VYTAUTAS MAGNUS UNIVERSITY

Artūras KIBIŠA

THE IMPACT OF EUROPEAN BISON, AMERICAN BISON AND CERVIDS ON ECOSYSTEMS

Summary of doctoral dissertation

Natural sciences, Ecology and Environmental (N 012)

Kaunas, 2019

This doctoral dissertation has been prepared during the period of 2012-2018 at the Vytautas Magnus University Agriculture Academy, under the doctoral program right conferred to Vytautas Magnus University and Lithuanian Research Centre for Agriculture and Forestry, on February 22, 2019, by the Order No. V-160 of the Minister of Education, Science and Sport of the Republic of Lithuania.

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The doctoral thesis will be defended in the public meeting at the Committee of Ecology and Environmental Science at 10 a.m on 28 June 2019, at the Conference Hall of Vytautas Magnus University Agriculture Academy, Room No. 217.
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The summary of the dissertation was distributed on 27 May 2019. This dissertation is available at Martynas Mažvydas National Library of Lithuania and at the libraries of Vytautas Magnus University Agriculture Academy and Institute of Forestry, Lithuanian Research Centre for Agriculture and Forestry.

VYTAUTO DIDŽIOJO UNIVERSITETAS

Artūras KIBIŠA

STUMBRŲ, BIZONŲ IR ELNINIŲ POVEIKIS EKOSISTEMOMS

Mokslo daktaro disertacijos santrauka
Gamtos mokslai, ekologija ir aplinkotyra (N 012)

Kaunas, 2019

Disertacija rengta 2012–2018 metais Vytauto didžiojo universiteto Žemės ūkio akademijoje pagal suteiktą doktorantūros teisę Vytauto Didžiojo universitetui kartu su Lietuvos agrarinių ir miškų mokslų centru Lietuvos Respublikos švietimo, mokslo ir sporto ministro 2019 m. vasario 22 d. įsakymu Nr. V-160.

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Disertacija bus ginama viešame Ekologijos ir aplinkotyros mokslo krypties tarybos posėdyje 2019 m. birželio 28 d. 10 val. Vytauto Didžiojo Žemės ūkio akademijos centrinių rūmų posėdžių salėje, 217 kab.
Adresas: Studentų g. 11, 53361 Akademija, Kauno r., Lietuva.

Disertacijos santrauka išsiuntinėta 2019 m. gegužės 27 d. Disertaciją galima peržiūrėti Lietuvos nacionalinėje Martyno Mažvydo, Vytauto Didžiojo universiteto Žemės ūkio akademijos ir Lietuvos agrarinių ir miškų mokslų centro filialo Miškų instituto bibliotekose.

INTRODUCTION

The scientific problem, the relevance of the study

European bison was rendered extinct in the early 20th century due to the spread of the human population, loss of suitable habitat territories and over-hunting, After the successful reintroduction of captivity-bred European bison, its populations have recovered, and their abundance is growing, but the populations of free-ranging European bison are isolated from each other, which causes problems with inbreeding and fragmentation of populations. The success of European bison conservation depends on the growth of abundance of isolated populations and assurance of the interconnection between populations. European bison is included in the IUCN Red List of Threatened Species, the Bern Convention Protected Fauna Species list, the Red Data Books of Lithuanian and other countries (The IUCN 2008).

In Lithuania, European bison became extinct in the 17th century and were reintroduced in 1969 (Balčiauskas, Kazlauskas 2014). 10 European bison were brought to the enclosure in the Pašilė forest from the Central breeding centre in Russia. In 1973, the first bison were released into Pašilė forest. In the beginning, the herd of 20-30 individuals lived sedentarily in Panevėžys district, and since 2003 (especially since 2013) the abundance of the herd was growing. In Lithuania, European bison live in a rather anthropogenic area of agricultural and forest mosaic landscape. The area of their distribution in central Lithuania covers 60,000 ha.

While wandering and feeding, bison select different habitats, some of which they avoid, some prefer. Bison affect the environment in many ways, while in contemporary landscapes they often cause certain conflicts with people (Kerley et al. 2012, Cromsigt et al. 2012, Balčiauskas, Kazlauskas 2014). Such animals require large areas and food resources; therefore, they often compete with domestic animals, damage farmland, and endanger roads. The damage to agriculture caused by protected large animals is a relatively new aspect in Europe and is currently particularly relevant in Lithuania. The growing abundance of European bison in central Lithuania is raising the debate on the optimal number of bison in the mosaic landscape and rising environmental problems.

The bison had a major impact on European broad-leaved deciduous forests and forest steppes in prehistoric times. At the same time, bison has always been an important

species of game. It is important to evaluate the importance of the bison in the forest ecosystem in regard to their relationship with other ungulates. Five species of ungulates play an important role in European forests: European bison, red deer, European roe deer, moose and wild boar, and therefore account must be taken of the proportion of all animals in the forest ecosystem (West, Parkhurst 2002). Highly abundant populations of these animals often have a negative impact on the species richness and abundance of plants, but they can have a positive impact on disturbance factors, seed distribution, etc.

In Lithuania, the influence of bison on ecosystems has been little studied (Mačionis 1995, Balčiauskas 1999, 2004, Balčiauskas, Kazlauskas 2014, Balčiauskas et al. 2017), and much of attention has been paid to the study of cervids (Baleišis, Bluzma 1999, Baleišis et al. 2003, Belova, 1997, 1999, 2005, 2012, Bluzma, Baleišis 1999, Marozas et al. 2009, Padaiga, 1996, 1998, 2010, Padaiga, Pėtelis 1995, Pėtelis, 1998, 2002, 2004, 2010, Navasaitis, Pėtelis 1998, Pėtelis, Brazaitis 2003, Brazaitis et al. 2014). Introduced and reintroduced large herbivores affect the ecosystem as competitors for native species (West, Parkhurst 2002), but there are not many detailed studies of this effect. The environmental impact of introduced animals has not been studied. Newly introduced species may have an impact on different plant species. Usually, the acclimatization disturbs the established ecological balance, changes the food chain formed during the evolution, and can suppress or completely eliminate the local species. Introduced animals can have a direct or an indirect impact on forest vegetation and altered soil properties can also lead to the emergence of one species and the loss of others.

Aim and objectives of the study:

The aim of the study - to investigate the impact of reintroduced European bison and introduced American bison and cervids on vegetation and soil, types of habitats selected by European bison and damage dealt to agroecosystems in mixed forest and forest-steppe regions.

Objectives:

1. Study the impact of enclosure-kept European bison, American bison and cervids on the physical and chemical properties of soil in mixed forest and forest-steppe regions.

2. Study the impact of enclosure-kept European bison, American bison and cervids on the vegetation in mixed forest and forest-steppe regions.

3. Study the habitat selection of free-ranging European bison and cervids and their impact on forest communities in mixed forest and forest-steppe regions.

4. Study the impact and damage of free-ranging European bison on agroecosystems.

Scientific novelty, the theoretical and practical significance of the study

The impact of bison and cervids on ecosystems (physical and chemical properties of soil, herb and shrub layer) under conditions of mixed forest and forest-steppe regions were studied. For the first time in Lithuania, the spatial distribution and the habitat selection of European bison was identified utilising the GPS method. The necessity to reduce the population density of European bison in central Lithuania was justified. For the first time in Lithuania, the evaluation of damage to agricultural crops was proposed and tested using aerial photographs taken by an unmanned aircraft (drone) and analysed using the ArcGIS software. This method can be used to estimate the damage caused by European bison on agricultural crops when farmers apply for compensation for losses.

Statement to be defended

- Ungulates kept in enclosure have impact to physical and chemical properties of soil. This impact differ according site type.
- European bison, American bison and cervids have impact on the vegetation composition and abundance. This impact differ according site type.
- Free-ranging European bison more frequently select forests habitats, which differing in stand age, species composition.
- The damage of free-ranging European bison to agroecosystems increased. The novel methods to evaluate damage of free-ranging European bison to agriculture crops using aerial photographs taken by an unmanned aircraft (drone) is appropriate to use.

Approval of the dissertation

Scientific publications published on the topic of the dissertation: 3 scientific articles in peer-reviewed publications, 1 of them in the publication referred in Clarivate Analytics Web of Science database and being indexed, 3 in other publications, 2 in popular science publications. The results were presented at 5 international conferences abroad and 2 seminars in Lithuania.

Volume and structure of the dissertation

This doctoral dissertation consists of an introduction, literature review, study object and methods, results of the study, conclusions, list of references and list of scientific

publications published on the topic of the dissertation. The results are presented in 6 chapters. The list of references includes 268 sources. The doctoral dissertation contains 93 pages, including 55 figures and 13 tables.

2. STUDY OBJECTS AND METHODS

2.1. Study objects

2.1.1. Study objects in the forest-steppe region

Fieldwork was performed in the "Bulandy meken" game farm in Akmolinsk region of Kazakhstan, where a large 8595 ha enclosure was installed, and in smaller enclosures for American bison (*Bison bison*) and Siberian red deer (maral) (*Cervus elaphus sibiricus*).

During the wildlife census count in 2014, there were four enclosures in the central part of the forest. Two large enclosures, one of which (975 ha) is for Siberian red deer (maral) and another (855 ha) - for wild boars' breeding and hunting. One larger enclosure (95 ha) for American bison and one small enclosure (65 ha) for fallow deer (*Dama dama*). In these enclosures, the animals are fed intensively feed during the cold season. Following the census count of cervid animals by pellets, in the summer of 2014, the entire game farm area was enclosed with a mesh fence. In the middle of the territory, two animal enclosures for breeding red deer and wild boar were disassembled and animals were released into a common game farm area of 8595 ha, thus forming a hunting enclosure.

In the American bison (*Bison bison*) enclosure, a herd of 12 bison was wintering in 2013. In the Siberian red deer (maral) (*Cervus elaphus sibiricus)* enclosure, a herd of 32 maral was wintering in 2013.

2.1.2. Study objects in the mixed forest region

The study in mixed forest region was performed in European bison enclosure (typological soil group - Lc) in the 64th block of Pašiliai forest of Krekenava Forest District of Panevėžys Forest Enterprise. The 50 ha enclosure was built in 1969 in the Red deer enclosure complex in Mažeikiai district. The 50 ha enclosure (typological soil group - Nd) was built in 2010 in Švenčionys district. The 14 ha enclosure (typological soil group

- Nb) was built in 2011. Study of the impact of free-ranging European bison and cervids on forest vegetation and agroecosystems was performed in Panevėžys and Kedainiai districts in central Lithuania.

Detailed studies using GPS of the European bison habitat selection and caused damage were carried out in the area near Kėdainiai, which is demarcated by the Juodkiškės water reservoir in the northern part and is bordered by rail on the western and south-western sides and Via Baltica motorway on the eastern side. The territory contains forests of Juodiškiai and Bubliai. The habitat selection of the free-ranging European bison was studied in the area of 1172 ha, comprising of 436 ha of forests and of 736 ha of agricultural land. The herd of 34 European bison entered the semi-isolated area in winter of 2016. This area is partly isolated on one side by the motorway, on the other side by the railway and in the northern part by the water reservoir and settlement.

The area under study is dominated by habitats of fertile, temporarily wet soil groups (Ld, Lf). The tree stands are dominated by soft deciduous trees - birch, black and white alder, hard deciduous trees (ash) are present. Of conifers, spruce occupies only 7 % of forests in the area. Agricultural areas are dominated by spring and winter wheat, corn and grasses.

2.2. Study methods

2.2.1. Soil compaction study in the enclosures

Soil compaction studies in the forest-steppe region were carried out in May of 2014 in American bison enclosure where a herd of 12 bison wintered and in Siberian red deer (maral) enclosure where 32 maral wintered. The soil compaction was metered using *Field ScoutTM SC 900 Soil Compaction Meter*.

Soil compaction studies were carried out in the most frequently visited places of the American bison - by the path and at a 1 m distance from the trampled path leading to the stationary feeding ground. Comparison of soil compaction in American bison enclosure in different biotopes: on the trampled path towards feeding facilities, adjacent to the trampled path, in the forest and in the meadow.

Soil compaction in American bison and maral enclosures was measured on the path and adjacent to the path at 2.5 cm intervals to the depth of 0 to 40 cm, and during the

measurement of soil compaction in different biotopes in American bison enclosure - at 2.5 cm intervals to the depth of 0 to 20 cm. Soil compaction was measured in 25 repeats.

2.2.2. Study of soil chemical properties in the enclosures

Studies of soil chemical properties in the forest-steppe region were performed in the American bison enclosure. In this enclosure, soil samples were taken at the depths of 5, 10, 20 cm in May of 2014 and May of 2017. In 2014, the duration of American bison being kept in the enclosure was 1 year, and in 2017 the duration of American bison being kept in the enclosure was 3 years.

In the mixed forest area, studies of soil chemical properties were carried out in the enclosures of 3 different soil group habitats. One enclosure was in the Pašiliai European bison sanctuary (Lc soil group types), the other two were the red deer enclosures (Nb and Nd soil group types). Soil samples were taken at depths of 0-10 cm in and around the enclosures. Soil samples were collected systematically from 8 sites for a composite sample of four repetitions.

Soil chemical analysis was performed at the Agrochemical Research Laboratory of the Lithuanian Research Centre for Agriculture and Forestry in Kaunas. The following soil chemical properties were determined: pH_{KCl}, P_2O_5, K_2O, C_{org} and N_{sum}. The following chemical analysis methods were used: pH 1mol/l in KCl suspension - ISO 10390:2005. The concentration of plant available forms of phosphorus (P_2O_5) and potassium (K_2O) - LVP D-07:2016. Egner-Riehm-Domingo (A-L) method developed by the Laboratory. Humus content determined in accordance with ISO 10694:1995, multiplied by factor 1,724. Total nitrogen (N_{sum}) - ISO 11261:1995.

2.2.3. Vegetation study in the enclosures

In the forest-steppe area, vegetation field studies were carried out in the American bison enclosure of the “Bulandy meken” game farm, in northern Kazakhstan. The study was conducted in May 2014 and May 2017. Vegetation studies in 2014 were carried out prior to the American bison entering the enclosure (1st year) and in 2017 the duration of bison being kept in the enclosure was 3 years. In sites with typical vegetation, 6 plots with an area of 100 m^2 each were set. Each plot was then divided into 25 count fields (with an area of 2x2 m^2 each), where all species of the understory, herbaceous plants and mosses were registered, indicating their projection cover as a percentage.

In the mixed forest area, vegetation field studies were carried out in the enclosures of 3 different soil group habitats. One enclosure was in the Pašiliai European bison sanctuary (Lc soil group types), the other two were the red deer enclosures (Nb and Nd soil group types). The study was also carried out in the impact area of free-roaming bison (in the bedding site) and in the adjacent forest. Studies were conducted in 2014-2016. 5 transects were set in the enclosure and 5 - adjacent to the enclosure (for control). Vegetation studies were carried out in transects of 2x10 m length, which were divided into five 2x2 m area plots. In these plots, all the understory trees and shrubs were counted, and their species were indicated. The species composition of the subshrubs, herbaceous plants and mosses and the projection cover of each species were also determined.

In the mixed forest region, five 2x2 m permanent plots were constructed and enclosed in the bison shelter to study the regeneration of herbaceous vegetation. The species composition of the understory, subshrubs, herbaceous plants and mosses and the projection cover of each species were also determined. Plant species were identified using field guides (Lekavičius 1989, Gudžinskas 1999, Vilkonis 2008, Jäger 2013).

A multivariate analysis method (RDA - redundancy analysis) was used to determine differences in vegetation: in the forest-steppe area - to identify changes within 3 years (2014-2017), in mixed forest region - to determine the impact in the enclosure compared to control. This method can be used to determine the species distribution in the ordinate space, depending on the factors analysed. The statistical reliability of the analysis (p) is determined by using normal distribution independent Monte Carlo 499 permutation test (Jongman et al. 1987, Kent, Coker 1992, Lepš, Šmilauer 2014, ter Braak, Šmilauer 2002).

Impact on species diversity is determined by the mean number of species in the plot (R) and the Shannon species diversity index (H'). The Dufrene and Legendre Indicative Species Analysis Method (ISA) was used in differently affected groups to assess the distribution of individual plant species. Indicator values for each species group were statistically evaluated using the Monte Carlo permutation test. Indicator values, expressed as a percentage, vary from 0 % (no indication) to 100 % (perfect indication) (McCune, Mefford 2011).

The Ellenberg indicator values (Ellenberg 1992) were used to evaluate the ecological conditions in the mixed forest area. H. Ellenberg has provided indicator values for plant species (Ellenberg 1992). Each indicator is measured on a 9-point scale

(humidity indicator - 12-point scale). In order to evaluate the ecological conditions of the studied community, the weighted averages of the mean indicator values of all community plant species are calculated (Diekmann 1995). The ecological conditions of the vegetation habitats were assessed according to 6 main indicator values: L - light; K - continentality; T- temperature; F- moisture; R - the reaction of soil (pH); N - nitrogen. Analyses were performed using software packages PCORD (McCune, Mefford 2011) and STATISTICA (Sokal, Rohlf 1997).

2.2.4. The abundance of European bison, American bison, cervids and their impact on woody vegetation

Study of the abundance of cervid animals and their impact on woody vegetation in the forest-steppe region was performed in the Akmolinsk region of Kazakhstan, at the "Bulandy meken" game farm. The 8595 ha enclosure was installed in 2013. In 2014, 12 bison were admitted to the territory, and in 2017 there were 29 individuals. Cervid census count, together with the evaluation of the condition of the wintering areas of cervids in the forest-steppe region was performed in 2014 and 2017.

In 2016, census count in the mixed forest region was performed in Kėdainiai and Panevėžys districts in central Lithuania in areas of 1775.2 ha, where free-roaming European bison wander. Cervid census count, together with the evaluation of the condition of the wintering areas of cervids in mixed forest region was performed in 2016. Census count was performed in Kalnelio forest (count area - 1775,2 ha) near Upytė town in Panevėžys district, where European bison herd of 30 individuals was located and in Šventybrasčio forest (count area - 1775,2 ha) in Kėdainiai district, where European bison herd of 17 individuals was located.

Determination of abundance and density of cervids

The abundance, density, gender (except roe deer) and age structure of the cervid population in the study area are determined by the McCain (1948) pellet count method (McCain 1948, Neff 1968, Putman 1984, Padaiga 1996, Campbell et al. 2004), which was adapted in Lithuania by V. Padaiga in 1964. The count criterion is the number of pellets left by the animal and the duration of winter feed. Transects are arranged to include habitats that are as diverse as possible in the forest. The count is performed in 4-meter wide transects, divided into 100-meter sections (1 km long transect per 100 ha of forest).

According to the form of pellets, the species, age (moose, red deer, roe deer, fallow deer) and sex are determined.

Evaluation of the impact of cervids on woody vegetation

In the course of the cervid census count, an evaluation of the impact of cervids on forest growth is also carried out. The impact of cervid animals on woody plants is most pronounced during the non-vegetation period when natural dietary resources become the minimum factor for cervid animals (Leopold 1933, Jurgenson 1971, Padaiga 1996). As a result, the interaction between cervids and forest vegetation is investigated at the end of the winter period until the growing period begins (Belova 1997, 2010, 2011, 2012). According to this method, the frequency, abundance of trees and shrubs, the intensity of shoot browsing, their use for nutrition and the portion of shoots of each species of trees and shrubs in the total winter feed balance are determined (Aldous 1944, Padaiga, Pėtelis 1995).

Counts in transects are performed by setting 100 m^2 area (with a radius of 5.65 m) circular sample plots, which are distributed in transects every 100 meters. In each sample plot all healthy and damaged (twig breaking, shoot browsing and bark scratching) understory trees and shrubs are counted. A tree is considered damaged (twig breaking, shoot browsing and bark scratching) if at least one shoot (side or top) is browsed and/or there is a bark scratching sign of any size. For shrubs, each stem which has grown from the ground, are recorded separately. Based on the count data obtained, the presence (S), abundance (G) intensity (I) of understory use, utilization factor (U) and each understory species portion in total winter feed balance (Q) is calculated for each of the species of trees and shrubs (Padaiga 1996).

2.2.5. Study of the habitat selection and impact on forest vegetation of free-ranging European bison in the mixed forest region

The habitat selection of the free-ranging European bison was studied in the area of 1172 ha, comprising of 436 ha of forests and of 736 ha of agricultural land. The herd of 34 European bison entered the semi-isolated area in winter of 2016. In the snow-free period lasting from early spring to late autumn, European bison form structured herds and depend on natural food resources in the forest or in agricultural fields (Krasińska et al. 1987, 2000). During March-November in 2016 a collar with GPS was attached to a female

European bison. The location of the European bison herd was recorded every 8 hours. A total of 1389 registration points were received.

Forest habitats (habitats, dominant stand species, age) have been described according to the standwise forest inventory database. Using GIS, areas of forests and agricultural fields were calculated, proportions of individual forest habitats were determined. Agricultural plants were identified visually, and their areas were identified using GIS.

The European bison location information obtained during March-November in 2016 was analysed using the ArcGIS software package. For every month the home range (Worton 1989) of European bison was estimated by the 100 % minimum convex polygon (MCP) method. The resulting points and available biotope information were used to determine habitat proportions and habitat selection.

To evaluate habitat selection, we used Jacobs' index (Jacobs, 1974): $D = (r - p) / (r + p - 2rp)$, where r is a fraction of habitat among habitats used by bison and p is a fraction of habitat in a territory. D values range from −1 for maximum avoidance to +1 for maximum positive selection. We set up the critical value of Jacobs' index at ±0.2. Chi-square test was used to verify significant differences between the proportion of the availability of a habitat based on the vegetation cover area and the habitat selection.

The impact of European bison on vegetation was studied in the bedding site and in the adjacent area according to the methods described in Item 2.3.3.

2.2.6. Study of the impact of European bison on agroecosystems and the damage caused

In the semi-isolated area near Kėdainiai, adjacent to the Juodkiškės and Bubliai forests, the visits of free-ranging European bison to individual agricultural fields was evaluated according to the methodology described above.

In order to evaluate the damage caused by the European bison to the agricultural plants, data on the damage caused by the bison and the compensations paid were collected from the Ministry of Environment and Kėdainiai Municipality.

A new method of evaluation of damage caused by European bison to agricultural plants has been tested using drone-made aerial photographs and the ArcGIS software package. For the evaluation of methods, a field of winter wheat was used, where the European bison were grazing. Comparison of the methods was based on the results of the

evaluation of two categories of damage (no damage and destruction of plants) and four categories of damage (no damage, minor damage, serious damage and destruction of plants). Differences in the results obtained by the two methods were evaluated using the chi-squared test.

3. RESULTS AND DISCUSSION

3.1. Influence of bison and cervids on physical and chemical properties of soil

3.1.1. Soil compaction study

Soil compaction on the bison trampled path at all measured depths was higher than beside the path and was about 4500 kPa at a depth of 40 cm. The soil compaction beside the path at the depth of 40 cm was about 3300 kPa. The greatest difference between the soil compaction on the path and beside it (about 2.5 times) was at the depth of 5 cm (2100 kPa and 800 kPa respectively). The soil compaction at the depths from 5 cm to 15 cm changed little both on the path and beside it. Soil compaction increased consistently at the depths from 15 cm to 35 cm. Soil compaction on the Siberian red deer (maral) trampled path at all measured depths was higher than beside the path and was about 2200 kPa at a depth of 40 cm. The soil compaction beside the path at the depth of 40 cm was about 1800 kPa. The greatest difference between the soil compaction on the path and beside it (about 2 times) was at the depth of 5 cm (1400 kPa and 650 kPa respectively). The soil compaction at the depths from 5 cm to 15 cm changed little or decreased slightly on the path, and consistently increased beside the path. The soil compaction at the depths from 15 cm to 35 cm consistently increased both on the path and beside it.

Soil compaction on the American bison path was statistically significantly different from the soil compaction in various other habitats. The greatest difference (about 2 times) between the soil compaction on the trampled path and the other habitats was at a depth of 5-10 cm. In other habitats, the soil compaction did not differ significantly and was lower at all depths than on the trampled path.

3.1.2. Study of soil chemical properties in the forest-steppe region

In the American bison enclosure, the pH of the soil at both the first and third years of study was the highest at the soil depth of 5 cm, the lowest at the soil depth of 20 cm. After 3 years, the soil pH was lower at all soil depths but differed significantly only at the soil depth of 5 cm.

In the American bison enclosure in the forest-steppe region, the plant available phosphorus (P_2O_5) in both the first and third years of the study showed a downward trend from the soil surface to a depth of 20 cm. Although, after 3 years a decline in plant available phosphorus at all soil depths was observed, there were no significant differences.

In the American bison enclosure, the concentrations of plant available potassium (K_2O) in the soil at both the first and third years of study was the highest at the soil depth of 5 cm, the lowest at the soil depth of 20 cm. After 3 years, soil concentrations of plant available potassium (K_2O) were higher at all soil depths but differed from concentrations observed 3 years ago only at the soil depth of 5 cm.

In the American bison enclosure, the concentrations of total soil nitrogen at both the first and third years of study were the highest at the soil depth of 5 cm, the lowest at the soil depth of 20 cm. After 3 years, concentrations of total soil nitrogen were higher at all soil depths but differed from concentrations observed 3 years ago only at the soil depth of 5 cm.

3.1.3. Study of soil chemical properties in the mixed forest region

In fertile habitats (Nd, Lc) of mixed forest region, soil pH was higher in the enclosures than in unaffected areas adjacent to the enclosure. Meanwhile, in an infertile soil habitat (Nb) the soil pH was lower in the enclosure (the soil was more acidic) than in the control area adjacent to the enclosure.

In animal enclosures in fertile habitats (Nd, Lc) of the mixed forest region, a similar (not significantly different) concentration of plant available soil phosphorus was observed both in the enclosures and in the areas adjacent to the enclosures. Meanwhile, in an infertile soil habitat (Nb) the concentration of plant available phosphorus in the enclosure was higher than in the control area adjacent to the enclosure.

In the mixed forest area, the concentration of plant available potassium in animal enclosures was higher in infertile soil habitat than in the areas adjacent to the enclosure. In fertile habitats, although there was a trend for concentrations plant available soil potassium to be slightly higher, there were no major differences.

Soil concentrations of total nitrogen in animal enclosures were higher than those in the areas adjacent to the enclosure, but significant differences were found only at the Lc habitat. In the mixed forest area, the concentration soil organic carbon in animal enclosures was higher than in the areas adjacent to the enclosure.

Long-term studies by other authors had shown that the nitrogen (N) mineralization process in the enclosures is faster than outside the enclosures (Frank, Groffman 1998). Soil acidity is one of the main soil indicators. H^+ ions produced during the nitrification process acidify the soil (Högberg et al. 2000). Mineral nitrogen content is mainly determined by humus content, soil C:N ratio, climatic conditions, soil acidity (Meysner et al. 2006).

Harrison and Bardgett (2004) found that in boreal forests the amount of mineral nitrogen decreased and C:N ratio increased due to ungulates. In the boreal forests of North America, it was observed that the influence of moose on soil has reduced amounts of carbon and nitrogen (Pastor et al. 1988). Changes in C:N ratio were also found in young stands of boreal forests with a high abundance of cervids (Kielland et al. 1997, Kielland, Bryant 1998).

3.2. The impact of enclosure kept European bison, American bison and cervids on species composition of herbaceous plants

3.2.1. Impact of American bison on herbaceous plants' species composition and abundance in the forest-steppe region

Plant multivariate RDA analysis in the American bison enclosure in the forest-steppe region showed differences in vegetation in 2014 when bison were admitted into the enclosure and 3 years later (in 2017). A wider distribution of plots in the ordinate space in 2014 shows a greater diversity of plants between the individual plots. This range decreased in 2017, suggesting that due to the impact of American bison, the vegetation diversity individual plots decreased.

Mean number of species per plot in 2014 was higher than three years later (in 2017). The Shannon diversity index was higher in 2017, but the difference was not significant. At the same time, the Shannon diversity index evaluates not only the number of species but also the distribution evenness of species abundance, so it can be concluded that although the number of plant species decreased in 2017, the dominance of individual species also decreased.

After evaluation of the distribution of individual species in 2014 and 2017, only 3 species (*Artemisia* sp., *Plantago* sp. and *Achillea millefolium*) were found to be more abundant in 2017. The abundance of other species in 2017 under the impact of American bison has decreased or remained unchanged.

3.2.2. Impact of European bison and cervids on herbaceous plants' species composition and abundance in the mixed forests region

3.2.2.1. Impact of cervids on herbaceous plants' species composition and abundance in the enclosure in Lc habitat

Plant multivariate RDA analysis in the cervid enclosure in the Lc habitat of mixed forest region showed differences in vegetation in the enclosure and control area adjacent to the enclosure. After evaluating the habitat conditions according to the Ellenberg indicators, it was found that more oceanic, more southerly distributed, nitrophilous plant species preferring more acidic soils were more abundant in the enclosure.

The mean number of species in the plot in the cervid enclosure was higher than in the control plot adjacent to the enclosure, and Shannon's diversity index in the enclosure was also higher, statistically significantly different from the control. We can see that in the enclosure in Lc habitat, the abundance of non-forest species and species diversity have increased due to the impact of cervids.

The projection cover of shrubs, understory trees and mosses significantly decreased in the enclosure, and the grass cover was also lower but statistically insignificant. The abundance of shrubs and understory trees (*Populus tremula, Picea abies, Padus avium, Sorbus aucuparia, Lonicera xylosteum*) was lower in the enclosure. The abundance of *Alnus incana* and *Fraxinus exelsior* was similar both in the enclosure and in the control plot. Herbaceous forest species *(Lamiastrum galeobdolon, Oxalis acetosella, Carex sylvatica, Asarum europaeum, Hepatica nobilis, Carex digitata, Aegopodium*

podagraria) were less abundant in the enclosure. Non-forest species (*Veronica chamaedrys, Galeopsis* sp., *Stellaria media, Urtica dioica, Taraxacum officinale, Rubus idaeus, Moehringia trinervia*) were registered in the enclosure. Moss species *Plagiomnium undulatum, Eurhynchium angustirete, Rhytidiadelphus triquetrus* were less abundant in the enclosure than in the control plot.

3.2.2.2. Impact of cervids on herbaceous plants' species composition and abundance in the enclosure in Nb habitat

Plant multivariate RDA analysis in the cervid enclosure in the Nb habitat of mixed forest region showed differences in vegetation in the enclosure and control area adjacent to the enclosure. After evaluating the habitat conditions according to the Ellenberg indicators, it was found that oceanic, more southerly distributed, nitrophilous plant species preferring less acidic soils were more abundant in the enclosure than in the control plot.

The mean number of species in the plot in the cervid enclosure in Nb habitat was significantly lower than in the control plot adjacent to the enclosure, and Shannon's diversity index in the enclosure was higher, but not significantly. In the enclosure in Nb habitat, species diversity has decreased due to the impact of cervids.

The projection cover of shrubs, understory trees, herbaceous plants and mosses was significantly lower in the enclosure compared to the control, especially lower was the projection cover of mosses. Shrub and understory species *Quercus robur, Betula pendula, Acer platanoides, Populus tremula, Picea abies, Frangula alnus, Sorbus aucuparia* and *Corylus avellana* registered in the control plot adjacent to the enclosure were not found in the enclosure in Nb habitat of the mixed forest region. The abundance of following subshrub or herbaceous species characteristic of pine forests was lower, or they were absent from the enclosure: *Vaccinium myrtillus, Melampyrum pratense, Trientalis europaea, Luzula pilosa, Chimaphila umbellata*. *Galium* sp., *Pilosella officinarum, Vaccinium vitis-idaea, Festuca ovina, Galeopsis* sp., *Agrostis capillaris, Rumex acetosella* were more abundant in the enclosure than in the control plot. Moss species *Pleurozium schreberi, Hylocomium splendens* were less abundant and *Dicranum polysetum, Polytricum juniperinum* more abundant in the enclosure compared to the control plot.

3.2.2.3. Impact of European bison on herbaceous plants' species composition and abundance in the enclosure in Nd habitat

Plant multivariate RDA analysis in the European bison enclosure in the Nd habitat of mixed forest region showed differences in vegetation in the enclosure and control area adjacent to the enclosure. After evaluating the habitat conditions according to the Ellenberg indicators, it was found that more southerly distributed, less nitrophilous plant species preferring less acidic soils and drier habitats were more abundant in the enclosure.

The mean number of species in the plot in the European bison enclosure in Nd habitat was significantly higher than in the control plot adjacent to the enclosure Shannon's diversity index was also significantly higher in the enclosure. As a result of the increase in abundance of non-forest species in the enclosure in Nd habitat, species diversity has increased.

The projection cover of shrubs, understory and mosses in Nd habitat was similar, and the projection cover of herbaceous plants was significantly higher in the enclosure than in the control. Shrub and understory tree species *Acer platanoides, Fraxinus exelsior, Ribes nigra, Frangula alnus, Corylus avellana, Sorbus aucuparia* were more abundant in the control plot and *Quercus robur, Rhamnus cathartica* were more abundant in the enclosure in the mixed forest region in Nd habitat. The abundance of following herbaceous plants in the enclosure was lower or they were absent: *Paris quadrifolia, Mycelis muralis, Ranunculus cassubicus, Viola riviniana, Filipendula ulmaria, Aegopodium podagraria, Sanicula europea*. *Poa pratensis, Pimpinella minor, Carex hirta, Carduus crispus, Lysimachia vulgaris, Dryopteris carthusiana, Maianthemum bifolium, Equisetum pratense, Galium mollugo, Potentilla erecta, Angelica sylvestris, Lychnis flos-cuculi, Geum urbanum, Athyrium filix-femina, Calamagrostis arundinacea, Rumex acetosa, Urtica dioica, Veronica chamaedrys, Lysimachia numularia, Brachypodium sylvaticum, Vicia sepium, Deschampsia caespitosa, Dactylis glomerata* were more abundant in the enclosure. Moss species *Eurhynchium angustirete* was more abundant in the enclosure and *Plagiomnium undulatum* more abundant in the control plot.

3.2.2.4. Regeneration of plant species' composition and abundance in European bison enclosure in Nd habitat

The multivariate RDA analysis of plant regeneration dynamics in the European bison enclosure in the mixed forest region showed differences in vegetation in 2015-2017. More significant vegetation changes were recorded 3 years after fencing off.

The mean number of species in the plot increased 2 years after fencing. Shannon's diversity index also increased 2 years after fencing. The projection coating increased 3 years after fencing. Understory species *Quercus robur* and shrub species *Corylus avellana*, *Sorbus aucuparia* increased in abundance after fencing. Herbaceous plant species *Chaerophyllum aromaticum, Fragaria vesca, Rubus idaeus, Geum rivale, Deschampsia caespitosa, Tusilago farfara* increased in abundance and *Lysimachia numularia, Veronica chamaedrys* - decreased.

The impact of ungulate animals on vegetation diversity is ambiguous. Various researchers report quite different results: from reduction to increase or no change in plant diversity (Grime 1973, Miller et al. 1992, Gough, Grace 1998, Olff, Ritchie 1998, Stohlgren et al. 1999, Horsley et al. 2003, Côté et al. 2004, Suzuki et al. 2012, Hegland et al. 2013, Habeck, Schultz 2015). Holtmeier (2015) and Vild et al. (2018) argue that due to the impact of red deer on the structure of vegetation, the number of plant species increases, while Horsley et al. (2003) propose that with the increase of cervid abundance, the number of plants decreases. Most commonly, a negative impact of ungulates on the diversity and abundance of herbaceous vegetation was determined (Russell et al. 2001; Rooney et al. 2004; Stockton et al. 2005), and it has also been observed that the impact of these animals reduced vegetation diversity in temperate forests (Rooney et al. 2004, Rooney 2009, Begley-Miller et al. 2014).

The nature of the impact of cervids depends on the plant group. Plants of grass and sedge families, as well as ferns, tend to increase in abundance as a result of the impact of ungulates (Gill 1992, Cooke, Farrell 2001, Kirby 2001, Rooney 2001, Takatsuki 2009). Most ferns contain poisonous substances and grazing animals try to avoid them (Rooney, Dress 1997). Most of the grass and sedge family plants are tolerant to browsing (Coughenour, 1985, Kirby 2001, Horsley et al. 2003, Rooney, Waller 2003, Côté et al. 2004, Collard et al. 2010), however, Kirby (2001) points out that the abundance of some grass family plants can decrease due to ungulates. Baines et al. (1994) and Côté et al.

(2004) found that browsing reduces the growth and height of European blueberry (*Vaccinium myrtillus*). The impact of ungulate animals can also increase the abundance of ruderal, nitrophilous species (*Urtica dioica, Angelica sylvestris, Filipendula ulmaria*) (Grime et al. 1988, Chytry, Danihelka 1993, Crampton et al. 1998, Boulanger et al. 2017).

In Poland, Falinski (1986) found that red deer and roe deer affected 137 species of plants in the Białowieża forest. In spring, the most used species were *Anemone nemorosa, Veronica chamaedrys* and *Oxalis acetosella*. *Vaccinium myrtillus* was mainly used in late winter and early spring (Falinski 1986).

3.3. The abundance of American bison and cervids and their impact on woody vegetation in the forest-steppe region

3.3.1. Abundance and density of American bison and cervid animals in the game farm in the forest-steppe region

12 bison were admitted to the territory in 2014. The American bison introduced into the game farm belong to the plains subspecies (*Bison bison bison*). In spring of 2017, 29 individuals were counted in the enclosed area utilising direct observation, 6 of them were juveniles (juvenile part of the population - 20.7 %).

After the census count of the cervids by pellets, it was found that in winter of 2014 the abundance of wintering animals in the area of 8595 ha was 55 moose, 64 Siberian red deer (maral) and 204 Siberian roe deer (Table 3.3.1). The density of cervids in the studied area: moose - 6.4 ind./1000 ha, red deer - 7.5 ind./1000 ha, o Siberian roe deer - 23.8 ind./1000 ha

In the wooded areas of the northern Kazakhstan forest steppe region, the usual density of moose is 10-30 ind./1000 ha. Prof. S. Schwarz (1969) points out that, when animals exceed the optimal number in the area unit of the living territory, the fecundity of the females increases, the growth decreases, and the mortality of the juveniles increases. The density of Siberian red deer (maral) and Siberian roe deer is below the maximum allowable density.

The optimal moose gender structure in the population is 1♂: 1♀ and the coefficient of offspring in population is 33 %. In studied territory in 2014 moose gender structure was 1♂:0.7♀ and the coefficient of offspring in the population was 16.4 %. In 2017, with

the decrease of moose abundance, gender structure improved to 1♂:0.8♀, however, there were still 20 % more males than females. The coefficient of offspring in the population increased to 25.5 %

Table 3.3.1 Abundance of cervids in the study area in the forest-steppe region in 2014-2017

Cervid species	**Abundance**							**Density, individuals / 1000 ha**	**Gender structure**
	Total	**Male**		**Female**		**Juvenile**			
	Ind.	**Ind.**	**%**	**Ind.**	**%**	**Ind.**	**%**		
2014									
Moose	55	27	49.1	19	34.5	9	16.4	6.4	1.0:0.7
Siberian red deer (maral)	64	27	42.2	27	42.2	10	15.6	7.4	1.0:1.0
Siberian roe deer	204	174			85.3	30	14.7	23.7	-
2017									
Moose	43	18	41.8	14	32.6	11	25.6	5.0	1.0:0.8
Siberian red deer (maral)	58	21	36.2	23	39.6	14	24.2	6.7	1.0:1.1
Siberian roe deer	289	221			76.5	68	23.5	33.6	-

The optimal red deer gender structure in the population should be 1♂: 1♀, similarly to moose, and the coefficient of offspring in the population should be 22-26 %. In 2014 gender structure was 1♂:1♀ but the coefficient of offspring in the population was just 15.6 %. In 2017 gender structure changed slightly - a slight decrease in females 1♂: 0.9♀, but the optimum (23.5 %) coefficient of offspring in the population indicates that the condition of the red deer population is good in terms of structural reproductive indicators.

The optimal roe deer gender structure in the population is 1♂:1.2♀ and the coefficient of offspring in the population is 30 %. The results of the census count show that in 2014, the offspring coefficient in the population was only 14.7 %, and in 2017 it was 23.5 %, meaning it was too low. However, the growth of a number of offspring indicates that the roe deer population is in good condition.

3.3.2. Spatial distribution of cervids in the study area in the forest steppe region in 2014-2017

In 2014, moose remained in the eastern and western parts of the study territory. No moose pellets were found in the red deer enclosure and in the northern part of the game farm. After the disassembly of red deer and wild boar enclosure fences, the territory occupied by moose increased and their pellets were found almost throughout the whole territory, including the area that was previously fenced. The emergence of a fence has reduced the potential for moose 'immigration' to the territory of the game farm. Meanwhile, moose sometimes happen to leave the fenced area through the opened gates. Perhaps this is the reason the abundance of moose in the study territory has declined for three years. Moose are animals of large forest massifs that tend to migrate seasonally from wintering areas to summer ranges and back. However, the need for migration is caused by a lack of suitable habitats and feed resources. Moose do not get accustomed to additional feeding and do not visit feeding grounds.

Maral concentrated in the central part of the area under study in 2014. Their highest concentration was in the central part of the enclosure. In 2017, when the central enclosure was dismantled, maral spread more extensively throughout the greater enclosure, but their concentration still remained in the central part. Siberian roe deer aggregated at the edges of the greater enclosure in 2014. In 2017, they were evenly distributed throughout the western part of the greater enclosure.

3.3.3. The impact of cervids on woody vegetation in the forest steppe region

The following understory tree species: *Pinus sylvestris*, *Betula* sp., *Populus tremula*, *Caragana arborescens* and shrub species: *Lonicera* sp. and *Rosa* sp. were most abundant in the forest steppe region. *Ribes nigrum*, *Cotoneaster* sp., *Spiraea* sp., *Prunus virginiana*, *Pyrus* sp., *Frangula alnus*, *Cerasus* sp., *Amelanchier* sp (Table 3.3.2) were also recorded.

After evaluating the intensity of use of understory trees and shrubs by cervids during winter, it was found that out of the main tree species, only aspen (> 50%) were highly intensively vulnerable to damage. In 2017, the intensity of the use of self-sown pines has increased significantly compared to 2014 and reached 48 %. Birch use intensity also increased in 2017 compared to 2014 and reached 39.9% (Table 3.3.2).

Table 3.3.2 Evaluation of winter pasture quality in a game farm in Northern Kazakhstan in forest steppe region in 2014 and 2017

Woddy plant species	Presence S, %		Abundance G, %		The intensity of use I, %		Utilization factor U, %		Part in feed balance Q, %	
	2014	2017	2014	2017	2014	2017	2014	2017	2014	2017
Pinus sylvestris	52.1	46.5	12.3	11.3	25.4	48.0	312.9	542.6	9.8	14.5
Betula sp.	29.3	42.0	4.5	10.3	34.6	39.9	155.5	408.9	4.9	11.0
Populus tremula	25.1	19.8	11.3	8.3	70.4	74.5	796.7	616.4	25.0	16.5
Caragana arborescens	15.5	17.0	30.4	26.8	41.5	26.4	1264.1	707.0	39.7	18.9
Malus sp.	0.6	0.7	0.1	0.1	87.5	60.0	7.8	5.3	0.2	0.1
Lonicera sp.	27.0	26.2	29.7	27.9	12.4	27.7	367.9	772.8	11.6	20.7
Rosa sp.	21.7	26.2	7.6	7.4	29.5	46.2	223.9	341.1	7.0	9.1
Ribes nigrum	0.8	0.2	0.2	0.1	39.0	50.0	6.4	5.9	0.2	0.2
Cotoneaster sp.	0.8	4.7	0.0	4.4	93.3	44.8	3.9	196.5	0.1	5.3
Spiraea sp.	7.3		3.6		7.2		26.0		0.8	
Prunus virginiana	0.8		0.1		5.0		0.6		0.0	
Pyrus sp.	2.0		0.2		81.7		16.2		0.5	
Frangula alnus		5.0		2.2		35.5		79.7		2.1
Cerasus sp.		1.9		0.8		22.1		17.8		0.5
Amelanchier sp.		0.2		0.4		89.3		39.7		1.1

The intensity of use of some other species (*Lonicera* sp., *Rosa* sp., *Ribes nigrum*), also increased in 2017 compared to 2014. Meanwhile, the intensity of use of *Cotoneaster* sp., *Malus* sp. and *Caragana arborescens* decreased.

3.4. The abundance of free-ranging European bison and cervids and their impact on woody vegetation in the mixed forest region

3.4.1. Abundance and density of European bison and cervid animals in Kėdainiai and Panevėžys districts in the mixed forest region

17 individuals of European bison were counted by direct observation in Laiveliai forest in Kėdainiai district in the mixed forest region. After the census count of the cervids by pellets in Laiveliai forest in Kėdainiai district, it was found that the abundance of wintering cervid animals in area of 1775.2 ha was the following: moose - 4.1, red deer - 30.4 and roe deer - 78.2 (Table 3.4.1) Density of cervids in the studied area: moose - 2.3 ind./1000 ha, red deer - 17.1 ind./1000 ha, roe deer - 44.0 ind./1000 ha.

The optimal moose gender structure in the population is 1♂: 1♀ and the coefficient of offspring in population is 33 %. In studied territory in 2016 moose gender structure was 1♂:1♀ and the coefficient of offspring in the population was lower than optimum - 20.4 %.

The optimal red deer gender structure in the population should be 1♂: 1♀ and the coefficient of offspring in the population should be 22-26 %. In 2016, gender structure was 1♂:1♀ but the coefficient of offspring in the population was slightly above the optimum - 27.9 % (Table 3.4.1).

The optimal roe deer gender structure in the population is 1♂:1.2♀ and the coefficient of offspring in the population is 30 %. Only adult and juvenile roe deer were counted by the pellets during the census count. The results of the census count show that in 2016, the offspring coefficient in the population was only 28.7 % (Table 3.4.1).

Table 3.4.1 Abundance and density of cervid animals in the studied area in Laiveliai forest, Kėdainiai district in a mixed forest region in 2016

Cervid species	**Abundance**							**Density, individuals/ 1000 ha**	**Gender structure**
	Total	**Male**		**Female**		**Juvenile**			
	Ind.	**Ind.**	**%**	**Ind.**	**%**	**Ind.**	**%**		
Moose	4.1	1.6	38.9	1.7	40.7	0.8	20.4	2.3	1:1
Red deer	30.4	10.5	34.5	11.4	37.6	8.5	27.9	17.1	1:1.1
Roe deer	78.2	55.7			71.3	22.4	28.7	44.0	-

30 individuals of European bison were counted by direct observation in Upytė forest in Panevėžys district in the mixed forest region.

After the census count of the cervids by pellets in Upytė forest in Panevėžys district, it was found that the abundance of wintering cervid animals in area of 1775.2 ha was the following: moose - 7.3, red deer - 23.3 and roe deer - 91.4 (Table 3.4.2) Density of cervids in the studied area: moose - 4.1 ind./1000 ha, red deer - 13.1 ind./1000 ha, roe deer - 51.5 ind./1000 ha. Percentages of juveniles were the following: elk - 17.4 %, the deer - 19.5 % and the roe - 20.6 %.

The optimal moose gender structure in the population is 1♂: 1♀ and the coefficient of offspring in population is 33 %. In studied territory in 2016 moose gender structure was 1♂:1♀ and the coefficient of offspring in the population - 32.0 % (Table 3.4.2).

The optimal red deer gender structure in the population should be 1♂: 1♀ and the coefficient of offspring in the population should be 22-26 %. In 2016, gender structure

was 1♂:1♀ but the coefficient of offspring in the population was above the optimum - 29.7 % (Table 3.4.2).

The optimal roe deer gender structure in the population is 1♂:1.2♀ and the coefficient of offspring in the population is 30 %. Only adult and juvenile roe deer were counted by the pellets during the census count. The results of the census count show that in 2016, the offspring coefficient in the population was above the optimum - 31.2 % (Table 3.4.2).

Table 3.4.2 Abundance and density of cervid animals in the studied area in Upytė forest, Panevėžys district in a mixed forest region in 2016.

Cervid species	**Abundance**							**Density, individuals/ 1000 ha**	**Gender structure**
	Total	**Male**		**Female**		**Juvenile**			
	Ind.	**Ind.**	**%**	**Ind.**	**%**	**Ind.**	**%**		
Moose	7.3	2.4	33.0	2.5	35.0	2.3	32.0	4.1	1:1
Red deer	23.3	7.9	33.7	8.5	36.6	6.9	29.7	13.1	1:1.1
Roe deer	91.4	62.9			68.8	28.5	31.2	51.5	-

In the studied area in Laiveliai forest, Kėdainiai district the number of moose was 3.5 times lower and number of roe deer 1.2 times lower than in the Upytė forest, Panevėžys district, but the number of red deer was 1.3 times higher. Agriculturally allowable density thresholds of moose - 4-5 ind./1,000 ha, red deer - 10-20 ind./1000 ha and roe deer - 40-60 ind./1000 ha (Padaiga 1996). Elk density in Laiveliai forest, Kėdainiai district was below the allowed threshold - 2.3 ind./1000 ha and in Upytė forest, Panevėžys district it was optimal - 4.1 ind./1000 ha. The density of red deer in both Kėdainiai and Panevėžys districts was agriculturally allowable (17.1 ind./1000 ha and 13.1 ind./1000 ha, respectively). The density of roe deer was within agriculturally allowable limits both in Upytė forest, Panevėžys district (51.5 ind./1000 ha) and in Laiveliai forest, Kėdainiai district (44.0 ind./1000 ha).

3.4.1. The impact of cervids on woody vegetation in Panevėžys and Kėdainiai in the mixed forest region

The following understory tree species were the most abundant in Panevėžys district in the mixed forest area: *Betula* sp. and *Picea abies*; also recorded - *Pinus sylvestris, Quercus robur, Alnus incana, Populus tremula, Alnus glutinosa, Salix caprea, Fraxinus excelsior* and *Tilia cordata*. The most abundant shrub species were the following: *Sorbus*

aucuparia, Corylus avellana and *Frangula alnus*; also recorded - *Lonicera xylosteum, Salix* sp. and *Padus avium* (Table 3.4.3).

Table 3.4.3 Evaluation of cervid winter pasture quality in a mixed forest region in Panevėžys district in 2016.

Woddy plant species	**Presence S, %**	**Abundance G, %**	**The intensity of use I, %**	**Utilization factor U, %**	**Part in feed balance Q, %**
Betula sp.	17.0	19.1	19.0	361.8	11.0
Picea abies	9.4	3.7	5.7	21.0	0.6
Pinus sylvestris	3.8	1.6	50.0	78.7	2.4
Quercus robur	3.3	1.0	26.3	26.2	0.8
Alnus incana	2.8	2.3	32.6	73.4	2.2
Populus tremula	2.8	3.0	36.8	110.1	3.3
Alnus glutinosa	2.4	0.9	0.0	0.0	0.0
Salix caprea	0.9	0.5	20.0	10.5	0.3
Fraxinus excelsior	0.5	0.6	83.3	52.4	1.6
Tilia cordata	0.5	0.2	0.0	0.0	0.0
Sorbus aucuparia	22.6	29.0	40.1	1164.1	35.2
Corylus avellana	13.7	13.3	28.9	382.8	11.6
Frangula alnus	11.8	20.9	43.2	901.9	27.3
Lonicera xylosteum	2.8	1.3	48.0	62.9	1.9
Salix sp.	1.9	2.4	24.4	57.7	1.7
Padus avium	0.5	0.3	0.0	0.0	0.0

Pinus sylvestris and *Fraxinus excelsior* (>50 %) were the most intensively damaged of main tree species but they were not abundant. Of the most present species, birch was more intensively damaged (19 %). *Sorbus aucuparia, Frangula alnus* and *Lonicera xylosteum* were the most intensively damaged of shrub species.

The following understory tree species were the most abundant in Kėdainiai district in the mixed forest area: *Betula* sp., *Populus tremula, Picea abies, Quercus robur, Salix caprea, Alnus incana* and *Fraxinus excelsior*; also recorded - *Alnus glutinosa, Acer platanoides* and *Tilia cordata* The most abundant shrub species were the following: *Frangula alnus*, *Corylus avellana* and *Sorbus aucuparia,* less abundant - *Padus avium* and *Salix* sp. and of lowest abundance - *Lonicera xylosteum, Daphne mezereum* and *Ribes* sp. (Table 3.4.4).

Populus tremula, Quercus robur, Fraxinus excelsior and *Acer platanoides* were the most intensively damaged of main tree species. Of the shrubs, the most intensively

damaged were the species of low abundance - *Ribes* sp., *Lonicera xylosteum*, other more damaged species were *Frangula alnus* and *Sorbus aucuparia* (Table 3.4.4).

In Kėdainiai district, the level of damage to woody vegetation was higher than in Panevėžys district. In Laiveliai forest, Kėdainiai district the number of moose was 3.5 times lower and the number of roe deer 1.2 times lower, but the number of red deer was 1.3 times higher (17.1 ind./1000 ha).

Table 3.4.4 Evaluation of cervid winter pasture quality in a mixed forest region in Kėdainiai district in 2016

Woody plant species	**Presence S, %**	**Abundance G, %**	**The intensity of use I, %**	**Utilization factor U, %**	**Part in feed balance Q, %**
Betula sp.	9.4	3.9	51.7	201.0	4.6
Populus tremula	8.0	6.9	62.6	433.2	9.9
Picea abies	6.6	4.2	21.1	89.3	2.0
Quercus robur	5.2	2.0	62.2	125.1	2.9
Salix caprea	6.6	5.3	37.0	196.5	4.5
Alnus incana	5.7	4.5	33.0	147.4	3.4
Fraxinus excelsior	5.2	1.9	61.9	116.1	2.7
Alnus glutinosa	2.8	3.0	10.4	31.3	0.7
Acer platanoides	0.9	2.2	90.0	201.0	4.6
Tilia cordata	0.9	0.1	33.3	4.5	0.1
Frangula alnus	27.4	39.6	48.4	1916.0	44.0
Corylus avellana	17.9	16.7	28.3	473.4	10.9
Sorbus aucuparia	5.2	2.6	34.5	89.3	2.0
Padus avium	5.2	3.6	25.0	89.3	2.0
Salix sp.	0.9	0.8	88.9	71.5	1.6
Lonicera xylosteum	0.9	0.4	80.0	35.7	0.8
Daphne mezereum	0.9	0.7	0.0	0.0	0.0
Ribes sp.	0.9	1.5	91.2	138.5	3.2

Other scientists have extensively studied the impact of the abundance of cervids on woody plants (Padaiga 1996, Augustine, Ammer 1996, McNaughton 1997, Duncan et al. 1998, Reimoser et al. 1999, Heuze et al. 2005, Reimoser, Putman 2011, Pierson, deCalesta 2015). Eiberle and Bucher (1989) found that the most intensively damaged were species of deciduous trees: *Fraxinus excelsior*, *Acer pseudoplatanus* and a shrub species - *Sorbus aucuparia*. In Sweden, Kullberg and Bergström (2001) determined the following arrangement of use of understory trees in descending order of browsing: *Quercus robur\Alnus glutinosa\Fagus sylvatica\Tilia cordata\Prunus avium \Betula*

pendula\Picea abies\Fraxinus excelsior. Other studies have also identified the vulnerability of oak (Siuda et al. 1969, Borowski, Kossak 1975).

In Great Britain, Gill (1992) states that cervids damage the following species very intensively: willows, aspen, fir, and less intensively - Sitka spruce, Scots pine. In Finland, it has been found that moose browse Scots pine most intensively (Danell et al. 1990, 1991, 2003).

3.5. The habitat selection and impact on forest vegetation of free-ranging European bison in the mixed forest region

3.5.1. Habitat selection of free-ranging European bison

In 2016, free-ranging European bison occupied territory of 57183 ha in Panevėžys and Kėdainiai districts in the central part of Lithuania (Fig. 3.5.1). This area is dominated by a mosaic landscape where agricultural land is interwoven with forest patches.

5 herds of European bison separated in this area in 2016. Originally, a herd consisted of 20-30 free-roaming individuals in Panevėžys district, later the population split into separate herds of males, females and juveniles. The size of the population has been increasing since 2003, with an extreme increase observed since 2013. In 2016, the population of the European bison in Panevėžys and Kėdainiai districts exceeded 200 individuals.

European bison herd entered the territory in early March 2016 and was tracked using GPS until the end of November. The largest home range area was in April, and it was larger in spring months compared to summer months. The home range was smallest in July and it increased again from August to October.

The mean daily walking distance of the herd was highest in March when bison had just entered the territory. In spring and early summer (April–June), the mean walking distance slightly decreased but remained rather high. The lowest mean walking distance was in summer and autumn (July–October) and it increased again in November.

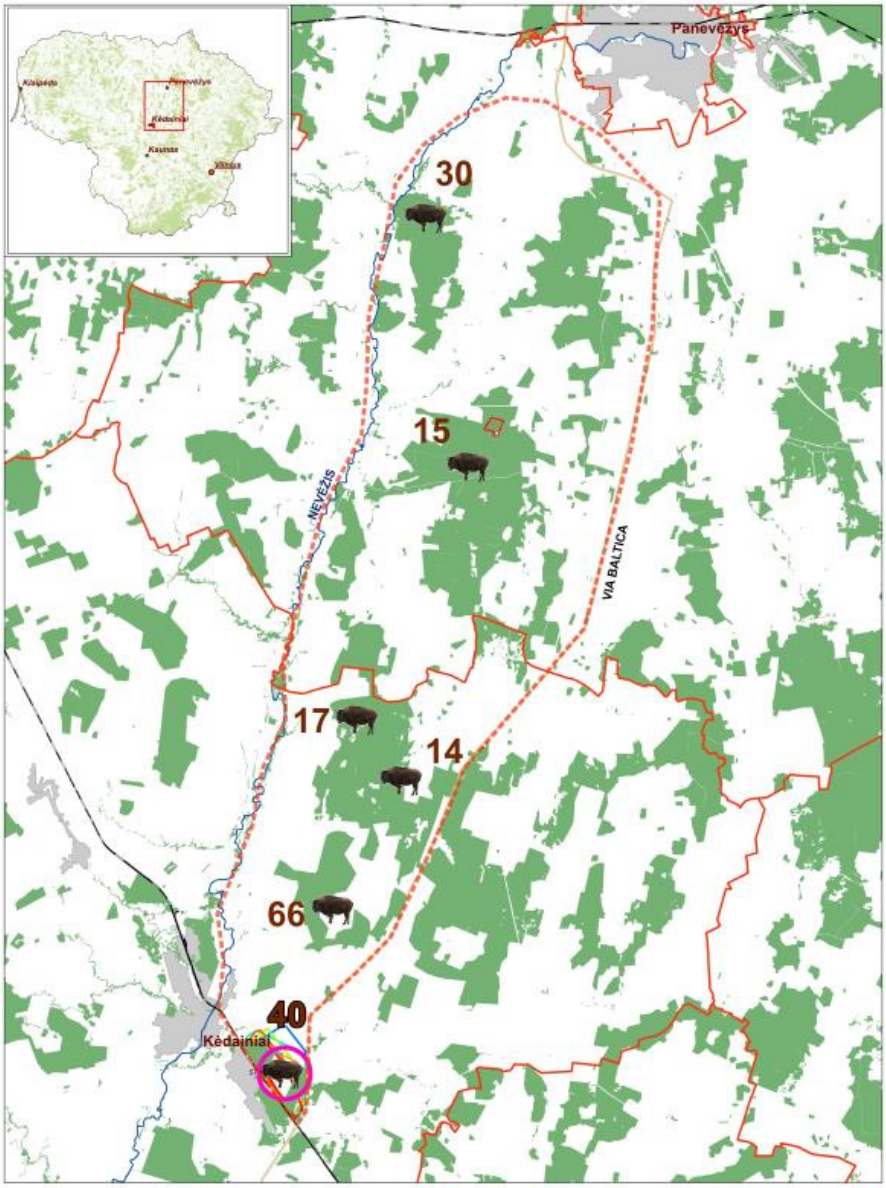

Fig. 3.5.1. The distribution of free-ranging European bison in 2016 (The numbers represent the herd size)

In spring, when the bison had just entered the territory, the home range and the mean daily walking distance were the highest, as the bison explored the area. The decrease of the home range and the mean daily walking distance in the summer could have been due to the bison feeding in the agricultural areas. The home range has increased again in autumn - it is believed to be caused by a decrease in the amount of feed. Černeny et al. (2014) in Židlove (Czech Republic) found, that the home range occupied by their studied

herd of European bison was the smallest in June, the largest in April. Seasonal migration of bison was also determined in Białowieża (Kowalczyk et al. 2013).

European bison studied by us spent more time in the forest than in the agricultural land. At the beginning (in early spring), the avoidance of the agricultural land was low, but it increased up to May. The avoidance of agricultural land decreased in summer, whereas it increased again in autumn. The bison spent more time in the forest during the daytime. At night, the bison preferences for forest or agricultural land were not significantly different.

In the mosaic landscape, the bison spend more time in the forest (especially in the daytime) - it is thought to be due to disturbance. On the other hand, in the summer, bison do not avoid fields at night. In the autumn, the bison preferred staying in the forest due to human activities in the fields. European bison living in the anthropogenic landscape are mainly feeding in agricultural lands and therefore are avoiding fields less frequently (Balčiauskas 1999; Balčiauskas, Kazlauskas 2014).

In Židlov (Czech Republic) the bison herd preferred forested habitats during the daytime and more open lands at night (Červený et al. 2014). European bison tend to be classified as a forest specialists in Central Europe (Verkaar et al. 2004). Other studies have indicated that European bison prefer open habitats (Pucek et al. 2004, Krasińska, Krasiński 2007, Daleszczyk et al. 2007, Kerley et al. 2012).

In the forest, European bison preferred clear-cut and small-leaved deciduous forests but avoided broad-leaved deciduous and coniferous forests. When viewed according to the dominant tree species, the bison preferred aspen and grey alder but avoided ash and birch.

In Białowieża forest, the bison mainly forage in fresh and moist deciduous forests, followed by mixed coniferous forests. Deciduous forests were preferred in spring, mixed coniferous forests in summer, and deciduous forests together with mixed deciduous forests in autumn (Dzięciołowski et al. 1975, 1991, Krasińska et al. 1987, Krasiński, Krasińska 1992, Krasińska, Krasiński 2007; Kuemmerle et al. 2011). European bison also forage in habitats where coniferous forests predominate (Krasiński et al. 1994). Brandtberg, Dabelsteen (2013) found that reintroduced bison in Denmark were fonder of coniferous forests during the vegetation season.

In our study, the bison preferred clear-cuts and stands of 30–40 or more than 90 years old and avoided 10–20- and 50–80-year-old stands. Habitat selection according to site humidity was insignificant, but the bison slightly more often ranged in dry and moist habitats

A study in Białowieża forest reported that European bison inhabited ranges that included open areas, such as meadows or clear-cuts (Krasińska, Krasiński 1995), where bison found more food easily available (Korochkina, Bunevich 1980, Kazmin et al. 1992). In Białowieża the bison rarely visited 10–20-year-old stands, but the preferred tree stands older than 20 years (Krasińska, Krasiński 1995, Krasińska et al. 1987).

3.5.1. Impact of European bison on herbaceous plants' species composition

Plant multivariate RDA analysis in the European bison bedding site in the Ld habitat of mixed forest region showed differences in vegetation in the bedding site and control area in the adjacent forest. After evaluating the habitat conditions according to the Ellenberg indicators, it was found that more northerly distributed, more light preferring, less nitrophilous plant species preferring less acidic soils and drier habitats were more abundant in the bedding site.

The mean number of species in the bison bedding site plot was significantly lower than in the control plot in the adjacent forest. Shannon's diversity index in the bedding site was also lower, but not significantly. In bison bedding site, the projection cover of shrub and understory trees was similar to the control, and the projection cover of herbaceous plants in the bedding site was significantly lower compared to the control.

Shrub and understory tree species that were more abundant in Ld habitat adjacent to bedding site in the mixed forest region: *Sorbus aucuparia, Corylus avellana, Frangula alnus, Euonymus europaea, Fraxinus exelsior, Ulmus minor*. The following herbaceous plant species that were less abundant or were absent from the bedding site: *Impatiens noli-tangere, Anemone nemorosa, Geum urbanum, Paris quadrifolia, Urtica dioica, Hepatica nobilis, Mycelis muralis, Oxalis acetosella, Ranunculus cassubicus, Viola riviniana, Dryopteris carthusiana, Carex sylvatica, Deschampsia caespitosa, Stachys sylvatica*. More abundant in the bedding site were *Stellaria media, Maianthemum bifolium, Carex digitata, Alliaria petiolata, Epilobium* sp.

3.6. The impact and damage of European bison on agroecosystems

3.6.1. Evaluation of the impact of European bison on agroecosystems

Since 2013, with a sharp increase in the population of free-ranging European bison, their damage to agricultural crops has also increased. There are many examples in Europe when a growing number of large animals causes conflicts in rural communities and damage to agricultural crops (Hofman-Kaminska, Kowalczyk 2012).

After studying European bison visiting agricultural crops near Kėdainiai in Lithuania, it was found that bison visit corn and maize crops more often, while avoiding grasses. After examining data on damaged agricultural plants in Kėdainiai district, it is clear, that largest damaged areas in 2016-2017 were of winter rape, winter wheat and peas, while crops of other agricultural plants were damaged less significantly.

The compensation to farmers for the damage done by European bison has recently increased and in Kėdainiai district alone total sum reached 259,000 Euro for the year 2017. In order to mitigate the damage caused by the bison, the Ministry of Environment has decided to start the relocation of bison to Telšiai and Druskininkai.

3.6.2. The method for evaluation of damage caused by European bison using drones and GIS

In order to evaluate the damage to crops more accurately, it is important to improve damage evaluation methods. The method for evaluation of damage to crops using a drone is based on photographing the area under evaluation and analysing the orthophoto plans obtained. During the investigation, an unmanned aeroplane route is programmed over an area 50 m above the agricultural crop area, where the area under evaluation is continuously photographed. Photography is performed vertically down. On average, 110 photos are taken per 1 hectare (1 frame in 2 seconds). Photo overlap - 60 %.

The orthophoto plans are generated from the received photos using Pix4D Field 1.1.0 software. The orthophoto plans are analysed using ArcMap 10.2 software. During the analysis, the colours of the orthophoto plan are grouped and classified using the spatial analyst tool “Reclassify”. With this tool, shades of the orthophoto plan are classified into 10 different groups. Each shade has a degree of damage attached: healthy, lightly damaged, severely damaged and dead. A raster image of an orthophoto plan is converted

to a vector GIS layer and areas of individual shades are calculated. By multiplying the percentage of damage intensity and the damaged area, the total degree of crop damage is calculated.

Comparing the method of analysis of aerial photographs with the usual visual evaluation method, it was found that there were no significant differences between the results of the methods in the allocation of four or two categories of damage, only the category of severe damage was some more different when using these methods.

In experimental studies, the use of a drone has proved its worth in the initial evaluation of field crop damage. In a short period of time, it is possible to go through the field under investigation and quickly and accurately determine the locations damaged by animals, their spatial distribution, and evaluate whether further investigation is purposeful. Photos taken by drone are of very high resolution (20 MP). In photos taken by a drone flying over the crop at the height of 50 meters, individual plants are visible. In most cases, computer-aided photo analysis has made it possible to determine quite an accurate percentage of damage. This method of evaluation is most suitable when healthy areas of agricultural plants are of contrasting colours with damaged ones, such as trampled pastures, meadows or recently germinated, young crops, or grain crops where animals have been laying.

A detailed method for evaluation of bison habitat selection and caused damage utilising aerial photographs and the ArcGIS software package applied in our study allows for a more accurate evaluation of the impact of European bison, reintroduced European bison, introduced American bison and cervids have on soil and vegetation. In other countries, only the first steps are taken to utilise this method. In Belgium and Switzerland, drones have been used to evaluate the damage of wild boar to agricultural crops and sufficiently good results have been achieved (Michez, et al. 2016, Rutten et al. 2018).

CONCLUSIONS

1. In the enclosures, even-toed ungulates (cervids and bison) had an impact on the physical and chemical properties of the soil in both mixed forest and forest steppe regions. The greatest effect was observed on the trampled paths at the depths of 5-15 cm, where the soil compaction was 2-2.5 times higher.

2. The concentrations of soil nutrients (plant available potassium, total nitrogen, organic carbon) have increased while keeping the even-toed ungulates in the enclosures. The most significant changes occurred in the upper layers of soil. The impact of even-toed ungulates was higher in infertile habitats than in fertile ones.

3. The impact of even-toed ungulates (European bison, American bison, cervids) on species composition and abundance of forest vegetation was determined in the enclosures. Due to animal impact, vegetation diversity decreased (beta-diversity), it became more uniform. In fertile habitats, the number of plant species, the number of non-forest species and the uniformity of abundance of individual species increased due to the impact of animals. In infertile habitats, the impact was stronger, and species' diversity decreased.

4. In the forest steppe region, over a period of 3 years, the impact of even-toed ungulates on woody forest vegetation and the intensity of use of the main tree species for nutrition increased. Aspen (>50 %) was most intensely damaged of the main tree species. The intensity of use of shrub species - honeysuckle, rose, and currant - has increased, while the use of cotoneaster, apple and caragana has decreased.

5. In the free-ranging European bison territory, in the studied Laiveliai forest, in Kėdainiai district, 17 European bison, 2.1 moose, 30.4 red deer and 78.2 roe deer were counted. In the studied Upytė forest, in Panevėžys district, 30 European bison, 4.1 moose, 23.3 red deer and 91.4 roe deer were visually counted.

6. In territories of free-ranging bison, the most intensively used understory tree species by cervids were *Populus tremula, Quercus robur, Fraxinus excelsior* and *Acer platanoides*. *Sorbus aucuparia, Frangula alnus* and *Lonicera xylosteum* were the most intensively damaged shrubs. Damage to woody vegetation by cervids was higher in Laiveliai forest in Kedainiai district, where the number of European bison was 17 individuals, their density was 9.6 ind./1000 ha, and the density of moose was lower than agriculturally allowable threshold (moose - 2.3 ind./1000 ha) and the densities of the red

deer and roe deer were within allowable limits (respectively - red deer 17.1 ind./1000 ha and roe deer 44.0 ind./1000 ha). In Upytė forest, in Panevėžys district, where European bison count was 30 individuals, their density was 16,8 ind./1000 ha, and the density of moose was agriculturally allowable (4,1 ind./1000 ha). The densities of the red deer and roe deer were within agriculturally allowable limits (respectively - red deer 13.1 ind./1000 ha and roe deer 51.5 ind./1000 ha).

7. In the mosaic landscape, bison spend more time in the forests (especially in the daytime) due to disturbance, however, bison do not avoid fields at night. In the forests, European bison preferred clear-cut, small-leaved deciduous (aspen, grey alder) forests and mature stands but avoided broad-leaved deciduous (ash), coniferous (spruce) forests and young stands. In areas visited intensively by European bison (especially in bedding sites), diversity of vegetation, the number and abundance of understory trees, shrubs, and characteristic herbaceous forest species have decreased. The number of species not characteristic to forests has increased.

8. In 2016-2017, the damage to crops caused by free-ranging European bison and the compensation payments to farmers have increased significantly (2.6 times). Bison inflicted the most damage to grain and corn crops. The proposed new innovative method utilising drone-made aerial photographs to evaluate the damage done by bison to crops has proved its worth. Further study to formulate recommendations for the evaluation of the damage to crops done by animals is necessary.

LIST OF SCIENTIFIC PUBLICATIONS ON THE TOPIC OF THE DISSERTATION

International publications in journals indexed in Clarivate Analytics Web of Science

1. Marozas V., Kibiša A., Brazaitis G., Jõgiste K., Šimkevičius K., Bartkevičius E. 2019. Distribution and habitat selection of free-ranging European bison in a mosaic landscape – a Lithuanian case. Forests 2019, 10, 345; doi:10.3390/f10040345.

Publications in peer-reviewed scientific journals, referenced in other databases

2. Kibiša A., Narauskaitė G., Pėtelis K., Šimkevičius K., Marozas V. 2015. Large herbivore abundance, distribution and winter pasture quality in two game farms in north Kazakhstan. Acta Biol. Univ. Daugavp., 15(1): 105–112.
3. Kibiša A., Marozas V., Talijūnas D., Papšys R., Sabalinkienė G., Šimkevičius K. 2017. Impact of Free-Ranging European Bison to Ecosystems in Fragmented Landscape, Lithuania. Balkan Journal of Wildlife Research. 4 (2), Special issue: 18–25.

Publications in other scientific publications

4. Sabalinkienė G., Šimkevičius K., Kibiša A., Brazaitis G. 2017. Population Quality of Free – Ranging European Bison in Lithuania // 33rd IUGB (International Union of Game Biologists) Congress: 14th Perdix Congress, Montpellier, France – 2017, August 22-25: Abstract Book / International Union of Game Biologists. Montpellier, 2017. 343–344 p.
5. Kibiša A., Marozas V., Talijūnas D., Papšys R., Sabalinkienė G., Šimkevičius K. 2016. Influence of free-ranging European bison in fragmented landscape, Lithuania. 5th International Hunting and Game Management Symposium, Debrecen, Hungary 10–12 November, 2016. Book of Abstract and Pproceedings, 46–46 p.
6. Kibiša A., Narauskaitė G., Pėtelis K., Šimkevičius K., Marozas V. 2015. Large herbivore abundance, distribution and winter pasture quality in two game farms in North Kazakhstan. // 8th international conference on biodiversity research,

Daugavpils, 28–30 April, 2015 : Book of Abstracts. Daugavpils : Daugavpils University Academic Press "Saule", 2015. ISBN 9789984146874. 79–79 p.

Publications in popular science magazines

7. Sabalinkienė G., Šimkevičius K., Kibiša A. 2016. Kokia stumbrų ateitis Lietuvoje? // Mūsų girios. ISSN 1392-6829. Nr. 9, p. 37–38.
8. Pėtelis K., Kibiša, A., Narauskaitė G. 2013. Stumbrų aklimatizacija Kazachstane. // Medžiotojas ir medžioklė. ISSN 1648-049X. Nr. 5, p. 16–17.

Study results presented

International conferences abroad

9. Sabalinkienė G., Šimkevičius K., Kibiša A., Brazaitis G., Population Quality of Free – Ranging European Bison in Lithuania. // 33rd International Union of Game Biologists Congress: 14th Perdix Congress, Montpellier, France – 2017, August 22–25.
10. Kibiša A., Narauskaitė G., Pėtelis K., Šimkevičius K., Marozas V. Large herbivore abundance, distribution and winter pasture quality in two game farms in North Kazakhstan. 8th international conference on biodiversity research, Daugavpils, 28–30 April, 2015.
11. Kibiša A., Marozas V., Talijūnas D., Papšys R., Sabalinkienė G., Šimkevičius K. 2016. Influence of free-ranging European bison in fragmented landscape, Lithuania. 5th International Hunting and Game Management Symposium, Debrecen, Hungary 10–12 November, 2016.
12. International conference ”Круглый стол по вопросам сохранения зубра” held on 5-7 April, 2013 in FGBU Prioksko-Terasnij national preserve (Приокско-Террасный государственный заповедник) in Russia, both poster and oral presentations “The european bison acclimatization in Kazakhstan” were presented, co-authors - K. Pėtelis, G. Narauskaitė.
13. International conference ”The conservation of the european bison health” held on 6-7 October, 2012 in Keirmusy, Poland, poster presentation “The european bizon acclimatization in Kazakhstan” was presented, co-authors - K. Pėtelis, G. Narauskaitė.

Tarptautinėse konferencijose, seminaruose Lietuvoje

14. Kibiša A. “European bison in Lithuania – present and future.” Scientific conference-practice „The relationship of the forest, human and wildlife”. 5 October 2017, ASU.
15. КибишаА. Результаты деятельности и причиненный ущерб лесным и сельскохозяйственным культурам в местах концентрации Литовской вольно живущей популяцией зубров. International seminar at the Ministry of Environment of Republic of Lithuania, Vilnius, Lithuania, 13 September, 2016.

SANTRAUKA

Darbo aktualumas, mokslinė problema

Stumbras dėl žmonijos populiacijos plitimo, tinkamos gyventi teritorijos praradimo, nesaikingo medžiojimo išnyko XX a. pradžioje. Sėkmingai reintrodukavus nelaisvėje išaugintus stumbrus, jų populiacijos atsikūrė ir tebegausėja, tačiau laisvėje gyvenančių stumbrų populiacijos yra izoliuotos viena nuo kitos, kyla problemos dėl inbrydingo ir dabartinių populiacijų fragmentacijos. Stumbrų išsaugojimo sėkmė priklauso nuo jų izoliuotų populiacijų gausinimo ir ryšių tarp populiacijų užtikrinimo. Stumbras yra įtrauktas į Tarptautinę raudonąją knygą, Berno konvencijos sąrašą, Lietuvos ir kitų šalių raudonąsias knygas (The IUCN 2008).

Lietuvoje stumbras išnyko XVII a. ir buvo reintrodukuotas 1969 (Balčiauskas, Kazlauskas 2014). Į aptvarą Pašilės miške iš Rusijos centrinio stumbryno buvo atgabenta 10 stumbrų. 1973 m. pirmieji stumbrai buvo išleisti į Pašilių mišką. Pradžioje 20–30 individų banda sėsliai laikėsi Panevėžio rajone, bet nuo 2003 m. ir ypač nuo 2013 m. stumbrų kaimenė gausėjo. Lietuvoje stumbrai gyvena gana antropogenizuotoje žemės ūkio ir miškų mozaikos teritorijoje. Vidurio Lietuvoje jie užima apie 60 000 ha plotą.

Stumbrai, klajodami ir maitindamiesi, renkasi įvairias buveines, iš jų kai kurių jie vengia, kai kurioms teikia pirmenybę. Stumbrai paveikia aplinką įvairiais aspektais, taip pat šiuolaikiniame kraštovaizdyje dažnai sukelia tam tikrus konfliktus su žmonėmis (Kerley et al. 2012, Cromsigt et al. 2012, Balčiauskas, Kazlauskas 2014). Tokiems žvėrims reikalingos gana didelės teritorijos ir maisto ištekliai, todėl jie dažnai konkuruoja su naminiais gyvuliais, daro žalą žemės ūkio naudmenoms, sudaro pavojų keliuose. Saugomų stambiųjų gyvūnų daroma žala žemės ūkiui gana naujas aspektas Europoje ir šiuo metu ypač aktualus Lietuvoje. Didėjanti stumbrų gausa Vidurio Lietuvoje kelia vis didesnes diskusijas dėl stumbrų optimalaus skaičiaus mozaikiniame kraštovaizdyje ir kylančių aplinkosauginių problemų.

Stumbrai turėjo didelės įtakos Europos plačialapių lapuočių miškams ir miškastepėms dar priešistoriniais laikais. Kartu stumbrai visada buvo svarbi medžiojamoji rūšis. Stumbro reikšmę miško ekosistemoje svarbu vertinti atsižvelgiant į santykį su kitais kanopiniais žvėrimis. Europos miškuose svarbų reikšmę turi penkios kanopinių žvėrių rūšys: stumbras, taurusis elnias, stirna, briedis ir šernas, todėl

atsižvelgtina į visų žvėrių proporcijas miško ekosistemoje (West, Parkhurst 2002). Pernelyg gausios šių žvėrių populiacijos dažnai neigiamai veikia augalų rūšinę įvairovę ir gausą, tačiau jie gali turėti teigiamos įtakos paveikdami trikdymo veiksnius, platindami sėklas ir kt.

Lietuvoje stumbrų įtaka ekosistemoms tirta mažai (Mačionis 1995, Balčiauskas 1999, 2004, Balčiauskas, Kazlauskas 2014, Balčiauskas et al. 2017), o elninių žvėrių tyrimams skirta gana daug dėmesio (Baleišis, Bluzma 1999, Baleišis ir kt. 2003, Belova 1997, 1999, 2005, 2012, Bluzma, Baleišis 1999, Marozas et al. 2009, Padaiga 1996, 1998, 2010, Padaiga, Pėtelis 1995, Pėtelis 1998, 2002, 2004, 2010, Navasaitis, Pėtelis 1998, Pėtelis, Brazaitis 2003, Brazaitis et al. 2014). Introdukuoti ir reintrodukuoti stambieji augalėdžiai žvėrys, kaip konkurentai vietinėms rūšims, veikia ekosistemą (West, Parkhurst 2002), bet detalių tyrimų apie šį poveikį nėra daug. Nėra ištirtas introdukuotų žvėrių poveikis aplinkai. Naujai introdukuotos rūšys gali daryti poveikį skirtingoms augalų rūšims. Paprastai aklimatizacija trikdo nusistovėjusią ekologinę pusiausvyrą, keičia per evoliuciją susidariusias mitybos grandis, gali slopinti arba visiškai eliminuoti vietines rūšis. Introdukuoti žvėrys gali tiesiogiai arba netiesiogiai veikti miško augaliją, o pakitusios dirvožemio savybės taip pat gali lemti vienų rūšių atsiradimą bei kitų nykimą.

Darbo tikslas, uždaviniai

Darbo tikslas – ištirti reintrodukuotų stumbrų ir introdukuotų bizonų bei elninių žvėrių poveikį augalijai bei dirvožemiui, stumbrų naudojamų buveinių tipus bei daromą žalą agroekosistemoms mišriųjų miškų ir miškastepių zonose.

Uždaviniai:

1. Ištirti aptvaruose laikomų stumbrų, bizonų ir elninių žvėrių poveikį dirvožemio fizikinėms ir cheminėms savybėms mišriųjų miškų ir miškastepių zonose.

2. Ištirti aptvaruose laikomų stumbrų, bizonų ir elninių poveikį augalijai mišriųjų miškų ir miškastepių zonose.

3. Ištirti laisvėje esančių stumbrų ir elninių žvėrių naudojamas buveines bei poveikį miško bendrijoms mišriųjų miškų ir miškastepių zonose.

4. Ištirti laisvėje esančių stumbrų poveikį agroekosistemoms bei nustatyti daromą žalą.

Darbo mokslinis naujumas, teorinė ir praktinė reikšmė

Atlikti stumbro ir elninių žvėrių poveikio ekosistemoms (dirvožemio fizikinėms ir cheminėms savybėms, žolinei dangai ir pomiškiui) tyrimai mišriųjų miškų ir miškastepės zonų sąlygomis. Pirmą kartą Lietuvoje nustatytas erdvinis stumbrų pasiskirstymas ir naudojamos buveinės panaudojant GPS metodą. Pagrįsta būtinybė mažinti stumbrų populiacijos tankį Vidurio Lietuvoje. Taip pat pirmą kartą Lietuvoje buvo pasiūlyta ir išbandyta stumbrų daromą žalą žemės ūkio augalams įvertinti panaudojant aerofotonuotraukas, padarytas bepiločiu orlaiviu (dronu), bei išanalizuoti panaudojant ArcGIS programą. Šį metodą galima būtų taikyti siekiant įvertinti stumbrų padarytos žalos dydį žemės ūkio pasėliuose, kai ūkininkai kreipiasi dėl kompensacijų už patirtus nuostolius.

Ginamieji teiginiai

- Aptvaruose laikomi porakanopiniai žvėrys turi įtakos dirvožemio fizikinėms ir cheminėms savybėms. Ši įtaka priklauso nuo augavietės tipo.
- Stumbrai, bizonai, elniai turi įtakos miško augalijos sudėčiai ir gausai. Ši įtaka priklauso nuo augavietės tipo.
- Stumbrų daugiau naudojamos miško buveinės, kurių skirtingas amžius, rūšinės sudėtis.
- Stumbrų daroma žala agroekositemoms didėjo. Tinkamas naujas inovatyvus stumbrų žalos pasėliams įvertinimo metodas, panaudojant dronu padarytas aerofotonuotraukas.

IŠVADOS

1. Aptvaruose laikomi porakanopiai žvėrys (elniai ir bizonai) turėjo įtakos dirvožemio fizikinėms ir cheminėms savybėms ir mišriųjų miškų, ir miškastepių zonose. Didžiausias poveikis nustatytas sutryptų takų dirvožemiui 5–15 cm gylyje, kur dirvožemio kietis buvo 2–2,5 karto didesnis.

2. Laikant porakanopius žvėris aptvaruose, padidėjo maistinių medžiagų (judriojo kalio, suminio azoto, organinės anglies) koncentracijos dirvožemyje. Didžiausi pokyčiai pasireiškė viršutiniuose dirvožemio sluoksniuose. Nederlingose augavietėse porakanopių žvėrių poveikis buvo didesnis nei derlingose augavietėse.

3. Aptvaruose nustatytas porakanopių (stumbrų, bizonų, elnių) poveikis miško augalijos sudėčiai ir gausai. Dėl žvėrių poveikio sumažėjo augalijos įvairovė plote (beta įvairovė), ji supanašėjo. Derlingose augavietėse dėl žvėrių poveikio padaugėjo augalų rūšių, atsirado daugiau miškui nebūdingų rūšių ir padidėjo atskirų rūšių gausos tolygumas. Nederlingose augavietėse poveikis pasireiškė stipriau, rūšinė įvairovė sumažėjo.

4. Miškastepės zonose per 3 m. padidėjo porakanopių žvėrių poveikis sumedėjusiai miško augalijai ir pagrindinių medžių rūšių panaudojimo mitybai intensyvumas. Iš pagrindinių medžių rūšių intensyviai pažeidžiamos buvo drebulės (>50 %). Krūmų rūšių – sausmedžio, erškėčio, serbento panaudojimo intensyvumas padidėjo, tuo tarpu kaulenio, obels ir akacijos – sumažėjo.

5. Laisvėje gyvenančių stumbrų teritorijoje Kėdainių r. Laivelių tirtame miške buvo suskaičiuota 17 stumbrų, 2,1 briedžių, 30,4 tauriųjų elnių ir 78,2 stirnų. Panevėžio r. tirtame Upytės miške vizualiai buvo suskaičiuota 30 stumbrų, 4,1 briedžiai, 23,3 taurieji elniai ir 91,4 stirnos.

6. Laisvėje klajojančių stumbrų teritorijose elninių žvėrių daugiausiai naudojami buvo Populus tremula, Quercus robur, Fraxinus excelsior ir Acer platanoides rūšių pomiškio medeliai, o krūmų – Sorbus aucuparia, Frangula alnus ir Lonicera xylosteum. Elninių sumedėjusios augalijos pažeidimai buvo didesni Kėdainių r. Laivelių miške, kur stumbrų buvo 17 vnt., tankis sudarė 9,6 vnt./1000 ha, briedžių tankis buvo mažesnis už ūkiškai leistiną, t. y. 2,3 vnt./1000 ha, o tauriųjų elnių ir stirnų tankis ūkiškai leistinas – atitinkamai tauriųjų elnių 17,1 vnt./1000 ha ir stirnų 44,0 vnt./1000 ha). Panevėžio r. Upytės miške, kur stumbrų buvo 30 vnt., tankis sudarė 16,8 vnt. /1000 ha, briedžių tankis buvo ūkiškai leistinas – 4,1 vnt. /1000 ha. Tauriųjų elnių ir stirnų tankis buvo ūkiškai leistinas – atitinkamai tauriųjų elnių 13,1 vnt. /1000 ha ir stirnų 51,5 vnt. /1000 ha.

7. Mozaikiškame kraštovaizdyje stumbrai daugiau laiko praleidžia miškuose, ypač dienos metu dėl trikdymo, tačiau naktį stumbrai nevengia laukų. Miškuose stumbrai teikė pirmenybę kirtavietėms, minkštiesiems lapuočiams (drebulei, baltalksniui), vyresnio amžiaus medynams ir vengė kietųjų lapuočių (uosio), spygliuočių (eglės) ir jaunų medynų. Stumbrų intensyvaus lankymosi zonose (ypač gulyklose) sumažėjo augalijos įvairovė, pomiškio, trako ir miškui būdingų žolinių augalų rūšių skaičius ir gausa. Padaugėjo rūšių, nebūdingų miškui.

8. 2016–2017 m. laisvėje esančių stumbrų daroma žala pasėliams ir mokamos išmokos ūkininkams labai padidėjo (2,6 karto). Stumbrai daugiausiai žalos padarė javams ir kukurūzams. Siekiant įvertinti stumbrų daromą žalą pasėliams, pasiteisino pasiūlytas naujas inovatyvus metodas, panaudojant dronu padarytas aerofotonuotraukas. Reikalingi tolesni tyrimai, kurie leistų parengti rekomendacijas žvėrių pasėliams padarytai žalai įvertinti.

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- 1974-1982 Kaunas S. Neris secondary school.
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Professional experience

- 1993-1995 Republican Council of the Lithuanian hunters and fishermen's association. Position - hunting expert.
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ACKNOWLEDGEMENTS

I will always remember my teacher, associate professor at the Institute of Forest Biology and Forestry at the VMU, the founder of the Game Management Laboratory, dr. Kęstutis Pėtelis, who encouraged me to study in the doctorate and encouraged me until his last breath to write, research, and never back down. I am grateful for his tireless faith and the legacy left in our articles.

While writing my thesis, unexpectedly died one of university lecturer, co-writer, scientist and public figure dr. Gintarė Sabalininkienė, whose works left behind, full of potential, encourages to work with her husband Mantas and continue on joint research.

I sincerely thank the supervisor of the scientific work prof. dr. Vitas Marozas, for guidance, training and advice, patience and wisdom, important remarks in preparing the dissertation. Thank you for your responsible text readings, the errors you have noticed and the constant support.

The implementation of research would be difficult without good cooperation with specialists working in the State Service for Protected Areas. Thank you for giving us access to the data and technical support. I would like to express my gratitude to Rytas Papšys, an expert in bison biology, whose concern and persistence promotes the survival of bison in Lithuanian forests. I would like to thank the veterinarian, Algimantas Lūža, for the scientific debate that has expanded my knowledge on the plants used in the ration of wild animals.

I would like to thank Lithuanian deer breeders Gintautas Čepas and Gediminas Vaitiekūnas for their help in dissertation research, sharing knowledge and experience. I say great THANK YOU, and RAHMET in the Kazakh language to the hunting farm "Bulandy meken" management and the hunters team for friendly receptions creating a working atmosphere.

I am grateful to VMU Dean of the Forestry and Ecology Dean of the VMU Agricultural Academy, Edmundas Bartkevičius for the encouragement to take the scientific path. I thank the dissertation reviewers prof. Algimantas Paulauskas and dr. Olgirda Belova for valuable, constructive remarks and help in improving the work, for purposeful observations and valuable advice that helped to improve the quality of this scientific work. Thank you colleagues for all the way to the goal, for scientific and life-long discussions, for a sense of community.

For my family members and friend dr. Vytenis Mikalauskas for his constant faith in my success and encouragement and support.

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THE IMPACT OF EUROPEAN BISON, AMERICAN BISON AND CERVIDS ON ECOSYSTEMS

Summary of doctoral dissertation

Spausdino – Vytauto Didžiojo universitetas
K. Donelaičio g. 58, LT-44248 Kaunas
Užsakymo Nr. K19-043. Tiražas 35 egz. 2019 05 20.
Nemokamai.