

How high is level of inbreeding within the PL subline of the European bison

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Abstract: Inbreeding is inevitable for the European bison population and the level of genetic diversity is very low due to the severe bottleneck of this species. All European bison are descended from only twelve founders, mainly Lowland Bison *bonasus bonasus*, with the exception of one male of the Caucasian subspecies *Bison bonasus caucasicus*. Consequently, there are actually two lines: lowland (LB) and lowland Caucasian (LC). Within the Lowland European bison there is the PL (Pszczyna) subline, which descends from only two founders: 42 PLANTA and 45 PLEBEJER. As a result of such a narrow gene pool, the degree of inbreeding in the PL subline is very high. With 346 animals born up to 2024, the average inbreeding coefficient was 0.514, but the maximum value was over 75%. It is interesting to note that there were no signs of inbreeding depression within this PL subline. The survival rate up to one month was 93.1%, which is higher than the rest of the population of the species. Hopefully the genetic pool of this subline is free of deleterious alleles. It is important to continue this subline, but in case of signs of inbreeding depression, it must be stopped as the welfare of the animals is most important.

Keywords: inbreeding value, survival, reproduction, European bison. Pszczyna subline

Introduction

The European bison *Bison bonasus* is a species that has undergone a serious bottleneck, making mating between relatives inevitable. At the same time, there are almost no signs of inbreeding depression. A century ago, the population of this species was drastically reduced and all natural populations disappeared (Raczyński 1978; Pucek *et al.* 2024). By the end of 1924, only 54 animals (29 males and 25 females) were still living in European zoos and enclosures (Groeben 1932; Pucek 1991). The world population of European bison increased very slowly at first, but later it had to increase more rapidly, and currently there are over 12,200 individuals, of which almost 1,725 are kept in captivity (EBPB 2025). Due to the very limited genetic variability, the European bison population is a unique object to study the problem of inbreeding.

All European bison are descendants of 12 founders (Slatis 1960; Olech 2006; Olech 2009). Eleven of the founders belong to the lowland subspecies *Bison bonasus bonasus* and only one male belongs to the subspecies *Bison bonasus caucasicus*. All animals with this particular founder in their pedigree belong to the Lowland-Caucasian (LC) line. The lowland line (LB) originates from the seven founders (Olech 1999), of which the founding pair 42 PLANTA and 45 PLEBEJER has the largest share. Within the lowland line, the not very numerous subline Pszczyna PL can be distinguished, which descends only from these two founders (Olech 2009). This special subline is only bred in a few places and is very inbred due to the very narrow gene pool. This line goes back to a founder pair that was rescued in the Pszczyna breeding herd after Silesian uprisings in the 20th century.

In first Pedigree Book Groeben (1932) used name “Pszczyna line” for animals born in Pszczyna. Actually the definition is exclusively used for descendants of pair of founder; PLANTA and PLEBEJER.

The average inbreeding coefficient calculated in second half of 20th century by Slatis (1960) and Olech (1987) for all living animals was at low values between 0.160 and 0.331. Later, the values of the inbreeding coefficient calculated in various works were higher (Ballou 1997; Pucek et al 2004; Matuszewska et al 2004; Sobieraj & Olech 2018). Most recent calculations showed that the European bison is a highly inbred species; for animals with fully known pedigree born in the years 1946–2021, the average value of the inbreeding coefficient for the Lowland line was 0.419, while for the LC line it was 0.253, which is due to the different number of founders. Survival up to one month is only negatively affected by inbreeding in animals of the LC line (Olech 2023).

The aim of this work was to show the current situation of the inbreeding level within the PL subline in comparison to all Lowland animals.

Material and methods

The analysis was carried out for all animals of the PL (Pszczyna) subline of Lowland European bison registered in the European Bison Pedigree Book (EBPB, 1946–2025) and born in the years 1923–2024.

The inbreeding coefficient was calculated according to the formula of Wright (1922), as well as the value of kinship between all actually living animals. Software developed by (Olech & Michalska 1999) based on the tabular method (Quass 1976) was used for the calculation.

For each animal, information was added as a binomial feature about its survival to the first month of life. The age was chosen based on the survival curve of Olech (2023). Comparison of the average value of inbreeding between

surviving and non-surviving animals and between males and females was performed using the t-Student test.

The year of birth was not considered in the analysis, as inbreeding value and year of birth are highly correlated ($r=0.88$). All results were divided into 6 periods of 17 years in length (the total period analyzed was 102 years, divided into 6 periods of equal length).

Results

Number of animals

Between the beginning (the first descendant of the founders PLANTA and PLEBEJER was the male 48 PLUNDER, born in 1923) and the year 2024, 346 animals of the PL line were born (Tabl. 1).

Table 1: Number of European bison of the PL subline born in Pszczyna, Pszczyna Park and other breeding centers (according to EBPB 1932–2025). In brackets the number of males and females.

Period	Breeding center				Together
	Pszczyna	Pszczyna Park	Białowieża	Others	
1923–1939	28 (17,11)				28 (17,11)
1940–1956	64 (33,31)		6 (3, 3)	10 (4, 6)	80 (40,40)
1957–1973	35 (21,14)		18 (7,11)	1 (0, 1)	54 (28,26)
1974–1990	54 (26,28)			14 (6, 8)	68 (32,36)
1991–2007	45 (27,18)			1 (0,1)	46 (27, 19)
2008–2024	48 (22,26)	15 (7, 8)		7 (4, 3)	70 (33,37)
1923–2024	274 (146,128)	15 (7, 8)	24 (10,14)	33 (14,19)	346 (177,170)

In the beginning, the PL subline was bred exclusively in the breeding centers in Pszczyna, later animals of this subline were transferred to other stations. The enzootic foot-and-mouth disease in Pszczyna in 1953 led to the death of all animals, so that later mainly animals from Białowieża were transported to Pszczyna. It is worth mentioning that in the last 17 years the number of animals born in the PL subline is greater than in previous years. This is the result of the implementation of the breeding program of this line (Tabl. 1).

At present, this line has 27 (9,18) animals – 24 in three Polish breeding centers: Pszczyna 14 (5,9) in Pszczyna Park 7 (2,5) and in Sycowice 3 (1,2). The age of the animals is between one and 17 years (Fig. 1), the average age of the females is 9.3 years and that of the males 3.6 years. Unfortunately, the females born in recent years have not survived.

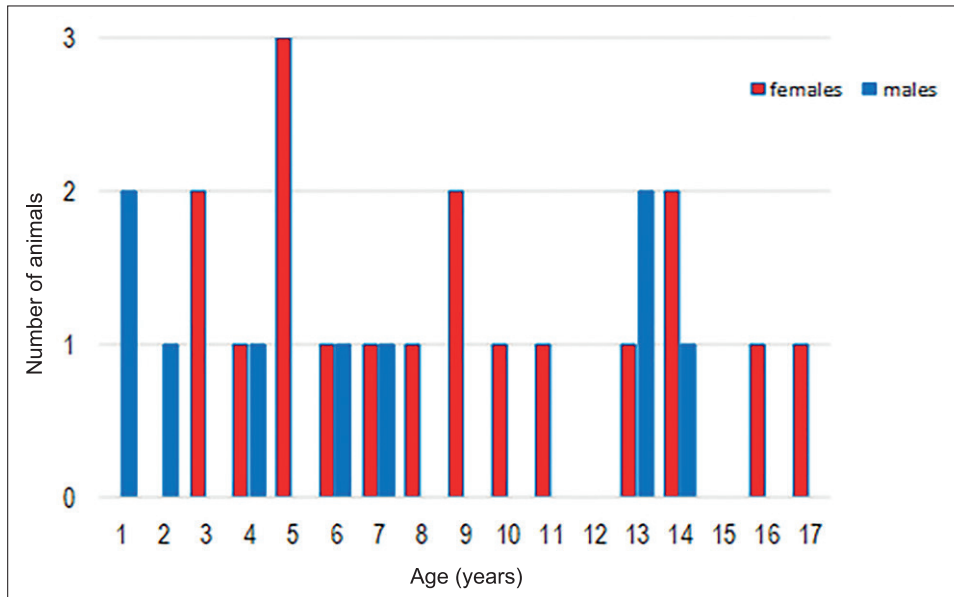


Figure 1. The number of European bison belonging to PL subline actually living according to the age

Inbreeding level

The inbreeding coefficient has risen constantly over the years (Fig. 2). The maximum value was 0.754, which has not been found in any other wild species. Only laboratory animals can be so highly inbred. The average value for all 346 animals was 0.514 (Tabl. 2) and is twice as high as in the European bison of the LC line and higher than in the LB line (Olech 2023).

It is obvious that inbreeding increases in the PL subline, which descends from only two founders. But in such a breeding system, the mating of very closely related animals cannot be avoided. For this reason, the inbreeding coefficient increases from zero to 25% shortly after the start of breeding, which is due to mating between full siblings or parents and offspring (Fig. 2). The average inbreeding coefficient of the animals of the LB line is 0.41 (Olech 2023), but the part belonging to the PL subline has a higher value of the inbreeding coefficient of 0.514. The average value of this coefficient in current population ($N = 27$) is equal to 0.647. In Table 2 are presented the average value of inbreeding in 6 periods of 17 years long.

The survival rate up to the first month was 90.2% in the total population of the species and 91.8% in the LB line (Olech 2023). Thus, the survival rate

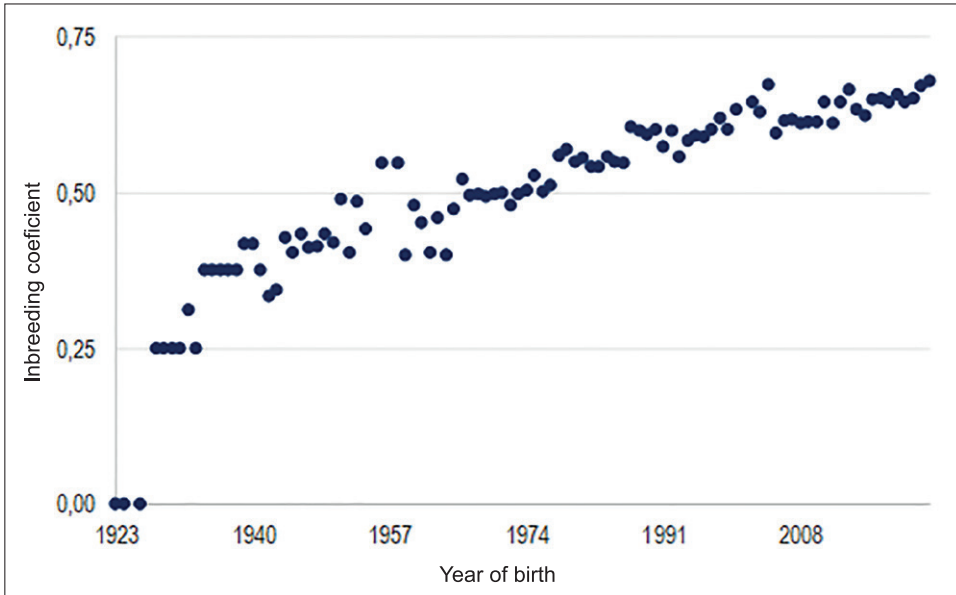


Figure 2. The averages inbreeding coefficient according the year of birth

Table 2: The inbreeding coefficient of European bison in 17-year periods and information on survival up to one month

Period	N	Survive until 1month (N and %)	Inbreeding coefficient			
			average	S.d.	min	max
1923–1939	28	28 (100%)	0.308	0.123	0	0,500
1940–1956	80	69 (86.2%)	0.421	0.070	0.313	0.586
1957–1973	54	52 (96.3%)	0.481	0.047	0.398	0.566
1974–1990	68	65 (95.6%)	0.557	0.040	0.479	0.633
1991–2007	46	44 (95.7%)	0.604	0.035	0.548	0.691
2008–2024	70	64 (91.4%)	0.640	0.036	0.585	0.754
	346	324 (93.1%)	0.514	0.123		

up to one month was higher in the animals of the PL line than in the LB line and was 93.1% (Tabl. 2).

To compare the degree of inbreeding in the group of surviving or non-surviving animals, the average value was calculated. There is no difference between the inbreeding level of the animals that survive or not. The average inbreeding coefficient of the animals that died up to one month was 0.5128 and that of the surviving animals was 0.5169. The same applies to the inbreeding level of the two sexes, the average value for the males was 0.5152 and for the females 0.5172. There was no difference between the groups.

Kinship and mating plan

The kinship values, i.e. the inbreeding coefficient of the potential offspring, are often used for mating planning. However, for the selection of the most important animals, the MK (Mean Kinship) was calculated – the average of all kinship values within the active population. The average MK for 27 living animals from the PL line was 0.671 (s.d.=0.011). The lowest value of 0.654 was for the female 13541 PLATANO and the lowest value for the male of 0.655 was for 12292 PLISAR. The MK is a very good way to select the best animals, but one should to keep in mind that the parameter is dynamic and can change a lot after changes within the population.

Very usefull are the values of the kinship coefficient between males and females, which are used for the mating plan because explain the kinship between animals. In Table 3 there is presented the value of relatedness between the currently living animals. The preferred mating should take place when the kinship is lower. The lowest kinship is for potential offspring of females 13541 PLATANO and males 12292 PLISAR or 14489 PLAGAT.

Table 3: The values of kinship between actual living males and females of European bison. Animals are identified by pedigree number and name.

		Males								
		12292	12185	16003	14070	15174	14489	16336	16337	12022
Females		PLISAR	PLUNTO	PLATAR	PLEBAN III	PLANEK	PLAGAT	PLAMBO	PLUMBO	PLESSNER
	11221	PLACKA	0.6470	0.6341	0.6561	0.7094	0.6394	0.6341	0.6751	0.7104
11493	PLITARA	0.6782	0.6887	0.6439	0.6404	0.6578	0.6887	0.6568	0.6698	0.6326
11964	PLANCKA	0.7277	0.6707	0.6378	0.6407	0.6441	0.6707	0.6678	0.6454	0.6391
11971	PLESZKA II	0.6782	0.7385	0.6439	0.6404	0.6578	0.7385	0.6568	0.6449	0.6326
12205	PLATANKA II	0.6566	0.6627	0.7136	0.6797	0.6897	0.6627	0.6662	0.6474	0.6645
12857	PLAGATKA	0.6568	0.6628	0.6436	0.6511	0.6529	0.6628	0.6439	0.7314	0.6539
13199	PLECIUGA II	0.6284	0.6220	0.6648	0.7067	0.6343	0.6220	0.6623	0.7104	0.7354
13461	PLUSZKA	0.6568	0.6877	0.6436	0.6511	0.6529	0.6877	0.6439	0.6723	0.6539
13541	PLATANO	0.6218	0.6175	0.6551	0.6597	0.6278	0.6175	0.6754	0.6539	0.6663
13715	PLUDA II	0.6816	0.6537	0.6406	0.6512	0.6461	0.6537	0.6494	0.6726	0.6572
14120	PLEJONE	0.6515	0.6386	0.6494	0.6606	0.6328	0.6386	0.7300	0.6626	0.6707
14490	PLAMINA	0.6425	0.6424	0.6663	0.7399	0.6620	0.6424	0.6642	0.7027	0.7894
14771	PLESSARIA	0.6330	0.6265	0.6839	0.6811	0.6276	0.6265	0.6572	0.6857	0.7025
14842	PLUSMENIA	0.8223	0.7034	0.6378	0.6425	0.6926	0.7034	0.6577	0.6426	0.6355
14843	PLUMKAŁA	0.7034	0.8298	0.6408	0.6424	0.6995	0.7374	0.6522	0.6424	0.6322
15107	PLARYSA	0.6378	0.6408	0.8128	0.6663	0.6528	0.6408	0.6528	0.6542	0.6655
15608	PLAPLUNTA	0.6926	0.6995	0.6528	0.6620	0.8347	0.6995	0.6569	0.6436	0.6481
15609	PLASKATA	0.7034	0.7374	0.6408	0.6424	0.6995	0.8298	0.6522	0.6424	0.6322

Discussion

Many papers present problem of inbreeding level and its consequences that is inbreeding depression on viability in captive populations (Ralls 1970; Ralls *et al.* 1988). The detrimental effects of inbreeding on fitness traits are well established for many species, and work based on homozygosity shows even greater effects on individual fitness than that based on pedigree analysis (Hedrick & Kalinowski 2000; Hedrick 2016). On the other hand, the pedigree is a very good source for calculating inbreeding if the information is complete. The information on the pedigree of the European bison was started more than a hundred years ago and was collected carefully because of the risk of cross-breeding with the American bison in captivity (Pucek *et al.* 2004).

The extent and even the direction of inbreeding depression is not the same in all species, and the differences in responses to inbreeding are very large. For example, Ralls *et al.* (1988) found that relative inbreeding depression ranged from negative (-98 %) to positive (+ 19 %) in many species. Even within a species, considerable differences were found in the reaction to inbreeding. In two wolf groups (Mexican and red wolf) kept in captivity, no effect of inbreeding on survival was found (Kalinowski *et al.* 1999), while inbreeding depression in these species was shown by a lower survival rate of adults (Ellegren 1999).

The PL subline is very unusual even for captive populations of wild species. The degree of inbreeding of over 70% is not found in any other populations. It is important to note that the animals of the PL subline show no signs of inbreeding depression. The survival rate of young animals is even higher than that of the entire European bison population. Reproduction is also not affected by inbreeding. The number of active (living) animals in the PL subline is very low and the animals are kept in three enclosures, which means that only three males per year participate in reproduction. For this reason, it is very important to use the information about the relationship between the animals in the breeding plan to make the increase in the inbreeding level as slow as possible.

Conclusion

The PL subline is very strongly inbred and so far there are no signs of inbreeding depression. It must be noted that the gene pool of this line consists of only two founders that were probably related to each other, so the inbreeding could be even greater. The line should be continued as a special subline of the European bison. However, it is important to say that where the animals show problems with health and fitness, the continuation of breeding within the subline

should be terminated. This situation is very interesting from a scientific point of view, but the most important thing is animal welfare.

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Zjawisko wysokiego poziomu inbrodu w Pszczyńskiej (PL) podlinii żubra

Streszczenie: Inbred jest nieunikniony dla populacji żubrów, a poziom zróżnicowania genetycznego jest bardzo niski ze względu na poważne wąskie gardło, przez które ten gatunek przeszedł. Wszystkie żubry pochodzą od zaledwie dwunastu założycieli, głównie żubra nizinnego *Bison bonasus bonasus*, z wyjątkiem jednego samca podgatunku kaukaskiego *Bison bonasus caucasicus*. W związku z tym istnieją w rzeczywistości dwie linie: nizinna (LB) i nizinna kaukaska (LC). W obrębie żubrów nizinnych istnieje podlinia PL (Pszczyna), która pochodzi od zaledwie dwóch założycieli: 42 PLANTA i 45 PLEBEJER. W wyniku tak wąskiej puli genów stopień inbrodu w podlinii PL jest bardzo wysoki. Dla 346 osobników urodzonych do 2024 r. średni współczynnik inbrodu wyniósł 0,514, ale maksymalna wartość przekraczała 75%. Co ciekawe, w tej podlinii nie ma oznak depresji inbredowej. Wskaźnik przeżywalności do jednego miesiąca wynosiła 93,1%, co jest wartością wyższą niż w przypadku reszty populacji gatunku. Mijmy nadzieję, że pula genetyczna tej podlinii jest wolna od szkodliwych alleli. Ważne jest, aby kontynuować hodowlę tej podlinii, ale w przypadku oznak depresji inbredowej należy ją przerwać, ponieważ dobrostan zwierząt jest najważniejszy
