A registry-based study of declined foaling rates in Finnhorses

Tiina Reilas[1], Terttu Katila[2], Mikko Kosola[3] and Anna-Maija K. Virtala[3]

[1] Natural Resources Institute Finland (Luke), Myllytie 1, FI-31600 Jokioinen, Finland

[2] Department of Production Animal Medicine, Faculty of Veterinary Medicine, University of Helsinki, Paroninkuja 20, FI-04920 Saarentaus, Finland

[3] Department of Veterinary Biosciences, Faculty of Veterinary Medicine, University of Helsinki, PO Box 66, FI-00014 University of Helsinki, Finland

e-mail: tiina.reilas@luke.fi

In Finland, the seasonal foaling rates of trotters began declining at the beginning of the 2000s. This retrospective study aimed to elaborate factors behind the declining foaling rates in Finnhorses using multivariable logit models. The mating records from years 1998 to 2000 (period 1, n = 5967) and 2002 to 2004 (period 2, n = 5373) originated from the Finnish trotting and breeding association. The over-all foaling rate was 66.6% during period 1 and 62.4% during period 2 ($p < 0.0001$). Foaling rate for on-site artificial insemination decreased from 70.2% to 64.8% ($p = 0.003$). The proportion of the most fertile mare groups, 2–9-year-olds and foaled mares, decreased by 8.2 and 7.1 percentage points, respectively. Differences in foaling rates between young and middle-aged mares, and maiden and foaled mares changed from non-significant to significant ($p < 0.0001$) due to the foaling rate decline in middle-aged ($p = 0.001$) and maiden mares ($p = 0.01$). The decline in foaling rate was also significant for barren and rested mares ($p < 0.05$), natural mating ($p = 0.01$), and book size >68 ($p < 0.0001$). It was concluded that multiple factors were responsible for the foaling rate decline.

Key words: horse, reproductive efficiency, age, reproductive status, artificial insemination, mating

Introduction

In Finland, the 21st century began with declining seasonal foaling rates for Finnhorses and Standardbreds, the two main trotting breeds in the country (Katila et al. 2010). Seasonal foaling rates in Finland increased in the 1980s because of better management and new reproductive technologies, particularly artificial insemination (AI) and ultrasonography (Katila et al. 2010). After a plateau in the 1990s, foaling rates began decreasing (Hippos 2018a, 2018b). The descriptive statistics revealed unfavorable development in the broodmare population from the most fertile mare groups to the less fertile ones (Katila et al. 2010). However, the data were not studied using multivariable analyses.

Finland is one of the world's northernmost countries and keeping costs for horses are therefore high. Low reproductive efficiency reduces breeding profitability in many ways. The Finnhorse is the only native horse breed in Finland. In 2016, the population size was 19200 (Hippos 2016). Finnhorses are versatile cold-blooded horses well suited as trotters, riding horses, and workhorses. Low foaling rates raise particular concern because, with a few exceptions, Finnhorses only exist in Finland, and the number of foals born per year decreased to less than 1000 in 2015 (Hippos 2017).

Age and reproductive status of mares significantly influence pregnancy (Sanderson and Allen 1987, Morris and Allen 2002, Nath et al. 2010, Hanlon et al. 2012) and foaling rates (Sanderson and Allen 1987, Morris and Allen 2002, Langlois and Blouin 2004, Katila et al. 2010). Mating type is another factor shown to affect seasonal foaling rates (Langlois and Blouin 2004, Katila et al. 2010, Haadem et al. 2015) and per-cycle foaling rates (Haadem et al. 2015). The electronic database of the Finnish trotting and breeding association (Suomen Hippos) is suitable for studying the effects of these factors on seasonal foaling rate, as practically all mated mares and foal births are reported in Finland. However, these data are not reliable for counting foaling rates per cycle because not all matings in every cycle have been declared.

The purpose of this retrospective study was to elaborate factors behind the declining foaling rates using multivariable logit models. Our hypothesis was that the decline in foaling rates was due to structural changes in the mare population. The study was limited to the Finnhorse because of its national importance and abruptly decreased seasonal foaling rates at the beginning of the 2000s.

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Material and methods

Data, definitions, and study design

The study was based on the mating and pedigree records of Finnhorses provided by Suomen Hippos. For this analysis, we included all reported Finnhorse matings in Finland during years 1998 to 2000 (period 1), which exhibited relatively high foaling rates, and years 2002 to 2004 (period 2) with declined foaling rates (Fig. 1).

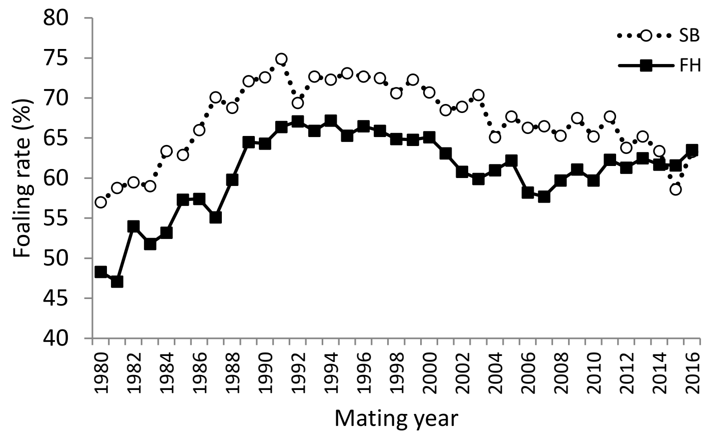

Fig. 1. Foaling rates for Standardbreds (SB) and Finnhorses (FH) from the annual reports of Suomen Hippos

Year 2001 mating data were not included, as we wanted to capture years with visibly different foaling rates. One mating record includes one mare bred with one stallion during one year. In the database, the following events were assigned a value of 1 (foaled): a filly born alive, a colt born alive, a foal born dead, or a foal that died after birth. Events where a mare did not conceive, aborted, or died while pregnant were given a value of 0 (not foaled). A dead foal refers to a foal born dead one month or less before the expected foaling time. Foaling rate is the proportion of foaled mares (%) out of all the mated mares. Mares with unknown mating histories, less than two years of age, or more than 25 years of age were excluded. In addition, stallions serving ≤ 2 mares per year were excluded. Only the outcome of the last mating per season (foal or not) was used.

The analyzed database had a total of 11 340 mating records: 5967 from period 1998–2000 and 5373 from period 2002–2004. The time periods had 3560 and 3292 individual mares and 184 and 168 individual stallions, respectively.

Factors used in the analyses

Mares were divided into four age groups: young (2–9 years), middle-aged (10–13 years), aging (14–16 years), and very old (17–25 years). According to their breeding histories, four reproductive status categories were formed: maiden (never mated), barren (mated earlier, but aborted or did not conceive), rested (not mated after the last foaling), and foaled (mare with a live or dead foal). Mating type was categorized as 1) on-site AI (mare inseminated with fresh semen at the same station where the stallion was resident), 2) transported (mare inseminated with cooled semen transported to another station or the home stable of the mare), and 3) natural mating (in-hand mating). An additional variable, book size, was calculated for stallions describing the number of mares they served per one season. Book size was further divided into four categories comprising approx. one-fourth of all mating records: 3–12, 13–27, 28–68, and >68 mares per stallion.

Statistical analysis

We used the last mating of each mating season for a single mare mated with a single stallion as the statistical unit in our study. The outcome of this mating (foaled or not) was used as the response variable. Mare age, reproductive status, mating type, and book size were the independent variables, whose effects on the outcome we studied. We calculated the foaling rates for all mare categories in the two time periods. The 95% confidence intervals were calculated with Epitools (Sergeant 2017) using the Wilson method (Brown et al. 2001).

We performed multivariable mixed logistic regression analyses on foaling rate separately for the two periods and between periods within groups. The original data had a complex cross-classified hierarchical structure (a mare could have been served by several stallions; a stallion could have served several mares). Therefore, PROC GLIMMIX (SAS 9.4 statistical package; SAS Institute Inc.) was used to adjust for clustering within the data; stallion and mare were included as random effects. Due to model fit issues, normal logistic regression was used instead of mixed logistic model on a few occasions. We expected to see interactions between mare age and reproductive status, and between mating type and book size, but we found interactions only between the last two. Therefore analyses for differences between mating types were done separately for each book size category. In general, analyses were interpreted as significant at a 95% confidence level, allowing for 5% Type 1 error.

Results

Descriptive statistics

The overall foaling rate was 66.6% in 1998–2000 and 62.4% in 2002–2004 ($p < 0.0001$). The foaling rates in all groups were lower in period 2, but the decrease was more pronounced in middle-aged mares (5.6 %-points), maiden mares (5.6 %-points), mares inseminated on-site (5.4 %-points) or mated naturally (5.0 %-points), and if stallions with a highest book size were used (6.7 %-points) (Table 1).

The proportion of young mares decreased by 8.2 percentage points from 37.7% in period 1 to 29.5% in period 2, while the proportions of middle-aged, aging, and very old mares increased by 4, 2.1, and 2.1 percentage points, respectively (Table 1). The age structure shifted towards older mares in all reproductive status groups, but particularly in maiden and rested mares (Fig. 2). The proportion of foaled mares fell by 7.1 percentage points from 39.3% to 32.2% (Table 1). The proportion of foaled mares decreased particularly in the age group of 10–13-year-olds (Fig. 3). The proportion of young foaled mares decreased from 9.9% (593/5967) in period 1 to 5.8% (309/5373) in period 2. During the study years, the proportion of naturally mated mares decreased from 42.5% to 32.9% (Table 1). The shift from natural mating towards AI occurred in the two smallest book size categories (Fig. 4). The proportion of middle-aged mares in the book size category of >68 increased from 22.6% to 31.9%.

Regression models

Foaling rate declined in middle-aged mares ($p = 0.001$) (Table 2): the rate was similar to that of young mares in period 1 ($p = 0.72$) but lower in period 2 ($p < 0.001$) (Table 3). When compared with aging mares, the foaling rate of middle-aged mares was slightly higher in period 1 ($p = 0.02$) but did not differ in period 2 ($p = 0.13$). Maiden, barren and rested mares did not perform as well in the second period as earlier ($p < 0.05$) (Table 2). In period 1, the foaling rate of maiden mares was slightly lower ($p = 0.01$) than in rested mares and similar ($p = 0.10$) to foaled mares, but in period 2 maiden mares differed significantly ($p < 0.0001$) from rested and foaled mares (Table 3). In both periods, the foaling rate of barren mares differed significantly ($p \leq 0.001$) from that of rested and foaled mares but not from maiden mares. Foaling rates between rested and foaled mares did not differ in either of the two periods.

The decline in foaling rate was significant for on-site AI ($p = 0.003$), natural mating ($p = 0.01$) and book size >68 ($p < 0.0001$) (Table 2). The foaling rates for on-site AI and transported semen did not differ in stallions with book sizes of >68 ($p = 0.08$) in period 1, but on-site AI was better than transported semen in period 2 ($p < 0.0001$) (Table 4). In the 28–68 book size group, foaling rates for on-site AI and transported semen were higher than for natural mating in period 1 ($p = 0.004$ and $p = 0.04$, respectively) but not in period 2.

Table 1. Proportions, mean ages, and foaling rates (FR) of Finnhorse mares during two time periods, and the difference in the number of mating records (n) and in the FR percentage between these periods (period 2 minus period 1)

Time period	1			2				
Years	1998–2000			2002–2004			Between periods	
	n (%)	Mean age (SD[1])	FR % (95% CI[2])	n (%)	Mean age (SD)	FR % (95% CI)	Difference in n	Difference in FR % points
Mare age (years)								
2–9	2250 (37.7)	7.1 (1.7)	69.0 (67.1–70.9)	1583 (29.5)	6.9 (1.8)	66.9 (64.5–69.2)	–667	–2.1
10–13	1957 (32.8)	11.4 (1.1)	69.3^{a} (67.2–71.3)	1976 (36.8)	11.5 (1.1)	63.7^{b} (61.6–65.8)	19	–5.6
14–16	987 (16.5)	14.9 (0.8)	64.6 (61.1–67.6)	1001 (18.6)	14.9 (0.8)	61.5 (58.5–64.5)	14	–3.1
17–25	773 (13.0)	19.0 (1.9)	55.4 (51.9–58.8)	813 (15.1)	18.9 (1.8)	51.4 (48.0–54.8)	40	–4.0
Mare status								
Maiden	1122 (18.8)	7.1 (2.4)	68.0 (65.2–70.7)	1157 (21.5)	7.7 (3.0)	62.4 (59.6–65.2)	35	–5.6
Barren	1572 (26.3)	12.6 (4.3)	60.8 (58.4–63.2)	1513 (28.2)	13.0 (4.0)	56.7 (54.2–59.2)	–59	–4.1
Rested	925 (15.5)	11.8 (3.8)	70.9 (67.9–73.8)	975 (18.3)	13.0 (3.7)	65.3 (62.3–68.3)	50	–5.6
Foaled	2348 (39.3)	12.4 (3.9)	68.2 (66.3–70.0)	1728 (32.2)	13.0 (3.9)	65.6 (63.4–67.8)	–620	–2.6
Mating type								
On-site AI	1697 (28.4)	11.6 (4.3)	70.2^{a} (68.0–72.3)	1753 (32.6)	11.9 (4.2)	64.8^{b} (62.5–67.0)	56	–5.4
Transported	1733 (29.0)	11.6 (4.2)	66.8 (64.6–69.0)	1851 (34.5)	12.0 (4.1)	63.1 (60.9–65.3)	118	–3.7
Natural	2537 (42.5)	11.0 (4.4)	64.2^{a} (62.3–66.1)	1769 (32.9)	11.7 (4.6)	59.2^{b} (56.9–61.5)	–768	–5.0
Book size[3]								
3–12	1534 (25.7)	11.2 (4.3)	68.7 (66.3–71.0)	1300 (24.2)	11.8 (4.4)	65.4 (62.8–67.9)	–234	–3.3
13–27	1493 (25.0)	11.3 (4.3)	62.5 (60.0–64.9)	1227 (22.8)	11.7 (4.5)	57.4 (54.6–60.1)	–266	–5.1
28–68	1660 (27.8)	11.2 (4.4)	64.6 (62.3–66.8)	1294 (24.1)	11.9 (4.3)	61.0 (58.3–63.6)	–366	–3.6
> 68	1280 (21.5)	11.8 (4.2)	71.6^{a} (69.0–74.0)	1552 (28.9)	12.1 (4.0)	64.9^{b} (62.5–67.2)	272	–6.7

[1]SD = standard deviation; [2]CI = confidence interval; [3]Book size = mares/stallion/year. $^{a-b}$FR within rows with different superscripts are different ($p < 0.05$) (confidence intervals do not overlap)

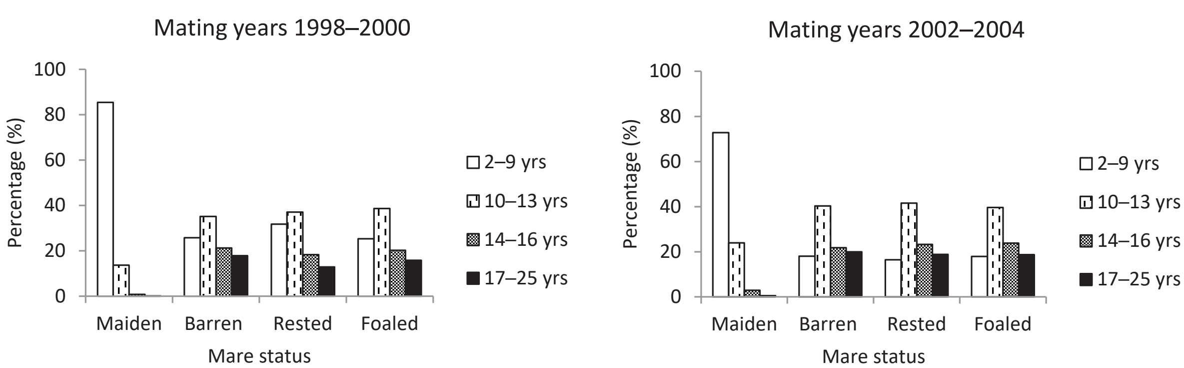

Fig. 2. Age distribution within different mare status groups during mating years 1998–2000 (period 1) and 2002–2004 (period 2)

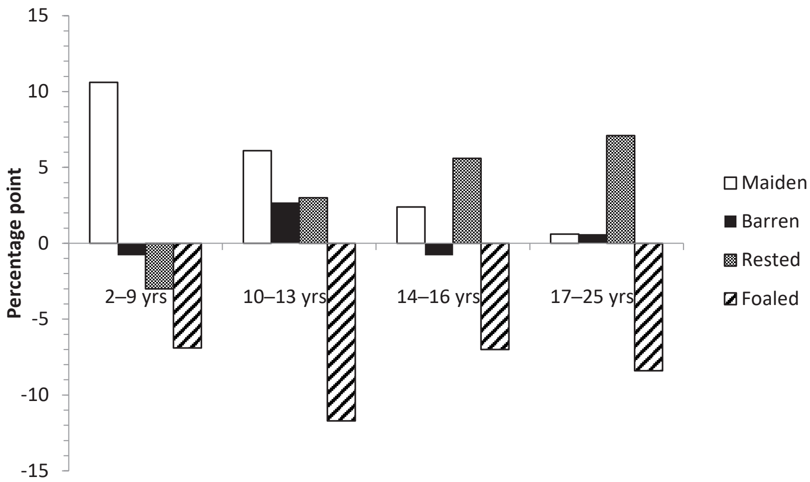

Fig. 3. Changes (percentage points) in the proportions of mare status groups within the mare age groups from the mating years 1998–2000 (period 1) to 2002–2004 (period 2)

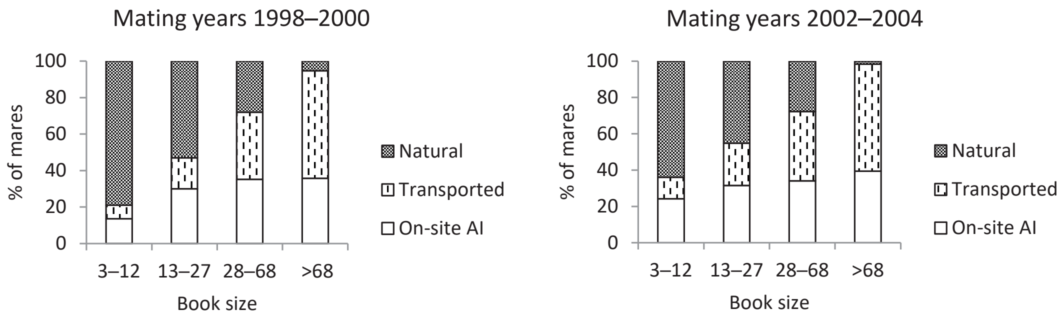

Fig. 4. Distribution of mating types within book size groups for mating years 1998–2000 (period 1) and 2002–2004 (period 2)

Table 2. Multivariable logistic mixed model results for mare age, mare status, mating type and book size to test differences in foaling rates (FR) of Finnhorse mares between two time periods. Results are adjusted for other independent variables, and for interaction of mating type and book size where appropriate. Mare and stallion were incorporated as random effects. An odds ratio (OR) between 0 and 1 indicates that the foaling rate in period 2 (2002–2004) was lower than in period 1 (1998–2000).

	FR % period 1	FR % period 2	OR	95% CI[1]	*p*-value
Mare age (years)					
2–9	69.0	66.9	0.90	(0.77–1.05)	0.17
10–13	69.3	63.7	0.77	(0.66–0.90)	**0.001**
14–16	64.6	61.5	0.84	(0.69–1.03)	0.10
17–25	55.4	51.4	0.83	(0.67–1.03)	0.09
Mare status					
Maiden	68.0	62.4	0.79	(0.66–0.95)	**0.01***
Barren	60.8	56.7	0.83	(0.71–0.98)	**0.03**
Rested	70.9	65.3	0.78	(0.64–0.95)	**0.02***
Foaled	68.2	65.6	0.91	(0.78–1.05)	0.19
Mating type					
On-site AI	70.2	64.8	0.76	(0.64–0.91)	**0.003**
Transported	66.8	63.1	0.87	(0.74–1.03)	0.10
Natural	64.2	59.2	0.83	(0.72–0.96)	**0.01**
Book size[2]					
3–12	68.7	65.4	0.90	(0.75–1.07)	0.22
13–27	62.5	57.4	0.86	(0.71–1.04)	0.12
28–68	64.6	61.0	0.84	(0.70–1.02)	0.08
> 68	71.6	64.9	0.70	(0.60–0.83)	**<0.0001***

[1]CI = confidence interval; [2]Book size = mares/stallion/year; Significant *p*-values <0.05 are bolded. *Due to model fit issues, normal logistic regression was used.

Table 3. Multivariable logistic mixed model results for mare age and mare status groups to test differences in foaling rates of Finnhorse mares within two time periods. Models were performed separately for both periods and adjusted for mating type, book size (mares/stallion/year), and their interaction. Mare and stallion were incorporated as random effects. An odds ratio (OR) >1 indicates that the foaling rate (FR) in the first-mentioned group was higher than in the comparison group, and 0<OR<1 indicates the opposite.

Time period	1				2		
Years	1998–2000				2002–2004		
Categories compared (n[1])	OR[2]	95% CI[3]	*p*-value[4]	Categories compared (n)	OR	95% CI	*p*-value
Mare age (years)				Mare age (years)			
2–9 (2250) vs. 10–13 (1957)	1.03	(0.89–1.19)	0.72	2–9 (1583) vs. 10–13 (1976)	1.33	(1.13–1.56)	**<0.001**
2–9 (2250) vs. 14–16 (987)	1.26	(1.05–1.50)	**0.01**	2–9 (1583) vs. 14–16 (1001)	1.51	(1.25–1.83)	**<0.0001**
2–9 (2250) vs. 17–25 (773)	1.94	(1.60–2.34)	**<0.0001**	2–9 (1583) vs. 17–25 (813)	2.28	(1.87–2.79)	**<0.0001**
10–13 (1957) vs. 14–16 (987)	1.22	(1.03–1.45)	**0.02**	10–13 (1976) vs. 14–16 (1001)	1.13	(0.96–1.34)	0.13
10–13 (1957) vs. 17–25 (773)	1.89	(1.58–2.26)	**<0.0001**	10–13 (1976) vs. 17–25 (813)	1.72	(1.44–2.04)	**<0.0001**
14–16 (987) vs. 17–25 (773)	1.54	(1.26–1.89)	**<0.0001**	14–16 (1001) vs. 17–25 (813)	1.51	(1.25–1.84)	**<0.0001**
Mare status				Mare status			
Maiden (1122) vs. Barren (1572)	1.11	(0.92–1.33)	0.29	Maiden (1157) vs. Barren (1513)	0.91	(0.76–1.09)	0.30
Maiden (1122) vs. Rested (925)	0.77	(0.62–0.94)	**0.01**	Maiden (1157) vs. Rested (975)	0.66	(0.54–0.81)	**<0.0001**
Maiden (1122) vs. Foaled (2348)	0.86	(0.72–1.03)	0.10	Maiden (1157) vs. Foaled (1728)	0.65	(0.54–0.78)	**<0.0001**
Barren (1572) vs. Rested (925)	0.69	(0.58–0.83)	**<0.0001**	Barren (1513) vs. Rested (975)	0.73	(0.61–0.87)	**<0.001**
Barren (1572) vs. Foaled (2348)	0.78	(0.68–0.90)	**0.001**	Barren (1513) vs. Foaled (1728)	0.72	(0.62–0.83)	**<0.0001**
Rested (925) vs. Foaled (2348)	1.13	(0.95–1.34)	0.18	Rested (975) vs. Foaled (1728)	0.99	(0.83–1.17)	0.87

[1]n=number of mating records; [2]OR=odds ratio; [3]CI=confidence interval; [4]Wald's p-value; Significant *p*-values <0.05 are bolded.

Table 4. Multivariable logistic mixed model results for mating types in different book size groups (mares/stallion/year) to test differences in foaling rates (FR) of Finnhorse mares during two time periods. Models were performed separately for different book size groups in both periods and adjusted for mare age and mare status group. Mare and stallion were incorporated as random effects. An odds ratio (OR) >1 indicates that the FR in the first-mentioned group was higher than in the comparison group, and 0<OR<1 indicates the opposite.

Time period	1				2		
Years	1998–2000				2002–2004		
Categories compared (n[1])	OR[2]	95% CI[3]	*p*-value[4]	Categories compared (n)	OR	95% CI	*p*-value
Book size 3–12				Book size 3–12			
On-site AI (n=208) vs. Transported	1.74	(1.03–2.93)	**0.04**	On-site AI (n=315) vs. Transported	1.24	(0.82–1.87)	0.31
On-site AI vs. Natural (n=1212)	1.45	(1.01–2.08)	**0.04**	On-site AI vs. Natural (n=832)	1.01	(0.76–1.36)	0.93
Transported (n=114) vs. Natural	0.83	(0.54–1.28)	0.41	Transported (n=153) vs. Natural	0.82	(0.56–1.19)	0.29
Book size 13–27				Book size 13–27			
On-site AI (n=448) vs. Transported	1.86	(1.31–2.65)	**<0.001**	On-site AI (n=387) vs. Transported	1.24	(0.88–1.75)	0.21
On-site AI vs. Natural (n=791)	1.19	(0.88–1.60)	0.25	On-site AI vs. Natural (n=554)	1.63	(1.19–2.23)	**0.003**
Transported (n=254) vs. Natural	0.64	(0.46–0.90)	**0.01**	Transported (n=286) vs. Natural	1.31	(0.93–1.84)	0.12
Book size 28–68				Book size 28–68			
On-site AI (n=584) vs. Transported	1.14	(0.87–0.87)	0.33	On-site AI (n=440) vs. Transported	0.81	(0.62–1.09)	0.17
On-site AI vs. Natural (n=466)	1.65	(1.17–2.31)	**0.004**	On-site AI vs. Natural (n=358)	1.06	(0.75–1.48)	0.75
Transported (n=610) vs. Natural	1.44	(1.02–2.03)	**0.04**	Transported (n=496) vs. Natural	1.29	(0.93–1.80)	0.13
Book size > 68				Book size > 68			
On-site AI (n=457) vs. Transported	1.28	(0.97–1.68)	0.08	On-site AI (n=611) vs. Transported	1.68	(1.31–2.15)	**<0.0001**
On-site AI vs. Natural (n=68)	1.52	(0.76–3.05)	0.24	On-site AI vs. Natural (n=25)	2.68	(1.09–6.60)	**0.03**
Transported (n=755) vs. Natural	1.19	(0.60–2.36)	0.62	Transported (n=916) vs. Natural	1.60	(0.66–3.89)	0.30

[1]n=number of mating records; [2]OR=odds ratio; [3]CI=confidence interval; [4]Wald's p-value; Significant *p*-values <0.05 are bolded.

Discussion

As the study design implies, the overall foaling rate of Finnhorses declined significantly from 66.6% in 1998–2000 to 62.4% in 2002–2004. Official records of Suomen Hippos show that the Finnhorse foaling rate reached a nadir (57.7%) in 2007; thereafter it has slowly increased to 63.5 percent in 2016 (Hippos 2018a). Recent studies on cold-blooded horse breeds have reported a seasonal foaling rate of 61.5% for Black Forest Draught horses in Germany in the mating years 2001–2009 (Müller-Unterberg et al. 2017) and 74.3% for the Norwegian Cold-blooded Trotter in 2006–2010 (Haadem et al. 2015). According to the Norwegian Trotting Association, annual foaling rates in Norwegian Cold-blooded trotters have been relatively stable (ca. 67%) since 2000 (Haadem et al. 2015). This foaling rate is similar to that of Finnhorses in 1998–2000 before the foaling rate decline.

Unfavorable changes occurred in the Finnhorse broodmare population, namely the proportions of young mares and foaled mares decreased by 8.2 and 7.1 percentage points, respectively. In the middle-aged mares, the proportion of foaled mares decreased by 11.7 percentage points. Following the Finnish Great Depression of the 1990s, the number of foals born per year decreased over four consecutive years, beginning in 1992 (Hippos 2017). The resulting smaller age groups may have decreased the number of young broodmares in 2002–2004. The increase in the proportions of maiden mares in the two youngest age groups, and rested mares in the three oldest age groups (Fig. 3) corroborate our belief that the changes in the broodmare population resulted from breeders' decisions. Consequently, mares started their breeding career later and breeding of foaled mares was postponed.

The well-known negative influence of aging on fertility was noticeable in this study. However, the great decline in foaling rate in middle-aged mares was an unexpected finding. The foaling rate began decreasing in 14- to 16-year-old mares in period 1, whereas in period 2 this decrease was visible already in 10–13-year-old mares. Studies on Thoroughbreds have shown declines in the live foal rates in mares older than eight (Allen et al. 2007) and 13 years of age (Bosh et al. 2009).

Descriptive statistics showed that the foaling rate decreased in all reproductive status groups by 2.6 to 5.6 percentage points. Regression models showed that the decrease was significant in maiden, barren and rested mares. Compared to foaled mares, maiden mares were significantly less successful at producing foals in period 2. A French study similarly showed seasonal foaling rates to be lowest for maiden mares and highest for foaling mares (Langlois and Blouin 2004). Contrary to our results, certain researchers have reported higher seasonal foaling rates for maiden Thoroughbred mares than for foaling mares (Brück et al. 1993, Bosh et al. 2009). The higher foaling rate of maiden mares was explained by their lower age (Brück et al. 1993). However, logistic regression modeling in an Irish study (Lane et al. 2016) showed that reproductive status did not influence the per-cycle pregnancy rate. Administrative data of the Finnish trotting and breeding association may only provide accurate information about foaling rates per season. Pregnancy and foaling rates per cycle, and particularly the pregnancy rate per first cycle, are better measures for fertility and reproductive efficiency than seasonal foaling rates. We were unable to calculate these measures because many stallion keepers had not reported all matings.

Rested mares seem to be a rare category in Thoroughbred broodmare populations. In the Newmarket region of the UK, only 1.5% of Thoroughbred broodmares were rested, whereas 65.5% were foaling mares (Morris and Allen 2002). In Sweden, these figures were 3% and 58.8%, respectively (Hemberg et al. 2004). The corresponding proportions in the present study were 15.5% and 39.3% in 1998–2000, and 18.3% and 32.2% in 2002–2004. The degree of professionalism and economic constraints probably explain the different broodmare population structures between the Thoroughbred breeding industry and Finnhorse breeding. In Finland, many breeders have one or two mares that they mostly breed as a hobby. When they are not in need of a new foal or foal prices are low, they refrain from breeding for a year or more.

Our results show that mares that are deliberately not mated after their last foaling achieve equally good seasonal foaling rates as foaled mares and better results than maiden and barren mares. A high fertility rate has also been found in rested Icelandic mares (Davies Morel and Gunnarsson 2000). Morris and Allen (2002) reported the lowest pregnancy rates per cycle for rested mares and speculated that having a year off may not be advantageous for subsequent fertility. We could not assess the pregnancy rate per cycle, but the large number of mares and a model accounting for the influences of mare age and mating method suggest that postponing the next mating by a year or more does not decrease the chances of producing a foal.

Seasonal foaling rate was highest for on-site AI and lowest for natural mating during both periods. This finding agrees with previous studies of French (Langlois and Blouin 2004) and Finnish (Katila et al. 2010) administrative data. Contrary to expectations, the decline in foaling rate was significant for on-site AI and natural mating but not for transported semen, as the confidence intervals of the foaling rates for transported semen overlapped (Table 1) and the null value of 1 was included in the confidence interval for transported semen (Table 2). Individual stallions and differences in management practices and intensity have probably contributed to a varying extent to the foaling rates for on-site AI and transported semen. Approximately one-fourth of the mares were bred to stallions with book sizes above 68. Only six stallions were in this book size group during both periods, and three of these served mares during both periods. In middle-aged mares, the proportion of this book size group increased by 9.2 percentage points. Moreover, 35% and 49% of all the mares inseminated with fresh or transported semen in period 2 were bred to these six stallions, respectively. The impact of these nine stallions and their semen quality has obviously affected the results. As on-site AI is recommended for problem mares (McCue 2008), the mares inseminated with fresh semen may have been less fertile than those inseminated with cooled transported semen. This possible source of bias was also considered in the study of Norwegian Cold-blooded trotters (Haadem et al. 2015). No variables for mare management, such as hormone treatments or uterine therapy, were available in the present study. Nath et al. (2010) calculated management intensity by scoring veterinary attendance, use of ovulation induction agents, and timing of early pregnancy diagnosis; a relationship between the intensity of farm management and the pregnancy rate was found in Standardbreds.

Foaling rates of young mares and foaled mares decreased less than those in the other age or reproductive status groups. These are the groups with the highest fertility. Aged mares, barren mares, and elderly maiden mares often require intensive management and good veterinary care to get in foal. The owners of these mares may lose their motivation during the season when they realize the dismal prospects of the sales view and the market price for future foals. Every additional cycle and all inseminations cost money, particularly when transport semen and veterinary services are utilized.

Conclusions

It is concluded that multiple factors rather than any single reason led to the decrease in foaling rates. To enhance the applicability and reliability of administrative data for assessing reproductive efficiency and fertility, stallion keepers should report all matings in every cycle. The decisions of mare owners concerning the breeding and inseminations are speculated to have led to an unfavorable development in the broodmare population: proportions of the highest fertility groups, i.e. young mares and foaled mares, decreased significantly, which was reflected in the foaling rates.

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