https://doi.org/10.17221/147/2024-CJAS

Pedigree analysis of the Latvian Warmblood horse heavy type population

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Citation: Nikonova V., Jonkus D., Paura L. (2024): Pedigree analysis of Latvian Warmblood horse heavy type population. Czech J. Anim. Sci., 69: 462–469.

Abstract: A breeding program has been developed for the Latvian warmblood heavy type horses in Latvia, with the aim to preserve this type, because the number of these horses is small and the status of the local endangered breed has been granted. The aim of the study was to analyse the genetic structure, inbreeding and effective population size of the Latvian warmblood heavy type (LSB) horse population. Horses that were living at the time of the study on January 1, 2023 were used for the study. A total of 374 genetic resources live horses were analysed. Population structure analysis, inbreeding and effective population size were investigated. Calculations were done by POPREP (v1.0) software. The effective population size (*Ne*) decreased, however, since 2018 the decline in the size of the effective population has not been so rapid. In 2000, the *Ne* was 316 animals, and in 2020, it was 101 animals. Over the years, changes in the average inbreeding level in the LSB population were observed from year to year. In 2000, inbreeding was 1.39%, and in 2020 it was 1.47% with the average inbreeding level of 1.12%. Over the last 20 years, large changes in *Ne* have been observed, thus, the loss of genetic diversity in the LSB breed should be controlled.

Keywords: effective population; generation interval; inbreeding; horse breeding

In Latvia, equine breeding has deep-rooted traditions. As early as in the 1920s, two state horse breeding farms were established with the aim of conducting targeted selective breeding to improve the local, small-statured horses of Latvia by crossbreeding them with stallions imported from Europe. One of these farms imported Oldenburg stallions from the Netherlands, which laid the foundation for the development of the Latvian Warmblood driving type. The other farm acquired Hanoverian stallions from Germany, focussing on refining the Latvian Warmblood sport type. The Latvian Warmblood horses were officially recognised as a breed in 1937.

The breeding of Latvian Warmblood horses of both the sport and the driving type in the 21st century continues to exhibit notable differences. This is evidenced by the analysis of body measurements of mares and stallions of both types. The study found that the withers height of heavy type mares as marginally lower than that of sport type mares (167.1 cm *vs* 167.4 cm). However, the chest circumference of heavy type mares was on average 4 to 5 cm larger, and the cannon bone circumference was 1 cm larger compared to sport type mares (Veidemane and Jonkus 2018a). A similar study compared heavy and sport type stallions of the

Supported by the Latvian Ministry of Agriculture, and Rural Support Service Republic of Latvia (Project Nos.: 20-00-SOINV05-000018 and 23-00-S0INZ03-000024).

https://doi.org/10.17221/147/2024-CJAS

Latvian Warmblood breed. It was determined that the average withers height of heavy type stallions was 167.6 cm, only 1 cm less than that of sport type stallions. However, the average chest and cannon bone circumferences of heavy type stallions were significantly larger than those of sport type stallions (201.4 cm *vs* 194.4 cm for chest circumference, and 23.7 cm *vs* 21.8 cm for cannon bone circumference) (Veidemane and Jonkus 2018b).

In the early 2000s, the Ministry of Agriculture in Latvia decided to preserve the Latvian Warmblood heavy type (LSB) horses due to a significant decline in their population. In 2004, the first breeding program for LSB genetic resources was developed, with the aim of maintaining the heavy type with its characteristic traits: strong constitution, good-natured and calm temperament, trust in humans, and resilience, along with the ability to efficiently utilise feed and adapt to various housing conditions. These traits are crucial for the use of horses in rural tourism enterprises, hippotherapy, and children's education.

According to the Database of Agricultural Animals (available at webpage) in Latvia and Database of Latvia's Warmblood horses there were 8 989 horses at the beginning of 2024 in Latvia, while only 1 249 horses were registered as Latvian warmblood heavy type horses.

Increasing popularity is observed in the equestrian sports of classical disciplines, dressage, show jumping (overcoming obstacles) and triathlon. Additionally, carriage driving holds a significant position in sports competitions. Horses are no longer used predominantly in agricultural activities; instead, they have become members of sports teams or serve as hobbies and pets at home. Nowadays, horse breeding plays a significant role in rural tourism businesses. Consequently, breeders have followed advances in horse breeds to ensure that horses are suitable for both sports and hobby purposes.

Research conducted globally indicates that an increase in the inbreeding coefficient in a specific horse population deteriorates work capabilities, conformation, and health (Kjollerstrom et al. 2015; Bussiman et al. 2018). In the Latvian warmblood horse population it can also be seen that more and more the same stallions are used in breeding.

To use the pedigree analysis for the development of the LSB conservation program, the objective of the study was to analyse the structure of the population age and generation interval, the rate of inbreeding and the effective population size (*Ne*) of the LSB horses. Obtained results can be used to develop the conservation program.

MATERIALS AND METHODS

Pedigree data set

The LSB pedigree data was provided byAgricultural Data Center Republic of Latvia (https://www.ldc.gov.lv/en). The LSB database includes horses that are defined as genetic resources and that currently are under the conservation program. In total, 331 live horses (235 females and 96 males) with their ancestors were included in the analysis. The total number of animals in the pedigree was 3 098 (1 048 sires and 1 839 dams) with 890 founders. In the pedigree data set five and more generations are available from 1918 to 2020, when results from the calculation starting in 1980 are presented in the article. The number of offspring born each year and their parents are shown in Figure 1.

When the conservation of genetic resources for LSB horses began in the early 2000s, horses of theLSB were categorised as those descended from the Latvian breed heavy type and related breeds. The breeds related to the Latvian Warmblood included Oldenburg, Hanoverian, and Holsteiner horses, as well as the Saxon-Thuringian heavy warmblood. Starting in 2019, with the approval of the new breeding program for genetic

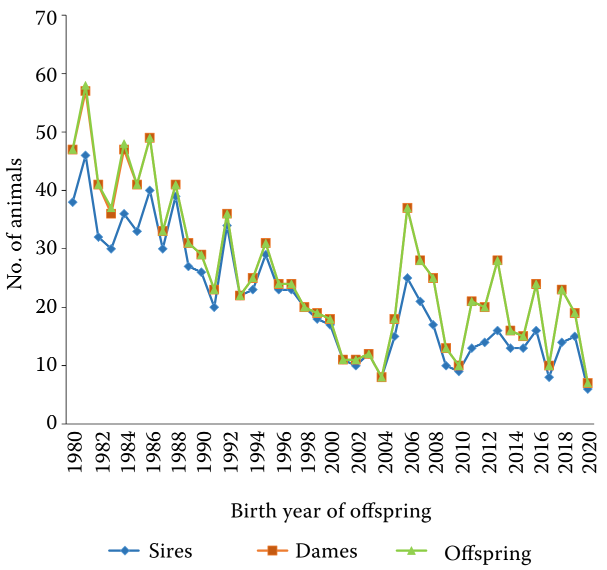

Figure 1. Number of Latvian Warmblood heavy type horse sires and dams in reproduction (the year of offspring birth)

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resources of horses of the Latvian Warmblood breed, a horse is considered to be of the conserved LSB if its pedigree has been known for four generations. In the pedigree of the LSB driving type horse, at least 75% of its bloodline must be LSB, and not closer than in the third generation, with up to 25% of Oldenburg, Hanoverian, or Holsteiner blood permitted.

In the 21st century, 20 lines have been conserved within the population, though some lines have a small number of animals. The largest lines include Ammons Old 7, Verdi Old 15, Finaldus Old 43, Juveelis Old 49, Banko Old 51, Kru Kru Old 56, Zengers Old 64, Germino Old 65, Siego Old 66, Markgraf Old 77, Goldengel Old 3561, Spēkonis Lsb 100, Mādis Lsb 164, Gotenfirsts Lsb 220, Graufalks Lsb 221, Gunārs Lb 313, Nekebolts Lb 314, Redžinalds Lb 320, Urians Lb 357, and Gaidis Lb 574. Breeding is conducted according to lines and related groups. To promote the conservation of genealogical lines with a small number of animals, relaxed requirements are applied to the certification of breeding for those continuing these lines. In the research were mainly used Ammon Old 7, Juveelis Old 49, Banko Old 51, Zengers Old 64, Siego Old 66, Markgraf Old 77, Goldengel 3561 Old, Spēkonis Lsb 100, Mādis Lsb 164, Redžinalds Lb320 lines descendants. The descendants of the remaining lines are very few, so it is nearly impossible to follow their pedigree.

Pedigree analysis

The analysis of population structure, pedigree completeness (PC), *Ne*, and inbreeding (F_x) was calculated using the freely available software POPREP (v1.0; Groeneveld et al. 2009).

The analysis of the population structure includes age structure of horses and generation interval based on gender and birth year of offspring. The generation interval defined as parent's average age when the foals are selected for breeding, has produced at least one progeny (Falconer and Mackay 1996). For a more comprehensive analysis of the population structure, mares and stallions with the highest number of offspring were also identified.

Distribution of animals by inbreeding levels is presented in five inbreeding classes with 5% step. The average F_x levels of all animals born in the years from 1980 to 2020 are summarised.

Pedigree completeness was calculated based on the proportion of known ancestors in each generation (MacCluer et al. 1983):

$$I_d = \frac{4 I_{dpat} \times I_{dmat}}{I_{dpat} + I_{dmat}} \quad (1)$$

$$I_{dk} = \frac{1}{d} \sum_{i=1}^{d} a_i \quad (2)$$

where:

d – the number of generations;
k – the paternal (pat) or maternal (mat) line;
a_i – the proportion of known ancestors in gener. *i;*
I_d – I_d =1 if all ancestors are known, I_d = 0 if one parent is unknown;
I_{dpat} – pedigree completeness from paternal line;
I_{dmat} – pedigree completeness from maternal line.

The effective population was calculated based on the number of parents (Falconer and Mackay 1996):

$$N_e = \frac{4 N_m \times N_f}{N_m + N_f} \times 0.7 \quad (3)$$

where:

N_m – the number of male parents;
N_f – number of male and female parents.

RESULTS AND DISCUSSION

Age structure of sires and dams by birth year of offspring and generation interval

The average age of stallions from 1980 to 2020 at the moment of offspring birth was 10.7 years, while for mares it was 10.1 years (Figure 2). According to the calculations stallions and mares were used for breeding at almost the same age, except the year 1985, when stallions were 12.1 years old and mares were 22.2 years old on average, but in 2020 stallions were in average 15 and mares 8 years old. The average age of stallions and mares by the year of offspring birth (10–15 years) is explained by the fact that before horses are used for breeding, horses participate in shows and the breeder has possibilities to evaluate the quality of the horse. The pedigree information for LSB horses has been available since 1927. Therefore, it can be concluded that the average age of breeding animals changed

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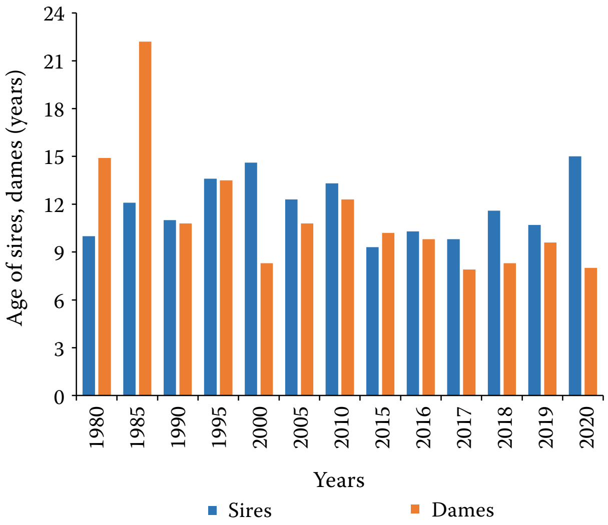

Figure 2. Average age of sires and dams in reproduction by the year of their offspring birth

within 100 years, with an average age of 12.9 years for stallions and 8.6 years for mares at the time of offspring birth. Mares started breeding earlier compared to stallions, while the quality of stallions is tested for a longer time based on their work abilities and exterior.

Since 2000 it has been observed that the stallions were older by the year of birth of their offspring compared to the mares, except in 2015. It can be explained by implementation of the genetic resources program for LSB when breeders used stallions from old breeding lines for mare mating. In 2020 the stallions' average age was 15 years, but for mares it was 8 years.

Throughout the period from 1980 to 2020, both stallions and mares were used for breeding starting from 2 years of age and older than 16 years. Nowadays, the use of older horses for mating is related to the limited number of horses that were defined as genetic resources. In a large population, stallions are usually used from the age of 3 years. Mantovani et al. (2013) suggested in Italian Heavy Draught horse to breed mares younger than 3 years when for foaling they should have correct growth, and 2-years-old young stallions can be used for mating compared to the more expensive stallions. For example, in the Campolina population, stallions younger than 3 years are not used, and their average age at the time of offspring birth is 8.3 years, while for mares this age is 8.9 years. The authors concluded mares younger than 4 years are not used for breeding (Bussiman et al. 2018). In a small population, the age of parents increases when the foal is born, for example in Old Kladruber horses, this age ranges from 8 to 11 years for both mares and stallions (Vostra-Vydrova et al. 2016).

The generation interval (GI) has a significant impact on genetic progress in the population; it is longer for horses than for other farm animals. In the horse breeding, the average and optimal generation interval is considered to be between 8 and 12 years, during which the most effective genetic development occurs. GI depends on the gender of the animal while males and females can be at different age at the birth of their selected offspring. Therefore, it is important to analyse the generation interval for the population as a whole and separately for the males and females (Falconer and Mackay 1996; Somogyvari et al. 2018). The generation interval for the LSB population since 1980 is presented in Figure 3. The GI changes in the population from year to year for both genders. Starting since 2003 the GI for a population is in the range from 8 to 13 years and it is on the recommended level for the horses. However, it was longer in some years (in 1985 and 2002) as well in the population before 1980 (not presented in the figure), when it was more than 20–30 years. The Campolina horse breed represents a large population. It has been determined that the generation interval for this breed is 9 years, falling within the optimal range for horses (8–12 years) (Bussiman et al. 2018). The Old Kladruber horse population, with a small number

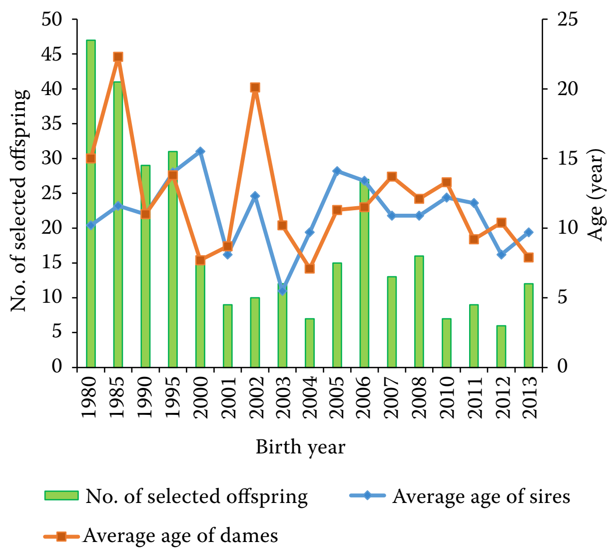

Figure 3. Average generation interval and number of selected offspring

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of horses, has a generation interval of 11.29 years, increasing by approximately 0.2 each year (Vostra-Vydrova et al. 2016). Also in the Dutch Warmblood horse population with 54 170 individuals, the average generation interval is 8.6 years (Schurink et al. 2012) and in the Andalusian horse population with 75 389 individuals 10.11 years (Valera et al. 2005).

In every animal species, it is crucial for the best breeding animals to produce as many offspring as possible. In the species where artificial insemination is used, the number of progeny for genetically superior males is higher. In Latvia artificial insemination in horses has been more widely used only in the last 10–15 years. Therefore, natural mating is used in horse breeding, as one breeding animal does not usually produce a large number of offspring. Genealogical lines and related groups of ten stallions exist in the LSB horse breed. Over the analysed period among the living LSB stallions, one stallion has the highest number of offspring – 18, as well as there are five stallions with the number of offspring higher than 10. The remaining stallions have fewer than 10 offspring. The maximum number of offspring for LSB mares is 5. For the most heavy type mares – around 80%, the number of offspring is less than 3. This is related to the fact that mares need to demonstrate their working abilities before they start to be used for breeding (mating) and with a 12-month gestation period, after which foals are separated only after 6 months. Additionally, not every mare is immediately used for the next breeding cycle after foaling. Moreover, older mares have health problems. Besides, at the beginning of the 21st century the popularity of the LSB decreased while in sport type horses it increased and farmers had problems with foal realisation. In the large populations, the number of stallion offspring can exceed 20 and the family size for stallions reaches 21.54 ± 2.02 animals and for mares only 3.42 ± 0.12 (Bussiman et al. 2018). In small populations, the number of stallion offspring is lower due to fewer mares (Vostra-Vydrova et al. 2016).

Pedigree completeness

In order to calculate the relatedness and inbreeding within a population it is important to know the pedigree of each individual in the population across multiple generations. In Latvia, pedigree information for heavy type horses has been recorded since 1927. The information for five and more generations is available for around 53% of animals in the pedigree. The maximum pedigree depth is 13. The completeness of the 6-generation pedigree information for the LSB population is summarised in Figure 4. The pedigree analysis indicates that the 1st and 2nd generation pedigree completeness has been 100% deep since 1985 and 2003, respectively. Additionally, since 2010 the pedigree information for the 3rd–6th generations has also been above 90%. The average pedigree completeness for animals born within the last 10 years ranged from 100% deep for 1st generation to 94% deep for 6th generation.

The pedigree completeness found in the LSB population was similar to that of the Campolina horse population in Bussiman et al. (2018), where the authors found PC for the first and second generation 100% and more than 99%, respectively, for horses born during the last 15 years. Our result is comparable to Giontella's et al. (2019) investigation, where PC in the Italian horse breed was higher than 80% for five generations.

Investigation on the Cleveland Bay population showed for horses in the pedigree that were born during the last five years (2015–2020) that the pedigree completeness was higher than in LSB and the pedigree of each animal was six generations deep and in animals that started foaling in the 1980s more than 95% (Dell et al. 2020, 2021), which could

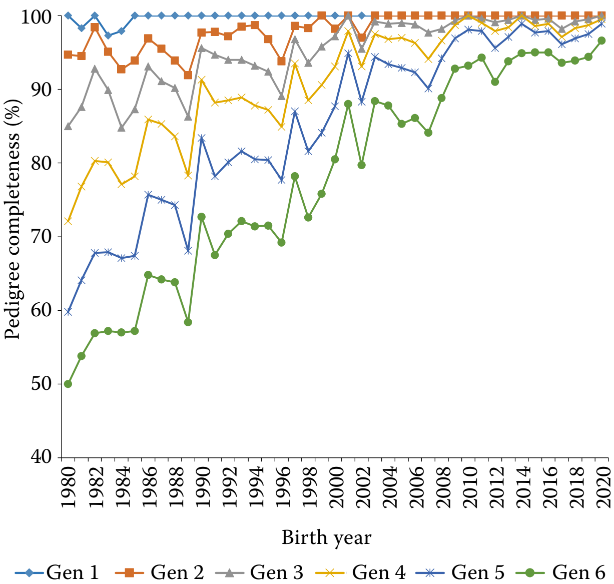

Figure 4. The average percentage pedigree completeness of the Latvian Warmblood horse heavy type population

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be related to digitisation of the horse studbook and breed management during the last decade. Before that time the pedigree completeness was lower, and it is explained by low interest from the government in the world about horse breeding; in addition, a lot of horses were kept on small farms for work and the owners did not make correct pedigree recording.

Inbreeding level in LSB population

In small populations, with a small number of the effective population sizes each year more inbred animals will be born. Around 45% of the LSB horses born since 1980 are non-inbred and more than 55% are inbred (Table 1). In the data set 3.42% are horses with the inbreeding level more than 5% and there are some horses with the high inbreeding level more than 10%.

The results of the study show that there is a trend observed that the overall inbreeding coefficient in the population of Latvian warmblood horses has not significantly increased since 1980 (Figure 5). However, the number of horses with an inbreeding coefficient above 10% has been increasing, making it more challenging to perform the proper mate selection. The increase in the number of horses with inbreeding can lead to inbreeding depression and negative influence on fertility and survival at birth (Kjollerstrom at al. 2015). It is important to monitor inbreeding in every population because of decreasing performance in animals, for example, in research on Czech Holstein cows every 10% increase in the inbreeding coefficient ends with 2.23% decrease in performance (Hofmannova et al. 2019).

In the evaluation period the average inbreeding level for offspring by the birth year was in the range from 0.25% to 2.30% (Figure 5). In the data set it has

Table 1. The distribution of animals by inbreeding coefficient born from 1980 to 2020

F levels(%)	Number of animal	Proportion (%)
F = 0	473	44.88
F ≤ 5.0	545	51.71
5.0 < *F* ≤ 10.0	29	2.75
10.0 < *F* ≤ 15.0	4	0.38
15.0 < *F* ≤ 20.0	2	0.19
F ≥ 20.0	1	0.10
Total	1 054	100

F = inbreeding coefficient

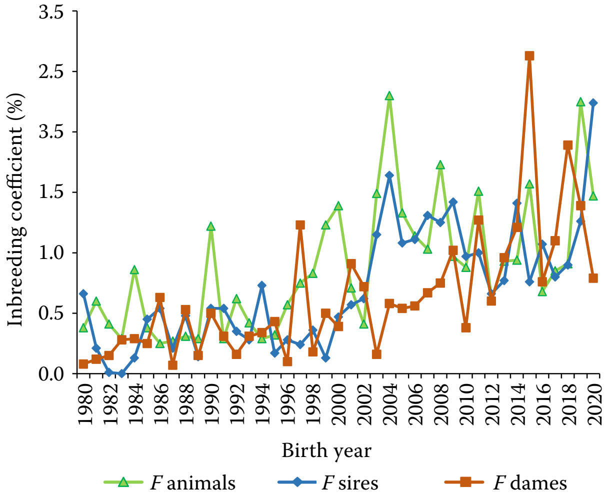

Figure 5. Average inbreeding coefficients (*F*) for the sires, dams and their offspring

been observed that the average level of inbreeding has increased over the last 20 years. It could be explained by the introduction of the genetic resources program for LSB in 2004. The highest inbreeding level of 2.60% was found for mares in 2015 and 2.45% for stallions in 2020 because of working with the same lines of sires.

The average inbreeding has been increased approximately by 1% in the LSB population after 2000 and reached 2.25% for offspring born in 2019; however, the level of inbreeding is in an acceptable range and it is similar compared with results in the Campolina horse population (average F_x = 2.45; Bussiman et al. 2018), Maremmano Italian horse population (average F_x=2.94%; Giontella et al. 2019) and Holstein warmblood horse population (average F_x = 2.27%, Roos et al. 2015). The above-mentioned populations are significantly larger compared to the LSB population. Fluctuations in the inbreeding coefficient may be linked to the introduction of the genetic resources program in 2004 and the increasing popularity of the heavy type after 2010, when carriage driving sport began to develop in the Baltic region, specifically using LSB horses.

The inbreeding coefficient has increased in the Hungarian horse population with the 83.38% proportion of inbred animals in the population and higher average inbreeding level of 5.57% (Somogyvari et al. 2018) compared to the LSB. In the Austrian Noriker draught horse population average inbreeding coefficients ranged from 4.5% to 5.5% (Druml et al. 2009). However, in Slovakia, where four local endangered breeds were studied, the lowest inbreeding coefficient

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of 2.67% was observed in the Slovak Sport Pony, while the highest inbreeding coefficient of 6.26% was found in the Hucul breed (Pjontek et al. 2012). The same tendency was shown in Mackowski's et al. (2015) study, where the inbreeding level in the Polish Konik population increased by 3.8% during the 30-year period and reached 8.6% in 2011. In very small populations the inbreeding coefficient is very high, for example, in the local Portuguese Sorraia breed with 12 founders the inbreeding coefficient is 38% (Kjollerstrom et al. 2015).

The level of inbreeding in the LSB population has fluctuated from year to year; however, in most years it does not exceed 1% and it is in an acceptable range.

Effective population size

There were changes in effective population size (*Ne*) during the analysed period (Figure 6). From 1989 to 1990 the Ne decrease was moderate, when a lot of farms used heavy type horses for work on the farm, but from 1990 to 2020 the Ne decrease was more rapid. In 2000 the Ne was 316 animals, by 2011 Ne decreased by half. In the next years Ne continued to gradually decrease with a sharp decline in 2017, when it reached 116 animals and 101 animals in 2020.

There is a general trend of an increase in the average inbreeding level in the LSB population (although it changes over the years) and of a decrease in *Ne* (Figure 7). The biggest *Ne* was from 1980 to 1990 with lower inbreeding. Since 1990 *Ne* started to decrease, but inbreeding was increasing and in the year 2000, the *Ne* was 316 animals, with average inbreeding of 1.39%. In 2008, the *Ne* was 197 animals, with an inbreeding rate of 1.73%. By the year 2020, the inbreeding was 1.47%, with an effective population size of 101 animals.

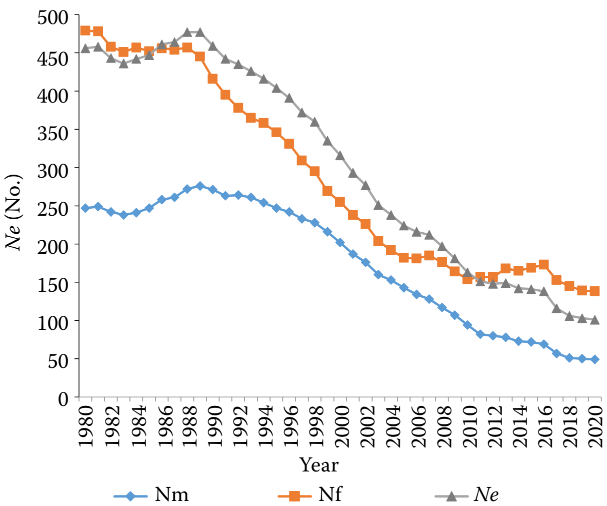

Figure 6. Effective population size (*Ne*) of Latvian Warmblood heavy type horses, depending on the number of males (Nm) and females (Nf) from 1980 to 2020

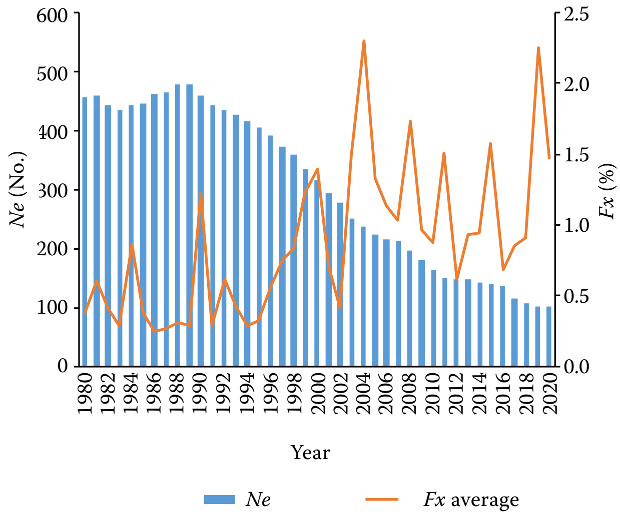

Figure 7. The effective population size (*Ne*) and the average inbreeding coefficient (*Fx*) over the years for Latvian warmblood heavy type horses

Overall, it can be concluded that the coefficient of inbreeding has increased and the *Ne* has decreased in the LSB horse population as well as in other small populations. Such a trend is observed in the Konik Polski horse breed population and in the local Hungarian horse breed, where the effective population size continues to decline (Kjollerstrom et al. 2015; Somogyvari et al. 2018). In the Lipizzan horse population in Bosnia and Herzegovina and in Serbia the *Ne* value was always < 100 during the last decade (Rogic et al. 2022).

CONCLUSION

According to the study in the LSB genetic resources population, inbreeding in the Latvian heavy type horse population has varied over the years since 1980 and more than 55% of animals are inbred. The effective population size of Latvian heavy type horses gradually decreased over 20 years from 316 animals in 2000 to 101 animals in 2020. The average level of inbreeding based on the pedigree information has increased over the last decade and in some years it reached more than 2% in the population. The pedigree completeness for six generations for 20 years

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is more than 80% with 100% completeness for the first and second generation. This study confirms after the implementation of the LSB genetic resources program that the number of LSB genetic resources horses is decreasing because additional requirements for LSB genetic resources horses were introduced and heavy type horses are not so popular any more in Latvia compared to the sport type horses. Until now, the level of inbreeding and *Ne* of the LSB genetic resources population have not been evaluated. Therefore, the obtained results will allow breeders to select horses based not only on their working abilities, but also to select them based on the relationship.

Conflict of interest

The authors declare no conflict of interest.

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Received: September 6, 2024
Accepted: October 20, 2024
Published online: November 14, 2024