Feasibility of Reintroduction of European Bison (*Bison Bonasus*) to Sweden

with Focus on Traffic Accidents

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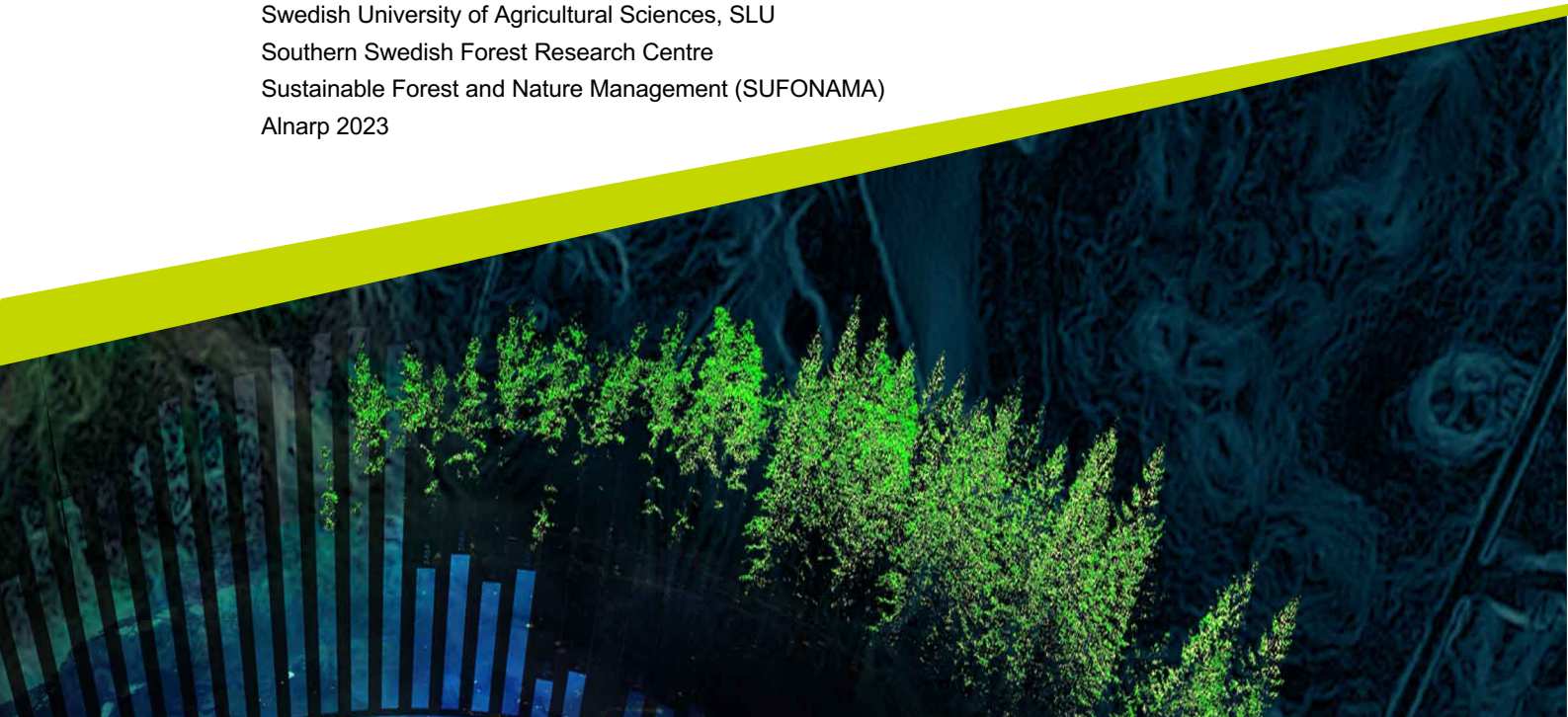

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Abstract

The historical occurrence of European bison (*Bison bonasus*) in Sweden during the early Holocene emphasizes the ecological significance for a potential reintroduction. The European bison, the largest herbivore on the European continent, is a keystone species with a significant influence on ecosystem dynamics. To restore populations of European bison is an important conservation concern Road collisions with wild animals are a significant problem on a global scale and an important aspect to consider when large terrestrial mammal populations are restored. This study aims to assess the relative involvement in traffic incidences of European bison and moose (*Alces alces*) in Poland, where both species occur in the wild. Accidents involving European bison were analyzed and compared with those involving moose during 2014-2022. Four regions were defined and analyzed: Lublin and Subcarpathian provinces; Podlaskie province; Warmian-Masurian province; and Northwest region comprising Lubuskie, Wielkopolskie, and Zachodnipomorskie provinces. The results revealed substantial variations in accident ratios between European bison and moose in different regions. In the Lublin and Subcarpathian regions a significant difference was observed ($p = 0.02$). The Podlaskie region demonstrated the most pronounced disparity ($p < 0.001$). In the Warmian-Masurian region, significant differences were again observed ($p = 0.003$). Conversely, in the Northwest region, no significant difference was found. Overall, the combined analysis across all regions also indicated a highly significant difference ($p < 0.001$). The overall average accident rate per 100 European bison was 0.49, while for moose it was 1.03. This suggests that moose had a 2.12 times higher accident rate compared to European bison. Additionally, European bison traffic collisions generally result in less severe outcomes compared to moose and other animals, typically causing no fatalities or only minor injuries to drivers and passengers. Considering the relatively low frequency and severity of the traffic collisions, European bison reintroduction efforts may face fewer traffic-related challenges than moose. European bison have demonstrated adaptability across varied landscapes including open areas, forests, and their transitional zones, all of which can be found in southern Sweden. As a generalist grazing species, the dietary requirements of European bison align with available food resources. Climate compatibility is affirmed, as historical and current distribution ranges of European bison encompass regions with more severe climates than southern Sweden. Along with the relatively low risk for traffic incidents as observed in this study, this underline the potential success of reintroducing European bison to the region. Nevertheless, it is important to effectively manage potential conflicts between humans and wildlife. It is advisable to engage in subsequent monitoring and research to gain a better understanding of these challenges during the implementation of reintroduction efforts in a new area.

Keywords: Wildlife-vehicle collision, Risk prediction, Reintroduction feasibility, European bison, *Bison bonasus*, Moose, *Alces alces,* Human-wildlife conflict

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1. Introduction

The European bison (*Bison bonasus*) is the largest herbivore on the European continent and as such, it has the potential to play an important role as a keystone species in ecosystems, including forests, semi-open, and open nature types (Kerley et al., 2012; Pucek et al., 2004). In the past, this animal was widely distributed across Europe, but due to overhunting and habitat destruction, the species became extinct in the wild in the early 20th century (Pucek et al., 2004). However, the European bison has been successfully reintroduced to several European nations thanks to a captive breeding effort (Krasińska & Krasiński, 2013). Its former range includes southern Sweden (Kuemmerle et al., 2012a; Benecke, 2005; Pucek et al., 2004; Liljegren & Ekström, 1996) and there are ongoing discussions about reintroduction. No practical reintroduction project has been initiated at this point.

Reintroducing European bison to southern Sweden is a crucial conservation step that might help the animal return to its previous range and enhance the area's ecology. The reintroduction is expected to have several positive effects on society as well, including educational benefits and tourism.

Traffic accidents involving wildlife are a major concern worldwide, and Sweden is not an exception to this issue. This study examines European bison accidents in Poland in detail. In order to investigate their impact they are compared to accidents involving moose (*Alces alces*). The relative incidence of moose and European bison is used to estimate what could the potential traffic accident rate be in Sweden after the reintroduction.

Additionally, this paper addresses the ecological feasibility of reintroducing European bison to southern Sweden based on climatic conditions, habitat requirements, and other anthropogenic components.

2. Materials and Methods

2.1 Overall Approach

This study was divided into two main sections: An examination of traffic accidents involving European bison in Poland, and an assessment of a potential number of incidents with European if reintroduced to southern Sweden. The study combined the collection of empirical data with literature analysis to thoroughly assess the plausability of reintroducing European bison in southern Sweden. The analysis of traffic accident data revealed information about what may be the most important aspect of human conflict, and the comparison and analysis of ecological requirements provided a thorough understanding of the viability of reintroduction in southern Sweden.

2.2 Analysis of Traffic Accidents Involving European Bison in Poland

Data Collection

Through correspondence with managers involved in wildlife conservation, governmental organizations, and local law enforcement, accident data involving European bison and moose in Poland were gathered (Table 2, Table 4). The information covered the years 2014 through 2022. Accidents were grouped according to the province they took place in and the corresponding year.

Data Compilation

Gathered data was compiled into unified dataset. The dataset listed the province, the year, and the total number of accidents involving European bison for each entry. European bison accidents were compared with the frequency of accidents with moose in each year and province. All the provinces with wild populations were included in the study (Figure 1). They include Lublin, Lubusz, Subcarpathian, Podlaskie, Warmian-Masurian, Greater Poland and West Pomeranian. Due to the low numbers of European bison in Lublin, it was merged with Subcarpathian province. Data from provinces of Lubusz, Greater Poland, and West Pomeranian were grouped into the Northwest region as the population of European bison in that region is managed together and data such as the number of individuals is provided only for the entire population.

Figure 1. Provinces of Poland included in the study due to the presence of European bison

Statistical Analysis

The statistical analysis employed in this study aimed to compare the ratio of traffic accidents per 100 animals between European bison and moose in selected provinces of Poland from the years 2014 to 2022. Regional population densities were obtained from the European Bison Pedigree Book for European bison, and the Statistical Yearbook of Forestry for moose (Raczyński, 2022; Statistical Yearbook of Forestry 2022). PAST statistical software (Hammer & Harper, 2001) was used fot data analysis. According to the Shapiro-Wilk test of normality, data significantly deviate from a normal distribution. The non-parametric nature of the data and the requirement to evaluate differences between two independent groups guided the choice of statistical method. The chi-squared (χ^2) test was used to assess the difference in accident ratios between European bison and moose in individual regions as well as across all regions. The dataset was divided into two categories: years with a high accident ratio and those with a low accident ratio. Due to the lack of a normal distribution and the presence of skewed data due to a large number of zeros, the median value was chosen as the point of division between the two groups. This choice was made as the median ensures a balanced partition between the two categories, offering a representative division of the data.

Data Visualization

In order to enable a more comprehensive understanding of the dynamics between traffic accidents and the two species a visual representation is made. Graphs illustrate the changes in accident ratios within specific regions and the overall average ratio from 2014 to 2022.

2.3 Literature Review of European Bison Requirements and Conditions in Southern Sweden

Literature Review

A comprehensive review of the available literature was done to learn more about the habitat and climatic needs of the European bison. The ecological preferences of the species, including climate, diet, and habitats, have been the subject of studies and reports that have been gathered and reviewed. To identify potential difficulties in a reintroduction context, literature addressing human-wildlife conflict involving European bison was also looked at.

Comparison with Southern Sweden Conditions

The habitat and climate of southern Sweden were evaluated using the meteorological data, and historical and ecological reports that were available. To assess whether the area would be suitable for the reintroduction of European bison,

literature regarding ecological requirements along with the environmental conditions in southern Sweden are discussed.

Validity and Reliability
By comparing data from various sources and relying on peer-reviewed literature, efforts were made to ensure the validity and reliability of the study. The high quantity of scientific sources used further strengthens the review.

3. Results and Discussion

3.1 Data Compilation

The number of European bison and moose and accidents involving those animals in selected regions of Poland between the years 2014 and 2022 are presented in Tables 1, 2, 3, and Table 4, 5 and Table 6 consequently present the ratio of accidents with European bison and moose. It was found that the average number of accidents per 100 European bison was 0.49, compared to 1.03 for moose. This information demonstrates that during the study period, moose experienced an accident rate per 100 animals that was 2.12 times higher than that of European bison.

Table 1. Number of European bison between 2014 and 2022 in selected regions of Poland.

European Bison Population									
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Lublin and Subcarpathian	301	344	402	487	551	668	707	738	759
Podlaskie	645	712	740	812	685	963	946	1011	1150
Warmian-Masurian	105	107	108	120	158	184	117	134	136
Northwest Region	159	184	205	216	265	305	334	340	349
Total	1210	1347	1455	1635	1659	2120	2104	2223	2394

Table 2. Number of accidents involving European bison between 2014 and 2022 in selected regions of Poland

European Bison Accidents									
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Lublin and Subcarpathian	0	0	0	0	0	0	0	0	1
Podlaskie	1	0	0	0	2	3	3	8	1
Warmian-Masurian	0	0	0	0	0	0	0	0	0
Northwest Region	2	3	5	8	2	3	7	8	1
Total	3	3	5	8	4	6	10	16	3

Table 3. Number of moose between 2014 and 2022 in selected regions of Poland.

Moose Population									
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Lublin and Subcarpathian	3111	4422	4549	4642	4909	5679	6387	6857	7603
Podlaskie	4378	4782	4961	5080	5260	5514	6429	6505	6256
Warmian-Masurian	3742	4285	4958	5390	5878	6711	8685	7943	8261
Northwest Region	173	230	256	275	303	447	463	559	606
Total	11404	13719	14724	15387	16350	18351	21964	21864	22726

Table 4. Number of accidents involving moose between 2014 and 2022 in selected regions of Poland.

Moose Accidents									
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Lublin and Subcarpathian	17	10	30	40	32	23	28	29	38
Podlaskie	34	35	49	49	65	65	33	54	46
Warmian-Masurian	30	49	43	26	31	59	51	38	48
Northwest Region	3	5	8	10	4	12	6	9	4
Total	84	99	130	125	132	159	118	130	136

Table 5. The ratio of accidents with European bison per 100 animals in select regions of Poland between 2014 and 2022. Due to the low numbers of European bison in Lublin, it was merged with Subcarpathian province. Data from the provinces of Lubuskie, Wielkopolskie, and Zachodnipomorskie were combined because the European bison population in those areas is managed jointly.

Accident Number Per 100 European Bisons										
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Average**
Lublin and Subcarpathian	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01
Podlaskie	0.16	0.00	0.00	0.00	0.29	0.31	0.32	0.79	0.09	0.22
Warmian-Masurian	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northwest Region	1.26	1.63	2.44	3.70	0.75	0.98	2.10	2.35	0.29	1.72
Total	0.25	0.22	0.34	0.49	0.24	0.28	0.48	0.72	0.13	0.49

Table 6. The ratio of accidents with Moose per 100 animals in select regions of Poland between 2014 and 2022. Due to the low numbers of European bison in Lublin, it was merged with Subcarpathian province. Data from the provinces of Lubuskie, Wielkopolskie, and Zachodnipomorskie were combined because the European bison population in those areas is managed jointly.

Accident Number Per 100 Moose										
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Average**
Lublin and Subcarpathian	0.55	0.23	0.66	0.86	0.65	0.41	0.44	0.42	0.50	0.52
Podlaskie	0.78	0.73	0.99	0.96	1.24	1.18	0.51	0.83	0.74	0.88
Warmian-Masurian	0.80	1.14	0.87	0.48	0.53	0.88	0.59	0.48	0.58	0.71
Northwest Region	1.73	2.17	3.13	3.64	1.32	2.68	1.30	1.61	0.66	2.03
Total	0.74	0.72	0.88	0.81	0.81	0.87	0.54	0.59	0.60	1.03

3.2 Statistical Analysis

The results of the chi-squared (χ^2) test:

In the Lublin and Subcarpathian regions, the chi-squared test indicated a statistically significant difference in the ratio of accidents between European bison and moose ($\chi2 = 5.1429$; df = 1; $p = 0.02$).

The Podlaskie region exhibited the most pronounced difference, with a highly significant p-value ($\chi2 = 14.4$; df = 1; $p < 0.001$), indicating a substantial variation in accident ratios between European bison and moose.

In the Warmian-Masurian region, the test showed a significant difference in accident ratios between the species ($\chi2 = 9$; df = 1; $p = 0.003$).

In the Northwest region, the p-value was not highly significant ($\chi2 = 1.0588$; df = 1; $p = 0.303$), suggesting no statistically significant difference in accident ratios between the two species.

When combining all regions for the total analysis, a very low p-value was obtained ($\chi2 = 20.071$; df = 1; $p < 0.001$), strongly suggesting a substantial statistical difference in accident ratios between the two species.

3.3 Data Visualization

The data from Table 5 and Table 6 is presented through separate graphs for each region, along with graphs depicting the total and average values (Figure 2).

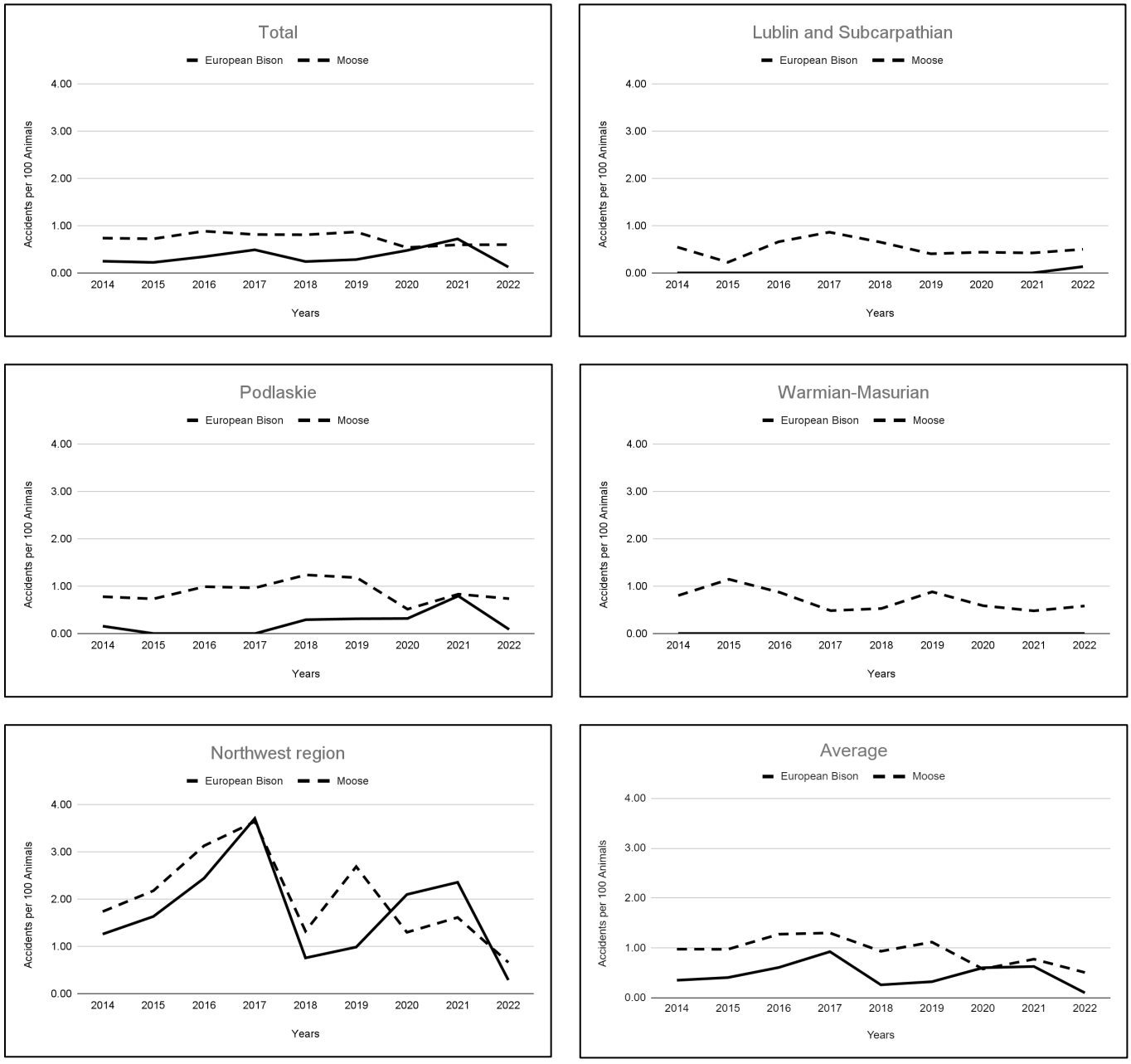

Figure 2. Changes in Accident Ratios (2014-2022). This figure presents a visual overview of the changing accident ratios involving European bison and moose in different regions over the period of 2014 to 2022. The subfigures depict the alterations in accident ratios for each species within specific regions, while the average graph provides a comprehensive representation of the overall trends during the study period.

3.4 Traffic Accidents

The analysis results indicate that European bison in Poland exhibit a notably lower accident ratio compared to moose, and this ratio can be further compared with incidents of moose collisions in Sweden. According to police reports the annual number of traffic collisions with moose in Sweden averages around 4500 incidents (Seiler, 2005), and upper estimates of the population number reach 400 000 individuals (Roth et al., 2016). This estimates 1.125 accidents per 100 moose in Sweden which is slightly higher than in the region of Poland included in this study. If we were to anticipate that the European bison collision ratio in Sweden would be equivalent to that in Poland in the future, which is 2.12 times less likely, the anticipated number of accidents would be 0.53 per 100 animals. However, the number of accidents post-reintroduction could be much lower as accidents in the northwest population territory skew the data significantly as the accidents are much more frequent there, and it is the only region where they do not deviate from the ratio of moose accidents. Considering that the initially reintroduced population is relatively small we could expect to see a very low number of accidents similar to that of the populations in eastern Poland. Furthermore, the moose population in Sweden has followed a declining trend in recent years (Kalén et al., 2022), which could lead to a decrease in collisions with those animals. Therefore, during the potential future reintroduction of European bison, the overall number of wildlife traffic accidents might be even lower compared to previous years. This could be further reinforced by proper choice of location and management by for instance reducing the moose population locally. With such action overall number of wildlife traffic accidents would be reduced, thus increasing the general road safety of the region.

In Polish populations of European bison, the birth rate ranged from 16.6% to as high as 27%. In contrast, the mortality rate remained relatively low, fluctuating between 1.2% and 2.2% (GIOŚ, 2008). Traffic accidents accounted for a negligible fraction of the overall mortality, suggesting that their impact on the health and growth of the population should be insignificant. In Poland, the number of free-roaming European bison is more than 2000, they are involved in about six annual traffic accidents. Thus, accidents are relatively rare, with some provinces experiencing no traffic collisions at all despite having numerous populations for many years, and the Northwest region is an outlier in that matter, with many more accidents, and a ratio not significantly deviating from moose collisions. There could be several reasons why traffic collisions are more frequent there. Perhaps the main one is the difference in habitat availability and density of people and traffic frequency which is higher than in eastern Poland. The hotspot for accidents with European bison is road no DK10. It is a high-speed road crossing the territory of the Miroslawiec herd (part of northwest populations), and although accidents are more frequent there, there were no casualties to people and injuries are minor,

although damage to the vehicle was quite severe in several cases (Dzika Zagroda, 2019). The reason for the high number of accidents is probably the fact that this road contains a straight stretch with high traffic of cars and trucks where drivers often exceed the speed limit and there is no wildlife passage (Lizoń, 2014). Despite road accidents being the main cause of mortality in the local herd, they still pose no threat to the population (Lizoń, 2014). In order to mitigate the risk of traffic collisions, preventive measures have been carried out in recent years, such as splitting the population into smaller groups, moving winter feeding stations away from the roads, and active management through the application of GPS collars and interventions (Grzegorzek, 2012; M. Tracz, personal communication, 2023).

Upon investigation, the problem of accidents in European countries is even smaller. The mortality of European bison in Lithuania for recorded years due to car accidents is only around 1% and poses no threat to the local population of bison (Balčiauskas, 2012). In Spain, Romania, and Bulgaria there are no recorded traffic collisions (F. Moran, M. Druga, A. Trifonova, personal communication, 2023). In Belarus, which is the second country when it comes to the number of European bison, there have been 4 accidents since 2018 (V. Shakun, personal communication, 2023). There is no information on lethal or even severe injuries to people in those countries.

European bison traffic collisions typically are substantially less severe compared to moose and other animals and have not so far resulted in the death of drivers and passengers. While the vehicles frequently sustain significant damage and the animals frequently suffer serious injuries or fatalities, people have typically not been hurt or only receive minor injuries in these accidents. A most serious incident involving European bison in Poland took place in the province of Podlaskie when a motorbike collided with a bison, sending the bike flying over the animal and into the road, causing serious injuries that required hospitalization. Comparatively, moose-related accidents are more severe, often causing serious injuries or even fatalities to people. This discrepancy may result from the two species' dissimilar body types and weight distributions. The upper portion of vehicles, where the heads of the passengers are located, are frequently hit by the main force of collisions with moose, posing a serious risk to life and health (Lavsund & Sandegren, 1991). This is demonstrated in Sweden, where over the past 20 years, 10 to 15 fatalities on average resulted from moose-vehicle collisions, with about one in ten moose-vehicle collisions injuring passengers (Seiler, 2005). A lower accident rate along with the fact that European bison accidents are much less dangerous, suggests that road safety should not be a major obstacle in reintroducti on efforts.

Similarly, accidents are less dangerous in the case of American bison (*Bison bison*), the North American relative of European bison. According to Conover (2019), no people die in vehicle collisions with bison, while collisions with other wildlife are estimated to result in around 450 deaths annually. Perhaps the

difference in the severity of traffic accidents with bison and other wildlife such as moose and deer is a result of differences in body type, height, and behavior of those animals. That bison is a social animal and lives in herds, presumably making it more visible, may also play a role.

Despite the very low risk of dangerous and lethal accidents, preventive measures should be carried out in order to minimize the risk of traffic accidents and related conflicts. Installing wildlife crossings, such as bridges or tunnels, to assist animals in safely crossing roadways is one of the most efficient strategies to decrease roadkill. To warn cars of the presence of European bison and other animals, additional signs, and reflectors can also be erected beside highways. It is crucial to inform drivers about posted speed restrictions in locations where they are likely to be present. Planting selected native vegetation can help make wildlife more visible next to roadways, and fence and barrier systems can be put in place beside roads to prevent bison from entering. Finally, promoting modern cars with safety systems like lane keep assist, adaptive cruise control, and blind spot monitoring can help reduce the number of collisions with wildlife through features such as collision warning, and autonomous braking (Ziebinski et al., 2017).

In this study, data was gathered from various sources. In cases of inconsistency among different sources in numbers for accidents for the same region and year, a higher number of accidents was used. Omitting a data point is more likely than overreporting given the nature of the data, thus this approach reduces the chance of an error. There is a chance that inaccurate accident reporting will result in underreporting or misclassification of incidents. Additionally, seasonal variations in animal movement and behavior, which can affect accident rates, have not been taken into account in the study. Furthermore, the accident rate could also be significantly influenced by external factors such as weather conditions, road visibility, traffic intensity, and speed. Furthermore, the study might not have taken into account possible variations in how moose and European bison behave and react to roads. Comparison of accident rates alone, may not accurately reflect the complex interplay of factors that contribute to accidents, such as human presence, road design, spread, and densities of populations of European bison and moose.

3.5 Other Concerns Regarding Anthropogenic Conflict

3.5.1 Land Damages

Concerning conflicts with people, particularly on arable land, land ownership emerges as a substantial challenge (Hofman-Kamińska & Kowalczyk, 2012; van de Vlasakker, 2014). Damage to crops can be attributed to European bison, with wheat, hay, and rape being the most susceptible (Hofman-Kamińska & Kowalczyk, 2012; van de Vlasakker, 2014). Overpopulation of European bison can

lead to significant crop damage, reflecting carrying capacity issues (Sobczuk & Olech, 2016). Reintroduction planning should avoid areas with intense farming (Klich et al., 2018), favoring larger, natural, state-owned territories like protected areas (van de Vlasakker, 2014).

Damages to the forest can also lead to conflict with the landowners. Forests suffer from bark stripping, fostering rot due to fungal infection (Paszkiewicz & Januszczak, 2010). Bison's impact on young trees and shrubs can severely damage regeneration areas. A density of 0.5 bison per km2 is considered safe for forests (Perzanowski et al., 2006). Collaborating with forest services can minimize tree damage (van de Vlasakker, 2014). While bison-caused forest damages might benefit ecosystems by creating structures like open habitats and deadwood, a location with minimal production forest and high unmanaged forest is ideal (van de Vlasakker, 2014). Population control through selective culling is vital for effective management (Perzanowski, 2016). Compensation plans, education, and workshops can mitigate conflicts (Klich et al., 2021).

Winter feeding is a potential solution for mitigating farm and forest damages and resulting conflicts (Klich et al., 2017). Supplementary winter feeding can resolve these issues to a high degree, but it is not a natural practice (Samojlik et al., 2019). It can alter behavior and increase parasite transmission (Haidt et al., 2018; Rouys, 2003; Kołodziej-Sobocińska et al., 2016). Winter feeding reduces the key environmental impact of European bison - creating and maintaining open patches. Although concerns might arise in highly populated areas, Southern Sweden's abundant space reduces these concerns for the initial release of a few dozen animals.

3.5.2 Farm Animals

European bison is a bovine animal and as such, it is susceptible to bovine diseases which pose a risk to its population and potential conflict with the owners of domestic animals. The biggest threat comes from livestock, although this is usually not a big concern in Western and Northern Europe due to high veterinary standards, the risk of the spread of the diseases still exists, especially in the presence of extensive domestic animal movements and industrial farming (van de Vlasakker, 2014). For instance, the bovine tuberculosis outbreak became a main threat to the Bieszczady population in southern Poland (Brewczyński & Welz, 2011; Krajewska et al., 2014). Given that the entire species descended from just 12 founding individuals, the susceptibility of European bison to diseases may be increased. (Larska & Krzysiak, 2019; Olech & Perzanowski, 2022).

3.5.3 Hunting

Hunting is another issue that if not addressed and properly managed can pose a risk to reintroduced populations. Illegal poaching alongside military conflicts is believed to be the main reason for the failure of the reintroduction of European bison in Russia and the Caucasian region (Klich & Perzanowski, 2013). Poaching and hunting is the main reason for the post-reintroduction population decline in Ukraine (Parnikoza et al., 2009). Therefore, hunting and poaching should not be overlooked, nevertheless, as long as bison are not actively hunted (including illegal poaching which should be averted), hunting is not a threatening activity (van de Vlasakker, 2014). Hunting of other animals should not interfere with bison behavior, as this can impact how they use their environment, additionally making them less visible to potential tourists (van de Vlasakker, 2014).

There is a potentially positive aspect of hunting, as in the future when the population starts to breed and grow in number, hunting of selected individuals is often a necessity (Perzanowski, 2016). In the long term perspective, this can be very attractive for hunters and can bring economic benefits.

3.5.4 Tourism

The reintroduction of European bison can positively impact tourism and the promotion of the area of the reintroduction. Not only presence of the animals can be attractive for visitors, but also an area of might be viewed as more “natural” due to the presence of European bison. There is also potential for education related to the role of large herbivores and keystone species in the environment. A study conducted by Akhshik et al., (2022) that even visiting enclosures of European bison leads to increased interest and engagement of tourists in overall nature conservation.

3.5.5 Attitude Towards Bison and Reintroduction

Another potential conflict can arise from the negative attitude of the population towards the reintroduction project and/or the species. Bergsten's (2014) Swedish survey found majority support for reintroduction, implying high potential acceptance during the actual reintroduction project. This aligns with trends in other countries where acceptance increases after reintroduction. Klich et al.'s (2018) study reveals that residents near long-established reintroduction sites hold more favorable attitudes compared to those in areas with planned reintroduction. Lithuania's case, where attitudes turned positive after over 40 years post-reintroduction, contrasts with Germany's less positive planning-phase survey results (Balčiauskas & Kazlauskas, 2014; Decker et al., 2010). Misconceptions

about bison risks and land damage may fuel such differences. Proximity to bison fosters an understanding of low negatives and benefits like increased tourism (Klich et al., 2018). However, attitudes do not always increase with time. In Bieszczady, home to a large bison population of more than 700 individuals (Raczyński, 2022), landowner attitudes declined due to damages (Klich et al., 2021). This highlights ongoing management's importance in post-reintroduction conflict reduction (Klich et al., 2019).

3.6 Climate Requirements

The European bison displays a notable degree of flexibility in relation to climatic requirements. Based on past distribution, it inhabited areas with annual temperature ranges between 0 and -13 °C could survive average winter temperatures as low as around -15 °C (Kuemmerle et al., 2012a). Due to their size and thick coats, even in the summer, bison struggle to withstand the heat, therefore, places that experience prolonged summertime heat with long periods of temperatures higher than 30˚C are not tolerable (van de Vlasakker, 2014). However, bison may still face difficulties from extremely persistent and deep snow cover because it may restrict their access to food and water and raise their energy requirements. Despite those concerns, European bison was observed to find food in such conditions (van de Vlasakker, 2014). In the case of the prolonged conditions of snow and freezing temperatures, the availability of wooden material is crucial for survival (van de Vlasakker, 2014).

3.6.1 Historical Records

The comparison of climatic conditions during the historical presence of the European bison in Southern Sweden with the current conditions can provide valuable insights into the climate's suitability. Bones found in this region area were dated to be 9.5 to 8.7 thousand years old, suggesting that presence in the early Holocene period (Benecke, 2005; Pucek et al., 2004; Liljegren & Ekström, 1996). According to reconstructions from fossil pollen from southern and central Sweden, temperatures of the early Holocene were slowly warming reaching temperatures of today's climate around 9.5 thousand years ago (Antonsson, 2006). According to palaeobotanical research from the Scandes, summertime temperatures between 9.5 to 8.0 thousand years ago continued to rise and were about 1°C higher than now (Paus & Haugland, 2017; Wastegård, 2022). The fact that periodically, the mean temperature was slightly higher during the historical presence of European bison in this area has small significance considering that temperature in Sweden is projected to increase as a result of climate change (Lind & Kjellström, 2008), potentially creating even more favorable conditions. Records suggest that European bison was again present in southern Sweden until at least XI century before going locally

extinct (Pucek et al., 2004). Mean temperatures and climate in this region at the beginning of the past millennium do not deviate significantly from current ones (Moberg et al., 2006). This again suggests that climate should not be a limiting factor for the thriving of a potentially reintroduced population.

3.6.2 Current Distribution

To better understand how European bison adapt to the climate, we can study places where they have been successfully reintroduced and are now thriving. Southern Sweden belongs to the ecoregion "Sarmatic Mixed Forests" (Figure 3) which is inhabited by free and semi-free herds of bison in Lithuania, Latvia, Belarus, and Russia (Raczyński, 2022). Populations in this region thrive and continue to grow in number since their reintroductions (Marozas et al., 2019; Anisimava et al., 2015; Sipko, 2009). This is a strong indication that European bison could prosper in the Swedish part of this ecoregion as well, as it is characterized by similar climatic conditions and the distribution of plants such as oak trees.

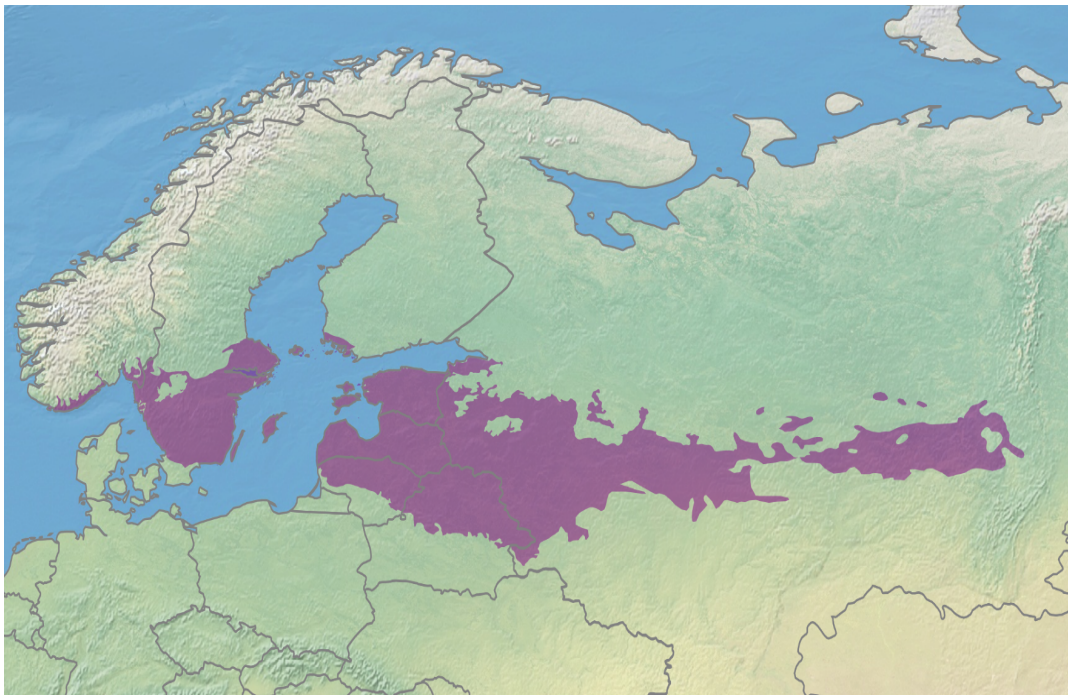

Figure 3. The ecoregion "Sarmatic Mixed Forests" (marked purple) is inhabited by European bison in several countries. Image adapted from Wikimedia Commons.

Given the northern location of a potential population in Sweden compared to the majority of current European bison distribution, winter severity, and length become a key climatic concern, therefore the most northern population is examined. The world's northernmost population (59°N to 60°N) resides in Russia's Vologda region, reintroduced in the early 90s. Despite lacking winter supplementary feeding, bison in this region thrive and increase in numbers (Sipko, 2009). These

animals successfully endure the region's challenging winter conditions (Figure 4) and exhibit successful reproduction (Gusarov, 2011). Gusarov (2011) identified climatic parameters for the Vologda region, including a 150-165 day period below 0°C, 55 days below -15°C, and 110 days above +10°C. Monthly precipitation averages 26-74 mm, wind speed varies between 3.8 and 5 m/sec, and snow cover thickness ranges from 50 to 95 cm. The most extreme conditions are -38.6°C and a 1.2m snow depth, with a mean snow depth of 65cm (Gusarov, 2019).

Figure 4. European bison in Ust-Kubinsky district, Vologda region, January 2022. Photo by Evgenii Panov.

3.6.2 Suitability of Southern Sweden's Climate

Most of the climatic parameters are usually much milder than in the territory of the northernmost population. The duration of snow coverage in Götaland varies annually. Some winters, like 2019/2020 and around 1990, see brief snow seasons, lasting only 1-3 weeks on average across twelve stations. Conversely, others have snowfall extending beyond three months. The longest snow season was 1969-1970, followed by a decrease since the mid-1980s (SMHI, 2023). Certain years in Götaland experience slightly higher or lower snowfall totals. The winter of 2009-2010 registered the highest average snow cover of 59 centimeters across 15 stations, while the 2019-2020 season fared poorly. Maximum snow cover has declined since roughly 1990 (SMHI, 2023). In the coldest and warmest months, southern Sweden averages around 0°C and 16-17°C, respectively. Götaland's vegetation period (days above 5°C) varies between 220 and 260 days annually (years 2012 - 2022), while

the regular number of sub-zero temperatures per year (1991-2020) ranges just below 70 in coastal areas (SMHI, 2023). Over the past decade, the geostrophic wind has hovered between approximately 34 and 36 m/sec (SMHI, 2023), with an average yearly precipitation of 600 to 800 mm, concentrated in autumn and winter months (SMHI, 2023).

Götaland's climate, including temperature and snow cover, aligns well with the European bison's tolerance range based on its current distribution. While more precipitation and wind prevail compared to the Volgoda region, the milder climate is unlikely to pose significant issues. Extreme and prolonged winters could limit resource access and necessitate foraging outside natural habitats. Despite their capacity to endure harsh winters, supplementary feeding is common. Political circumstances and severe winters in the Northern Caucasus resulted in a population decline in the 90s due to discontinued feeding (Klich & Perzanowski, 2012). Mortality risk in winter seems habitat and terrain-related, evident in Ukraine's study where over a quarter of deaths are linked to winter food scarcity, mainly in highland areas (Khoyetskyy, 2010). A study in Bialowieza indicated elevated mortality and reduced reproduction in severe winters (Mysterud et al., 2007). Adequate food sources and management strategies, including supplemental feeding, would likely support European bison survival and prosperity in Götaland's climate.

3.7 Habitat Requirements

The European Bison's adaptability to habitat requirements, albeit with preferences, is noteworthy. It prefers low human-disturbance areas, including national parks, yet can inhabit lightly human-affected zones. Daytime forest preference and nighttime open area selection likely stem from human disturbance avoidance (Červený et al., 2014; Marozas et al., 2019), rather than strict habitat preference. The European Bison occupies diverse habitats such as grasslands, wetlands, meadows, and forests (Daleszczyk et al., 2007). Edge habitats between forests and open ecosystems are also utilized (Kuemmerle et al., 2011; Lord et al., 2020). For cover and foraging, undisturbed forests with dense understory are vital, affording protection from weather and human interaction. With a primary diet of grasses and herbs, grasslands and meadows are preferred feeding grounds (Bocherens et al., 2015; Lehto, 2015). Wetlands, like alder fens and riparian forests, also benefit bison (Daleszczyk et al., 2007). Wetland plants are part of their diet, observed in Bornholm (Denmark) and Doeberitzer Heide (Germany) populations (Kowalczyk et al., 2019; Hartvig et al., 2021; Zielke et al., 2019). However, very wet areas like raised bogs are avoided (van de Vlasakker, 2014), and instances of bison getting stuck and dying in boggy terrain are known (Krasińska & Krasiński, 2013). Based on the evidence of utilization of different types of habitat, the preferred habitat of European bison appears to be a mosaic of landscapes including wooded and open areas, including

sufficient natural meadows and deciduous forests with good and varied vertical and horizontal structures and connectivity between different habitat types (van de Vlasakker, 2014).

The utilization of a variety of habitats can be explained by the generalistic nature of European bison. DNA barcoding study carried out by Hartvig et al., (2021) showed that the its diet compromised 71 plant species from 36 families, of which the most were forbs (56%), followed by trees (20%), graminoid (17%) and shrubs (7%). Regarding preference of trees, they usually prefer broadleaved species such as oak (*Quercus robur*), hornbeam (*Carpinus betulus*), hazel (*Corylus avellana*), ash (*Fraxinus excelsior*), birches (*Betula* sp.) and willows (*Salix* sp.), although Norway spruce (*Picea abies*) and scots pine (*Pinus silvestris*) (Kowalczyk et al., 2011; Krasińska & Krasiński, 2013). Different studies identified even more diverse compositions in the diet with as many as over 170 species of plants (Kowalczyk et al., 2019). Oaks have an additional role as they provide acorns which are often part of the diet of European bison (Cromsigt et al., 2018).

The proportion of browsing and amount of consumed woody material depend on supplementary feeding and availability of habitats. It can increase even up to 65% if bison are not supplementary fed and utilize the forest (trees and shrubs) (Kowalczyk et al., 2011). Population in the Voldoga region in Russia occupies an area which, despite having a large proportion of various habitats and plant species preferred by bison, has a forest dominated by conifers (55%) (Gusarov, 2019), showing that such habitat can also be utilized.

The significance of open habitats aligns with the concept of refuge species. European Bison is often considered a refuge species due to historical habitat loss and hunting that led to a decline in its population (Bocherens et al., 2015; Cromsigt et al., 2012; Kerley et al., 2012; Kuemmerle et al., 2012b). This forced the species into sub-optimal habitats, such as coniferous forests, for refuge (Kerley et al., 2012). Despite changes in their former range, European bison continue to inhabit suboptimal habitats where they face challenges like food scarcity and competition from other herbivores. However, their adaptations, such as efficient digestion of hard plant matter, enable them to endure (Bocherens et al., 2015). Conservation efforts for European bison should focus on restoring populations to more optimal habitats while recognizing the importance of suboptimal habitats as well (Kerley et al., 2012). This concept suggests that restoring species from refuge status can be challenging, particularly if ideal habitats no longer exist (Kuemmerle et al., 2012b). Although historical distribution debates whether open areas are optimal, recent ecological studies highlight the species' versatility in forests, open areas, and marginal habitats (Bocherens et al., 2015). Bison introduced to forest environments expand into open habitats over time, potentially causing conflicts with agriculture (Kowalczyk et al., 2013; Hofman-Kamińska & Kowalczyk, 2012). This underscores the need for accessible open-area habitats like meadows, grasslands, or wetlands in reintroduction areas.

3.7.1 Natural Predators

European bison have very few natural predators, thus there is a small chance that they would significantly influence reintroduction efforts. Although, wolves can be a natural predator, observations from Białowieża show that attacks are very infrequent and rarely end up in the mortality of animals (Jędrzejewski et al., 2012; Krasińska & Krasiński, 2013) and their presence do not alter the behavior of European bison (Hayward et al., 2015). Although cases are rare, bear predation on European bison is also possible (Khoyetskyy, 2010; Kuemmerle, et al., 2011). Wolf presence is very scarce in southern Sweden, with rare sightings in the northern part of Gotaland, as their main distribution is in central Sweden (Eriksson & Dalerum, 2018). Bears are not present at all in southern Sweden (Kindberg et al., 2011). Therefore, predation of either of those animals should not cause a threat to the potential population of European bison in this area.

3.7.2 Suitability of Habitats in Southern Sweden

Previously mentioned ecoregions are a good indication of habitat requirements as they are not only geographically bound but also feature comparable ecosystems and communities and quantities, qualities, and types of natural resources (Loveland & Merchant, 2004). Southern Sweden falls into the category of “Sarmatic Mixed Forests” ecoregion (Figure 3) which is within the current range of European bison in several countries (Raczyński, 2022).

If areas for grazing and browsing are available, there are only a few exceptions of habitats not suitable for bison such as very wet areas like raised bogs, or areas with terrain of very rough topography (van de Vlasakker, 2014). Since European bison is a generalist species, with a broad diet, if climatic and topographical conditions are suitable, and the area is relatively natural with the occurrence of shrubs, herbs, and grasses, there will be most likely enough resources to sustain a population of European bison (van de Vlasakker, 2014).

In Götaland, there are many different kinds of habitats, such as wetlands, grasslands, forests, and coastal ecosystems. In the forested regions of Götaland, deciduous trees like oak, beech, and birch are present along conifers like pine and spruce. As with Tiveden National Park, some of the forests are designated as protected nature reserves. In Götaland, there are fens, swamps, and marshes. Wetland-containing protected nature reserves include Hornborgasjön Bird Lake and Getterön Nature Reserve. In Götaland, various grasslands provide essential grazing habitats, including meadows, pastures, and heathlands. Additionally, many of such habitats are protected such as Store Mosse National Park.

The region's diverse ecosystems, including deciduous forests, grasslands, and wetlands, can most likely provide a suitable habitat for European bison. Since

the grasslands and wetlands in Götaland frequently have a high diversity of grasses and other herbaceous plants that the bison could consume, they might serve as important grazing habitats for the animals. The forests in Götaland may be an important bison browsing area providing woody vegetation in trees and shrubs.

The range for the bison population is on average around 10,000 ha thus an area of at least that size should be required for a 'true' reintroduction of a free-ranging population (van de Vlasakker, 2014). Reintroduced groups should count at least five to seven individuals, but ideally more than 10 (van de Vlasakker, 2014). A study of populations in the Carpathian Mountains estimated a carrying capacity of 0.4 European bison per square kilometer (Dănilă et al., 2022). Carrying capacity, or the maximum number of European bison that could survive in a specific area, is almost always significantly higher than the socially acceptable carrying capacity, or the number of European bison that can coexist without experiencing significant conflicts with humans, agricultural or forestry practices, or significant competition from other large ungulates (Kuemmerle et al., 2017). Fulfillment of those requirements in southern Sweden, should not be a significant challenge as the current distribution covers places with much less availability of natural areas and a much higher human population.

3.8 Future Research Directions

To effectively manage the risks associated with traffic collisions and to reduce human-wildlife conflicts involving European bison, there is a need for further research and consideration of various contributing factors. These factors encompass the assessment of habitat preferences, traffic patterns, and the effectiveness of mitigation techniques. An in-depth investigation is warranted to develop targeted strategies that can efficiently minimize the impact of traffic accidents and enhance harmonious coexistence between European bison and human activities.

A crucial aspect of successful reintroduction efforts is acknowledging the potential variability in feeding requirements across different regions. Achieving a comprehensive understanding of the dynamic relationship between European bison and their food sources in a new area calls for post-reintroduction monitoring and additional research. This approach will enable a thorough evaluation of the species' ability to adapt to local food availability and resource utilization.

Significant gaps in knowledge remain concerning the health of European bison in new habitats, the prevalence of diseases, and reproductive dynamics, as underscored by Gusarov (2019). In the event of reintroduction in Sweden, diligent monitoring with a focused emphasis on these aspects is imperative to promptly address any emerging health challenges and ensure the overall well-being of the population.

4. Conclusion

In summary, this study provides support for the reintroduction of European bison to southern Sweden, and while challenges exist, they seem to be manageable. According to this research, European bison accidents are significantly less common than moose accidents. Additionally, usually, they pose less risk to health and life in comparison to accidents with other animals. This suggests that there may not be many significant road-related challenges posed by the reintroduction of European bison to Sweden. It is crucial to remember that difficulties could still result from interactions between people and European bison. However, with careful planning and cooperation with regional communities, these difficulties can be effectively handled. The climate and habitats in southern Sweden are also suitable for European bison, according to the review of the literature. The conditions align well with the needs of European bison. The apparent gap in knowledge resulting from the reintroduction of species to novel territories can be effectively bridged through extended research and monitoring.

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Popular Scientific Summary

European Bison Reintroduction in Sweden - Addressing Traffic Accidents Risk and Other Challenges

Wildlife Challenges on Roads - European Bison and Moose in Focus

The interactions between wildlife and roads raise serious concerns in our constantly connected world. This study sheds light on the problems caused by collisions between moose and European bison in Poland.

Exploring the Risk of Traffic Accidents

My aim was to ascertain the frequency of traffic accidents involving these animals. Between 2014 and 2022, I looked into moose and European bison-related incidents in Poland. The objective was to determine whether incidents involving European bison were more or less frequent than those involving moose.

Promising Findings

It turns out that traffic accidents involving European bison were much less frequent than those involving their moose counterparts. In fact, moose accidents were more than twice as common as those involving European bison. This suggests that the European bison may experience fewer difficulties than moose in terms of road safety.

What's even more reassuring, European bison accidents are not only less common but also less harmful. They typically only cause minor or nonexistent injuries. This raises hopes for their coexistence with human activities yet again.

Other Aspects of Reintroduction

I also looked into whether southern Sweden's climate and habitats would be appropriate. What I found was quite encouraging. It is well known that European such bison can survive in a variety of environments, including open spaces, forests, and the transitional areas between them. In fact, southern Sweden has a variety of habitats. In addition, given the bison's dietary requirements, the region's food resources seem to be adequate. This is important because a balanced diet is crucial to their survival and well-being.

According to historical records, the climate in Sweden during the time the European bison lived there was similar to the one there is now. The fact that European bison can currently survive in areas with harsher climates than southern Sweden is significant because it lends support to the possibility of their reintroduction here.

Future of Reintroduction

In conclusion, my research suggests that the path toward reintroducing European bison to Sweden may be less difficult than initially anticipated. Despite the difficulties, they can be overcome. The reintroduction of European bison is not only important for its own sake but also as the largest herbivore on the continent, playing a crucial role in ecosystem dynamics.

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