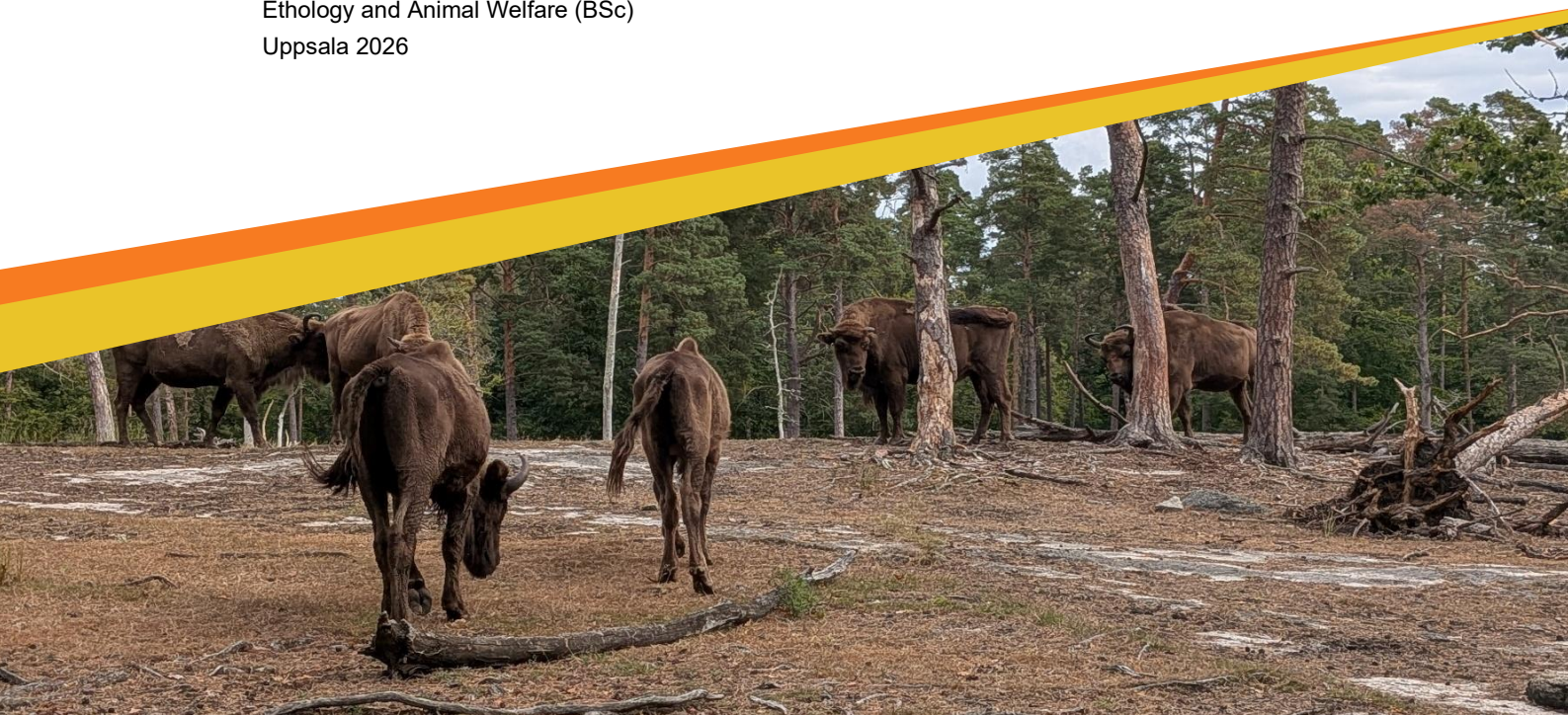




# Seed dispersal by European bison (*Bison bonasus*) and fallow deer (*Dama dama*): Implications for biodiversity

Alicja Bogdalska Postrożny

Bachelor's thesis • 15 credits  
Swedish University of Agricultural Sciences, SLU  
Department of Animal Biosciences  
Ethology and Animal Welfare (BSc)  
Uppsala 2026





# Seed dispersal by European bison (*Bison bonasus*) and fallow deer (*Dama dama*): Implications for biodiversity

*Fröspridning av visent (Bison bonasus) och dovhjort (Dama dama): Implikationer för biologisk mångfald*

Alicja Bogdalska Postrożny

**Supervisor:** Carl-Gustaf Thulin, Swedish University of Agricultural Sciences, Department of Animal Biosciences  
**Assistant supervisor:** Petter Kjellander, Swedish University of Agricultural Sciences, Department of Ecology  
**Assistant supervisor:** Wanda Olech, Warsaw University of Life Sciences  
**Examiner:** Claes Anderson, Swedish University of Agricultural Sciences, Department of Applied Animal Science and Welfare

**Credits:** 15 credits  
**Level:** First cycle, G2E  
**Course title:** Independent project in Biology  
**Course code:** EX0867  
**Programme/education:** Ethology and Animal Welfare (BSc)  
**Course coordinating dept:** Department of Applied Animal Science and Welfare  
**Place of publication:** Uppsala, Sweden  
**Year of publication:** 2026  
**Cover picture:** Alicja Bogdalska Postrożny  
**Copyright:** All featured images are used with permission from the copyright owner.

**Keywords:** Ecology, diet, foraging, rewilding, grazing, biodiversity loss

**Swedish University of Agricultural Sciences**  
Faculty of Veterinary Medicine and Animal Science  
Department of Animal Biosciences

## Abstract

The decline of animal dispersers poses a global threat to plant communities already challenged by climate change and habitat fragmentation. Herbivores with broad diets and large home ranges, such as the European bison (*Bison bonasus*) and fallow deer (*Dama dama*), are crucial for maintaining seed dispersal networks by endozoochoric dispersal. This study investigates the number of plants and species germinating from the dung of wild and captive populations of European bison and fallow deer, with the goal to assess their potential impacts on biodiversity. Faecal samples for both species were collected from two captive populations in Poland (Pszczyna) and Sweden (Eriksberg) and one wild population in Poland (Forest District Drawno). Droppings were stratified and cultivated in optimal greenhouse conditions for ten weeks. The results indicate that both European bison and fallow deer are capable of being efficient seed dispersers. European bison, however surpassed fallow deer across all sites in both seedling abundance and species richness. Furthermore, European bison dispersed five unique species of plants that did not appear in any fallow deer faecal samples. The unique dispersal profile of the European bison, thus, appears to be particularly valuable for biodiversity restoration efforts.

*Keywords: Ecology, diet, foraging, rewilding, grazing, biodiversity loss*

## Sammanfattning

Minskningen av antalet fröspridande djur utgör ett globalt hot mot växtsamhällen som redan utmanas av klimatförändringar och habitatfragmentering. Växtätare med bred diet och stora hemområden, såsom visenten (*Bison bonasus*) och dovhjorten (*Dama dama*), är avgörande för att upprätthålla fröspridningsnätverk genom endozookorisk fröspridning. Denna studie undersöker antalet växter och arter som gror från spillning av vilda och hägnade populationer av visent och dovhjort, med målet att bedöma deras potentiella effekter på den biologiska mångfalden. Avföringsprover för båda arterna samlades in från två hägnade populationer i Polen (Pszczyna) och Sverige (Eriksberg) och en vild population i Polen (skogsdistriktet Drawno). Spillningen stratifierades och odlades under optimala växthusförhållanden i tio veckor. Resultaten indikerar att både visenten och dovhjorten kan vara effektiva spridare av frön. Visenten spred dock betydligt mer frön och överträffade dovhjorten på alla områden, både vad gäller växtmängd och artrikedom. Dessutom spred visenten fem unika växtarter som inte hittades i dovhjortens avföring. Visentens unika spridningsprofil verkar således vara särskilt värdefullt för insatser inom restaurering av biologisk mångfald.

*Nyckelord: Ekologi, diet, födosök, återförviltning, bete, förlust av biologisk mångfald*

# Table of contents

<b>List of tables</b> .....	<b>7</b>
<b>List of figures</b> .....	<b>8</b>
<b>1. Introduction</b> .....	<b>9</b>
1.1 Endozoochoric seed dispersal .....	9
1.2 European bison ( <i>Bison bonasus</i> ) .....	10
1.2.1 European bison diet and ecological importance .....	11
1.3 Fallow deer ( <i>Dama dama</i> ) .....	12
1.3.1 Fallow deer diet and ecological impact .....	13
<b>2. Aim of the study</b> .....	<b>14</b>
<b>3. Materials and methods</b> .....	<b>15</b>
3.1 Study areas .....	15
3.2 Collection of stool samples .....	16
3.3 Germination and cultivation .....	17
3.4 Identification of species .....	18
3.5 Data analysis .....	18
<b>4. Results</b> .....	<b>19</b>
4.1 Seedlings germinating from droppings .....	19
4.2 Plant species dispersed by European bison and fallow deer across sites .....	20
4.3 Seedling abundance and species richness in samples with growth .....	22
<b>5. Discussion</b> .....	<b>24</b>
5.1 Seed dispersal of European bison and fallow deer .....	24
5.1.1 Seed dispersal in different habitats .....	25
5.2 Biodiversity benefits for fauna and flora .....	26
5.3 Rewilding for a sustainable future .....	27
5.4 Discussion of the chosen literature and method .....	29
5.4.1 Method .....	29
5.4.2 Literature .....	30
5.5 Future research .....	31
<b>6. Conclusion</b> .....	<b>33</b>
<b>References</b> .....	<b>34</b>
<b>Popular science summary</b> .....	<b>41</b>
<b>Appendix 1</b> .....	<b>42</b>
<b>Thank you</b> .....	<b>44</b>

# List of tables

<b>Table 1.</b> Total number of samples and pots used for each treatment and species, together with the mean sample weight per pot.....	18
--------------------------------------------------------------------------------------------------------------------------------------------	----

# List of figures

<b>Figure 1.</b> Locations where samples were collected. Cultivated field near Drawno: fallow deer ( <b>A</b> ), Borówiec forest clearing: European bison ( <b>B</b> ), Żubrowisko reserve: European bison/fallow deer ( <b>C</b> ). Eriksberg: European bison/fallow deer ( <b>D</b> )... 16	
<b>Figure 2.</b> Total number of seedlings and species dispersed by European bison (green) and Fallow deer (orange)..... 19	
<b>Figure 3.</b> Total number of seedlings in droppings of wild European bison collected in Drawno..... 20	
<b>Figure 4.</b> Total number of seedlings in droppings of captive European bison collected in Eriksberg..... 21	
<b>Figure 5.</b> Total number of seedlings in droppings of captive Fallow deer collected in Eriksberg..... 21	
<b>Figure 6.</b> Total number of seedlings in droppings of captive European bison ( <b>A</b> ) and Fallow deer ( <b>B</b> ) collected in Pszczyna. Note that the panels have different numeric scales. .... 22	
<b>Figure 7.</b> Total number of seedlings in stool samples with growth collected at all sites. EB = European bison, FD = fallow deer. .... 23	
<b>Figure 8.</b> Total species richness in stool samples with growth collected at all sites. EB = European bison, FD = Fallow deer. .... 23	

# 1. Introduction

Biodiversity loss poses a major challenge for ecosystems worldwide (Cardinale, 2012). The average size of studied wildlife populations has according to a report by WWF (2024) fallen by approximately 73% since 1970. It is also no secret that the large herbivore fauna in Europe was much more diverse and abundant before modern humans arrived at the continent (Bergman *et al.*, 2023). The decline of large herbivores is expected to have caused drastic changes in ecosystem composition and functioning and as of 2026, one in three habitats protected under EU law depends on grazing (Galetti *et al.*, 2017; European Environment Agency, 2026). Grazing animals are important for biodiversity as they keep grass levels low and allow light dependent plants to germinate which would not be possible if the sites were overgrown with shrubs (Kowalczyk *et al.*, 2021). It is important to note that not all wild herbivores are grazers who feed on grasses and herbs, many are browsers that prefer to feed on leaves and forbs which is not as helpful in keeping the landscapes clear (Hofmann, 1989). According to Hofmann (1989), wild herbivores in Europe with diets most closely resembling that of domesticated grazers such as sheep and cattle are the European bison, mouflon and fallow deer. These animals contribute to a plethora of ecosystem functions beyond shaping the lands through grazing, one of which is seed dispersal (Howe & Smallwood, 1982)

## 1.1 Endozoochoric seed dispersal

Seed dispersal is a critical stage in a plant's life and the sole opportunity for plants to move locations (Schupp & Fuentes, 1995). Plant recruitment benefits from seed dispersal by allowing seeds to escape mortality in the vicinity of the parent plant and increase the likelihood of reaching suitable sites for germination (Howe & Smallwood, 1982). More than half of all seed-bearing plants are dispersed by animals (Rogers *et al.*, 2021). Seeds disperse in various ways based on their morphological features, such as, hooks that attach to animals (epizoochory) or fleshy seeds that the animals ingest (endozoochory) (Trakhtenbrot *et al.*, 2005)

Digestion and teeth grinding destroys numerous seeds ingested by ruminants, yet other seeds potentially benefit from the process (Zidon *et al.*, 2016). Dung provides a nutrient rich substrate, and gut passage can weaken seed coat, making germination easier (Howe & Smallwood, 1982). Moreover, through animal movement, endozoochory facilitates seeds to disperse further away from the parent plant, which enables establishment of plant populations on new sites (Howe & Smallwood, 1982; Pakeman & Small, 2009). However, this dispersal mechanism

also involves a certain risk, such as withstanding the gut passage and that animals may carry them to sites unsuitable for germination (Pakeman & Small, 2009).

Several studies show that the composition of dispersed plants within the same habitat differs among herbivore species (Eycott *et al.*, 2007; Picard *et al.*, 2016; Lepková *et al.*, 2018; Leiva & Fedriani, 2026). The observed differences can be attributed to variations in diet, digestive system, body mass and grazing behaviour (Eycott *et al.*, 2007). These differences determine both the amount and type of seeds dispersed (Picard *et al.*, 2016). Smaller herbivores mainly contribute to local dispersal as their home ranges usually are not as big as that of larger species moving over greater distances (Cederlund & Okarma, 1988; Krasíńska *et al.*, 2000; Borkowski & Pudelko, 2007; Picard *et al.*, 2016). Ultimately, herbivore species each shape plant growth and habitats differently.

## 1.2 European bison (*Bison bonasus*)

The European bison is the largest existing land mammal native to Europe and has likely played a significant role in shaping the continent's prehistoric landscapes (Gottlieb *et al.*, 2024). The last wild European bison's were poached in 1919 (Białowieża Forest) and in 1927 (Caucasus Mountains), leaving only 54 individuals alive in captivity (Samojlik *et al.*, 2023). Through international effort and coordinated breeding programs the European bison was able to make a comeback and as of 2024 the population has risen to 12209 individuals worldwide according to the European Bison Pedigree Book (Raczyński, 2025). Out of the three prior existing subspecies, Lowland, Caucasian and Carpathian, only the pure Lowland European bison remains today, along with a hybrid between Lowland and Caucasian (Olech & Perzanowski, 2002). The largest wild populations can be found within Poland, Russia and Belarus (Raczyński, 2025).

There are two basic units of herds, bull groups containing 2-3 individuals and mixed groups with roughly 20 animals (Krasíński, 1967; Krasíńska *et al.*, 2000). Mixed groups include cows, calves, sub-adults of both sexes and occasionally adult bulls, especially during mating season (Krasíński, 1967). Food availability, habitat and season influence how many animals a herd contains (Krasíńska *et al.*, 2000). It is difficult to estimate home range sizes as these are greatly influenced by landscape, population density and supplementary feeding (Krasíńska *et al.*, 2000; Lehto, 2015; Thulin, 2023). Herds in the Polish Białowieża forest demonstrate a clear seasonal home range variation, with winter estimates averaging 8-11km<sup>2</sup> compared to 69-70km<sup>2</sup> during summer (Krasíńska *et al.*, 2000; Lehto, 2015). The much smaller home ranges in winter are connected to supplementary feeding which, as mentioned earlier is a key influencing factor (Krasíńska *et al.*, 2000; Lehto, 2015). Herds living in West Pomerania exhibit home ranges nearly twofold larger

than herds in the Białowieża Forest, which ties back to how the landscape influences the movement (Lehto, 2015)

There is debate over whether European bison can be classified as a refuge species, restricted to forests by progressive habitat loss and human pressure (Karley *et al.*, 2012; Bocherens *et al.*, 2015). European bison have over a long period of time been viewed as a forest-dwelling species, occasionally feeding in open areas but preferring mainly clearings in deciduous forests (Kraśńska *et al.*, 2000; Pucek *et al.*, 2004). Several studies based on GPS-tagged animals have contradicted this hypothesis and found a preference for meadows (Lehto, 2015). This preference is also supported by isotopic analysis of early Holocene bones, showing ancient specimen consumed more open steppe vegetation than their modern counterparts (Bocherens *et al.*, 2015). However, a recent study compiled of the largest GPS tracking data set for the species found no clear selection for grasslands (Retez *et al.*, 2026). This recent discovery points to European bison being mixed feeders and preferring mixed landscapes as opposed to being grassland specialists (Retez *et al.*, 2026). Ultimately classifying megafauna such as the European bison as specialist confined to certain habitats risks oversimplifying their ecological flexibility (Retez *et al.*, 2026)

### 1.2.1 European bison diet and ecological importance

The diet of European bison under natural conditions consists of herbs, grasses and the leaves and branches of shrubs and trees (Gebczynska & Krasinska, 1972). All these food resources are readily available in forest habitats, cultivated fields and forest glades although the quantity of accessible forage fluctuates seasonally (Gebczynska & Krasinska, 1972). European bison are not selective when grazing on the ground due to their wide muzzle, taking larger bites of patches rather than focusing on individual plants (Hofmann, 1989). The summer diet is more diverse and drastically different from that of winter (Zielke *et al.*, 2017). Winter supplementary feeding is commonly provided for wild populations to mitigate human-bison conflict and minimize damage on agricultural fields (Hofman-Kamińska & Kowalczyk, 2012). The duration of a single feeding bout largely varies from 15 minutes to roughly five hours (Caboń-Raczyńska *et al.*, 1987). Studies indicate that feeding occurs in three to four phases during the day, one post sunrise, either one or two during midday and one pre sunset (Caboń-Raczyńska *et al.*, 1987; Pedersen *et al.*, 2019).

European bison have a positive effect on vegetation by keeping landscapes open and grass heights low (Gebczynska & Krasinska, 1972). In Denmark fenced herds have shown to significantly increase plant diversity in both swamps, forests and meadows over just a period of five years (Hartvig *et al.*, 2021). The same positive effect can be seen in the Polish Białowieża forest, where the animals reduce both

the density and volume of woody vegetation on meadows (Kowalczyk *et al.*, 2021). Without large herbivores such as the European bison meadows become overgrown, making it harder for light dependent plants to grow and decreasing biodiversity (Kowalczyk *et al.*, 2021).

### 1.3 Fallow deer (*Dama dama*)

Fallow deer is the most widespread cervid in the world and one of the most common cervid species found in Europe (Bijl & Csányi, 2022). Ancestral populations of fallow deer are historically restricted to Asia Minor, the Middle East, and Macedonia, with their widespread presence in Europe attributable to translocation by humans from the Middle Ages and onwards (Gryz *et al.*, 2022). As of today, fallow deer live on all continents except Antarctica (Esattore *et al.*, 2022). Data from 24 European countries suggest a minimum annual harvest of 500 000 wild fallow deer, underscoring the species robust population growth (FACE, 2025). The practice of fallow deer farming for venison products has also seen notable growth in response to the rising demand for game meat (Żmijewski *et al.*, 2020). Among cervid species, fallow deer display the highest diversity in pelage variation, with four main colours: common, menil, melanistic and leucistic (Feldhamer *et al.*, 1988).

Large groups of fallow deer, between 70 and 100 individuals, frequently form on open fields when foraging on resource rich feeding grounds (Putman, 1988). Such herds are not socially coherent but rather temporary groups composed of multiple different core groups (Putman, 1988). The home range size of male and female fallow deer can vary a lot (Putman, 1988; Borkowski & Pudełko, 2007; Christensson, 2010). In Swedish and Polish populations, female fallow deer exhibit mean home range sizes of 2.1- 2.9 km<sup>2</sup> whereas male fallow deer can display ranges approximately three times greater (Borkowski & Pudełko, 2007; Christensson, 2010). Home range for ungulates tends to be larger the patchier or poorer the preferred habitat is, something that is also influenced by season and population density (Putman, 1988; Turner *et al.*, 1993)

Fallow deer are well adapted to a plethora of environments (Putman, 1988). Studies have identified meadows, arable land, thickets and deciduous forests as preferred habitats (Apollonio *et al.*, 1998; Borkowski & Pudełko, 2007; Christensson, 2010). Males typically display bolder foraging behaviour than females, frequently utilizing more high-risk areas (e.g., close to human settlements), whereas females use these sites after dusk when disturbance is low (Ciuti *et al.*, 2004). Fallow deer have also been shown to display competitive dominance over smaller ungulates, such as roe deer, when grazing on preferred feeding sites, often with direct aggression (Ferretti *et al.*, 2011). This defence of

resources from competing species can be attributed to an evolutionally strategy evolved during past ice ages to survive relatively poor habitats (Ferretti *et al.*, 2011).

### 1.3.1 Fallow deer diet and ecological impact

Fallow deer are generalist herbivores and intermediate grazers with an extremely wide spectrum of food preferences (Esattore *et al.*, 2022). While their broad diet enables them to explore various resources, fallow deer are not random foragers and often select for more nutritional plants to optimize energy gain (Benge, 2002; Rautiainen *et al.*, 2021). Season and local forage availability also strongly influences their diet of mostly grasses, herbs, leaves, bark and fruits (Bruno & Apollonio, 1991; Morse *et al.*, 2009; Rautiainen, 2017). Feeding periods occur mainly at dusk and dawn but fallow deer may forage at various intervals throughout the day and night (Feldhamer *et al.*, 1988).

High densities of fallow deer may lead to overgrazing which can result in loss of vegetation structure and flower richness (van der Spek, 2024). The negatives of overgrazing lead to monotonous grassy plains with only small herbs still flowering (van der Spek, 2024). Still, fallow deer at moderate densities can be very useful for promoting biodiversity, much like other grazing herbivores (van der Spek, 2024). The ecological impact of fallow deer is thus not linear but often has a certain threshold (Putman *et al.*, 2011). In certain densities fallow deer can act as ecosystem engineers while above that threshold their impact shifts towards degradation of the landscape (Putman *et al.*, 2011).

## 2. Aim of the study

The purpose of this study is to compare the endozoochorous seed dispersal of European bison and fallow deer. The goal is to assess their relative contributions to seed dispersal and potential impacts on biodiversity. The hypotheses tested are as follows:

- Are there significant differences in seed dispersal between European bison and fallow deer?
- Are there significant differences in seed dispersal between captive and wild populations?

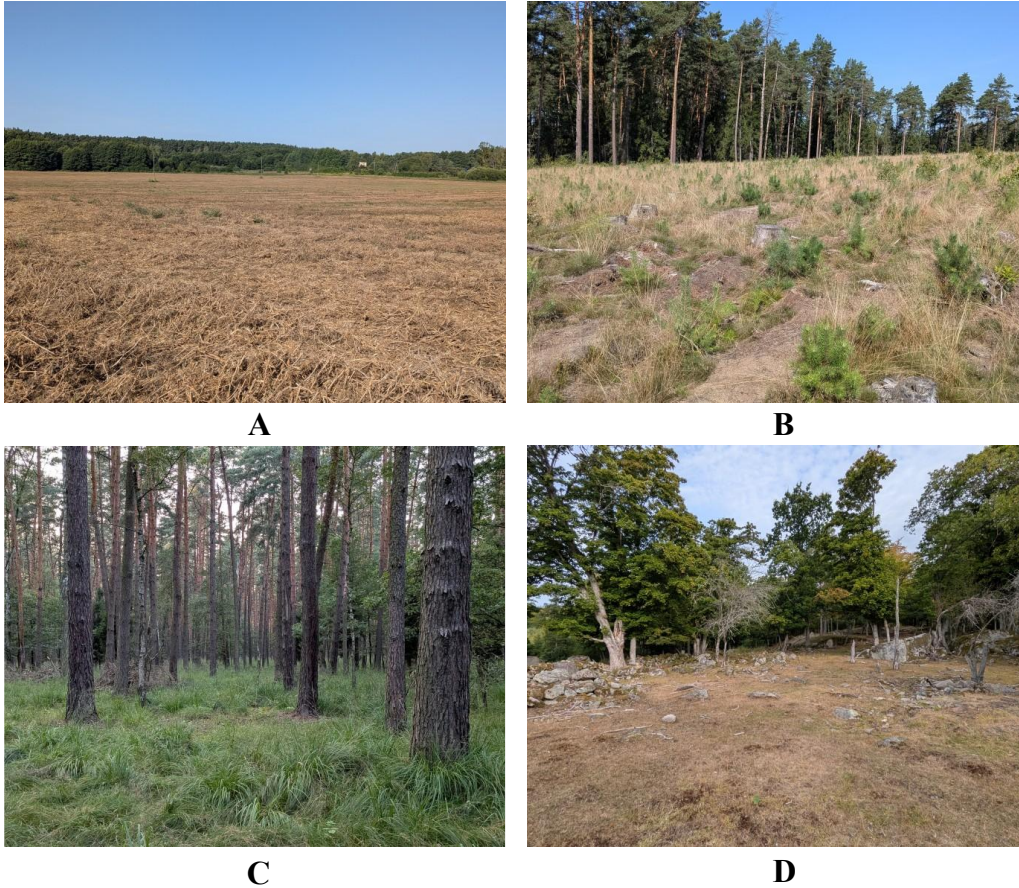
The assessment is done by testing the relative germination of seeds in faecal droppings from wild and captive European bison and fallow deer.

## 3. Materials and methods

### 3.1 Study areas

Faecal samples from wild specimen were collected in Drawno forest district, West Pomerania, North-western Poland (see Figure 1A and B). The forest district covers 21 107 hectares and includes 11 forest areas, of which only Borówiec and Kiełpno were included in the sampling scheme (Bachorski, 2023). All faecal samples from fallow deer were furthermore collected on cultivated fields surrounding Drawno. The area has a relatively mild climate shaped by the influence of the Baltic Sea and infrequent frost days which favour forest growth (Bachorski, 2023). Scots pine (*Pinus sylvestris*) is the dominating tree species, forming roughly 86,2% of the forest strands (Bachorski, 2023).

The gathering of samples from captive animals in Poland took place at reserve “Żubrowisko” in Pszczyna (see Figure 1C). The reserve is dominated by moist coniferous forest communities, especially wet reed grass pine forests with patches of coniferous forest and boggy pine forest (Wójtowicz, 2021). A relatively small area (17 hectares) is covered by non-forest vegetation which mainly consists of economically used wet ryegrass meadows. Bogs and peatland also occur within the area (Wójtowicz, 2021). Approximately 40 European bison are kept within the enclosure, whereas the number of fallow deer present is unknown (Śląskie.travel, 2025). The entire enclosed area covers 744,61 hectares and is closed to the public (Śląskie.travel, 2025). The second part of the sample collection from enclosed animals was conducted in Eriksberg, Blekinge, Sweden (see Figure 1D). This is one of the largest wildlife enclosures in northern Europe, covering an area of 925 hectares (Eriksberg, 2026). The parks landscape is shaped by long term grazing and most of the area is covered by broadleaf forests (Länsstyrelsen Blekinge, 2018). The reserve also contains various other forest and coastal vegetation types such as juniper shrubland, coastal meadows, pine forests and grasslands (Länsstyrelsen Blekinge, 2018).



**Figure 1.** Locations where samples were collected. Cultivated field near Drawno: fallow deer (**A**), Borówiec forest clearing: European bison (**B**), Żubrowisko reserve: European bison/fallow deer (**C**). Eriksberg: European bison/fallow deer (**D**)

### 3.2 Collection of stool samples

Faecal samples from European bison and fallow deer were collected at three different field locations during late summer, 2025 (12-25<sup>th</sup> August). Drawno forest district, reserve Żubrowisko in Pszczyna (Poland) and Eriksberg wildlife park (Sweden). Collected samples varied in weight but the material was later corrected for weight and evenly distributed in planting pots.

Samples from wild populations were collected at different locations within Drawno forest district over the course of two days. Faecal samples from European bison were obtained from two sites, a forest habitat, where 12 samples were collected and the other an open meadow area, where additional 19 samples were gathered. Fallow deer droppings were scarce and not as easy to locate, most samples were collected in the agricultural fields adjacent to Drawno. Although fallow deer were observed in the area, their population density was very low, and it cannot be excluded that some faecal samples originated from the same fallow deer specimen, roe deer or even wild boar. A total of 12 faecal samples were gathered. Faecal

samples from captive specimens in Poland were collected by staff members at “Żubrowisko” reserve. This was a precaution implemented to minimize the risk of disease transmission as this particular European bison population was genetically vulnerable (Śląskie, 2025). A total of 31 samples from European bison and 29 samples from fallow deer were received from the “Żubrowisko” reserve. At Eriksberg samples were collected without assistance from park staff, prior to park opening. However, the presence of both red deer and mouflon within the area increased the risk of including faeces from non-target species. In the end 30 faecal samples from fallow deer and 18 faecal samples from European bison were gathered. In total, 80 samples from European bison and 71 samples from fallow deer were collected and brought to Uppsala for the germination experiment (Table 1).

Samples were frozen immediately or within one day after collection to prevent decomposition and mold development. Everything was kept frozen for one to three weeks to stimulate natural winter stratification experienced by seeds in the field. This freezing period also helped eliminate insects present in the faeces that might otherwise have been harmful during the seed germination phase of the study.

### 3.3 Germination and cultivation

Faecal samples were crumbled lightly and mixed gently with the upper soil layer (S-jord, Hasselfors Garden AB) to retain moisture and potted in 11x11x12 cm pots. The weight of the collected faecal material varied among samples. To ensure an even distribution, all samples exceeding 35 g were divided in two pots to equalize weights. In addition, three control pots containing only soil were established as blanks to check for potential seed contamination originating from the soil. All samples were potted on September 1<sup>st</sup> and allowed to grow until November 14<sup>th</sup>, corresponding to slightly more than ten weeks of growth (light between 06:00 and 22:00, 20°C and daily supervision) in a greenhouse at the Ecology Centre, Department of Ecology, SLU, Uppsala, Sweden. Species identification occurred on a rolling schedule, but not all seedlings were possible to identify within the appointed time frame. These unidentified saplings were re-planted and given two additional weeks of growth outside the greenhouse in indoor conditions.

Although all faecal samples were subjected to a freezing period, which likely eliminated many insects present in the dung, fungus gnats (*Sciaridae*) nevertheless emerged as a problem a few weeks into the cultivation period. These insects were mainly perceived as just a nuisance, but their larvae may have damaged the roots of young plants, contributing to reduced growth or plant mortality. Sticky insect traps were used to mitigate the problem, however, it's difficult to assess the extent to which these insects affected plant growth.

**Table 1.** Total number of samples and pots used for each treatment and species, together with the mean sample weight per pot.

Species	Site	Samples	Total pots	Mean $\pm$ SD
<i>European bison</i>	Drawno	31	41	30.32 $\pm$ 5.65 (g)
	Eriksberg	18	23	25.15 $\pm$ 5.74 (g)
	Pszczyna	31	31	23.64 $\pm$ 7.64 (g)
<i>Fallow deer</i>	Drawno	12	14	20.10 $\pm$ 5.71 (g)
	Eriksberg	30	31	17.33 $\pm$ 6.57 (g)
	Pszczyna	29	32	16.72 $\pm$ 5.35 (g)

### 3.4 Identification of species

All germinated seedlings were initially classified as monocotyledons or dicotyledons. When more precise identification was possible, plants were first subjected to AI-based image analysis with Perplexity, version 2.62.0., to determine the genus, followed by conventional identification using taxonomic keys and species information from SLU Artdatabanken (2026). The cell phone application PictureThis, version 5.17.0., was also used to a limited extent to support the identification process.

### 3.5 Data analysis

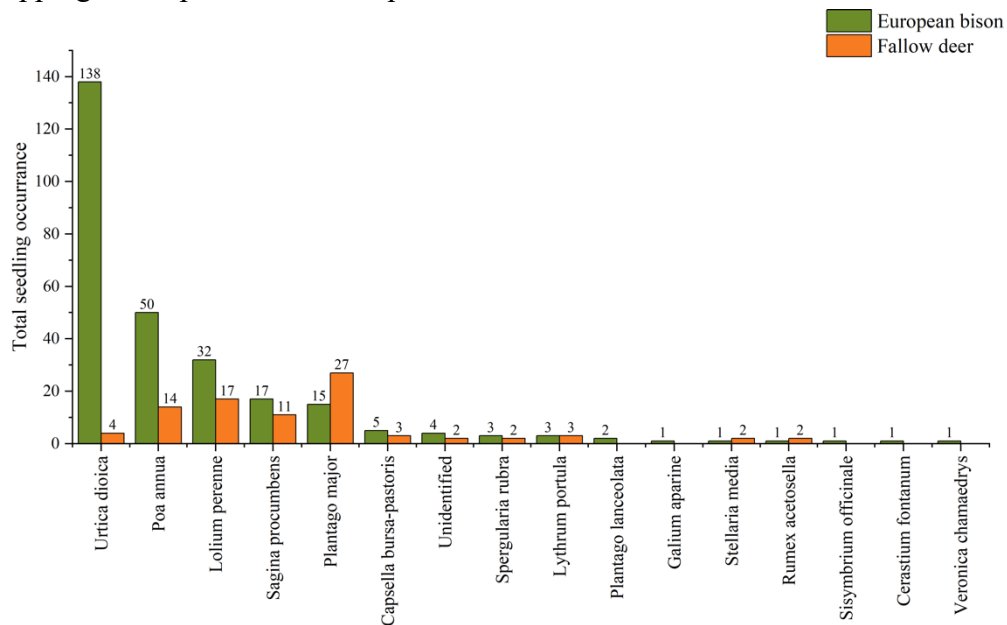
Raw data of species identification and germination was stored and organized in Microsoft Excel, version 2508. Minitab, version 21.3.1., was used for statistical calculations and analyses. Data was tested for normality, but not all datasets met the required assumption of normal distribution, therefore the Kruskal-Wallis test was chosen as it is suitable for non-normally distributed data. The threshold for statistical significance was set at  $p \leq 0.05$ . Variables included in the analysis were the number of seeds and species in samples with growth. These variables were analysed in relation to the three sites of stool sample collection (Drawno, Eriksberg and Pszczyna), comparisons were also made between fallow deer and European bison. Figures were created with OriginLab, version 10.1.0.170.

## 4. Results

### 4.1 Seedlings germinating from droppings

Seedlings emerged from 74% of droppings produced by wild European bison and 47% of those from captive individuals (100% in Eriksberg and 16% Pszczyna). Only one dropping from wild fallow deer produced a seedling (8%) whereas 51% of samples from captive fallow deer showed seedling emergence (83% in Eriksberg and 17% in Pszczyna).

In total 15 plant species (13 forbs and two grasses), and a handful of unidentified seedlings grew from all the collected faecal samples, yielding 361 plants altogether (see Figure 2, Appendix 1). *Lythrum portula*, a red listed species in Sweden, classified as Near Threatened by Artdatabanken (2026), was found in multiple droppings of captive fallow deer and European bison as well as one dropping from wild European bison. *Plantago lanceolata*, *Galium aparine*, *Sisymbrium officinale*, *Cerastium fontanum* and *Veronica chamaedrys* were only found in European bison droppings. No species were unique to fallow deer.

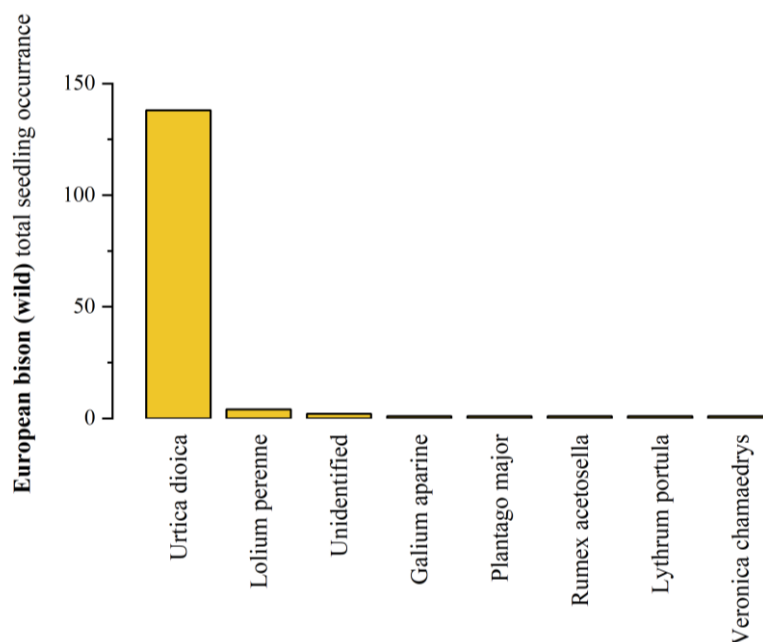


**Figure 2.** Total number of seedlings and species dispersed by European bison (green) and Fallow deer (orange).

## 4.2 Plant species dispersed by European bison and fallow deer across sites

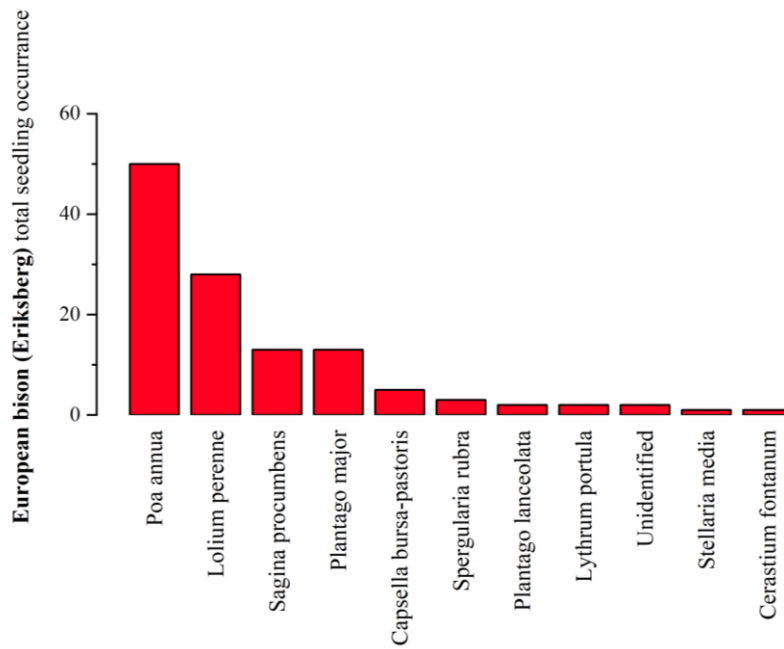
Plant growth was observed in all European bison and fallow deer samples, although some sites showed less growth than others. No single species was consistently the most abundant across all locations. In general, samples were dominated by a few plant species whereas the remaining species occurred in low abundance.

The most abundant species found in wild European Bison samples was *Urtica dioica*, which was also the most occurring species overall (Figure 3). Samples were collected across two distinct habitats, pine forest clearing (12 samples) and meadow adjacent to deciduous forest (19 samples), both yielding 12 and 137 seedlings respectively. In total seven species of vesicular plants and two unidentified seedlings were dispersed, and 149 plants grew from both sites.



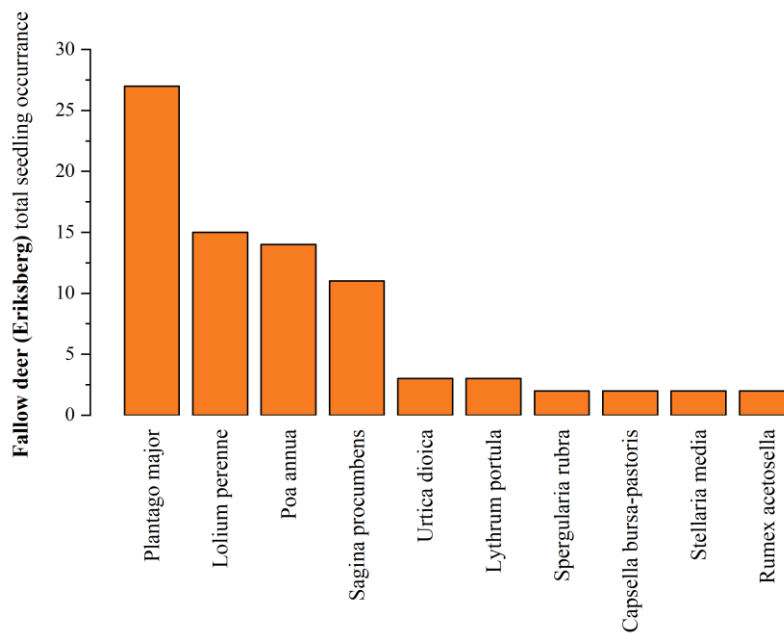
**Figure 3.** Total number of seedlings in droppings of wild European bison collected in Drawno.

In total, eleven different species and four unidentified saplings were dispersed by captive European bison in Eriksberg, of which *Poa annua* and *Lolium perenne* were the most prevalent (Figure 4). A total of 120 plants germinated from the Eriksberg samples.



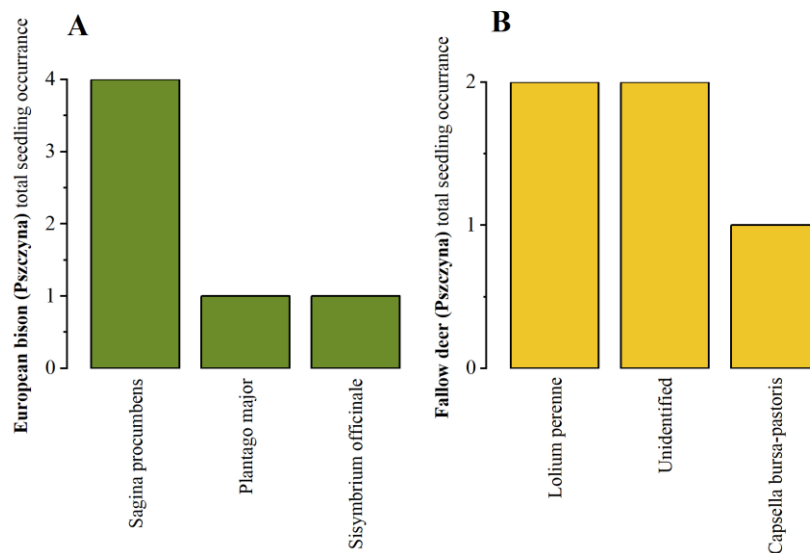
**Figure 4.** Total number of seedlings in droppings of captive European bison collected in Eriksberg.

*Urtica dioica* was the only plant that grew from wild fallow deer droppings. Captive fallow deer samples collected in Eriksberg grew ten species of plants and two unidentified seedlings of which *Plantago major* was the most abundant followed by *Lolium perenne* (Figure 5). Wild fallow deer samples only grew one plant while samples from Eriksberg produced 80.



**Figure 5.** Total number of seedlings in droppings of captive Fallow deer collected in Eriksberg.

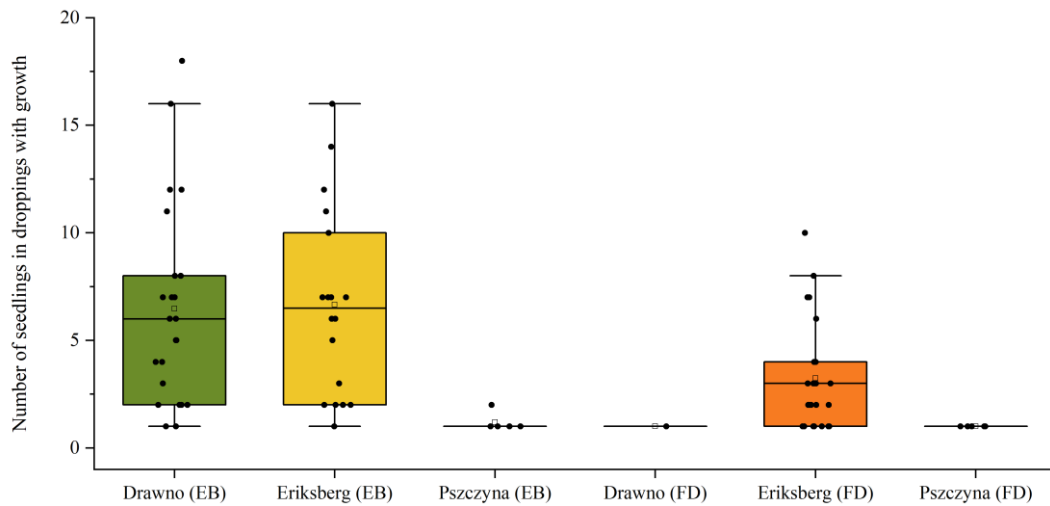
Samples from European bison and Fallow deer collected in Pszczyna showed very little growth. Altogether three species were dispersed by European bison; *Sagina procumbens*, *Plantago major* and *Sisymbrium officinale* (Figure 6A). Fallow deer samples grew two unidentified seedlings as well as *Lolium perenne* and *Capsella bursa-pastoris* (Figure 6B). Altogether six plants germinated from European bison droppings and five from that of fallow deer.



**Figure 6.** Total number of seedlings in droppings of captive European bison (A) and Fallow deer (B) collected in Pszczyna. Note that the panels have different numeric scales.

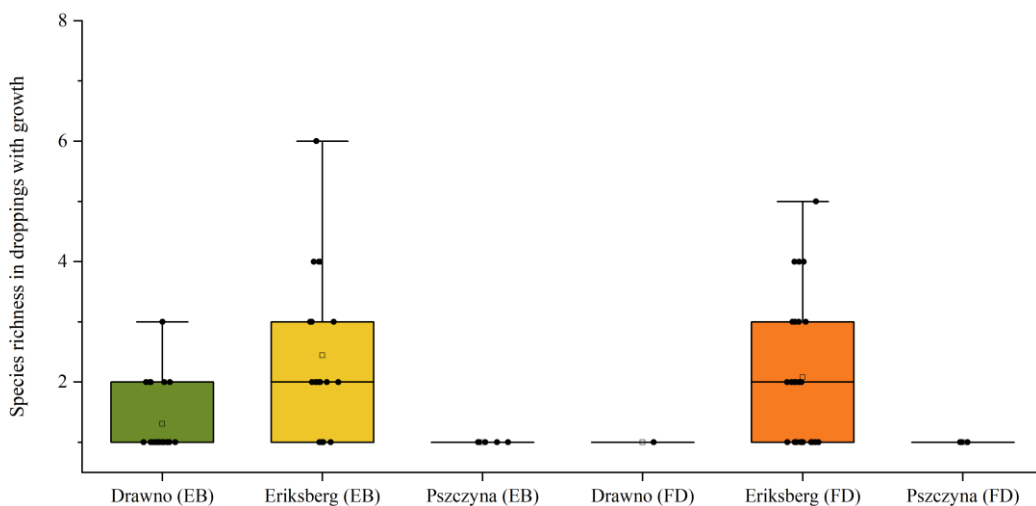
### 4.3 Seedling abundance and species richness in samples with growth

The number of seedlings in European bison stool samples with growth varied significantly among the three sites (Kruskal Wallis:  $H(2) = 10.17$ ,  $p = 0.006$ ) (Figure 7). Pszczyna stood for most of the overall difference, having the lowest median number of plants (1.0), while Drawno and Eriksberg had similar mean values (6.5 and 6.7). A significant difference in the number of seedlings was also found between fallow deer from Eriksberg and Pszczyna ( $H(1) = 6.79$ ,  $p = 0.009$ ), where Eriksberg fallow deer, similarly to European bison, had a higher mean number than Pszczyna (3.2 and 1.0 respectively), similarly to what was observed from the European bison. The single fallow deer sample from Drawno from which seeds germinated was excluded from the analysis as to not make chi-square approximation unreliable. A comparison between fallow deer and European bison samples from Eriksberg also indicated a significant difference ( $H(1) = 6.84$ ,  $p = 0.009$ ), whereby European bison had a twofold higher mean value than fallow deer. No significant difference was found between European bison and fallow deer in Pszczyna ( $p = 0.371$ ).



**Figure 7.** Total number of seedlings in stool samples with growth collected at all sites. EB = European bison, FD = fallow deer.

Captive European bison droppings from Eriksberg had the highest species richness with eleven different plants germinating and with up to six distinct species found in a singular sample (Figure 8). No significant difference in species richness between European bison and fallow deer samples from Eriksberg was found (H (1) = 0.85,  $p = 0.356$ ), samples from Pszczyna also showed no significant difference between the species ( $p = 1.000$ ). However, there was significant difference between all sites (Kruskal-Wallis: (H (2) = 14.31,  $p = 0.001$ ). Fallow deer samples from Pszczyna and Eriksberg also showed significant difference (H (1) = 4.53,  $p = 0.033$ ).



**Figure 8.** Total species richness in stool samples with growth collected at all sites. EB = European bison, FD = Fallow deer.

## 5. Discussion

### 5.1 Seed dispersal of European bison and fallow deer

Common species such as *Urtica dioica*, *Poa annua*, *Lolium perenne*, *Sagina procumbens* and *Plantago major* were abundant in both fallow deer and European bison droppings. Numerous studies on European bison, as well as wild boar and red deer, have identified *Urtica dioica* as the most frequently occurring species in their results, indicating that it is a commonly dispersed plant (Jaroszewicz *et al.*, 2009; Jaroszewicz *et al.*, 2013; Lepková *et al.*, 2018). *Urtica dioica* produces many seeds in summer and herbivores often graze it for its nutritional value, which explains the substantial number of seedlings found in droppings (Šrútek & Teckelmann, 1998; Adhikari *et al.*, 2016; Kowalczyk *et al.*, 2019).

European bison dispersed most seedlings and species across all sites. This was expected and can be explained by their wider diet, bigger body mass and foraging style (Hofmann, 1989). European bison graze less selectively, consuming larger patches of grass per bite rather than targeting individual plants like fallow deer (Hofmann, 1989). A mediterranean study on European bison and fallow deer showed a moderate overlap of summer diet between the two species (Fiella *et al.*, 2024). While both species showed overlaps in diet, fallow deer consumed more legumes and forbs whereas European bison seemed to have a larger graminoid intake (Fiella *et al.*, 2024). The findings of Fiella *et al.* (2024) support the results found in Eriksberg, where graminoids such as *Poa annua* and *Lolium perenne* were most abundant in European bison dung and *Plantago major*, a forb, most dominant in fallow deer droppings. Despite both species in Eriksberg sharing a similar diet with no significant difference in species richness, their distinct preferences further emphasize the influence of grazing strategies on seed dispersal outcome. Another factor to consider is the size of both animals. The larger body mass of the European bison allows higher food intake and consequently greater defecation volumes with more seeds present in the dung (Košnář & Rajnyšová, 2012; Eycott *et al.*, 2013).

In addition to dispersing the highest number of seeds, European bison samples also contained five unique plant species (Appendix 1). Although a smaller proportion of plants germinated in this study, Jaroszewicz *et al.* (2013) working with more taxa, reported finding 32 species exclusive to European bison dung compared to other ungulates in the polish Białowieża forest. The findings of this study seem to be following the same pattern, thus implying that plant dispersal in European forests has been greatly reduced since the disappearance of this species (Jaroszewicz *et al.*, 2013). While red deer and fallow deer seem to effectively

disperse many seeds across European forests, they lack the unique species dispersal that European bison provide (Jaroszewicz *et al.*, 2013).

### 5.1.1 Seed dispersal in different habitats

The highest species richness for both captive and wild European bison reported by Jaroszewicz *et al.* (2009) occurred between the end of August and the middle of November. Faecal sample collection for this study took place between 12<sup>th</sup>-25<sup>th</sup> of August which almost fits the given timeframe of peak species richness in droppings identified by Jaroszewicz *et al.* (2009). This suggests that the results are based on samples with potentially the highest species richness of the year. Even with this in mind, far fewer seedlings germinated in this study than reported in similar research (Jaroszewicz *et al.*, 2013; Lepková *et al.*, 2018). This outcome may be related to the availability of seed-bearing plants in the surrounding environment.

No vegetation inventory was done in this study, limiting the analysis of species occurring in the area of sample collection. Despite this, some conclusions can still be drawn from published literature and visual observations made during field work. Surrounding vegetation varied across all three sites (see Figure 1). Eriksberg: broad leaf forest with many clearings, Pszczyna: coniferous forest and Drawno: pine forest clearing, meadow and agricultural land.

Surprisingly, Eriksberg showed the highest species richness for both European bison and fallow deer in this study, despite the intense grazing pressure and high density of herbivores in the park. High grazing pressure often leads to less mature seeds remaining on plants which in turn reduces the probability of animals consuming them and dispersing them via endozoochory (Wang *et al.*, 2021). Studies such as Jaroszewicz *et al.* (2009) on European bison and Hermann (2025) on muskox (*Ovibos moschatus*), have reported greater seed dispersal by captive herbivores. Hermann (2025) attributed this to the superior species richness of forage available within muskox pens compared to the sparse diet of wild muskox on the tundra, whereas Jaroszewicz *et al.* (2009) argues that supplementary feeding is a leading factor.

Stool sample collection from wild European bison in this study took place in two different habitats, a pine forest clearing and meadow. Meadow samples showed a ten times greater seedling growth than those collected at the pine forest clearing. European bison are known to supplement their diet with trees and shrubs, of which Scots pine (*Pinus sylvestris*) can make up 9.7% (Kowalczyk *et al.*, 2011; Kowalczyk *et al.*, 2019). This could explain why so few seedlings germinated as European bison in that area could have been foraging primarily on young pine saplings, which typically lack dispersible seeds (Peltola *et al.*, 2025).

Similar conclusions could be drawn from the samples collected in Pszczyna where the forest habitat likewise is mostly composed of Scots pine (Borkowski & Obidziński, 2003). However, the diet composition of fallow deer in Pszczyna during autumn only consisted of 30% foliage from broadleaf and pine trees, with the remainder dominated by graminoids and forbs (Borkowski & Obidziński, 2003). This undermines the argument of a heavy browsing diet being the primarily cause of low seedling recruitment. Lastly, wild fallow deer droppings also grew very few seedlings, only one sample had a single *Urtica dioica* plant. Sample collection occurred at a harvested pea (*Pisum sativum*) field, suggesting that the collected droppings came from fallow deer that had fed on peas residues. Notably, no peas germinated from these droppings despite studies on cattle indicating that legumes such as peas often survive digestion (Deminicis *et al.*, 2020). A plausible explanation for this could be the advanced age and dryness of the droppings, likely leading to pre germination mortality or simply all peas getting crushed upon ingestion (Vignolio & Llobet, 2011).

## 5.2 Biodiversity benefits for fauna and flora

Large herbivores contribute significantly to biodiversity through their role in seed dispersal and their influence on vegetation structure (Kowalczyk *et al.*, 2021). In summer, European bison defecate approximately 7.5 times a day (Eycott *et al.*, 2013). In contrast, fallow deer defecate up to 20 times per day, but their droppings are considerably smaller, leaving less room for seeds (Košnář & Rajnyšová, 2012).

A study by D'hondt *et al.* (2012) proved that ungulates can disperse seeds in a way that is not random, often defecating in suitable habitats such as grasslands. This is highly relevant as dispersal relies on seeds reaching suitable locations for establishment and survival (Pakeman & Small, 2009). It remains unclear whether European bison or fallow deer exhibit similar dispersal patterns as no comparable studies have been done. However, it can be hypothesised that their habitat use and movement likewise influences dispersal patterns especially looking at their home ranges (Kraśńska *et al.*, 2000; Borkowski & Pudełko, 2007; Christensson, 2010; Lehto, 2015). European bison typically move over greater distances than fallow deer, increasing the potential for seeds to be transported both within and between habitats (Kraśńska *et al.*, 2000; Lehto, 2015). By moving, scraping and wallowing, large ungulates additionally disturb the soil surface, thus simultaneously creating gaps and allowing seeds to sprout but also trampling and destroying weeds (Warda & Rogalski, 2004). Ultimately, European bison appear to be more effective seed dispersers, reflected by the higher number of species and seedlings found in faecal samples, as well as their behaviour and foraging leaving a positive influence on dispersal outcomes.

*Urtica dioica*, the most frequently dispersed species in this study, exemplifies the ecological value that European bison bring. Although a common plant, it fulfils a critical ecological function by serving as food source and host for numerous insects, slugs and butterflies (Davis, 1975; Davis, 1989; Šrútek & Teckelmann, 1998). *Urtica dioica* often forms dense strands which can support numerous species even in isolated patches (Davis, 1975; Davis, 1989). *Plantago lanceolata*, which likewise germinated from droppings albeit in much lower numbers, has also been associated with hosting numerous insects (Nieminen & Vikberg, 2015). An inventory concluded by Nieminen and Vikberg (2015) suggested that several hundred species associate with the food web of *Plantago lanceolata*. This illustrates how herbivores drive cascading benefits, seed dispersal not only enhances plant recruitment but also supports numerous insects and animals within the food web of the plant (Nieminen & Vikberg, 2015).

Dispersal effectiveness becomes particularly relevant for vulnerable species. *Lythrum portula* a red listed species in Sweden, classified as Near Threatened by Artdatabanken (2026), germinated from both fallow deer and European bison droppings. The decline of *Lythrum portula* partly stems from the disappearance of grazers, resulting in shrub and tree overgrowth and habitats unsuitable for species dependent on open areas (Artdatabanken, 2026). In Europe, each year nearly one million hectares of land is completely abandoned by farmers, leading to a few species dominating the overgrown landscapes and overall loss of biodiversity (Helmer *et al.*, 2015; Schneider & Hering, 2024). Most wild European herbivores are browsers who are incapable of maintaining open grasslands due to primarily feeding on leaves and twigs (Hofmann, 1989). Intermediate feeders such as red deer, fallow deer and European bison alternate between grazing and browsing to varying degrees which can be beneficial and keep grass levels down (Valdés-Correcher *et al.*, 2018; Hartvig *et al.*, 2021; van der Spek, 2024). Mowing or grazing by domesticated livestock such as cattle and horses is a widely accepted solution to keeping vegetation down, yet rewilding with Europe's lost megafauna, the European bison, could also be a strategy worth considering for these purposes (Metera *et al.*, 2010; Valdés-Correcher *et al.*, 2018; Hartvig *et al.*, 2021).

### 5.3 Rewilding for a sustainable future

The increasing abandonment of land in Europe provides a historic opportunity to create more space for wild nature (Helmer *et al.*, 2015). One can argue that humans are ethically responsible for life on earth due to our ability to exterminate, preserve or support most other life forms (Thulin & Röcklinsberg, 2020). Through our activities, we have contributed to substantial environmental damage, and it is thus our responsibility to future generations of humans to preserve the diverse life on this planet (Thulin & Röcklinsberg, 2020). This study aimed to investigate the

seed dispersal of the European bison and fallow deer, with the goal to understand their contributions to biodiversity. The results can be used to argue that both species should be given a greater role in our ecosystems. The concept of rewilding has in recent years emerged as a strategy to restore ecosystems we have altered, by reintroducing species and allowing nature to become more self-sustaining (Perino *et al.*, 2019). These kinds of initiatives have the potential to significantly enhance biodiversity and not only benefit animals and plants but also us humans (Perino *et al.*, 2019).

Rewilding is often seen as an easier and more cost-efficient alternative to other restoration methods that require more human management (Wang *et al.*, 2023). With relatively low public investments, rewilded landscapes can benefit people in a plethora of ways (Svenning, 2020; Wang *et al.*, 2023). Nature can for instance improve mental wellbeing and support local communities by creating jobs through eco-tourism and hunting (Wang *et al.*, 2023). A global meta-analysis by Selwyn *et al.* (2025) showed that rewilding often also makes ecosystems more resilient to fires, droughts and invasive species. The positive impacts of rewilding are therefore not only important environmentally, but also socially and economically. We need natural resources and ecosystem services and for those to exist, healthy and functioning ecosystems are essential (Svenning, 2020).

Large herbivores are of high value for rewilding as they serve as ecosystem engineers by facilitating seed dispersal, nutrient cycling and trophic diversity (Ripple *et al.*, 2015). The results of this study and several other studies across Europe confirm this. Increase in plant species richness in forest habitats has been documented in Denmark after European bison reintroduction (Gottlieb *et al.*, 2024). In the Romanian Carpathians, reintroduced European bison have been estimated to substantially increase carbon capture through nutrient cycling, grazing and soil compaction (Ruzzuto *et al.*, 2024). Studies on how fallow deer impact the ecosystems they inhabit are scarce, but their grazing strategies still suggest that they play a key role (van der Spek, 2024).

In conclusion, rewilding can generate positive cascading effects that benefit both nature and humans (Perino *et al.*, 2019). As land abandonment continues across Europe, rewilding offers a unique opportunity to strengthen the relationship between us and nature (Helmer *et al.*, 2015). The action to restore ecosystems damaged by our activity can be viewed as a moral responsibility but it requires careful consideration (Thulin & Röcklinsberg, 2020). Land use conflicts, public acceptance and long-term management goals must be regarded (Perino *et al.*, 2019; Thulin & Röcklinsberg, 2020). If implemented responsibly, it can create a more

sustainable and stronger relationship between humans and nature (Perino *et al.*, 2019).

## 5.4 Discussion of the chosen literature and method

### 5.4.1 Method

The choice to study European bison and fallow deer, two intermediate grazers with overlapping diets, provided a balanced basis for comparison. The findings are less influenced by dietary variation and more likely to be a result of species-specific differences in digestion and foraging behaviour. A comparison between European bison or fallow deer and a browser such as roe deer or moose could still produce interesting results, albeit investigating the diet differences more than the forage behaviour differences.

Samples were collected in three distinctly different locations, providing a nuanced basis for analysis. Pszczyna, Drawno and Eriksberg have relatively few studies on European bison and fallow deer, particularly regarding their diet. Most studies on wild European bison are conducted in Białowieża forest, a distinctly unique and protected habitat (Jaroszewicz *et al.*, 2019). It was therefore valuable to study the wild population in Drawno, which receives much less attention. The habitat of Drawno also offers a more representative picture of typical Polish nature, unlike Białowieża, a forest with a highly unique environment (Jaroszewicz *et al.*, 2019). The downside of selecting less studied sites was the absence of published plant inventories which could have contributed to a more comprehensive understanding of the local vegetation as no flora inventories could be conducted on site due to time constraints. Conducting an independent inventory or utilizing published research would aid in interpreting the findings and identifying which dispersible species were truly available in the animal utilized habitats. Furthermore, inventories would help significantly in later seedling identification by providing a reliable reference for the species more probable to germinate.

Faecal samples for European bison and fallow deer were standardized by weight as closely as possible. The larger size of European bison dung was adjusted to match the size of an average fallow deer pile. This yielded relatively small sample volumes and enabled collection from more individuals which was beneficial as it provided more material for the analysis. However, both fresh and old faeces were collected, complicating the weight standardization due to their different moisture content. The size of the samples likely also impacted the results negatively as other studies on seed dispersal generated far greater growth with bigger samples (Jaroszewicz *et al.*, 2013; Lepková *et al.*, 2018). An additional challenge was distinguishing fallow deer droppings from those of other herbivores similar in size. Gryz *et al.* (2022)

describes it as very difficult and even though fallow deer were sighted on the sites of collection, some droppings might have come from other animals.

The cultivation approach had both advantages and disadvantages. Numerous seed dispersal studies let the samples dry before potting, often also separating the seeds from the faeces (Schulze *et al.*, 2014; Lepková *et al.*, 2018). This creates nearly ideal conditions for seeds to grow and increases seedling survival substantially (Lepková *et al.*, 2018). In this study, droppings were simply slightly crushed and mixed with the topsoil layer, closely mimicking natural conditions. This form of cultivation more accurately reflects the number of seeds capable of germinating from faeces in natural setting without artificial enhancements to survival rates. Seedlings were also not removed from pots upon identification, which may have diminished survival for still dormant seeds as the plants ended up blocking the light. Fungus gnats (*Sciaridae*) appeared in the greenhouse after a couple of weeks and their larvae may have damaged the roots of young plants, also contributing to reduced growth or plant mortality (Cloyd, 2015). Furthermore, a few young seedlings remained unidentified, due to an insufficient cultivation period. With all this in mind, it can be concluded that cultivation in this study more authentically represented the conditions under which plants germinate in the wild but in turn also generated less growth than other greenhouse studies (Jaroszewicz *et al.*, 2013; Lepková *et al.*, 2018)

Species were identified repeatedly in the greenhouse to ensure accuracy. Multiple methods and reliable websites as Ardatbanken (2026) were utilized. Numerous plants moreover developed distinctive traits which permitted confident identification. Nevertheless, certain species may have been misidentified, particularly grasses which are challenging to accurately distinguish between in their early developmental stages. The challenges associated with identifying certain species highlight the knowledge gaps created by omitting an inventory which could have provided critical contextual information.

## 5.4.2 Literature

This study was based on mostly peer-reviewed publications. Many of the sources in this study such as Eycott *et al.* (2007) and Jaroszewicz *et al.* (2013) have been cited in previous research on seed dispersal, which strengthens their reliability. Older sources as Krasieński (1967) and Putman (1988) were used to find information about the natural history of European bison and fallow deer. These sources were seen as reliable since descriptions of morphology and basic behaviour often remain unaffected by modern study methods. However, older publications on rapidly evolving topics as biodiversity loss and rewilding were mostly avoided and selected from the 2010s and onward. Old sources should not automatically be discredited as

they can bring a lot of nuance and points for discussion, though it is important to have in mind that a lot of information may have been updated since their publication and choose articles accordingly.

A lot of the used publications that investigated endozoochoric seed dispersal did not share similar sample sizes and used different units of measure which made comparisons between them more difficult. This was considered a weakness since it influenced the results substantially. For instance, Jaroszewicz *et al.* (2013) collected fresh faeces and used volume to measure sample size while Lepková *et al.* (2018) dried all samples and instead used mass. A source that was considered very valuable with providing nuance to the short time frame of sample collection performed in this study was provided by Jaroszewicz *et al.* (2009). This study investigated seed dispersal over the span of many months and contributed to a broader understanding of what seeds disperse outside of the most studied time frame of autumn and summer.

European studies on diet and seed dispersal were prioritized as this was where the sample collection was conducted. Articles such as Gottlieb *et al.* (2024), carried out in Denmark, provided valuable information about what European bison fed on in habitats more akin to Sweden. Another strength of this study besides the similarities in vegetation between Denmark and Sweden was the use of modern analytical methods which made it more reliable compared to older studies on diet such as Bruno and Apollonio (1991). Literature directly comparing the seed dispersal and diet of both the European bison and fallow deer was hard to come by. Filella *et al.* (2024) was one of the few studies that investigated the diet of both European bison and fallow deer in the same habitat. However, as data originated from a single study area, the results of Filella *et al.* (2024) may not be representative of other habitats. Furthermore, this study was carried out in Spain, in a landscape not remotely similar to that of Sweden or Poland and the animals were moreover given supplementary feed which may have altered their diet composition making this source less reliable. The lack of studies comparing both species within the same environment made direct comparisons more difficult and is considered one of the limitations of this study.

## 5.5 Future research

Most studies on the seed dispersal of European bison have been conducted in the Polish Białowieża forest, a unique ecosystem with high biodiversity and minimal human influence (Jaroszewicz *et al.*, 2019). One can argue that this unique habitat has an impact on the number of species and seedlings recorded in previous studies. Investigating other sites frequented by wild European bison would therefore

provide further knowledge on their seed dispersal effectiveness across habitat gradients.

Many seed dispersal studies focus on quantifying the number of seedlings and plant species that emerge from animal dung under controlled greenhouse conditions (Jaroszewicz *et al.*, 2013; Lepková *et al.*, 2018; Hermann, 2025). This approach identifies potential viable seeds but tends to overestimate dispersal success. In natural conditions, only a fraction of dispersed seeds successfully germinate and survive, meaning that optimal greenhouse conditions may not reflect the true ecological contribution of animal dispersers. More studies resembling Karimi *et al.* (2020), with research questions such as “How does seed survival differ between greenhouse and non-greenhouse conditions for seeds dispersed by animals?” should be done to better understand which plants truly establish in harsher conditions. Future research should also prioritize field studies akin to Jaroszewicz *et al.* (2008), which investigate plant recruitment directly on and around dung piles providing a much more accurate picture of dispersal effectiveness. “What plant species establish on undisturbed dung piles left by wild European bison and fallow deer?” would be an interesting research question to investigate.

Internal dispersal by ingestion is the most studied form of seed dispersal but external dispersal, epizoochory, by seed attachment to fur and entrapment under hoofs is equally significant. Plants overlooked by herbivores or deemed unpalatable can spread through attachment to fur and move over even greater distances than internally ingested seeds (Manzano & Malo, 2006; Liehrmann *et al.*, 2018). It would thus be insightful to study these research questions: “What seeds do European bison and fallow deer disperse through their fur?” and “How long can seeds stay attached to European bison and fallow deer fur?”.

Lastly, the ongoing debate surrounding the reintroduction of the European bison to Sweden underscores the need for more studies mapping out dietary preferences within Nordic ecosystems (Thulin *et al.*, 2023). Studies on the diet of captive European bison in Sweden could provide useful information for optimal release sites and refine management strategies.

## 6. Conclusion

The results of this study indicate that both European bison and fallow deer are capable of being efficient seed dispersers. Overall, European bison dispersed more seeds and species on all sites compared to fallow deer, suggesting that grazing strategies do influence dispersal outcome. European bison dispersed five unique species absent from fallow deer droppings, highlighting their irreplaceable role as dispersers. No definitive conclusions regarding captive versus wild populations could be drawn as the results appeared to be more influenced by site-specific conditions than management alone. As no flora inventories were conducted, knowledge of site-specific vegetation composition and its influence on seedling abundance remained highly limited. Although both species contribute to ecosystem functions, the unique dispersal profile of the European bison is particularly valuable for biodiversity restoration efforts.

# References

- Adhikari, B.M., Bajracharya, A. & Shrestha, A.K. 2016. Comparison of nutritional properties of Stinging nettle (*Urtica dioica*) flour with wheat and barley flours. *Food science & nutrition*, 4 (1), 119–124.
- Apollonio, M., Focardi, S., Toso, S. & Nacci, L. 1998. Habitat selection and group formation pattern of fallow deer *Dama dama* in a submediterranean environment. *Ecography* (Copenhagen), 21 (3), 225–234.
- Artdatabanken. 2026. <https://artportalen.se/> used: 2026-01-16
- Benge, S.E. 2002. Nutrient selection by fallow deer (*Dama dama*) and roe deer (*Capreolus capreolus*). Doctoral thesis, University of Southampton, England.
- Bergman, J., Pedersen, R.Ø., Lundgren, E.J., Lemoine, R.T., Monsarrat, S., Pearce, E.A., Schierup, M.H. & Svenning, J.-C. 2023. Worldwide Late Pleistocene and Early Holocene population declines in extant megafauna are associated with *Homo sapiens* expansion rather than climate change. *Nature communications*, 14 (1).
- Bijl, H. & Csányi, S. 2022. Fallow Deer (*Dama dama*) Population and Harvest Changes in Europe since the Early 1980s. *Mammal Status: Diversity, Abundance and Dynamics, Sustainability*, 14 (19), 12198.
- Bocherens, H., Hofman-Kamińska, E., Drucker, D.G., Schmölcke, U. & Kowalczyk, R. 2015. European Bison as a Refugee Species? Evidence from Isotopic Data on Early Holocene Bison and Other Large Herbivores in Northern Europe. *PloS one*, 10 (2).
- Borkowski, J. & Obidziński, A. 2003. The composition of the autumn and winter diets in two Polish populations of fallow deer. *Acta Theriologica*, 48(4), 539–546.
- Borkowski, J. & Pudelko, M. 2007. Forest habitat use and home-range size in radio-collared fallow deer. *Annales zoologici fennici*, 44(2), 107–114.
- Bruno E, Apollonio M. 1991. Seasonal variations in the diet of adult male fallow deer in a submediterranean coastal area. *Revue d'écologie, Terre et Vie*, 46(4), 349–362.
- Caboń-Raczyńska K., Krasieńska M., Krasieński Z. 1987. Rhythm and daily activity and behaviour of European bison in the Białowieża forest in the period without snow cover. *Acta Theriologica*, 32, 335–372.
- Cardinale, B. 2012. Impacts of Biodiversity Loss. *Science (American Association for the Advancement of Science)*, 336 (6081), 552–553.
- Cederlund, G. & Okarma, H. 1988. Home range and habitat use of adult female moose. *Journal of Wildlife Management*. 52, 336-343.
- Christensson, M. 2010. Despotic distribution in female fallow deer (*Dama dama*) groups. Master thesis, Swedish University of Agricultural Sciences, Sweden.
- Ciuti, S., Davini, S., Luccarini, S. & Apollonio, M. 2004. Could the Predation Risk Hypothesis Explain Large-Scale Spatial Sexual Segregation in Fallow Deer (*Dama dama*)? *Behavioural ecology and sociobiology*, 56 (6), 552–564.

- Cloyd, R.A. 2015. Ecology of Fungus Gnats (*Bradysia spp.*) in Greenhouse Production Systems Associated with Disease-Interactions and Alternative Management Strategies. *Insects*, 9;6(2), 325-32.
- Davis, B.N.K. 1975. The Colonization of Isolated Patches of Nettles (*Urtica dioica L.*) by Insects. *The Journal of applied ecology*, 12 (1), 1–14.
- Davis, B.N.K. 1989. The European distribution of insects on stinging nettles, *Urtica dioica L.*: A field survey. *Bollettino di zoologia*, 56 (4), 321–326.
- Deminicis, B. B., Vieira, H. D., de Carvalho Almeida, J. C., Valente, T. N. P., do Carmo Araujo, S. A., & Lima, R. V. 2020. Recovery and seeds germination of four important tropical forage legumes in bovine dung. *Australian Journal of Crop Science*, 14(1), 7–12.
- D'hondt, B., D'hondt, S., Bonte, D., Brys, R. & Hoffmann, M. 2012. A data-driven simulation of endozoochory by ungulates illustrates directed dispersal. *Ecological modelling*, 230, 114–122.
- European Environmental Agency. 2026. <https://www.eea.europa.eu/en/newsroom/news/extensive-grazing-essential-for-one-in-three-of-europes-protected-habitats>. used: 2026-05-16
- Eriksberg. 2026. <https://www.eriksberg.se/djuren-floran>, used 2026-01-01
- Esattore, B., Saggiomo, L., Sensi, M., Francia, V. & Cherin, M. 2022. Tell me what you eat and I'll tell you...where you live: an updated review of the worldwide distribution and foraging ecology of the fallow deer (*Dama dama*). *Mammalian biology: Zeitschrift für Säugetierkunde*, 102 (2), 321–338.
- Eycott, A.E., Watkinson, A.R., Hemami, M.-R. & Dolman, P.M. 2007. dispersal of vascular plants in a forest mosaic by a guild of mammalian herbivores. *Oecologia*, 154 (1), 107–118.
- Eycott, A., Daleszczyk, K. & Drese, J. 2013. Defecation rate in captive European bison, *Bison bonasus*. *Acta Theriol*, 58, 387–390.
- FACE. 2025. Ungulate Harvest Report 2025: Europes Ungulate Management in Numbers. European Federation for Hunting and Conservation.
- Feldhamer, G.A., Farris-Renner, K.C. & Barker, C.M. 1988. Mammalian Species. *The American Society of Mammalogists*, 317, 1-8.
- Ferretti, F., Sforzi, A. & Lovari, S. 2011. Behavioural interference between ungulate species: roe are not on velvet with fallow deer. *Behavioral ecology and sociobiology*, 65 (5), 875–887.
- Filella, J.B., Morán, F., Kemp, Y.J.M., Munir, H., Gort-Esteve, A. & Cassinello, J. 2024. Diet comparison between sympatric European bison, red deer and fallow deer in a Mediterranean landscape. *Biodiversity and conservation*, 33 (5), 1775–1791.
- Galetti, M., Moleón, M., Jordano, P., Pires, M.M., Guimarães, P.R., Pape, T., Nichols, E., Hansen, D., Olesen, J.M., Munk, M., Mattos, J.S., Schweiger, A.H., Owen-Smith, N., Johnson, C.N., Marquis, R.J. & Svenning, J. 2018. Ecological and evolutionary

- legacy of megafauna extinctions. *Biological reviews of the Cambridge Philosophical Society*, 93 (2), 845–862.
- Gottlieb, L., Schäfer, B.A. & Buttenschön, R.M. 2024. European bison (*Bison bonasus*) increase plant species richness in forest habitats. *Forest ecology and management*, 561.
- Gryz, J., Krauze-Gryz, D. & Klich, D. 2022. Alien or Native? How to Distinguish Feces of Fallow and Roe Deer Using Central Poland as a Case Study. *Animals (Basel)*, 12 (3), 290.
- Hartvig, I., Howe, A.G., Schmidt, E.N.B., Pertoldi, C., Nielsen, J.L. & Buttenschön, R.M. 2021. Diet of the European bison (*Bison bonasus*) in a forest habitat estimated by DNA barcoding. *Mammal research*, 66 (1), 123–136.
- Helmer, W., Saavedra, D., Sylvén, M. & Schepers, F. 2015. Rewilding Europe: A new strategy for an old continent. In: *Rewilding European Landscapes*. 171–190.
- Hermann, E. 2025. Seed dispersal of muskoxen (*Ovibos moschatus*) and semi-domesticated reindeer (*Rangifer tarandus tarandus*), in Sweden. Master thesis, Uppsala University, Sweden.
- Hofmann, R.R. 1989. Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia*, 78 (4), 443–457.
- Hofman-Kamińska, E. & Kowalczyk, R. 2012. Farm Crops Depredation by European Bison (*Bison bonasus*) in the Vicinity of Forest Habitats in Northeastern Poland. *Environmental management (New York)*, 50 (4), 530–541.
- Howe, H.F. & Smallwood, J. 1982. Ecology of Seed Dispersal. *Annual review of ecology and systematics*, 13 (1), 201–228.
- Jaroszewicz, B., Cholewińska, O., Gutowski, J. M., Samojlik, T., Zimny, M., & Latałowa, M. 2019. Białowieża Forest—A Relic of the High Naturalness of European Forests. *Forests*, 10(10), 849.
- Jaroszewicz, B., Pirożnikow, E. & Sagehorn, R. 2008. The European bison as seed dispersers: the effect on the species composition of a disturbed pine forest community. *Botany*, 86(5), 475-484.
- Jaroszewicz, B., Pirożnikow, E. & Sagehorn, R. 2009. Endozoochory by European bison (*Bison bonasus*) in Białowieża Primeval Forest across a management gradient. *Forest ecology and management*, 258 (1), 11–17.
- Jaroszewicz, B., Pirożnikow, E. & Sondej, I. 2013. Endozoochory by the guild of ungulates in Europe's primeval forest. *Forest ecology and management*, 305, 21–28.
- Karimi, S., Hemami, M.-R., Tarkesh Esfahani, M. & Baltzinger, C. 2020. Endozoochorous dispersal by herbivores and omnivores is mediated by germination conditions. *BMC ecology*, 20 (1).

- Košnář, A. & Rajnyšová, R. 2012. Assessment of a daily defecation rate of fallow deer upon a closed population study. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 60 (6), 173–180.
- Kowalczyk, R., Wójcik, J.M., Taberlet, P., Kamiński, T., Miquel, C., Valentini, A., Craine, J.M. & Coissac, E. 2019. Foraging plasticity allows a large herbivore to persist in a sheltering forest habitat: DNA metabarcoding diet analysis of the European bison. *Forest ecology and management*, 449 (2).
- Kowalczyk, R., Kamiński, T. & Borowik, T. 2021. Do large herbivores maintain open habitats in temperate forests? *Forest ecology and management*, 494.
- Krasińska, M., Krasiński, Z.A. & Bunevich, A.N. 2000. Factors affecting the variability in home range size and distribution in European bison in the Polish and Belarussian parts of the Białowieża Forest. *Acta Theriologica*, 45(3), 321–334.
- Krasiński, Z. 1967. Free living European bison. *Bisoniana XXIV. Acta Theriologica*, 12(28), 391-405.
- Lehto, C. 2015. Habitat selection of the European bison. Master thesis, Swedish University of Agricultural Sciences, Sweden.
- Leiva, M.J. & Fedriani, J.M. 2026. Spatial pattern of herbaceous seed dispersal by ungulates in grasslands of Doñana, SW Spain. *PloS one*, 21(3).
- Lepková, B., Horčíčková, E. & Vojta, J. 2018. Endozoochorous seed dispersal by free-ranging herbivores in an abandoned landscape. *Plant ecology*, 219 (9), 1127–1138.
- Liehrmann, O., Jegoux, F., Guilbert, M.A., Isselin-Nondedeu, F., Saïd, S., Locatelli, Y. & Baltzinger, C. 2018. Epizoochorous dispersal by ungulates depends on fur, grooming and social interactions. *Ecology and Evolution*, 8(3), 1582-1594.
- Länsstyrelsen Blekinge. 2018. <https://www.lansstyrelsen.se/blekinge/besoksmal/naturreservat/eriksberg.html?sv.target=12.382c024b1800285d5863a87c&sv.12.382c024b1800285d5863a87c.route=/&searchString=&counties=&municipalities=&reserveTypes=&natureTypes=&accessibility=&facilities=&sort=none>, used 2026-01-01
- Manzano, P. & Malo, J.E. 2006. Extreme Long-Distance Seed Dispersal via Sheep. *Frontiers in ecology and the environment*, 4 (5), 244–248.
- Metera, E., Sakowski, T., Sloniewski, K. & Romanowicz, B. 2010. Grazing as a tool to maintain biodiversity of grassland - a review. *Animal Science Papers and Reports*, 28(4), 315-334.
- Morse, B.W., McElroy, M.L. & Miller, K.V. 2009. Seasonal Diets of an Introduced Population of Fallow Deer on Little St. Simons Island, Georgia. *Southeastern naturalist (Steuben, Me.)*, 8 (4), 571–586.
- Nieminen, M. & Vikberg, V. 2015. The insect community of *Plantago lanceolata* spikes in the Åland islands, SW Finland. *Entomologica Fennica*, 26 (1), 30–52.
- Olech, W. & Perzanowski, K. 2002. A genetic background for reintroduction program of the European bison (*Bison bonasus*) in the Carpathians. *Biological conservation*, 108 (2).

- Pakeman, R.J. & Small, J.L. 2009. Potential and realised contribution of endozoochory to seedling establishment. *Basic and applied ecology*, 10 (7), 656–661.
- Pedersen, P.B.M., Olsen, J.B., Sandel, B. & Svenning, J.-C. 2019. Wild Steps in a semi-wild setting? Habitat selection and behavior of European bison reintroduced to an enclosure in an anthropogenic landscape. *PloS one*, 14 (11).
- Peltola, P., Pikkariainen, L., Hallikainen, V., Rautio, P. & Peltola, H. 2025. Natural regeneration and development of Scots pine seedlings in continuous cover forestry in northern Finland. *Forest ecology and management*, 593.
- Picard, M., Chevalier, R., Baltzinger, C. & Barrier, R. 2016. Functional traits of seeds dispersed through endozoochory by native forest ungulates. *Prinzinger, A. Journal of vegetation science*, 27 (5), 987–998.
- Pucek, Z. 2004. European bison: status survey and conservation action plan. (Eds. Belousova, I., Krasińska, M., Krasiński, Z. A. & Olech, W) 1st. ed Gland, Switzerland; Cambridge: IUCN/SSC Bison Specialist Group. ISBN 2831707625.
- Putman, R.J. 1988. *The Natural History of Deer*, Christopher Helm, Bromley.
- Putman, R., Langbein, J., Green, P. & Watson, P. 2011. Identifying threshold densities for wild deer in the UK above which negative impacts may occur. *Mammal review*, 41 (3), 175–196.
- Raczyński, J. 2025. *European Bison Pedigree Book 2024*. Białowieża National Park. pp.9.
- Rautiainen, H. 2017. Nutritional ecology of roe deer (*Capreolus capreolus L.*) and fallow deer (*Dama dama L.*): a case study of the browser - grazer dichotomy. Master thesis, Swedish University of Agricultural Sciences, Sweden.
- Rautiainen, H., Bergvall, U.A., Felton, A.M., Tigabu, M. & Kjellander, P. 2021. Nutritional niche separation between native roe deer and the nonnative fallow deer—a test of interspecific competition. *Mammal research*, 66 (3), 443–455.
- Retez, G., Oeser, J., Bluhm, H., Chistopolova, M., Hernandez-Blanco, J.A., Klich, D., Olech, W., Perzanowski, K., Pkhitikov, A., Kowalczyk, R., Quétier, F., Skorupski, J., Aldea, A., Borowik, T., Catanioiu, S., Grancea, A., Heidelberg, A., Iosif, R., Kamiński, T., Kibiša, A., Minaev, A.N., Paulauskas, A., Seyidova, Z., Sipko, T., Šimkevičius, K., Tracz, M., Tracz, M. & Kuemmerle, T. 2026. Habitat preferences of European bison in contemporary European landscapes. *The Journal of applied ecology*, 63 (1).
- Ripple, W.J., Newsome, T.M., Wolf, C., Dirzo, R., Everatt, K.T., Galetti, M., Hayward, M.W., Kerley, G.I.H., Levi, T., Lindsey, P.A., Macdonald, D.W., Malhi, Y., Painter, L.E., Sandom, C.J., Terborgh, J. & Van Valkenburgh, B. 2015. Collapse of the world’s largest herbivores. *Science advances*, 1 (4).
- Rogers, H.S., Donoso, I., Traveset, A. & Fricke, E.C. 2021. Cascading Impacts of Seed Disperser Loss on Plant Communities and Ecosystems. *Annual Review of Ecology, Evolution, and Systematics*, 52 (1), 641–666.

- Samojlik, T., Daszkiewicz, P., Fedotova, A., Ričkienė, A., Cielemecka, O. & Szczygielska, M. 2023. Evolution of European bison image and its implications for current species conservation. *PloS one*, 18 (1).
- Schneider, A.R. & Hering, D. 2024. Effects of extensive grazing and mowing compared to abandonment on the biodiversity of European grasslands: A meta-analysis. *Applied vegetation science*, 27 (4).
- Schulze, K.A., Buchwald, R. & Heinken, T. 2014. Epizoochory via the hooves - the European bison (*Bison bonasus* L.) as a dispersal agent of seeds in an open-forest-mosaic. *Tuexenia*, 34, 131-143.
- Schupp, E.W. & Fuentes, M. 1995. Spatial patterns of seed dispersal and the unification of plant population ecology. *Écoscience (Sainte-Foy)*, 2 (3), 267–275.
- Selwyn, M., Lázaro-González, A., Lloret, F., María Rey Benayas, J., Hampe, A., Brotons, L., Pino, J. & Espelta, J.M. 2025. Quantifying the impacts of rewilding on ecosystem resilience to disturbances: A global meta-analysis, *Journal of Environmental Management*, Volume 375, 124360.
- Śląskie.travel. 2025. <https://www.slaskie.travel/poi/3761/rezerwat-zubrowisko-w-jankowicach>, used 2025-12-31.
- Šrůtek, M. & Teckelmann M. 1998. Review of biology and ecology of *Urtica dioica*. *Preslia Praha*, 70, 1-19.
- Svenning, J.-C. 2020. Rewilding should be central to global restoration efforts. *One earth (Cambridge, Mass.)*, 3 (6), 657–660.
- Thulin, C.-G., Ausilio, G.M., Sannö, A., Niklasson, M., Kjellander, P. & Sveriges lantbruksuniversitet. 2023. Genomförbarhetsanalys av återintroduktion av visent (*Bison bonasus*) till Sverige. Swedish University of Agricultural Sciences, Sweden.
- Thulin, C.-G. & Röcklinsberg, H. 2020. Ethical Considerations for Wildlife Reintroductions and Rewilding. *Frontiers in veterinary science*, 7.
- Turner, M.G., Wu, Y., Romme, W.H. & Wallace, L.C. 1993. A landscape simulation model of winter foraging by ungulates. *Ecological modelling*, 69, 163-184.
- Trakhtenbrot, A., Nathan, R., Perry, G. & Richardson, D.M. 2005. The importance of long-distance dispersal in biodiversity conservation. *Diversity & distributions*, 11 (2), 173–181.
- Valdés-Correcher, E., Rodríguez, E., Kemp, Y.J.M., Wassen, M.J. & Cromsigt, J.P.G.M. 2018. Comparing the impact of a grazing regime with European bison versus one with free-ranging cattle on coastal dune vegetation in the Netherlands. *Mammal research*, 63 (4), 455–466.
- van der Spek, V. 2024. The impact of fallow deer (*Dama dama*) grazing on the biodiversity of a Dutch coastal dune system. *Lutra*, 67(1-2), 3-20.
- Vignolio, O.R. & Llobet, M. 2011. Lotus tenuis (Fabaceae) Seedling Emergence from the Soil Seed Bank Covered with Cattle Dung. *Annales botanici fennici*, 48 (1), 13–20.
- Wang, L., Pedersen, P.B.M. & Svenning, J.-C. 2023. Rewilding abandoned farmland has greater sustainability benefits than afforestation. *Npj Biodiversity*, 2 (1).

- Wang, S., Hu, A. & Hou, F. 2021. Effect of sheep grazing on seed circulation on the Loess Plateau. *Ecology and evolution*, 11 (23), 17323–17331.
- Warda, M., & Rogalski, M. 2004. Zwierzęta na pastwisku jako element krajobrazu przyrodniczego. *Agronomy Science*, 59 (4).
- Wójtowicz, E. 2021. <https://www.gov.pl/web/nadlesnictwo-kobior/ochrona-przyrody>, used 2025-12-31
- WWF. 2024. Living Planet Report 2024. World Wide Fund for Nature.
- Zidon, R., Leschner, H., Motro, U. & Saltz, D. 2016. Endozoochory by the Persian fallow deer (*Dama mesopotamica*) reintroduced in Israel: species richness and germination success. *Israel journal of ecology & evolution*, 63 (1), 28–34.
- Zielke, L., Wrage-Mönnig, N. & Müller, J. 2017. Seasonal preferences in diet selection of semi-free ranging European bison (*Bison bonasus*). *European Bison Conservation Newsletter*, 10, 61-70.
- Żmijewski, T., Modzelewska-Kapituła, M., Pomianowski, J. & Ziomek, A. 2020. Farmed-raised fallow deer (*Dama dama L.*) carcass characteristics and meat nutritional value. *Journal of food science and technology*, 57 (9), 3211–3220.

# Popular science summary

Biodiversity loss, otherwise known as the alarming decline in the variety of life on earth, is happening faster than many of us realize. The number of wild herbivores that once roamed freely across all of Europe has substantially dropped. Animals that in the past helped to keep down grass levels and transported seeds over great distances are now less numerous which is a great threat to plant communities already challenged by climate change. Many plants rely on animals to disperse their seeds by ingestion, so called endozoochoric seed dispersal. The seeds are consumed and travel through the digestive tract before the animal defecates. Seedlings then germinate from the dung and due to the constant movement of the animal have likely dispersed successfully to another habitat.

The aim of this study was to investigate the seed dispersal and potential impacts on biodiversity by the European bison and fallow deer, two species that share roughly the same diet but differ in how they graze and forage vegetation. This study also aimed to investigate if there were any significant differences in seed dispersal between both species as well as differences between wild and captive populations. Faecal samples were collected from wild populations in Poland and two fenced populations in both Sweden and Poland respectively. The faecal samples were then cultivated in a greenhouse where all the seedlings that emerged were counted and identified.

The result of this study shows that both European bison and fallow deer can disperse seeds successfully and contribute to biodiversity. European bison was however a more successful disperser than fallow deer and the findings of this study thus suggest that grazing strategies may influence dispersal outcome. Moreover, European bison also dispersed five unique species of plants not found in any fallow deer droppings which highlights the irreplaceable role they play as dispersers. No definitive conclusions regarding captive versus wild populations could be drawn as the results appeared to be more influenced by site-specific conditions than management alone.

This study highlights how important big herbivores are for seed dispersal and promoting biodiversity. Due to the increasing abandonment of land in Europe a historic opportunity to create more space for wild nature has arisen. Reintroducing and restoring populations of large herbivores such as fallow deer and European bison could help build environments that can withstand the challenges of climate change better.

# Appendix 1

The total number of dispersed species on all sites. Species marked in bold are unique to European bison.

Species	European bison	Fallow deer	Total
<i>Sagina procumbens</i>	17	8	25
<i>Spergularia rubra</i>	3	2	5
<b><i>Galium aparine</i></b>	1	0	1
<i>Capsella bursa-pastoris</i>	5	3	8
<i>Urtica dioica</i>	138	4	142
<i>Plantago major</i>	15	27	42
<i>Stellaria media</i>	1	2	3
<b><i>Plantago lanceolata</i></b>	2	0	2
<i>Poa annua</i>	50	14	64
<i>Rumex acetosella</i>	1	2	3
<i>Lolium perenne</i>	32	17	49
<b><i>Sisymbrium officinale</i></b>	1	0	1
<b><i>Cerastium fontanum</i></b>	1	0	1
<i>Lythrum portula</i>	3	3	6
<b><i>Veronica chamaedrys</i></b>	1	0	1
<i>Unidentified</i>	4	2	6

The total number of dispersed species from faecal samples collected in Drawno.

Species	European bison	Fallow deer	Total
<i>Urtica dioica</i>	138	1	139
<i>Lolium perenne</i>	4	0	4
<i>Galium aparine</i>	1	0	1
<i>Plantago major</i>	1	0	1
<i>Rumex acetosella</i>	1	0	1
<i>Lythrum portula</i>	1	0	1
<i>Veronica chamaedrys</i>	1	0	1
<i>Unidentified</i>	2	0	2

The total number of dispersed species from faecal samples collected in Pszczyna.

Species	European bison	Fallow deer	Total
<i>Sagina procumbens</i>	4	0	4
<i>Plantago major</i>	1	0	1
<i>Sisymbrium officinale</i>	1	0	1
<i>Lolium perenne</i>	0	2	2
<i>Capsella bursa-pastoris</i>	0	1	1
Unidentified	0	2	2

The total number of dispersed species from faecal samples collected in Eriksberg.

Species	European bison	Fallow deer	Total
<i>Poa annua</i>	50	14	64
<i>Lolium perenne</i>	28	15	43
<i>Sagina procumbens</i>	13	11	24
<i>Plantago major</i>	13	27	40
<i>Capsella bursa-pastoris</i>	5	2	7
<i>Spergularia rubra</i>	3	2	5
<i>Plantago lanceolata</i>	2	0	2
<i>Lythrum portula</i>	2	3	5
<i>Stellaria media</i>	1	2	3
<i>Cerastium fontanum</i>	1	0	1
<i>Rumex acetosella</i>	0	2	2
<i>Urtica dioica</i>	0	3	3
Unidentified	2	0	2

# Thank you

Firstly, I would like to thank my supervisor, Carl-Gustaf Thulin for making this thesis happen and accompanying me to do field work. Without him this project would have stayed as an idea in my head, and I am eternally grateful for the opportunity he has given me. I would also like to thank my co-supervisors, Petter Kjellander, for all his suggestions and guidance and Wanda Olech, for the incredibly valuable contacts that made the field work possible. A huge thank you to everyone who helped with the sample collection in Drawno and many thanks to Eriksberg and Żubrowisko for opening their doors and allowing sample collection from their animals.

Finally, I would also like to thank my family and friends for always being there and supporting me through this whole journey.

## Publishing and archiving

Approved students' theses at SLU can be published online. As a student you own the copyright to your work and in such cases, you need to approve the publication. In connection with your approval of publication, SLU will process your personal data (name) to make the work searchable on the internet. You can revoke your consent at any time by contacting the library.

Even if you choose not to publish the work or if you revoke your approval, the thesis will be archived digitally according to archive legislation.

You will find links to SLU's publication agreement and SLU's processing of personal data and your rights on this page:

- <https://libanswers.slu.se/en/faq/228318>

YES, I, Alicja Bogdalska Postrozny, have read and agree to the agreement for publication and the personal data processing that takes place in connection with this

NO, I/we do not give my/our permission to publish the full text of this work. However, the work will be uploaded for archiving and the metadata and summary will be visible and searchable.