Rewieved Report

A decision support tool for litter size management in mink, based on a regional farm reproduction database

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Received: November 1999 Accepted: July 2000

Abstract

Due to the strictly synchronised annual mink production there is a significant time lag in the management feedback at the tactical level. Annual variation in production conditions and results therefore makes it difficult for the farmer to evaluate the significance of a deviation between a goal and the annual production results. If the deviation is due to general uncontrollable factors, the need for adjustments depends on the expected effect of these factors next year.

Based on data from 27 mink farms, a decision support (DS) tool for reproduction management has been developed. The DS tool provides information each year for the farmer to: I. Define feasible goals for litter size, relative to the litter size from a sample of farms in the same region. II. Analyse deviations between the goal and the actual litter size and estimate the effect of the farm's deviation from the average level of the management factors, dam age, length of gestation and selection intensity on litter size. III. Evaluate the need for adjustment in each of these factors. The DS tool is documented by an example and it is concluded that the DS tool offers the mink farmer an operational picture of the development in litter size from year to year.

Key words: management support, individual farm analysis.

Introduction

Farm management can be described as a cyclic pro??cess initiated by defining the production goals, followed by planning the production in order to meet the goals, implementation of the plans and control of the production by monitoring the outcome. Management feedback is based on comparison of the outcome and the goal, analysis of significant deviations, and finally evaluation of the need for adjustments in goals, plans or implementation (*Bernard and Nix, 1979; Kristensen & Jørgensen, 1996*).

A distinction between strategic, tactical and operational time horizons is often found to be relevant in farm management (e.g. *Huirne, 1990*). Management at the strategic level has a time horizon of several years and is closely related to the overall objective for the farm. Management at the tactical level has an intermediate time horizon of months to years, and is related to the goals of the production. Adjustments are based on an intermediate period of measurements and evaluations. Management at the operational level has a short time horizon of hours to weeks, and is related to production plans. The tactical level of management is of special interest to mink production, because the strict seasonal cycle of production periods interacts with the time lag in the chronological sequence of measurement, comparison and adjustment in the feedback-loop of management. Due to this interaction the management feedback is often postponed almost one year *(Møller & Sørensen, 1999*).

Many production results vary from year to year (e.g. litter size, body weight, skin size) due to variation in production factors. For example, the animals and their health and immune status change from year to year, as more than half of the breeding stock is replaced each season. At farm level, climate *(Møller, 1991*) and feed quality are believed to be the most important uncontrollable factors causing variation in production results, as mink feed in Denmark is produced at feed plants. In most cases the effects of climate are unknown and adjustments in order to compensate the effects are not possible. Such variation in production factors makes it difficult to define a feasible goal, because the potential production results are not the same each year. The annual variation makes it difficult for the mink farmer to establish the cause of deviation from a goal and to determine to which degree controllable or uncontrollable factors are involved. Even if the cause is established, it is difficult to determine whether adjustments should be implemented next year, as the uncontrollable factors will be different. Mink farmers therefore need management tools to set feasible goals, to evaluate deviations from the goal and to evaluate the need for adjustments in tactical management.

Production data on reproduction, pelt characteristics and feed supply are gathered for use in breeding programmes, for farm statistics and feed kitchen or sector analysis on productivity, use of production factors or economy. If such data are also useful for tactical management, the marginal cost will be negligible. The aim of the present paper is to describe a tool for decision support (DS) at the tactical level of mink production, based on reproduction data from a central database.

Material

In order to estimate the average annual level of production, homogenous and reliable data from a number of farms are required. As each mink farm is a breeding unit, data on reproduction is registered each year for the selection of breeding animals. In order to extract more information from these data, a regional Danish extension service unit has developed a database of reproduction data from the "DanMink" breeding programme, and a set of routine calculations for each *farm (Sønderup et al. 1992*). In 1997, the database contained information from 99 farms, of which 27 farms, that had supplied data each year since at least 1993, were selected for the present investigation. The farms received feed from two different feed kitchens. Reproduction data from 1992 to 1997 were extracted from a total of 129700 litters, in which both parents were of either the Standard black or Standard brown phases of the non-mutant colour type, respectively. Information on mating dates, date of birth, litter size at birth, litter size three to four weeks after whelping, parity and colour type of the sire and the dam, were extracted for each litter. The litter-size index from the previous year calculated by the DanMink programme (average=100) was also extracted for each female producing a litter. Length of gestation was calculated as days between last mating and whelping. In order to investigate the biological effects, remating was defined according to days between matings in the following manner: I. An interval of at least 6 days between two matings was defined as remating, in order to induce a second ovulation. II. An interval of 1 or 2 days between two matings was defined as double mating, in order to provide fresh semen at the time of ovulation. III. A mating 3-5 days after a previous mating (120 observations) were defined as a single mating.

Due to high kit mortality during whelping and the first days thereafter *(Schneider & Hunter, 1993*), and the mink's habit of eating dead kits as well as the placenta, counting of dead or stillborn kits can never be accurate. Consequently, many farmers do not count the kits until some days after whelping. Information on litter size at birth is therefore not comparable between farms. In order to compare valid figures, the number of live kits 3-4 weeks after birth is used in calculations in the present paper, as well as for estimation of litter size index in Danish mink breeding programmes.

Methods

Data were analysed using the Univariate and GLM procedures in SAS version 6.11. The average and the upper quartile (top 25%) of the mean litter size on all farms were calculated for each colour type, using the Univariate procedure in SAS. For each farm the mean litter size per year and colour type was calculated in order to compare the farm results with the annual level in the region (Table 2).

The variation of litter size was investigated in an analysis of variance (Model 1) with the relevant factors covered by the registrations in the database. The effects of year, feed plant, colour type and farm were included in Model 1 as well as year-farm interactions and year and colour type interacting with all breeding policy and management factors in the model, in order to investigate the stability of effects across years and colour types. The breeding policy included distribution of dam age and litter size index, while the breeding management included remating, double mating, length and squared length of gestation.

Due to significant year and colour type effects, the DS tool was based on Model 2, which was a subset of Model 1 applied separately for each year and colour type. Model 2 included farm, litter size index, dam age, length and squared length of gestation. Based on Model 2, the following calculations were performed as part of the DS tool:

- The general effect of litter size index, dam age and length of gestation were estimated for each year and colour type (Table 1). For each farm the actual effect of each factor was estimated, by multiplying the model estimates, and the difference between the farm and the average values of each variable (Table 2).
- The potential litter size for each farm was estimated as least squares means, expressing the litter size achieved if the distribution of female parity, the litter size index and the length of gestation had been as the average of all farms (Table 2; Fig. 2 and 3). As the dams were not evenly distributed on age 1 to 3 the actual distribution was used in the lsmeans calculations (SAS Institute Inc., 1996).

Results

The general results of the DS tool development are presented and the decision support provided in each of the steps: I. "Defining a goal" II. "Analysis of deviation from the goal" and III. "Evaluation of adjustment" is demonstrated for the black colour type of farm no. 88 in the database.

Model 1 accounted for 8.7 % of the variation in litter size. A significant difference in litter size was found between years, colour types and farms ($p<0.001$), while in this data the feed kitchen had no effect. The management factors dam age, reproduction index and length of gestation, accounted for a significant part of the variation ($p<0.001$). Re-mating as well as double-mating, though statistically significant, accounted for less than 0.1% of the variation in litter size, when length of gestation was already in the model. Significant interactions between year and length of gestation, and between year and dam age, indicate that the effects of these factors are not the same each year. An interaction between colour type and length of gestation showed that the effect of gestation was not the same for both colour types. The effect of litter size index did not vary between years, and neither the effect of dam age nor litter size index varied between the two colour types. In order to keep the DS tool simple and avoid year-management and management-colour type interactions, the effects were estimated separately for each year and colour type by Model 2. A separate annual run of the model also makes it easier to include or exclude farms from the calculations.

Defining a goal

The need for DS on defining a feasible goal for litter size is based on annual variation in uncontrollable factors, resulting in different potential levels of production each year. Model 1 confirmed a difference between years, in the realised litter size, on all farms in the geographic region. As a general part of the DS tool for defining a goal, the "Regional Annual Litter Size" (RALS) was defined as the average litter size for each colour type. As another candidate, for a goal for litter size, relative to the potential, the upper quartile (top 25%) was calculated (Table 1, Fig. 1).

Table 1. Average reproduction results and effect of management factors in black mink from 1992 to 1997 from 27 farms in the same geographic region.

Parameter	**Year**					
	92	**93**	**94**	**95**	**96**	**97**
RALS[1] (Mean litter size)	5.63	5.52	5.68	5.63	5.71	5.66
Litter size, top 25% of farms	5.92	5.75	5.92	6.06	5.90	6.00
Length of gestation, days	46.71	46.80	45.98	46.07	46.29	45.93
Effect of -1 day on litter size[2]	+0.08	+0.09	+0.10	+0.09	+0.08	+0.10
% of dams age 1, 2, and 3	54, 37, 9	52, 30, 17	59, 25, 14	52, 35, 12	59, 25, 14	60, 28, 12
Effect of age on litter size[3]	+0.07	+0.06	+0.07	+0.07	+0.05	+0.06
Litter size index	105.0	104.5	103.0	104.1	104.4	104.7
Effect of 1 point on litter size	0.03	0.02	0.03	0.03	0.03	0.03
Re-mated %	81.73	76.37	76.69	75.49	80.03	77.73
First mating, day in March	7.36	7.57	8.33	8.08	7.68	7.65
Re-mating, day in March	14.54	14.2	15.21	14.85	14.91	14.64
Whelping, days from May 1.	0.25	0.00	0.19	-0.08	0.20	-0.43

[1] Regional Annual Litter Size. [2] Estimated effect of 45 days in stead of 46 days. [3] Estimated effect of parity distribution 60, 40, 0 instead of average 57, 28, 15.

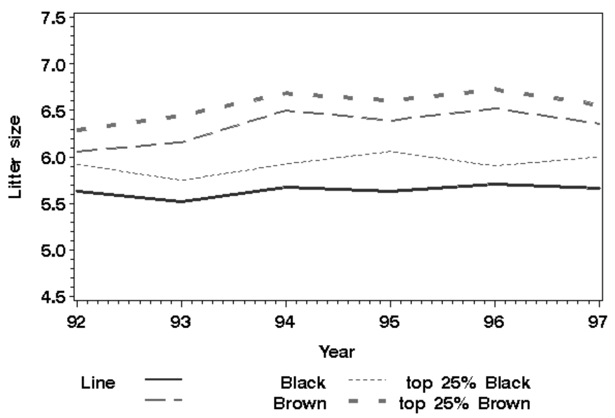

Fig. 1. Average and upper quartile of litter size in black and brown colour type mink from 27 mink farms.

From 1992 to 1997, the average litter size increased by 0.03 and 0.30 kits, in the black and brown colour types respectively, corresponding to 0.006 and 0.06 kits per litter each year. A fixed goal for litter size would therefore not reflect the increasing RALS.

The difference between succeeding years varied from –0.12 to +0.16 for black mink (and from –0.16 to +0.13 for brown mink). A steady increasing goal for litter size would therefore not take the variation in RALS into account. By use of the DS tool, each farmer could define a more feasible goal for litter size relative to the RALS or the top 25% of the farms. The litter size on farm 88 was at or above the upper quartile every year except in 1995 (Fig. 2, Table 2) and a feasible goal for farm 88 would therefore be to stay in the top 25%. If the goal was set too high it could not be achieved, however a subsequent analysis would not reveal any sufficient adjustments. If the goal was set too low, further investigation would never be initiated. In both cases the goal should be adjusted relative to the actual uncontrollable factors each year, as facilitated by the DS tool.

Analysis of deviation from the goal

The second step in management is to compare the achieved litter size with the farmer's goal and analyse the deviation. The DS tool facilitates the comparison by plotting the farm specific results besides the potential goals for each year (Fig. 2). On farm 88, the decline in litter size in 1993 and the increase in 94 followed the fluctuations in the goal (top 25%) and do therefore not call for further analysis. The decline in litter size in 1995 was a significant deviation from the goal (the top 25%). The DS tool supports the analysis of this deviation by information on the potential (lsmeans) litter size, as well as the actual value and estimated effect on the actual farm of litter size index, dam age and length of gestation on the actual farm (Fig. 2, Table 2).

In all years except 1995, the combination of management factors on farm 88 was more efficient than on the average farm, as the litter size was above the lsmeans (Fig. 2, Table 2). The factors dam age, reproduction index and length of gestation explained a major part of the difference between the RALS and farm 88 each year, except in 1994 and 96. In 1995 the three factors explained -0.24 out of the -0.26 kits the litter size was below the RALS in 1995. An extremely skewed distribution of dam age and a low litter size index, affected the litter size by -0.19 and -0.12 kits, respectively. A gestation length 0.65 days shorter than average contributed +0.06 kits. These effects were caused by replacement of the entire group of black females on farm 88 in 1995. Obviously, the farmer knows the reason for the replacement, but the DS tool shows that a large part of the decline in litter size in 1995 is a direct consequence of the replacement. The need for adjustment is therefore smaller than the actual decline in litter size of 0.70 kits per litter from 1994 to 1995 would suggest. The corresponding plot for the brown colour type illustrates that there was no general decline in litter size on farm 88 in 1995 (Fig. 3). The part of the decline in litter size not accounted for by the lsmeans, is therefore not due to general farm factors, but probably also related to the total replacement of the black breeding stock. The drastic increase in litter size by 1.03 kits in 1996 is not explained by the three factors as the effect of short gestation (+0.12 kits) is counterbalanced by a skewed dam age distribution (-0.03 kits) and a low litter size index (-0.06 kits). The very high litter size in both colour types in 1996 was due to farm specific factors, not accounted for by the lsmeans. In 1997, the litter size in both colour types declined, but not beneath the goal of the top 25%. The effect of the three management factors was back to the level of 1992 – 1993 as length of gestation and parity contributed to a litter size above the lsmeans value. However, the distribution of dam age was still skewed as more than 50% of the females should be from first parity in a continuous production.

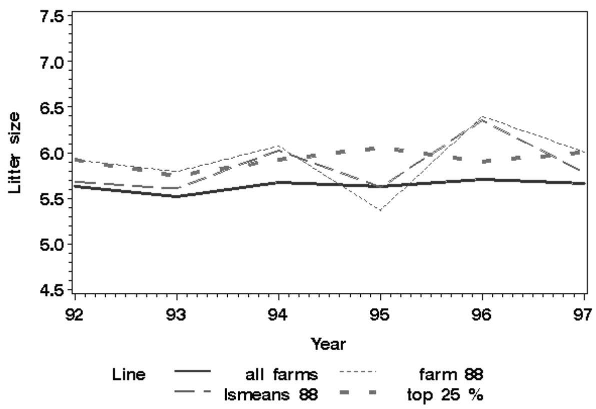

Fig. 2. Actual and estimated litter size (least squares means) of farm 88 and average and upper quartile of black colour type mink from 27 mink farms.

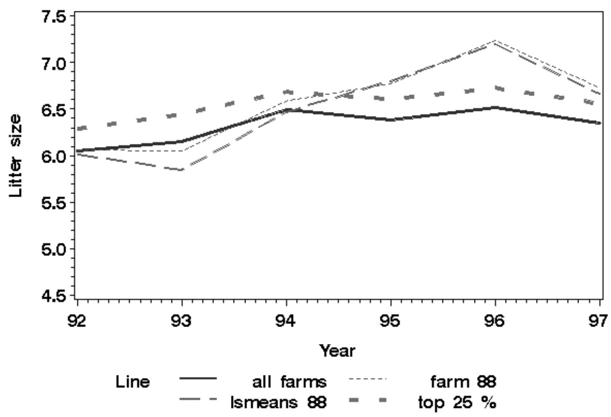

Fig. 3. Actual and estimated litter size (least squares means) of farm 88 and average and upper quartile of brown colour type mink from 27 mink farms.

Table 2 Table for evaluation of the annual development in litter size and the effect of length of gestation, parity and litter size index in black mink at farm no. 88 from 1992 to 1997.

Farm no. 88 Parameter	**Year**					
	92	**93**	**94**	**95**	**96**	**97**
Farm litter size	5.92	5.79	6.07	5.37	6.40	6.01
Farm - RALS[1] difference	+0.29	+0.27	+0.39	-0.26	+0.69	+0.35
LS Means litter size	5.67	5.60	6.02	5.61	6.35	5.78
Farm - lsmeans difference	+0.25	+0.19	+0.05	-0.24	+0.05	+0.23
Length of gestation, days	44.79	45.35	44.66	45.42	44.90	44.39
Effect on litter size	+0.16	+0.13	+0.13	+0.06	+0.12	+0.15
% of dams age 1, 2, and 3	44, 51, 5	34, 44, 20,	70, 13, 17	100, 0, 0	74, 26, 0	35, 54, 11
Effect on litter size	+0.09	+0.09	-0.05	-0.19	-0.03	+0.12
Litter size index	104.2	101.7	102.0	100.6	102.5	103.0
Effect on litter size	-0.02	-0.05	-0.03	-0.12	-0.06	-0.05
No. Of dams	228	134	215	57	118	103
Re-mated %	81.14	80.60	83.26	84.21	89.83	91.26
First mating, day in March	8.32	8.69	8.30	7.25	6.30	5.59
Re-mating, day in March	15.77	15.69	15.85	14.42	14.44	13.76
Whelping, days from may 1.	-0.44	0.04	-0.49	-1.16	-1.66	-2.85

[1] Regional Annual Litter Size

In Table 2, other farm specific information of relevance to the litter size (e.g. no. of dams, percent re-mated, average dates of mating, re-mating and whelping) is included to further explain the realised litter size and a deviation from the goal. In 1992, the percent of re-mated females on farm 88 was below the group average, but due to late mating and early whelping dates, the length of gestation was 1.92 days shorter than average (Tables 1 and 2). Since 1993 the percent of re-mated females increased steadily on farm 88 and in 1997 it was 13.5 points above the average level. In the same period the matings were performed earlier and earlier in March, but as the date of whelping also appeared earlier, the length of gestation continued to be approximately 1.5 days shorter than average (Table 1 and 2). This is quite unusual and indicates application of artificial light on farm 88 in order to induce implantation of the blastocyts in late March. When examining Table 2, the farmer should add such farm specific information (also including e.g. disease outbreak, kit mortality) that may further explain the litter size obtained.

Evaluation of adjustment

The third step in the management feedback cycle is adjustment in the goal, in plans for allotment of controllable factors or in implementation of plans, as indicated by the analysis of the deviation from the goal. If a feasible goal was defined it should not need adjustment. If a realistic goal was not achieved because the plans were not followed, the adjustment should focus on the implementation of the plans during the production. The DS tool deals with the situation where a realistic goal for litter size was not achieved although the plans were followed. In this case, potential adjustments in controllable management factors should be evaluated.

As revealed by the DS tool analyses, the dam age distribution as well as the litter size index should be adjusted, in response to the low litter size in 1995. Both management factors may be adjusted directly, and the DS tool shows that the adjustments actually took place in 1996 and that the litter size changed accordingly (Table 2). Although the litter size on farm 88 did not indicate a need for general adjustments in management, the DS tool indicated that the short length of gestation could be obtained by postponing the mating season, instead of the apparent use of artificial light. Furthermore, the litter size index was below the average and thus had a negative effect on the realised litter size on farm 88 each year. Compared to other farms, farm 88 would therefore be expected to benefit from putting more weight on the litter size index in the selection of dams.

In case the analysis had shown a need for adjustment of the gestation length, this could only be done indirectly through date of last mating, re-mating (but not through double mating) or by use of artificial light. In order to facilitate the farmer's choice of which factor to adjust, the general relation between these factors and length of gestation, as well as their effect on litter size, was investigated. The length of gestation was on average 46 days with 99% of the observations between 40 and 59 days for both colour types. The estimated effect of length of gestation on litter size, for each year and colour type, is illustrated in Fig. 4 and 5. Overall, 82.4% of the litters came from females re-mated for a second ovulation, while only 3.1% of the litters came from females double-mated prior to ovulation. Neither re-mating nor double mating increased litter size except for the effect of a reduction in gestation length. In fact both re-mating and double mating had a very small but negative effect on litter size, when length of gestation was included in the model. In a model without length of gestation, the estimated effect of re-mating was 0.30 kits more per litter while double mating had no significant effect on litter size. On average, re-mated females of the black and brown colour types had 4.8 and 4.6 days shorter gestation period and 0.4 and 0.2 kits more per litter than not re-mated females, respectively. The majority of the first matings took place between March 4th and 11th, while the majority of re-matings took place 8-9 days later, resulting in the last mating before 20 March. For each day the last mating was postponed, the date of birth was delayed by 0.4 days (as the length of gestation was reduced by 0.6 days) and the litter size increased by 0.02 kits. In other words, mating procedures, date of last mating and date of whelping, all have small effects on litter size. These effects seem to be mediated through the effect of each factor on the length of the embryonic diapause, and therefore length of gestation describes most of the combined effects of mating procedures, date of last mating and date of whelping.

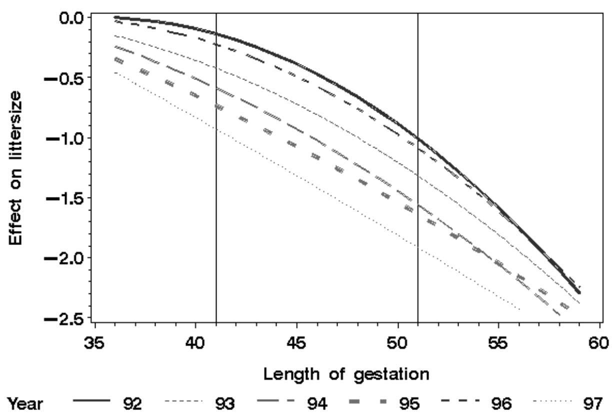

Fig. 4. Estimated effect of length of gestation on litter size of brown colour type mink from 27 farms from 1992 to 1997.

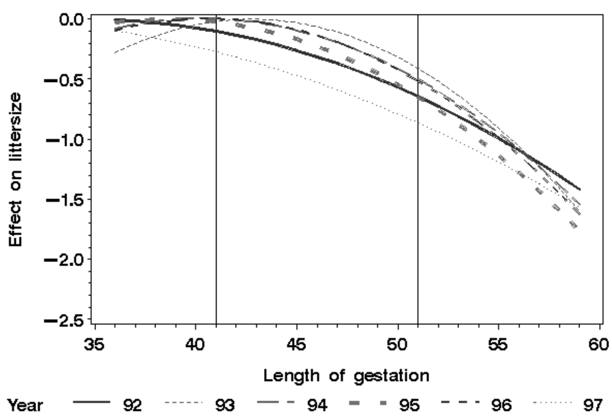

Fig. 5. Estimated effect of length of gestation on litter size of black colour type mink from 27 farms from 1992 to 1997.

Discussion and conclusions

The statistical models used in the DS tool account for less than 10 % of the variation in litter size, reflecting the high degree of random variation. The minkfarmers therefore have limited, yet important means to control the litter size in a normal production situation.

The estimated effects of length of gestation and remating are of the same direction but smaller in magnitude than estimates from mating system experiments (*Lagerkvist, 1992*). A deliberate change in the mating management may therefore have larger impact on litter size than reflected by the production data. This is because the production data reflects how different animals reacted differently to the same management procedures, while experimental data reflect their reaction to different management procedures.

The RALS declined by 0.05 and 0.11 kits in 1995 for the black and brown colour type, respectively. This could lead to a common understanding of 1995 as a "bad" year with respect to litter size. Without a goal adjusted to the annual production level, this "bad" year could be used to explain the decline in litter size on farm 88, even though the decline in litter size of 0.70 kits was 14 times the general decline in litter size in 1995.

As suggested by the DS tool, farm 88 adjusted the dam age distribution in 1996, in response to the low litter size in 1995. The adjustment towards an average distribution of dam age continued in 1997. It is not known whether the adjustment was a deliberate management decision or merely a natural consequence of keeping some of the dams for a second breeding season. However the DS tool revealed, that an adjustment was needed, which factors should be adjusted and the subsequent effects of the adjustments. The DS tool also revealed that the positive effect of some factors might cover the negative effects of others. In that case, adjustment in a factor with negative effect may improve the production even in situations where the defined goal is achieved.

The effect of length of gestation varies between years and the same management procedures may therefore give different results in different years. A deviation from the goal caused by an extraordinary large annual effect of a management factor may therefore not need adjustment, as the effect of the management factor will probably be smaller next year. An adjustment in management is mainly needed for factors expected to have a significant effect next year. The evaluation procedure of the DS tool reveals whether a deviation from the goal is caused by variation in the controllable component (length of gestation) or in the uncontrollable component (annual effect of length of gestation). If the estimated effect of a management procedure shows large variation, adjustments should be chosen to minimise the average negative effect.

The DS tool is based on an existing database, and similar databases are under development in the three other regional Danish Fur Breeders Associations. These data are collected for farm specific management calculations and the additional cost of the DS tool is thus limited to the cost of performing the calculations and discussing the results with the farmer. The DS calculations are performed by a series of SAS macros, extracting data directly from the database. The manpower needed is therefore limited to entering parameter estimates into a data set and transforming the output into figures and tables.

In order to limit the variation in uncontrollable production conditions, the DS tool should be restricted to geographic regions, or to the farms within a feed plant. This will assure that the estimates are relevant and recognisable to the farmers. Comparisons between regions or feed kitchens would then indicate whether differences at this level should be investigated.

A similar analysis of individual sow-herd performance, comparing actual farm performance with the average performance of similar farms, has been described by Huirne et al. (1992). In order to evaluate the improvement of a farm's performance over time, the performance was also compared with the trend of the farm or with the average trend of similar farms (*Huirne et al., 1992*). Due to the annual variation in mink reproduction, comparing the litter size with a historical trend does not seem relevant at the tactical level.

Danish mink production systems and management routines are quite uniform irrespective of farm size (*Møller, 1992*). Therefore, the general part of the DS tool (Fig. 1 and Table 1) may be used to define a goal for litter size relative to RALS by all farmers with similar uncontrollable production conditions, i.e. within the same geographic area or feed kitchen. With such a goal the effect of common uncontrollable factors like climate and feed is excluded from the evaluation of the litter size. However, farm specific parts of the DS tool (i.e. Fig 2 and Table 2) can only be calculated for farms in the database.

It is concluded that the general part of the DS tool offers all mink farmers in a region an operational picture of the development in litter size from year to year and facilitates the definition of a feasible goal. The farm specific parts of the DS tool help the farmer to analyse the effect of management factors and to choose relevant adjustments.

Acknowledgements

The Danish Research Academy is acknowledged for financing the investigation. Michael Sønderup, Fuenen and South Jutland Fur Breeders Association and Ejner Børsting, Scanbrid Int. A/S, are gratefully acknowledged for their assistance with the database.

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