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Indicative factors for European bison refuges in the Bieszczady Mountains

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European bison *Bison bonasus* refuges in the Bieszczady Mountains were characterised using four habitat variables: elevation above sea level, slope exposure, tree crown closure, and stand composition. We compared habitat composition of ranges representing a 95% probability of bison use with ranges representing a 25% probability of bison use, on a seasonal basis (summer, winter). During the growing season ("summer"), the 25% probability ranges contained more high elevation (550–749 m), other than northern-exposure areas with more open-canopied, fir-dominated forest than did the 95% probability ranges. During winter, the 95% probability ranges contained less high elevation (550–749 m), northerly exposure areas with more close-canopied, beech–fir, alder, and Scotch pine forests.

Introduction

Most data on the European bison are from long-term studies performed in lowland forest at the Białowieża Primeval Forest, Poland (Sztolcman 1926, Jaczewski 1958, Gębczyńska & Krasińska 1972, Pucek 1986, Gill 1999, Krasińska & Krasiński 2004). However many factors influencing habitat preferences and spatial distribution, such as elevation and slope exposure, could not be studied in the flat terrain of Białowieża. Because the European bison is a priority species in the Natura 2000 system, and the Bieszczady Mountains (Carpathian Range) have been declared a Natura 2000 "special protected area," there is a need to delineate refuges for this species in the Bieszczady Mountains (Baranowski & Makomaska-Juchiewicz 2004). The bison population of Bieszczady, the only mountain population of this species in Poland now numbering more than 200 individuals, occupies a seasonally varying range of 23 000 to > 28 000 ha (Perzanowski *et al*. 2006a). At least 90% of that area consists of commercial forests, so there is an urgent need to identify factors that will allow for optimal planning of a network of bison refuges there. The objective of this study was to determine habitat variables that can be used for the selection of areas appropriate for the establishment of bison refuges in the Carpathian Range of Poland.

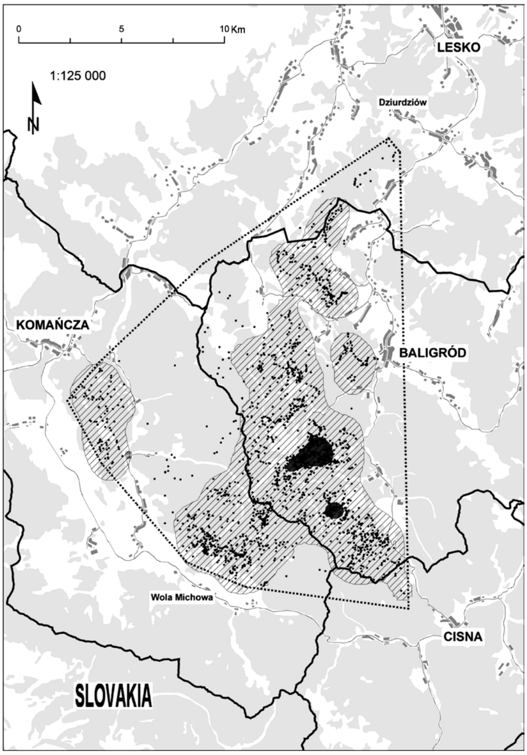

Fig. 1. The range of the western subpopulation of the European bison in the Bieszczady Mountains (dotted line), and the areas with: 95% probability (raster), and 25% probability (black) of bison locations calculated by pooling all locations obtained for growing seasons ("summer"). Single points represent animals' locations.

Material and methods

Data on the distribution of the European bison were collected within the area of four forest districts in southeastern Poland (Baligród, Komańcza, Cisna, and Lesko). All four were within the range of the western subpopulation of the species in the Bieszczady Mountains, estimated at the time of the study to be about 100 individuals (Perzanowski & Paszkiewicz 2000). Collection of the data for this analysis started in winter 2002/2003, and was completed in autumn 2005.

Sources of the data were direct observations and signs of bison presence (tracks, faeces, signs of foraging, etc.) that were collected in the field during routine monitoring (twice a week, observers moving along forest roads and trails within the subpopulation home range, were searching for any evidence of the presence of the bison). Additionally, foresters working within the area recorded all accidental observations of the bison or signs of their presence. Another source of the data was ground triangulation of four radio collared bison (Telonics MOD 600NH Transmitter), from at least two bearings taken from different locations at time intervals of 5–10 minutes. Bison localities were determined with GPS (Garmin eTrex Venture) with minimal accuracy estimated at 30 m. Radio telemetry provided 1812 (536 in winter and 1276 from growing season), and field observations 2160 (615 in winter and 1545 in growing season) locations of animals. Locations obtained from field observations and telemetry were pooled to obtain a common home range for all animals. According to earlier reports there is no evidence for a spatial fragmentation of this subpopulation. Except few seasonally solitary males, the majority of animals move within the subpopulation's home range, in dynamically changing groups (Perzanowski & Paszkiewicz 2000, Perzanowski *et al.* 2006a, 2006b).

Bison localities plotted on numeric maps became a thematic layer of a GIS model of the area (ArcGIS 9.0) that included elevation, slope exposure, tree canopy closure, and tree species composition (based on canopy closure). A tree species that composed > 70% of a stand was regarded as a dominant, if up to three species together composed > 70% of a stand, the one exceeding 40% was regarded as a dominant, while in multi species stands if deciduous or coniferous species together composed over 60% of the stand, it was respectively regarded as mixed deciduous or mixed coniferous. Open areas were classified as all parts of a home range outside the forest. Seasonal (summer, winter) spatial distribution of the bison was analysed according to the Kernel method (Worton 1989), determining two geographic ranges of probable occurrence: 25% probability and 95% probability (Figs. 1 and 2). The 25% probability range was assumed to be the area of the "refuge" (2.3% of the home range in summer and 4% in winter), while the 95% range was the area representing 47.9% and 42.7% in the summer and winter, respectively, of a home range estimated as the maximal convex polygon.

We used the χ^2-test to compare the number of bison localities within habitat features of the two ranges (95% *vs*. 25% probability) on a seasonal basis. We defined "summer" as the growing season (April–November) and "winter" as the vegetatively dormant season (December–March).

Results

Significant differences ($P < 0.01$) occurred in all four habitat variables in the seasonal comparisons. During the summer season, 95% probability ranges had significantly less ($P < 0.01$) high-elevation area (550–749 m) than did the 25% probability ranges (75.7% *vs*. 93.6%, respectively; Fig. 3A and B). In winter, this relation was reversed but not significantly so ($P > 0.05$; 76.3% *vs*. 67.0%, respectively); the greatest difference occurred in the 350–549-m zone (23.2% *vs*. 33.0%, respectively; Fig. 3C and D).

No significant differences ($P > 0.05$) between ranges occurred for slope exposure in summer (Fig. 4A and B) or in winter (Fig. 4C and D).

Stands with open tree canopy structure (low canopy closure) were more common in the 25% probability ranges than the 95% probability ranges in summer but the difference was not significant ($P > 0.05$; 62.9% *vs*. 57.5%, respectively; Fig. 5A and B), while in winter, the opposite was true ($P < 0.01$; 91.9% *vs*. 63.6%, respectively for high canopy closure; Fig. 5C and D) but here the difference was significant.

Tree species composition of the 25% probability ranges differed significantly ($P < 0.05$) from that of the 95% probability ranges during both seasons, containing more fir (*Abies alba*), spruce (*Picea abies*) and mixed conifer during summer (35.8%, 11.7%, 11.0% *vs*. 18.5%, 10.1%, 2.1%, respectively; Fig. 6A and B) and

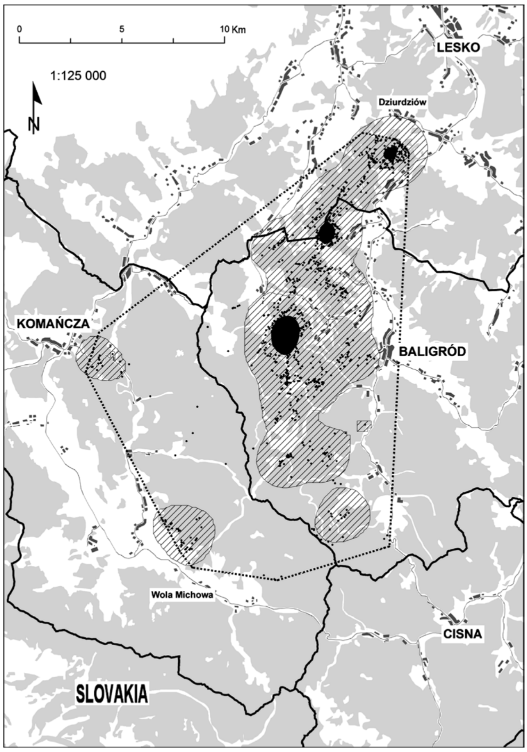

Fig. 2. The range of the western subpopulation of the European bison in the Bieszczady Mountains (dotted line), and the areas with: 95% probability (raster), and 25% probability (black) of bison locations calculated by pooling all locations obtained for "winter" seasons. Dots represent animals' locations.

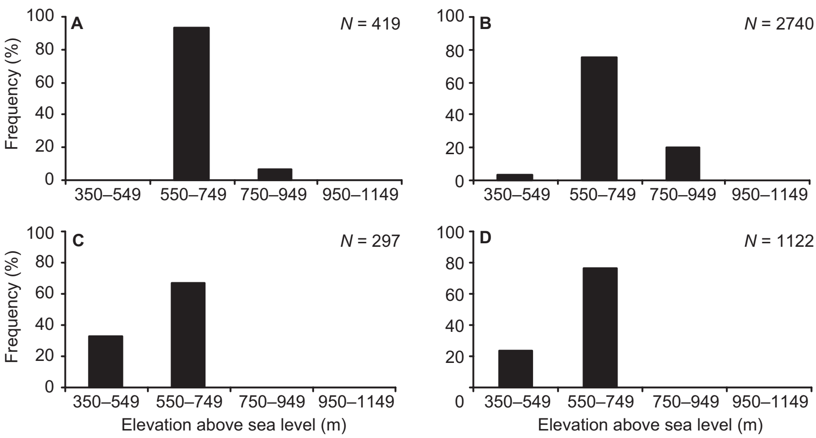

Fig. 3. Comparison of frequencies of European bison presence in summer (**A**, **B**) and winter (**C**, **D**) seasons within areas with 25% (**A**, **C**) and 95% (**B**, **D**) probability of bison locations, depending on elevation above sea level.

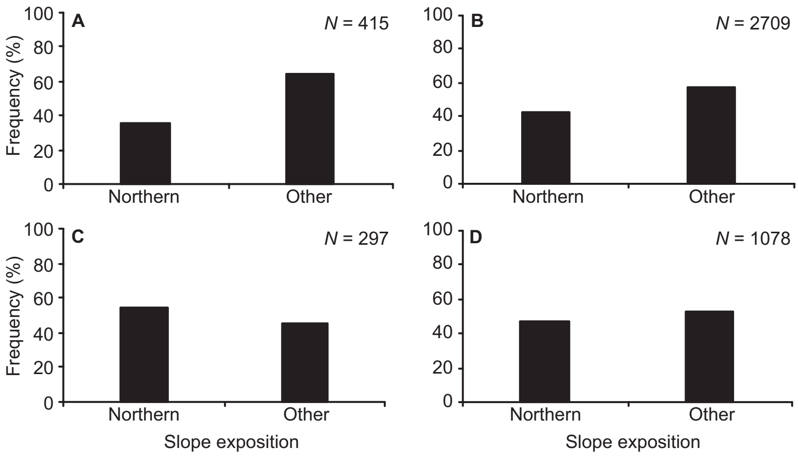

Fig. 4. Comparison of frequencies of European bison presence in summer (**A**, **B**) and winter (**C**, **D**) seasons within areas with 25% (**A**, **C**) and 95% (**B**, **D**) probability of bison locations, depending on slope exposure.

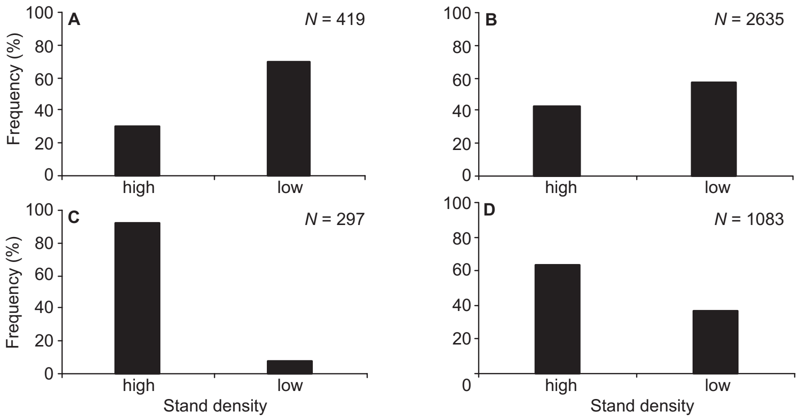

Fig. 5. Comparison of frequencies of European bison presence in summer (**A**, **B**) and winter (**C**, **D**) seasons within areas with 25% (**A**, **C**) and 95% (**B**, **D**) probability of bison locations, depending on tree canopy closure.

more Scotch pine (*Pinus sylvestris*), alder (*Alnus incana*), and beech-fir (*Fagus sylvatica-Abies alba*) during winter (45.5%, 29.0%, 17.8% *vs*. 26.6%, 20.5%, 11.2%, respectively; Fig. 6C and D).

Discussion

Identification and delineation of refuges for priority species within Natura 2000 habitat sites are requirements for all EU countries (Baranowski, Makomaska–Juchiewicz 2004). Implementation of this task in the case of the European bison in the Bieszczady Mountains, which range over 30 thousand hectares of mostly commercial forest, is difficult to achieve with regular forestry practices in this area (Perzanowski *et al*. 2006 a, 2006b). Any attempt to establish a protective zone equal to the estimated range of this population would inevitably stimulate initiatives to regulate bison numbers. Therefore, a more detailed analysis of the spatial distribution and habitat use by the bison was necessary to determine what environmental factors prevail in areas of bison concentration, and to use that knowledge to identify ranges that may function adequately as bison refuges.

Ungulates inhabiting the Bieszczady region display well-defined seasonal movements, from high elevations in the south in late spring/summer to lower valleys situated in the northern part of the range in winter. In some cases (red deer and wild boars), the distance between summer and winter ranges exceeds 20 km (Kanzaki & Perzanowski 2000, Perzanowski & Krzakiewicz 2000). The same pattern is observed in the bison, which excludes the possibility of delineating just one set of areas that could be used by animals as refuges during the whole year. Experience in the Białowieża Primeval Forest cannot be helpful, because phenomena on such a scale do not occur

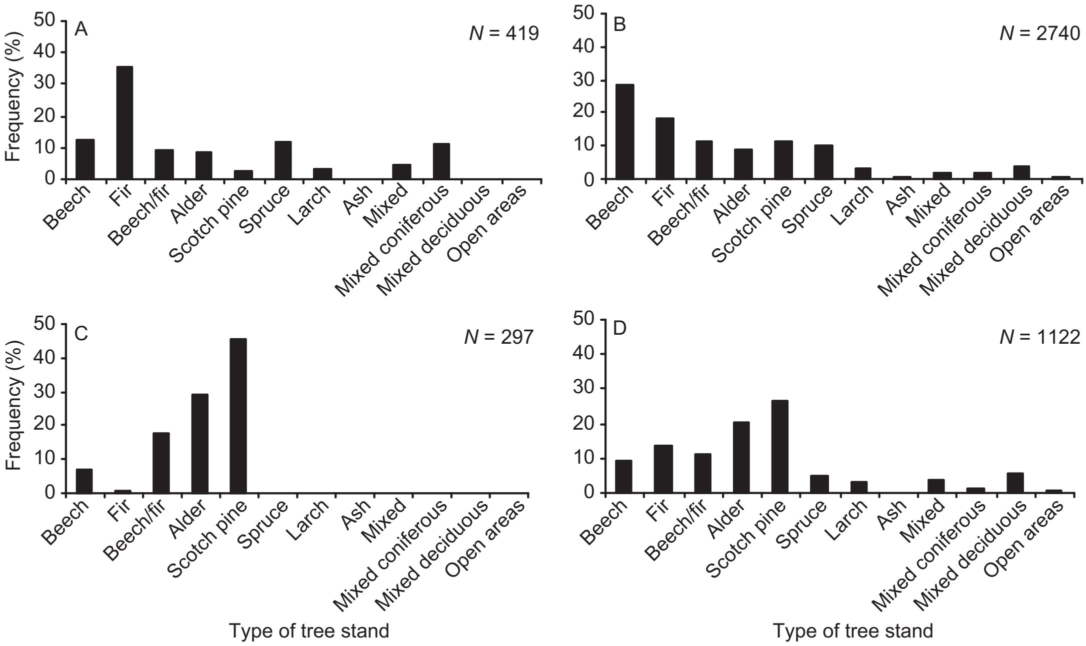

Fig. 6. Comparison of frequencies of European bison presence in summer (**A**, **B**) and winter (**C**, **D**) seasons within areas with 25% (**A**, **C**) and 95% (**B**, **D**) probability of bison locations, depending on tree species composition.

there (Krasińska & Krasiński 2004). Because of the paucity of studies of mountain-dwelling bison, no helpful guidelines were available.

Application of Kernel analysis (Worton 1989) to summer and winter ranges of bison populations enabled us to determine areas with high probability of bison presence. All four of the habitat variables that we analysed (elevation, slope exposure, tree canopy closure, and forest species composition) were important factors in differentiating between areas of intensive use (25% probability) and less intensive (95% probability) seasonal use. The fact that the factors differed in their relative importance between summer and winter was further evidence of the need to plan for seasonal variation in the identification of potential refuges. Here, we conclude that we should be seeking summer ranges that are at higher elevations, open canopied, and dominated by fir, spruce, and mixed conifers, while winter ranges should be at lower elevations, northerly exposures, closed canopied forests dominated by Scotch pine, alder, and beech-fir.

Given that our conclusions were derived from four forest districts representing habitats typical for the region, we suspect that they may be applicable to other potential refuges in the broader Carpathian ecoregion as well.

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