	
30 и >	***Dominant***	***Very large***	А	

Fig. 2. Changes in the structure of Belarus microtheriocomplexes in the Late Glacial and Holocene
Ryc. 2. Zmiany w strukturze mikroterikompleksów Białorusi w okresie późnego glacjału i holocenu

tundra biotopes (33.6%) were marked out as a part of communities of this time. The intrazonal group of species dominates: *Arvicola terrestris* L., *Microtus oeconomus* Pall., *M. agrestis* L. (> 50% of the fossils). There are first representatives of zone forest biotopes – *Clethrionomys glareolus* Schreb., *Sorex minutus* L., *S. araneus* L. (more than 13%). Considerable reduction of representatives of steppes (to 2.5%) were happens at this time.. Highly specialized steppe and semidesertic species (*Lagurus* sp, *Ellobius talpinus* Pall., *Marmota bobac* Mull.) were disappear at all. They were emigrated to the southern and eastern regions. Micromammalian complexes was acquired tundraforest with steppe elements shape (Fig. 2).

The dominant environmental groups: intrazonal (more than 50% of the residues) and tundra (33.6%), with the subordinate role of the representatives of the zonal forest (over 13%) and grassland (2.5%) of habitats (Fig. 3).





1 – interstadial warming (AL); 2 – stadial cooling (DR-3); 3 – (PB-1); 4 – (PB-2); 5 – (BO-1); 6 – (BO-2); 7 – (AT); 8 – (SB); 9 – (SA) – Present day (habitats of river valleys of the north of Belarus)

Fig. 3. Dynamics of the structure Belarusian micromammal assemblages in the Late Glacial-Holocene
Rys. 3. Zmiany struktury białoruskich zespołów mikrossaków w późnym glacjale i holocenie

Fig. 4. Changes in the structure of small mammals in the forest complex of the Late Glacial-Holocene
Ryc. 4. Zmiany w strukturze drobnych ssaków w kompleksie leśnym w późnym glacjale i holocenie

Stadial cooling: **[DR-3].** *Tundrasteppe association of periglacial tundra faunas with domination elements*. Locations: Gozha-2, Volosovo.

Tundrasteppe predominate animal habitats (Fig. 4) forest and intrazonal of species were absent completely or almost completely (to the south of the country). Widespread (up to 90% of the residues) were received *Dicrostonyx torquatus (gulielmi)* Sanford, *Lemmus sibiricus* Kerr, *Microtus (Stenocranius) gregalis* (Pallas). The share of steppe species (~ 4%) were increased and enriched species composition of the complex. Highly specialized representatives of the steppes and semideserts were appearing – *Lagurus lagurus* Pall.

The dominant environmental groups were: tundra (over 90% of the residues) for the subordinate role of the steppe (about 4%) and highly specialized of species – *Lagurus lagurus* Pall. Completely were absent forest species.

The Late Glacial micromammalian fauna of Belarus was formed as a result of the gradual transformation periglacial faunas after Poozerie maximum cooling. She had getting a transitional character between tundrasteppe periglacial and forest Holocene fauna. Fauna were combines the features of both communities. Micromammalian complexes of Belarus were tundraforest with steppe elements appearance during Allerød Oscillation. The faunal complexes were acquired typical tundrasteppe appearance with a predominance of tundra elements Late Dryas time.

Holocene stage. *Preboreal period:* **[PB-1].** *Forest fauna with elements of tundra and steppes*. Locations: Buroe, Plaskovcy.

Tundrasteppe microtheriocomplex of Late Dryas were gradually replaced by wild animals and forest-meadow communities in the first half Preboreal (Fig. 3). The dominant environmental groups: intrazonal (about 65% of the residues). In her structure were *Neomys* cf *appear. anomalus* Cabr., *Desmana moschata* L. The specific structure of a forest complex considerably were increased (29%) and enriched.

Group open forest-meadow habitats (over 55%) of and north-middletaiga species (over 30%) were dominant in the composition of the paleocommunity. The species of South taiga and mixed forests *Sorex isodon* Tur., *Apodemus silvaticus* L., *Erinaceus* aff. *europaeus* L., *Sicista betulina* Pall. (about 9%) were appeared. Tundrasteppe complex was represented by a wide range of species (of 6), but was fell from its structure highly specialized steppe species. The proportion of representatives of tundra and steppe habitats among fossils were reduced to 4.7 and 1.2%, respectively.

PB-2. *Association of North-middle taiga and mixed forests of the forest complex*. Locations: Peski-4, Peski-5, Lopatino, Cherikov, Zabolot'e.

Tundrasteppe communities were replaced by forest. Completely disappeared steppe elements of periglacial fauna. Number of extinct species roughly were commensurate with the number of new emerged species. The first were identified *Apodemus flavicollis* Melchior., *Talpa europaea* L., *Mus* cf. *musculus* L., *Rattus norvegicus* Berk. and appeared *Castor fiber* L., *Neomys fodiens* Pen. Forestry species were dominates in Belarus since that time.

The dominant environmental groups: intra-zonal and forestry (~ 52% and 44 fossils, respectively). As part of the forest groups were reduced the proportion of representatives of public forest-meadow habitats (~ 30%) and the share of northern-middle taiga of species (over 50%) and southern taiga species (mixed) forests (over 20%). Species diversity and abundance tundrasteppe groups (slightly more than 4%) were reduced.

Boreal period: **BO-1.** *Middle taiga association of forest complex with elements of broad-leaved forests.* Locations: Peski-2, Brod, Sloboda Dvinskaja, Drozdy, Kyharovka, Sinjavskaja Sloboda, Pionerskii 1-2, Lunno.

The dominant environmental groups: Remember trend further were increase in the share of representatives of forest habitats (> 43% of the residues), which together with a group of species of waterfowl intrazonal habitats (54%) were dominant. In forest communities was the tendency of reducing the proportion of the group of public forest-meadow habitats (20%) and increasing the proportion of middle-north of species (over 70%) and southern taiga species (mixed) forests, there are appeared the first highly specialized representatives of the broad-leaved forests. Tundra species were found singly in individual localities (up to 3% of the residues).

BO-2. *Association of South taiga and deciduous forests. Locations:* Zel'va; Semenovichi-2; Peski-1 (clear. 5), Peski-3; Luzinovka.

The dominant environmental groups: representatives of zonal forest zoocenoses were becoming dominant (70% fossil), with the subordinate role of intrazonal group (about 30%). Association species of taiga and mixed forest was reached it maximum for the entire Holocene (73%) (Fig. 2) as part of the forest complex. The participation of representatives of public forest meadow habitat were reduced (less than 5%). The increase in the proportion of species diversity and representatives of southern taiga, deciduous forests were observed up to 14%, and highly specialized species deciduous forests (over 8%). Tundrasteppe complex (less than 1%), almost entirely were ceased to exist, represented only *Microtus gregalis* Pall. in a location that time. Tundrasteppe complex (less than 1%), almost entirely were ceasing to exist, it was represented only *Microtus gregalis* Pall. in one location at that time.

Atlantic period **[AT].** *Association of broad-leaved forests of the forest complex*. Locations: Voroncha; Zarech'e, Kirovo, Pionerskii (level 1).

Widespread were receive *Microtus subterraneus* Sel.-Long., *Apodemus flavicollis* Melch., *Appear Glis glis* L., *Dyromys* cf. *mitedula* Pall., *Muscardinus* sp., *Crocidura suaveolens* Pall., *A. agrarius* Pall.

The dominant environmental groups: the forest complex of species reached of the maximum size for the entire Holocene (> 80% of the residues). Representatives of associations of southern taiga and deciduous forests (40 and 31%) were dominate in the composition of the forest animal communities. Their species composition was added more than twice. The value of intra-zonal group of animals (about 12%) were lowest for the entire Holocene. Representatives of public forest meadow communities were kept a minimum value (about 1%).

Subboreal **[SB].** *Association of South taiga and deciduous forests of the forest complex.* Locations: Novye Rutkovochi; Semenovichi-1.

New species were not appear in the fauna of small mammals. Representatives of the forest complex of associations dominate, but their share were reduced to 50% due to an increase in the role of intra-zonal species (47%) (see Fig. 4). The role of the representatives of taiga and mixed forests (52%) as a part of the forest sector and forest-meadow open habitats (18%) was increased by reducing the proportion of the communities of southern taiga and broad-leaved and broad-leaved forests (15%). This was indicates the beginning of an active transformation of the landscape as a result of human impact on the broad-leaved forests.

Late Holocene-Present days **[SA].** *Association of middle and forest-meadow habitats with elements of broad-leaved forests.* Locations: Yastrebka; retsentny modern fauna.

Species deciduous forests: *Glis glis* L., *Dryomys nitedula* Pall., *Muscardinus avellanarius* L. were rare and very rare. Number of *Sicista betulina* Pall. were reduced to the rare level. *Crocidura suaveolens* Pall. were virtually disappeared from the region. Solid area *Microtus subterraneus* Sel.-Long. were broke up into isolated areas and this species is very rare now in the southern regions of Belarus.

The dominant environmental groups: were dominance of representatives of associations of coniferous and mixed forests (about 61%) increases significantly. They were based on *Clethrionomys glareolus* Schreb. and *Apodemus flavicollis* Melch. (The latter can be replaced by *Sorex araneus* L. depending on the nature of habitats – *Microtus agrestis* L.). The proportion of species of open forest-meadow landscapes and agricultural habitats – *Microtus arvalis* Pall. and *Apodemus agrarius* Pall. were increases considerably. Eucommensal species (*Rattus rattus* L., *Rattus norvegicus* Berk., *Mus musculus* L.) were widely spread. Many species (*Apodemus flavicollis* Melch., *A. agrarius* Pall., *Cl. Glareolus* Schreb., *Microtus arvalis* Pall., and others.) gemicommensal were acquired traits (Motuzko, Ivanov 2007).

Significant changes occurred not only among the dominant groups, but also in the composition of the dominant species during the Late Glacial-Holocene. Were dominated tundra species in Late Dryas time during the Allerød Oscillation – intrazonal, in the early Holocene – intrazonal and forest (secondary southern taiga), in the middle Holocene – forest (coniferous-deciduous and deciduous forests), in recent communities – representatives of middle-southern taiga forests and of open habitats. The number of species of dominant were decreased from the Late Dryas period to the Atlantic of Middle Holocene. Species dominance was not clearly expressed. Species with high domination* were reappeared in recent communities during the late Holocene.

Studies have established the typical associations and small mammals dominant environmental groups for each time slice of the Late Glacial-Holocene and allowed to identify the most characteristic indicator group and marker species. By marker attributed not only and not always the dominant species, but relatively few and rare species (who only appeared or were on the verge of extinction because of the structure of fossil communities) of each chronointerval. They are:

– *Dicrostonyx* cf. *gulielmi* Sanf, which in the Late Glacial were replaced by more evolutionarily advanced views – *Dicrostonyx torquatus* Rall.;
– highly specialized steppe and semi-desert species: *Lagurus lagurus* Pall., *Marmota bobac* Mull, *Elobius talpinus* Pall. etc., were widely represented in pozdnepoozerskih and driasovyh stadial endangered fauna and flora from the region in interstadial warming interglacial and Holocene;
– *Ochotona* cf. *hyperborea* Pall. and *Ochotona* cf. *Pusilla* Pall., disappeared in Preboreal time;
– *Dicrostonyx* cf. *torquatus* Rall. and *Lemmus sibiricus* Kerr, who disappeared from the fauna of the republic to the top of Boreal (BO);
– *Microtus gregalis* Pall. – finally disappears in the Boreal time (BO);

* The absolute dominant in habitats in Belarus was Clethrionomys glareolus Schreb. Codominantami were: for riverine habitats – one or more intra-zonal species (M. agrestis L. – M. oeconomus Pall – Arvicola terrestris L.); for forest formations – Apodemus flavicollis Melch. – Sorex araneus L.; for open habitats – Microtus arvalis Pall, here reaches levels of absolute dominance. None of the habitat was not currently marked as a dominant or highly specialized representatives subdominants deciduous forests Microtus subterraneus Sel.-Long., Crocidura suaveolens Pall., Glis glis L., Muscardinus avellanarius L., Dyromys mitedula Pall. All of them were at the level of secondary (rare) and tertiary (very rare) species.

– *Cletrionomus glareolus* Schreb. – appears in the Late interstadial warmings and passes through the Holocene;
– highly specialized representatives of the broad-leaved forests: *Microtus subterraneus* Sel.-Long, *Glis glis* L., *Dyromys mitedula* Pall., *Muscardinus* sp., became widespread in the mid-Atlantic during the Holocene.

An analysis of the dynamics of the composition and evolution of the ecological structure on micromammaly chronointerval Late Glacial communities was allowed for the culmination of environmental groups and the relationship within their species composition in the history of micromammalian complexes during Late Glacial and Holocene – nine phases were allocated by the region. They were reflect the quantitative and qualitative changes in the microtheriocomplexes. These changes were caused by changes in climatic conditions and successional dynamics of landscapes. Anthropogenic effects on biocenoses were evident in the second half of the Middle Holocene (Ivanov 1999, 2008c, 2011). This accelerated the process of disintegration of communities of deciduous forests and dramatically changed the composition and proportion of species in riparian habitats.

The sequence of community development phases micromammaly Late Glacial-Holocene Belarus is the most comprehensive and detailed. This sequence of the dynamics of faunal associations in the composition corresponds to microtheriocomplexes event of chronostratigraphy and linked with those of other biostratigraphic and paleogeographic methods.

Conclusions

1. Microtheriofauna of the Late Glacial and Holocene within the area of Belarus at the current state of knowledge includes 42 species (orders *Insectivora*, *Lagomorpha* and *Rodentia*) that exceeds its our days diversity. It combines species of tundra, steppe and forest communities, supplemented with representatives of intrazonal semiaquatic biotopes.

2. Contemporary microtheriofauna of Belarus is not autochthonous, it does not inherit elements of periglacial faunas, and consists of forest species communities. It belongs to the migrational type and was formed due to intensive expansion of forest complex representatives during the Preboreal-Atlantic Periods of the Holocene. Changes in microtheriologic associations have occurred in the direction of gradual replacement of tundra and steppe elements with the forest ones. A combination of migrating species during that period of time has being gradually changed. Appearance of new species within the area of Belarus is not recorded since the Subboreal time (SB) of the Middle Holocene.

3. The changes occurred from the Late Glacial to the Middle Holocene on were conditioned, first of all, by the natural course of climate change and evolution of biological communities, as well as were depended on migration processes. Nevertheless, anthropogenic factor has been increasingly influential on changes in biodiversity of mictotheriofauna since the Late Holocene.

4. The analysis of dynamics of composition and evolution of ecological structure of micromammalian communities by the chronological events of the Late Glacial and Holocene allowed defining nine phases. These phases reflect culmination of certain ecological groups and ratio of certain species within these groups during the history of development of mictotheriocomplexes over that period of time. They also reflect quantitative and qualitative changes in the composition of micromammalian complexes caused by climate change and successive landscape dynamics, as well as, starting from the second half of the Middle Holocene, by human impact on biogeocenoses.

5. Nine phases are defined in the evolution of micromammalian communities within the area of Belarus during the Late Glacial and Holocene. Relevant to these phases ratios of dominant ecological communities, species forming these communities, and typical faunistic associations of certain chronological events have also been defined. All these issues, together with certain marker species can be used in chronostratigraphy and for correlation of development of Holocene faunistic complexes in the adjacent to Belarus regions.

6. Directed changes in microtheriological complexes and associations have taken place during the Late Glacial and Holocene. These complexes and associations form a dynamic sequence: periglacial, with a predominance of tundra elements; periglacial tundra-steppe, with steppe elements; and forest. The following sequence of microtheriological associations is defined in Holocene within the letter, forest complexe; forest with tundra and steppe elements – north and middle taiga and mixed forest – middle and south taiga with broadleaf elements – south taiga and broadleaf forest – middle taiga and meadow communities with elements of broadleaf forest.

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Summary

The dynamics of species composition and community structure of Micromammalia on chronological periods from Late Glacial to Holocene are analyzed. For each time period typical associations and the dominant ecological groups are identified, as well as the most typical marker species of micromammalia.

By the ecological groups superlative and the relationship in the species composition within the history of microtheriocomplex during Late Glacial-Holocene nine phases were outlined for Belarus. These phases reflect the quantitative and qualitative changes in the microtheriocomplex due to changes in climatic conditions and successional dynamics of the landscapes, and anthropogenic impacts on the biocenosis since the second half of the Middle Holocene.