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Effects of long-term European bison presence on the floristic species inventory of a forest glade at Damerower Werder

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Abstract: The increasing number of free-roaming European bison in the last decade enables us to look closely at their functions as 'ecosystem engineers' in particular landscape contexts. Among the most mentioned ecosystem services European bison provide are keeping landscapes open and structuring vegetation. We have verified these potential effects in the Damerower Werder's release area by analyzing aerial photograph time series and vegetation surveys of a recent wood pasture. We found a high diversity of vascular plants (taxaS ~ 90/ha) along gradients of light exposure. European bison influenced vegetation patterns not only by biting. Scratching, grooming on thorny plants, sand-bathing, and nutrient redistribution can explain the occurrence and absence of a single species, too. This study demonstrates the positive impact of European bison on forest glade phytodiversity and reveals some of the mechanisms by which this occurs.

Keywords: *Bison bonasus*, forest clearing, ecosystem services, biodiversity, vegetation survey, floristic inventory

Introduction

Successful *ex situ* breeding was a prerequisite for the increase in European bison populations (Wehrenberg *et al.* 2024). Even though *in situ* conservation management is still crucial, with close to 9000 European bison in the wild (Raczyński and Bołbot 2023), ecology questions are becoming increasingly important. The (re)introduction of large herbivores like the European bison should not only aim at the conservation of the species itself. Still, it should also lead to the restoration of functioning natural ecosystems containing the full range of species at all trophic levels (Carver *et al.* 2021). Today, the ecological context of rewilding initiatives is characterized by the overwhelming societal goals of increasing biodiversity and avoiding greenhouse gases in general (European Commission 2020). Only recently, Schmitz *et al.* (2023) argued that the restoration of wild animals and their functional roles can enhance natural carbon capture and storage. Kaštovská *et al.* (2024) were able to deduce from their investigations in reintroduction areas, including European bison, that the soil can absorb more carbon than in compared areas. Such effects can be explained by the impact of extensive grazing and are mediated by the vegetation. As primary producers within the ecosystem, plants play a pivotal role in the diversity of trophic interactions and, therefore, in the overall biodiversity of a reintroduction area (Zhou *et al.* 2023). Hence, open areas grazed by European bison in forests dominated surroundings can offer additional ecosystem services. Such special services are well known from historic woodland pastures that harbor a vegetation and invertebrate inventory of high diversity and nature value (Plieninger *et al.* 2015). However, these were traditionally grazed by domestic animals, a form of extensive husbandry that is now rarely found due to a lack of economic viability and legislative limitations (Pérez-Barbería *et al.* 2023).

A recent woodland pasture is also located inside the rewilding area "Damerower Werder" (Mecklenburg, Germany, see Kelterborn *et al.* (2009) for history and site characteristics). This pasture, named "Wacholderkoppel", has a long history of extensive grazing in a farming context but was abandoned at the beginning of the 1950s. When European bison were reintroduced into the rewilding area in 1957, this increasingly wooded pasture became available to these animals as a grazing area. Now, after 66 years, we are interested to find out what influence the presence of the European bison had on the development of this forest glade and what kind of vegetation has developed at this ancient pasture ground. Such information is rare, but is urgently needed in order to monitor the hoped-for ecological successes. Despite numerous reintroductions of European bison for biodiversity purposes, the empirical evidence for their impact is highly limited (Gottlieb *et al.* 2024). Against this background, we conducted a study to answer the following questions:

(1) Can reintroduced European bison keep an abandoned forest pasture open?

(2) What is the state of the botanical species inventory of this area?

(3) In which ways does the European bison influence the composition of local vegetation?

Material and Methods

We have reconstructed the development of the former woodland pasture with the help of aerial photographs from archives. We were able to capture images from 1953, 1991, 2002, 2004, 2008, 2011, 2016, 2018 and 2020. Unfortunately, no aerial photographs could be found for the period from 1958 to

1989. The available images were first uniformly scaled and georeferenced. The subsequent measurement of the open areas was carried out using the software DatInf©Measure (DatInf GmbH, Tübingen, Germany). The corresponding European bison populations of the reserve were taken from the stud books. The number of calves and young animals was multiplied by a factor of 0.3 to create a rough estimated equivalent to the adult animals.

In spring 2023, nine recording areas (plots) in a total of 25 m^2 each were defined and marked along three transects following a light gradient (bright, semi-bright, semi-shade; see Fig. 1). We have recorded all the vascular plants that occur and taxonomized them. The coverage of every species in every plot was assessed twice (in May and in June). We used multivariate statistics (NMDS) to analyze the vegetation composition in the context of its environments. The Simpson- and the Shannon-indices were calculated to describe the phytodiversity of the surveyed area. We assessed the total number of vascular species based on our plots by species accumulation curves. All vegetation analyses were conducted using the package VEGAN (Oksanen *et al.* 2017) embedded in the R-Environment (R development core team 2016).

The European bison's influence on single vegetation components was assessed by observations and documented photographically.

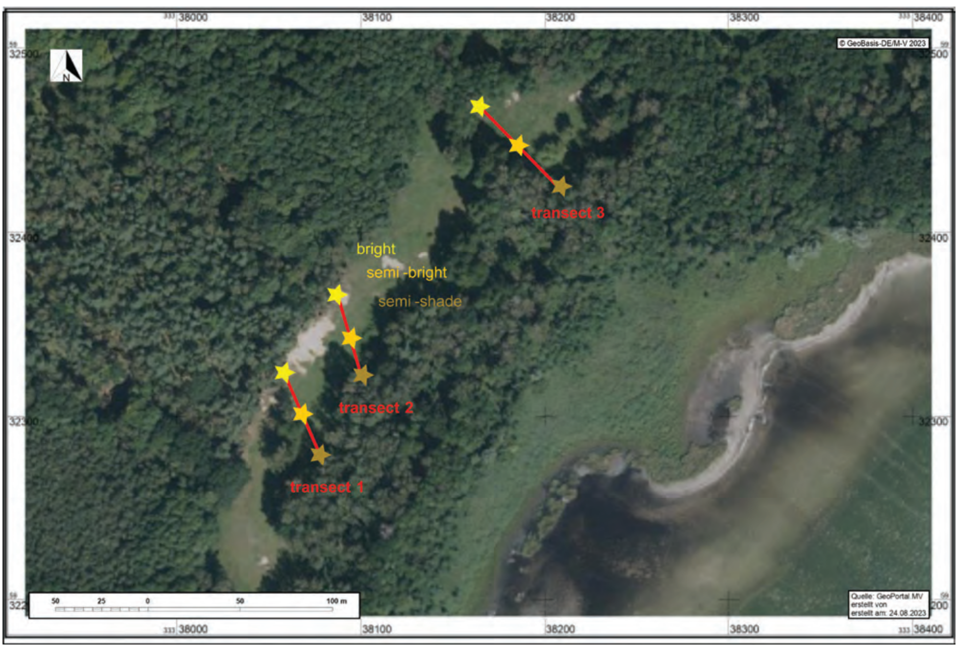

Figure 1. Arrangement of the plots within the study area "Wacholderkoppel" (aerial photo from GeoPortal.MV, 08-2020). red – positioning of the transects; stars – light leveled plots along these transects

Results and Discussion

The change in the open vegetation of the "Wacholderkoppel" from the abandonment of agricultural use and after 67 years of European bison introduction in the area is shown in Fig. 2. During this period, 28,261 m^2 (54 %) of grassland-like vegetation cover has been lost through shrub and tree encroachment. Remarkably, the natural reforestation started almost exclusively on the moist, shady south-eastern side facing the lake, while the higher north-western border changed its contour only slightly. At least a core of the pasture was preserved, which is not self-evident considering the initially low stocking density.

Figure 3 shows the process of open space development over time and in relation to the number of European bison in the reserve. Despite the lack of aerial photographs in the decisive reforestation phase, it is quite clear that

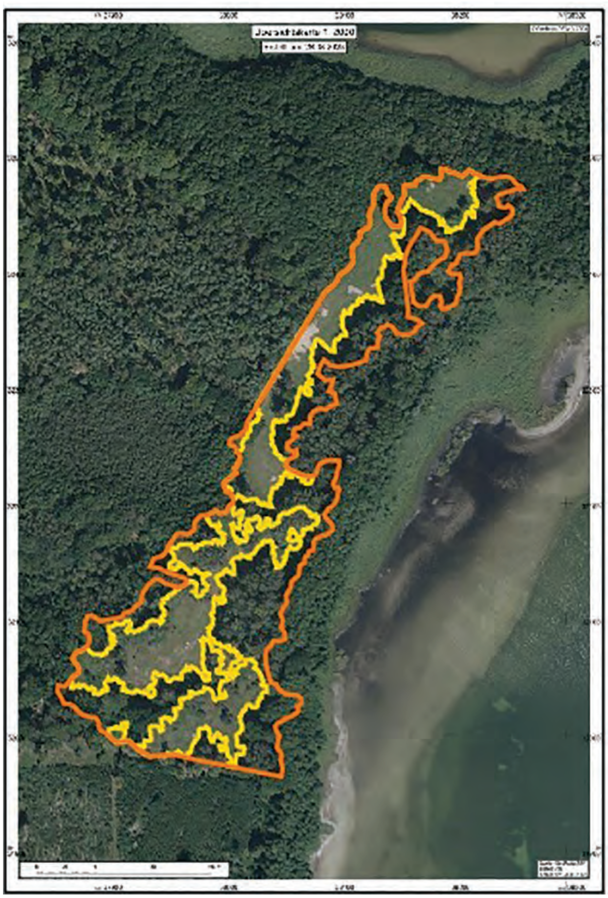

Figure 2. Change of the open grassland area inside the "Wacholderkoppel" from 1953 (orange line) after abandonment to 2020 (yellow line)

the open vegetation area remains constant from a stocking level of approx. 20 animals. This finding is still surprising when one considers that these few animals are distributed over 283 ha. Apparently, the pasture is an attractive place for the animals to stay and is therefore used more frequently than other areas in the reserve.

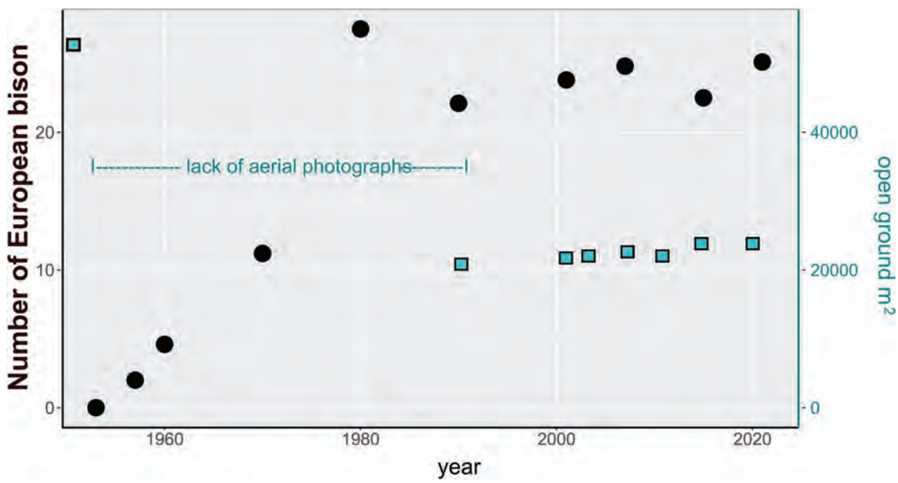

Figure 3. The number of adult-adjusted European bison (black dots) related to open-ground area in last 70 years (turquoise rectangles)

Botanical surveys reveal a high level of phytodiversity (taxaS=76). The mean Shannon-Diversity-Index of the relieves was 3.255 (sd 0.192), and the mean Simpson-Diversity-Index was 0.961 (sd 0.008). These values even exceed those of a tropical rainforest, which is considered to be particularly rich in species (Chen *et al.* 2002). Scaling up the number of species by applying an area-accumulation statistic, we get an estimate of 88.47 species per hectare without mosses and lichens.

A closer look at the composition of the vegetation according to its functional groups is shown in Figure 4. It can be seen that the group of dicotyledonous non-leguminous plant species (herbs) is mainly responsible for the high diversity. These include species such as *Agrimonia eupatoria*, *Armeria maritima*, *Fragaria vesca*, *Knautia arvensis*, or *Thalictrum flavum*, which are not extremely endangered but hardly found in farmed grasslands in the surrounding of the reserve. *Avenula pubescens* was the another rare species found among the grasses. The diversity of plant species observed is a prerequisite for many trophic interactions and a sign of high ecosystem functionality. The appendix seriation overview provides further information on the distribution of the individual species according to their positions (Fig. A1 Annex).

No significant influence of light exposure on the number of species was observed (ANOVA, $p=0.251$). However, the species assemblages differed depending on their light exposure (see Fig. 5). Decreasing light exposure was accompanied by increased pH and N eutrophication. The spatial differences in the soil reaction can be partly explained by the increasing proportion of sand in the soil in the more light-exposed parts of the gland. In the case of N-trophy, however, this explanation does not apply. This tendency is probably due to unequal excrement distributions by the European bison. This issue requires further investigation. In any case, it is clear that such a small-scale trophic gradient contributes to species diversity and is caused by European bison presence.

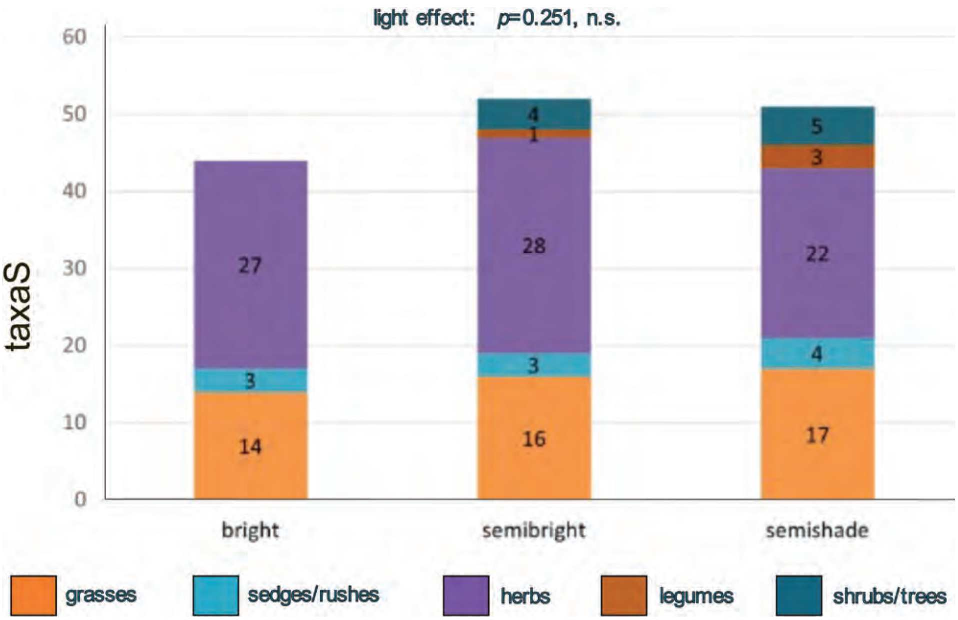

Figure 4. Number of vascular plant species (taxaS) of different functional groups separated according to their light conditions

We identified an accumulation of nitrophilous plants in the immediate vicinity of faeces. As also observed in the Döberitzer Heide (Germany, Brandenburg), the European bison bite sedges as well as sweet grasses, thereby limiting their tendency to dominate. Thorny shrubs such as *Rosa canina* are particularly affected in the course of grooming (see Fig. 6). Wallowing and sand bathing areas harbor very hardy species that can withstand the mechanical stresses (e.g., *Carex* species), but also pioneer plants such as *Conyza canadensis*, which benefit from the soil disturbance. Thus, various pathways

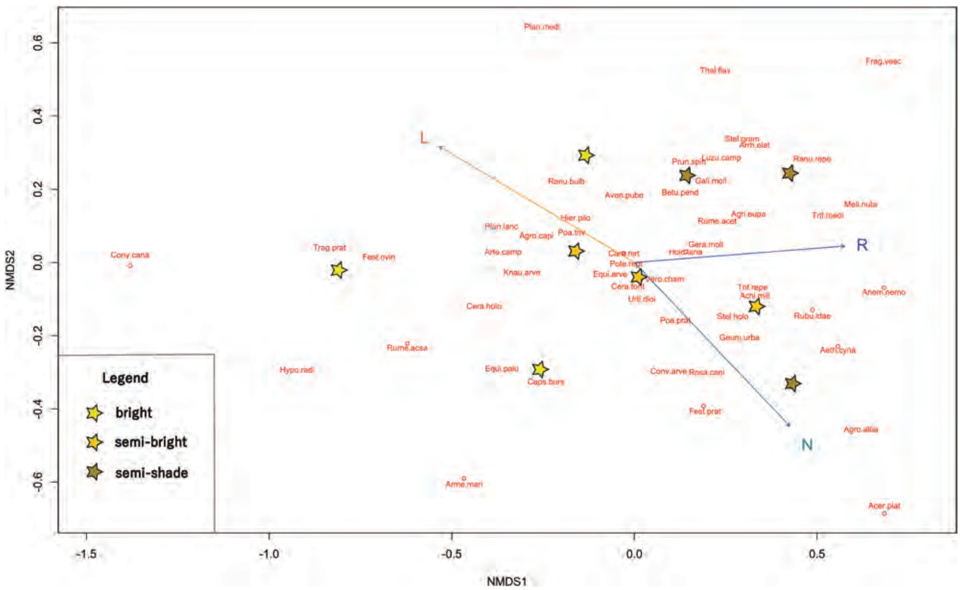

Figure 5. The vegetation cover's NMDS ordination (main axes 1 and 2). Stars symbolize the position of the plots, their brightness level (see legend). L, R,, and N arrows represent the gradients of light, soil reaction, and nitrogen according to the Ellenberg indicator values

explain the biodiversity-enhancing effect of European bison in such forest glands. They have in common that these open areas are obviously centers of attraction for the European bison. They benefit from a temporarily higher stocking density than in the tree-dominated surroundings.

This case study demonstrates the positive impact of European bison on forest glade phytodiversity and reveals some of the mechanisms by which this occurs. The results support Garrido *et al.* (2021), who stated that rewilding could be a potential avenue for wood-pasture restoration and biodiversity conservation. The way in which a reintroduction is planned and implemented should take into account not only the suitability of the habitat for the European bison but also its impact on the affected ecosystems (Tanentzap *et al.* 2023). Due to the diversity of reintroduction concepts and the large number of reintroduction habitats, it is imperative to monitor the important biotic and abiotic area resources in order to be able to intervene if necessary (Nogués-Bravo *et al.* 2016). As most reintroduction concepts aim to limit human influence and ecosystems can also change in unpredictable directions, this is no easy task. Nevertheless, the European bison research community should face up to these challenges, as they are inevitable for the continued spread of this impressive and conservation-worthy species.

Figure 6. Wild brier (*Rosa canina*) damaged by European bison in the course of grooming (photo: C. Jaeger)

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Efekt wieloletniej obecności żubra na florę przestrzeni otwartych w Damerower Werder

Streszczenie: Rosnąca w ostatniej dekadzie liczba wolno żyjących żubrów pozwala nam bliżej przyjrzeć się funkcjom tego gatunku jako „inżyniera ekosystemów" w określonych kontekstach krajobrazowych. Wśród najczęściej wymienianych usług ekosystemowych świadczonych przez żubry jest utrzymywanie otwartych krajobrazów i kształtowanie roślinności. Zweryfikowaliśmy te potencjalne efekty na obszarze zagrody w Damerower Werder, analizując serie czasowe zdjęć lotniczych i badania roślinności na użytkowanym przed laty przez zwierzęta gospodarskie pastwisku leśnym. Stwierdziliśmy wysoką różnorodność roślin naczyniowych (gatunki ~ 90/ha) wzdłuż gradientów ekspozycji na światło. Żubry wpływały na układ roślinności nie tylko poprzez zgryzanie. Drapanie, ocieranie o kolczaste rośliny, kąpiele piaskowe i redystrybucja składników odżywczych mogą również wyjaśniać występowanie i brak pojedynczych gatunków roślin. To studium przypadku pokazuje pozytywny wpływ żubra na fitoróżnorodność leśnych polan i ujawnia niektóre mechanizmy, dzięki którym to się dzieje.

Annex

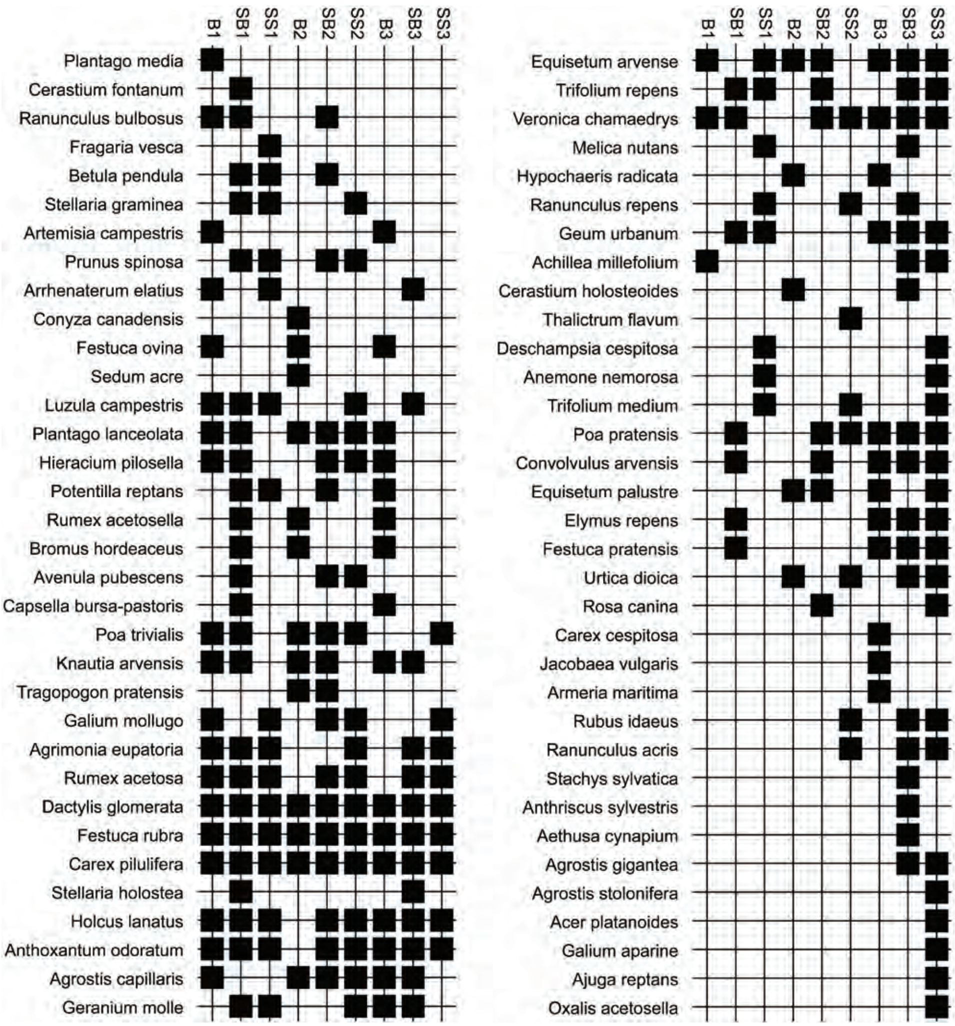

Figure A1. Seriation plot showing occurrence of the plant species in relation to the light conditions (B-bright, SB-semibright, SS-semishade) and the transect number (1-3).