

THE KRASNOBORSKY POPULATION OF THE EUROPEAN BISON: HISTORY OF EMERGENCE, PRESENT STATE, AND GROWTH PERSPECTIVES

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The Krasnoborsky population of the European bison: history of emergence, present state, and growth perspectives. — A. Kashtalian. — A new free-living population of the Bialowieza bison (*Bison bonasus bonasus* L., 1758) emerged in 2015 in the northern part of Belarus, in the territory of the Verkhnedvinsky and Rosonsky districts, Vitebsk region, Belarus. We had been monitoring the population for four years, from the moment of its emergence until the beginning 2019. Visual bison observations, search for traces of their vital activity, questionnaires of rangers and local peoples were used for data collection. Information was accumulated on population dynamics, fertility, mortality, age and sex structure, seasonal characteristics of the spatial and territorial structure of herds and small groups. There was a rapid increase in the number of animals at the initial stage of the Krasnoborsky population's existence. This can be explained by the large number of introduced bison founders (68 individuals), high birth rates, low mortality, and predominance of young and middle-aged animals (about 87 % of the total abundance). The population's abundance reached 155 individuals by the beginning of 2019. It is characterised by the predominance of females over males in a ratio of 1.84 : 1. The Krasnoborsky population consists of two territorial groups. Each of them has several herds, which are extremely unstable by their abundance, seasonal, and sex structure. The area on which the population lives exceeds 17 thousand hectares. Bison use this territory unevenly. Key habitats, regular migration routes and rarely visited areas are highlighted. Adult males often leave the habitat of the population and move from its territory for a long time. Practical measures are indicated, the implementation of which will contribute to the long-term conservation of the Krasnoborsky population. The main directions of ensuring the population's existence are creation of a functional system of its livelihoods, including a complex of biotechnical, conservational, preventive veterinary measures, and genetic control. To achieve this goal it is necessary to develop and implement a management plan for the Krasnoborsky population.

Key words: European bison, population dynamics, habitat, birth rate, mortality.

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Introduction

The European bison (*Bison bonasus* L., 1758) is the only surviving species of wild representatives of the Bovinae subfamily on the European continent. According to the latest data obtained on the basis of mitochondrial DNA analysis, it was formed as a separate systematic unit about 120 thousand years ago as a result of hybridization of the extinct steppe bison (*Bison priscus*) and urus (*Bos primigenius*) (Soubrier et al., 2016). The American bison (*Bison bison* L., 1758) is the closest to the European bison among the other living species of Bovinae, and it is represented by two subspecies — the steppe bison (*Bison bison bison*) and forest bison (*Bison bison athabascae*). The American and European bison are capable of producing viable hybrids. Such hybridization together with cross breeding was used to create modern populations of the Caucasian bison (*Bison bonasus bonasus* × *Bison bonasus caucasicus* × *Bison bison*) (Belousova, 1999; Rautian et al., 2000).

The extinction of the European bison in the wild was caused by anthropogenic factors such as uncontrolled hunting, forest burning and clearing, transformation of forested areas into agricultural lands and pastures for livestock. It led to fragmentation of the previously continuous species range, and then to its reduction in the 19th century to two small territorial groups — Bialowieza and West Caucasus. Wild bison populations in these territories were completely destroyed in the early 20th century. The restoration of the species was initially carried out in zoos and specialised breeding centres as semi-free and free herds, most of which are still controlled by humans.

Bison populations are characterised by low genetic diversity (Krasinska, Krasinski, 2007). The level of inbreeding is higher than that of 0.2 in general for the species (Olesh, 1987). The low heterozygosity of the current world population is confirmed by data obtained using biochemical and molecular markers (Sipko et al., 1994; Sipko, 2002; Radwan et al., 2007).

The bison has a historical, cultural, cognitive, scientific and environmental importance for Belarus. There are 10 free-living populations in the country, of which Krasnoborsky is one of the youngest (emerged in 2015). Bison are also kept in some zoos of the country.

The national “Program on the resettlement, conservation and use of bison in Belarus” has been operating in the country for more than two decades. Its main goal is to create reserve populations of the species in several regions of the republic. The Program is aimed to increase the number of bison in Belarus. Significant success has been achieved in recent years. The country ranks first in the world in total bison population. At the same time, the issue of maintaining genetic diversity of the species is of secondary importance to the Program. Most of the proposed measures to preserve the gene pool of Belarusian bison populations remains unrealised.

The creation of the Krasnoborsky free-living population was a private initiative of the owner of the large Krasny Bor Game Husbandry, which is located in the northern part of the country. All activities related to the herd formation were carried out within the framework of the State program “Environmental Protection and Sustainable Use of Natural Resources of the Republic of Belarus”. Their financing was provided only from private sources. A scientific and practical centre and a genetic laboratory were created at the Game Husbandry allowing to conduct detailed studies at the initial stage of emergence of the free-living population and to assess the genetic diversity of bison from various Belarusian populations. However, the owner of the Krasny Bor Game Husbandry ended to provide financial support for the Krasnoborsky population scientific research in early 2019. The issue of financial support remains open to this day.

This publication presents the results of field studies into the Krasnoborsky bison population conducted from September 2013 to January 2019 during the periods of enclosed keeping and free-living of animals in the territory of the game husbandry.

Material and methods

Studies were conducted in habitats of the Krasnoborsky bison population in 2015–2018. The area was regularly surveyed by both car and walk in order to study and monitor the territorial structure of bison groups and localisation of solitary individuals. The animals were visually observed, and traces of their vital activity were studied. All data were mapped using a GPS navigator.

Surveys and questionnaires of game husbandry attendants, foresters, and locals were conducted, which helped to locate bison beyond the habitat of the Krasnoborsky population. The Reconyx Hyper Fire HC500 camera traps were used to determine the number, sex, age and physical condition of the animals. Behavioural characteristics of the bison were also studied.

Parasitological studies of the Krasnoborsky population included collection and analysis of faecal samples. Samples were taken at the bison wintering sites before and after deworming.

Research area

The present range of the Krasnoborsky free-living bison population is located in the territory of the Krasny Bor woodland within the administrative boundaries of Verkhnedvinsky district, Vitebsk region, Belarus. This area is geographically confined to the Osveisk-Ezerishchensky landscape region of the Poozersky province (Martinkevich et al., 1989). Loamy soils prevail here, often in a consistency of water saturation. Hilly landscape with kames and eskers predominate. They are often covered with pine or, occasionally, spruce. Primary forests are replaced sporadically by small-leaved forests and by meadow ecosystems. Swampy depressions of irregular configuration with rugged outlines are often found between the hills. This area has a dense network of small rivers.

According to the geobotanical subdivision of Belarus (Yurkevich et al., 1972), this territory belongs to the West Dvina geobotanical district of the subzone of oak and dark coniferous forests and is a part of the Polotsk geobotanical region. Local forests have a typical southern taiga outlook with

predominance of coniferous trees and boreal species in the lower layer of vegetation. A large part of the territory is occupied by secondary pine-lichen-shrub forests and pine shrub-green moss forests, which play an insignificant role in maintaining the viability of the Krasnoborsky bison population. Black alder forests represented by indigenous and derivative species mixed with other deciduous species (aspen, birch, elm, etc.) should be noted among other types of forest vegetation. They are located in low-lying areas with a high level of soil moisture and in floodplains of streams and small rivers. These forests have a rich grass cover and together with regenerating clearcuttings are the main places for bison pasturage from spring to autumn.

Few floodplain meadows are present in the study area most of which is located near the two largest rivers in this area — the Svolna and Pizhevka. Other types of meadows of natural origin are absent and substituted by grasslands on areas of former clearings and by artificial meadows created on former arable lands.

There are several feeding fields within the habitat of the Krasnoborsky bison population.

Results and discussion

The history of the Krasnoborsky population

The emergence of the Krasnoborsky population began in May 2013, when the first batch of 9 animals entered Krasny Bor Game Husbandry. All these animals were captured from free-living herds of Belovezhskaya Pushcha National Park. The bison were placed in an enclosure located in the tract Ardavskoye. A batch of 30 animals brought from the Ozyorsk free-living population was placed in the same enclosure in December 2013 and January 2014. One bison from Belovezhskaya Pushcha was brought to Ardavskoye in March 2014. All these bison were here on semi-free living maintenance until January 2015.

Information on the bison founders brought in 2013–2014 is shown in Fig. 1a. Thirteen calves were born, one in 2013 and twelve in 2014. Three animals died — two adult males and one yearling.

Fifty bison, i.e. the 38 individuals brought from Belovezhskaya Pushcha and from the Ozyorsk free-living population and 12 calves born in the game husbandry, were released on 23 January 2015. Another group of animals, consisting of 20 bison (3 males and 17 females), ran through Krasny Bor Game Husbandry from the Ozersky population in December 2015 – January 2016. At the same time, 8 animals (2 males and 6 females) were delivered from the Volozhin population that lives in the territory of Naliboksky Republican Landscape Reserve. All bison were captured from free-living herds. Bison that arrived to the game husbandry were divided into two groups. A group of 18 individuals (2 males and 16 females) was enclosed in the tract Ardavskoye, while another group of 10 animals (3 males and 7 females) in the tract Losinka. No bison died while in captivity. Ten calves were born in 2016 in the stow Ardavskoye and 3 calves were born in Losinka.

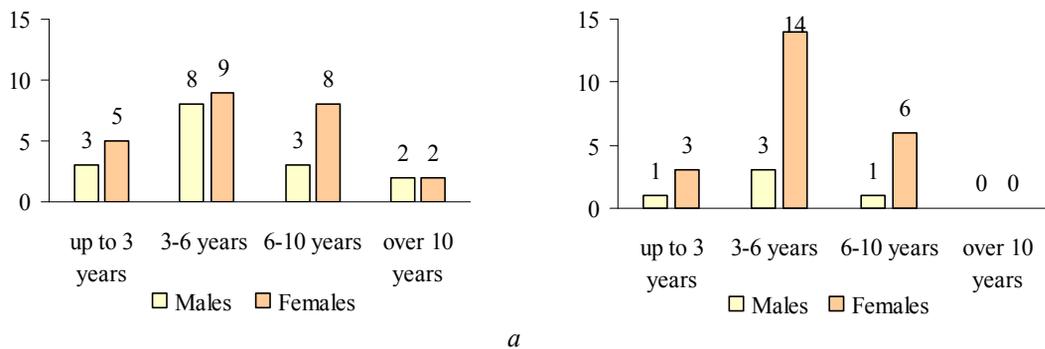


Fig. 1. The sex-age composition of bison brought to the Krasny Bor game husbandry in: a, 2013-2014 (N = 40); b, 2015–2016 (N = 28).

рис. 1. Статеві-вікова структура зубрів, завезених на територію мисливського господарства «Красний Бор» а) у 2013–2014 рр. (N=40); б) у 2015–2016 рр. (N=28).

Table 1. Data on bison imported to and released in the territory of Krasny Bor Game Husbandry

Таблиця 1. Дані про завезення і випуск зубрів на території мисливського господарства «Красний Бор»

Time period	Enclosed			Released			
	♂	♀	Arrived from	♂	♀	Calves	Established the
May 2013	5	4	Belovezhskaya Pushcha				
Dec. 2013 to Jan. 2014	11	19	Ozyorsk population				
March 2014	1		Belovezhskaya Pushcha				
Jan. 2015				14	24	12	Ardavskaya group
Dec. 2015 to Jan. 2016	3	17	Ozyorsk population				
Dec. 2015 to Jan. 2016	2	6	Volozhin population				
Oct. 2016				2	16	10	Ardavskaya group
Oct. 2016				2	6	3	Losinka group

Information on the bison founders brought in 2015–2016 is shown in Fig. 1 b.

Forty-one bison (28 individuals from Ardavskoye and 13 individuals from the stow Losinka) were released in October 2016. Animals from Ardavskoye joined the main free-living herd that wintered near this stow in January 2017. Bison from Losinka formed a free-living group separated from the main herd by the Svolva River.

Data on bison imported to Krasny Bor Game Husbandry and on their release into the wild are presented in Table 1.

According to February 2019 winter census data, the Krasnoborsky free-living population consisted of 155 individuals.

Animal numbers and breeding

Increase in abundance of the Krasnoborsky population in the beginnings of its existence (2013–2016) was determined by two unrelated factors (Fig. 2). On the one hand, it was the import of animals from other Belarusian populations, while on the other it was reproduction. Therefore, it will be incorrect to talk about a natural herd dynamics during the first years. In total, 68 individuals were imported to the territory of Krasny Bor Game Husbandry, 66 of which became founders of a free-living population. Four individuals (3 males and 1 female) died after they were released into the wild. At the beginning of 2019, 40.0 % of the herd consisted of animals imported into Krasny Bor from other populations.

Comparison of calf fertility in females of reproductive age over the indicated period gives a more objective picture of growth rates of the Krasnoborsky population (Fig. 3). It reached a value of 66.6 % in captivity. In the first year (2016), when both the rutting and birth of young animals took place in the wild, the rate was 50.0 %. Such high growth rates were common for the first years of existence of most free-living Belarusian bison populations (Kozlo, Bunevich, 2009).

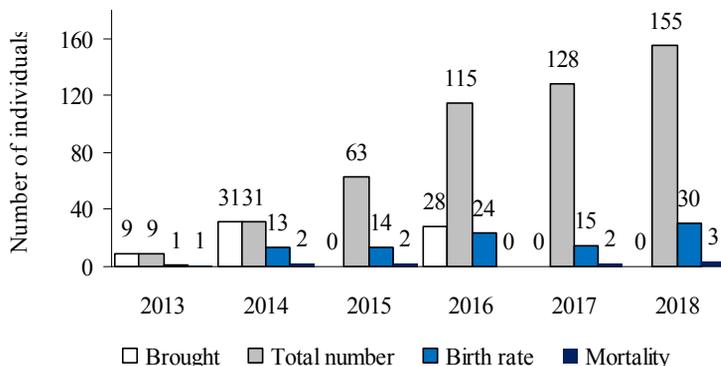


Fig. 2. Dynamics of the Krasnoborsky population from 2013 to December 2018.

Рис. 2. Показники чисельності красноборської популяції зубрів за період з 2013 р. до грудня 2018 року.

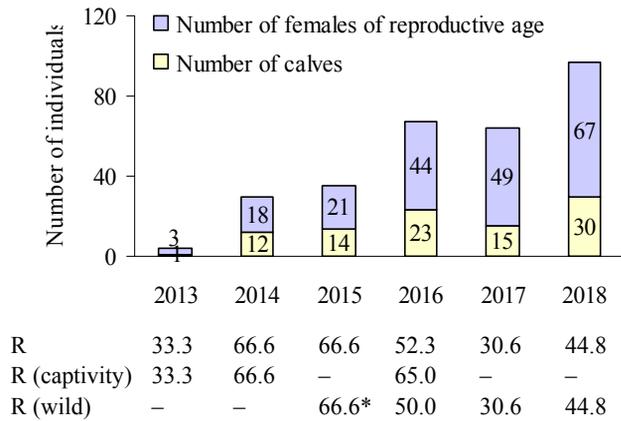


Fig. 3. The ratio between the number of calves and the number of reproductive females (in absolute and relative (R) values) in the Krasnoborsky bison population for the period from 2013 to December 2018; * the rutting period occurred during the time of enclosed keeping.

Рис. 3. Співвідношення кількості народжених телят до кількості самок репродуктивного віку (в абсолютних і відносних (R) величинах) у красноборській популяції зубра за період з 2013 р. до грудня 2018 р.

Mortality

Bison mortality in the Krasnoborsky population is low. It is usually caused by injuries and accidents. The death of ten animals from the Krasnoborsky population was reliably recorded for the period from 2013 to 2018. Three bison died during keeping in captivity and seven more after the herd was released into the wild. Causes of death were as follows: injuries caused by other bison (2 cases, both during captive keeping), death in reclamation canals, streams, and rivers in winter and spring (4 cases), infection following injury (1 case), death of young animals from infectious disease (2 cases), and unknown reasons (1 case). The sex-age composition of the dead animals was the following: 1 male over 10 years old, 4 males aged 6 to 10 years, 1 male aged 4 to 6 years, 3 calves (2 males and 1 female), 1 female over 10 years old.

Sex-age structure

Predomination of animals of the younger age groups is characteristic for the Krasnoborsky bison population (Fig. 4). The ratio between males and females is 1 : 1.84. However, it is not the same for different age groups. Males predominate in a ratio of 1.08 : 1 to 1.18 : 1 in groups of yearlings, one-year-old, and 2 to 3 years old animals. The proportion of females is significantly higher in older age groups. The “male-female” ratio is 1 : 2.8 among animals of 3 to 6 years of age and 1 : 1.95 for bison aged over 6 years.

The sex ratio developed naturally in the first three age groups, but it was formed artificially in older age groups in the process of bison selection for the Krasnoborsky population. The Krasny Bor Game Husbandry during the first deliveries of animals in 2013–2014 was oriented towards creating a maternal herd with a sex ratio close to 1 : 1.5. Subsequently, this number changed in favour of females to 1 : 9 for the group in the tract Ardavskoye and to 1 : 2.33 for the group based in Losinka. In 2015–2016, this ratio was 1 : 9 for bison located in the enclosure in the stow Ardavskoye and 1 : 2.33 for animals based in the stow Losinka.

Despite the significant predominance of females in older age groups, males from the Krasnoborsky population often go beyond the herd's habitat, moving away for a considerable distance. Such vagrancy has become a common feature of behaviour for some males.

The Krasnoborsky free-living population is a young formation of bison. The portion of animals of more than ten years of age is only 10.3 % of the total abundance. The high percentage (61.9 %) of animals of younger age groups (less than 6 years old) indicates a high growth potential of this population (Fig. 5).

Spatial and social structure

The free-living Krasnoborsky population is geographically divided into two groups: Ardavskoye and Losinka, named after the places they were released (Fig. 6). The first group emerged in 2015, while the second was formed in 2016–2017.

The area of forested habitat of the Ardavskoye group's core herd is over 14 thousand ha.

The Losinka group inhabits a forested area of about 3 thousand ha. Both groups are constantly expanding the boundaries of their range.

The population density of bison of the Ardavskoye group was 8.6 ind. / 1000 ha according to data from January 2019. The density of animals in the Losinka group was 11.3 ind. / 1000 ha. These parameters are slightly higher than that for the bison population from Belovezhskaya Pushcha (Bunovich, 2003). Up to 90 % of animals from the Ardavskoye group lived on an area of 700-800 ha for a long time during winter feedings in 2016–2018.

Several key sites exist within the distribution area of the Krasnoborsky population. Their location is crucial for the territorial distribution of bison (Fig. 5).

Both groups demonstrate selective preferences to various habitats in their territory. The most significant role in the formation of their spring-autumn structure is played by floodplains of small forest rivers, clearings with a dense grass cover, forage fields, and meadows of artificial origin. River floodplains are also ways of local seasonal migrations of the animals. Most of the coniferous and mixed forests are unattractive to bison and they do not play a significant role in the formation of the population's territorial structure.

In winter, bison are concentrated near feeding sites. Middle- and old-growth spruce forests located nearby become important at this time as resting places and the animals use them regularly as daytime shelters. Up to 5–7 males permanently live outside the Krasnoborsky population's area.

The social structure of the Ardavskoye group is extremely unstable. Bison are able to form large herds in seasonal concentration places. They include animals of all sex-age groups. The number of such herds can reach 50–60 individuals in spring until autumn and 90–100 individuals during winter. Some adult males are in these herds all the time. Apparently, this behaviour has developed because of the long period of enclosed keeping.

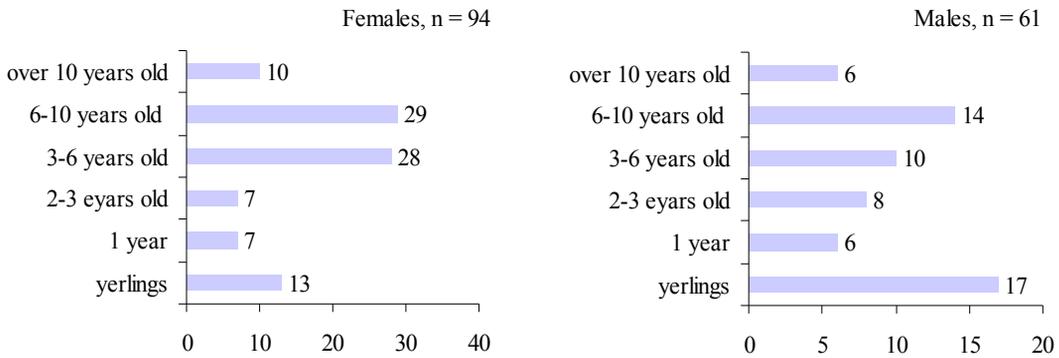


Fig. 4. Sex-age structure of the Krasnoborsky population based on data for January 2019.

Рис. 4. Статевно-вікова структура красноборської популяції за даними за січень 2019 року.

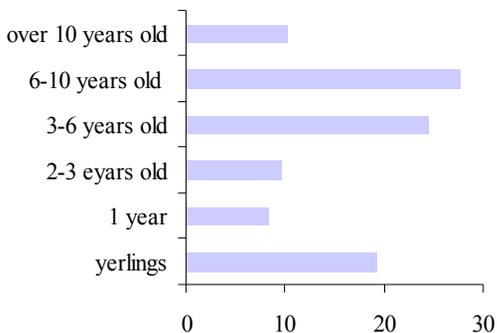


Fig. 5. The percentage of age groups in the Krasnoborsky free-living bison population (for January 2019).

Рис. 5. Відсоткове співвідношення вікових груп у красноборській вільноживучій популяції зубрів (станом на січень 2019 року).

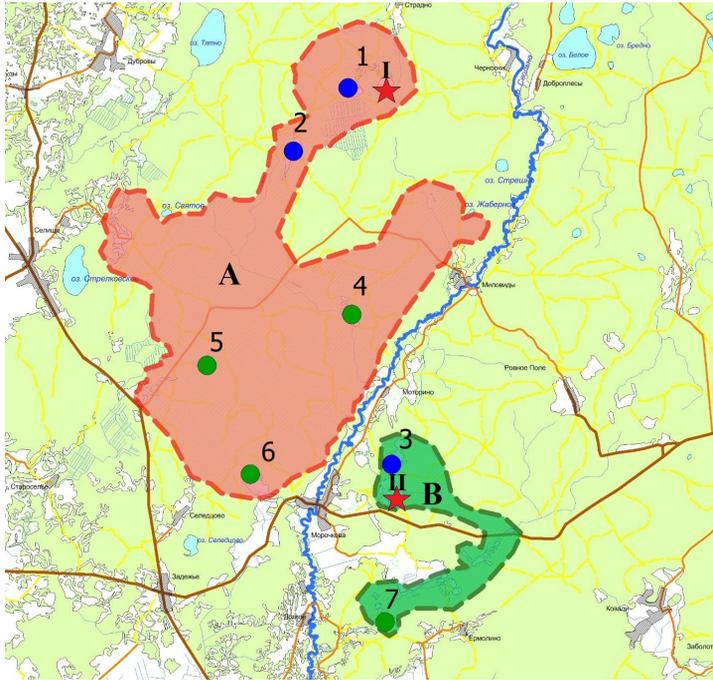


Fig. 6. Distribution map of the Krasnoborsky bison population.

★ — bison release sites (I — Ardavskoye; II — Losinka); A — territory of the Ardavskoye group; B — territory of the Losinka group; ● — key wintering areas; ● — key summering areas.

Рис. 6. Карта сучасного поширення краснобоської популяції зубрів.

★ — місця випуску зубрів (I — Ардавське; II — Лосинка); А — територія існування групи «Ардавська»; В — територія існування групи «Лосинка»; ● — ключові місця зимівання; ● — ключові місця літуння.

Parasites

Nematodes (*Nematodirus* sp. and *Trichocephalus* sp.) and trematodes (*Fasciola hepatica* and *Paramphistomum* sp.) were found in the samples. One sample also contained a cestode (*Moniesia expansa*). All these parasites are widespread not only in animals from the maternal population of Belovezhskaya Pushcha (Krasochko et al., 1996) but also in other bison populations in Belarus and Russia (Kashtalian et al., 2013).

Parasites were found in 60 % of the studied samples collected before deworming, which indicates a high level of infection. However, the intensity of infection with each of these helminths was low (up to 10 eggs in the field of view). The level of infection decreased twice after deworming during the winter feeding.

Monitoring points were established at six water bodies to assess the charge of gastropods as intermediate hosts of ungulate parasites. Four of them, classified as foci of infection, revealed molluscs containing digens that parasite in bison. *Parafasciolopsis fasciolaemorpha* and two other parasite species belonging to the family Paramphistomidae were discovered. The degree of infection in some territories reached 37.8 % (Akimova et al., 2017). Parasites of ungulates were not detected in gastropods at two monitoring sites, although there were mollusks that were their carriers. This allowed to classify these water bodies as potentially hazardous.

In general, the parasitological situation in the habitats of the Krasnoborsky population is assessed as complex. It requires regular monitoring and taking measures to reduce invasive activity in identified foci of infection.

Conclusions

Analysis of the bison distribution indicates that only a third part of the game husbandry forested area has suitable conditions for their habitation, which is about 27 thousand ha. The game husbandry maintains a population density at a level close to 10 ind. / 1000 ha thanks to intensive biotechnological measures. Based on this, an abundance of 280–330 individuals is considered optimal for the Krasnoborsky population.

A rapid increase in the number of animals occurred at the initial stage of the Krasnoborsky population's existence. This is due to the numerous founders, high birth rates and low mortality. How-

ever, in addition to maintaining a stable growth, ensuring the highest possible level of genetic diversity is important for the population's long-term existence. The development and implementation of a management plan for the Krasnoborsky population can help to achieve this goal.

It would allow to create:

- 1) a functional life support system for the Krasnoborsky population by performing a complex of biotechnical, conservational, and veterinary preventive measures;
- 2) a system of genetic control over the state of the Krasnoborsky population;
- 3) a system of interaction between stakeholders regarding the management and rational use of the Krasnoborsky population.

Among the priority measures to maintain the Krasnoborsky population, the following should be noted:

- 1) Studies to assess the bison number and the state of habitat of bison herds. In addition to census work, continuous monitoring of the population's sex and age structure, studies the phenology characteristics, social behavior, reproduction and spatial distribution of animals should be conducted. An important role should be given to the study of the bison's influence on forest tree plantations in places of concentration of herds.
- 2) Parasitological studies and preventive measures. They suggest an assessment of the parasite fauna structure, identification of trematodoses foci and determination of the degree of their danger to the bison, continuous monitoring of the parasitological situation in the Krasnoborsky population habitats. It is necessary to carry out measures of veterinary control over the condition of animals and conduct regular sanitary measures in places of its concentration and places of winter feeding.
- 3) Genetic monitoring. It involves the collection of biological samples for genetic research, the formation of genetic database and genetic samples bank. The result of such work will be the development of genetic control system for the Krasnoborsky population state.
- 4) Breeding work. It is necessary to identify animals from the Krasnoborsky population that have breeding value by genetic and morphometric indicators. It is necessary to increase the genetic diversity of the population by selecting and importing bisons of the lowland Bialowieza line (*Bison bonasus bonasus*) from other keeping places.
- 5) Improving the effectiveness of measures for bison protection. It involves training events among game managers of Krasny Bor Game Husbandry, continuous monitoring of the bison's territorial distribution and seasonal migration by them, the exchange of operative information on animals leaving the Game Husbandry's territory, raid activities in the bison habitats, and annual assessment of the effectiveness of protection measures.
- 6) Biotechnical activities. Expanding the network of feeding stations to prevent excessive bison concentration in places of seasonal feeding, regular food quality monitoring, creating additional and maintaining existing forage fields and meadows.
- 7) Conflict situations resolution. Continuous monitoring of the situation when bison leave the Krasnoborsky population's habitats. Work with the local population to prevent conflict situations between humans and animals and to clarify the rules of conduct when meeting them. Search for common interests with government agencies, land and forest users in the work to preserve the Krasnoborsky population and minimize the damage caused by bison to forestry and agriculture.
- 8) The use of the Krasnoborsky population for the purposes of ecological tourism and environmental education as an alternative to other ways of its exploitation (hunting, etc.).

Indicators of effective implementation of such management plan would be the absence of poaching in the population's territory, stable growth of abundance, balanced qualitative parameters and increased genetic potential, as well as improved parasitological situation in bison habitats.

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References

- Akimova L. N., P. A. Shibekin, A. P. Kashtalian. 2017. Investigation of gastropods for detection a natural focus of trematodosis of Ungulata in the Krasny Bor Game Husbandry. In: *Current Issues of Zoological Science in Belarus. Volume 2* (Materials of the XI Zoological Conference, Minsk, November 1–3, 2017). Minsk, 28–36. (In Russian)
- Belousova, I. P. 1999. *The value and evaluation of genetic diversity indicators to solve the problem of the European bison preservation*. ONTI PNC RAS, Pushchino, 1–108. (In Russian)
- Bunevich, A. N. 2003. Analysis of the bison population formation in the Belarusian part of Belovezhskaya Pushcha. *Belovezhskaya Pushcha. Research. Vol. 11*. Publishing house of S. Lavrov, Brest, 178–204. (In Russian)
- Kashtalian, A., A. Subbotin, T. Shendrik. 2013. Helminthofauna of European bison from Borisov-Berezinsky free-living population. *European Bison Conservation Newsletter*, 6: 95–106.
- Kozlo, P. G., A. N. Bunevich. 2009. *Bison in Belarus*. Belarus. Navuka, Minsk, 1–318. (In Russian)
- Krasinska, M., Z. A. Krasinski. 2007. *The European Bison. A Nature Monograph*. Bialowieza, 1–317.
- Krasochko, P. A., I. A. Krasochko, A. S. Shashenko, Yu. P. Kochko, V. I. Gayevsky, A. N. Bunevich. 1996. The spread of infectious and invasive diseases in Bialowieza bison. *Biological Diversity Conservation of the Belovezhskaya Pushcha Forests*. Kamenyuki, 225–233. (In Russian)
- Martinkevich, G. I., N. K. Klizunova, G. T. Haranicheva, O. F. Jakushko, L. V. Loginova. 1989. *Landscapes of Belarus*. University, Minsk, 1–239. (In Russian)
- Olesh, W. 1987. Analysis of Inbreeding in European bison. *Acta Theriologica*, 30: 373–387.
- Radwan, J., A. Kawalko, J. M. Wojcik, W. Babik. 2007. MHC-DRB3 variation in a free-living population of the European bison, *Bison bonasus*. *Molecular Ecology*, 16: 531–540.
- Rautian G. S., Kalabushkin B. A., Nemtsev A. S. 2000. A new subspecies of the European bison, *Bison bonasus montanus* ssp. nov. (Bovidae, Artiodactyla). *Doklady Biological Sciences*, No. 375: 636–640. (In Russian)
- Sipko, T. P., I. G. Udina, Yu. Badagueva, N. G. E. Suklimowa. 1994. Polymorphism of k-casein gene in the family Bovidae: comparative analysis. *Russian Journal of Genetics*, 30: 203–207. (In Russian)
- Sipko, T. P. 2002. Bison. Population genetic analysis. *Issues of Modern Hunting* (Materials of the International Conference December 5–6, 2002), Moscow, 386–405. (In Russian)
- Soubrier, J., G. Gower, K. Chen, S. M. Richards, B. Liams et al. 2016. Early cave art and ancient DNA record the origin of European bison. *Nature Communications*. Online: 18 October 2016. Article No.: 13158.
- Yurkevich I. D., D. S. Golod, V. S. Adericho. 1972. *Vegetation of Belarus, its mapping, protection and use*. Science and Technology, Minsk, 1–248. (In Russian)