Breeding value evaluation in Polish fur animals: Statistical description of fur coat and reproduction traits – relationship and inbreeding

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ABSTRACT: Three data sets were available: records on conformation and coat traits for the arctic fox from one farm (5 540 observations, collected between 1983 and 1997), and the same traits for the silver fox from three farms (8 199 observations, collected between 1984 and 1999). The third set comprised 5 829 observations on reproductive performance of the arctic fox from one farm, collected between 1984 and 1999. The GLM procedure was used to test the significance of fixed effects on the analysed reproduction traits as well as differences between groups. Phenotypic trends as well as relationship and inbreeding across the studied years were computed. Most of the phenotypic trends were positive. Low relationship and inbreeding coefficients in the arctic and silver fox populations under study were estimated. The average relationship coefficients for the silver and arctic fox populations were 0.015 and 0.010, respectively, whereas the average inbreeding coefficients for the same species were 0.0039 and 0.0016, respectively. No inbreeding was found in the arctic fox breeding females.

Keywords: fur animals; fur coat; inbreeding; relationship; reproduction

In some countries (Finland, Norway, Denmark, Russia) fur production is of economic importance. High quality pelts provided by fur-bearing animals (silver fox, arctic fox, mink, ferret, racoon dog, chinchilla, nutria) are sold at international auction houses (Helsinki, Copenhagen). Competition on the international market forces fur animal farmers to produce pelts of large size and high quality hair cover. Thus the implementation of a breeding programme aimed at genetic improvement of economically important traits (coat, conformation and reproduction traits) is an important tool for the production of competitive pelts.

Although fur production in Poland is not among the main branches of animal breeding, for many farmers this activity provides a substantial part of their income. According to the Central Animal Breeding Office (2000) the number of breeding females under recording in Polish herds was: silver fox 6 059, arctic fox 9 344, mink 2 589, racoon dog 686, nutria 1 690, chinchilla 3 121, and rabbit 3 489. In contrast, in 2002 farmers in Finland kept the following number of breeding females: silver fox 23 000, arctic fox 490 000, mink 520 000, and racoon dog 15 000. What is extremely important, such big production goes together with the high quality of pelts. It has been achieved through implementation of the breeding programme based on the selection of animals on the basis of best linear unbiased predictions (BLUPs) of their breeding values (Smëds, 1992). The breeding value evaluation on Finnish fur farms was described by Wierzbicki and Filistowicz (2002).

In Norway where the fur animal breeding also plays a significant role in agriculture, high quality of pelts has been achieved by developing a system for live grading, using the SAS System for Information Delivery and a standard matrix index with full-sibs and half-sibs in the calculations. The system helps the farmer in grading and selection while it is underway (Johannessen *et al.*, 2000).

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Although the situation on the international fur market is promising (growing demand, high prices paid for high quality pelts), the pelts produced by Polish farmers cannot compete with the pelts of Nordic countries origin, mainly because of their small size and low quality of hair cover (Sławoń, 1994, 1995). Studies carried out by Wierzbicki (1999) revealed that only 0.2% of the arctic fox pelts produced at one of the best Polish farms were of a very large size. Furthermore, the pelts described as high quality ones constituted only 13.4% of the total. Worse properties of Polish pelts are most likely the result of the old system of breeding value evaluation still used in Polish fur farming. Instead of breeding values estimated by the BLUP procedure (EBVs), breeders use phenotypes (scores) or a simplified form of selection index as selection criteria. The principles and disadvantages of both methods were described in detail by Wierzbicki and Filistowicz (2001).

According to Filistowicz *et al*. (1999) three factors determining the pelt price the most are: skin size, hair coat quality and colour type. Depending on the year (1996 or 1998) and the auction number (1–4) from 57.7% to 80.9% of the total variation of the arctic fox pelt price was determined by skin size, whereas pelt quality determined from 13.7% up to 36.5% of the total price variation. The results clearly show that a greater emphasis should be laid on genetic improvement of coat traits affecting the pelt price the most.

Other traits that influence the efficiency of fur animals farming are those connected with reproduction. Litter size (at birth, 2–3 weeks after birth, at weaning) is used as an indicator of female reproductive performance when constructing a selection index. This trait can be easily measured (objectively by counting pups), which is important when processing data. Although litter size has a negative effect on body size (Johannessen *et al*., 2000), in a combined selection index the litter size has a relatively large weight. If a reliable breeding programme is applied, litter size can be improved effectively. In Finland, reproduction results on farms using BLUP EBVs are 0.1–0.4 pups/litter above the national average (Finnish Fur Breeders Association, www.stkl-fpf.fi).

In Poland, reproduction traits have been genetically improved without using EBVs. However, most likely because of the objective measurement of the traits, reproduction results obtained on Polish farms are comparable to those noted in Scandinavia. According to the Central Animal Breeding Office (2000) the average litter size at birth for the silver fox and the arctic fox was 3.8 pups and 6.4 pups, respectively, whereas in Denmark the same results reached 3.9 pups and 5.8 pups, respectively.

This paper presents the results of the first part of research on the development of BLUP-based method for the evaluation of breeding value in Polish fur animal farming. Presented is the statistical analysis of the data used in the study as well as relationship and inbreeding resulting from the pedigree analysis.

MATERIAL AND METHODS

Data

Three data sets were available: records on conformation and coat traits for the arctic fox from one farm (5 540 observations), and the same traits for the silver fox from three farms (8 199 observations). The third set comprised 5 829 observations on reproductive performance of the arctic fox from one farm. The data on the silver fox (2 colour types: silver and gold) were collected between 1984 and 1999, whereas the data on the arctic fox (2 colour types: white and blue) were collected between 1983 to 1997 (conformation and coat traits), and 1984 to 1999 (reproductive performance).

The fur coat and conformation traits were evaluated according to grading standard accepted by the Central Animal Breeding Office. In order to ensure scores consistency over the years of the data collecting (the grading standard has changed a few times), for the study purposes, only the grading standard introduced in 1984 was used when foxes were evaluated (CSHZ, 1984a,b). The following traits were graded: (1) silver fox – body size (BS), colour type (CT), colour purity (CP), coat density (CD), hair length (HL), purity of silvering (PS), general appearance (GA), total score (TS), skin length (SL); (2) arctic fox – body size (BS), colour type (CT), colour purity (CP), coat density (CD), hair length (HL), general appearance (GA), total score (TS), and skin length (SL). The traits were graded annually (in November) when the fur coat was fully developed and mature.

Three birth seasons (in each season about 30% of individuals were born) of foxes under study were distinguished: 1st birth season (arctic fox: born before May, 7th; silver fox: born before April, 7th), 2nd birth season (arctic fox: born 8–15 May; silver fox: born 8–15 April), 3rd birth season (arctic fox: born after May, 15th; silver fox: born after April, 15th). Within the group of the arctic fox females five whelping (breeding) seasons (defined as a year of giving birth or being used for reproduction) were found.

The reproductive performance of the arctic fox was characterised by the following traits: litter size at birth (LSB), litter size at weaning (LSW), number of dead pups (NPD), pup weight at weaning (PW), pregnancy length (PL), and whelping age (WA). The pups were weaned at the age of 7 weeks, whelping age was measured as the number of days from female birth to the whelping day, the number of dead pups was determined as the difference between the litter size at birth and the litter size at weaning, and the pregnancy length was measured as the number of days from the last mating to the whelping day. The foxes were naturally mated (one male was mated to five females). Only the animals related less than 6.25% were mated (this requirement was introduced into the mating schemes in the mid-1980s). The data summary is given in Table 1.

Table 1. Statistical description of the data sets

Trait	n	Scale of scores	Mean	SD	Kurtosis	Skewness	Phenotypic trend (b)
Silver fox							
BS	8 199	0–6	4.66	1.15	–0.67***	–0.17***	0.118
CT	8 199	0–3	2.62	0.62	0.93***	–1.38***	–0.002
CP	8 199	0–3	2.73	0.53	2.65***	–1.81***	–0.045
CD	8 199	0–6	5.48	0.57	–0.40***	–0.59***	–0.036
HL	8 199	0–6	5.60	0.59	0.81***	–1.22***	0.022
PS	8 199	0–3	2.77	0.47	3.11***	–1.62***	0.019
GA	8 199	0–3	2.72	0.51	10.03***	–0.39***	0.020
TS	8 199	0–30	26.59	1.75	1.54***	–0.95***	0.097
SL	5 339	(cm)	70.43	2.61	–1.05***	0.01	0.054
Arctic fox							
BS	5 540	0–3	2.75	0.53	3.57***	–2.24***	0.024
CT	5 540	0–6	5.67	0.87	5.65***	–3.13***	0.051
CP	5 540	0–6	4.70	1.11	–0.68***	–0.38***	–0.012
CD	5 540	0–6	5.23	0.72	2.57***	–2.38***	-0.009
HL	5 540	0–6	5.46	0.75	4.25***	–2.83***	0.003
GA	5 540	0–3	2.91	0.35	16.85***	–4.86***	0.010
TS	5 540	0–30	26.73	2.55	5.18***	–6.06***	0.068
SL	5 536	(cm)	61.36	2.01	–1.30***	–0.05	–0.011
LSB	3 080	no. of pups	9.63	3.19	–0.21	–0.16	0.010
NPD	3 080	no. of pups	0.44	1.16	18.24***	3.86***	–0.014
LSW	3 080	no. of pups	9.18	3.16	–0.37***	–0.17	0.023
PW	3 080	(g)	1 283	325	17.62***	3.00***	–0.158
WA	2 443	days	366.74	11.79	29.53***	1.63***	1.078
PL	5 829	days	51.79	1.57	–0.46***	–0.17	–0.061

***significant at $P \leq 0.001$

Statistical analyses

The GLM (General Linear Models) procedure of the SAS package (2000) was applied to test the significance of fixed effects on the analysed reproduction traits (conformation and fur coat traits were not tested due to non-normality of their scores distribution). Two linear models were fitted for the arctic fox's reproduction traits. The model for the analysis of the whole reproduction data was as follows:

$$X_{jklm} = \mu + Y_j + S_k + (YS)_{jk} + C_l + e_{jklm}$$

where: X_{jklm} = an observation of m-th animal
μ = overall mean
Y_j = effect of j-th year (1, 2, …, 10)
S_k = effect of k-th whelping season (1, 2, …, 5)
$(YS)_{jk}$ = an interaction between respective main effects
C_l = effect of l-th colour type (1, 2)
e_{jklm} = residual corresponding to m-th animal ($e_{jklm} \sim N(0, \sigma^2_e)$)

The second model was fitted to the sub-set of reproduction data (n = 947) in which karyotypes of females (2n = 48, 2n = 49, 2n = 50) were available. This data set was analysed separately, since many studies (Świtoński, 1981; Christensen and Pedersen, 1982; Mäkinen and Lohi, 1987) indicated that the relation between reproductive performance and karyotype polymorphism existed. The following model was used for the analysis:

$$X_{jklmno} = \mu + Y_j + S_k + (YS)_{jk} + C_l + K_m + L_n + e_{jklmno}$$

where: X_{jklmno} = an observation of o-th animal
μ = overall mean
Y_j = effect of j-th year (1, 2, …, 10)
S_k = effect of k-th whelping season (1, 2, …, 5)
$(YS)_{jk}$ = an interaction between respective main effects
C_l = effect of l-th colour type (1, 2)
K_m = effect of m-th karyotype (1, 2, 3)
L_n = effect of n-th litter size the female was born in (1, 2, 3, 4)
e_{jklmno} = residual corresponding to o-th animal ($e_{jklmno} \sim N(0, \sigma^2_e)$)

The significance of differences between means calculated within groups (colour type, female karyotype, breeding season) was tested using Duncan's multiple range test. The phenotypic trends were estimated as a regression of average scores of traits on year using the linear regression procedure.

Pedigrees of the animals from the 3 data sets used in the study were taken for computing relationship and inbreeding. These coefficients were calculated within each data set separately because the arctic fox's coat and conformation traits, and reproductive performance, were collected independently and did not overlap each other. The algorithms described by Tier (1990) were used. The coefficients of relationship and inbreeding were computed within the groups (year, farm, gender), and for the whole arctic and silver fox populations. Within the analysed data sets, the base population was defined as the parents of the first generation of animals included in the study.

RRESULTS AND DISCUSSION

Means and their standard deviations of fur coat and conformation traits (Table 1) revealed that average scores calculated for the traits were close to the upper limits on the scale of scores. It means that according to classifiers who graded both species of foxes, phenotypes of the studied individuals almost fulfilled requirements described in the grading standards.

The tendency of grading foxes rather higher than average was reported by Wierzbicki *et al*. (2000), who carried out the study in the arctic fox population. They found that classifiers mainly scored the highest grades, which led to overevaluation of animals and reduction of phenotypic variability. The present study confirms these remarks, since most of the traits have small standard deviations. Furthermore, the skewness computed for the traits indicates that the scores were not normally distributed (a problem typical of discrete or categorical traits). The scores distributions with heavier-than-normal tails were found in both fox species, but in the arctic fox they were more significant (skewness ranged from –0.05 to –6.06 whereas in the silver fox skewness ranged from 0.01 to –1.81). Measurements of the skin length, the only trait evaluated objectively on a metric scale, were found to be normally distributed. Although minor departures from normality may be acceptable, heavy-tailed distributions can compromise statistical estimates. Thus, in the further statistical analysis, (estimation of variance components) methods of data normalization or non-linear methodology will need to be applied. However, according to Levin *et al*. (1996) even the best transformation may not provide an adequate approximation to normality. Moreover, a transformed variable may be hard to interpret and conclusions drawn from it may not apply to the original, untransformed variable.

The fourth moment of the distribution – kurtosis was found to be negative (platykurtic) for 8 out of 23 analysed scores. The distribution with positive kurtosis (leptokurtic) characterised most of the scores.

In Norway where all fur coat traits are scored on a scale 1–5 with 3 as the typical animal, and the body size recorded as weight (kg) in mink or length (cm) in foxes the problem with heavy-tailed data as well as scoring animals higher than it should be, has been solved. According to Johannessen *et al*. (2000) this way of grading traits provides data showing normal distribution in classes, and more objective evaluation of traits. For example, the average score of pelt quality defined as a combination of hair quality, underfur density and general impression in 1989–1998 ranged from 2.50 at the beginning, through 2.94 in the middle to 3.23 at the end of that period. According to Uribe *et al*. (1999), human classifiers could potentially be replaced by laser cameras that could take three-dimensional images of animals. Laser images would be free from classifier biases and would be consistent across countries and breeds.

Reproductive performance of the arctic fox characterized by 6 traits is statistically described in Table 1. Despite its categorical nature, data on litter size (at birth and at weaning) were only slightly skewed (–0.16 and –0.17, respectively). Other trait measurements showed larger departures from normality with largest skewness of 3.86 calculated for the number of dead pups.

The GLM procedure showed that reproduction traits were significantly influenced ($P \leq 0.01$) by all effects (year, whelping season, year × whelping season, colour type, female karyotype, litter size the female was born in) included in the linear models. Depending on the trait, R^2 of the models ranged from 0.63 (LSW) to 0.88 (LSB).

Phenotypic trends of the silver and arctic fox conformation and coat traits across the studied years are presented in Table 1. In the silver fox population the trends estimated for 6 of the studied traits were positive, ranging from 0.019 (PS) to 0.118 (BS). However, the estimates of phenotypic trends for CT, CP and HD were negative, ranging from –0.002 to –0.045.

Phenotypic trends in the population of the arctic fox were found somewhat lower than in the silver fox (Table 1). Out of eight, three estimates of phenotypic trend computed for CP, HD and SL were negative, ranging from –0.009 to –0.012. Surprisingly, the negative trend (–0.011) was estimated for SL, the only trait evaluated objectively on the metric scale. In the analysed time period (1983–1997) two years (1984 and 1995) were not included in the study because the data collected in those years were not available or not reliable.

Negative trends (both phenotypic and genetic ones) were usually estimated for discrete traits (Socha, 1996; Wierzbicki *et al*., 2000; Wierzbicki and Filistowicz, 2003) indicating an unfavourable effect of subjective evaluation on phenotypic and genetic progress.

Most animals in the studied silver and arctic fox populations were born in the 2nd birth season (Table 2). This is not surprising since most females come into heat in the middle of the breeding season. Considerably more differences between average scores of the traits given to animals born in different seasons were found in the silver fox. Higher scores of BS, CP, CD, HL and TS were found for silver foxes born in the 2nd birth season than for those born in the 1st and 3rd seasons. GA of silver foxes born in the 2nd season was scored lower than of animals born in the other two seasons. Small differences were found for skin length. This is somewhat surprising since skin length is positively correlated with body size. If the body size of foxes born in the 2nd birth season was largest, one would expect the longest skins from those animals. The possible explanation is that body size is scored subjectively on the point scale, while the skin length is measured objectively on the metric scale.

In the arctic fox differences between average scores from animals born in different seasons were found only for CP and SL (Table 2). The arctic foxes born in the 2nd season were given lower CP score than those born in the other two seasons. The SL of arctic foxes born in the 3rd season was longer than in the other two groups. No association was found between body size and skin length assessments.

Within each of the arctic and silver fox populations, two colour types were distinguished: silver and gold in the silver fox, and blue and white in the arctic fox. Comparison of the traits average scores between colour types is presented in Table 2. In the arctic fox differences between blue and white individuals were found for CT, CP, CD, HL,

Table 2. Average scores of the silver and arctic fox conformation and fur coat traits in relation to birth season and colour type

Trait	Birth season			Colour type	
	1st	2nd	3rd	silver	gold
Silver fox	(*n* = 1 439)	(*n* = 5 009)	(*n* = 1 751)	(*n* = 4 698)	(*n* = 3 501)
BS	4.63	4.75	4.46	4.71	4.60
CT	2.63	2.65	2.54	2.68	2.54
CP	2.60	2.81	2.63	2.91	2.49
CD	5.39	5.54	5.40	5.60	5.32
HL	5.51	5.70	5.41	5.77	5.39
PS	2.75	2.77	2.79	2.75	2.78
GA	2.82	2.65	2.81	2.59	2.89
TS	26.33	26.86	26.03	27.01	26.03
SL	70.43 (*n* = 373)	70.44 (*n* = 4 462)	70.31 (*n* = 504)	70.43	not measured
Arctic fox	(*n* = 1 793)	(*n* = 2 726)	(*n* = 1 021)	blue (*n* = 4 960)	white (*n* = 580)
BS	2.75	2.76	2.73	2.75	2.77
CT	5.66	5.67	5.72	5.64	5.97
CP	4.81	4.60	4.80	4.65	5.13
CD	5.25	5.23	5.19	5.21	5.38
HL	5.47	5.46	5.48	5.51	5.08
GA	2.89	2.91	2.91	2.91	2.84
TS	26.82	26.63	26.83	26.67	27.22
SL	60.83	61.47	62.00	61.37	61.29

Significance of differences between average scores within groups (birth season, colour type) was not tested due to not normal distribution of the data

GA and TS. Considerably higher scores were usually given to the white-coated foxes (4 scores out of 6 were higher). It might be that more attention was paid to white animals, since the white pelts usually achieve a higher price at the auction. Moreover, breeders carefully prepare the mating scheme due to the lethal factor carried by the white (shadow) foxes (Filistowicz *et al*., 1997). No differences were found for BS and SL.

In the silver fox, differences between colour types were found for all studied traits (Table 2). The silver coated animals were generally graded higher (6 scores out of 8 were higher) than gold animals. The gold fox is not widely bred on farms. The individuals of this colour variety were obtained by crossing silver foxes with wild red foxes (Filistowicz *et al*., 2000b). Better scores of silver foxes may have resulted from the genetic improvement of traits resulting from intense selection that has been carried out since the beginning of fox farming. The gold colour type, being "younger", is still away from its grading standard definition.

Phenotypic trends of reproduction traits of the arctic fox in the studied years are given in Table 1. Due to the small number of records collected in the first years of the analysed period (1984–1992) and in the years 1997–1998, these data were grouped into classes: 1984–1986, 1987–1990, 1991–1992 and 1997–1998. The rest of the data were analysed within years. Phenotypic trends estimated for LSB, LSW were positive (0.010 and 0.023, respectively), whereas the trend estimated for NPD was negative (–0.014, positive tendency). A positive trend was also estimated for WA (b = 1.078). This means that the average age of female at the 1st whelping has increased significantly (14 days) in the last decade. It may result from reaching the sexual maturity later than it was a few years ago, or postponing the day of conception during the breeding season. Analysis of changes in PW and PL revealed the negative phenotypic trends for both traits (more pronounced for PW, this can be connected with a slight increase in LSB and LSW).

Analysis of the pastel fox reproductive performance carried out by Jakubczak (2002) showed that the litter size at birth, at the beginning of the analysed period (1978) was higher than in 1997 (3.83 vs. 3.21, respectively). A positive tendency was noted for litter size at weaning (2.10 vs. 2.15, respectively). In contrast, a steady increase in the number of born pups was observed by Ślaska (2002), who studied reproduction traits in racoon dog. In 1997–1999 the average litter size increased from 5.59 to 5.81 pups.

Arctic foxes are karyotypically polymorphic. This phenomenon is caused by Robertsonian translocation involving two pairs of chromosomes (23rd and 24th). As a result three karyotypes are determined in the arctic fox population: $2n = 48$, $2n = 49$ and $2n = 50$ (Filistowicz *et al*., 2000a). The karyotype polymorphism resulting from centric fusion was also found in wild boar (Rejduch *et al*., 2003).

The effect of karyotype polymorphism of the arctic fox females on reproduction traits is shown in Table 3. In the studied females, karyotypes $2n$ = 48, 49 and 50 constituted 10.7%, 40.6% and 48.7%, respectively. The distribution of polymorphic forms presented here differs from that reported by Świtoński *et al*. (1991), who found that 22.9% of females had 48 chromosomes, 46.1% had 49 and 31.0% had 50.

The karyotype polymorphism did not influence NPD, PW and PL. The largest LSB (9.60 pups) was found in females with $2n = 48$, and was significantly higher ($P \leq 0.05$) than LSB found in females carrying 50 chromosomes (8.94 pups). Most of the studies carried out so far have reported that females with the centric fusion in a homozygous condition ($2n = 48$) were more fertile and delivered larger litters (Świtoński, 1981; Christensen and Pedersen, 1982; Mäkinen and Lohi, 1987). However, Möller *et al*. (1985) did not find any significant differences in litter size between polymorphic forms of the arctic fox. The smallest litters were delivered by females with karyotype $2n = 48$, and the largest by females carrying 50 chromosomes. Significant differences between polymorphic forms were also noted for LSW and WA. The largest LSW was found in the females with $2n = 48$, and the smallest in the females with $2n = 50$. It was a consequence of the differences found for LSB. Females carrying 48 chromosomes were found to be the oldest at 1st whelping. These females delivered the first litter at the age of 365.9 days, which was significantly later in comparison with the other polymorphic forms.

Table 3. Means of the arctic fox reproduction traits in relation to the female karyotype

Trait	Karyotype		
	$2n = 48$	$2n = 49$	$2n = 50$
LSB ($n = 910$)	9.60^{a} ($n = 96$)	9.28^{ab} ($n = 371$)	8.94^{b} ($n = 443$)
NPD ($n = 910$)	0.43^{A} ($n = 96$)	0.53^{A} ($n = 371$)	0.51^{A} ($n = 443$)
LSW ($n = 508$)	9.76^{A} ($n = 55$)	9.01^{AB} ($n = 208$)	8.61^{B} ($n = 245$)
PW ($n = 785$)	$1\,120^{A}$ ($n = 78$)	$1\,095^{A}$ ($n = 329$)	$1\,083^{A}$ ($n = 378$)
WA ($n = 309$)	365.90^{A} ($n = 31$)	363.69^{C} ($n = 126$)	364.82^{B} ($n = 152$)
PL ($n = 947$)	51.93^{A} ($n = 101$)	51.97^{A} ($n = 385$)	52.04^{A} ($n = 461$)

Within lines means with the same letter are not significantly different: capital letter at $P \leq 0.01$, small letter at $P \leq 0.05$

A comparison of reproductive performance of the arctic fox blue and white colour types is given in Table 4. Most of the studied animals were blue coated. No significant differences between colour types were found for NPD and PL. Significant differences in favour of blue foxes were observed for LSB (0.49) and LSW (0.52). Similar results were reported by Filistowicz *et al*. (1997), who found that the blue type of fox had a significantly larger litter size (7.50 pups) than white-coated foxes (5.59 pups). Jeżewska *et al*. (1987) also found this fact on other Polish farms where white foxes were mated. Compared to other colour types the average litter size at birth and at weaning was reduced by 2.7 and 1.7 pups, respectively. Significant differences in favour of white foxes were found for PW and WA. The average weight of the white pup was 1 327 g, whereas the average weight of the blue pup was 1 279 g. White pups are reared in smaller litters

Table 4. Means of the arctic fox reproduction traits in relation to the colour type

Trait	Colour type	
	blue	white
LSB (n = 3 080)	9.66^{a} (n = 2 856)	9.17^{b} (n = 225)
NPD (n = 3080)	0.44^{A} (n = 2 855)	0.47^{A} (n = 225)
LSW (n = 3080)	9.22^{a} (n = 2 855)	8.70^{b} (n = 225)
PW (n = 3080)	1 279^{a} (n = 2 856)	1 327^{b} (n = 225)
WA (n = 2443)	366.92 ^{A} (n = 2 294)	364.05 ^{B} (n = 149)
PL (n = 5829)	51.77^{A} (n = 5 453)	51.95^{A} (n = 376)

Within lines means with the same letter are not significantly different: capital letter at $P \leq 0.01$, small letter at $P \leq 0.05$

and it may be the reason for their heavier weight at weaning.

Five subsequent breeding seasons of females were studied in order to find changes in the female reproductive performance in the course of time (Table 5). LSB and LSW were significantly higher in the second breeding season (10.12 and 9.66, respectively) as compared to other seasons. The smallest LSB and LSW were found in the oldest females and in primiparous ones. However, larger litters in the 2nd, 3rd and 4th breeding seasons were accompanied by higher NPD. Similar conclusions were drawn by Ślaska (2002), who reported significantly smaller litter size at birth and at weaning in one-year-old racoon dog females as compared to older ones. According to the author it may result from less-developed nursing ability of young females. PL was found to be significantly longest in the 1st breeding season (51.9 days), whereas in the following seasons no significant differences in pregnancy length were found.

Figure 1 presents changes in relationship coefficient across the studied years. In the silver fox (3 farms taken into account in the study) a clear increasing tendency was found. At the beginning of the period (1984) the average relationship coefficient was 0.007 whereas at the end of that period the relationship coefficient was five times higher (0.038). The average relationship computed for individuals kept on farms no. 2 and no. 3 was similar (0.010 and 0.014, respectively), whereas individuals kept on farm no. 1 were related closer (0.050).

In the arctic fox (1 farm studied) the average relationship coefficient estimated for the studied period (1983–1997) was comparable to that estimated for the silver fox (0.010). However, no clear increasing tendency over time was noted. The highest relationship coefficient was found in 1990 (0.0257), and after a decreasing tendency in 1991–1992 the relationship stabilised at the level of 0.008. The highest level of relationship in 1990 may have been caused by a reduced number of foxes in that year (n = 191; the

Table 5. Means of the arctic fox reproduction traits in relation to the breeding season

Trait	Breeding season				
	1st	2nd	3rd	4th	5th
LSB (n = 3 080)	9.41^{BC} (n = 1 155)	10.12^{A} (n = 855)	9.67^{AB} (n = 526)	9.55^{B} (n = 307)	8.96^{C} (n = 237)
NPD (n = 3080)	0.41^{b} (n = 1 155)	0.46^{ab} (n = 855)	0.44^{ab} (n = 526)	0.59^{a} (n = 307)	0.37^{b} (n = 237)
LSW (n = 3080)	8.99^{b} (n = 1 155)	9.66^{a} (n = 855)	9.23^{b} (n = 526)	8.96^{b} (n = 307)	8.58^{c} (n = 237)
PW (n = 3 080)	1 263^{b} (n = 1 155)	1 287^{ab} (n = 855)	1 312^{a} (n = 526)	1 300^{ab} (n = 307)	1 280^{ab} (n = 237)
PL (n = 5829)	51.90^{a} (n = 2 477)	51.72^{b} (n = 1 450)	51.71^{b} (n = 923)	51.68^{b} (n = 509)	51.72^{b} (n = 470)

Within lines means with the same letter are not significantly different: capital letter at $P \leq 0.01$, small letter at $P \leq 0.05$

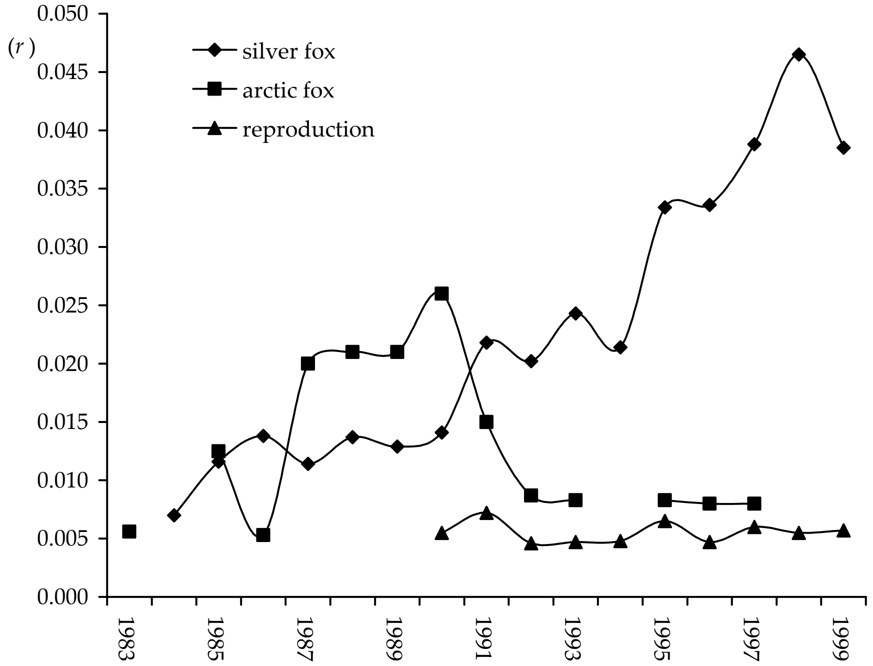

Figure 1. Average relationship coefficient (*r*) across studied years

number of foxes was reduced as a response to low demand on the fur market) as compared to earlier and subsequent years. In 1984 and 1995, when records on the arctic fox were not available, the relationship coefficient could not be computed.

Analyses of relationship within the arctic fox gender groups revealed that males were related more closely (0.015) than females (0.0089).

The relationship coefficients from the data on the arctic fox reproductive performance were found to be low. Due to incomplete or not reliable pedigree information on females from the breeding stock before 1990, relationships in this group of foxes was computed since 1990. The relationships between breeding females across the studied years were low, oscillating around 0.005.

Figure 2 shows the changes in the average inbreeding coefficient across the studied years in silver and arctic foxes. In the silver fox population the highest level of inbreeding was noted in 1996 ($F = 0.0089$) and in 1993 ($F = 0.0079$). No inbreeding was found in the first (1984) and last three years (1997–1999) of the study. The lack of inbred foxes in the last years was probably caused by the low number of silver foxes originating from one farm only and produced by not related parents.

No inbreeding was found in the arctic fox population within the first 3 years of the study. The highest average inbreeding coefficient was in 1989 ($F = 0.0088$), followed by a decreasing tendency to $F = 0.00004$ in 1997. The average inbreeding coefficient for the whole arctic fox population was $F = 0.00159$ (out of 5 287 individuals 85 foxes were inbred).

In the group of the arctic fox females (data on reproductive performance) no inbreeding was found.

In summary, low relationship and inbreeding coefficients in the arctic and silver fox populations under study were found. The highest average relationship coefficient was found in 1998 in the silver fox population reaching only 0.046, whereas the highest average inbreeding coefficient for the whole population was lower than 1% ($F = 0.0088$), and was at the same level for the arctic (in 1989) and silver (in 1996) foxes. Most likely low inbreeding was achieved by: (1) mating animals related not more closely than 6.25%; (2) inflow of new genes through importing foxes from domestic and foreign farms; and (3) using natural mating instead of artificial insemination.

In small populations under random mating or undergoing selection for either phenotypes or estimated breeding values, an increase in levels of inbreeding over generations is inevitable (Mehrabani-Yeganeh *et al.*, 2000). An increasing level of inbreeding negatively affects productivity of animals as well as reproductive performance

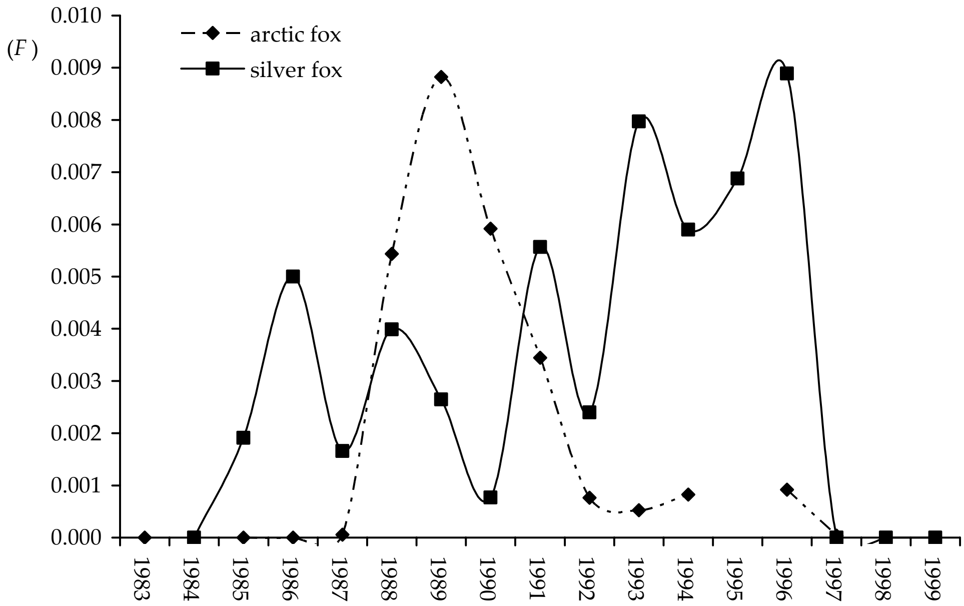

Figure 2. Average inbreeding coefficient (*F*) across studied years

(so-called inbreeding depression). Thus, various strategies have been developed in order to control the rate of inbreeding when maximizing genetic progress (Quinton and Smith, 1995).

Jakubczak (2002), who carried out the study in the population of Polish pastel fox, found a decreasing level of inbreeding in 1979–1990. At the beginning of that period the average inbreeding coefficient was estimated at 0.047, whereas in 1990 the magnitude of *F* was significantly lower reaching 0.0019.

The effect of inbreeding on reproductive performance of the mink and the arctic fox was studied by Berg (1996) and Bernacka (1986), respectively. It was found that a 10% increase in inbreeding in mink resulted in the reduced litter size by 0.4 pups. In arctic fox females inbreeding higher than 0.125 had a negative effect on litter size at birth and at weaning. According to Fioretti *et al*. (2002), who studied the effect of inbreeding on reproductive and growth traits in Piedmontese cattle, inbreeding increased the age at first insemination and calving, and decreased 120-day and yearling weights of males and females.

Sternicki *et al*. (2003) studied the inbreeding effects on lifetime in David's deer and found a low inbreeding level in this population. In 1947–2000 the average inbreeding coefficient of all studied individuals (2 042) was 0.0289. They also found that depending on the model used for estimation (linear or quadratic regression), a 2.8% increase in inbreeding resulted in a reduction of the length of life by 24–70 days.

The effect of inbreeding on livestock productivity has been studied intensively and is well known. However, only a few studies have been carried out on how much genetic response is lost by ignoring inbreeding. An interesting study was conducted by Mehrabani-Yeganeh *et al*. (2000), who used stochastic simulation to study the effect of accounting for inbreeding versus ignoring it in the construction of the inverse of the relationship matrix on selection response. They found that although theoretically more correct accounting for inbreeding in BLUP evaluation of individuals did not change the ranking of individuals and did not lead to greater genetic response or greater levels of inbreeding.

CONCLUSIONS

Statistical description and analysis of the data intended to be used for studies on the BLUP-based method for the breeding value evaluation in Polish fur animal farming revealed that scores of most fur coat characteristics as well as some reproduction traits were distributed with heavier-than-normal tails. Thus, statistical analyses (further studies will deal with estimation of (co)variance components for the studied traits with the use of REML – Restricted Maximum Likelihood) will need to employ methods of data normalisation. Average scores of fur coat traits in both studied fox species were differentiated across the studied classes. The phenotypic variability of reproduction traits was higher than that found in the fur coat characteristics. Reproductive performance studied in the arctic fox was significantly influenced by year, whelping season, colour type, litter size the female was born in, and female karyotype.

Estimated average relationship and inbreeding coefficients were very low. Females from the arctic fox breeding stock were not inbred at all. The low level of inbreeding in the studied populations suggests that mating schemes used on Polish farms effectively avoid mating closely related individuals. Provided that this strategy is continued, inbreeding is not going to be a problem in fox breeding in the near future. Inbreeding will become more difficult to avoid as genetic relationship between individuals increases. Increased relationship is a natural consequence of using the best males in AI programmes. Nonetheless, at present the artificial insemination is not widely used in Polish fur animal breeding.

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ABSTRAKT

Hodnocení plemenné hodnoty u polských kožešinových zvířat: statistický popis kožešiny a reprodukčních znaků – příbuznost a příbuzenská plemenitba

K dispozici jsme měli tři soubory dat tvořené záznamy o znacích exteriéru a kožešiny u lišky polární z jedné farmy (5 540 pozorování shromážděných v letech 1983 až 1997) a o stejných znacích u lišky stříbrné ze tří farem (8 199 pozorování shromážděných v letech 1984 až 1999). Třetí soubor se skládal z 5 829 pozorování týkajících se reprodukčních schopností, která byla shromážděna v letech 1984 až 1999. Pro testování významnosti pevných efektů na analyzované reprodukční znaky jakož i rozdílů mezi skupinami jsme použili metodu GLM. Vypočítali jsme fenotypové trendy, a dále koeficienty příbuznosti a příbuzenské plemenitby za sledované roky. U sledovaných populací lišky polární a lišky stříbrné jsme zjistili nízké koeficienty příbuznosti a příbuzenské plemenitby. Průměrný koeficient příbuznosti dosahoval u populace lišky stříbrné hodnoty 0,015 a u populace lišky polární hodnoty 0,010, zatímco hodnota průměrného koeficientu příbuzenské plemenitby u stejných druhů činila 0,0039 resp. 0,0016. U chovných samic lišky polární nedocházelo k žádné příbuzenské plemenitbě.

Klíčová slova: kožešinová zvířata; kožešina; příbuzenská plemenitba; reprodukce

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