IUCN

European Bison (*Bison bonasus*) Strategic Species Status Review 2020

Edited by Wanda Olech and Kajetan Perzanowski

SSC Species Survival Commission

EBCC

This document has been prepared by top level specialists on European bison, both theoreticians and practitioners, representing all European countries where the species occurs either in the wild or in captivity. A majority of co-authors is associated either with EBCC and BSG or with various universities, governmental institutions or NGOs, involved in conservation and management of European bison

More information on the IUCN SSC Bison Specialist Group is available at https://www.iucn.org/commissions/ssc-groups/mammals/mammals-a-e/bison and the European Bison Conservation Center at: https://ebcc.wisent.org/.

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OVERVIEW

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This report was developed in 2019-2020 by the editors and contributing co-authors through the European Bison Conservation Center (EBCC) in accordance with its stated goal “to coordinate the flow and exchange of information between wisent breeders from different European countries;” and “to create a platform of communication between European bison breeders, decision makers, conservationists and other interested parties to develop a common policy for wisent conservation in Europe, despite the existence of differences in the rules of E. bison conservation in the various European countries” (available at: https://ebcc.wisent.org).

In early 2021, the editors provided the draft EBCC report to the International Union for Conservation of Nature Species Survival Commission (IUCN SCC) for consideration of publication by the IUCN SSC Bison Specialist Group (BSG). After extensive review and discussion, the editors and the BSG Chair reached agreement to co-publish the EBCC report as non-peer reviewed grey literature under the IUCN SCC banner in accordance with IUCN Publishing Guidelines.

As the Bison Specialist Group was not formally consulted, or substantively involved as an organization, in the preparation of the EBCC report, the contents herein represent only the views of the contributing authors for each section; and do not necessarily reflect any views, suggestions, or recommendations of the IUCN SSC or the Bison Specialist Group, nor any non-government organization aside from EBCC, nor any national government or agency.

While progress has indeed been made in improving knowledge about the species and in implementing actions that have increased its abundance and distribution, there remains a diversity of viewpoints on what future success for the species might look like (Plumb et al. 2020). The Bison Specialist Group and EBCC share that co-publishing this report will contribute to collaborative preparation of a new IUCN SSC European Bison Conservation Action Plan to be published in 2023 (Plumb 2022).

Photo courtesy of Katarzyna Borek


Photo courtesy of Ruud Maaskant

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1 | PREFACE

Wanda Olech and Kajetan Perzanowski

This report has been prepared 17 years after the publication of the first "Status Survey and Conservation Action Plan" for the European bison *Bison bonasus*, (the wisent). During that time, major changes have taken place regarding the numbers of the world population of the species, its range of occurrence, as well as conditions both economic and social, crucial for its further conservation. The results of the rescue program for the European bison, initiated almost 100 years ago, can be considered as spectacular. By the end of 2020, the total numbers of this species reached about 9100 individuals, including over 6800 animals in the wild. In total, 45 free-ranging herds exist now in 10 European countries. Such an achievement may allow us to think that the threat of extinction of those magnificent animals does not exist anymore.

There are however several issues which still raise doubts about whether the future of European bison is safe. The appearance of relatively large numbers of individuals both in captivity and in the wild, may be a reason for various conflicts, especially with agriculture and infrastructure. Additionally, it also makes it more difficult to maintain a control over the breeding of those animals and their transfers. Until now, legal status of this species varies considerably, even within the European Union - from strictly protected to having the same status as domestic cattle. So far, it has been impossible to establish unified rules concerning obligatory tests and treatments against infectious diseases as well as standards for transporting of those animals. Very different, approaches applied towards nuisance individuals causing damages to crops, migrating into settlements or transport routes. And last but not least, regulations concerning the possibility for the commercial use of products like meat, pelts, trophies, etc. vary tremendously among the countries of Europe.

There is of course no solution for an improvement of the genetic structure of this species, and since the main threat for its further existence is the extremely low level of heterogeneity, it can only be mitigated to a certain extent through careful, prescribed breeding, based on pedigree data and DNA analyses. However so far only those animals that are included into the programs coordinated by European Bison Conservation Center and EEP are managed according to such rules. Such a situation is a significant obstacle in the introduction of a consistent, coherent program for further conservation and management of this species, at least within countries of European Union. Therefore, the most urgent action seems to be the unification of the legal status of the species among European countries. This would allow us to treat all the animals within the continent, both captive and free ranging, as one metapopulation. Another important issue is standardization of health monitoring and treatment against infectious diseases and parasites, many of them not occurring or not recognized previously.

The growing number of animals, and increasing costs of their protection and management, raise a question about sources for financing all related activities and necessary measures towards conservation of this species. Already in the "Status Survey and Conservation Action Plan" issued in 2004, a practical aspect related was raised to the full recovery of the historic status of European bison as a game animal. Presently, in the majority of European countries, either due to the lack of and fragmentation of suitable habitats or because of low social acceptance for free-ranging European bison, there are only a few spots remaining that are, appropriate for releasing further animals to the wild. Nevertheless in some countries such conditions still exist, and together with the incorporation of this species back into natural ecosystems, there is a need to work out reasonable regulations allowing for the management of those animals together with other species of wild fauna.

This report was prepared by a team of 32 experts representing 15 countries, both having European bison only in captivity as well as those also managing free-ranging herds of this species. Among the authors, there are 19 members of IUCN SSC Bison Specialist Group and 13 are active in European Bison Conservation Centre. Therefore hopefully this document covers the whole range of issues necessary for the preparation and implementation of a long term strategy that allows for further effective protection of this species. The aim of this report is to provide possibly the most current, detailed knowledge on the species' status all over the continent, and contributing co-author views of how to improve its present situation in terms of population parameters, health and welfare, accessibility of optimal habitats and conservation measures. The accuracy of proposed solutions and measures will be possible to be evaluated generally - on the basis of subsequent trends in European population of the species and locally - upon the development of free-ranging, viable herds.

Photo courtesy of Antoni Piasecki

2 | EVOLUTIONARY ORIGIN OF THE EUROPEAN BISON

[The evolutionary origin of the European bison (the wisent) remained mysterious for a long time. Thanks to the advance of ancient DNA analyses (aDNA) and radiocarbon dating techniques, numerous remarkable and sometimes unexpected aspects of the origins of this species were revealed during the last 15 years.

Bovines (tribe Bovini) represent a small monophyletic group of bovids composed traditionally of five genera (*Bison*, *Bos*, *Bubalus*, *Syncerus* and *Pseudoryx*) with 13 recognized species (Grubb 2005), or up to 17 species according to the Phylogenetic Species Concept (Groves and Grubb 2011). Under a phylogenetic approach, Bovini would be composed of only four genera, because *Bison* would be included in *Bos* based on dated fossil record and estimations of diversification times, both under 5 Myr (Groves, Grubb 2011 and Groves 2014; see also Hassanin et al. 2012, 2013, Bibi 2013).

The earliest Bovini can be dated to Late Miocene localities in Asia, Europe and Africa (McKenna and Bell 1997), the oldest *Bison* is dated to the Late Pliocene (3.3–2.6 Mya) of Pakistan. Later it colonized the rest of Eurasia, specifically Europe between 1.8–1.5 Mya, and much later into North America between 240–220 kya (Hassanin et al. 2013, Tong et al. 2017). Considering molecular dating analyses, the common ancestor of tribe Bovini is estimated from betweeen 12–10 Ma (Bibi 2013), while the common ancestor of extant Bovini has been estimated to stern from the Pliocene between 4.8–3.4 Ma (Bibi 2013).

Diversification of Bovini had been realized within a relatively short time, and the group is capable of hybridization (Gray 1954). Interspecific hybrids are often fertile, but some exhibit f1 male infertily, consistent with Haldane´s Rule of heterogametic crosses (Soubrier et al. 2016). Natural intercrossing between a number of bovine lineages (= reticulation) was common in this group (Wu et al. 2018), and the European bison itself has been considered one such case (see below). Therefore, detection of phylogenetic relationships between bovines is a great challenge (e.g., Hassanin et al. 2013, Hassanin 2014). At the moment, there is a consensus, that buffalloes (Bubalina = *Bubalus* + *Syncerus*) represent a sister lineage to other bovines, and that yak form the sister group to American bison and European bison, but other relationships vary according to taxonomic sampling and the choice of genetic markers (see reviews, for example Groves, Grubb 2011, Hassanin et al. 2014). The current genomic data reveals the following relationships: (((buffalo ((taurine, zebu)((banteng (gaur, gayal))(yak (wisent, bison))) (Wu et al. 2018).

Recent genetic studies based on subfossil, historical and recent bone material revealed that three distinct bison forms inhabited the Palearctic in the Late Pleisocene and Holocene. Steppe bison (*Bison priscus*) distinguished by its large size and several features from the other bison forms has been long recognized thanks to its rich Pleistocene paleontological records in Eurasia and North America. Although it was one of the dominant faunal elements of the mammoth steppe biome, its range shrank dramatically due to climatic changes at the end of the last glaciation. In the early Holocene, the species remained restricted to several refugia in the far north-east and east-central Asia. The date and place of the last stand of the steppe bison remains to be revealed according to occurrence data by Markova et al. (2015), but it possibly took place in the South Siberian forest steppe refugium in southern Irkutsk oblast west of Lake Baikal as late as the 10th century AD.

The other two Late Pleistocene and Holocene (P/H) Palearctic bison forms represent two phylogenetically and probably ecologically distinct lineages of European bison including i) direct ancestors of the extant wisent *B. bonasus* (referred to as wisent or wisent lineage here after), and ii) so called Clade X, which apparently became extinct sometime during the P/H transition 12-9 ky BP. Undetected in the paleontological record, the existence of the two distinct wisent forms was revealed only recently by multiple aDNA studies (Soubrier et al. 2016, Wecek et al. 2016, Grange et al. 2018, Hofman Kamińska et al. 2019). Both wisent forms were apparently restricted to the western Palearctic. Although Clade-X specimens were restricted to northern Europe in the Late Pleistocene to early Holocene and wisent line specimens to more southerly regions, they overlapped in rather broad zone from france to the Caucasus. Clade-X specimens appear to be associated with open grazing habitats, while wisent line specimens are apparently associated with wooded habitats. It is not settled yet, whether these sister European bison lineages should be considered as two ecological forms or distinct taxa. Their geographic range confirmed thus far by aDNA analyses included most of Europe from the Ural Mts. and south-west Siberia in the east, to the Caucasus Mts. in the south, and all the way across Central and Western Europe to the Atlantic ocean. The two wisent forms have alternated ecological dominance with steppe bison in association with major environmental shifts since at least 55 ky BP (Soubrier et al. 2016). In different times of the Late Pleistocene, all three forms were apparently present in most parts of their overlapping ranges in Europe and western Asia. There are even localities in the Caucasus and Ural Mts. where all three bison forms were identified in different layers of single paleontological sites (Soubrier et al. 2016).

Traditionally, two hypotheses were proposed for the origin of European bison (reviewed by Kowalski 1967, Markova et al. 2015). Some experts (M. Hilzheimer) assumed the smaller and more woodland-adapted mid Pleistocene *Bison schoetensacki*, with less massive horns and slender legs, was a direct progenitor of European bison (e.g., Palacio et al. 2017). others proposed the following sequence leading to European bison: *B. schoetensacki*–larger and steppe specialized *B. priscus*–*B. bonasus* (e.g., V. I. Gromova, K. K. flerov, R. Croitor). *Bison priscus* was a typical highly specialized mammoth-steppe element distributed across the northern Palearctic and Beringia (Guthrie 1990, Kahlke 2014, Tong et al. 2017), i.e., much more widely than *B. schoetensacki* which occurred from western Europe to southern Siberia (Palacio et al. 2017). Therefore, under the first scenario, the phenotype of European bison and possibly also its scarcity in the fossil record might reflect a spatially restricted optimal habitat shared between an ancestor-descendent form, and some Pleistocene localities assigned to *B. priscus* could represent *B. bonasus* (Markova et al. 2015). Under the second scenario, the European bison would develop from the much more specialized, larger and widely distributed steppe bison into an ecologically and socially generalized, cattle-like form with a rather restricted distribution (cf. Geist 1971). More recently, a third hypothesis was proposed, that the extant European bison is a natural hybrid species combining genomes of two extinct species *B. schoetensacki* or *B. priscus*, and aurochs *Bos primigenius* (Verkaar et al. 2004 and references below).


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In addition, alternative hypothesis suggested the origin of European bison from re-emigrant bison from North America, or considered European and American bison to be conspecific, often based on morphological similarity and fertile hybrids produced under human control (see review by Krasińska et al. 2014). However, American and European bison are currently classified as separate species for good reasons. First, there are significant phenotypic differences (see reviews by Krasińska et al. 2014, Groves, Grubb 2011) and second, because interbreeding under human control does not give any indication of species status, especially in allopatric populations (Groves, Robovský 2011, Groves et al. 2017). Although the re-migration of bison from America to Eurasia is supported by genetic studies (Shapiro et al. 2004), it involved *B. priscus* and following admixture influenced its Siberian population, but not *B. bonasus*. Apart from that, this admixture event occurred well after the geographic separation of ancestral lineages of *B. bonasus* and *B. bison* (Gates et al. 2010). Importantly, the conspecifity of European and American bison is not supported by any current genetic or genomic studies (e.g., Prusak et al. 2004, Massilani et al. 2016, Soubrier et al. 2016, Palacio et al. 2017, Grange et al. 2018).

Although some authors expected divergence between *B. priscus* and *B. bonasus* lineages during the Early Pleistocene (e.g., Hilzheimer 1918, Spassov, Stoytchev 2003, see review by Markova et al. 2015), most literature presented European bison as an evolutionarily very young species that emerged in the early Holocene (e.g., Kowalski 1967, Vereshchagin 1967, Pucek 1986, Pazonyi 2004, Benecke 2005, Németh et al. 2016). However, as mentioned above, European bison (= wisent clade) has a much older history as it was demonstrably present in Caucasian region between 56–22 kya, in the Urals 58-12 kya and in western Europe between 47–34 kya (Massilani et al. 2016, Soubrier et al. 2016). Estimations of divergence dates based on genomic data indicated an even much older date varying between 395 to 96.8 kya (Massilani et al. 2016, Soubrier et al. 2016, Grange et al. 2018). As Markova et al. (2015) pointed out, *B. priscus* and *B. bonasus* are morphologically almost identical. There is an overlap in some bones, and some former assignments of *Bison* remains could be biased towards the locality age. Obviously, the putative Holocene age of European bison accepted for decades by many authors is the reason for the more or less automatic assignment of Late Pleistocene bison remains to *B. priscus* and those of Holocene age to *B. bonasus* in the paleontological literature. Further aDNA analyses of Pleistocene bison remains are required for recognition of the earliest appearance of European bison as a species.

The European bison exhibits close affinities to taurine cattle (domestic ox, zebu, aurochs) based on mitochondrial DNA, but to *B. priscus* and *B. bison* based on nuclear, Y-chromosome and genomic data (e.g., Verkaar et al. 2004, Nowak, Olech 2008, and references below). Verkaar et al. (2004) proposed three explanations: phenotypic convergence, lineage sorting and ancient hybridization event in which the Eurasian cattle-like population was influenced by genetic introgression from *Bison bison*, *B. priscus* or *B. schoetensacki*. This last scenario would be compatible with the social structure of this species, paleontological records, and the "cattle-like" phenotype of European bison (Geist 1971, Verkaar et al. 2004, Marsoller-Kergoat et al. 2015). Other extensive genetic studies considered an incomplete lineage sorting with more recent secondary contacts with taurine cattle lineages as the most parsimonious interpretation of the obtained results (Gautier et al. 2016, Massilani et al. 2016, Grange et al. 2018, see also Spassov 2016). There is no consensus yet, which of the explanations is valid, but different authors apparently agree that there was some admixture with the *Bos* lineage in the population history of European bison. Importantly, all published analyses suggest that this admixture results from ancient events rather than recent hybridization with domestics (e.g., Węcek et al. 2017).

Grange et al. (2018) conducted a detailed revision and comparison of these last studies and offered a comprehensive synthesis; they estimated that the divergence between *Bos* and *Bison* was completed by ca. 850 kya, with a low-level gene flow from *Bison* to *Bos* (0.6%, after 260 kya) and from *Bos* to *Bison* (2.4-3.2%, after 70 kya) (see also Węcek et al. 2017). In addition, Grange et al. (2018) concluded that both morphometric and genome analyses reveal that European bison belonging to different *B. priscus* and *B. bonasus* lineages maintained parallel evolutionary paths with gene flow during a long period of incomplete speciation that ceased only after the migration of *B. priscus* to the American continent, establishing the American bison lineage.

Demographic analyses of European bison suggest marked fluctuation during the Pleistocene (Gautier et al. 2016) with a sharp decline since the Last Glacial Maximum (Gauthier et al. 2016, Massilani et al. 2016, Soubrier et al. 2016). Soubrier et al. (2016) demonstrated that modern European bison have drifted towards their Pleistocene and Holocene counterparts. All bison species appear to be sensitive to natural habitat changes and more recent human pressure (hunting, poaching, habitat loss and fragmentation). Severe population bottlenecks experienced by ancestral populations are well documented during the Late Pleistocene and early Holocene in both extant bison, the European and the American (for American bison see Shapiro et al. 2004, Drummond et al. 2005, Metcalf et al. 2014) as well as in B. priscus (Lorenzen et al. 2011, Markova et al. 2015). Marked demographic fluctuation in Pleistocene European bison in contrast to aurochs (Gautier et al. 2016) and much mitochondrial differentiation of European bison in contrast to steppe bison (Massilani et al. 2016) could be in agreement with a scenario in which European bison survived in refugia pockets during glaciations, while aurochs and steppe bison could migrate southward or eastward, respectively (Gautier et al. 2016).

Concerning the recognized subspecies of the European bison, two subspecies (lowland E. bison - *B. b. bonasus* and Caucasian E. bison - *B. b. caucasicus*) are accepted by all scholars, a third subspecies *B. b. hungarorum* is accepted only by some authors, and sometimes only tentatively (for different perceptions see, for example, Grubb 2005, Krasińska, Krasiński 2013, Groves, Grubb 2011, Németh et al. 2016). In addition, Rautian et al. (2000) described a new subspecies, *B. b. montanus*, based on specimens from the hybrid population of European bison and American bison in the Caucasian State Nature Reserve, Russia. However, the description has not been accepted as rational act by other scholars.

Lowland and Caucasian bison exhibit numerous morphological differences, which make them diagnostically different from each other (e.g., Zukowsky 1924, Pfizenmayer 1929, Kulagin 1940, Flerov 1979, Groves, Grubb 2011). Current genetic studies did not recognized their separateness at a species level (e.g., Massilani et al. 2016, for a support at subspecies level see Węcek et al. 2017), the observed morphological differences therefore became formed and fixed over a relatively short time.

Photo courtesy of Serban Calin

3 | HISTORICAL AND GEOGRAPHICAL DISTRIBUTION

3.1 Direct evidence

Bone finds of the Holocene age were traditionally considered a reliable evidence of European bison geographic range. However, discovery of existence of the two forms of European bison in Late Pleistocene and Holocene, and the longer evolutionary history of the species revealed much complex evolution of European bison, and provide an opportunity to reassess distribution records and other available sources of evidence (Soubrier et al. 2016, Wecek et al. 2016, Grange et al. 2018, Hofman-Kamińska et al. 2019). As discussed in Chapter 2 “Evolutionary origin of European bison”, the two phylogenetically distinct forms of European bison include the extant 'wisent' lineage associated with mesic and more wooded environments that gave rise to all European bison living today. The other form was the so-called Clade-X which was apparently associated with cold, open and treeless environments and eventually became extinct during the P/H transition period 12-9 kya. The two forms are readily recognized by aDNA analyses and their ancient range(s) apparently included much of the north-western Palearctic, particularly the area between the Urals, the Caucasus and western Europe. The oldest evidence of European bison belonging to the extant wisent lineage, dated over 50 kya and 20 kya, originate from the Caucasus and Ural Mts., respectively (Soubrier et al. 2016). Dated bones from the rest of Europe, genetically assigned to the extant wisent lineage, are of the Holocene age (see Supplementary data by Soubrier et al. 2016). Bones assigned to Clade X are dated between more than 60 kya and the P/H transition period 12-9 kya (Soubrier et al. 2016, van Loenen et al. 2018).

Although seldom discussed in the literature explicitly, it is obviously the mid Holocene warm period, i.e., Boreal 9.0-7.5 kya + Atlantic 7.5-5 kya, which should be considered the baseline for reconstruction of the Holocene range of European bison. There are several lines of scientific evidence for this. First, the faunal turnover from the Late Pleistocene mammoth steppe community to that of the mesic Holocene was completed, with all glacial megafaunal elements long gone (e.g., Markova et al. 2015, 2019). At the same time, the current climatic and vegetational zonation of Eurasia was established due to increased temperature and humidity. The birch-dominated woody plant communities of the Preboreal (10.3-9.0 kya) were replaced in the Boreal by hazel-pine woodlands and subsequently by complex mixed forest communities as a result of expansion of oak and other broadleaved taxa such as elm, lime and alder. It was during the so-called climatic optimum of the Atlantic period, when the Holocene maximum extent of woodlands and minimum extent of non-forest areas complementarily occurred in Europe. Subsequently, the Subboreal period (5.0-2.5 kya) witnessed expansion of beech and hornbeam, which resulted in remarkable changes in the composition of European forest communities. Importantly, the Subboreal is equivalent to most of the Neolithic, i.e., onset of large scale anthropogenic environmental changes throughout Eurasia.

As shown by multiple aDNA, tooth microwear and stable isotope studies, the extant wisent lineage of European bison readily adapted to gradual Holocene afforestation of the north-western Palearctic. As revealed by isotope analyses of subfossil bone/tooth material, the ecological adaptation to forest habitats included a dietary shift to mixed herbivory, i.e., grazing enhanced with browsing, allowing utilization of the abundant woody plant food base (Hofman-Kamińska et al. 2018, 2019). The preadaptation to fundamental changes in dietary habits (from grazer to mixed feeder), and general lifestyle to more forested habitats, is probably one of the main features that facilitated survival of the European bison into modern times (Hofman-Kamińska et al. 2019). Vice versa, lack of habitat and dietary plasticity in the context of spreading modern human is the possible cause of extinction of the aurochs, which was apparently more widespread and abundant than wisent throughout their overlapping Holocene ranges (Hofman-Kamińska et al. 2019).

Thus far, all lines of evidence suggest that it was the spread of human civilization, not environmental factors, that dove the dynamics of the European bison distribution in (pre) historic mid- to late-Holocene past. However, it has been disputed, whether the mid- to late Holocene range of European bison in the last 9 ky, or earlier distribution, should be considered a baseline for restitution of the species range. Kerley et al. (2011) proposed a refugee species concept based on the ecological shift of European bison to suboptimal forest habitats probably due to coinciding Holocene afforestation, persistent hunting and spread of agriculturists with numerous livestock. The concept of a refugee species itself was generally accepted as there are numerous other candidates of such species that have receded geographically and ecologically (e.g., Kerley et al. 2012, Kaczensky et al. 2017). On the other hand, later claims by Cromsigt et al. (2012) that European bison habitat and range was significantly altered in the early Holocene and even earlier seems rather unsubstantiated by available knowledge. It was argued by Kuemmerle et al. (2012), that it might be reasonable to consider European bison range in the last 8 ky as a baseline for species distribution, because this is the range, where European bison survived alongside human civilization. In fact, there is quite a robust body of evidence, that climatic and vegetation shifts shaped distribution of all three bison forms inhabiting the western Palearctic in the late Pleistocene and Holocene (see Chapter 2). At the same time, there is also solid evidence, that megafaunal species pushed to geographically limited refugia by shifting climates are exceptionally susceptible to human-mediated extinctions (Lorenzen et al. 2011). DNA analyses revealed important refugia of European bison which must have been important for its spread and persistence. These include especially the Caucasian region, where a continuous presence of the wisent lineage is documented from 60 kya until the 20th century. Genetic analyses also suggest another intriguing pattern: not only did the extant wisent lineage inhabit much of the north-western Palearctic and ecologically alternated with two other bison forms, it apparently disappeared during the P/H transition period by receding to yet unidentified refugia. Subsequently, the extant wisent lineage recolonized Europe and possibly parts of western Asia during the mid Holocene, before it disappeared again due to human action (van Loenen et al., unfinished MS published online since 2018). Finally, it should be mentioned, that virtually all authors dealing with paleontological and archaeozoological evidence of European bison highlight that numerous wisent finds probably remain unrecognized due to their close similarity to aurochs and/or cattle bones.

3.2 Indirect evidence

The two large bovines of Europe were notoriously misidentified throughout the continent since antiquity. It was possibly the Roman naturalist, Pliny the Elder in his Naturalis Historia in the 1st century AD, who listed and correctly distinguished between the two species, European bison and aurochs, referring to them as "iubatos bisontes" and "velocitate uros", respectively. Interestingly, the scarce (but correct) information by Pliny was countlessly recycled, but completely misinterpreted for the following 15 (sic) centuries (Kyselý and Meduna 2009). Most authors merely compiled written (dis)information by other authors, including errors and fictitious inventions. During the middle ages, numerous names for the European bison and aurochs from different languages were introduced to the literature and mistakes were commonplace, especially in the west of Europe. The same names were used for aurochs or European bison by various authors, both species were sometimes hidden under one name, the two species were commonly mistaken for each other, considered the same kind of animal, or any combination of these. For example, one of the most competent medieval naturalists, Thomas Cantimpratensis (13th century), apparently uses eight different names for both species! Nomenclature was similarly varied and confused in countless official documents and chronicles, in which large bovines are mentioned throughout the middle ages. The resulting confusion even led to the emergence of imaginary types of wild cattle in the scientific literature, i.e., white Scottish bison "Bison albus Scoticus." It was not until the second half of the 16th century, when two Swiss authors, Siegmund von Herberstein and Conrad Gessner, almost concurrently properly distinguished the European bison and aurochs again. In conclusion, during the first 1.5 millennia A.D., the knowledge on and recognition of large bovines of Europe made a great loop from well informed authors of antiquity, across the confusion of medieval literature, to realistic recognition of the two species again from the 16th century onwards (reviewed by Kyselý and Meduna 2009). Unfortunately, this re-recognition of the European bovines came too late, since by the 16th century the geographic ranges of both species were severely depleted. The European bison was restricted to a few disjunct areas in eastern and south-eastern Europe, while the last small aurochs herd hung on the verge of extinction in a single royal hunting ground in Poland, and eventually became extinct in 1627 (Rokosz 1995). For this reason, the only reliable written records of European bison come from the 15-20th century

Russian empire and the kingdoms of Poland and Lithuania, where the last wisent populations dwindled gradually towards the 20th century. The most comprehensive account of the written wisent records from this period/region was provided by Heptner et al. (1988) for the area of the former Soviet Union.

3.3 Setting the baseline(s) for range reconstruction

Obviously, the two views on European bison range, i.e., a climate-driven (+ humans?) range in Late Pleistocene, versus the mid- to late Holocene human-driven range and extinction of European bison, do not exclude each other and both should be considered. The Pleistocene and early Holocene range informs us about a remarkable potential for European bison to inhabit a much wider array of both non-forest and forest habitats and a much larger geographic area than traditionally acknowledged (see below). This Late Pleistocene distribution implies the potential range to which the species could have recolonize the north-western Palearctic after the turbulent P/H transition if it was not impacted by the presence of modern human. On the other hand, the mid- to late Holocene refugee range shows the great adaptability of the species to suboptimal forest habitats with rather limited grazing opportunities and its readiness to survive alongside human civilization. Importantly, there is a considerable body of evidence, that the mid- and late Holocene geographic range definitely was not limited to forests, but included much of the forest steppe and even steppe zone of East Europe (Figure 3.1). This steppe and forest steppe part of the range was repeatedly highlighted by some authors (see Heptner et al. 1988), but because of scarcity of available records was not taken into consideration by others (e.g., Kuemmerle et al. 2012). See also Chapter 5.1.

It is reasonable to conclude, that both the Late Pleistocene and Holocene ranges of the extant wisent lineage of European bison should inform conservation practice and restitution of the species. Existence of the former refugia (e.g., now extralimital Urals), the widespread presence in neglected parts of its former range (see below), and the adaptability of the species should be utilized when identifying sites for re-establishment of European bison within its (pre)historic range. Obviously, sticking to a particular period or ecoregion would hamper restitution of European bison (as shown by common practice during the 20th century when the species was erroneously strictly associated with and repatriated to forests). This recommendation is of special importance now, during the climatic and environmental changes being experienced by the World in the Anthropocene.

As shown in this chapter, the European bison clearly was not limited by terrain or elevation whenever the food base and absent/relaxed hunting allowed its occurrence. From a scientific point of view, it is the extant wisent clade of European bison that recolonized Europe after the P/H transition period, identity, geographic range and habitat requirements of which is the most relevant baseline for current and future restitution of wisent as a species. In addition, it might be legitimate to include the ceased wisent range in the Urals region in restitution attempts.

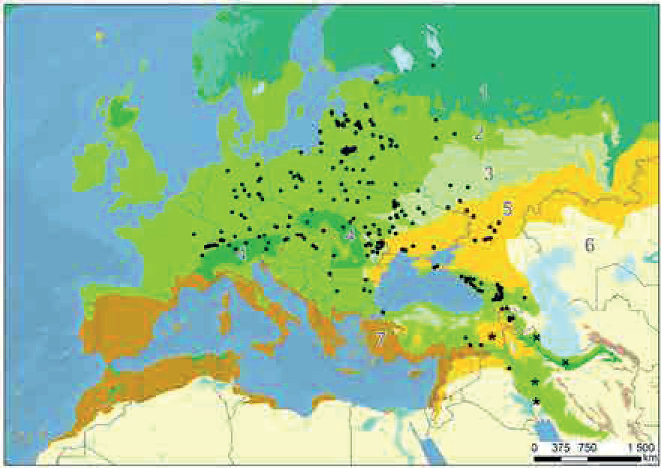

Figure 3.1. Bone and reliable written records of European bison from mid - and late Holocene (= last 9 ky) in north-western Palearctic. Asterisks indicate origin of some Sumerian artefacts decorated with wisent depictions, crosses show Talysh and Elborz Mts. where unconfirmed reports on “wild forest cattle/bulls” existed from 18th century and earlier times. Topographic map shows biomes according to Ecoregions 2017 © https://ecoregions2017.appspot.com/. Numbers indicate relevant biomes and the forest steppe transition ecoregion: 1. Boreal Forests/Taiga, 2. Temperate Broadleaf & Mixed Forests, 3. East European forest steppe ecoregion, 4. Temperate Conifer Forests (Alps and Carpathians), 5. Temperate Grasslands, Savannas & Shrublands, 6. Deserts & Xeric Shrublands, 7. Mediterranean Forests, Woodlands & Scrub

3.4 Elevational range

Concerning altitudinal range, European bison finds are known from sea level in the Baltic region up above the tree line well into the alpine zone of the Caucasus and the Alps. As stated by Bauer (2001) for the Austrian Alps: "The accumulation of the discovery points (of European bison) in the Styrian, Lower and Upper Austrian Limestone Alps is due to the large number of shaft traps acting as animal traps in the plateau karst, and probably does not indicate a concentrated distribution of European bison there. The discovery (of European bison bones) in the Wilder Loch at 1,800 m a.s.l. on the 1870 m high Mt. Grebenzen, an isolated karst stick in the middle of the crystalline region of the Central Alps, makes it clear that the species also climbed high into the mountains." Three radio-carbon dated finds from between AD 410-780 from the shaft caves in the forest-alpine border region of Totes Gebirge, Hochschwab and Grebenzen, indicate the wide occurrence of wisents in high Alps during the early Middle Ages, when the region was still little affected by human activity (Bauer 2001). In the Caucasus, occurrence of wisents in the 19th and early 20th century was reportedly most common between 900-2,100 m a.s.l., with sightings both in lower and higher elevations. Heptner et al. (1988) reported wisent occurrence in high elevations as follows: "Tracks (of European bison) were detected in the mountains at heights of over 2,100 m even in steep places, a few kilometres away from the forest; in the upper reaches of the Abago (Beloe basin) wisent tracks and faeces were discovered at a place under a high mound of snow in summer (cca. 2,500 m a.s.l. in Sanchar pass). Wisent tracks were invariably detected on lower alpine meadows in summer."

3.5 Ecoregions inhabited by European bison

The European bison has been long considered a forest specialist associated with temperate broadleaved and mixed forests of Europe (Pucek et al. 2003). Obviously, the putative affinity of European bison to forests is rather a misinterpretation given by the refugee nature of the species historical range being limited to large uninhabited forests. Currently, the closed forest habitats are being considered suboptimal for this mixed feeder that require grazing opportunities. In fact, the affinity of European bison to forest habitats was repeatedly disputed based on numerous historical records of its occurrence as well as direct evidence, for example Heptner et al. (1988, translated from Russian original published 1961): "...it was firmly believed until recently, in spite of objections (Koppen, 1883), that the European bison was an inhabitant of dense, tall, even wet forests. This view is incorrect. It arose as a result of observations on animals living in Białowieska Forest, which turned out to be the last refuge of a dying species driven by human persecution to conditions that were not only (sub)optimal for them, but even unfavourable. As shown by new ecological data, the results of studies on re-acclimatization, and information available on the former distribution of wisent, sparse deciduous forests with glades and open expanses, forest-steppes and even steppes with bottomland deciduous forests, and forests in catchment areas represent the normal habitats conducive for their survival. "

As shown in Figure 3.2, the mid- to late Holocene range of European bison included wide array of ecoregions from the temperate grasslands, savannahs and shrublands of the Pontic steppe region, across temperate broadleaf, mixed and conifer forests of western, central and eastern Europe, to the south-western margins of the great boreal forest/taiga belt. On the other hand, there seem to be no records from the Mediterranean forests, woodlands and scrub, or from the Caspian deserts and xeric shrubland, possibly indicating avoidance of the sclerophyllous evergreen vegetation and arid regions, respectively.

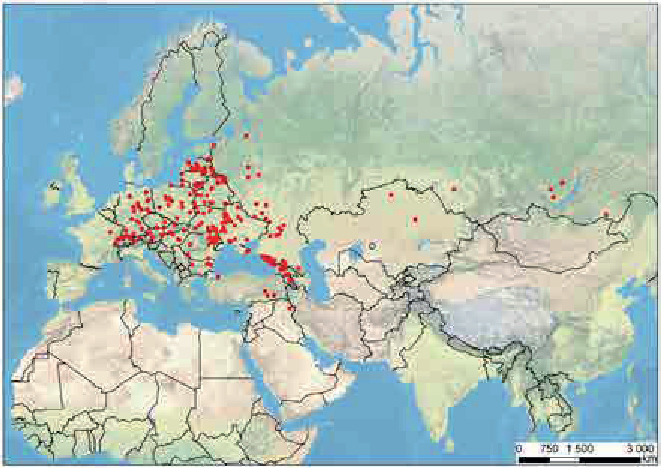

Figure 3.2. Mid- to late Holocene range of *Bison* spp. in Eurasia. Note that the records in Europe and the Middle East refer to European bison (*B. bonasus*), while those in Central Asia and southern Siberia probably refer to relic populations of the steppe bison (*B. priscus*); the two bison forms were separated by an arid semidesert region avoided by both species.

3.6 Reconstruction of the historical geographic range of European bison

According to available evidence, the extant European bison, i.e., wisent lineage, is a near-endemic of Europe, marginally penetrating (pre)historically beyond the Caucasus main range into Asia. The continuous mid - to late Holocene distribution range is well documented by osteological evidence and reliable historic written records, which spans from present-day mid-eastern France (Plateau de Langres), Switzerland and Germany in the west, throughout the whole of Central and East Europe north and east of the Alps and north of the Balkan Mts. as far east as Don basin, Caspian depression and both Greater and Lesser Caucasus ranges. In the north, wisent occurred throughout the Baltics up to the southern shore of the Gulf of Finland. Although the eastern limit of the wisent's range remains unclear, available evidence indicates its course along the line connecting the west coast of the Caspian Sea in the south, the region of Moscow in the centre and Lake Onega in the north. Markova et al. (2015) provide the most northerly wisent record, a radiocarbon dated skull (3 kya), from Oyat' River, Vologda province in Russia (60.416, 35.317). As noted by various authors, the presence of European bison farther north was probably hampered by prolonged deep snow cover in winter (Heptner et al. 1988, Pucek et al. 2003). Although not confirmed by bone finds, the presence of European bison is virtually certain in regions such as the high Italian Alps, Julian Alps in Slovenia, the Serbian part of the Balkan Mts. and other regions directly connected to areas in which European bison presence was proven (compare Figure 3.2).

Evidence of European bison in the Iberian Peninsula remains unconfirmed. However, rich Pleistocene material of *Bison* bones found throughout the Iberian region, in the well-recognized glacial refugium indirectly radiocarbon dated to Preboreal (9.5 kya), Boreal (8 kya) and Atlantic (7.6-4.9 kya), was routinely assigned to *B. priscus* but has never been subjected to DNA analyses, leaving the question open. Nevertheless, this implies the possible role of the Cantabrian Atlantic sub province as a long-term refugium of extant wisent lineage during the Pleistocene cold dry periods. Therefore, the Iberian bones of European bison deserve special attention and should be subjected to direct radiocarbon dating and genetic analyses.

All records of European bison from the Balkan Peninsula are limited to the Balkan Mts. (Stara Planina) and the Danube valley. Multiple records from higher elevations of the western (Mt. Ponor) and north-eastern foothills of the Balkan Mts., imply its distribution from the deep mountainous interior up to the Black Sea coast (Benecke 2005, Hofman-Kamińska et al. 2019). Otherwise, there seem to be no Late Pleistocene and Holocene European bison finds from the Balkan Peninsula south and west of the Balkan Mts. However, its striking absence in the Balkan interior might be in part be of an artificial nature, an assumption supported by a recent find of a European bison skull from Byzantine period (7-8 century AD) in the Istanbul area (Onar et al. 2017). Although this important finding implies possible wisent presence in more southerly parts of the Balkans, it might have been imported to this ancient trading centre from elsewhere.

In Scandinavia, relatively numerous bone finds confirm early Holocene colonization of Jutland and the southern part of what is now the Scandinavian Peninsula by European bison, shortly after deglaciation. All Holocene European bison bones from South Sweden and Denmark originate from the P/H transition period. Danish records were dated to Preboreal while direct radiocarbon dating of bones from South Sweden confirmed wisent presence between 9.5-8.7 ky BP, i.e., during the Late Preboreal to the Early Boreal (Benecke 2005). All wisent bones analysed genetically to date assigned the early Holocene Scandinavian population to the extinct Clade X. Obviously, the population in the southern part of the Scandinavian Peninsula became isolated from the mainland after the formation of the Baltic Sea that occurred about 9.5 ky BP. The population apparently disappeared shortly after, possibly due to gradual afforestation and an increasing human population in the region. Subsequent recolonization and replacement of the Clade X by the extant wisent lineage that occurred elsewhere in the Europe was effectively prohibited by the Baltic Sea and no confirmed mid or late Holocene wisent records exist from Scandinavia.

Mid- to late Holocene bison finds from the Lake Baikal area (from as old as 8.3 kya to as recent as 10th century!) and from the Irtysh and Ob basins north-west from the Altai Mts. (5-3 kya) most probably refer to relic populations of the steppe bison (*B. priscus*) confined at that time to a few forest steppe refugia of southern Siberia and even northern parts of the central Asian zonal steppes (Figure 3, see also Markova et al. 2015).

3.7 Caucasian bison hotspot

According to paleontological and archaeozoological evidence, the Caucasian region was of paramount importance for the persistence and dispersal of all three bison forms found in the western Palearctic, all of which occurred and/or co-occurred here in late the Pleistocene and early Holocene. Accordingly, the extant wisent clade of European bison has the longest and most continuous record in the Caucasus, spanning over the last 60 ky. Mid- to late Holocene bone finds imply wisent occurrence throughout the Greater and Lesser Caucasus, Transcaucasia, and possibly beyond (see below). Historical written information refers mostly to the 18-20th centuries. In the 18th century, the wisent range in the Caucasus encompassed the forest zone on the northern slope of the main range and its foothills ("Chernye gory") from its western extremity in the region south of Krasnodar to at least North Ossetia-Alania in the east, as well as the southern slopes of the main range in Abkhazia. Written evidence shows a rapid reduction of the wisent's range. By the late 19th and early 20th century, wisents were preserved only in the upper Kuban basin in the present Caucasian preserve formerly set aside for royal hunts. In 1919, the wisent population in Białowieska forest in the Poland/Russian borderland, disappeared as a result of World War I, and the Caucasian wisent herd became the last wild population in the world. Unfortunately, the last of the Caucasian wisents were killed there by poachers in 1926 and the species became extinct in the wild (Vereshchagin 1967).

3.8 The forest/open space species issue

There is inconsistency in the literature concerning historical habitat preferences of European bison. For the whole of the 20th century, mainstream literature presented European bison as a forest specialist (e.g., Pucek et al. 2003). Also, some contemporary authors claimed that none of the European bison occurrences, used by them for reconstruction of historic wisent range, occurred in steppe areas, although their own analyses do not really support this claim (Kuemmerle et al. 2012a, b). However, other authors, both old and recent, repeatedly disputed the view of the European bison as a forest dweller (e.g., Koppen 1883, Heptner et al. 1988, Kerley et al. 2011). Written records from high Medieval and the modern era Russian empire are of special importance, because eastern Europe was the last region where European bison were not restricted to forest refugia only. In fact, the broad distribution of European bison there and then in both forest and forest-steppe regions shows the remarkable habitat amplitude of the species. Heptner et al. (1988) collected the most comprehensive, largely referenced, account of historic written records of wisent in the former Russian Empire and later Soviet Union. They refer to multiple historic reports explicitly mentioning the presence of European bison throughout the Ukrainian and Russian Pontic steppe and forest-steppe zone north of the Black Sea and the Caucasus Mts., providing the following conclusion: “Even in the sixteenth and seventeenth centuries, wisent were distributed in the Russian forest-steppes from the Dnestr to the Don and were reported at places even in the steppe zone”. These included Ochakiv steppe (referred to as Ochakov) on the Black Sea coast in south-west Ukraine in the 16th century, the Ukrainian lower Don (referred to as Don Cossack lands), Russian Belgorod and the Voronezh districts (oblasts) and Moldavia between the 16th and the beginning of 18th centuries. The authors also mention indications of wisent extinction in the Voronezh district and along the Dnieper River around 1800. Included among the records is even a capture of live wisent in the Budyonnovsk steppe (referred to as Prikumsk) in the western part of the Caspian depression in mid 19th century. Concerning the forest zone of the former Soviet Union, Heptner et al. (1988) mentions wisent presence in the Carpathians and Lithuania in the 12th century and in Ukrainian Volynya in the early 15th century and 16th century, and later, an abundant wisent population in the Białowieska Forest (much bigger at that time) spreading from the current-day tri-national Ukrainian-Polish-Belarussian border region all the way to Lithuania.

3.9 Historical abundance

The European bison is considered not particularly numerous according to the relatively low frequency and number of bones in archaeological and paleontological sites (Benecke 2005). Although there are generally few historical reports that allow a gross estimation of wisent abundance, there are a few anecdotal notes implying that large herds might have existed in some places. While highlighting the abundance of wisent in the Białowieska forest in 15-17th century, Heptner et al. (1988) note that “The extent to which they (European bison) were common in these groves can be judged from the fact that all of the 36 divisions into which Perestunsk Forest was divided were based on wisent populations,”. Elsewhere, the same authors mention that “In Volynya in the early 15th century, wisent were so common that every week about 100 were killed as entertainment by participants to the royal conference convened by Vitovt in 1431." At another place, the authors provide another interesting note related to abundance: "...animals (European bison) interfered with the patrol service of the border regions of Barsk organized by village elders, since they obliterated tracks of Tatar horsemen who were infiltrating the area." Concerning the last wild populations of European bison, an estimation exists of 2,000 wisents in the Caucasus at the end of 19th century (Heptner et al. 1988), while official accounts report 729 animals in the Białowieska forest in 1915, just after the onset of World War I (Pucek 1991, 1994).

3.10 Neglected wisent of Middle East

Apart from the widely accepted (pre)historical range between France or Iberia and the Volga River, there are indications of probable mid - to late Holocene bison occurrence outside this traditionally more or less recognized wisent range. There are remarkably numerous indices of European bison occurrence especially from the Middle East. These include artefacts depicting bison from Turkey, Iran and Iraq, reported wisent bones which were not subject to thorough examination by modern methods (Jarmo in Iraq, Anatolia in Turkey) as well as vague written records of the occurrence of unspecified big bovines in the Elborz and Talysh mountains in north Iran and Azerbaijan (Hatt 1959, Heptner et al. 1988, Uerpmann 1987). The Middle East remains the most neglected and least understood part of the wisent geographic range. As stated by Uerpmann (1987): "Early pictorial representations of the wisent from the Middle East suggested its ancient occurrence before any osteological evidence was found in that area. ... One can be almost certain that some wisent specimens are hidden among bone remains more or less tentatively identified as *Bos primigenius*. Therefore, the wisent bones described from Jarmo and ... Keban dam area may only be the tip of the iceberg". To date, bone finds of European bison were reported from at least four Neolithic (9-2 kya) or later localities in north-east Iraq (Jarmo) and south-east Turkey (Norsuntepe, Körtepe and Tepecik, Uerpmann 1987). All the putative wisent bones from these locations were parts of mammal assemblages from Neolithic sites representing combination of northern temperate Palearctic faunal elements such as aurochs, roe and red deer, wild boar and wild horse, and southern Palearctic taxa like wild ass, gazelles and wild sheep/goat (Uerpmann 1987). Importantly, being known to historians/archaeologists but long neglected by zoologists, there are a surprisingly large number of ancient artefacts from the Middle East displaying wisent. These include for example pots, plates and statuettes from 2nd and 3rd millennium BC from Turkey (Lake Van), Iraq (e.g., Al Ubaid, Diyala, Uruk), and Iran (e.g., Tepe Giyan, Susa), some of them preserved in collections of the British Museum in London and the Louvre in Paris. The number and variety of wisent-decorated items and their broad geographic distribution in the region are remarkable. Of particular interest is the striking anatomical detail and correctness of the depictions implying that the artists were familiar with the species, probably based on direct observations of live animals, and they obviously distinguished it from aurochs/cattle (Figure 3.3).

Figure 3.3. Artefacts with wisent representations from the Middle East. Left – solid copper Sumerian bison (right horn is missing), found near Lake Van, Turkey, 2.3 ky BC, British Museum, CC BY-NC-SA 4.0. Right - Mesopotamian marble bison statuette, note the depression for placement of a horn (possibly made of a different material?) in front of the ear, 3rd millennium BC, The Metropolitan Museum of Art, New York, Public Domain CC0 1.0.

From the bioclimatic point of view, locations of Middle East wisent bones and artefacts mostly originate from seasonally dry or mesic highlands at the northern and eastern fringes of the Fertile Crescent and only marginally from its arid lowlands (Figure 3.1). Occurrence of the wisent in lowland (semi)deserts of the region is extremely unlikely, especially in the context of mid-Holocene desertification of the region (Weiss et al. 1993). On the other hand, its presence might be possible in the highlands within the ecoregions of the Eastern Anatolian and Zagros Mountains forest and forest steppe oak-pistachio woodlands from where majority of the Near East records originate.

4 | BIOLOGY AND POPULATION ECOLOGY

4.1 Physical features and senses

European bison are the largest, terrestrial mammals in contemporary Europe. Their body weight may exceed 900 kg in males and 650 kg in females. The height at the withers of adult individuals ranges between 150 - 190 cm, and total body length between 240 - 300 cm. Adult bulls develop an obvious hump that makes their silhouette markedly distinct from cows (Krasińska et al. 2014). Determination of the sex of European bison from a distance is possible on the basis of its silhouette, body size, and the size/shape of the horns. Also, the age of an individual can be determined by the dimensions of the body and shape of the horns. Horns of two-month-old calves are already about 2 cm long. Up to the age of 12 months it is not possible to determine the sex of an individual on the basis of horn dimensions. At the age of two years, males' horns are becoming markedly larger than females. After the third year of life, differences in the the shape of the horns between males and females are already distinct. Adult bulls have longer, thicker and more widely set horns than cows, however the curvature is much more pronounced in females (Krasińska, Krasiński 2007, Perzanowski et al. 2015).

At post mortem or in tranquilised animals, the age can be determined by reference to the teeth pattern. Full formation of deciduous teeth takes until the 6th month of life. Twelve-month-old individuals have 8 deciduous teeth in the mandible. At the age of four years, European bison have a full set of permanent teeth (Węgrzyn, Serwatka 1984). The crowns of the incisors in old individuals are severely worn – only slightly protruding beyond the gum line. Incisors become more worn in bulls than in cows (Wróblewski 1927). Precise age of an individual may also be determined through the count of annual rings of cement in microtome-sliced sections of a tooth (Klevezal, Pucek 1987).

The coat of adult animals may vary between tawny and dark brown, while calves before the first change of fur are reddish brown. The hair at the head, neck and front of the body is longer and that below the lower jaw, forms the so called "beard". Adult animals begin to moult usually at the beginning of March and this process may continue until summer (Krasińska, Krasiński 2007). Sounds emitted by European bison are described as a "grunt", and are given out by both sexes: cows communicating with calves and bulls during the rut. Also, calves call their mothers with grunts for feeding. Bulls however produce lower and hoarser calls than those of cows. The hearing of European bison is excellent, though their ears are small, and scarcely protrude from the fur. They have a well-developed sense of smell. Males follow females during the rut, smelling their tracks on the ground. Also, animals that are temporarily separated from the group, use this sense to detect and re-join their counterparts.

European bison do not have very good eyesight, and are more likely to notice moving objects than, for example, people standing still amongst trees. Their eyes are relatively small, set in protruding eye sockets directed to the sides. Their bony rims protect the eyes against damages from tree branches during movements through dense vegetation. European bison have well developed spinal processes of the thoracic vertebrae supporting strong muscles holding their massive skull. They have 14 pairs of ribs - one more than domestic cattle (Krasiński, 1993, Krasińska et al. 2014, Krasińska, Krasiński 2017). Footprints of the European bison are similar to those of cattle and moose. Their front hooves leave larger footprints than those of their hind legs. They are able to run fairly fast, especially when scared or making a charge towards a threat, but only for a short distance. Usually after a few hundred meters they become overheated, have to make a stop and relax for a while. An adult bull is able to jump over a 2m fence (Krasińska, Krasiński 2007).

4.2 Ecology

Systematic, long term studies on European bison ecology have so far been conducted only for populations of the Białowieska Forest and Bieszczady Mountains (Krasińska, Krasiński 2017, Marszałek, Perzanowski 2018). Data on other populations are irregular, and often limited to single seasons, which makes it difficult to extrapolate available data to the whole range of living conditions and variety of habitats inhabited by this species.

4.2.1 Social organization

European bison are a gregarious species, so for most of the time, a majority of animals remains in various social units. Basic units are mixed and bull groups. Mixed groups are composed of cows, immature animals 2-3 years old, and calves. In Białowieska Forest the mean size of mixed groups is 13 individuals (in winter maximum recorded 92), while in Belarus - larger groups were observed (21 on average, maximum 120). Such large aggregations are mostly connected with sites where supplementary feeding is provided. However mixed groups of up to 20 animals are the most common. Bulls up to four years old may join both: mixed and bull groups. Young, sexually mature bulls (4-5 years) form bachelor groups usually of several individuals. Bulls over six years of age often stay in pairs or remain solitary (Krasińska, Krasiński 2007, Żoch 2007, Kozlo Bunevich 2009). The age/sex structure of free-ranging populations of European bison is usually determined on the basis of four categories that are possible to distinguish in field conditions: adult bulls and cows (four years old and older), 2-3-year-old adolescents, and calves up to one year old. The largest in the world, wild population of Białowieska Forest, consisted on average of 25% adult bulls, 37% adult cows, 2.5% adolescents, and 15.5% calves (Krasińska et al. 2014).

The structure of the largest mountain population that of Bieszczady was as follows: bulls 38%, cows 48% and calves 13%. The most frequently observed were groups of between 3-10 individuals (up to 64.3% of all observations). Also frequently recorded were groups of 11 – 20 individuals (up to 32.1% of all observations). Thus, even over 90% of all observed groups could were of up to 20 animals, similarly to observations of lowland populations. Solitary individuals were recorded in 3.6 -24.5% of all observations. Moreover, relatively high rotation of animals among groups was observed during the whole year (Perzanowski et al. 2005). Groups of bulls are also not stable, in the pre-rut season animals are very active, but their home ranges are smaller than in the rutting season. The proportion of solitary males increases during the rut, as bulls then tend to disperse, while searching for receptive cows (Krasińska et al. 2014).

4.2.2 Life span and reproduction

In captivity, females may survive over 30 years, while males only up to 20 although this is rare (Koch 1956, Krasińska, Krasiński 2007). In free-ranging populations, the oldest known female reached her 24th year of life, comparing to 18 years recorded for bulls. Natural mortality in free-ranging populations is fairly low (the coefficient of mortality does not exceed several percent). Apart from constraints connected with age, recorded cases of natural death were as a result of fights among bulls in the rut, animals being killed by falling trees, calves being trampled by adult individuals or animals dying due to diseases or parasites. Generally, in few cases so far, European bison were killed by predators (brown bears and wolves) or poached, however in some populations (e.g., in Ukraine) poaching used to be a serious problem. Although fairly rare (i.e., in Poland several per year), road traffic accidents involving this species occur, but their frequency is growing with the increase of wisent population density. This applies especially to the ranges of wild wisent populations that are intersected by or adjacent to major highways, for example West Pomerania (Perzanowski et al. 2014, Smagol 2016, Smagol, Gavris, 2016, Kaczor, Perzanowski 2017).

In captive conditions, males may reach sexual maturity at the age of 15-20 months, although this is very rare, however in free-ranging populations, their sexual activity starts between 3-4 years of life (Zablockij 1949, Mohr 1952, Jaczewski 1958, Czykier et al. 1999). Females may become pregnant at the age of between 24 and 28 months, but they are most often first mated in the 3rd year of life. Therefore, first calving usually happens in their fourth year (Jaczewski 1958, Krasiński, Raczyński 1967, Krasiński 1978, Belousova 1986). In captivity, females sometimes remain fertile until the age of 20 years. In free-ranging populations and semi-free herds, they are usually calving every second year. Cows are the most fecund between 5-13 years of life. On average, a cow produces 7-9 calves in a lifetime. The coefficient of births (the ratio of the number of calves to the total population) was estimated at 14 - 17% (ranging between 5 and 35%), while the coefficient of fecundity (the ratio of the number of calves to the number of reproductive cows) assessed for the population of Białowieska Forest was 40-50% (Krasiński Raczyński, 1967, Krasiński 1978, Bunevich, Kochko 1988, Bunevich 1999, Pucek et al. 2004, Krasińska, Krasiński 2007, Kozlo, Bunevich 2009, Daleszczyk 2011).

The rut of European bison lasts mostly from August to October, however cows in the wild may be receptive from July to November – December, while in captivity up to February. (Kiseleva 1974, Krasiński 1978, Caboń-Raczyńska et al. 1983). Oestrus lasts for one to three days. Females that are not impregnated often display repeated oestrus at intervals of about 20 days (Krasiński, Raczyński 1967). An ultimate proof that a female is in oestrus is her readiness to be covered by a bull. During the rut, a bull accompanies a cow for 1-2 days, only occasionally allowing himself to eat or rest. Before copulation, the bull tries to separate a receptive female from the herd (Krasiński, Raczyński 1967, Krasiński 1978, Caboń-Raczyńska et al. 1987). Females as a rule, give birth to a single calf. Twins were observed only occasionally. Usually the sex ratio of new-born is 1:1, but in years

2003-2011 it was observed that there was a significantly higher percentage of females born in Białowieża herd. According to various authors, the period of gestation lasts between 254-279 days (Jaczewski 1958, Krasiński, Raczyński 1967, Kiseleva 1974, Krasińska, Krasiński 2017). It is difficult to recognise the pregnancy on the basis of visual observations, so exact determination of its progress is not easy to ascertain until close to the birth. Parturition takes place over 1 - 3.5 hours (Daleszczyk, Krasiński 2001, Zięba 2007).

Calves are most often are born in late spring. The peak of calving occurs in May - July. Occasionally, especially in captivity, calves may be born late up to December. About 3% of captive births were recorded between January and March in captivity while in free roaming herds there were none. At birth, male weight on average 28 kg (16-35) while females only 24 kg (15-33) (Koch 1956, Krasiński, Raczyński 1967, Kiseleva 1969, 1974, Belousova 1986). A cow just before calving, sometimes accompanied by fellow female(s), leaves the herd to deliver the calf in a safe place. After several days the mother with calf re-join the herd. During first three months, calves raised in captivity suckle for 5 -7 minutes at time. In free-ranging populations, calves up to three months old suck for 2-6 minutes frequently. Older young, feed for 4-19 minutes but less frequently. Calves may suck beyond the age of one year. Usually, suckling ends in spring, with the arrival of the next calf, but non pregnant cows, may continue nursing until October (Caboń-Raczyńska et al. 1987, Daleszczyk 2002, 2004, Krasińska et al. 2014). Body mass of males increases proportionally with age until they become seven years old, while females grow until five years of age. Until the end of the second year, the body mass does not differ significantly between males and females (Krasińska, Krasiński 2002).

4.2.3 Activity patterns

The daily activity rhythm of European bison consists of three phases: feeding, resting and movements. Resting is when rumination occurs. In the vegetative season, feeding makes up about 60% of daily activity. Some 30% of the time remains for resting, and about 10% for movements not connected with feeding (Korochkina 1972, Caboń-Raczyńska et al. 1983, 1987). Summer activity of all members of a group is well synchronised. In winter though, there is little synchronicity in activity among herd members. The most highly-synchronised winter activities are: resting and walking to watering places (Caboń-Raczyńska et al. 1983). Generally, two periods of rest are observed in this season: in the evening between 18:00 and 21:00, and again between midnight and the early hours of the morning. In winter, rumination takes 10-22% of the diurnal time budget. When supplemental food is provided in winter, the feeding pattern of European bison is significantly affected as they tend to stay around the feeding sites. Feeding on permanently available hay may occupy some 30% of a day, while resting takes up 60% of the remaining time. Provision of forage at permanent feeding points, causes an aggregation of animals around such sites. During snowless winters however, European bison do not feed much upon the supplemental food, and apart from food available at forest floor, consume browse and tree bark (Caboń-Raczyńska et al. 1983, 1987, Rouys 2000, Krasińska and Krasiński 2007, Kowalczyk et al. 2011).

Aggressive behaviour is rare among cows, adolescents, and calves. Antagonistic interactions between adult bulls are however observed quite frequently, as well as those by dominant bulls toward younger rivals. Nevertheless, fights between bulls during the rut, are witnessed only rarely, because the probability for males of the same size and strength, to enter into a direct contact, is


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low. The reaction of European bison to predators was so far been rarely observed. A few cases of bear attacks were reported from the Caucasus, eastern Carpathians (Ukraine) and Bieszczady Mts (Poland). In the population of Bieszczady, wolves approaching a herd - was observed several times. European bison reacted by gathering closely together, with calves in the centre of the group surrounded by adult animals. The group kept facing the wolves until they gave up and left. Few records exist of calves being left behind in a deep snow and subsequently being eaten by wolves (Krasińska, Krasiński 2007; Paszkiewicz 2008; Perzanowski et al. 2014, Kaczor, Perzanowski 2017).

4.2.4 Movements

Long distance movements of males are usually unidirectional and apparently are not driven by abundance nor availability of food resources. Hence, most long-distance movements of males are probably of an exploratory nature. Such movements are usually one-way. The longest single recorded movement was that of a solitary bull, that in 1981, left the area of the Bieszczady Mts and moved off in a northerly direction over a distance of 700 km. According to the data from Białowieska Forest, most frequent visits to agricultural lands are by lone bulls (50% of observations). The average distance of such movements was 2.0 ± 3.9 km (range: 0.1 to 33.9 km) from the forest edge (Baker 1978, Krasińska et. al. 2014). Movements of mixed groups (cows with young and immature males), are related to the abundance and availability of food resources. The average distance of mixed groups' movements beyond the boundaries of the forest was 2.4 ± 3.1 km (range: 0.1 to 17.2 km). Animals regularly fed with hay, moved on average 560 m in 24 hours, compared to 860-900 m in the case of animals without access to supplemental feeding (Kowalczyk et al. 2010). Generally, in winter conditions, i.e., with deep snow cover and low temperatures, the mobility of European bison decreases (Krasińska, Krasiński 1994, 1995, Krasińska et al. 2000). In Bieszczady mountains, seasonal movements are observed in late autumn, towards lower valleys, triggered by the arrival of the first snow, and the return to higher elevations usually occurred by late March/early April, synchronised with an increase in temperature. During such movements, animals may cover 10 - 20 km (Paszkiewicz 2004, Perzanowski, Januszczak 2004). In Bieszczady Mts. there were significant negative effects of roads with heavy traffic upon spatial dispersion of European bison, which is more restricted there by an avoidance of busy roads than habitat availability (Ziółkowska et al. 2016, 2017).

4.2.5 Home range

According to the data from Białowieska Forest, the home range of this population did not increase proportionally to population growth. It remained fairly stable during the increase from 50 - 150 individuals (Korochkina, Kochko 1983, Bunevich, Kochko 1988, Krasińska, Krasiński 2007). In the Carpathians (Bieszczady Mts.), the correlation between population numbers and the area of their home range was not high ($r2=0.567$ $p<0.5$) (Perzanowski, Januszczak 2004, Krasińska et al. 2014). However, in one population at Belarus (Volozhinskaya), and the herd at Knyszyńska Forest (north-eastern Poland) considerable expansion of the home range was observed during a relatively low increase in numbers. This phenomenon could be triggered by the rather poor nutritional conditions of those ranges.

The size of winter home ranges estimated for the population of Białowieska Forest ranged in the case of bulls of between 0.8 - 32 km2 (11 km2 on average), and between 0.4-34 km2 (8 km2 on average) in the case of cows. The largest area of a population home range (32-34 km2) coincided with a mild winter. Those figures were much smaller when animals gathered around supplementary feeding sites, presence and intensity of which significantly affects European bison activity. Home ranges of animals regularly (daily) using supplemental food were on average just 3 km2, while less intensively fed animals (1-2 times a week) used 16 km2, and animals not attending feeding sites at all utilised 30 km2 on average (Krasińska et al. 2000, Kowalczyk et al. 2010).

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In vegetative seasons, home ranges of cows in mixed groups averaged 69 km2 (between 45- 97 km2) while those of bulls were 70 km2 on average (29-152 km2). Ranges of bulls 4-6-year-old were 44 km2 on average, while older individuals participating in reproduction were 84 km2 on average (Krasińska et al. 2000). Characteristic for European bison is an intensive use of central parts of their home ranges. Such" core" part of the range estimated for Białowieska Forest, as the area with 95% probability of an individual's occurrence, equalled to about 20% of the whole home range. At the probability level of 50% though, the area of the "core" part was only about 0.5 % of the whole home range area (Kowalczyk 2010). Very similar results were obtained for the population of the Bieszczady Mts (Perzanowski, Januszczak 2004). In a mixed forest-field habitat, (e.g., Knyszyńska Forest, Poland), where forests are dominated by coniferous stands, and resources of ground flora are rather poor, individual home ranges were 130 km2 on average (Kowalczyk 2010). For individuals released in the Bieszczady Mts. estimated individual home ranges varied between 58.7 – 122.6 km2 in winter (average 83.3 km2), and 1.0 – 62.1 km2 (average 26.8 km2) in summer (Perzanowski, Januszczak 2004).

4.2.6 Occupied habitats

In the Holocene, European bison dwelled in a mosaic of semi-open areas and various types of forests (see also Chapter 3). Following the expansion of agriculture, natural habitats of this species become reduced and strongly fragmented (Heptner et al. 1966, Kaplan et al. 2009, Kuemmerle et al. 2011, Kuemmerle et al. 2012). The last natural population of European bison surviving until 1919 in the Białowieska Primeval Forest, preferred mixed and deciduous forests, together with alder woods and alluvial meadows along river valleys crossing the forest (Wróblewski 1927).

Restitution to the wild initiated in 1952, resulted in a number of European bison herds inhabiting various lowland and montane habitats. Lowland herds in Poland and Belarus mostly dwell in mixed/deciduous forests or in forest stands dominated by conifers, but always with a certain proportion of meadows and forest glades. Importantly, forests in these regions have generally well-developed ground vegetation. Wisents in Lithuania, and a population in north-western Poland inhabit mixed forest/field habitat. One herd of the LB line lives in mixed habitats in the foothills of the Altai Mts (Russia). Numerous free-living European bison herds/populations representing the LC line were established in montane regions with a forest/meadow mosaic in Poland, Slovakia, Ukraine and the Caucasus (Northern Ossetia). One herd was established in the southern taiga in the Vologda region, in the north of the European part of Russia (Krasińska et al. 2014).

According to data from Białowieska Forest, habitat selection differs between adult bulls and mixed herds. Adult bulls prefer fresh and moist deciduous forest, and tend to avoid coniferous stands, while mixed groups generally are less discriminating towards conifers, positively selecting deciduous forests, and frequent alder woods proportionally to their availability (Daleszczyk et al. 2007). In other lowland populations, the habitat selection pattern is however different. The herd "Volozhinskaya" (western Belarus), is foraging between spring and midsummer in cultivated meadows close to the forest, and in the autumn - winter period, those animals mostly stay within birch, alder and mixed spruce-deciduous forests because of ground vegetation available there (Shakun 2011). The West-Pomeranian population (north-west Poland) dwelling in a mixed forest-field landscape, with only some 40% of forests within its home range, prefers large scale fields, where they are not disturbed by farmers (Janicka et al. 2008, Tracz et al. 2008). European bison form Knyszyńska Forest (north-eastern Poland), where coniferous stands dominate, leave the forest from late autumn up to the early spring and search for food in cultivated fields (Krasińska, Krasiński 2007). Also, the Lithuanian population intensively forages in fields and managed meadows (Balčiauskas 1999). All this data indicates a very high plasticity of the species towards its habitats.

In the Carpathians, the dominating habitat within European bison ranges is mixed beech-fir forest with a mosaic of grassland patches, situated in areas of low human disturbance. The proportion of cultivated fields is marginal there, and the majority of open areas is composed of meadows or pastures in various stages of secondary succession (Augustyn, Kozak 1997, Winnicki, Zemanek 2009, Kuemmerle et al. 2010). In terms of the use of the mountain terrain, European bison in the Carpathians were in summer mostly recorded at elevations between 550-849 m above sea level (92.9%), while in winter between 450 – 749 m a.s.l. (98.0%). They were not observed at the elevations below 450 m a.s.l in summer and never above 949 m a.s.l. in winter. These seasonal differences are mostly connected with presence and depth of snow cover (Marszałek, Perzanowski 2018).

European bison like domestic cattle are true grazers, so while foraging, they need conditions allowing for the consumption of large quantities of food in a relatively short time. That can be achieved through access to abundant, possibly uniformly distributed vegetation, which typically occurs in grasslands or in some tree stands on the forest floor. Thus, an access to meadows, glades and other open spaces in the forest is so important for this species. It was estimated that the optimal share of open spaces within European bison ranges should be at least 20%. Forest stands with closed canopy are important as hides, and cover during unfavourable weather conditions. Although European bison may lick the snow during winter, nevertheless they require year-round access to drinking water. Except in the Caucasus Mtns, where they can be observed at elevations exceeding 2000m, their ranges rarely reach 1000 m above sea level (Klich, Perzanowski 2012, Krasińska et al. 2014, Marszałek, Perzanowski 2018). European bison use their home range in a rotational way. They forage continuously while slowly moving, following the herd leader (an old cow). The herd makes a loop around its range, returning to the same area in several days or after a few weeks, without remaining in one place for a longer time. Since they tend to graze on the upper parts of ground vegetation, the passage of even a numerous herd does not leave visible signs of its presence. Such an effective foraging pattern makes it possible for the effective regeneration of plant cover (Krasińska et al. 1987, Korochkina 1973, Krasińska, Krasiński 2007).

4.2.7 Foraging and diet

The main food items in the diet of European bison are herbs and grasses. Its alimentary tract is adapted to fibrous fodder, consumed in large amounts, and with little selectivity (Hoffman 1978). Therefore, an access to open areas with grassy vegetation is so essential for the species. Intensity of grazing in open areas (clear-cuts, young plantations, forest glades and meadows) depends on the management system. Typically, mown meadows are used mostly in spring and between August and October. Abandonment of mowing of forest meadows reduces the use of such areas by European bison. Cultivated fields (rape, winter crops) are used frequently in early spring and late autumn. (Daleszczyk et al. 2007, Krasińska, Krasiński 2007, Krasińska et al. 2010).

Food intake of European bison depends on their age: 25-30 (27 kg on average) of fresh food biomass per day in the case of 2-3 year-old animal, and 40-50 (48 kg on average) in the case of 4-5 year old or older animals (Aleksandrov, Golgovskaya 1965, Kalugin 1968, Gębczyńska, Krasińska 1972, Holodova, Belousova 1989). Compared to domestic cattle, European bison are able to more effectively digest food (especially fibrous plant tissues with high contents of lignin), which is its specific adaptation to life in the forest (Gębczyńska et al. 1974). Its natural diet consists of ground flora vegetation: herbs, grasses, sedges, and woody material: browse and tree bark. Approximately, ground vegetation makes up to 80% of a bison's diet, while remaining 20% consists of woody plants (Wróblewski 1927). Therefore, the level of competition for food resources between European bison and deer is low, since their feeding niches do not overlap considerably (Vera 2000). As reported by Hofman-Kamińska et al. (2011), the diet composition of bulls and cows differs significantly during some months, possibly indicating differences in foraging strategies between both sexes.

According to Borowski and Kossak (1972) the diet of European bison in the Białowieska Forest includes 137 plant species, 27 of which were trees and shrubs, 14 grasses and sedges, and 96 forbs. However, according to Jaroszewicz and Pirożnikow (2008), on the basis of of seed identification in faeces, they reported 454 vascular plants of which 409 were herbaceous, and 45 woody species. Tree species significantly important for forestry amounted to 19% of total food intake. The most preferred tree and shrub species there were: hornbeam *Carpinus betulus*, sallow *Salix caprea*, ash *Fraxinus excelsior* and raspberry *Rubus idaeus*. Among grasses and sedges, the most frequently eaten were: rough small-reed *Calamagrostis arundinacea*, wood sedge *Carex sylvatica* and hairy sedge *Carex hirta*. Most often selected herbaceous plants were: ground elder *Aegopodium podagraria*, common nettle *Urtica dioica*, woolly buttercup *Ranunculus lanuginosus* and cabbage thistle *Cirsium oleraceum*. The most intensively debarked trees were: oak *Quercus robur*, hornbeam *Carpinus betulus*, ash *Fraxinus excelsior* and Norway spruce *Picea abies* (Borowski and Kossak 1972). Important for European bison are mast years when they intensively feed on acorns and beech nuts (Paszkiewicz 2004, Mysterud et al. 2007). The proportion of food items in the diet, depends also on their availability (composition of local flora) and weather conditions, especially the depth of snow cover. In winter, the share of browse and tree bark usually increases, while in mountains, a very important food component in winter is the winter green leaves of brambles (*Rubus* spp.), a standing crop of which may reach even several hundred kg per ha (Shakun 2011, Marszałek, Perzanowski 2018).

In Białowieska Forest, the most intensively browsed species was oak (60% of trees belonging to this genus were damaged), followed by ash (46%), lime (42%) and hornbeam (32%). The least intensively browsed were: spruce, birch and alder (Dackiewicz 2000). Cut down aspen trees, lying on the ground, were browsed and debarked in 100% of cases. Intensive debarking of young ash trees around supplemental feeding points was also observed in the Bieszczady Mts, browsing of woody species there was much less intensive than that of red deer (Baraniewicz, Perzanowski 2015, Marszałek, Perzanowski 2018). In winter, European bison living in the vicinity of cultivated fields search for winter cereals and rape hidden under the snow. In north eastern Poland, 50-76% of all damages occurred to cereals, some 13% of rape, and up to 35% of hay left in stacks for winter in the meadows. In the Bieszczady Mts., a majority of damages was of cultivated trees, while damage to cereals was marginal (Hofman 2008, Hofman-Kamińska, Kowalczyk 2010, Marszałek, Perzanowski 2018).

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5 | HABITAT SUITABILITY

What constitutes a suitable habitat for European bison is a key question for the species' conservation. Answering this question is more difficult than it may seem at first, because habitat selection of only a few extant subpopulations has been rigorously evaluated (Krasińska et al., 2014). Moreover, many extant populations are managed to various extents (e.g., supplementary feeding during winter, provision of artificial salt licks, subject to animal transfers, culling, etc.), all of which affect the habitat use of those animals (Balciauskas, 2000; Pucek et al., 2004; Kowalczyk et al., 2011; Smagol & Gavris, 2013; Anisimava et al., 2015). Finally, all extant wild European bison subpopulations have been reintroduced, and it is unclear to what extent this biases the species' association with particular habitat types (Kerley et al., 2012; Kuemmerle et al., 2012). Gaining a better understanding of European bison habitat thus requires combining information on *historical habitat use*, from times when European bison roamed freely across larger areas of Europe (see also Chapter 2), as well as on *contemporary habitat use* of European bison in our now human-dominated landscapes. A key message emerging when considering all available information is that a view of European bison as a strict forest specialist, as argued for in classic studies (e.g., summarized in Pucek et al., 2004; and Krasińska & Krasiński, 2007) is outdated. Current scientific evidence instead highlights that European bison are more generalist in their habitat use, preferring forest-meadow mosaic landscapes, and inhabit ranges with varying proportions of forests and open areas, both today and in the past (Kuemmerle et al., 2011; Kuemmerle et al., 2012; Krasińska et al., 2014; Bocherens et al., 2015; Kuemmerle et al., 2018; Hofman-Kamińska et al., 2019). Overall, this suggests that European bison conservation should primarily focus on establishing new subpopulations in areas where conflicts with people (e.g., with traffic, agriculture or forestry) can be assumed to be low, regardless of the specific landscape composition and degree of forest cover.

5.1 Historical European bison habitat use

Considerable research has gone into understanding which habitats European bison utilized during the Holocene, before large-scale human influence transformed their range and drove the species to extinction in the wild. Paleo-ecological data can provide important insights in this respect and suggest that European bison displayed high diet plasticity and fairly generalist habitat use, and thus are neither a strict forest nor a strict grassland specialist. Several lines of evidence support such a view (See also Chapter 3). For example, isotope analyses of European bison bones suggest intermediate diets between true grazers and true browsers throughout the early and middle Holocene (Bocherens et al., 2015; Hofman-Kamińska et al., 2019). Also, a range of life history, behavioral, evolutionary, and morphological factors are not consistent with framing European bison as a forest specialist (Kerley et al., 2012). Paleozoological data suggest that European bison have occurred from denser forests to open forest steppes (but likely not in tree-less steppes (see also chaper 2) Heptner et al., 1961; Benecke, 2005) (Figure 5.1).

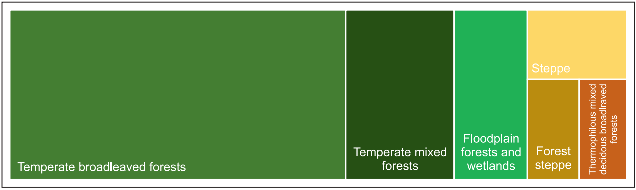

Figure 5.1. Distribution of historical locations where European bison occurred during the Holocene (see Kuemmerle 2012 for data sources) according to potential natural vegetation classes (see Bohn et al., 2003).

Land cover reconstructions from dynamic vegetation models further suggest that during Holocene, European bison have mainly been associated with mostly forested landscapes during the last 8,000 years (figure 5.2) – landscapes that contained various shares of open land (Kuemmerle et al., 2012). Thus, although some evidence indicates that European bison evolved from the Pleistocene steppe bison (*B. priscus*) (Soubrier et al., 2016) (see also Chapter 2), they likely adapted to more forested conditions as the climate became warmer and forests spread across Europe after the last ice age. Such a view is also consistent with increasing evidence that large mammals by themselves were not able to maintain open landscapes in the Holocene (Svenning, 2002; Sandom et al., 2014).

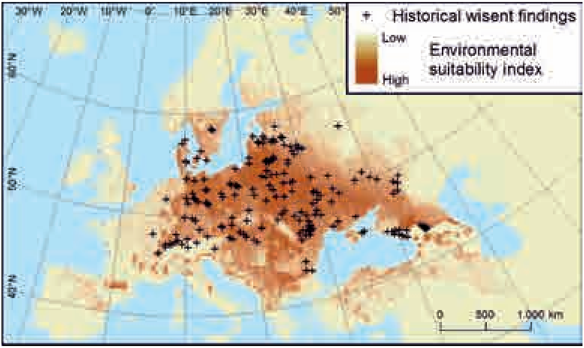

Figure 5.2. Historical distribution of environmentally suitable areas for European bison (here: 2000 BP). This reconstruction is based on historical occurrence locations that are combined with climate and vegetation reconstructions (see Kuemmerle 2012 for details).

While analyses of past habitat use and the potential distribution of European bison can be revealing, it is also important to recognize that the historical range of European bison have been transformed as heavily as few other regions on Earth. Growing human populations have led to massive agricultural expansion, and the widespread establishment of settlements and infrastructure all across Europe, particularly during the last 2000 years (Gaillard et al., 2010; Kaplan et al., 2012). Most importantly, this has led to the almost complete loss of steppe and forest steppe habitats in Europe, as well as the transformation of almost all European lowland forests, with minimum forest cover during the 18th and 19th centuries (Meyfroidt & Lambin, 2011; Kuemmerle et al., 2015; Sabatini et al., 2018). This has undoubtedly contributed to the species decline, directly via the severe loss and fragmentation of habitat, and indirectly via making the species more vulnerable to hunting. As a result, the geographic distribution of European bison has been shrinking, particularly since the middle ages (Kuemmerle et al., 2012), with the species holding out longest in larger, sparsely inhabited, and densely forested landscapes (Cromsigt et al., 2012; Kerley et al., 2012).

5.2 Habitat use of contemporary subpopulations of European bison

At present, more than 6,200 free-ranging European bison occur in more than 40 subpopulations across their former range. While considerable research has gone into understanding habitat use in these subpopulations, only a few of these subpopulations have been studied rigorously, most notably in the Białowieska Forest in Poland where European bison had been holding out until the 20th century, and where the species was first reintroduced. Such early studies concluded that European bison are a forest species (Karcov 1903, Pucek 2004, Krasińska, Krasiński 2007, Krasińska et al. 2014), yet analysing European bison habitat use across larger numbers of subpopulations reveals, that its subpopulations today occur in many different types of landscapes, with a preference for mosaics of forests and open areas (see below). Thus, the past adaptation of the species to a broad variety of environmental conditions as described in the previous section is still reflected in contemporary European bison habitat use, underlining views that the species should be seen as intermediate feeders and fairly generalist regarding habitat use (Hofmann, 1989; Vera, 2000; Jaroszewicz & Pirożnikow, 2008; Krasińska et al., 2014; Kuemmerle et al., 2018; Hofman-Kamińska et al., 2019). Comparing past and current habitat use further suggests that habitat use and forest association of European bison might not have changed as dramatically as sometimes postulated (Kerley et al., 2012), and that although the species likely have been pushed towards more forested landscapes during the last millennia, they are today not strictly confined to the interior of forests.

Factors determining suitable European bison habitat can be structured across spatial scales. At continental scales, the species historically and today has been clearly linked to the temperate zone, and here particularly to the temperate forest and forest steppe zones of Central and Eastern Europe, as described above. Wild European bison subpopulations today occur from the lowlands to highly mountain and even alpine areas (> 2,000m above sea level in the Caucasus), and from areas with temperate-warm climates (e.g., southern Romania) to areas in the temperate-boreal transition zone (e.g., the Vologda Region in Russia).

At the landscape scale, a broad range of studies across multiple subpopulations now suggests that the species prefers mosaic-type landscapes, typically utilizes forests, prefers fragmented stands, and selects for grasslands where the share of open areas is low (Balciauskas, 2000; Daleszczyk et al., 2007; Perzanowski et al., 2008; Smagol & Gavris, 2013; Krasińska et al., 2014; Yanuta & Velihurau, 2015; Wołoszyn-Gałęza et al., 2016; Zielke et al., 2019). For example, telemetry data from five Polish free-ranging subpopulations showed that about two thirds of European bison occurrences were from inside forests, that forest association generally differed widely among subpopulations (lowest in Western Pomerania while the highest in Białowieska Forest and in the Bieszczady Mountains in the Carpathians), and that some subpopulations selected for open areas while others did not, which perhaps was connected with lower atheroprogression within forests (Kuemmerle et al., 2018). Similarly, analysing the ranges of 36 free-ranging European bison subpopulations showed a similar picture, with the species being predominantly associated with mosaic-type landscapes with widely varying shares of forests and open areas (Kuemmerle et al., 2011). European bison generally prefer landscapes away from human influences, such as settlements or roads (Perzanowski et al., 2019a) and, except during dry, hot summers, avoid bogs and wetlands (Krasińska & Krasiński, 2007). On the other hand, topography (e.g., terrain ruggedness, slope) have not been found to limit the species substantially.

At local scales, forage availability drives habitat selection heavily, with European bison critically dependent on grass and forb forage (Borowski & Kossak, 1972). Forage availability, in turn, depends on land cover (e.g., availability of grasslands or forest glades), available habitats (e.g., preference of broadleaved and mixed forests over coniferous forests), their actual state, as well as soil and micro-climatic conditions which determine forage quality (Gębczyńska et al., 1974). There are also important legacy effects: as the most productive sites were historically converted to agriculture, even where forest have returned after agricultural abandonment, European bison use such sites more frequently than those forests that had never been converted to agricultural fields (Perzanowski et al., 2019a). Finally, as at the landscape scale, those animals typically avoid human pressure, such as roads with higher traffic volumes, and areas where direct encounters with people are likely (Balciauskas, 2000; Yanuta & Velihurau, 2015; Wołoszyn-Gałęza et al., 2016; Ziółkowska et al., 2016). Importantly, local-scale factors (e.g., habitat type, forage quality) and landscape-scale factors, (e.g., ratio of forests and open areas) interact across scales to determine the carrying capacity of a landscape (and thus the size of an area needed to sustain a viable subpopulation of the species). In addition to factors determining forage quality, year-round access to freshwater and habitat with cover in which European bison can rest, are important factors determining local habitat suitability.

Although European bison typically avoid areas of human disturbance, there is considerable potential for conflict between those animals and people, particularly in areas where agriculture and forestry are widespread which applies almost everywhere in contemporary Europe. European bison especially in very high densities may cause considerable browsing damage to forest plantations and tree seedlings, as well as mature trees through bark striping, particularly if subpopulations are not fed in winter and/or do not have access to appropriate grazing grounds (Baraniewicz & Perzanowski, 2015; Valdés Correcher et al., 2018; Zielke et al., 2019, Klich et al. 2021). Such feeding behavior driven by insufficiency of adequate natural forage, has been a main reason for conflicts with forest owners in the recently established European bison herd in the German Rothaargebirge (Schröder et al., 2019). Agricultural areas, and particularly crop fields and meadows, are very attractive food sources for European bison, and agricultural damage can be substantial (Hofman-Kamińska & Kowalczyk, 2012). Abandoned agricultural areas already widespread in some regions of Europe and projected to increase further (Estel et al., 2015; Schulp et al., 2019), as well as former and even active military training grounds, can provide good resources for the species. Yet, abandoned farmland provides forage of much lower quality than managed grasslands or crop fields (Perzanowski, Olech 2014), and where abandoned field occur next to active agriculture, conflict potential can be high. Finally, a likely source of conflict exists with livestock husbandry, as European bison share all the infective agents with the closely related cattle (Kita, Anusz, 2006).

5.3 Implications for European bison conservation planning and management

The advances of wisent (paleo)ecology research in the past two decades revealed that European bison are able to thrive in a wide range of landscapes, not only in large dense forests as thought throughout the 20th century. This major shift in knowledge, hence perception of species ecological requirements, substantially enlarges the potential space for the restitution of the species throughout its (pre)historic range. Yet, the potential for conflict between European bison and land use is likely high in many human-dominated landscapes. Conflicts can dramatically undermine the acceptance of European bison and thus the success of individual restitution projects, as demonstrated by the reintroduction project in Western Germany (where once free-ranging European bison, now have to be fenced in to avoid further conflicts). Obviously, future reintroduction sites should first and foremost focus on areas where human population density is low, infrastructure density and traffic volumes are minimal, ecological requirements of the species are fulfilled year-round, and conflict potential with agriculture and forestry is low. At the continental scale, such areas are considerably more widespread in Eastern Europe compared to Western Europe, due to lessening land-use pressure, large scale land abandonment, and rural emigration since 1989 (Lerman et al., 2004; Griffiths et al., 2013; Estel et al., 2015). However, forest-grassland mosaic landscapes with low or declining human pressure are found across the historical range of European bison (Kuemmerle et al., 2011; Estel et al., 2015; Schulp et al., 2019).

When identifying places for establishing new European bison subpopulations, both top-down and bottom-up strategies can be usefully combined. Top-down analyses identify potential candidate sites for reintroductions at broad scales, enabling conservation planning and priority setting across larger regions and across political boundaries. Model-based assessments of where potentially suitable habitat with comparatively low conflict potential occurs can be helpful tools in such a context (Kuemmerle et al., 2010; Kuemmerle et al., 2011; Perzanowski et al., 2019b). Often, the most promising candidate sites will be at least partly protected or inside *de-facto* restricted areas (e.g., military training grounds).

Every additional subpopulation of European bison is a contribution to safeguarding the species, but candidate sites can serve two complementary conservation strategies. The first is the establishment of larger, viable metapopulations of the species (Perzanowski et al., 2019b). Few habitat patches are large enough to establish viable populations (e.g., >1,000 individuals) and thus in most cases individual subpopulations need to be functionally linked into larger metapopulations. Identifying candidate sites under such a strategy would seek to expand and/or link existing subpopulations (e.g., in northwestern Poland, Belarus and the Baltics, European Russia and the Carpathians). A second strategy seeks to identify patches that are effectively isolated from other subpopulations (Perzanowski et al., 2019b). Such patches, though harboring smaller subpopulations, nevertheless can play an important role as reservoirs of animals in case of disease outbreaks or other calamities in other larger populations. Such catastrophic events have occurred in the past (Kita & Anusz, 2006), and would become more of a threat as subpopulations are gradually being linked into metapopulations. Isolated subpopulations can in such situation serve as an insurance and should be actively managed against the loss of genetic diversity through translocation of animals. Figure 5.3 exemplifies a top-down assessment of suitable habitat for Poland, where candidate sites for both strategies (metapopulations vs. reservoir populations) were identified (Perzanowski et al., 2019b).

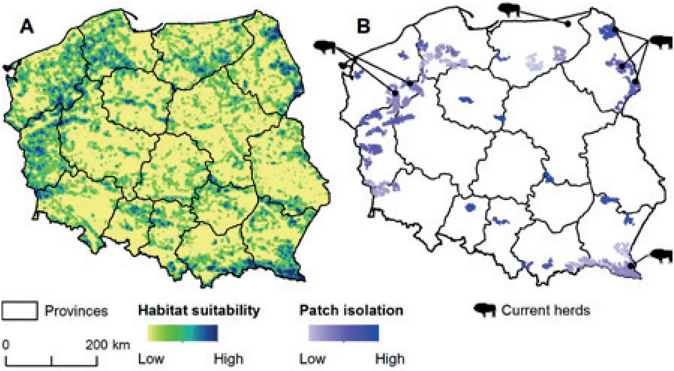

Figure 5.3. Potentially suitable European bison habitat in Poland (A), potential habitat patches and their level of isolation in relation to the closest extant subpopulation of European bison (B). Well-connected patches are candidate sites for expanding extant populations into metapopulations, whereas isolated patches are candidate sites for insurance subpopulations (after Perzanowski et al. 2019).

Crucially, any top-down, model-based analyses have to be accompanied by bottom-up, field-based assessments to ultimately select the most promising reintroduction sites among a range of candidate sites. Such bottom-up assessments must include a thorough assessment of habitat quality (e.g., forage quality and quantity and access to freshwater), and human-dimension factors (e.g., conflict potential with forestry and agriculture, ownership, infrastructure and attitudes towards European bison). Both together will determine whether a candidate site has the potential to host a larger subpopulation of adequate size to avoid considerable loss of genetic variability (or a functional metapopulation composed of a few smaller connected subpopulations), a smaller 'insurance' subpopulation, or no subpopulation at all. It cannot be stressed enough that particularly the human-dimension factors are critical here: introducing European bison to conflict-prone areas and ignoring the species ecological requirements and/or concerns of local people will likely ruin chances for successful establishment of any new population of the species.

5.4 Closing remaining knowledge gap regarding European bison habitat use

While the last decades our understanding of European bison habitat use and the distribution of potential home ranges for the species has considerably increased, some knowledge gaps prevail. First and foremost, still only a minority of extant European bison subpopulations have been assessed scientifically regarding their habitat use. Further and more detailed assessments, particularly for subpopulations in mountain regions (e.g., Carpathians, Caucasus), for subpopulations outside the European Union (e.g., Belarus, European Russia, Ukraine), and for subpopulations at the northern and southern range limits would be very beneficial. Second, studies focussing on fine-scale habitat selection patterns would be helpful, particularly regarding finer temporal resolution (e.g., seasonal habitat use, daytime vs night-time habitat use). As more and more European bison are monitored using GPS telemetry, the opportunities for such types of studies are increasing. Likewise, the data gathered through GPS collars can provide new insights into movement patterns, home range size, and dispersal behaviour, all of which would be important for determining what characterizes places that can host larger metapopulations of the species. Collecting, consolidating, and making available GPS tracking data across individual subpopulations, as done for other species (http://euromammals.org) would be a major step forward to enable such studies. Third, most European bison populations are managed in some way, including widespread winter feeding as well as population regulation. How different management strategies affect habitat selection and space use by this species, urgently needs to be understood better. Fourth, a broader evaluation of which habitats and landscapes are more or less prone to conflicts between European bison and people would be highly informative for conservation planning and management. Finally, the species is Europe's largest remaining herbivore, and there is hope that these animals could act as landscape engineers, which could benefit other species. Therefore fine-scale studies of how free-ranging, wild subpopulations and semi-free herds of European bison may interact with vegetation cover, and to what extent they can maintain semi-open landscapes, would therefore be beneficial.


Photo courtesy of Idor Adrian

6 | GENETIC ISSUES

6.1 Genetic lines

European bison as a species underwent an extreme population bottleneck as only a few animals survived extinction in the wild (Slatis 1960; Olech 2009). All pure-bred European bison (wisents) are the descendants of a basic group of 12 animals therefore they represent a recombination of only 12 diploid sets of genes (Slatis 1960). Eleven of those 12 founder animals originated solely from the Białowieża Primeval Forest, but were maintained in the Berlin and Budapest zoos, and breeding reserve at Pszczyna. All these 11 founders represented the nominotypical subspecies *B. bonasus bonasus*. One bull of *Bison bonasus caucasicus*, born in 1907 in the Caucasus Mountains, was brought to Germany in 1908 and mated with the number of *B. b. bonasus* females. Due to the very limited founder gene-pool, population genetics are considered a major issue in European bison conservation with possible implications for the long-term viability, and adaptability of its captive, semi-free as well as free-living populations.

Two genetic lines are currently: the Lowland line or Lowland-Białowieża or Białowieża line (LB) that originates from only seven founders (4 males; 3 females) and represents the pure lineage animals of *B. b. bonasus* . The second line (Lowland–Caucasian - LC) is derived from all ancestors (5 males and 7 females), including the one male captured in the Caucasus Mts, where the subspecies *B. b. caucasiscus* still existed at that time. A small, but important, part of the Lowland line included a group derived from a few animals brought from Białowieża to Pszczyna in 1865 (1 bull and 3 cows) and supplemented throughout 1909 by five cows from Białowieża and three other bulls. Three animals (2 males; 1 female) survived until 1922 (Czudek 1930; Pucek 1991). This group was later (after World War II) mixed together with other Białowieża line animals.

Because a large part of the European bison population (25%) is still kept in captivity, where the breeding strategy could be implemented, some important measures for conserving the genetic variability have been used in recent decades. First of all, the genetic lines Lowland and Lowland-Caucasian have to be reproductively separate. The reason for ths separation is saving the genetic pool of the LC line. Over time the proportion between common and unique founders in this line changed towards domination of a pair of founders (Nos. 42 and 45) (Tabl.6.1). The most important role for the captive population is the preservation of the unique part for LC line gene pool from founders Nos. 100; 95; 96; 35 and 46.

Table 6.1. The list of all the founders after the bottleneck, and their contribution to the gene pool of the European bison population in captivity at the end of years: 1924, 1954 (source: Slatis 1960), 2000 and 2015-2019 (source: Pucek et al. 2004; Olech 2009, unpublished data). “na” = not applicable.

<table>
<tr><th rowspan="3">Founders in 1924</th><th rowspan="3">Founders of the current population</th><th colspan="6">Founder contribution</th></tr>
<tr><th rowspan="2">In 1924</th><th rowspan="2">In 1954</th><th colspan="2">In 2000</th><th colspan="2">In 2015-2019</th></tr>
<tr><th>LB line</th><th>LC line</th><th>LB line</th><th>LC line</th></tr>
<tr><td colspan="2">42 Planta</td><td>0.028</td><td>0.188</td><td>0.294</td><td>0.183</td><td>0.299</td><td>0.182</td></tr>
<tr><td colspan="2">45 Plebejer</td><td>0.028</td><td>0.264</td><td>0.545</td><td>0.229</td><td>0.575</td><td>0.233</td></tr>
<tr><td>85</td><td rowspan="2">87 Bill</td><td rowspan="2">0.050</td><td rowspan="2">0.072</td><td rowspan="2">0.026</td><td rowspan="2">0.089</td><td rowspan="2">0.019</td><td rowspan="2">0.086</td></tr>
<tr><td>86</td></tr>
<tr><td colspan="2">89 Bilma</td><td>0.042</td><td>0.096</td><td>0.026</td><td>0.117</td><td>0.019</td><td>0.114</td></tr>
<tr><td>1</td><td rowspan="3">15 Begrunder</td><td rowspan="3">0.060</td><td rowspan="3">0.082</td><td rowspan="3">0.027</td><td rowspan="3">0.077</td><td rowspan="3">0.022</td><td rowspan="3">0.076</td></tr>
<tr><td>2</td></tr>
<tr><td>7</td></tr>
<tr><td colspan="2">16 Plavia</td><td>0.106</td><td>0.091</td><td>0.055</td><td>0.082</td><td>0.044</td><td>0.080</td></tr>
<tr><td>122</td><td rowspan="2">147 Bismarck</td><td>0.028</td><td rowspan="2">0.009</td><td rowspan="2">0.027</td><td rowspan="2">0.005</td><td rowspan="2">0.022</td><td rowspan="2">0.006</td></tr>
<tr><td>123</td><td>0.046</td></tr>
<tr><td colspan="2">100 Kaukasus</td><td>0.109</td><td>0.061</td><td></td><td>0.071</td><td></td><td>0.073</td></tr>
<tr><td colspan="2">95 Garde</td><td>0.081</td><td>0.038</td><td></td><td>0.038</td><td></td><td>0.039</td></tr>
<tr><td colspan="2">96 Gatczina</td><td>0.046</td><td>0.063</td><td></td><td>0.064</td><td></td><td>0.064</td></tr>
<tr><td>32</td><td rowspan="2">35 Plewna</td><td rowspan="2">0.070</td><td rowspan="2">0.027</td><td rowspan="2"></td><td rowspan="2">0.032</td><td rowspan="2"></td><td rowspan="2">0.034</td></tr>
<tr><td>33</td></tr>
<tr><td colspan="2">46 Placida</td><td>0.037</td><td>0.009</td><td></td><td>0.013</td><td></td><td>0.013</td></tr>
<tr><td>11 founders without representation in current population</td><td></td><td>0.269</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

As a result of the breeding program the proportion of unique founders’ genes in the LC line is not decreasing now, even from 2000 to 2015 it slightly increased. The assessment of each founders’ contribution is based upon data from the European Bison Pedigree Book (EBPB), where all animals in captivity are individually registered. Using the pedigree data, it is possible to calculate many parameters such as inbreeding coefficient, mean kinship, etc. Those parameters are very useful for a breeding programme in which plans for mating and animal transfers between different herds are prepared Olech 2003). The aim of the programme is the mitigation of inbreeding, through avoidance of mating very close relatives and making best choice of males for transfers among herds. The results obtained from SNP analysis allowing to compare large group of animals sampled between 1986 and 2011, provided conclusion that observed stabilization of the inbreeding level and the reduction of HBD segment lengths indicate that the restoration plan has been successful in control inbreeding (Druet et al. 2020).

In the current population only three male founders have representation through their sons. So, all males in the LB line have copy of the Y chromosome from #45 Plebejer, while in the LC line except this dominating male some individuals have the Y chromosome from #100 Kaukasus and #15 Begrunder, though the number of such males is very limited (Olech 2009). Therefore, in the breeding programme a key goal is to increase the percentage of males with the Y-chromosome of these two founders. Also, the maternal line of the founder #16 Plavia is underrepresented and mitochondrial DNA of three females #95, 96 and 46 has already disappeared.

6.2 Genetic monitoring of population

There is no doubt that the European bison population after passing through a drastic decline in numbers (bottleneck), has low genetic variability. Due to technical capabilities, allowing for the use of increasingly accurate analyzes, its genetic structure can be estimated using various techniques. It is routinely determined on the basis of a dozen of microsatellite markers, less often using a large number (10-50 thousand) SNP markers and markers using coding sites. Alternatively, the genetic variability can be determined by combined methods (Wojciechowska et al. 2012).

The parameters of genetic variation of the species vary depending on the method used. They are determined as an inbreeding ratio of 47%, based on an analysis of 50,000 SNP markers (Pertoldi et al. 2010), or an overall variation of 15 - 22%, when analyzing variation in the region of the DRB3 MHC II gene (Radwan et al. 2007). Low variability is also confirmed by studies using microsatellite markers (Luenser et al. 2005, Roht et al. 2006; Tokarska et al. 2009), or analysis of mtDNA haplotypes (Burzyńska et al. 1999, Wójcik et al. 2009). The average expected heterozygosity based on microsatellite data was estimated to 29% for LB line and 35% for LC line (Plumb et al. 2021). The inbreeding level of individuals based on SNP analysis varied from 12 to 47% within LC line and from 28 to 56% within LB line (Druet et al., 2020). The main problem in the research conducted so far, is the presentation of data only on one part of the population - the Lowland line living in the Białowieska Forest, as well as due to many methods whose results are difficult to compare with each other. Therefore, data published so far do not include animals from both lines and concern only a relatively small number (maximum 300 individuals) inhabiting mainly the same area.

Despite the extension of the scale of the study, no relationship was found between an increase of inbreeding and the occurrence of symptoms of inbreeding depression. There was not evident relation between inbreeding level and mortality or other negative traits (Olech 2003; 2006). Some slight inbreeding depression on skull measurements was found in LC line (Kobryńczuk 1985). Generally it it possible to say that impact of inbreeding is limited, and some authors comment this as possible that founders genotypes were by a chance free of deleterious genes (Tokarska 2011; Kowalczyk & Plumb 2021). To date, the potential negative effects of low genetic variation are being attributed to a reduced resistance to pathogens (Rzewuska et al. 2016, Radwan et al. 2010, Osińska et al. 2010, Krajewska et al. 2015, Kesik - Maliszewska et al. 2018, Krzysiak et al. 2015). However, the research is ongoing on the relationship between the propensity for selected diseases and a specific genotype (Oleński et al. 2015, 2019).

In 2000, the European bison Gene Bank (EBGB) was established. By the beginning of 2020, the EBGB had collected 3,520 samples of biological and/or genetic material. As part of its activity, the genotype database (based on analysis of 11 microsatellite loci) of over 1,800 animals belonging to both genetic lines and originating from both: free, semi-free and captive herds, from all sites of species occurrence registered in the EBPB, was established. On the basis of this extensive dataset, the overall degree of inbreeding was estimated. Its average values range between 28-42%. Captive LB herds showed the highest degree of inbreeding. The level of inbreeding is mainly influenced by the structure of the founders' contribution (Nowak-Życzynska data unpublished). These data show, that the most important factor will reduce the increase of inbreeding, is proper population management, by minimizing the proportion of genes of the strongly dominating pair of founders, which are #42 Planta and #45 Plebejer.

The results of recent research have enabled the identification of genetic markers determining line membership (Kamiński et al. 2012, Tokarska et al. 2015, Michailova & Voitsukhovskaya 2017, Wojciechowska et al. 2017). Despite the overall low genetic variability of the species, it was possible to find loci, whose frequency shows a great diversity between the lines. The conducted analysis showed, that among the individuals belonging to the Lowland line there are animals, whose genetic profile is characteristic for the Lowland-Caucasian line. The LB line is a closed line therefore, individuals with a genetic profile not compatible with the line profile should not be used in reproduction. If "genetic purity", understood as compliance with the genetic profile of the line, becomes a selection factor for the Lowland line, the question arises: what percentage of incompatibility with the line profile will be determined as acceptable and depending on that criteria whether an average inbreeding level of about 40% can such selection criteria be applied without fear of a very rapid decrease in genetic variation?

Main threats resulting from, or leading to low genetic variation

- Potential weak resistance towards pathogens and diseases connected with low genetic variability
- Limited gene pool as a consequence of extreme bottleneck
- Fragmentation and isolation preventing the exchange of genetic material

Suggested solutions

- Obligatory, unified genotyping system (in captive and semi-free herds)
- Standardized methods of advanced genetic analysis, i.e., SNP + GWAS (Genome-Wide Association Study) for genetic management, health research, and planning
- Saving the genetic variability through continued line separation in captivity
- Planning of further reintroductions and/or supplementations of existing populations/ herds using animals with genes from underrepresented or unrepresented founders
- Use of genetic information to save rare founders genes and/or genes showing a high correlation with resistance to diseases

So far used system of genetic monitoring of individuals, forming closed and free living groups, using a panel of microsatellite markers, allows for an effective description of genetic variability of a metapopulation. A similar system was used for the American bison metapopulation (Halbert, Derr 2008; Halbert et al. 2005). However, the differences in the management of these both species, mainly lie in the fact that European bison populations are very scattered and under the management of different countries. Therefore, it is important to coordinate the animals exchange not only within country but among countries. For such activity the role of European Bison Pedigree Book is crucial, as well as international networks as EBCC or EAZA. Previous studies (Wecek et al. 2017), comparing the genetic pool before and after the bottleneck, confirm the success of the restitution of European bison concentrated on maintaining a reasonable level of genetic variation and paying attention to the irretrievable loss of part of the gene pool from the LC line.

When using genetic markers, it is possible to identify animals that are hybrids of wisents and American bison, as well as wisents and domestic cattle. Introgression will be a more accurate term here, because in most cases the next generation is already born, being backcrosses of an interspecific or interfamily hybrid. The long-lasting process of fixing American bison genes in the wisent genome has already happened in the so-called “mountain bison” population in the Caucasus Mountains (Russia). This population has been isolated so far.

The use of genetic markers has enabled the detection of European bison individuals that are descended from hybrids with domestic cattle. So far, all such cases were recorded in Russia and Azerbaijan - in a private enclosure in Gabala (Yudin et al. 2011, Nowak-Życzynska- data unpublished). These cases mainly concern semi-free or free herds. The markers used allow for successful identification of hybridization of the maternal linked mitochondrial DNA (mtDNA) and particular paternally-inherited loci within nuclear DNA. It should be noted here, that the genetic test used in the US for detection of cattle introgression in American bison (described by Ward et al. 1999), should not be used for European bison, due to reported cases of false positive results (Nowak, Olech 2008). These results are caused by ancient natural introgression of an ancestor of modern domestic cattle, i.e., *Bos primigenius* - aurochs, which was possible because both species inhabited the same regions (Verkaar et al. 2004, Zeyland et al. 2012) (see Chapter 2). Nevertheless, all genetic markers used for the purpose of detection of allospecific introgression in European bison do not show to wat degree. This however should rather not matter, because in each case the detection of a contribution from any foreign species to the genome excludes such individual from conservation programs and from gene pool of the species.

Main threats resulting from hybridization from B. bison *and* Bos taurus *species*

- Loss of species purity!
- Loss of protected species status

Suggested solutions

- Unified system for identifying hybridization (in doubtful cases; upon first registration of the herd in the EBPB)
- All individuals in which introgression is detected should be immediately isolated, and eliminated form European bison herds, definitely not be allowed to breed, and each such finding should be reported to the EBPB.

6.3 European Bison Gene Bank

The European Bison Gene Bank (EBGB) serves for data collection & data mining. All scientists, veterinarians, foresters and breeders dealing with European bison should be involved in information delivery that will be processed into an integrated dataset. The primary source of information is the collection of tissues (and gametes) and/or extracted DNA and wherever possible, information on microbiology, parasitic information, and health status. All collected tissues are to be marked with the QR code, which allows for easier access to information on the availability of biological material and related data. Therefore, the main task of the EBGB is to provide information to supplement the Pedigree Book data with: genetic profile, genetic line, inbreeding coefficient and kinship value within living animals and within the genetic line, contribution of ancestors, genetic position within the given herd, and amongst animals of that particular line. EBGB is organized in Warsaw University of Life Sciences.

Photo courtesy of Ruud Maaskant

6.4 European Bison Pedigree Book

At present, the most important tool allowing for current monitoring of genetic status of the species, is the European Bison Pedigree Book (EBPB), a studbook issued since 1932. It is the only official document, where all newborn animals should be registered. It also contains annually updated information on numbers of European bison in all captive, semi-free herds and free-ranging populations. For every animal registered there - its individual pedigree number, the name, names and pedigree numbers of its parents, the name of the owner or breeder and affiliation to either the LB or LC lineage are given.

This database allows for tracking the ancestry of particular individuals, preparing optimal mating and transfer patterns, monitoring of changes in numbers of captive herds as well as population dynamics in the wild. The EBPB is the only one register of animals/herds, hence without formal registration there, an animal or a herd cannot be involvewwd in European. bison restitution programs.

7 | DISTRIBUTION AND STRUCTURE OF THE WORLD POPULATION OF EUROPEAN BISON AT THE END OF 2020

The captive part of the European bison population is kept in various types of enclosures like breeding centers, zoological gardens and reserves. In the year 2000, for which the analysis of the captive part of the world population was presented in the former Action Plan for the Species (Pucek et al. 2004), a decrease in the number of centres, maintaining wisents in captivity was indicated - only 191 listed in EBPB 2001. By the end of year 2000, only 27% of the world's captive population lived in relatively large herds of at least 25 individuals, while 59% of captive animals were kept in herds of 10 animals or less (Raczynski, Bolbot 2001 = EBPB 2001). Important at that time, almost one fourth of the enclosures (23%) kept just a single animal. Moreover, during the 1990s. A dramatic decrease in the numbers of both captive herds and absolute numbers of animals in captive population had been observed (Pucek et al. 2004).

According to data from EBPB 2001, captive herds of European bison were well distributed in 30 countries, but most of them consisted of the the LC line animals (148 herds), 22 kept only the LB line (16 in Poland), and in 21 breeding centers were animals representing both lines. In captivity, the proportion of the LB line was then very low (25,6%). There were at that time only 295 animals of the LB line and 858 representing the LC line.

At the end of year 2000, there were 28 free living herds/populations, and 2 semi-free herds in large enclosures (EBPB 2001). From these, 30 free and semi-free populations, 14 belonged to the LB line with 931 animals, and 16 to the LC line, with 714 animals in total. In Table 7.1 captive herds larger than 14 animals are presented. There are 15 breeding centers maintaining larger captive herds (N≥15) of the LC line individuals. Most of them are situated in Germany, but also in Great Britain, Russia and Sweden. Herds that reach or exceed 15 animals of the LB line are maintained in 10 breeding centers. In Poland, the Netherlands and Spain there are more than one such breeding center (Table. 7.1). In the Action Plan of 2004, there were certain recommendations to secure the future of the species. It was important increase the number of herds as well as the total population size, especially through the creation of free living semi-free or large captive herds. For captive breeding, it was important to consider: (a) a separation between the LB and LC breeding lines, which is particularly significant for preserving the genetic variability of the latter one, and (b) an increment in the number of LB animals in captivity. For the free living part of the world population it is important to increase the number of LC herds and enhance the genetic variability within free living herds, through releases of captive born animals, bearing genes from genetically important but underrepresented ancestors.

Table 7.1. Larger captive herds (N≥15) (according to EBPB 2021)

Country	Name	Herd size	Line
CZECH REPUBLIC	Prachatice	37	LC
FRANCE	Margeride	28	LB
GERMANY	Damerower Werder	23	LC
	Donaumoos	32	LC
	Hardehausen I	23	LC
	Leipzig	20	LC
	Sababurg	19	LC
	Springe	24	LC
GREAT BRITAIN	Pitcastle	15	LC
	Port Lympne	16	LC
HUNGARY	Nagykanizsa	25	LB
IRELAND	Carrigtwohill	15	LC
LITHUANIA	Panevėžys-Pašilių Stumbrynas	28	LB
NETHERLANDS	Lelystad	29	LB
	Maashorst	17	LB
POLAND	Białowieża	31	LB
	Niepołomice	19	LB
	Pszczyna	45	LB
RUSSIA	Okskijj zapovednik	46	LC
	Prioksko-Terrasnyjj zapovednik	43	LC
SLOVAK REPUBLIC	Topoľčianky	26	LC
SPAIN	Encinarejo	17	LB
	La Serreta	24	LB
SWEDEN	Avesta	24	LC
	Eriksberg	55	LC

7.1 World population

On the basis of data on the world population of the species from the European Bison Pedigree Book, to explain and present its dynamics, the situation in 2000 is compared to the year 2010 and finally to the year 2020. Analysed were data on the number of individuals, the number of herds of different types, and the proportion of both genetic lines.

A number of wisent herds grew dynamically (by 50%) in last 20 years (2000-2020). Recently, established were many semi-free herds (now there are 18 of them), requiring large fenced areas - usually of at least several tens hectares (Table. 7.2). Such conditions are beneficial for a gregarious animal like the wisent. one of the issues which is considered problematic is the existence of breeding centres maintaining animals of both LB and LC lines. Hopefully the numbers of such herds are decreasing and usually such groups consist of only a few animals. The number of single sex holders increased from 43 in 2000 to 60 in 2020, however their proportion slightly increased from 22.5 to 23.8%, due to the overall increase in the number of breeding centres. In facilities maintaining just one sex, the average number of animals is equal to 2.28, so the average size of a herd in the remaining captive enclosures is larger and equals to 8.62.

Table 7.2. Numbers of wisent herds (captive, semi free and free ranging) in years 2000, 2010 and 2020 (EBPB 2001; 2011; 2021)

Year / Line	Captive				Semi free			Free ranging			Total
	LB	LC	mix	total	LB	LC	total	LB	LC	total	
2000	22	148	21	191	1	1	2	13	15	28	221
2010	41	164	14	219	3	4	7	12	21	33	259
2020	67	175	10	252	10	8	18	17	28*	45	315

*numbers of herds are given according to Pedigree Book list, but 4 free-ranging herds in Russia are now registered as one population because of a small distance from each other (details in section 7.3 below).

The total numbers of the world population tripled between 2000 and 2020, and now it exceeds 9,100 individuals. Especially visib La Serreta le is an increment of wisent numbers in semi-free herds, which perhaps reflects a chance for a compromise between the need to increase the number of herds, and actual possibilities to maintain wisents in anthropogenically transformed environment (see Chapter 5) (Table. 7.3).

Table 7.3. Numbers of individuals in three types of wisent herds (captive, semi free and free ranging) in years 2000, 2010 and 2020 (EBPB 2001; 2011; 2021)

Year / Line	Captive			Semi free			Free ranging			Total
	LB	LC	total	LB	LC	total	LB	LC	total	
2000	296	858	1154	30	11	41	908	761	1669	2864
2010	403	1071	1474	98	89	187	1782	994	2776	4437
2020	659	1133	1792	245	256	501	3951	2868	6819	9112

The rate of population growth was different in both lines bred in captivity. Between the year 2000 and 2010, the numbers of LB line grew by 223% while the LC line grew by 132%. Also, the number of herds where both lines were kept simultaneously, dropped down from 21 to 10. This indicates that isolation of both lines was maintained (Olech et al. 2008), and the recommendation regarding an increase of the LB line in captivity has been followed (Table. 7.2).

Free-ranging populations increased in a different way. In the year 2000, they existed only in five countries, i.e., Belarus, Lithuania, Poland, Russia and Ukraine. By 2015, additional herds were established in Germany, Slovakia, Latvia, Bulgaria and Romania, resulting in ten European countries harbouring free-ranging wisents (Krasińska et al. 2014; EBPB 2021). An increment of the LB line in freedom during those 18 years came to 435%, while the LC line came to 377% (Table. 7.3).

Photo courtesy of Yvonne Kemp

During the analysed period (2000 - 2020) there occurred small but welcome decrease in the proportion of the number of small herds that maintain ≤5 animals (from 64.9 to 56.7%), and a fourfold increase of the percentage of relatively large herds (>10 animals) from 4.2 to 16.3% (Figure 7.1; Table 7.4).

Table 7.4. The number of herds and numbers of animals in particular sized of captive wisent herds.

Year	Size of captive herds							
	≤ 5 individuals		6-10 individuals		11-20 individuals		>20 individuals	
	herds	animals	herds	animals	herds	animals	herds	animals
2000	124	347	47	340	12	156	8	311
2010	138	420	50	366	13	165	18	523
2020	143	422	68	492	24	335	17	543

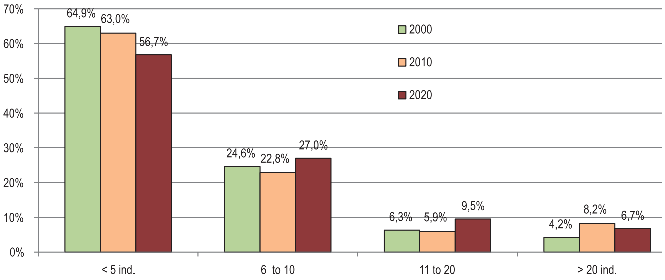

Figure 7.1. Changes in the size of wisent groups maintained in captivity between years 2000 and 2020.

Not only the number of small herds dwindled over those 20 analysed years, but the number of animals in such small herds (<5 animals) became significantly lower, while the number of individuals forming larger herds (11-20 animals) is now considerably larger (Figure 7.2). However, the average size ca 2.79 – 2.95 individuals, of the smallest herds (up to 5 individuals) has remained stable over this period of time (Table. 7.4).

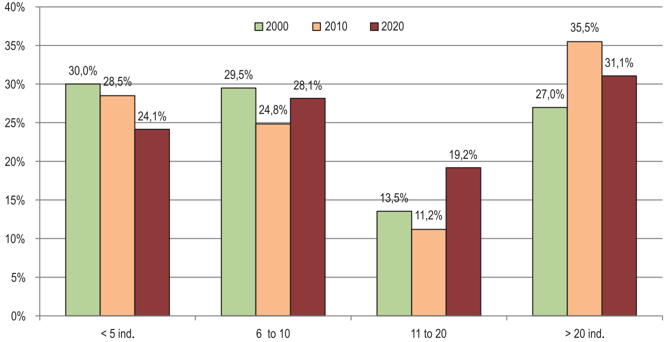

Figure 7.2. Changes in the numbers of animals forming four various size categories of captive wisent herds over the period: 2000 - 2020.

Currently, captive European bison account for slightly less than 20% of the entire population of the species, and semi-free herds less than 6% (Tabl.7.5). Captive animals from the LB line are mostly found in Poland (over 200 individuals) and in Spain (ca. 115 ind.). In other countries their numbers vary from a few to several dozen individuals. Most of them live in Germany and the Netherlands. Generally, females predominate in the population (60,2%), however in some countries (eg. Czech Republic, Lithuania) males are in the majority. European bison belonging to the LC line are mostly in the breeding centres of Germany (387 individuals) followed by Russia and Sweden where are maintained over 100 individuals. The sex structure of this line in captivity is similar to the lowland line, females account for over 65% of this population. The number of animals of LB and LC lines maintained in semifree herds are similar. Only in 12 countries is this form of breeding found. Usually, in a country there are several dozens of European bison individuals, mostly belonging to one line. Free-ranging European bison of the LB line occur only in 4 countries, with a strong dominance in Belarus and Poland, where 92% of the whole population are found. Over 50% of the LC line in free conditions is bred in Russia, and the majority of remaining European bison of this line occur in the Carpathian Mountains (Poland, Slovakia, Ukraine and Romania) (Table 7.5).

Table 7.5. Current total numbers of European bison with regard to type of maintenance and generic line (EBPB 2021).

Country	Captive					Semi-free			Free ranging			Total
	LB		LC		sub total	LB	LC	sub total	LB	LC	sub total	
	M	F	M	F								
AUSTRIA			5	6	11							11
BELARUS	7	9	2	1	19	67		67	2270			2356
BELGIUM			10	12	22							22
BULGARIA			1	2	3		54	54		11	11	68
CROATIA			0	2	2							2
CZECH REPUBLIC	28	21	9	13	71	71		71				142
DENMARK	5	3			8	8		8				16
ESTONIA			3	9	12							12
fINLAND			5	10	15							15
fRANCE	10	18	20	27	75	48		48				123
GERMANY	25	44	154	260	483		100	100		26	26	609
GREAT BRITAIN			27	34	61							61
HUNGARY	16	32	10	10	68							68
IRELAND			6	9	15							15
ITALY			0	3	3							3
LATVIA										5	5	5
LITHUANIA	25	15	4	3	47				282		282	329
MOLDOVA REPUBLIC	5	2			7							7
NETHERLANDS	26	40			66	12		12				78
POLAND	75	124	5	8	212				1397	707	2104	2316
PORTUGAL			0	2	2							2
REPUBLIC OF MACEDONIA			1	0	1							1
ROMANIA	1	0	18	19	38		49	49		127	127	214
RUSSIA	3	4	60	96	163	39		39	2	1594	1596	1798
SLOVAK REPUBLIC			17	14	31					54	54	85
SPAIN	40	75	8	19	142							142
SWEDEN			54	88	142							142
SWITZERLAND	1	5	17	27	50							50
UKRAINE			5	3	8		35	35		344	344	387
NON-EUROPEAN COUNTRIES												
AZERBAIJAN						6	12	18				18
CANADA			1	5	6							6
GEORGIA			1	2	3							3
INDONESIA			4	1	5							5
KAZAKHSTAN			0	1	1							1
TOTAL	267	392	441	677	1777	251	250	501	3951	2968	6819	9112

7.2 Semi-free herds

Currently, semi-free herds are defined by EBPB as those, kept in larger enclosures and in which paternity is not recorded in detail. The method to prevent inbreeding in such large herds could be regular transfers of young animals and/or exchanges of bulls. Semi-free herds are increasingly important for European bison, as they allow the existence of the species in natural social groups, fully interacting with the environment even in densely populated areas of Central and Western Europe. Importantly, semi-free herds are reservoirs of individuals well adapted to natural lifecycle with limited human intervention. Such individuals can better adapt and establish functional social groups in new sites and therefore are well suited for reintroduction programs.

Starting from two herds with a total of 41 animals in 2000 (< 1.5 % of the global population), their number grew steadily to 18 semi-free herds with 501 animals (5.49 % of the global population) in 2020 (Table. 7.3). The number of larger herds has grown as well (Table. 7.1, 7.6), which is a positive trend since those herds are important for the species development, because of proper social structure and behaviour. Two semi-free herds were registered in 2000 in the EBPB (in Russia and Ukraine). The herd in Voden (Bulgaria) which existed then as well, was not at that time in contact with the Pedigree Book. The present number of semi-free herds is 18 with 501 animals in total, so the average size of a herd is equal to 27.8. The representation of both genetic lines is almost the same regarding the number of herds and the number of animals.

Table 7.6. Changes in the number and the size of semi-free herds of both genetic lines.

Country	Herd	Genetic line	2000	2010	2020
Belarus	LJASKOVICHSKOE STADO	LB			23
	MOGILEVSKIJJ ZOOSAD	LB		24	41
	NACIONAL'NYJJ PARK "BRASLAVSKIE OZERA"	LB			3
Bulgaria	VODEN	LC	?	?	54
Czech Republic	MILOVICE	LB			27
	ROKYCANY	LB			5
	ŽIDLOV	LB			39
Denmark	BORNHOLM	LB			8
France	RÉSERVE BIOLOGIQUE DES MONTS D'AZUR	LB		32	48
Germany	DÖBERITZER HEIDE – WKZ	LC		6	100
Romania	FAGARAS MOUNTAINS	LC	–	–	6
	NEAGRA BUCSANI	LC		41	35
	VANATORI NEAMT	LC		22	8
Russia	CHERGA SO RAN	LB	30	42	39
Ukraine	FOREST RANGE "STOROZHYNETSKE"	LC			13
	STATE RESIDENCY "ZALISSIA"	LC	11	20	12
Netherlands	KRAANSVLAK	LB		10	12
Azerbaijan	ŞAHDAĞ NATIONAL PARK	LC			18
TOTAL			41	197	501

The LB line is maintained in 7 semi-free herds, in addition to the existing Cherga herd in the Altai (Russia), 7 new ones have been created since 2000 in Europe. One new semi-free herd each was created in: France, the Netherlands, and Denmark as well as in Azerbaijan outside Europe. Three semi-free herds were created in the Czech Republic and three in Belarus. There are also plans to transform 4 breeding centers into semi-free herds: two in the Netherlands (Veluwe- 5 ind., Maashorst – 25 ind. and Slikken Van Den Heen – 14 ind.), and one in Hungary (Nagykanizsa Liszó – 20 ind.).

New semi-free herds of the LC lines are mainly located in the south-eastern part of Europe. Apart from Zalissia and Voden herds in 2000, there are three new herds within the Carpathian range, one in Ukraine and two in Romania. Two other semi-free herds were created in Germany and Latvia. Outside of Europe, a herd was established in Tajikistan (Novobod) and in the Far East (Plejjstocenovyjj Park, Russia), however for some time just one individual was reported in this location, therefore it cannot be fully considered a semi-free herd. Both those herds do not exist anymore.

The spatial distribution of semi-free herds in Europe is presented at Fig 7.3.

● Lowland line ● Lowland-Caucasian line

1. KRAANSVLAK (Netherlands)
2. RÉSERVE BIOLOGIQUE DES MONTS D'AZUR (France)
3. BORNHOLM (Denmark)
4. ŽIDLOV (Czech Republic)
5. MILOVICE (Czech Republic)
6. ROKYCANY (Czech Republic)
7. BRASLAVSKIE OZERA NP (Belarus)
8. MOGILEVSKIJJ ZOOSAD (Belarus)
9. LJASKOVICHSKOE STADO (Belarus)
10. DÖBERITZER HEIDE – WKZ (Germany).
11. STATE RESIDENCY "ZALISSIA", KYIV REGION (Ukraine)
12. FOREST RANGE "STOROZHYNETSKE", CHERNIVTSI REGION (Ukraine)
13. VANATORI NEAMT (Romania)
14. FAGARAS MOUNTAINS (Romania)
15. NEAGRA BUCSANI (Romania)
16. VODEN (Bulgaria)

Figure 7.3. Spatial distribution of semi-free herds of European bison in Europe by the end of 2020

7.3 Free-ranging herds

The condition for free populations has improved significantly. Since the year 2000, the numbers of animals in free-ranging herds more than four folded (an increase by 4.08 times, but herds number increased from 28 to 48). Five new countries have released wisents to the wild during this period. In Table 7.7, the list of free-ranging herds in particular countries with information on their genetic status and size is given.

In the 2015 edition of the EBPB two free-ranging herds in Russia «KALUZHSKIJE ZASEKI» ZAPOVEDNIK and NACIONAL'NYJJ PARK «UGRA» were listed as one population. In the 2021 edition of the Pedigree Book there are listed additionally three other herds: KARACHEVSKIJJ ZAKAZNIK, «ORLOVSKOE POLES'E» NACIONAL'NYJJ PARK and TULA REGION because the ranges of those herds are very close, so they can be treated as one metapopulation under the name: MIDDLE RUSSIAN POPULATION (SREDNIERUSSKAJA POPULACIJA).

In Ukraine, wisents inhabiting the territory of the "Forest and hunting range "BEREGOMETSKE" and Forest range "STOROZHYNETSKE" constitute a single subpopulation of the Chernivtsi region. Wisents freely move there from one territory to another. Previously, this population was called "BUKOVYNSKA", but since 2012 both ranges are considered separately. Similarly, in the subpopulation of European bison of the Volyn region which previously was called "TSUMANSKA" and was in the hunting reserve "ZVIRIVSKE", a majority of the herd has moved to the neighboring territory of the Limited Liability Company "MAIDAN MYSLYVSKYI".

The spatial range of the entire European bison population has also increased, but still a majority of herds remain isolated. By the end of 2000 there were 28 free living populations registered in the EBPB, currently there are 45, of which 43 are situated in Europe (Figure 7.4). One population in Russia used to be registered as five separated herds.

Table 7.7. Changes of free-ranging herds in particular countries, their genetic status and size.

Country	Herd	Genetic line	2000	2010	2020
Belarus	BEREZINSKIJJ BIOSFERNYJJ ZAPOVEDNIK	LB	1	36	14
	BORISOWSKIJ LESKHOZ	LB	33		
	DIATLOVSKIJJ LESKHOZ	LB			30
	LANDSHAFTNYJJ ZAKAZNIK «NALIBOKSKIJJ»	LB			120
	LESOOHOTNICHE KHOZJAJJSTVO «LJASKOVICHI»	LB	13		
	NACIONAL’NYJJ PARK «BELOVEZHSKAJA PUSHHA»	LB	265	422	675
	NACIONAL’NYJJ PARK «PRIPJATSKIJJ»	LB	30	87	93
	OKHOTKHOZJAJJSTVO «KRASNYJJ BOR»	LB			230
	OSIPOVICHSKIJJ OPYTNYJJ LESKHOZ	LB	28	152	510
	POLESSKIJJ RADIACIONNO-EKOLOGICHESKI ZAPOVEDNIK	LB	26	76	184
	SEL’SKOKHOZJAJJSTVENNYJJ PROIZVODSTVENNYJJ KOOPERATIV «OZERY»	LB	35	139	414
	VOLOZHINSKIJJ LESKHOZ	LB	39	79	
Bulgaria	NANOVITSA	LC			11
Germany	BAD BERLEBURG	LC			26
Latvia	LAKE PAPE	LC			5
Lithuania	DZŪKIJA REGION	LB			18
	PANEVĖŽYS AND KĖDAINIAI DISTRICTS	LB	30	62	264
Poland	BIESZCZADY	LC	140	304	707
	PUSZCZA AUGUSTOWSKA	LB			17
	PUSZCZA BIAŁOWIESKA	LB	306	473	715
	PUSZCZA BORECKA	LB	60	81	117
	PUSZCZA KNYSZYŃSKA	LB	16	94	214
	STADO ZACHODNIOPOMORSKIE	LB	26	81	334
Romania	ARMENIS	LC			64
	FAGARAS MOUNTAINS	LC			9
	POIENI	LC			4
	VANATORI NEAMT	LC			50

Table 7.7. Changes of free-ranging herds in particular countries, their genetic status and size.

Russia	ARKHYZSKIJJ UCHASTOK TEBERDINSKOGO ZAPOVEDNIKA	LC	38	19	40
	«BRJANSKIJJ LES» ZAPOVEDNIK	LC	3		114
	CEJJSKIJJ ZAKAZNIK I SEVERO-OSETINSKIJJ ZAPOVEDNIK	LC	85	67	115
	FOMINSKIJJ ZAKAZNIK	LC	6	1	
	KLJAZ'MINSKO-LUKHSKIJJ ZAKAZNIK	LC			73
	KONOSHSKIJJ RAJJON	LC			
	MORDOVSKIJJ ZAPOVEDNIK	LC			17
	MUROMSKIJJ ZAKAZNIK	LC		26	101
	NACIONAL'NYJJ PARK «SEBEZHSKIJJ»	LB			2
	PETROVSKOE OKHOTKHOZJAJJSTVO	LC		13	95
	SKNJATINSKOE I KIMRSKOE OKHOTKHOZJAJJSTVO	LC	30	37	9
	SMOLENSKOE POOZER'E	LC			36
	SREDNIERUSSKAJA POPULACIJA				855
	TALDOMSKOE ROOR	LC		7	15
	TURMONSKIJJ ZAKAZNIK	LC			18
	UST'-KUBENSKOE OKHOTKHOZJAJJSTVO	LC	10	39	106
	VELIKOOZERSKOE OKHOTKHOZJAJJSTVO	LC	15	20	
	-------	--	--	--	--
	«KALUZHSKIJE ZASEKI» ZAPOVEDNIK and NACIONAL'NYJJ PARK «UGRA»	LC			*
	KARACHEVSKIJJ ZAKAZNIK	LC		8	*
	«ORLOVSKOE POLES'E» NACIONAL'NYJJ PARK	LC	19	217	*
	TULA REGION	LC			*
Slovakia	NÁRODNÝ PARK POLONINY	LC		9	54
Ukraine	FOREST HUNTING RANGE "BEREGOMETSKE" AND FOREST RANGE "STOROZHYNETSKE"	LC	138	31	33
	DANIVSKA	LC	70		
	NADVIRNJANSKA	LC	4		
	FOREST RANGE "KHMILNYTSKE"	LC	91	92	107
	FOREST RANGE "KONOTOPSKE"	LC	32	41	64
	HUNTING RANGE "STYR"	LC	9	21	84
	HUNTING RANGE "ZVIRIVSKE" & LLC "MAIDAN MYSLYVSKYI"	LC	56	25	19
	MAIDANSKA	LC	15	11	
	NATIONAL NATURE PARK "SKOLE BESKIDS"	LC		6	37
TOTAL			1531	2754	6836

* «KALUZHSKIJE ZASEKI» ZAPOVEDNIK , NACIONAL'NYJJ PARK «UGRA», KARACHEVSKIJJ ZAKAZNIK, «ORLOVSKOE POLES'E» NACIONAL'NYJJ PARK and TULA REGION are treated as one population.

● Lowland line

Poland
1. STADO ZACHODNIOPOMORSKIE
2. PUSZCZA BORECKA
3. PUSZCZA AUGUSTOWSKA
4. PUSZCZA KNYSZYŃSKA
5. PUSZCZA BIAŁOWIESKA

Lithuania
6. PANEVĖŽYS AND KĖDAINIAI DISTRICTS
7. DZŪKIJA REGION

Belarus:
8. SPK "OZERY GRODNENSKOGO RAJJONA"
9. NP "BELOVEZHSKAJA PUSHHA"
10. DIATLOVSKIJJ LESKHOZ
11. ZAKAZNIK "NALIBOKSKIJJ"
12. BEREZINSKIJJ BIOSFERNYJJ ZAPOVEDNIK
13. OKHOTKHOZJAJJSTVO "KRASNYJJ BOR"
14. OSIPOVICHSKIJJ OPYTNYJJ LESKHOZ
15. NP "PRIPJATSKIJJ"
16. POLESSKIJJ ZAPOVEDNIK

Russia:
17. NP "SEBEZHSKIJJ"

● Lowland-Caucasian line

Germany
18. BAD BERLEBURG

Latvia
19. LAKE PAPE

Poland
20. BIESZCZADY

Slowak Republic
21. NÁRODNÝ PARK POLONINY

Bulgaria
22. NANOVITSA

Romania
23. ARMENIS
24. POIENI
25. FAGARAS MOUNTAINS
26. VANATORI NEAMT

Ukraine
27. FOREST RANGE "STOROZHYNETSKE" and FOREST RANGE "BEREGOMETSKE"
28. NNP "SKOLE BESKIDS"
29. HUNTING RANGE "STYR"
30. HUNTING RANGE "ZVIRIVSKE" and LL COMPANY „MAIDAN MYSLYVSKYI"
31. FOREST RANGE "KHMILNYTSKE"
32. FOREST RANGE "KONOTOPSKE"

Russia:
33. "BRJANSKIJJ LES" ZAPOVEDNIK
34. KARACHEVSKIJJ ZAKAZNIK
35. "ORLOVSKOE POLES'E" NP
36. "KALUZHSKIJE ZASEKI" ZAPOVEDNIK and NP "UGRA"
37. TULA REGION, BELEVSKIJJ DISTRICT
38. SMOLENSKOE POOZER'E
39. PETROVSKOE OKHOTKHOZJAJJSTVO
40. TALDOMSKOE ROOR
41. SKNJATINSKOE I KIMRSKOE OKHOTKHOZJAJJSTVO
42. MUROMSKIJJ ZAKAZNIK
43. KLJAZ'MINSKO-LUKHSKIJJ ZAKAZNIK
44. MORDOVSKIJJ ZAPOVEDNIK
45. UST'-KUBENSKOE OKHOTKHOZJAJJSTVO
46. KONOSHSKIJJ RAJJON
47. ARKHYZSKIJJ UCHASTOK TEBERDINSKOGO ZAPOVEDNIKA
48. TURMONSKIJJ ZAKAZNIK
49. CEJJSKIJJ ZAKAZNIK

* SREDNIERUSSKAJA POPULACIJA

● up to 100 individuals
● over 100 individuals

Figure 7.4. Spatial distribution of free-ranging herds of European bison in Europe at the end of 2020

In Latvia (Lake Pape), Bulgaria (Nanovitsa) and in Russia (Smolenskoe Poozer'e) new semi-free herds were released. The largest concentration of Lowland line herds is in the central part of Europe, at the borders of Poland, Lithuania and Belarus. The situation improved as a result of the creation in 2020 a new population in the Augustowska Forest (Poland) and two others are already created on the beginning of 2021 (Lasy Janowskie and Puszcza Romincka). In addition, a new population has been established in this region in Lithuania (Dzūkija) and Belarus (Diatlovskij Leshoz). This area may in the future constitute the most important metapopulation of the European bison, within which a spontaneous exchange of individuals between herds is still possible. Other populations do not show mutual connectivity, with the exception of the Belarussian-Russian border, where a new population has been created on the Russian side (NP Sebezhskij), which may form a joint cross-border population with the already strong Krasnyj Bor herd in Belarus.

Three potential metapopulations may be formed for LC line herds in Europe. One of them is within the Carpathian Range, relatively close to the already existing populations in Poland and Slovakia, three new ones were created in Romania, and two herds exist in Ukraine. Therefore, currently there are 7 herds potentially able to establish mutual connectivity.

The second potential metapopulation may be established within the area of south-western Russia in the region called Orel-Kaluga-Bryanks, where 5 herds belong to one population (Orlovskoje polesje, Kaluzhskiye zaseki, Ugra, Karachevskijj and Tula) with no barriers between them and no distance greater than 10 km from each other. Bryanskij les and Petrovskoe Okhotokhosjastvo are more than 50 km far away from groups mentioned above, but still within the range of ecological corridors.

In the Orel-Bryansk region there are 5 wisent populations registered. Another potential metapopulation, may be established within the Caucasus. There are now three wisent populations, of which two can connect spatially (Turmonskij and Cejskijj zakaznik). So far in the Caucasus region there were observed significant population shifts through, drastic extinctions, but also the emergence of new populations. However, until now, the chances for the establishment of a stable metapopulation in the near future are low. A new wisent population (Petrovskoe Okhotkhozjajjstvo) was created in the Kaluga Region 80km to the North from Ugra National Park.

7.4 Conclusions

The world population of wisents grew dynamically, and by 2020 its numbers were larger than 9,000. Simultaneously, the proportion of individuals in captivity in relation to free-ranging and semi-free parts of the population decreased. In the year 2000, this proportion was over 41%, while in 2020 it dwindled to only 19.5%. This trend is very positive, indicating the development of the population structure towards large free-ranging and semi-free herds. Wisents being gregarious animals, have a tendency to form herds of 40 individuals. Therefore, in captivity it is preferable for herds to exceed 20 animals, which may fulfil all of the social requirements of that species. The proportion between the numbers of wisents belonging to Lowland and Lowland-Caucasian line also changed. Particularly in captivity, the proportion of the LB line grew from 25.6 to 37.1% since the year 2000. At the same time, there were changes in the proportion of animals belonging to this line in free-ranging and semi-free herds. In 2000, individuals belonging to the Lowland line constituted 56.6%, comparing to 57.9% at present. The nature of isolated populations is a major limitation in population development. Only a few of the existing free-ranging herds have spatial connectivity with others and only several regions are appropriate for the creation of a stable metapopulation in the near future.

8 | LEGAL STATUS AND CONSERVATION OF EUROPEAN BISON IN EUROPEAN COUNTRIES

8.1 At the European level

The European bison is listed in Appendix III of the Bern Convention. According to the Habitats Directive (Council Directive 97/62 EC), the species is subject to strict protection. It is listed in both Annex II and IV of the Directive. At present, the species has a status of near threatened (NT) on the IUCN Red List (Plumb et al. 2020). In the majority of European countries (except for Belarus, Poland, Russia, Ukraine) it is not included in their national endangered species lists.

8.2 Situation in particular countries

Azerbaijan

European bison (*Bison bonasus*) currently have neither the legislative status of an indigenous species (listed in the list of the fauna of Azerbaijan), nor is it currently mentioned in the national red data book of Azerbaijan. To include the European bison into the national list of fauna and the red data book, the Ministry of Ecology and Natural resources initiated the legislative process in 2017. Relevant documents have been submitted to, and approved by the intergovernmental commission and will be submitted during 2020 to the Cabinet of Ministers for final ratification. As the red data book in Azerbaijan is revised every 10 years, and the last edition was published in 2013, it is expected that European bison will be listed there with a status similar to CR-critically endangered in the 2023 edition.

Belarus

Generally, the European bison in Belarus the legal status of an indigenous wild animal. The Belarussian population of wisents is divided into two groups: the main and the reserve gene pool. All newly born animals receive the status of main gene pool individuals. The affiliation of an individual to the reserve gene pool is decided by a special commission. Wisents belonging to the main gene pool are listed as VU – vulnerable, in the national Red Book and in the National Endangered Species Catalogue. Every breeder has its own European bison reserve gene pool list, not necessarily shared with other breeders. Complete information is only held by the Ministry of Natural Resources. Individuals belonging to the reserve gene pool have the status of game animals. About 30-40 such individuals are shot annually during commercial hunts.

Czech Republic

Until recently, all wisents were registered in the category 'animal requiring special care', having similar status as pet and zoo animals (meaning that their meat and other products cannot be used for human consumption or as animal feed). However, since 2020, there is a new regulation that European bison must be registered as farm animals. At the same time, veterinary legislation treats wisent as cattle, while also recognizing it as a wild species. Therefore, it is possible to ask the Ministry of Agriculture for dispensation from the requirements for farm animals (see below). However, the dispensation is not guaranteed, which allows for a range of interpretations, as well as conflicting treatments of the same animals in different administrative regions (kraje) which have significant autonomy. There are two major drawbacks of the current situation, placing the wisent in a dead end position in the Czech Republic: i) consequences of the "farm animal" status, and ii) consequences of dispensation from requirements on farm animals. First (i), if European bison were considered a conventional farm animal, it would become subject to relatively frequent veterinary examinations and testing of all or at least some of the animals for infectious diseases, examinations of production performance (e.g., weight gain), ear-tagging, audits of animal identities, etc. All these interventions would require frequent physical manipulation of untamed animals, thus violating animal welfare and EU legislation. Importantly, it would pose enormous excess costs associated with handling facilities, veterinary services, etc. In addition, this would negate the existence of wisent herds in most suitable locations due to secondary conflicts with other legislation (e.g., because permanent infrastructure required for regular handling of European bison herds cannot be built in nature reserves). Finally, frequent manipulations of animals would impose numerous undesired impacts due to excessive contacts with humans (e.g., habituation to people, stress, and exposure to pathogens). The second major drawback is related to the dispensation from farm animal-related requirements (ii). The dispensation implicitly does not allow the use of meat from wisents for any form of consumption by humans or animals. Farm animal status also means that individuals cannot be culled no matter how and where they live. Imports of wisents have to be confirmed by the Ministry of Environment, and local governments and conservation authorities must not dispute such import. European bison are not considered game animals and imports/exports of wisents, therefore, do not require approval by a hunting association. The wisent is not included in the Czech list of specially protected species (Decree No. 395/1992 Coll., Act No. 114/1992 Coll., on nature conservation and landscape protection). Only general animal welfare and veterinary legislation applies to the species, together with international conventions (Bern Convention, EU Habitats Directive). Thus, species protection of European bison in the Czech Republic is completely based on EU, and not national, legislation.

Denmark

All fenced animals (regardless of the size of the enclosure) are considered domestic, which also applies to the European bison. Presently, three areas with semi-wild bison living in large enclosures are thus all covered by traditional livestock rules including animal welfare regulations. In the foreseeable future a free roaming population of European bison in Denmark is not likely. Zoo animals follow special rules and are not included in this overview. Until 2019, individual identification (either ear tag or chip) was compulsory. However, in 2021 a new EU animal health law will be introduced, which probably will include better opportunities for avoiding invasive identification. Therefore, the Danish authorities have already allowed calves not to be identified until the moment they (dead or alive) leave their enclosures. It is currently unclear whether European bison in Denmark may be used for human consumption due to their international protection status. The European bison is not included in Danish hunting legislation. Dead animals cannot be left for natural decomposition in the wild, since they are considered as livestock which means, regardless of the cause of death, the body must be sent for proper disposal.

France

As a wildlife species, the European bison is classified as “extinct” by the National Institute of Natural Heritage (INPN: Institut National du Patrimoine Naturel), the French reference organization affiliated with the National Museum of Natural History. Neither, is it on the list of species that can be hunted. As for European bison kept in captivity, they have the same legal status as every wild animal in similar conditions. The owner of the animals has to hold a “certificate of competence” issued by an approved committee after a hearing of the applicant. They have to submit a file presenting their project beforehand. The main population in captivity in France is in a reserve dedicated to eco-tourism in the South- east of the country (Réserve des Monts d’Azur) where European bison live on more than 300 ha with Przewalski’s horses, red deer, wild boar and more recently elk. This reserve is governed by a specific administrative regulation called a “Prefectorial order”. It lists various obligations, in particular concerning the type of fences, sanitary control or the access by the general public. It seems unlikely that the species could be reintroduced to the wild in the short term.

Germany

The wisent is strictly protected by the Federal Nature Conservation Act §44. The wisent is considered a game species according to § 2 Federal Hunting Act (BJagdG) but is not listed in the federal hunting regulations (BJagdZ-VO). Thus, wisents enjoy year-round protection. However, like in the case of the Rothaargebirge wisent project it is allowed to cull “surplus” bulls for herd management purposes, and subsequently to sell the meat. According to the law for the prevention and control of animal diseases (Animal Health Act - TierGesG) §2 (4b), wisents are regarded as livestock.

Hungary

According to the 13/2001 (V. 9) Decree of the Minister of the Environment, the European bison is classified as an "animal species of high conservation value in the European Community". The Nature Conservation Act 53 of 1996 provides satisfactory protection for the species. The Act requires permission for all activities related to the species, in particular its possession, reproduction, repopulation, export, import, etc. The species is not listed in the Decree as a game species, so it cannot be hunted, not even in game preserves.

Lithuania

The wisent is included in the National List of Protected Species and has been protected in Lithuania since 1969. It also has the status of strictly protected species following the requirements of Annex IV of the EU Habitats Directive. In 2018 a National Species Protection Plan was developed. Protected areas are not established for the protection of this species as its population mainly occurs within a mosaic of agriculture and small forests, and home ranges of herds are changing. The wisent is also listed among game species, however, there is no hunting season set for it, so as a consequence it is not hunted in practice. About 30 individuals are kept in captivity. The Environmental Protection Agency may issue permits to take selected wisents from the wild. The fine for illegal killing of wisents is over 10,000 €. Damages caused by wisents to agricultural crops are compensated from the state budget.

Poland

The species is protected according to the Bill on Nature Conservation (16.04. 2004). In the decree of the Ministry of Environment on 6.10.2014, Annex 1 - the wisent is listed as a strictly protected species requiring active conservation. It is also included in the National Red List. In exceptional cases, the Minister of Environment may allow for forbidden or restricted actions towards the species, including the elimination of selected individuals. Carcasses of naturally dead or culled animals can be destroyed (obligatory in case of infectious diseases) or left in the wild. Damages caused by European bison are compensated from the state budget.

Romania

In Romania, the European bison is a strictly protected species according to environmental legislation (G.O. 57/2007). It is also a game species, for which hunting is forbidden, according to Hunting Law 407 /2006. The Ministry of Environment, Water and Forests has a contradictory approach, recognizing the European bison presence in freedom as a Natura 2000 priority species (e.g., the species is included in the Natura 2000 Standard Data Form for Vanatori Neamt) but, at the same time, does not recognize its presence as a game species. For this reason, the actual compensation mechanism, designed for game species, cannot be applied in the case of European bison.

Russia

The European bison is considered one of the most important and valuable wildlife species in Russia. In the past, the species was listed in the Red Book of the USSR since 1978, and in the Red Book of the Russian Federation since 1997. In the latest 2020 edition, the European bison belongs to category I–endangered. The first Action Plan for this species was approved in 2002. In Russia, the protection of European bison and conservation of its environment are regulated by several legal acts of varying legal force, the key of which are the Federal Law of 10.01.2002 Num. 7-FZ “On Environmental Protection”; Federal Law of 04.24.1995 No. 52-FZ “On the Animal World” and Federal Law of March 14, 1995 “On Specially Protected Natural Territories.” The main legislative act in this area (Federal Law of 04.24.1995 No. 52-FZ “On the Animal World”) regulates the use of the animal world and its habitat to ensure biological diversity, sustainable use of all its components, creation of conditions for the sustainable existence of the animal world and conservation of the genetic pool of wild animals. This legislative Act provides for measures to preserve wildlife habitat, to protect rare and endangered wildlife, as well as wildlife and its environment in specially protected natural areas. Following the Law, the main powers of the federal government authorities include the determination of state policy in the field of wildlife conservation and use, the maintenance of the Red Book of the Russian federation, the creation of protected areas, and the organization and implementation of the protection and restoration of wildlife located in federally protected areas. The powers assigned for execution to state authorities of the constituent entities of the Russian Federation (except for territories of federally protected areas) by the Law include: organizing and implementing the protection and restoration of wildlife, maintaining state counts, state monitoring and the state cadastre of wildlife within the Russian Federation, federal-state supervision in the field of protection and use of wildlife and their habitats in the territory of the Russian Federation. Funds for exercising the powers delegated to the regions are provided in the form of subventions from the federal budget, the volume of which is small, and in the last three years has not exceeded 8.8 million rubles for the whole of the Russian Federation. The powers of state authorities of a constituent entity of the Russian Federation in the field of protection and use of wildlife include the establishment and maintenance of a Red Book of a constituent entity of the Russian federation, the development and implementation of regional programmes for the protection and reproduction of wildlife. The law establishes the right of citizens and legal entities to exercise public control, take measures to protect wildlife and its environment, and also to facilitate the implementation of relevant state programmes. The law provides for the mandatory state environmental review before the adoption of an economic decision that could affect the animal world and their habitat, as well as the inadmissibility of actions that could lead to the death, reduction in the number or disturbance of the habitat of the animal species listed in the Red Books. Besides, the civil, criminal and administrative legislation of the Russian federation contains various rules that contribute to the preservation of the animal world and its environment. To increase responsibility for the illegal extraction, keeping, acquisition, storage, transportation, transfer and sale of especially valuable wild animals and aquatic biological resources belonging to species listed in the Red Book of the Russian Federation, and protected by international treaties ratified by Russia, which includes European bison, in 2013 amendments were made to the Criminal Code of the Russian Federation: a new article 258.1 was introduced providing for criminal liability for the above illegal actions concerning especially valuable wild animals (for the commission of these crimes criminal liability was established for up to seven years in prison), and additions were made to article 226.1, providing criminal liability for smuggling of animals and resources listed in the Red Book. To implement articles 226.1 and 258.1 of the Criminal Code of the Russian Federation, the Government of the Russian Federation on October 31, 2013 No. 978 approved the List of especially valuable wild animals and aquatic biological resources related to species listed in the Red Book of the Russian Federation and protected by international treaties. The European bison is also included in this list. As mentioned above, the European bison is listed in the Red Book of the Russian Federation in the first category as an "endangered taxon, whose numbers have decreased to such a critical level that it may disappear in a short time". Hunting of this species is strictly prohibited. For illegal extraction of European bison, criminal liability and substantial amounts of compensation for damage are provided. According to the "Methodology for calculating the amount of damage caused to subjects of the animal world listed in the Red Book of the Russian federation, as well as other subjects of the animal world that are not objects of hunting and fishing and their habitat" (order of the Ministry of Natural Resources of Russia dated April 28, 2008 No. 107) the value of damage for the destruction or illegal acquisition of European bison is 250 thousand rubles. The extraction of fauna belonging to the species listed in the Red Book of the Russian federation (including the European bison) is regulated by the Decree of the Government of the Russian Federation dated 06.01.1997 No. 13 "On approval of the Rules for the extraction of fauna belonging to the species listed in the Red Book of the Russian Federation, except for aquatic biological resources," and is allowed in exceptional cases. A change in the status of the species in the National Red list is conditional to populations reaching 1000 animals. Currently, the largest one has 746 individuals. The procedure for issuing special permits is defined by the Administrative Regulations of the federal Service for Supervision of Natural Resources for the issuance of permits for the extraction of animal and plant life listed in the Red Book of the Russian Federation (Order of the Ministry of Natural Resources of Russia dated April 30, 2009 No. 123). The trade or transfer of wildlife belonging to species listed in the Red Book of the Russian federation (including the European bison) is regulated by the Decree of the Government of the Russian federation of February 19, 1996 No. 156 "On the Procedure for Issuing Permits (Administrative Licenses) for the trade or transfer of Wild Animals Belonging to Species listed in the Red Book of the Russian Federation", as well as "Administrative Regulations of the Federal Service for Supervision of Natural Resources Management in fulfilling the state function of issuing permits (regulatory licenses) for the trade or transfer of wild animals belonging to species listed in the Red Book of the Russian Federation", approved by order of the Ministry of Natural Resources of Russia dated January 15, 2008, No. 4.

Photo courtesy of Ryszard Stasiewicz

Slovakia

In the Slovak Republic the European bison is a protected species under national legislation regulations, in particular Act No. 543/2002 Coll. on Nature and Landscape Protection, as amended by later regulations, and Order of the Ministry of Environment of the Slovak Republic No. 170/2021 Coll. by which the Act No. 543/2002 Coll. on nature and landscape protection is executed. It is, among others, prohibited to knowingly capture or kill a protected animal in its natural environment, disturb it in its natural environment, especially during breeding, rearing, hibernation or migration; or to disturb and damage its habitat. According to the Act No. 543/2002 Coll. on nature and landscape protection as amended by later regulations and Order of the Ministry of Environment of the Slovak Republic No. 170/2021 Coll. by which the Act No. 543/2002 Coll. on nature and landscape protection is executed, the European bison is protected year-round. It is a Species of European Conservation Concern and a Priority species (Annexes 4B, 6A). According to the Act No. 274/2009 Coll. on hunting, as amended by later regulations, and Order of the Ministry of Agriculture No. 344/2009 Coll. by which the Act No. 274/2009 Coll. on hunting is executed, the European bison is considered as a protected game species. The species is also included in the Act No. 274/2009 Coll. on hunting as amended by later regulations, as game species. The European bison is however protected all year. Illegal killing of European bison is dealt with according to the Criminal Code 300/2005 Coll., Chapter VI Crimes of public danger and crimes against the environment, Section 305/4/b – Breach of Plant and Animal Protection. The State Nature Conservancy of the Slovak Republic has been involved in the process of Natura 2000 sites designation. A rescue plan for this species has been developed and adopted (2007-2011). The social value of the European bison is estimated at 10000 Euro. According to the Act No. 543/2002 Coll. on nature and landscape protection and the Order of the Ministry of Environment of the Slovak Republic No. 170/2021 Coll. by which the Act No. 543/2002 Coll. on nature and landscape protection is executed, the Government has a duty to compensate the damage caused by European bison on: a) agricultural crops not harvested according to the agro-technical schedule, b) fruit trees or forest stands.

Spain

The species is being classified in the National Environmental Regulation, through the extension of European law, as a Species of Community Interest, for which it is stated that: “Member countries must enable territories for their conservation.” A National Conservation Plan or Strategy for this species is not being developed in Spain as National Authorities adduce there is no regulation to do so. The species therefore is not included in the National Endangered Species Catalogue nor any Regional Endangered Species Catalogue despite efforts undertaken since 2015, to encourage the National Government to classify the species as endangered in Spain. At present, all European bison living in Spain are privately own and are classified as wildlife in Zoological Nucleus, a special category between a stockbreeding site and a Zoo Park. Spanish sanitary veterinarian authorities are trying to include all European bison in Spain into an annual testing campaign for zoonoses obligatory for cattle, and consider this endangered species as cattle in all respects.

Sweden

According to the Swedish Species Protection Legislation, SFS 2007:845, based mainly on the EU Council Directive 92/43, the European bison in Sweden is considered a wild animal species, even if it is kept in captivity and in enclosures. If a free living population of European bison were to be established in Sweden, those animals could not be hunted but would be considered as "protected" according to the status of the species (few individuals, vulnerable population), following the Swedish animal species protection legislation. Sweden lacks large forest areas belonging to the state so all arrangements regarding European bison have to be negotiated with municipalities and/or private land owners. Since presently there are no wild European bison in Sweden, a majority of individuals held outside of regular zoo settings are kept in large "game/ wildlife" enclosures. In some large enclosures which contain a natural environment, it is in some cases allowed to hunt the surplus animals according to Swedish animal welfare legislation (Animal Welfare Law, SFS 1988:539) and Swedish hunting legislation (Hunting law, SFS 1987:259) and to use the meat for human consumption according to Swedish food hygiene legislation based on the EU Directive No. 853/2004. In small enclosures the animals are subject to the same rules as livestock. In zoos, the use of meat for feeding carnivores, is regulated by rules for so called feed suppliers. Recently, there is an increase in the use of this species as a grazer for land conservation and biodiversity maintenance, but still this is limited to fenced areas. Since the regulations are very complicated, depend on the reasons for keeping European bison in captivity in Sweden and not always consistent, in 2016 the Swedish Centre for Animal Welfare (SCAW) at the Swedish University of Agricultural Sciences (SLU), did an in-depth analysis of the regulatory framework. Presently in Sweden, there are four national administrative authorities responsible for different aspects related to the legal status of European bison: The national Environmental Protection Agency - responsible for the rules that apply to wildlife management including hunting; The national Board of Agriculture - responsible for the protection of wildlife in captivity, and the management and slaughter of wildlife; The national Swedish Food Agency - responsible for the inspection before and after slaughter for human consumption; The regional County Administrative Boards - responsible for the control and approval regarding the management and welfare of wild animals in enclosures kept as public exhibits.

The Netherlands

The Dutch government has not mentioned the European bison on any of its animal legislation lists. A working group is currently active to make this happen. Although European bison are protected under Annex IV, they are currently not recognized as an indigenous wild species in the Netherlands. This is because the Dutch authorities do not yet recognize the Netherlands as part of the natural range of European bison. It would help the conservation efforts of E. bison in the Netherlands if the European bison would be included in the national indigenous wild species list. According to the NVWA (The Dutch food and consumer product safety authority, which is also involved when exporting European bison) the species falls in the same category as zoo animals. European bison are not regarded as farm animals nor as production animals. Since all European bison in the Netherlands are kept in secluded areas of a maximum of several hundred hectares, the species is considered a captive wild animal. All European bison in the Netherlands have an owner, who is responsible in case legal matters arise (damage to property, attack on humans). Owners are responsible for the wellbeing of the herd. The animals do not have to be checked by a veterinarian annually, but the owners do have a “duty of care”. This means that it is punishable by law to withhold proper care or when failing to provide the animals with enough food, drinking water, shelter and company. Ear tags or other forms of individual identification are not required, and even unwanted. But identification is possible as most animals are chipped and individual DNA samples are routinely collected. When an animal is culled, in theory there are several options: the carcass can be destroyed, the carcass can be left in the wilderness or the meat can be consumed. It would be preferable to leave the carcass for decomposition, for the benefit of scavengers. Legislation is however not yet clear whether and under which circumstances this is allowed. Managers of European bison herds are negotiating with Dutch authorities to establish relevant legislation. t is currently not allowed to consume the meat of European bison, because the species is not on the list of wild animals that may be consumed. Because of an expected surplus of animals that cannot be placed elsewhere, it is important to investigate under which conditions selective culling for limited consumption would be possible as an exclusive and sporadic by-product of nature management. In conclusion, the aim is to declare the species endemic. A regulation is being developed to allow for leaving carcasses in nature and to determine the optimal procedure to deal with surplus animals.

Ukraine

The European bison is listed in the Red Book of Ukraine; therefore the species has the highest protection status, which excludes its hunting under any circumstances.

Conservation of wisents in Ukraine is regulated by five legal documents:

- The Law of Ukraine “On the Red Book of Ukraine” of February 07, 2002 № 3055-III;
- The Law of Ukraine “On Fauna” of December 13, 2001 № 2894-III;
- The Law of Ukraine “On Environmental Protection” of June 25, 1991 № 1264-XII;
- The Law of Ukraine “On the Nature Reserve Fund of Ukraine” of June 16, 1992 № 2456-XII, which refers to animals living within a protected area;
- The Law of Ukraine “On Hunting Economy and Shooting” of February 22, 2000 № 1478-III applies to wisents living within hunting grounds, which are the responsibility of land users.

Special cases may be regulated by:

- The Law of Ukraine “On Ukraine’s Accession to the Convention on the Conservation of Migratory Species of Wild Animals” of March 19, 1999 № 535-XIV;
- The Law of Ukraine “On Ukraine’s Accession to the Convention on International Trade in Endangered Species of Wild Fauna and Flora” of May 14, 1999 № 662-XIV.

Violation of any of these laws would be prosecuted under the Criminal Code of Ukraine (of April 05, 2001 No. 2341-III) or the Code of Administrative Offences of Ukraine (of December 7, 1984 № 8073-X). The Ministry of Ecology and Natural Resources of Ukraine is the highest state authority issuing decisions regarding the management, restoration, and protection of wild animals. At the regional level, the regional branches of the State Environmental Inspectorate of Ukraine supervise the conservation of endangered and vulnerable species (including wisent). As the majority of managed wisent populations are maintained within the territory of hunting grounds (including forest fund), those animals receive additional protection from the State forest Guard of the State Forest Resources Agency of Ukraine and the wildlife rangers of the respective hunting grounds.

Photo courtesy of Adam Kolator

8.3 Proposed changes

8.3.1 Creation of a Pan European body (authority) dedicated to the conservation of the species

During discussions within EBCC community it has been suggested, that for better and more effective coordination of efforts towards the conservation of European bison in the future, it would be advisable to establish a pan-European structure allowing for establishing a communication channel between institutions and people involved directly in species conservation and authorities at a national and an EU levels. This could facilitate the implementation of actions recommended in next SAP. Such structure would require an involvement of administrative representatives of particular European countries, EU officials and experts on biology, conservation and management of the species, as well as appropriate financing, provided either by participating countries or through an EU budget.

Nevertheless, at the moment there are two bodies cooperating on this issue: European Bison Conservation Centre and Bison Specialist Group within IUCN. The EBCC focuses more upon practical aspects of species conservation and management, while the BSG is more oriented towards the formal side of the framework devoted to conservation efforts.

The necessity for further closer coordination of EBCC and BSG actions, and feasible solutions for its implementation in the practice, should be discussed within as wide a representation of people/institutions involved in European bison conservation and management as possible.

8.3.2 Unification of the legal status of the species

At present, the legal status of the species varies considerably among European countries. That means sometimes completely different approaches towards issues concerning animal' health, species conservation, transport, welfare, captive breeding, etc. This creates some obstacles to the international exchange of animals or maintenance of genetic purity of the species which is aided through animals being able to cross international borders, etc. The present status of a strictly protected species resulting from its listing in Annex IV does not reflect recent population growth of European bison at it was shown in the latest issue of IUCN Red LIst (Plumb et al. 2020, Kowalczyk, Plumb 2021). In practice, the high ranking in Annex IV is rather counterproductive as it does not facilitate better prospects for the species' ecological restitution on the one hand, and sometimes hampers rational species' active management on the other. For the reasons above, it is suggested herein to list European bison in Annex V: "animal and plant species of community interest whose taking in the wild and exploitation may be subject to management measures". Species listed in Annex V, may be exploited by human beings, while member states must ensure that their exploitation and taking in the wild is compatible with maintaining them in a favorable conservation status (ungulates currently listed in Annex V: *Capra ibex, Capra pyrenaica, Rupicapra rupicapra)*.

Management goals for the species should consider:

- o Maintenance of species' purity with respect to the risk of hybridization with American bison (e.g., escaped farm animals) and A. bison x European bison hybrids (e.g., Caucasian region)
- o Maintenance of both natural and man-mediated gene flow focused on the prevention of loss of genetic diversity and rare founder genes
- o Ecological control on free and semi-free populations, including the maintenance of population/herd sizes according to carrying capacity models
- o Health surveillance and control in free-ranging, semi-free and captive herds

Allowed management measures should consider:

- o Capture, transport and other types of manipulation including: population regulation of selected individuals/groups for population/herd management purposes. This action is accepted in most European countries but if rules for species protection under Natura 2000 for species listed in Annex IV are strictly applied - it is illegal.
- o Supplemental temporary feeding and temporary or permanent fencing in home ranges of free-ranging herds to mitigate human-wisent conflicts (prevention of unwanted migrations, traffic accidents, crop damages, famine during severe winters, spread of diseases, etc.).
- o Selective culling according to prescribed procedures.

A proposal prepared by herd keepers or relevant authorities (e.g., state conservation, forest or national park service, veterinary service, hunting ground administrators) justifying a need for the selection of individual animals or an annual plan for population regulation. The approval (decision) for selective culling, including required conditions, should be issued by national authorities on the basis of verification of such proposal by,for example, EBCC or a new Pan European structure (see above) concerning the reasons for such action. Elimination of an animal should be done by a licensed hunter in the case of free-ranging animals or a veterinarian or other suitably licensed individual in captive conditions. A necropsy for health monitoring/surveillance, and collection of samples for genetic and microbiological analysis should be recommended as obligatory (see details in Chapter 7).

Any profits resulting from elimination (e.g., selling the license, trophy, meat) should be used for the maintenance of a given herd/population. To facilitate procedures connected with elimination and further processing of the carcass, animals approved for elimination should have their status formally changed to "game", so appropriate regulations could be applied avoiding the standard requirements for farm animals.

Such an approach would solve the problem of the need to deal with so called "surplus animals" (e.g., bulls in captivity), nuisance individuals (e.g., bulls migrating into densely inhabited areas, and allow for obtaining samples necessary to monitor health and genetic status of animals. Additionally, it would create an added value to European bison breeding, allowing the acquisition of some financial returns and minimizing management costs.

In the EU, this procedure means to include the species in Annex V in the Habitats Directive and delete it from Annex II (no need to protect special habitats for this species) and IV (the species can not be strictly protected without active management), with the idea to implement this protocol in all countries, including non-EU, that have ratified the Convention on the Conservation of European Wildlife and Natural Habitat (Bern Convention). In this Convention *Bison bonasus* is listed in Apendix III – as animal species whose exploitation should be regulated on the national level with the condition that the populations of such species are maintained at an appropriate level. The ratifying states may, for example, establish conservation periods for these species or regulate their exploitation and sale. The position of wisent in Bern Convention is more proper that in Habitats Directive.

8.3.3 Inclusion of European bison in National Endangered Species Lists and introduction of legal changes allowing for private participation in European bison conservation

The inclusion of an endangered species in a National Endangered Species List or Catalogue makes the development of a National Conservation Program and Strategy possible, which is lacking in many European countries. In some European countries (especially in the east), the conservation of European bison is performed exclusively by governmental institutions while in some other countries, private individuals and non-governmental organizations are also involved. Therefore the conservation efforts are often weakly coordinated and difficult to connect into larger, international initiatives. Such unification and enhancement of the conservation status would be helpful in extending collaboration at the European level.

Due to the growing interest of private investors in European bison breeding and contributing to the conservation of the species, new legal regulations should be introduced, to consider opening this new opportunity for an extension of efforts leading to an increase in European bison numbers in Europe, and therefore increasing further chances for the survival of the species.

8.3.4 Standardized veterinary and welfare requirements for wisent transport between EU and other countries

A number of countries with populations of European bison of at least several hundred animals (Belarus, Russia, Ukraine) are not EU member states. Nevertheless, those animals are very important reservoirs for the gene pool of the species, and it is of significant importance to involve them in an exchange program oriented towards the mitigation of further loss of genetic variability. Within the European Union, human-induced movements of European bison must be performed according to procedures obligatory for all state members. They include clear identification of individuals, regulations for transport that considers animal welfare and sanitary requirements including compulsory tests for diseases common to all bovine species in the EU. More complicated are transfers of animals into and out of the EU due to different standards and requirements approved by various countries. Therefore a unified protocol describing conditions required for movements of European bison should be agreed between EU state members and other countries regarding testing for diseases, deworming (upon an agreement between donor and acceptor of animals), vaccinations, disinfection of transportation crates, etc.


Photo courtesy of Katarzyna Borek

9 | MANAGEMENT OF FREE-RANGING HERDS

There are several different systems of recommended management for free-ranging wisent herds, depending on the size of the herd, its social/genetic structure, and characteristics of its home range, as well as the degree of its overlap with protected areas and these of commercial use. The management system should then consider the genetic structure of the herd, its effective size, habitat fragmentation, a potential for human related conflicts and constraints resulting from the occurrence of such large herbivores within protected areas. The system must be adaptive and indicate specific tools for achieving particular goals. Nevertheless, whatever management system is actually applied, it must ponder also the legal situation of the species in a given country as well as local social constraints.

In general, it should be taken into account, that carrying capacity of presently available ranges suitable for European bison is limited, especially in the western part of the continent. Therefore, for the sake of sound management, for both: home ranges of already existing populations and planned introduction sites, a maximum carrying population should be determined. At first, it should be decided whether it is possible to aim at a self sustaining, viable population or if the size of a new group should be limited (e.g., to 20-30 individuals), with all the consequences of maintaining such group through active management. For that purpose it is necessary to consider three aspects: (1) actual carrying capacity of the site for large herbivores, (2) potential for the emergence of conflicts with agriculture, livestock, forestry, road traffic, tourism, infrastructure, etc. (3) the degree of isolation of the selected site and considering the possibilities for natural migrations, but also a danger of disease transmissions (Perzanowski, Olech 2004, Perzanowski et al. 2005, Perzanowski 2016). Carrying capacity usually allows for larger population numbers to be maintained, than the potential level of social acceptance. Thus, the maximum population number is crucial as a key to combine into one model all the issues (very often inherently contradictory) and make sure that none of them is neglected.

Determination of the maximum allowed number of animals implies the necessity of setting up rules for its regulation. In the case of European bison, it can be done either by capturing and translocating of animals or by selective culling. For both of these solutions precise procedures should be established according to the legal order of a particular country (Pucek et al. 2004, Perzanowski 2016). The decision for the need to regulate numbers of a given population has to be based upon its precise inventory which requires an application of a reliable monitoring system. Monitoring of population numbers should also comprise the collection of data on population sex and age structure, its spatial distribution with seasonal changes, and health status - including collection of samples from sick or dead animals (Perzanowski 2005, Perzanowski, Olech 2014). Information on damage to field crops and other sources of conflicts with human activity is also necessary.

It has been assumed (Pucek et al. 2004) that a wisent population needs at least 100 individuals to be demographically safe. According to Plumb et al. (2020) this should be at the level of 250 adult individuals. However, guaranteed steady long-term development requires an effective number of 500, unrelated and successfully reproducing animals Franklin and Frankham (1998). Population viability analysis, despite its limitations, is regarded as a useful tool for the management of threatened species (Brook et al., 2002, McCarthy et al., 2003), which provides predictions of extinction risk. Only few such studies have been carried out on the European bison, but the analysis performed indicate that even not very large population of this species is quite resistant to the risk of extinction. PHVA carried out in the Polish and Belarusian part of the Białowieska Forest indicate a low risk of extinction, regardless the lack of gene exchange between the two parts of the forest complex (Daleszczyk, Bunevich 2009). However, when the real kinship value among founders was considered, the mean number of alleles decreased and gene diversity was reduced. Moreover, due to the lack of gene exchange between the two parts of the forest complex the probability of extinction grows, especially in the Belarusian part. In recent study Suchecka et al. (2021), simulated was an initial herd of 100 individuals in larger forest complex (with the carrying capacity of 250 individuals) and low extinction risk (PE < 0.01) and high genetic diversity retention (0.97) have been found. The parameters of the analysis were based on data from large ex-situ European bison herds in Europe. Low extinction risk was estimated for large North American populations (PE < 0.01) with predation pressure and disease risk (Traylor-Holtzer 2016). However, maintaining or increasing the genetic diversity of individual herds needs some level of gene flow in form of moderate translocations using either least-related herds as source populations or alternating source herds (Hartway et al. 2020). In contrary, studies on plain American bison showed a high risk of population extinction and loss of genetic diversity in a hunted population of less than 420 individuals (Cherry et al. 2019). A high risk of population extinction was found in the Texas State Bison Herd, and only supplementation with unrelated males significantly changed PE to 0% over the 100-year simulation period (Halbert et al. 2005). Suchecka et al. (2021) analyzed variants of the development of small connected populations of European bison as an alternative to large forest complexes. Despite the use of restrictive demographic parameters, it has been shown, that a metapopulation consisting of three small (20 individuals in beginning) populations with a stable structure placed in environments with relatively low carrying capacity (up to 50 or 70 individuals) has a satisfactory low risk of extinction (PE<0.4% depending on the scenario). Moreover, the genetic diversity retention was around 0.95.

Taking into consideration the results of PHVA simulation, while larger herds present low extinction risk and chance for maintaining the genetic diversity, the gene flow must be possible, at least in the form of translocations. Moreover, metapopulation consisting of just few small herds could be very promising for the European bison future, over the large part of Europe (Suchecka et al. 2021). Hence, considering present size of even the largest current wisent populations it is obvious, that all of them require active measures to mitigate the loss of genetic heterogeneity. In the case of small herds often consisting of 10 - 20 individuals, especially those that are effectively isolated from other populations, it is necessary to apply a prescribed periodical exchange of animals, preferably breeding bulls. Additional risk regarding the genetic variability of European bison is the loss of rare or underrepresented founder genes. This problem can only be mitigated only by supplementing with animals of known pedigree to improve the genetic structure of the herd. This can be done only through the cooperation with breeding centres which are able to select animals with the optimal pedigree for that purpose. Therefore, it is important to have a coordination of efforts between captive centers and managers of free-ranging herds (Olech, Perzanowski 2011, 2016).

Population management is often strictly connected with habitat maintenance and improvement. That includes cultivation of grazing grounds like meadows or feeding glades, and assuring a year-round availability of drinking water, either securing the safe access to watercourses or the establishment of permanent watering places. Therefore, a program of small water retention should be implemented whenever it is possible within the ranges of wisent herds. Under the framework of the management of forest stands within European bison ranges, clear cutting and thinning should not be intensive, and prolonged over the autumn-winter season to facilitate browsing and debarking on desired tree species. In sites, where accessibility of ground flora in winter is severely limited, seasonal supplemental feeding should be considered as an option. All these activities should be consistent and considered as a tool for the management of spatial distribution of the animals. These measures may also serve for mitigating conflicts with inhabitants of local villages through preventing animals from foraging on field crops (Klich et al. 2018). Moreover, prevention of feeding on crops minimizes the as yet unknown consequences of exposure to pesticides (Klich et al. 2020) and changes in mineral status (Klich et al. 2021). In regions, where damage to field crops is significant, an introduction of a system of compensation is recommended (Perzanowski, Olech 2014).

Although in the majority of countries the European bison has a legal status of endangered and is a strictly protected species, because of significant costs connected with wisent' maintenance, supervision, monitoring, compensations, etc. it is reasonable to consider selective culling on a commercial bases, which could cover at least a part of the total necessary expenses. Nevertheless, it is recommended that such costs should be mainly covered from the state budget on routine basis as a part of expenses for nature conservation (Pucek et al. 2004, Perzanowski 2016). The management of a wisent population that inhabits a protected area like a national park or a nature reserve must remain in accordance with its rules, so in many cases active measures like supplemental feeding, introduction of cultivated foraging plots or selective culling may not be possible there. On the other hand, sizeable protected areas like national parks or Natura 2000 sites may be very helpful in the maintenance of ecological connectivity among otherwise isolated European bison ranges, facilitating spontaneous migrations of animals through ecological corridors or "stepping stones" (Perzanowski et al. 2009, Krasiński et al. 2014, Perzanowski 2017).

9.1 Present management system for free-ranging herds in particular countries

Azerbaijan

First 12 (3.9) European Bison (LC-Line) arrived to the Bison Reintroduction Center in Shahdag National Park in 2019. All the animals are still in the fenced 300 ha rewilding area of the National Park, which has a total size of 130,000 ha of mixed broadleaf forests and mountain meadows. The herd is maintained by specially trained bison rangers and caretakers. The release into the core zone of the NP will take place in 2020. The program is managed and implemented by the Ministry of Ecology and Natural Resources of Azerbaijan, International Dialogue for Environmental Action and WWF-Azerbaijan. Financing comes from the German Cooperation (BMZ/KfW) and WWF-Germany.

Belarus

There are 9 sites where free-ranging European bison populations are maintained. Two of them (Nacionalnyj Park "Pripjatskij" and Polesskij Radiacionno-Ekologicheski Zapovednik), have the status of a protected area (the national park and the Chernobyl Exclusion Zone). Three populations living in Nacional'nyj Park "Belovezhskaya Pushha", Berezinskij Biosfernij Zapovednik and Landshaftnyj Zakaznik "Nalibokskij" partly live within the protected area, but partly in the territory of general economic use (forestry, hunting grounds, agriculture, etc.). The remaining 4 populations live exclusively within the area of general economic use. Managers of particular herds are responsible for their management (protection, supplemental feeding, etc.). A small part of the finance comes from the State budget, but the main part of the costs is covered by institutions managing those areas. General management rules (at the State level) are imposed by the Ministry of Natural Resources and Environment Conservation of the Republic of Belarus. Compensation for damage to crops are usually covered by regional budgets, but sometimes such claims remain not compensated at all.

Lithuania

There are two free-ranging herds in the central part of the country (Kėdainiai and Panevėžys regions - EBPB 2020), mainly in privately owned agricultural lands mixed with small forests. In 2018, Lithuania started a project on wisent protection and management activities. Annual census and monitoring of the population (sex and age structure), movement of herds and genetic research are performed. Every year, a certain number of wisents with particular features (sick, old, aggressive, likely hybrids, those staying near roads or railways, therefore, causing threat to human life, health and safety) are identified for elimination. Such a solution is allowed exceptionally, under permits issued by the Environmental Protection Agency. There are plans to translocate a number of individuals from the central part of the country to its southern area, where it is more suitable for this species. For that purpose, an infrastructure for adaptation of transferred animals is under preparation. From the beginning of 2020, specially designed mobile snares are used to catch wisents from the wild in the central part of Lithuania for translocation. Additionally, it is planned to explore the possibilities to establish migration corridors to connect with the wisent populations of Belarus and Poland. In order to minimise damage caused by free-ranging wisent to agricultural crops, supplemental feeding places are established.

Poland

Of the eight free-ranging herds in the country, in two cases (Białowieska and Bieszczady) their ranges overlap partially with the area of national parks and the rest is situated mostly within commercial forests. The herd of Western Pomerania Province dwells partially in the area of a military training ground, and partially within commercial forests or large-scale agriculture. Herds in Knyszyńska, Borecka and Augustowska Forests and two new established in 2021 inhabit mostly state-owned forest stands. In most cases (Bieszczady, Białowieska Forest, Knyszyńska Forest, Borecka Forest and Augustowska Forest, Romincka Forest, Lasy Janowskie institutional supervision of wisent herds is provided by State Forest Administration, while the population of Western Pomerania is under the custody of a local NGO. Actions concerning all herds are consulted with Regional Directorates for Environment Conservation. Financing comes partially from the budget of State Forests and partially from long term research or nature conservation projects. For all free-ranging wisent herds, compensation for damage to crops is covered by the State budget.

Winter supplemental feeding (in the form of hay or root crops depending on site) is provided for all free-ranging herds. It is either being provided especially for European bison or supplied under the framework of winter maintenance of other ungulates. In Knyszyńska, Borecka and Augustowska forests, permanent watering places were constructed and they are renewed every few years, depending on the financial possibilities. Annual maintenance of meadows in all sites is the basis for improving the food base for the European bison. In the vicinity of the Białowieska forest, pastures are rented from farmers who are obliged to make hay available for wisents. Active chasing wisent in Western Pomerania Province is carried out when a herd enters an area of farmland. This can be considered in our sites when numerous herds tend to feed on crops. Although the European bison is strictly protected in Poland, after obtaining the consent of the General Director for Environmental Protection in Poland, selective culling is occasionally practiced. Selection of animals for culling is done by a special commission that considers signs of a disease, severe injuries or aggressiveness of particular individuals. Eliminated animals are sampled for health and genetic monitoring.

Romania

In 2020, there were four free-ranging herds at Vanatori Neamt, Tarcu-Armenis, Poieni-Densus, and Fagaras Mountains. The first three free herds inhabit mostly state owned forests managed by Romsilva (the National Forest Administration), but in each case the free wisent home range includes also private lands (forests, pasturelands, hayfields, orchards, small scale agriculture, etc). Also hunting grounds are set up, some of them administrated by Romsilva, the others by private hunting associations. The fourth mentioned herd dwells in private land especially dedicated for the future Fagaras Mountains National Park. Home ranges of all four herds overlap with Natura 2000 sites. The herd in Vanatori Neamt roams in a nature park, and the herd from Fagaras Mountains in an area of the future national park. The actual free herds were established as a result of external funding projects implemented by the Vanatori Neamt Nature Park Administration in the case of Vanatori Neamt herd by WWF Romania, the Rewilding Europe funded Tarcu-Armenis and the Poieni-Densus herds, and Conservation Carpathia Foundation in the case of Fagaras Mountains.

Until now, the management of free-ranging wisents and the associated financing has been provided primarily by the organizations mentioned above. In each case, the herds were supplemented with animals with known pedigree, additional food was provided rarely and only during winter, just to prevent conflicts with the local communities. The herds are monitored regarding number, sex ratio, health status, spatial distribution, and an annual evaluation takes place. There is no mechanism regarding selective culling. In Romania the European bison is a strictly protected species according to environmental legislation, but at the same time, taking into account the hunting legislation, a game species (for which hunting is totally forbidden). Being a legal game species, the further management of the free wisents should be done by the hunting ground administrators. Being a game species for which hunting is totally forbidden the compensation for damage should be paid by the Ministry of Environment, Water and Forests. The actual compensation mechanism seems to be stuck, because until now the Ministry has simply delayed the transfer of responsibilities regarding the free wisents from the actual custodians to the hunting ground administrators.

Russia

The European bison is a strictly protected wild species, listed in the Red book of Russia. The availability of vast territories with low atheroprogression and high carrying capacity, including a huge network of specially protected areas and ecological corridors that connect them, allows for establishing numerous herds. Harsh weather conditions with a predominantly continental climate in the central and northern European part of Russia facilitates the task of natural selection and adaptation of the populations. To restore the species in Russia, the main emphasis was on creating a sufficiently large population that would guarantee sustainable long-term development with an effective number of 500 unrelated and intensively breeding animals. Thus, the total number of such populations should be nearly 1000 animals. Taking into account the danger of an outbreak of a disease, more than just one site must be considered as a guarantee to achieve this. In practice, out of 12 home ranges of European bison, only one site in Russia is close to meeting the criteria.

The so-called Middle-Russian European bison population is scattered along a network of strictly protected areas with Orlovskoye Polesye national park and Kaluzhskiye zaseki State Zapovednik on the lead, followed by national park Ugra, Karachevskiy regional reserve and several hunting grounds. The total area of those ranges is almost 3000 sq. km, inhabited by over 850 European bison forming several herds. Core herds remain within the borders of Orlovskoye Polesye National park (Orel region) and Kaluzhskiye Zaseki State Zapovednik (Kaluga region) and act as a reservoir of animals (mainly bulls) that disperse into neighboring regions, i.e., Tula and Bryansk. Administrations of both Kaluzhskiye Zaseki S.Z. and Orlovskoye Polesye N.P. monitor herd numbers and the condition of individuals, and arrange for the translocation of animals to other regions of Russia. Winter feeding in this area is maintained mostly to stimulate a concentration of animals in that season to facilitate their monitoring rather than for provision of additional food. Nevertheless, the population consists of separate small herds, many of them being extremely vary of humans and able to cope perfectly without supplementary feeding.

Recent studies on habitat modeling using the MaxEnt method identified good habitats for European bison in Kaluga region with a corridor linking them with Smolensk region, where a new free-ranging herd has been released in 2017 in Smolenskoye Poozerye National park. In addition to the Middle-Russian European bison population, there are 4 other herds in Russia counting together about 100 individuals: Ust-Kubenskiy (Vologda region), State Zapovednik Bryanskiy Les (Bryansk region), Muromsk reserve (Vladimir region) and Tseyskiy reserve of North Ossetian State Zapovednik (Respublic of North Ossetia). The last three of seem to have reached carrying capacity of their ranges, and only the Ust-Kubenskiy herd remains well below this threshold. The carrying capacity of the Vologda region is estimated for up to 1000 animals. Another four free-ranging herds count almost 50 animals: Petrovskaya hunting ground (Kaluga region), Klyazminsko-Lukhskiy regional reserve (Vladimir region), Smolenskoye Poozerye National Park (Smolensk region) and Teberdinskiy State Zapovednik (Respublic of Karachevo-Cherkesia). Only Smolensloye Poozerye has carrying capacity that allows for the maintenance of a larger herd. The remaining five herds are small and their future is not clear. They are: Mordovskiy State Zapovednik (Republic of Mordovia), Turmonskiy regional reserve (Republic of North Ossetia), Sebezhkiy National Park (Pskov region), Sknyatinskoe (Tver region) and Taldom (Moscow region) hunting grounds. Russian government attention to the European bison has increased in recent years. An expert group was formed under the umbrella of the Ministry of Natural Resources, formed by scientists and environmental professionals involved in the restoration of the species in the country. The expert group is called upon to coordinate decisions on animal translocation, approving unified monitoring techniques, taking into account the latest developments in habitat assessment and population management.

Slovakia

There is one free-ranging herd at Poloniny National Park (north-eastern part of the country) consisting of 54 individuals. The national plan for the restitution of this species has been developed and adopted (2007-2011). Presently the social value of an individual European bison was estimated for 10000 €. According to the Act No. 543/2002 Coll. on nature and landscape protection and the Order of the Ministry of Environment of the Slovak Republic No. 170/2021 Coll. by which the Act No. 543/2002 Coll. on nature and landscape protection is executed, the Government has a duty to compensate damage caused by European bison in: a) agricultural crops not harvested according to the agro-technical schedule and b) fruit trees or forest stands. In the Slovak Republic, monitoring of European bison is performed by the routine collection of data in defined areas (so-called permanent monitoring plots) using standardized methods. For the purpose of collecting, processing, evaluating and publishing of field monitoring data, new information system has been developed – *Comprehensive Information and Monitoring System* (CIMS), which is managed by staff from the State Nature Conservancy of the Slovak Republic. Monitoring data are the basis for the development of reports on the status of species and habitats of European interest according to Art. 17 of the Council Directive No. 92/43/EEC of 22 May 1992 on the conservation of natural habitats, and of wild fauna and flora (Habitats Directive). SNC SR was, according to Art. 17 of the Habitats Directive, obliged to submit the report on the status of species and habitats of European interest for the reporting period 2013-2019. This report also included European bison. An up to date overview of the conservation status of habitats and species is available online and is made public at the following website: www.biomonitoring.sk.

Ukraine

The subpopulation of the Volyn region (within the Hunting range "Zvirivske" and Limited Liability Company "Maidan Myslyvskyi"), the subpopulation of Sumy region (Forest range "Konotopske"), and the majority of the subpopulation of Chernivtsi region (Forest and hunting range "Beregometske" and Forest range "Storozhynetske") inhabit areas of hunting grounds with minimal human care. This is the least favorable method of herd management, considering the poor level of protection and substantial disturbance due to forestry and logging activities. The subpopulation of Vinnytsia region (Forest range "Khmilnytske") and the subpopulation in the north of the Lviv region (Hunting range "Styr"), also dwell within hunting grounds, although they are under constant observation and actively implemented security measures, which is beneficial for the condition of both herds. However in both localities conflicts frequently occur with forest and farmland owners due to the lack of compensation schemes for damage to forest and agricultural crops, as well the inconsistency in the management of land and animal resources. The subpopulation in the National Nature Park "Skole Beskydy" (Lviv region) occupies the territory belonging to the nature reserve fund, which reduces the threats related to anthropogenic pressure and the conflicts with land users. These conditions are the most favorable for the maintenance of wisent as well as the most promising conditions for their further introductions. The subpopulation of the State Residency "Zalissia" (Kyiv region) lives in semi-free conditions. The fenced area there is of 14.8 thousand ha, so the maintenance costs of the fence are high. Moreover, the high density of various ungulate species occurring within the enclosure requires intensive feeding. A small part of the wisent subpopulation on the territory of Forest range "Storozhynetske"(11 individuals) is kept in an enclosure of 80.2 ha, and this group is expected to grow to 15-16 animals, out of which surplus animals (mostly youngsters) are planned to be released to the wild. Additionally, animals remaining in the enclosure are supposed to attract free-ranging wisent from the vicinity, and therefore prevent their migration in undesirable directions.

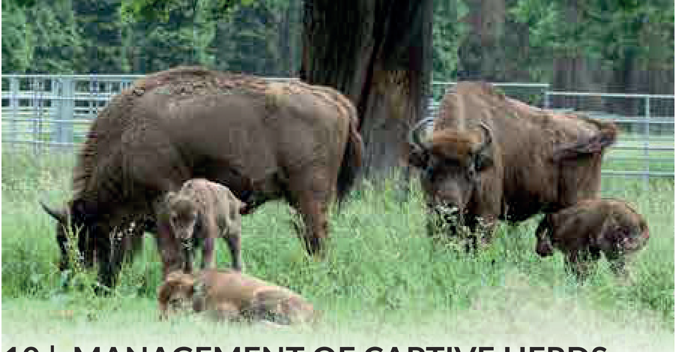

Photo courtesy of EBCC archive

10 | MANAGEMENT OF CAPTIVE HERDS (FEEDING, BREEDING, PROPHYLAXIS)

10.1 The importance of wisent breeding in captivity

- Captive herds are the most important reservoir for the establishment and improvement of current or future free-living wisent populations.
- Captive herds represent a survival reservoir in the event of epizootic outbreaks or other calamities. They live under controlled conditions with veterinary care, and should there be an outbreak of a disease they can be provided with appropriate treatment.
- Breeding in captivity gives an opportunity to prevent the loss of genetic variability and to compensate for the uneven distribution of the original 12 founders.
- Captive herds provide the best opportunity to raise public awareness of species conservation and to provide environmental education.

10.2 Feeding

Wisent are herbivorous animals whose diet consists of grasses, sedges, herbaceous plants, as well as the leaves and twigs of trees and shrubs. It eats the bark of oaks, hornbeams and ashes, but also many other deciduous and coniferous trees. Among favorite food items of European bison are acorns and beechnuts. In summer, some 2/3 of their feed intake is composed of grass, sedge and herbaceous plants.

An adult animal eats daily from 30 to 45 kg of fresh green mass. Wisents need access to water every day. Under natural conditions they use various water courses and small ponds. In winter they may supplement their fluid needs by eating snow.

Feeding of wisents in captivity must meet the nutritional requirements provided by the diet outlined above. Since only a few facilities (breeding centres or zoos) are able to provide an adequate natural food supply, animals in captivity generally have to be fed an artificial diet throughout year. In growing season, if natural grazing is unavailable fresh grass mowed from meadows should be offered daily. Hay or also hay silage should be offered *ad libitum* in winter, but should be accessible during the whole year if there is no seasonal access to grazing.

Tree bark, buds, leafy twigs and tree branches should be provided during the whole year and in winter they can be given similar material from certain coniferous tree species like pine. This basic feed, should be occasionally supplemented with small amounts of various components such as pellets, cereals, beets, beet pulp, tree fruits such as acorns and beech nuts but soft, high sugar content fruit like apples, should not be offered. Additionally, carrots and green vegetables can be provided in very small quantities. If beets are used for feeding, they cannot have more than a 6% sugar content. It is recommended that they should have provision of mineral mixtures if not fed a suitable pellet diet and *ad libitum* access to salt licks. For example: Vita Miral Red in 25 kg paper bags: 20% calcium, 8% sodium, 5% phosphorus and 4% magnesium. Plus, vitamins A and D3, copper, zinc, manganese, iodine, selenium, and cobalt. The permanent access to minerals significantly suppresses the urge to debarking trees, because the animals have sufficient supply of minerals and trace elements. This is particularly important for the management of enclosures that have a high proportion of trees but they should still be provided with regular supplies of cut tree branches.

Supplemental concentrated feed should be provided in feeding stations, which should be combined with catching facilities, separation stalls and pens and a loading station. The provision of a suitable bison restraint device is also advantageous. The animals become familiar with such facilities through positive reinforcement of daily feeding. Daily provision of food provides animal keepers the best opportunity for routine health checks, and for the administration of necessary treatments as advised by the veterinarian. The most common and most serious mistake in feeding is excessive provision of concentrates soft fruit or vegetables which can lead to permanent problems with diarrhoea and other severe malfunctions of their gastrointestinal tract. It is absolutely basic to ensure the quality of forages provided to wisents, including the hay and hay silage. It is advisable to have an occasional quality inspection carried out by an institute for animal nutrition. Wisents need daily access to fresh water. To avoid its contamination with faeces and parasites, the maintenance of open water bodies in smaller enclosure should be avoided. Simple but robust water troughs are suitable being regularly emptied, cleaned and refilled with fresh water. An ideal solution are self-drinkers with a connection to a mains water supply.

10.3 Breeding

The limited genetic pool of the species with only 12 founders, constitutes potentially the most serious threat for the species' future. Therefore, making breeding decisions based on a chance or the easiest opportunities, for example short transport routes, cheaper purchase price, or even allowing inbreeding is dangerous to the genetic health of the breeding stock. Such a risk is even higher in small herds which are the most common. Outside of more structured programmes like the EEP, some breeders are not familiar with proper procedures for transporting and exchange of breeding animals. In some cases breeding bulls are used for years in the same herd, mating the same cows in several consecutive breeding seasons. If female offspring are not moved out or the bull exchanged, the level of inbreeding increases because the exchange of genetic material is insufficient or non existing. Due to such improper practices two paternal lines were lost. Therefore the decisions on breeding selection must not be done randomly, but always with consideration of the parental lineage of the animals and their pedigree. In the long term, a balanced distribution of lineages for both, bulls and cows must be established. The further loss of underrepresented lineages must be prevented. Hence, through training and further education, all wisent breeders must be made aware of genetic issues and at the same time have access to up-to-date knowledge and data.

In order to facilitate recognition of an origin of particular individuals, it is recommended to microchip all animals whenever possible to allow for certain identification of every individual. Microchip IDs should be linked to the corresponding studbook numbers in the European Bison Pedigree Book. Regular microchipping though of all calves shortly after birth (as required by agro legislation in most EU countries), is not congruent with wisent welfare from veterinary (sedation), safety. To facilitate the identification of individuals, a standard optimal location of microchips should be agreed. Ear tags however, should be completely avoided, microchips should be considered sufficient for individual identification. In cases when ear tag use is necessary, small models (as in sheep) should be used instead of the large yellow plastic ear tags used in cattle which are usually quickly lost when animals are moving across the forest.

Surplus animals, animals unsuitable for breeding or of low genetic value should be removed from breeding groups as soon as possible to ensure that limited resources are used for the best breeding benefit and to maintain optimal genetic variability. New breeding groups should be assembled accordingly to requirements that ensure proper genetic and population structure. For best results, herd composition should be possibly close to that of wild herds as is practical for the individual circumstances. If a zoo or park can only hold a small number of animals, i.e., <10 adults and offspring, it may be wise if they reconsider their decision to keep European bison. Since the common problem is an excess of bulls, it is necessary to introduce a new approach for the management of this sex. Since in free conditions a natural formation of bachelor groups occurs, it could be advisable to establish more pure bull herds in captivity, as it has been done within the EEP population. The maintenance of such groups of bulls would create a possibility to make choices of breeding males at the age of 4 or 5 years, when their potential suitability for reproduction is much easier to judge. In such herds, only bulls of rare genetic lines and of high genetic value should be gathered, while males of low genetic value or apparent phenotypic deficiencies should be excluded. Additionally such groups could be effectively used in landscape management. Especially for grazing projects, an involvement of bull herds could be beneficial while maintaining a constant prescribed number of animals. Also, for zoological facilities with a limited area, groups consisting only of bulls are possibly easier to maintain and therefore may be a good alternative to breeding groups. It is of course important to monitor the adjacent presence of bovid females as this can trigger aggression within a bachelor herd of sexually mature individuals.

10.4 Prophylaxis

Preventive and protective measures are essential means allowing for keeping wisent populations healthy, breeding them successfully and minimizing both the risk of loss of individual animals and even entire subpopulations. In addition to the measures already mentioned above, such as feed analysis, adding minerals, access to fresh water, avoiding inbreeding, animal welfare issues must always be observed. Therefore, the highest standards of animal husbandry and veterinary care must be the norm.

A list of recommended measures for prophylaxis in European bison captive breeding:

- Enclosures, stalls, fences and animal holding areas should be constructed in a secure way that promotes normal herd behaviour and prevents injuries by eliminating risky layouts or construction details.
- If the maintenance of a natural environment within enclosures is not possible, a dynamic programme of food presentation and enrichment opportunities must be provided to promote normal individual and herd behaviour and prevent stereotypic, stressed or antisocial behaviour.
- Individual animal records are crucial to secure proper long-term management and animal welfare in managed herds! They should include records of health observations/deviations, time of deworming and other routine procedures, test results, temporary isolation/observation, medication and veterinary treatment, heat display, mating, calving, etc. (Zielke et al. 2018).
- Everyday health monitoring of all animals by the animal keeper is vital, preferably during the daily feeding time. Daily observation should include the general impression, body condition score, eyes, nostrils, mouth, visible injuries on head and body, skin/ectoparasites, movements and locomotor functions, resting, eating/appetite, rumination, drinking, individual behaviour and social interactions (especially heat display and mating), herd level of behaviour and social interactions, calves (suckling, following mother, playing, normal development) and any variation in what would be normal for that individual.
- Reporting of all observed irregular looks or behaviour of animals to a senior member of the animal staff and if warranted, the veterinarian.

- All sick, injured, or conspicuous animals must be examined by the veterinarian and treated if necessary.
- In the case of a casualty, an autopsy must be obligatory to determine the cause of death. The most important is the exclusion of an infection problem.
- Also culled and seemingly healthy animals should undergo a post-mortem examination, or if slaughtered an extended meat inspection, as a valuable part of a general health monitoring plan.
- Regular (weekly) visits by the attending veterinarian.
- Regular (at least every three months) faecal examinations for parasites.
- Daily cleaning of feeding places (removal of food remnants, collecting faeces), water troughs and self-drinkers.
- Weekly inspection of enclosures, regular fencing and also electrical fencing (plus daily voltage checks), stalls and other facilities to insure they are intact and do not pose a risk of physically injuring the animals.
- Weekly documentation of feed consumption (increase or decrease), inspection of feed hygienic quality, and records of food supply (new roughage, concentrate batch, etc).
- Regular (every three months) disinfection of feeding points and stable boxes with chemical agents approved for livestock and that are environmentally safe.
- Disinfection of stable boxes after any case of recorded disease.
- In the case of severe contamination with faeces, a treatment of meadows and pastures in spring and autumn with substances accelerating the breakdown of faeces and urine can be considered.
- Control of parasites if necessary. Minor infestation is acceptable. If there is a problem with individual animals, deworming treatment can be administered with feed if animals are fed individually, otherwise treatment via tele-injection. If the problem concerns the whole herd, deworming should be provided with feed. Regular (preferably twice a year - early spring and autumn) check up of an efficacy of antihelminthic treatment through analysing faecal egg count reduction (FECR) and rotate the treatment products used to avoid and adaptive immunity by the parasites
- Regular blood tests for diseases such as BHV1, BVD, brucellosis, leukosis, para-TB, and in high-risk areas also the Schmallenberg virus and the bluetongue virus. For this purpose, every possibility must be used, i.e., when wisents are under anaesthesia, are restrained or trained for sampling or the access to animals is otherwise available. When blood sampling, take extra serum whole blood and freeze as a biobank, to be able to trace back in case of outbreaks.

- Blood tests mentioned under point 18 should be obligatory for all acquired or translocated animals, to exclude the spread of the diseases into healthy herds. There should be obligatory four week pre- and post-transport quarantine. Some locations are free of bovine TB or brucellosis and these regional situations should be accounted for.
- It must be ensured that suitable medication and an understanding of the correct doses required - especially for anaesthesia - as well as equipment and staff are available if necessary.
- If available, vaccinations are recommended (there is good experience in Germany with the vaccination against the bluetongue virus), as a suitable measure to exclude epidemics or to keep them under control.

- Availability of an infrastructure useful in herd management like: stable boxes, pens allowing for separation of animals and quarantine, restraint devices and facilities helpful in administration of treatments and loading for transport.
- Implemented security measures and strict regulations governing access to animal facilities, stables, pens, etc. to prevent the transfer of diseases by outsiders.
- Especially in the event of epizootic diseases, only the staff should have an access to the animals and suitable barrier techniques, equipment and procedures should be put in place.
- Direct or indirect contact with other ruminants should be avoided or reduced to a necessary minimum and it is specifically important for bison not to have any close contact with sheep due to the high risk of infecting them with malignant catarrhal fever (MCF) which is often endemic and asymptomatic in sheep.
- Approved procedures for a case of epizootic disease should exist in every breeding centre. In Germany, the decision for an exception to killing a wisent in the event of an epidemic must be issued prior to any such event, and has to be coordinated with the veterinary office of the local government authority.
- A contingency plan and necessary equipment should be prepared for handling escapes.

10.5 The European bison EEP

The EAZA Ex-situ Programme (EEP) through the European Association of Zoos and Aquariums are defined thus (copied from the EAZA Website): “EEPs are defined as population management activities that are endorsed by EAZA for species that are managed by EAZA Members aiming towards (maintaining) healthy populations of healthy animals within EAZA or beyond. For species that are not considered for active management, the TAG (Taxon Advisory Group) monitors the population trend. For each new EEP that is recommended in an RCP (Regional Collection Plan), in the following a serious of questions concerning the envisaged participants, governance and general biological characteristics of the EEP that guide the TAG to make conscious decisions, rather than automatic assumptions, is discussed by the TAG. The decisions are captured in an EEP application leading to tailor made EEPs fully focused on the species needs, aiming towards (maintaining) healthy populations of healthy animals within EAZA and beyond

The EEP is the most intensive type of population management for a species kept in EAZA zoos. Each EEP has a coordinator (someone with a special interest in and knowledge of the species concerned, who is working in an EAZA zoo or aquarium). He or she is assisted by an elected Species Committee. The coordinator has many tasks to fulfill, such as collecting information on the status of all the animals of the species for which he or she is responsible kept in EAZA zoos and aquariums, producing a studbook, carrying out demographic and genetic analyses, and producing a plan for the future management of the species. Together with the Species Committee, recommendations are made each year on which animals should breed or not breed, which individual animals should go from one zoo to another, and so on. Not all wisent breeders are EAZA/EEP , , but the EEP includes over 450 European bison in 77 participating institutions with a particular focus on providing animals for reintroduction. It is also important to note that all animals that are transferred within or out with the EEP (e.g., to a reintroduction project) are provided at no charge to the recipient, other than possibly transport costs.

10.6 European Bison Conservation Center (EBCC)

The European Bison Conservation Center (EBCC) is an International Network gathering European bison breeders from Poland, Germany, Russia, Denmark, Sweden, Spain, Romania, Belgium, Czech Republic, Belarus and Ukraine. The EBCC is the long-term project of the European Bison Friends Society.

The main goal of the EBCC is to coordinate the flow and exchange of information between wisent breeders from different European countries. Secondly, the function of the EBCC is to create a platform for communication between European bison breeders, decision makers, conservationists and other interested parties to develop a common policy for wisent conservation in Europe, despite the existence of differences in the rules of European bison conservation in the various European countries.

According to Status Survey and Conservation Action Plan for European Bison (IUCN 2004) the main task of an International Network is the “coordination of restitution, reintroductions, monitoring of

Photo courtesy of EBCC archive

captive and free-ranging herds, and most of all – gene pool preservation, and genetic management of particular herds. This center is supposed to provide all kinds of information, and be available to all interested users, possibly free of charge". The Center started to work (October 2008) at the University of Life Sciences in Warsaw. The IUCN was informed about the fact that the EBCC started to operate as an implementation of recommended action within the Species Action Plan.

Both networks EAZA and EBCC aim to treat the captive part of population as a part of metapopulation including both genetic lines. This implies the arrangement of regular exchanges of animals between herds. This mating program is based on pedigree data, which is a very good source of information, and as in the case of many other endangered species calculation of kinship, founder contribution, relationship is the main part of planning. The problem is an effective implementation of such plans because wisent herds are scattered among many countries, remain in various ownership, with different economic status. Nevertheless results obtained up to now prove that so far, such planning towards saving the genetic variability within the species is done properly (Druet et al. 2020; Wecek et al. 2017)

Photo courtesy of EBCC archive

11 | DISEASES/HEALTH STATUS, WELFARE

11.1 Protection of wisent' health - risk of illness

The health of a wisent is an element influencing the proper development of the individual and its position in the social hierarchy as well as its proper functioning in the herd. Only healthy individual will have good welfare.

The health status of the population generally determines the viability of the species. It is closely related to the environmental factors. From its environment, the animal derives the components necessary for proper development and health, and finds shelter there. But the environment is also the source of threats which can create difficulties for the species and individuals. Wisent, regardless of where they live, are influenced by various factors that may have a positive or negative impact.

These factors include:

- soil richness, conditioning the supply the right quantity and quality of food - its failure to meet the body's needs may result in poor development or diseases;
- a nutritional base that allows for achieving proper body condition, which is necessary for maintaining an adequate level of immunity, and protecting against infection or infestation;
- the presence of infectious agents (bacteria, viruses, fungi, parasites), threaten wisent' health; in which includes contact with domestic and wild animals, in particular ruminants; and,
- injuries.

Since the beginning of the species recovery, infectious and parasitic diseases have been the greatest threat to the health of wisents.

11.2 Infectious diseases with potential or real significance for wisents

Tuberculosis (TB), a recently re-emerging zoonotic disease in many European countries. The disease was diagnosed in the free-living bison population in the Bieszczady mountains in the 90s' (Żórawski i Lipiec, 1998; Krajewska et al., 2015), European bison are very susceptible to mycobacterial infections, and since no vaccination programmes or treatment could have been introduced in the wild, the only method of disease control and prevention of its spreading was the elimination of infected animals. Tuberculosis affecting European bison in Poland is caused by Mycobacterium caprea (Krajewska et al., 2018). The management of the disease is extremely difficult especially in wild conditions, since the mycobacteria transmit readily between different wild species such as wild boar, deer and wolves in Bieszczady mountains (Krajewska et al., 2015). American bison bred in Poland are also considered a potentially important reservoir of tuberculosis (Krajewska et al. 2017).

- **Foot and mouth disease (FMD)**, a viral disease that caused the extinction of the herd (17 individuals) in Pszczyna Breeding Center and in Gorce, and the serious reduction of the herd in the Niepołomice Breeding Centre. It seems that in these cases the reason for the high mortality was the severe frost prevailing in the winter of 1953/1954 and the poor condition of the animals. The foot-and-mouth disease virus is transmitted by the droplet route. The disease develops within 2-8 days of infection. Symptoms include fever, apathy and lack of appetite, blisters and erosions appear on the mucous membranes and skin (intercrotic fissure). Its incidence can reach up to 100% of the vulnerable population, but the mortality only exceptionally exceeds 1 - 5%. Isolation and removal of sick animals may prevent the spread of disease to healthy ones.
- **Brucellosis**, a zoonotic disease caused by the bacteria *Brucella abortus*. Although eradicated in most, but not all European countries, brucellosis is of importance at the wildlife/livestock/human interface. Human brucellosis remains the commonest zoonotic disease worldwide with more than 500.000 new cases annually (Godfroid, 2017). Therefore direct contacts between wisents and livestock should be avoided.
- **Respiratory diseases caused by bacterial infections** (*Pasteurella multocida, Mannheimia haemolytica, Mycoplasma bovis, Arcanobacterium pyogenes, Trupeurella pyogenes, Fusobacterium necrophorum*) and viral (BoHV-1 - Bovine herpes virus-1, BPIV-type 3, BAdV-3 - Bovine adenovirus B serotype 3, BRSV - Bovine respiratory syncytial virus). The contribution of these factors is poorly understood, but due to their origin from ruminants, they pose a potentially important threat of immunosuppression. Pathogens can cause bronchopneumonia or interstitial pneumonia. Symptoms include discharge from the nostrils (mucous or mucous-purulent), shortness of breath, cough, lack of appetite, and sometimes apathy.
- **Bluetongue disease** - a viral disease caused by BTV-8 (Bluetongue virus serotype - 8) and other strains. The virus is transmitted through a vector (a blood-borne insect from the *Culicoides* spp.). In 2007, this disease caused the death of 10 individuals out of 33 at the Hardehausen Breeding Center (Germany). About 20% of wisents in

zoological gardens within a 20 km radius from Hardehausen died. Clinical symptoms of the disease are manifested by corneal edema, fever, apathy, salivation, reduced or no appetite, which is associated with ulceration of the mucous membrane, hoof inflammation, and lameness. Death usually happens suddenly.

- **Gastrointestinal diseases** - mainly diarrhea caused by BVDV (Bovine viral diarrhea virus). This virus is not widespread in the European bison, but its presence in cattle is a potential threat to the health of the wild species. Potential etiological factors for diarrhea may also be coronaviruses, rotaviruses or *Escherichia coli*, and protozoa of coccidia. Regardless of the type of pathogen, the symptoms of the disease are diarrhea, dehydration, and weakness.
- **Schmallenberg virus infection** (SVB, Schmallenberg virus) - transmitted by bloodsucking from the *Culicoides* spp. The virus appeared in Europe in 2011. Its role as a pathogen in the European bison is unknown, however, it is necessary to monitor the problem, because in cows (*Bos taurus*) it causes reproductive disorders as well as developmental disorders and mortality in infected newborns. The wisent population in Poland has a marked seroprevalence of this virus.

Parasitic diseases are the second health issue, after the significant infectious bacterial or viral diseases for the wisent population, due to the ease with which they can infect large number of animals at the same time and the effects on their health. Among the many parasites, those that play the most important role in the pathogenesis of wisent diseases are:

- **Hepatic fluke** *Fasciola hepatica*, which damages the liver and its metabolism products may be the cause of the reduced condition of the host. It is especially dangerous for juveniles.
- **Pulmonary nematode** *Dictiocaulus viviparus is the cause of chronic bronchiolitis and interstitial lung inflammation. Clinical sign*s are rarely seen in wisents, even during a heavy case of infestation. However, severe clinical signs and even death from lungworm infections were seen when the parasite appeared in a free-roaming herd of European bison. Animals born from lungworm positive females never show clinical signs despite high faecal larvae counts and positive serology. The use of oral vaccination with radiated larvae (Bovilis® lungworm, MSD Animal Health) has become a routine when new wisents are introduced into this herd (Hoyer, unpublished data).
- **Gastrointestinal nematodes** (Trichostrongylidae) are a group of parasites that have a serious impact on the condition of wisents. Depending on the severity of the infection, they can cause diarrhea or anemia (blood-sucking *Ashwortius sidemi*), thereby affecting the animal's physical condition.
- **Nematodes of the genus *Thelazia*** – they live in the wisent's conjunctival sac and cause inflammation of the eye, which results in progressive visual impairment, including blindness.
- **The tapeworm *Moniezia benedeni*** - a parasite where intense invasion may lead to closing of the intestinal tract making the passage of food impossible or causes diarrhea, which decreases the condition of the animal.

The pathogens listed above are not the full list of biological factors potentially threatening the wisent, but they are the most important. Other significant health threats, are the anthropopression and globalization processes, as well as climate change. Historically (in the period before the extinction of the European bison in Poland in 1919), the movement of people and farm animals through the Białowieska Forest was a factor determining an increase in diseases occurrence and mortality in the wisent population. These threats and many new are still an issue today. Diagnosis of wisent diseases should be based mainly on post-mortem examinations. However, because a corpse found in the wild is often in an advanced state of decay, hence the most important autopsies are those performed on individuals eliminated selectively. Only in the "fresh" diagnostic material is it possible to fully assess the condition of tissues and organs, thereby determining the animal's health status and by inference, that of the population.

for the protection of the wisent's health, especially in breeding centers, the application of biosecurity principles is crucial, including the limitation of access by people but also other species, especially ungulates. However, in the process of new herd creation it is important to carry out a retrospective assessment of habitats. This assessment should take into account the risk of infectious diseases that threaten the European bison there in the past. Previous experience indicates that some diseases may have reappeared after many years in areas where cattle were ill in the past (e.g., due to tuberculosis or telaziosis). An increase of the wisent population density has a consequence for its health. Very high population density may negatively affect the welfare of wisent populations because:

- It facilitates the transmission of pathogens between individuals as well as between herds – through direct and /or indirect contact, including via vectors (insects).
- It facilitates contact with other species (especially other ungulates) creating the risk of infection.
- It increases nutritional needs and competition for food resources.
- It increases the pressure of the wisent on the environment.

11.3 Risk assessment - monitoring of wisent diseases

The risk assessment should be carried out by a veterinarian who is responsible for a given herd. Such a veterinarian performs the protective functions through continuous, routine health monitoring, including:

- **veterinary (passive) supervision** - registration of fatal cases and sick individuals;
- **epidemiological monitoring** - review serological tests;
- **autopsy** (directional checking of dead and eliminated individuals);
- **bacteriological, virologic, parasitological tests** in accordance with veterinarian principles;
- **supervision of wisent transfers**; and
- **environmental research** - vector determination (entomological), checking other species living in the same habitat

Obtained results should be summarized, and are the most important criterion for the determination of the animals' health status.

11.4 Remedies to protect wisent' health

The basic remedial activities in the protection of wisent' health is primarily ongoing monitoring, and in the situation of a disease suspicion - the isolation of the suspect or / and its elimination. Isolation should primarily take place in dedicated enclosures. In free-living herds, isolation of animals is not advisable or practical, as it is a serious stressor, thus it may aggravate the animal's discomfort and exacerbate the health issue. Therefore, it is more rational to eliminate (euthanize) a suspected individual from the population.

11.5 Purpose of killing a suspected animal

The purpose of killing a suspected animal includes

- o elimination of the potential threat of the spread of the infectious and contagious agents; and/or,
- o protecting the welfare of the sick individual.

For reasons of welfare, after observing signs indicating pain and suffering of the animal, it is necessary to consider its elimination for humanitarian reasons. Elimination should be done in a way that minimizes stress and pain. Euthanasia with the use of pharmacological agents is not recommended due to the negative impact on the natural environment, because the carcass of such animals must be utilized and cannot be left to predators or transferred to human consumption. Therefore, such an individual should be killed with a bullet from a suitable caliber of rifle. The body of each eliminated animal should be dissected to assess the cause of the symptoms that were observed during the individual's lifetime which will also dictate the appropriate outcome for the carcass.

11.6 Welfare protection

Animal welfare is defined as a state of physical and mental health achieved in conditions of full harmony of the animal in its environment. This concept also includes the conditions during animal transports and humanitarian killing. The World Organization for Animal Health considered welfare as a state in which the animal is healthy, lives in appropriate conditions, is well nourished, is able to express innate behavior and does not suffer from pain, fear and stress (WOAH, 2008). The concept of animal welfare includes three components: the natural biological functioning of the animal (the animal is healthy and well nourished), its emotional state (no negative emotions such as pain and chronic fear), and its ability to express certain standard behaviors (e.g., to socialize and reproduce) (Fraser et al., 1997).

For the Farm Animal Welfare Council, it is necessary to point out the animal welfare criteria, expressed in the five freedoms:

- o free from hunger, thirst and malnutrition,
- o free from mental trauma and pain,
- o free from pain, wounds and diseases,
- o free to express natural behavior, and
- o free from fear and stress.

In this context, the welfare of the wisent is to a great extent dependent upon good health, which is expressed by the absence of injuries, diseases and the absence of pain caused by disease and / or injury. Disease is often associated with pain / suffering, so in the absence of treatment the ill animal is not in a state of well-being, and has to be killed. It is cruel to leave a sick, suffering animal alive when it is not possible to treat it or for it to regain its health. Protection against prolonged hunger and prolonged thirst is also very important. Currently, the size of the European bison population allows for the implementation of a policy towards applying restrictive rules for the protection of the species' health, consisting of eliminating individuals suspected of having significant health issues. The maintenance of such individuals in the population may pose a potential threat to the well-being of the entire group.

Photo courtesy of Maria Sobczuk

11.7 Proceedings necessary in captive conditions

11.7.1 Preventing the transfer of diseases/parasites

Animals in captivity are on the one hand relatively easy to control and to apply necessary treatments, but at the same time since they are completely dependent on man, they require constant care. In breeding centers, following of biosecurity principles is crucial, including the limitation of access not only for people but also other species, especially ungulates. There should be secured conditions allowing for implementing quarantine; performing tests for infectious diseases (e.g., tuberculosis, brucellosis, leukemia or BTV), and the application of deworming, based on routine fecal examination for parasites. Sites for new enclosures should be selected taking into account the risk of infectious diseases that occurred there in the past, that are potentially dangerous for European bison. Some diseases may appear even after many years in areas where they occurred in cattle in the past. This problem concerns also movements of animals between various breeding centers. There are two possible scenarios: (1) new diseases and/or parasites may be introduced into a local population by (sub-clinically) infected animals, (2) healthy introduced animals may be exposed to endemic disease/parasites occurring in a new site. Therefore of crucial importance is the testing of animals prior to transport and vaccination or other preventive treatment when there is a known risk of disease/parasites at the destination. A pre- and post-transfer quarantine should be used prior to an animal's introduction to a new herd

11.7.2 Capture and transportation

Transport of European bison is a quite common procedure considering its European captive population is managed as a single metapopulation, so genetic exchanges are recommended. Also new projects receive individuals and those must be transported from source herds to destination sites. Quarantine/deworming/disease diagnostic should be performed in European bison transported between different locations, even in the same country.

When moving animals from one location to another two scenarios are of importance:

- o New diseases and/or parasites might be introduced into a vulnerable /native population by (sub-clinically) infected / carrier animals, for instance: bovine tuberculosis and other bacterial, viral or protozoal infections, intestinal and lungworms, ticks and others. It is therefore of crucial importance that the animals are tested and based on the importance of a positive result either, treated or excluded from translocation.
- o Introduction of vulnerable animals into an area with endemic disease/parasite, BHV1, tick-borne diseases. These animals should be vaccinated if possible (as in lungworm and *Moraxella bovis*) or given a pre-exposure preventative treatment, for example, imidocarb (Carbesia®, MSD) in case of babesia.

Safe and harmless systems of capturing animals are indispensable for every breeding centre. The best option is to allow for the selected individuals to be separated from the other animals and either be isolated in an individual pen or trapped in a transportation crate without sedation or tranquilization. However when such a solution is not possible or some medical treatment requires direct access to an animal, then complete sedation should be considered. The moment when an animal is sedated is the best for performing treatments like: vaccination, deworming, taking blood samples, injecting a microchip, etc. In the case of a need to collect tissue samples, to avoid the necessity of sedation, the use of biopsy darts is recommended. Although expensive, restraint devices designed for American bison present an alternative to an anesthesia for all of the procedures detailed above.

Considered as the best method for wisent' transportation is the use of individual crates, allowing for animals to safely stand or lie down, with an access hatches for the staff to feed and water the animals. The risk with crates is when an animal tries to turn and gets trapped or is stuck in an upside-down position; this often results in the death of the animal so the width and height of the crate should be catered to the specific individual. The other method is to use specialized vehicles or trailers that are designed for the transportation of livestock that are the size and weight of European bison with individual compartments. In the case of young animals, it is preferable to transport several individuals together, and if the transport cannot be avoided, moving a female and her calf in the same compartment can be acceptable. The benefit of this sort of transport is that the animals have more freedom of movement and so the risks of crate transport are negated. This sort of "loose box" transport is also preferable when moving bison long distances and where the transport may last a number of days.

Before transport, the type and dimensions of the transportation crates, determined the number of animals, their ages and sex, and appropriate facilities for handling, loading and reloading the animals should be determined in advance.

Because the time transported animals spend in crates should be as short as possible, to avoid any delays, all the required paperwork, necessary permits, health certificates, etc. should be completed and in order, ideally with duplicate copies of everything, before the beginning of a transport operation (for details see Appendix 1).

11.7.3 Veterinary drugs suggested for sedation and anesthesia of European bison

Anesthetics for wild animals can be divided in five different groups:

- **Opioids:** Etorphine (as in Immobilon®), fentanil, thiafentanil, carfentanil (USA only), butorphanol
- **Dissociatives/cyclohexanes:** ketamine, tiletamine (as in Zoletil®)
- **Alfa-2 agonists:** xylazine, detomidine, medetomidine, dexmedetomine, romifidine
- **Tranquillizers/Neuroleptics:**
  - Major tranquillizers: Phenotiazine derivatives: acepromazine, Buterophenone derivatives: azaperone, haloperidol
  - Minor tranquillizers/benzodiazepines: diazepam, midazolam, zolazepam (as in Zoletil®)
  - Long acting neuroleptics (LAN's), are phenothiazine- derivates dissolved in vegetal oil for depot effect: perfenazine, zuclopentixol
- **Antagonists:**
  - Alfa-2 antagonists: yohimbine, tolazoline (xylazine only), Atipamezole (all)
  - Opioids antagonists: pure antagonists naloxone, naltrexone, partial antagonists) deprenorphine, nalorphine
  - Benzodiazepine: flumazenil, sarmazenil
  - There are no antagonists for the major tranquillizers and dissociatives (ketamine, etc.).

For details (update for 2020) see Appendix 2.

Photo courtesy of Ruud Maaskant

12 | MAIN THREATS FOR EUROPEAN BISON CONSERVATION

12.1 Universal threats/problems

Habitat deterioration, fragmentation and connectivity disruption

There are only a few areas in continental Europe left that can accommodate large enough, long-term genetically sustainable European bison populations. Such sites become rarer and more isolated as human populations, agriculture, intensive forestry, etc. continue to grow. The option to create meta-populations composed of less numerous herds, that could achieve long-term genetic sustainability via the exchange of individuals through migratory corridors becomes increasingly difficult in larger scale but is the only solution in fragmented habitat of many European countries. The main problem is rather of the lack of adequate linkage among suitable habitat patches often impossible to restore to allow animals translocation.

Lack of coordination between European national regulatory authorities and directives

Even within single countries, there is a problem of inconsistent, uncoordinated, non-uniform legal regulations regarding species status, health surveillance, captive requirements, management of free and semi-free-ranging herds, etc. This lack of harmonization only grows and multiplies when crossing international borders even within the EU.

Inappropriate law and regulations

Free-ranging herds of European bison occupy home ranges of various conservation status and type of land use. Therefore, the decision process concerning this species usually involves a number of various authorities which makes it excessively long and ineffective.

Emerging and re-emerging diseases, possibly facilitated by climate change

The wisent, as a species that is still recovering from the brink of extinction, is very vulnerable to any form of stochastic events (e.g., outbreaks of contagious diseases). Apart from outbreaks of long known diseases/pathogens such as Foot and Mouth Disease, TB or liver fluke, new or newly recognized diseases and parasitic infections are being recorded, i.e., blue tongue, paratuberculosis, ashworthiosis, neosporosis, thelaziosis, etc. With changing climate and an increasing rate of animal trade, more outbreaks and emerging infectious diseases are to be expected in European bison. So far, there is lack of a standardized approach towards monitoring of health status, protecting hitherto disease-free habitats, and preventing the spread of diseases to new areas via reintroductions or by supplementing already existing smaller subpopulations.

Genetics

Even though the world population of the species exceeds already 9100 individuals, the problem of its extremely narrow genetic pool still remains valid. Populations exceeding 100 individuals are still rare, and only a very few are over 500 animals. In all populations there is, a constant reduction in the frequency of rare (underrepresented) founders' genes (especially EBPB No. 89 and 87 in the LB line and No. 46 in the LC line). At the same time there is a continuing increase in the prevalence of two founders' genes (Planta and Plebejer, EBPB No. 42 and 45).

Lack of social acceptance and disagreement on the model of active conservation of free-ranging herds

In the areas where European bison population have grown dynamically there is an increased likelihood of problems of crop damage, dissatisfaction of farmers and foresters. On the other hand there are enthusiastic attitudes of naturalists, NGOs, tourist guides and other similar groups with an interest in wildlife. Any decisions, especially those of effective management including culling, can be difficult to implement. What is worse, is that scientists are often split in their opinions. In such circumstances when the topic appears to be hot, and under the eye of the media, the authorities seem to be unable to solve the problem or be ready to manage the issue. Such an impasse in effective management is widely observed and discourages managers of suitable areas for European bison from taking a decision to consider reintroduction.

12.2 Threats/problems specific for particular countries

Azerbaijan

Legal status: Due to the fact that European bison conservation in the country just started few years ago, the process to define the legal status as a wild animal (listed in the fauna of Azerbaijan) and be listed in the national red data book of Azerbaijan is ongoing.

Genetics: The first 12 (3.9) pure breed European Bison (LC-line) arrived to the country in 2019. Therefore, the genetic variability of this group is extremely small and its improvement depends on further supplementation of animals from other countries which is ongoing.

Diseases: Because of short term presence of the species (since 2019) there are no recorded health issues, except of a *Moraxella* eye infection that has been successfully treated in captive conditions in 2019.

Poaching: Not registered.

Human conflicts: No conflicts registered, because until now all 14 animals are still inside of the fenced rewilding area of Shahdag National Park.

Belarus

Habitat availability: home ranges of existing populations are effectively, and mutually isolated, due to habitat fragmentation and insufficient ecological connectivity. Hay meadows in the vicinity of wisent' home ranges have become converted into cultivated fields which leads to a reduction of natural grazing grounds. This stimulates intraspecies competition, emigration, and damage to agriculture. Animals migrating outside of a herds' home ranges cause traffic accidents.

Poaching: very rare, single cases occurring mostly due to hunters' mistakes.

Population numbers: some populations living in: Nacional'nyj Park "Belovezhskaya Pushha", Osipovichskij Opytnyj Leskhoz, Sel'skohozjajstvennyj Proizvodstvennyj Kooperativ "Ozery Grodnenskogo Rajona have already exceeded environmental capacity. In those sites emigration of animals and damage to crops has increased. Some other populations such as in Nacionalnyj Park "Pripjatskij" are quite small and threatened with inbreeding. The population in Berezinskij Biosfernij Zapovednik is threatened, because all the individuals there, are post reproductive.

Diseases: not a significant problem at the moment, however some cases of casualties happen every year. The problem is a lack of access to legal tranquilizers for immobilization of animals.

Genetics: lack of data on current population structure because the only available samples are from dead animals. Despite recommendations for periodical exchanges of males between particular populations to reduce inbreeding, no such action has taken place so far.

Photo courtesy of Maciej Januszczak

Czech Republic

Legal status: the species is considered as a free-living/wild animal and as such is distinguished from cattle, but not included in the national list of specially protected species or as game animals. European bison are classed as 'species requiring special care' (pet, zoo, etc.). Subject to the varying attitudes of municipal veterinary authorities. There have been periodical attempts to treat some herds as farm animals with all the negative consequences which worsen the welfare of the animals (frequent handling, sedation, etc.) and make wisent' keeping unbearably difficult and costly. Lack of regulations allowing for commercial use of legally culled animals (meat, pelts, etc.). Potential inclusion in the game species list would involve hunter associations in official decision processes concerning import and exchange of animals, establishment of new herds, etc., which might seriously hamper wisent breeding at a national level.

Genetics: i) some herd owners refuse to separate LB and LC lines, ii) existence of herds not registered in EBPB, iii) escapes of American bison into the wild are infrequent, but real: for example in 2019, a herd of 80 American bison escaped in South Bohemia in mid April, a number of them were still free-roaming in July (no information about their fate).

Space and habitat availability: military training ranges (MTR) contain major areas suitable for wisents in the Czech Republic. However, the area of all MTRs was significantly reduced in recent years and vast areas of natural habitats were lost due to intensive farming and EU agro-subsidy "business". National parks and other state protected areas are either too small, or too preoccupied with forest conservation and/or management practices that strongly hamper the presence of large wild ungulates. Uncertain status of the species is considered a legal obstacle to the establishment of wisents in forest lands outside designated fenced game parks. Current hunting legislation does not allow most land-owners with sites smaller than 600 ha, to manage game and hunting on their land by themselves.

Germany

Legal status: inconsistent regulations among Federal Nature Conservation Act §44 (strictly protected), § 2 Federal Hunting Act (game species but without hunting season) and Animal Health Act (treated as livestock). That imposes all the procedures and treatments required for farm animals - very expensive, difficult and dangerous, and in the case of less manageable individuals, very risky for the animals. In the case of an outbreak of a contagious disease, all wisents in the region are eliminated together with the cattle. No satisfactory procedures for the selection and removal of excess bulls.

Genetics: due to the small size of the majority of German captive herds there is a constant risk of deterioration of the gene pool and the loss of rare and valuable genetic lines. There is still insufficient coordination of mating patterns and exchange of animals among the herds.

Diseases: lack of appropriate measures allowing the prevention of outbreaks of contagious diseases.

Poaching: very rare, but may occur due to the lack of knowledge and low level of awareness among local inhabitants and authorities.

Human related conflicts: lack of support and very low acceptance for free-ranging wisents, preventing their reintroduction to the wild.

Hungary

Legal status: there is no national-level of coordination for their herds.

Genetics: wisent herds in Hungary are few and small. Genetic diversity cannot be maintained within the country.

Diseases: not recorded so far.

Poaching: not recorded.

Human conflicts: all European bison are living in captivity. Since the country is densely populated, there is limited possibility for the maintenance of free-ranging herds. In the potential habitats for European bison reintroduction the damage caused by wildlife is already very high, therefore the introduction of another large herbivore would provoke a vigorous resistance.

Lithuania

Human-related conflicts: a large part of the Lithuanian population is migrating freely through agricultural landscape, contributing to wildlife related damages to crops

Financing: lack of stable institutional financing for European bison conservation and management. At the moment various activities are financed by projects.

Poaching: estimated at about 5 animals per year.

Genetics possible incidence of inbreeding

Health: casualties likely caused by chemicals used in agriculture, possible incidence of balanoposthitis

Traffic accidents: several wisents have been killed in traffic and railway accidents in recent years.

Poland

Legal status: slow, inefficient decisive process regarding permits for reintroduction to the wild, animal transfers and cases of necessary culling. Lack of regulations allowing for commercial use of carcasses, pelts, etc. of legally culled animals.

Financing: there is a lack of based upon state budget - stable, systematical financing for European bison conservation. Current financing is unpredictable, mostly supported by various projects. An effective model of selling hunting licenses for animals selected for elimination, that provided significant income dedicated for the species' conservation, has been discontinued.

Poaching: very rare, single cases occurring mostly due to hunters' mistakes or illegal trophy trade.

Traffic accidents: in most home ranges of free-ranging herds they are very rare, but are increasing in north-western Poland where the home range of the wisent population is bisected by a busy highway, and in Knyszyńska Forest due to the traffic towards the border crossing.

Diseases: periodically occurring outbreaks of diseases transmitted from the cattle (TB, F&M disease, Thelazia parasite), dangerous when appearing in free-ranging herds, leading to their elimination.

Human-related conflicts: mostly related to damages to crops, especially in agricultures situated close to over dense large populations, mitigated to a certain extent by the compensation system.

Habitats: significant fragmentation and increasing isolation of many habitats suitable for reinstating wisent populations, but there are still available some areas administered by State Forests that are suitable for reintroduction and sufficient for herds of 20-40 individuals. Lack of legally protected migration corridors.

Genetics: constant loss of genes of several underrepresented founders, prevented by periodical exchange of animals among herds within the country and from abroad.

Difficulties in establishment of new herds: Managers of the areas suitable for reintroduction are hesitant because of legal and financial problems connected with management of this species, uncertain cooperation with state authorities, and expected harassment from environmental activists.

Romania

Legal status: lack of uniform legal status for European bison both for free-ranging and captive animals ranging from strictly protected to game with restricted hunting. Undefined legal procedures related to management, translocations, reintroduction to the wild, veterinary treatment. Lack of a uniform national strategy for the species.

Human-related conflicts: lack of a compensation system for wisent related damages mostly due to different recognition of the species' legal status by responsible state ministries. Increasing competition for an access to open pastures due to growth in extensive animal husbandry.

Poaching: mostly related to prevention of damages to crops and to the presence of wandering solitary males. Weak legal regulations concerning poaching of protected species.

Research, education, and awareness: insufficient level of research on the species, inadequate public education and therefore unsatisfactory public awareness regarding the protected status of the species and its ecological role.

Habitats: considerable fragmentation and lack of established ecological corridors along the Carpathian chain. In many cases potentially suitable habitats are degraded due to intensive logging.

Management: very intensive artificial feeding of wildlife which potentially affect habitat preferences and spatial distribution of free-ranging wisents.

Diseases: potential threat of diseases transmitted from the domestic livestock, grazing in the mountains without adequate supervision.

Russia

Diseases: lack of an effective monitoring system and veterinary procedures. Rules for maintaining and treatment of captive animals are the same as for cattle.

Habitat fragmentation: despite identified ecological corridors and sites suitable for the establishment of new populations, there is no approved strategy for the resettlement and translocation of animals.

Population management: lack of legal rules for selection, culling, and dealing with wisent related conflicts outside of protected areas. Lack of coordination regarding population management, resettlements, etc.

Population census: lack of reliable, standard procedures for population census. Impossible to obtain comparative data for some populations.

Genetics: lack of routine, standard monitoring. Populations are too small, mostly below the secure viable numbers, uneven distribution of founders' genes, threatened viability of particular maternal and paternal lines.

Poaching: especially significant outside of protected areas, insufficient coordination of preventive measures between state authorities and managers of protected areas.

Hybridization: the threat of hybridization with American bison released from private enclosures. There is an unlikely, but not impossible threat of hybridization between purebred bison and hybrid bison (B. bonasus x B. bison) in the Western Caucasus, in the case of the decision on resettlement or spontaneous dispersion of hybrid bison. This issue requires special attention and management measures. This is connected with an existence of the herd of so called "mountain bison" originating from American-European bison hybrids brought there in 1940. Released to the wild in 1946, now the herd counts about 1200 individuals. Fortunately for the purity of the native species, range of that herd is separated effectively by natural barriers.

Slovakia

Inbreeding: due to low population numbers (48 individuals) and isolation of particular herds, there is a high probability of inbreeding. Among a few herds the gene flow is maintained only through migrating individuals, mostly males.

Diseases and infections: disease may be considered as a serious threat for the entire Slovak population. In the population neighboring the Bieszczady Mts., Foot and Mouth Disease (*Aphte epizooticae*) (causing 5% mortality) represents a serious threat. Other potential diseases are balanoposthitis as well as some parasites.

Habitat decrease: current habitats available for free-ranging Slovak wisents including forests and meadows – so called "poloniny" (mosaic habitats) – represent an optimal landscape structure for the species. Natural succession within such meadows may lead to the decrease of such habitat types. The presence of wisents contributes to preservation of such habitat structure, but due to relatively low population numbers the effects of their grazing is not very pronounced.

Human disturbance: common habit of collection of forest fruits, mushrooms and antlers by local dwellers. Hunting is also an important disturbance factor. Traffic at touristic trails does not seem to be an important factor.

Poaching: despite strict protection of the species, there is a potential risk of poaching to obtain trophies but also connected with an attempt to eliminate competition with game species for the food supply. In the Poloniny National Park, there was one individual illegally killed, but poaching has not been confirmed so far.

Scandinavia

Legal status: lack of national strategy for reintroduction of the species, long term planning and coordination at the state level.

Financing: insufficient access to financial support for translocation projects, especially those related to reintroductions outside of Scandinavia.

Education and awareness: low level of societal acceptance and awareness in connection with the establishment of free-ranging European bison populations. Lack of support for such initiatives from authorities and NGOs.

Habitats: sites not defined that are suitable for potential resettlement or reintroduction of European bison within Scandinavia in connection with limited availability of public land.

Spain

Legal status: unclear, species not included in the National Endangered Species List, nonexistent national strategy for its conservation, constant attempts to treat European bison as cattle, including obligatory veterinary checkups, ear tagging, etc. No legal way to establish free-ranging population.

Financing: lack of public support, all initiatives based upon private funding.

Research: lack of basic local studies on the species.

The Netherlands

Legal status: at the moment the European bison in the Netherlands does not have the status of an indigenous species, and is considered a captive wild animal. There is no legislation allowing for leaving carcasses in nature for scavengers, and there is no regulation on the consumption of meat by people.

Population management: small size of herds, all below 30 individuals. Frequent need to translocate animals between herds representing a risk for transported animals and an increasing possibility to transfer diseases or parasites from herd to herd. No sufficient space to transfer surplus animals. Although the interest from nature managing organizations in European bison has increased substantially in the past decade, and in recent years several have started to host bison in their nature areas, land managers remain generally very reserved when it comes to enlarging current bison areas and introducing them elsewhere.

Genetics: all animals belong to the Lowland line with very high level of homogeneity Small size of particular herds and low number of breeding bulls contribute to this situation.

Habitat: very small areas available for maintaining wisent herds (50 - 400 ha). None of the present facilities are able to support a herd of 50+ animals. A part of some sites where wisent herds are maintained are situated on very nutrient poor sandy soils. Frequently those sites show deficiencies of trace-elements like selenium, copper and cobalt.

Human-related conflicts: since all wisents in the Netherlands are confined to fenced areas there is no danger of damages to crops or forestry. Nevertheless, low awareness among the public and insufficient knowledge about this species may cause dangerous situations with people visiting wisent enclosures.

Diseases and health problems: the Kraansvlak European bison area is infested with lungworm which creates a risk for the spread of this parasite to other herds together with translocated animals. Wisents there have access to a poisonous plant species called common ragwort (*Senecio jacobaea*) which has already caused one case of poisoning.

Ukraine

Legal status: inconsistency between the current environmental legislation and its implementation.

Human-related conflicts: lack of any compensation system for damages caused by European bison. Within hunting grounds, they are perceived as a burden because of the costs of their protection and feeding without any perspective of their commercial use.

Genetics: very high level of inbreeding due to very limited numbers of founders of particular herds or due to substantial reduction of the population numbers in the early 2000s.

Poaching: happens quite often, very difficult to prevent. Prosecution of poachers is very rare due to corruptive judicial system.

Habitat: degradation of many suitable habitat patches due to long term socioeconomic crisis.

Photo courtesy of Maciej Januszczak

13 | CONCLUSIONS

Upon consideration of the information presented in this report, it is unlikely for the European bison to achieve full long-term recovery under prevailing management, and we offer thematic suggestions below to improve the likelihood of long-term recovery. As the latest IUCN Red List Assessment finds that the species is entirely dependent on conservation management (Plumb et al. 2020), it is also unlikely to develop one identical approach for European bison conservation for the whole of Europe, given unpredictable changes in socio-political and economic factors, and considering the variety of legal regulations, traditions or local customs. Undoubtedly, to be effective, specific solutions and appropriate local actions will differ among European countries. For example, in some countries initiatives for European bison conservation have to come from the government while in others - NGOs or private herd owners may take the lead. Nevertheless certain measures appear as universal and their implementation should be supported at international level. Of course their effectiveness can be evaluated only after at least several years, when changes in population numbers, structure and spatial distribution will become visible. A measure whether any suggestions contained in this report is correct, will be further trends in the development of E. bison world population and reaching the minimal viable numbers of presently existing populations of the species in the wild. By all means, the most important is the maintenance of positive population growth, keeping current records on population status (EBPB) allowing for proper population planning, and absolute preference for maintaining wisents in groups, avoiding keeping just single animals.

13.1 Legal status

As a priority, European bison should remain a strictly protected species which must be properly managed and be regarded as a native representative of the European fauna. Urgently required is the introduction of uniform, consistent legal regulations for the species at least for all EU member states, and preferably for all signatories (member organisations) of the IUCN. Wisents kept in captivity cannot have the status of the cattle. That also relates to procedures obligatory for farm animals in the case of an epidemic disease. Appropriate standards for health monitoring, veterinary care and general animal' welfare should be approved. There should be an endorsement of common guidelines for the maintenance, transportation, handling facilities, culling, as well as for limited commercial use of carcasses and other body parts of eliminated individuals. Future conservation and management of the species would be facilitated by changing of its status in the Habitats Directive into that of Bern Convention, i.e., include the wisent in Appendix V but exclude from Apendixes IV and II.

13.2 Population management

An ultimate objective of conservation of this species is to bring it back to the wild whenever it is possible. Optimally, the European population of the species should be treated as one metapopulation with coordinated exchanges of animals between local free-ranging populations and captive herds. The rules for the management of European bison should be clearly divided into standards for their maintenance in captivity with pointing out semi-free herds and guidelines for managing free-ranging herds. For captive individuals it is necessary to set out uniform rules for the size and structure of enclosures, fencing, handling facilities, feeding, veterinary care, exposition to the public, etc. assuring the welfare of animals. Creation of a common database (preferably based upon European Bison Pedigree Book) registering all information about pure blood animals in captivity should be considered. Captive herds must be of proper structure and co called "surplus" animals must be defined. There is an urgent need to work out principles for proper dealing with those "surplus" individuals, especially groups of bulls, and avoiding the excessive density of animals in enclosed space. In the case of free-ranging herds, the most important issues are: routine monitoring of population numbers and the social/genetic structure, habitat use and health status, securing of refuges, ensuring an access to adequate food supply and home range area, and dealing with animals migrating out of their herd's home range, which usually is a sign of overpopulation.

13.3 Habitat

It would be advisable to identify habitat patches suitable for the maintenance of larger, viable populations (>100 individuals) and patches adequate for small herds (about 20-40 individuals) similar to what has already been done in Poland (Perzanowski et al. 2019). Apart from large protected areas like national or nature parks, in many European countries new vast areas become available, where previous forms of use have ceased and such land becomes abandoned (agriculture on poor soils, military training sites, exploited open coal mines, etc.). In many cases such areas are suitable for "rewilding" projects which along with other wildlife could include the introduction of free-ranging or semi-free European bison. Whenever possible, adequate migratory corridors between home ranges of free-ranging herds should be identified and legally secured. Identification of most suitable sites for the establishment of herds in the wild, should be possibly done over the whole of species' historical range.

13.4 Human-related conflicts

As a rule, it should be stated that any damage in crop fields caused by the free-ranging population should be compensated for by the state. Such a policy would address the fears of land owners and managers about future reintroductions. Another option could be a subsidised insurance of crops. Such a system (regulated by law) for evaluation of damages should be simple and effective. For each free-ranging population, an adaptive model of mitigating damage based on protection of crop fields, the control of population numbers and its dynamics, modification of spatial distribution and prescribed use of artificial feeding should be developed. Current problems of many contradictory opinions from different interest groups regarding the management of this species should be solved on the base of broadly accessible information and promotion of good practices.

13.5 Diseases

Because of generally low immunity of the species against various infections, it is suggested to develop unified rules for health monitoring, and prevention for the spread of epidemic diseases, including obligatory requirements for exchange and transfer of the animals. In every country where either captive or free-ranging wisents occur, a system for monitoring the incidence of contagious diseases should be introduced. The list of obligatory health tests for all trans-located animals should be internationally agreed. There should be a compulsory quarantine period of at least four weeks prior to the transport followed by another four weeks of quarantine after arrival for all transferred animals, before they join an already established free-ranging herd, a breeding group or are to be released to the wild in a new site. The transport is a great stressor which can suppress the immune system facilitating both: activation of latent infections to emerge as well as contraction of novel ones at the new destination more easily (Klich et al. 2021). Whenever possible, available vaccinations against diseases affecting ruminants should be applied. Cases of an incidence ofd diseases should be recorded in a common database.

13.6 Genetics

The overall priority is the prevention of further loss of the genetic variability of the species. To mitigate this process, strict coordination among all E. bison managers and keepers at European level of the exchange of animals, "blood refreshing" projects, mating patterns, formation of new breeding groups, etc. should be introduced across the whole population. Special attention should be devoted to remaining carriers of underrepresented founders' genes, paternal and maternal lines.

13.7 Poaching

Unification of the legal status of the species as strictly protected all over Europe should create sufficient measures to prevent illegal exploitation. All animals culled or found dead due to any reason should be genetically sampled to provide a possibility for further identification of any European bison tissues or trophy suspected of having been obtained illegally.

13.8 Education and awareness

In the majority of European countries wisents are perceived as mysterious animals that became extinct a long time ago. There is a need for changing this picture and the creation of an image of a rare but very valuable component of the European fauna. Restitution of the wisent is one of the most successful examples in the world of saving a threatened animal species from extinction. This story can be effectively disseminated through TV programs, internet and other mass media. Another issue is the education and improvement of awareness about this species among inhabitants of areas where its reintroduction is planned. This includes farmers, foresters and school children, but also tourists, campers, etc. For this purpose, educational programs in the form of presentations, workshops, informative materials like leaflets, brochures, posters, etc. are necessary and valuable. An excellent opportunity for the education of the public is provided by captive herds. Germany itself has about 70 wisent breeders. Many of them are zoos and game enclosures. These facilities have about 53 million visitors per year. There is an incredibly good opportunity to do environmental education and publicity for the wisent. We need a campaign to introduce the wisent, to tell its story of near extinction and recovery, to explain its ecological significance as a large herbivore. The wisent needs to get a new, positive image and must become a charismatic animal people want to relate to. Open, broad discussion over possibly optimal methods of species' management and the presentation of good practices should be initiated in the media of countries with considerable numbers of free-ranging wisent. Achievements as well as problems and proposed solutions should be presented as opposed to unrealistic expectations expressed by some activists and journalists.

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APPENDIX 1

Table A1. Veterinary preparations for the translocation of European bison (© Mark Hoyer)

Test	Notes	Check	Method
Compulsory / EU regulations			
Tuberculosis (TB)	If positive, animal cannot go on transport	Skin, blood	Intradermal skin test (IDST) still only accepted test in many countries, the second is blood test
Brucellosis	If positive, animal cannot go on transport	Blood	Antibodies
Compulsory depending on country regulations			
Enzootic bovine leucosis	Presently not applicable	Blood	Antibodies
Blue Tongue	Presently not applicable	Blood	Antibodies or antigen
Additional requirements - optional			
Bovine Viral Diarrhea (BVD)	If positive, animal cannot go on transport	Blood	Antibodies, antigen (antigen should be negative)
Infectious bovine rhinotracheitis (IBR)	If positive, animal cannot go on transport	Blood	gB test
Para tbc	If positive, animal cannot go on transport	Blood / faeces	Antibodies / faecal culture
Leptospirosis	If positive, animal cannot go on transport	Blood	Antibodies
Babesia	If positive, treat	Blood	Smear / PCR
Endoparasites: Blood	If positive, treat	Blood	Antibodies: Lungworm, Liver fluke
Endoparasites: Faeces	If positive, treat	Faeces	Liver fluke, Gastrointestinal worms (Trichostrongylus/ Strongylus) flotation. Lungworm larvae
Infectious Balanoposthithis	If positive, animal cannot go on transport	Clinical signs	Clinical signs / Culture
Treatment / vaccination / additional			
Treatment	Ectoparasites, endoparasites, liverfluke, lungworm, Babesia		
Vaccination	Lungworm, Babesia		
Miscellanious	Chip, genetic samples, blood samples (serum / heparine) for future reference		

APPENDIX 2

Table A2. Veterinary drugs used for sedation and anesthesia of European bison (© Mark Hoyer)

Generic name	Strenght (mg/ml)	Tradename	Company	Websites
Acethylpromazine	10	Neurotranq®	Alfasan, Nl	www.alfasan.nl
Atipamezole	5	Antisedan®	Orion, Finland	www.orionpharma.com
		Atipam®, Sedastop®, etc	Various companies	
Azaperone	40	Stresnil®	Elanco	https://www.elanco.nl
	100	Zapnil®	Wildlife Pharmaceuticals, RSA	www.info.wildpharm.com
	50, 100	Azaperone	Kyron Laboratories, RSA	www.kyronlabs.co.za
Biperideen	5	Akineton®	Sirton Pharmaceuticals, Itali	https://www.sirton.it
Butorfanol	10	Torbugesic®	Zoetis	www.zoetis.nl
		Dolororex®	Intervet, NL	www.intervet.nl
	20, 50	Butorphanol 20, 50	Kyron Laboratories, RSA	www.kyronlabs.co.za
	50	Butonil®	Wildlife Pharmaceuticals, RSA	www.info.wildpharm.com
Diazepam		Valium®	Roche	https://www.roche.nl
Diprenorfine	3	LA-Revivon	Novartis, UK; off the market	www.novartis.co.za
		M5050®	Novartis, UK	www.novartis.co.za
	12	Activon®	Wildlife Pharmaceuticals RSA	www.info.wildpharm.com
Detomidine	10	Domosedan®	Véticinol	https://www.vetoquinol.com
		Domidine®, Detosedan®	Dechra Vet. Products, AST Farma	https://www.dechra.com/

Table A2. Veterinary drugs used for sedation and anesthesia of European bison (© Mark Hoyer)

Generic name	Strenght (mg/ml)	Tradename	Company	Websites
Etorfine	2,25	LA-Immobilon®	Novartis; off the market	www.novartis.co.za
		Etorfine 2.25	Pharmacy, Fac.Vet. Med., Nl	www.apotheek.uu.nl
	9,8	Captivon®	Wildlife Pharmaceuticals, RSA	www.info.wildpharm.com
		M99	Novartis Animal Health UK	www.novartis.co.za
Flumazenil	0,1	Anexate®	Roche	https://www.roche.nl
Haloperidol	20	Perinil®	Wildlife Pharmaceuticals, RSA	www.info.wildpharm.com
		Haloperidol 20	Kyron Laboratories, RSA	www.kyronlabs.co.za
Ketamine	100	Many		
	1000 dry	Ketamine 1 gram	Kyron Laboratories, RSA	www.kyronlabs.co.za
Medetomidine	1	Domitor®, Sedastop®	Véticinol	https://www.vetoquinol.com
	10	Zalopine®	Orion Cooperation, Finland	www.orionpharma.com
	10, 20, 40	Medetomidine	Kyron Laboratories, RSA	www.kyronlabs.co.za
	40	Metonil®	Wildlife Pharmaceuticals, RSA	www.info.wildpharm.com
Midazolam	5	Dormicum®	Roche	https://www.roche.nl
	50	Dazonil®	Wildlife Pharmaceuticals, RSA	www.info.wildpharm.com
		Midazolam 50	Kyron Laboratories, RSA	www.kyronlabs.co.za

Table A2. Veterinary drugs used for sedation and anesthesia of European bison (© Mark Hoyer)

Generic name	Strenght (mg/ml)	Tradename	Company	Websites
Naloxone	0,4	Narcan®	DuPont Pharma	https://www.pharma.dupont.com/
Naltrexone	50	Trexonil®	Wildlife Pharmaceuticals, RSA	www.info.wildpharm.com
		Naltrexone 50	Kyron Laboratories, RSA	www.kyronlabs.co.za
		Naltrexone 50	Pharmacy, Fac. Vet. Med., Nl	www.apotheek.uu.nl
Perfenazine	100	Trilafon LA®	Sherag, Gujarat, India	http://chiragpharmaagency.com/
		Perfenazine 100	Kyron Laboratories, RSA	www.kyronlabs.co.za
Romifidine	10	Sedivet®	Boehringer Ingelheim	https://www.boehringer-ingelheim.nl
Sarmazenil	0,1	Sarmsol®	Graub AG, Ch.	https://www.graeuboffice.ch/
Thiafentanil	10	Thiafentanil®	Wildlife Pharmaceuticals, RSA	www.info.wildpharm.com
Tiletamine	250	Zoletil 100® en 50®	Virbac, Nl	https://www.virbac.nl
Xylazine	20	Various tradenames	Various	
	100	Sedazine 10%	AST-Farma BV, Nl	https://www.astfarma.nl/
	500 powder	Xylaset 500 mg®	Bioveta, A.S Czech Republic	https://www.bioveta.cz/
		Xylazine dry powder	Kyron, RSA	www.kyronlabs.co.za
Yohimbine	6,25	+ aminopyridine	Kyron Laboratories, RSA	www.kyronlabs.co.za
Zolazepam	250	Zoletil 100® and 50®	Virbac, The Netherlands	https://www.virbac.nl
Zuclopenthixol	50	Cisordinol Acutard®	Lundbeck, Denmark	https://www.lundbeck.com/dk
	200	Cisordinol 200 depot®	Lundbeck, Denmark	https://www.lundbeck.com/dk
	500	Cisordinol 500 depot®	Lundbeck, Denmark	https://www.lundbeck.com/dk

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