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Spatio-temporal distribution of European bison (*Bison bonasus* L.) in Poloniny National Park, East Carpathians, Slovakia

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Abstract. This study focused on analysis of spatio-temporal distribution of endangered European bison in Poloniny National Park (PNP). The main aim of the study was to analyse bison territory during both winter and the vegetation season for the whole period of reintroduction to show differences in occurrence at different altitudes, slopes and aspects as well as relationships between them during seasons and changes in territory utilization during 3-year periods. The animals change their habitat requirements according to actual season. Bison visit higher altitudes and steeper slopes mainly during the summer. During winter, bison remain in the valleys of displaced villages and feed on apple orchards and supplementary hay. The population is conservative in their territory and it still visits the same area.

Key words: altitudinal movements, habitat utilization, seasonal distribution, Poloniny National Park, East Carpathians

Introduction

The European bison (*Bison bonasus*) is Europe's largest terrestrial mammal. Pucek *et al.* (2004) state that in the past European bison were distributed all over the European continent, specifically in south-eastern, central and western Europe.

In Slovakia, the last bison was killed in the 16th-17th century (Pčola and Adamec 2007). Only two populations of European bison survived in the wild to the end of the 19th century; one in the Białowieża Forest at the borders between Poland and Belarus (*B. b. bonasus*) and the other in the West-Caucasus Mountains (*B. b. caucasicus*) (Pucek *et al.* 2004). History of the European bison extinction was summarised in studies by Pucek (1991, 1994). In many European countries the reintroduction of European bison is accomplished using animals previously kept in zoological enclosures (Pucek *et al.* 2004; Eliáš 2006, 2008). Release of captive animals into the wild to restore wild-living populations was at first attempted in the Polish part of Białowieża Forest in 1952 (Krasiński 1978, 1983) and then in forests in Belarus, Lithuania, Russia, Slovakia, Ukraine (Raczyński 2011, Pucek *et al.* 2004) and Kyrgyzstan (Pucek *et al.* 2004). However, all free-ranging as well as semi-free herds are isolated and these small populations quickly lose their genetic heterogeneity and are more vulnerable to extinction (Franklin 1980). High genetic similarity in all wild-living populations is indicative of inbreeding as the result of the bottleneck effect. Several studies reported the high (and still rising) inbreeding coefficient in European bison from Białowieża Forest (Matuszewska *et al.* 2004, Wołk and Krasińska 2004). Inbreeding has a detrimental effect on health, particularly on skeleton growth in females, and reduces disease and pathogen resistance of bison population (Kobryńczuk 1985, Olech 2008). Therefore, it is necessary to create conditions to facilitate migration of bison between herds. The first step should be to search for natural migratory routes and space use by individuals at sites of potential interconnections between neighbouring Slovak and Polish bison herds.

The State Nature Conservancy of the Slovak Republic developed and in 2004 implemented a project entitled "The Foundation of wild-living population of European bison in Slovak Carpathian Mountains, Poloniny National Park" (Adamec 2004, 2006; Eliáš 2008). This project aimed to create a stable population of European bison in Slovakia (Fig. 1). Five individuals from Italy, the Netherlands and Switzerland were imported in June 2004 and on December 10th, 2004 were released into the wild and monitored by telemetry (Adamec and Pčola 2004; Perzanowski *et al.* 2006; Pčola and Adamec 2007; Eliáš 2006, 2008). Shortly after their release, (December 25, 2004) one

Fig. 1. The European bison in the Poloniny National Park, Slovakia (Photo: M. Janiga, 2013).

wild-living bull called Pišta joined the group (Adamec 2006; Perzanowski *et al.* 2006; Pčola and Adamec 2007; Eliáš 2008). The chronology of reintroduction in Poloniny National Park was summarised in a study by Pčola and Gurecka (2008).

Different individuals often use the same area and their territories overlap considerably. Central parts of territories, including meadows and watering holes are the most intensively utilised (Krasiński *et al.* 1999). In Lithuania, animals frequented an area between 100 and 200 km^2 with large core areas measuring approximately 20 km^2 (Balčiauskas 1999; Pucek *et al.* 2004). A satisfactory area to sustain a population of 50-70 animals looks to be approximately 200 km^2 (Pucek *et al.* 2004).

The territories of European bison in Slovakia were analysed during the first four years following reintroduction (December 10th, 2004 to August 3rd, 2008) and mentioned in studies of Adamec (2006), Pčola and Adamec (2007) and Pčola and Gurečka (2008). At this time relationships were observed between distribution of European bison herds and individual animals and their occurrence at different altitudes, slopes and aspects during the year, but were never completely analysed. There are only a few free-ranging and semi-free herds of European bison in the world, and they occur in the wild only in a few places (Pucek *et al.* 2004). Therefore, the sustainable management of each population is key to survival of the species on a global scale.

Research on habitat utilization and patterns of herd movement during the whole period of population existence are essential to improving the reintroduction and the long-term management of European bison in European reserves.

We decided to compare winter and summer area of European bison and changes in their dimensions during years after reintroduction. The main objective of this paper is to analyse spatio-temporal distribution and identify potential connection of Slovak herd with Polish herd during the period of reintroduction of European bison populations in the Poloniny National Park, East Carpathians, Slovakia since 2004 to 2017.

Material and Methods

Poloniny National Park is located in north-eastern Slovakia, at the border with Poland and Ukraine, in the Bukovské vrchy mountain range. Areas of PNP (Poloniny National Park) are included in the East Carpathian Biosphere Reserve and several locations have been proclaimed by UNESCO as World Heritage Sites.

Data was collected between December 10th, 2004 and February 17th, 2017 (including 13 winter periods (December to March) and 12 vegetation periods (April to November)). It was collected by staff from The State Nature Conservancy of the Slovak Republic, the Administration of PNP, located in Stakčín and university students through telemetric monitoring. Monitoring was conducted once per week using the ICOM IC-R 10 receiver a Telonics RA 14 antenna (Pčola and Gurečka 2008, Eliáš 2008), and random observers. Between 2016 and 2017, data from authors' regular observations (several days each month) was added. Position data of herd and solitary individuals was collected, including date and coordinates as well as abundance and gender when possible (mainly since year 2010). Visual observations and field remnants (fresh droppings, footprints, lying areas, nibbled trees and shrubs) were recorded. Coordinates of hay feeders in the area, used as a source of food during winter were also recorded. Geographic information software (ArcGIS 10.0) was used for data analysis, specifically the ArcMap component. The data of basic matrix was analysed and standardized using the STATISTICA 12.1 program. Two-way analysis of variance (ANOVA) was used to determine significant differences between the means of two or more independent groups. The data is expressed as mean ± standard deviation (SD). Values of P less than 0.05 were admitted as statistically significant.

Results

540 out of a total of 560 position coordinates were used for analysis of area of territory. 20 coordinates (3.6%) were not used (11 of the Polish herd, one of migrating bull near Zboj village and 8 of migrating bull near Stakčín village). The Polish herd was observed in period between January 2016 and February 2017 and we found potential interconnection between Slovak and Polish bison herds near Hostovický creek. However, direct encounters of bison from two transboundary herds were not recorded (Fig. 2).

540 position coordinates were used for analysis during whole period. Total area included in analysis of the reintroduction period is 106.79 km^2 (Fig. 2). If we include the Polish herd and Slovak migrating bulls, the total area of European bison occurrence in the wild in Slovakia is 265.19 km^2. Maximal distance of occurrence data was 31.45 km (Svetlice – Zboj).

218 position coordinates were recorded during the period between October and March. The total area recorded in all winter periods was 81.33 km^2. Maximal distance of occurrence data in winter was 12.1 km (Fig. 3a).

322 position coordinates were recorded during the period between April and September. The total area recorded in all vegetation periods was 104.27 km^2. Maximal distance of occurrence data in vegetation period was 15.1 km (Fig. 3b).

In spring, eastern slopes were the most occupied by bison (39.3%), followed by western (23.6%), southern (20.2%) and northern slopes (16.9%) (Fig. 4). In summer, western slopes were the most occupied (28.0%), followed by southern (27.2%), eastern (26.4%) and northern slopes (18.4%). In autumn, western slopes were the most occupied (29.7%), followed by eastern (26.6%), southern (25.9%) and northern slopes (17.7%). In winter, eastern slopes were the most occupied (45.5%), followed by western (28.7%), southern (15.7%) and northern slopes (10.1%).

There were no seasonal differences observed between altitude of occurrence of herds and solitary animals. Herds inhabited lower altitudes in spring and then moved to higher altitudes. Conversely, individual animals inhabited higher altitudes in spring than herds and then moved to lower altitudes during summer. Nevertheless, interaction between these factors was deemed statistically insignificant.

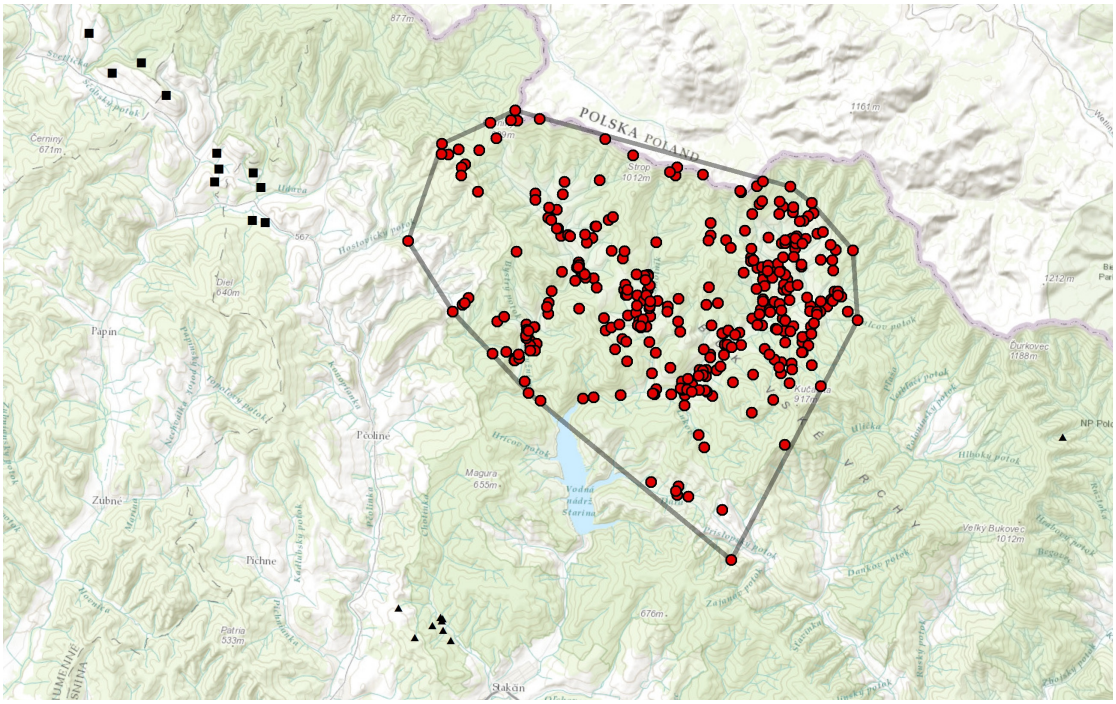

Fig. 2. Map of total area of the European bison occurrence in Poloniny National Park. Squares are data of Polish herd, which occurred on Slovak territory since January 2016 and triangles are data of Slovak migrating bulls. The data was not included to calculation of area of territory. Line encloses core area of bison occurrence in PNP.

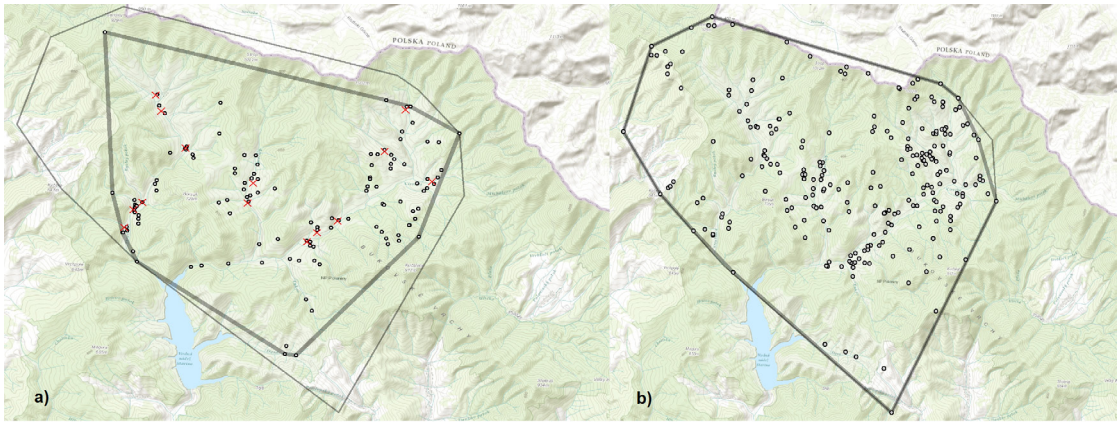

Fig. 3. Maps of territories of European bison in Poloniny National Park in **a)** winter season (October to March) and **b)** vegetation season (April to September). Thick lines show winter/summer area and thin lines total area of bison occurrence. Crosses show hay feeders. Data of Polish herd and Slovak migrating bulls are not included.

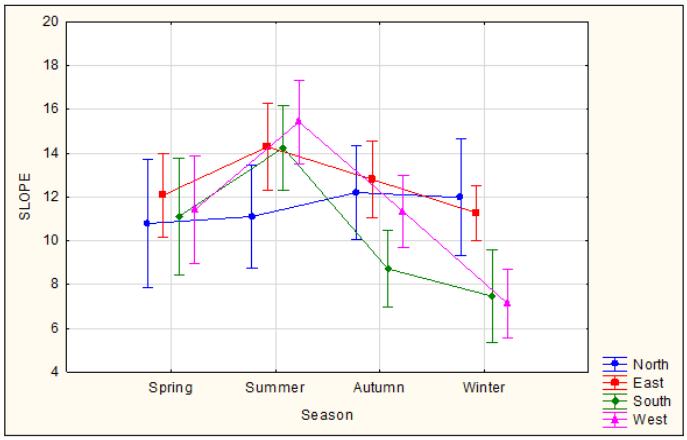

Fig. 4. Relationship between seasons, aspect and altitude. Southern and western slopes at higher altitudes from 620 to 650 m a.s.l. were commonly occupied by European bison in summer season (Two way ANOVA; effects: $F(9. 534) = 3.0178$; $p = .00159$; vertical bars denote 0.95 confidence limit). In spring, autumn and winter, bisons were at altitudes from 440 to 520 m a.s.l.

Period	Total area (km²)	Winter area (km²)	Vegetation period area (km²)
10 December 2004 to 2 February 2006	72.53	No data	No data
10 December 2004 to 3 August 2008	78.24	22.04	69.13
10 December 2004 to 17 February 2017	106.79	81.33	104.27

Table 1. Overview of territory expansion of European bison in Poloniny National Park. Processed according to Adamec (2006), Pčola and Adamec (2007), Pčola and Gurečka (2008).

Discussion

During the reintroduction period in Poloniny National Park between December 17th, 2004 and February 17th, 2017, the total area of territory was 106.79 km2. When compared to studies by Adamec (2006) and Pčola and Adamec (2007), this area grew from 72.53 km^2 to 106.79 km^2 (Table 1). Pucek *et al.* (2004) state that a satisfactory area for a population of 50-70 animals is approximately 200 km^2. According to observations, approximately 25 European bison live in PNP as part of the Slovak herd within a core area of 106.79 km^2 (not including the Polish herd and Slovak migrating bulls). Compared to Pčola and Gurečka (2008), the winter area (October to March) was larger, growing from 22.04 km^2 to 81.33 km^2 (59.29 km^2 growth) and the area inhabited during the vegetation period (April to September) grew from 69.13 km^2 to 104.27 km^2 (35.14 km^2 growth). Boundaries of total area were reached mostly in vegetation season, first in the period after reintroduction (December 10th, 2004 to December 31st, 2007). During other periods, bison inhabited the core area. This data confirms the conservation of European bison territory in PNP.

The individuals from Slovak herd were recorded several times at the border with Poland that runs along the ridge of the Poloniny Mountains. On the other side of the border are the Bieszczady Mountains, where the Polish population of European bison lives (Wołoszyn-Gałęza *et al.* 2016). Slovak individuals have repeatedly moved into the border area and might possibly get across the border into the Polish territory, but this behaviour was not recorded, because observers did not collected transboundary data. It can be assumed that potential interconnections with Polish herd could be near Hostovický creek and along the intersection of the boundary with the territory of the bison from Slovak area (Fig. 2).

Total average altitude for the year is 501 m a.s.l. Bison inhabit the lowest altitudes in winter, followed by spring. During autumn and summer animals inhabit the highest altitudes. Winter incidence at lower altitudes is influenced by the availability of supplementary food in hay feeders, long-lasting snow cover, low temperatures and decreased movements of visitors due to winter conditions. Occurrence at higher altitudes during vegetation period, specifically summer, may be due to a sufficient amount of food and higher movement of visitors in valleys of displaced villages, specifically owners of cottages and tourists. Seasonal migration could also be caused by bison preference for open habitats, which are more frequently used during winter period by both sexes. However, bison rarely move further than 5 km from the forest edge (Kowalczyk *et al.* 2013). The valleys with displaced villages in Poloniny achieve these conditions.

In general, eastern slopes were the most occupied (34.7%), followed by western (28.0%), southern (22.0%) and northern slopes (15.3%). Southern and western slopes at higher altitudes from 620 to 650 m a.s.l. were commonly occupied by bison during summer. Small incidence on northern slopes may be caused by the coldest climatic conditions and consecutive influence to composition of flora. On the other hand, incidence on slopes with eastern, southern and western exposures may be caused by long-lasting sunshine and stronger solar radiation. The quality of winter refuges depends on the amount of canopy cover and the dominant tree species (Wołoszyn-Gałęza *et al.* 2016). In winter, bison remained in displaced villages and fed mainly on apple orchards similarly to the reintroduced European bison in the Bieszczady Mountains (the Eastern Carpathians, Poland), which actively selected broken canopy forests with a high density of understory vegetation (Wołoszyn-Gałęza *et al.* 2016).

The European bison is a gregarious animal. The most observed units are small bull groups and groups composed of cows, calves and bulls. In this second type of group cows, calves aged 2-3 years and sometimes adult bulls were observed (Krasiński and Krasińska 1992, 1994; Krasiński *et al.* 1994b, 1999; Pucek *et al.* 2004). Groups of European bison are not family units and changes in structure and size of groups are influenced by other factors. Seasonal factors include bulls joining new groups in the rutting season and calves being introduced following calving. Others changes are a result of behavioural factors. Individuals move between groups at frequent group meets. Switching between groups is most common in young bulls (Krasińska *et al.* 1987). Environmental factors influence the average size of these groups. In different populations, groups are most often comprised of an average of 8-13 animals (Krasiński and Krasińska 1992, 1994; Krasiński *et al.* 1994b, 1999; Pucek *et al.* 2004) or 6-20 animals (Pčola and Adamec 2007). Occasionally, groups of 2-92 animals were observed in the Białowieża Forest, but more frequently groups of 20 animals (65-85%) were observed in this location (Krasińska *et al.* 1997, Pucek *et al.* 2004). Small bull groups occur in all populations and include two animals on average (1-11). A solitary life is led by more than 50% of the bulls (Krasiński and Krasińska 1994, Krasiński *et al.* 1994a, Pucek *et al.* 2004). Large mixed groups of cows, calves and bulls and groups comprised entirely of bulls are observed in winter around feeding sites. The number of groups of different sizes is affected by the size of population. Mean air temperature during the winter period and duration of permanent snow cover influence home ranges of bulls in winter. Mobility of individuals is limited by low temperatures and long-lasting snow cover (Krasińska *et al.* 2000, Pucek *et al.* 2004). Food supplementation

can also be responsible for their low mobility and staying in valleys during winter (Krasińska *et al.* 2000). We found that during the winter period, bison remain close to the feeders when supplied with hay. However, supplementary feeding alone cannot represent a sustainable solution, because it causes bison aggregation and may lead to higher parasitic transmission (Ramos *et al.* 2016). Individuals wander the forest constantly due to its high claim to food. In the first year of life, calves eat 8.5 kg per day, while young animals (2-3 years) consume19.5-28.5 kg per day, and adults eat 23-32 kg of fresh food per day. 40% of this food is composed of leaves and sprouts (Gębczyńska and Krasińska 1972, Pucek *et al.* 2004). Feeding habits of European bison were researched mostly in Cejjskijj zakaznik in Russia, Białowieża Forest (Poland and Belarus) and Prioksko-Terrasnyjj reserve in Russia (Pucek *et al.* 2004). 131 plant species, with 27 species of trees and shrubs, 14 species of grasses and sedges and 96 species of dicotyledonous plants were described in the study of Borowski and Kossak (1972) as part of the bison diet in the Polish part of Białowieża Forest. Herbs, grasses and sedges represent 67% and trees and shrubs 33% of the whole diet. All wild-living groups formed in Białowieża Forest in winter are fed with supplementary food, specifically with hay (Krasiński 1978, 1983; Krasiński and Krasińska 1994; Pucek *et al.* 2004).

European bison went extinct in the wild until populations were restored during the 20th century. Today, the species is still listed by the International Union for Conservation of Nature (IUCN Red List of Threatened Species) as a species vulnerable to extinction. Despite of the increasing number of European bison, there are some specific problems regarding their sustainability in human inhabited areas (Hofman-Kamińska and Kowalczyk 2012), low genetic diversity (Oleński *et al.* 2018) and sufficient size of their territory with adequate habitat connectivity (Ziółkowska *et al.* 2016). Expansion of European bison populations is necessary, and analysing long-term data about bison space utilization, habits and movement patterns in existing populations may help to achieve this goal.

The European bison, as an extremely inbred extinct species requires effective management to sustain maximum genetic diversity (Oleński *et al.* 2018). Our results provide better understanding of bison space utilization and location of natural migratory routes during the period of their reintroduction to the Poloniny NP. The findings obtained in this study are beneficial for sustainable management of the European bison and for facilitate and subsequently maintenance migration of bison between neighbouring trans-border herds.

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