Factors affecting length of productive life in Swedish commercial sows

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ABSTRACT: The objective of this study was to investigate factors that might influence the length of productive life in Swedish crossbred (Landrace × Yorkshire) sows. The data set consisted of 20,310 sows farrowing between 2001 and 2004 in 21 commercial piglet-producing herds. Productive life (PL) was defined as the number of days between first farrowing and removal or termination of data collection. In addition to the overall risk analysis of PL, another 4 longevity traits were analyzed (competing risk analyses): reproductive disorder-determined length of PL (RPL), udder problem-determined length of PL (UPL), lameness-determined length of PL (LPL), and mortality-determined length of PL (MPL). Analyses were performed by using survival analysis, applying a Weibull model with 6 time-dependent and 1 time-independent variable (age at first farrowing). The factor with the largest contribution to the likelihood function for PL was days after farrowing, followed by parity, the herd × year combination, the total number of piglets born, days between weaning and next farrowing, farrowing month, and age at first farrowing. For all 4 competing risk traits, the factors contributing most to the likelihood function were days after farrowing, the herd × year combination, and parity, with a varied order between traits. The hazard for removal was greatest 30 to 40 d after farrowing (after weaning) for PL, UPL, and LPL (P < 0.001). However, for MPL the hazard was greatest just after farrowing (0 to 10 d), and for RPL the hazard peaked at 70 to 100 d after farrowing. The hazard for removal was, compared with parity 1, less in parities 2 to 7 and greater from parity 8 for PL (P < 0.001). The hazard was greatest in parity 1 (P < 0.01) for RPL, UPL, and LPL, whereas for MPL the hazard increased with greater parity number and was markedly greater from parity 9 (P < 0.001). Sows with litters of 9 piglets or less had a greater hazard for removal than sows with litters of 12 to 13 piglets (P < 0.001). Intervals between 120 and 122 d from weaning to the next farrowing showed the lowest hazard for removal (P < 0.001). The influence of farrowing month displayed no clear pattern for PL. Sows of 14 mo or older at their first farrowing had a 20% greater hazard for removal than younger sows (P < 0.001). The hazard for removal was greater for smaller litters in all parities but was more accentuated in greater parities. Overall, days after farrowing was the main risk factor for sow removal. Removal hazard was greatest shortly after weaning, and this peak increased with greater parity number.

Key words: longevity, mortality, removal reason, removal risk, sow, survival analysis


INTRODUCTION

Every year, approximately 50% of sows in piglet production are replaced (Boyle et al., 1998; Rodriguez-Zas et al., 2003; Engblom et al., 2007). The high removal rate of mainly young animals is both ethically and economically important. Approximately 15 to 20% of the sows removed have produced only 1 litter, and more than 50% are removed before their fifth parity (Boyle et al., 1998; Lucia et al., 2000; Engblom et al., 2007). Removal is mainly unplanned in early parities and largely reflects reproductive disorders and lameness. Planned removal, connected with low production and old age, increases with greater parity numbers (Dijkhuizen et al., 1989; Boyle et al., 1998; Engblom et al., 2007).

Longevity of a sow is determined by many factors. Not only the sow’s biology, but also season, management, and housing are important. In addition, it is the

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herdsman’s subjective decision that determines whether a sow will be removed. In this decision, the herdsman considers the sow’s parity number, production, reproductive status, health status, and herd structure, as well as access to replacement gilts of relevant reproductive status. To improve our understanding of sow removal, it is necessary to identify the relevant causal factors and quantify their impact.

Previous studies have shown that an older age at first farrowing is unfavorable for sow longevity (Koketsu et al., 1999; Yazdi et al., 2000b), as well as small litters (Brandt et al., 1999; Yazdi et al., 2000a; Guo et al., 2001). Season also has been reported to influence removal of sows, with greater mortality rates during summer (D’Allaire et al., 1996; Deen et al., 2000; Koketsu, 2000).

The aim of this study was to identify and assess factors influencing removal of crossbred Swedish commercial sows. Factors affecting overall removal, as well as their impact on removal attributable to reproductive disorders, udder problems, lameness, and mortality, were investigated by using survival analysis.

MATERIALS AND METHODS

Because the data were obtained from existing databases, no approval was applied for from an animal care and use committee.

Herds

The study used data from 21 commercial piglet-producing herds in the south-central part of Sweden. Herds were selected on the basis of their ability to make reliable registrations. All herds used the PC-based herd-monitoring program PigWin Sugg (Quality Genetics HB, Hörby, Sweden). Mean and median herd sizes were 475 and 318 sows, respectively, with a range from 122 to 2,126 sows. Four of the herds were “sow pools” (leasing systems in which a central herd unit supplies satellite herds with pregnant sows, which are returned to the central unit after the lactation period at weaning). Batchwise production, a fixed circulatory system, was practiced in all herds. All herds practiced cross-fostering, and the average lactation period was 4 to 5 wk (Swedish animal welfare legislation requires at least 4 wk of lactation). After weaning, estrus was checked twice (18 herds) or once (3 herds) daily. Artificial insemination was used extensively in all herds. Boars were used for repeated breeding of sows that returned to heat in 6 herds. Pregnancy was monitored with different types of ultrasound equipment in all but one of the herds. In 4 herds, sows were culled if they returned to estrus after the first mating. Two returns resulted in culling in 13 herds, whereas the remaining 4 herds permitted 3 or more returns to estrus.

During the dry period, sows were kept in groups. Sows were in 14 herds kept in the breeding and gestation units in groups (30 to 50 sows/pen) on deep litter bedding (mostly straw), mainly in uninsulated buildings. Five herds kept sows on deep litter bedding in the mating unit (groups of 30 to 50), but during at least part of gestation, these sows were kept in smaller groups (5 to 9 sows/pen) on a concrete-partially slatted floor with access to straw. In 2 herds, sows were kept in pens (5 to 9 sows/pen) with a concrete-partially slatted floor during both mating and gestation. All herds had farrowing units in which sows were housed in individual pens. A more detailed description of the herds, covering the housing system and management, was presented previously (Engblom et al., 2007).

Data

Data collection started in January 2002 and continued for 3 yr. After an initial visit, the 21 herds were revisited approximately 3, 6, 12, 20, and 30 mo later. At each visit, data were collected electronically from the herd-monitoring program PigWin Sugg and additional information was recorded on paper. Data were checked for obvious errors and, if possible, they were corrected. Data included sows farrowing from January 2001 to December 2004 and incorporated information on removals during that period. Only crossbred Landrace × Yorkshire sows with at least one farrowing during the period were included in the analyses. Sows whose first litter was recorded to be born before 290 d of age or later than 480 d of age were excluded from the analyses to avoid sows with erroneously reported dates of birth or farrowing. Sows that produced their first litter in another herd were excluded from the analyses, as were sows sold to another herd (these restrictions affected only a few herds). The final data set consisted of 20,310 sows.

Productive life (PL) was defined as the number of days between first farrowing and removal or termination of data collection. Data were left-truncated at January 1, 2001. Left-truncation allowed inclusion of all sows present in the herds, irrespective of parity number. Records were treated as censored if the sow was still alive at the end of the study period on December 31, 2004. This resulted in 22.6% truncated and 33.8% censored records. In addition to PL, another 4 longevity traits were defined: reproductive disorder-determined length of PL (RPL), udder problem-determined length of PL (UPL), lameness-determined length of PL (LPL), and mortality-determined length of PL (MPL). Table 1 lists reasons for removal included in these 4 longevity traits. In the competing risk analyses, in addition to the censoring rules for PL, records were treated as censored when the removal code did not correspond with the specific cause of removal being analyzed. For example, in the analysis of the risk for being removed attributable to reproductive disorders, sows either removed for other reasons or still alive on December 31, 2004, were treated as censored. The proportion of censored records was 84% for RPL, 87% for UPL, 93% for LPL, and 97% for MPL.
Table 1. Grouping of the removal reasons included in the 4 competing risk analyses of sow removal in Swedish commercial herds

<table>
<thead>
<tr>
<th>Longevity trait</th>
<th>Removal reasons included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive disorder-determined length of productive life (RPL)</td>
<td>Not pregnant, weak or no estrus, discharge to estrus, abortions, metritis, long intervals between farrowings, mummification, dystocia, vaginal prolapse, and rectal prolapse</td>
</tr>
<tr>
<td>Udder problem-determined length of productive life (UPL)</td>
<td>Low or no milk production, mastitis, or udder abscess (chronic granulomatous mastitis)</td>
</tr>
<tr>
<td>Lameness-determined length of productive life (LPL)</td>
<td>Arthritis, claw injuries, and claw abscess</td>
</tr>
<tr>
<td>Mortality-determined length of productive life (MPL)</td>
<td>Animals found dead on farm (no autopsy was performed)</td>
</tr>
</tbody>
</table>

Statistical Analyses

This study was performed by using survival analysis to identify and evaluate the impact of factors influencing removal of commercial crossbred sows in Sweden. Advantages of survival analysis are that it can handle individuals being alive when the study period ends (censored observations) and allows variables to change value during the animal’s life (time-dependent variables), as described by Kalbfleish and Prentice (1980). This, together with left-truncation of the data set, resulted in an effective use of the available information. Furthermore, we could, in addition to the investigation of the overall removal, also investigate removal attributable to 4 important removal reasons with competing risk analyses, resulting in new information.

Hazard for removal during PL was analyzed by using Survival Kit version 3.12 (Ducrocq and Sölkner, 1998). The Weibull model used was

\[
h(t) = h_0(t) \exp[x(t)' \beta],
\]

where \( h_0(t) \) is the baseline hazard function \( \lambda \rho(\lambda t)^{\rho-1} \), assumed to follow a Weibull distribution with scale parameter \( \lambda \) and shape parameter \( \rho \); \( t \) is time in days from first farrowing; and \( \beta \) contains the covariates (possibly time-dependent) affecting the hazard with the corresponding design vector \( x'(t) \). Where \( \rho < 1 \), the hazard decreased with time, and where \( \rho > 1 \), the hazard increased with time. To test whether a Weibull distribution properly fitted the data, the log of minus the log of the Kaplan-Meier estimate (nonparametric) of the survivor curves was plotted against the log of time. If the assumption for Weibull holds, a straight line should be obtained. All 5 traits analyzed (PL, RPL, UPL, LPL, and MPL) displayed approximately straight lines when tested graphically (Figure 1).

Three models (1 to 3) were applied to determine the overall risk for removal. In the competing risk analyses of RPL, UPL, LPL, and MPL, only model 1 was used. The models were as follows:

Model 1: \( \text{DAF} + \text{PAR} + \text{HY} + \text{PB} + \text{WF_INT} + \text{F_MO} + \text{AFF} \);

Model 2: \( \text{DAF} + \text{PAR} \times \text{PB} + \text{HY} + \text{WF_INT} + \text{F_MO} + \text{AFF} \); and

Model 3: \( \text{PAR} \times \text{DAF} + \text{HY} + \text{PB} + \text{WF_INT} + \text{F_MO} + \text{AFF} \).

The covariates in these statistical models were as follows:

1. Number of days after farrowing (DAF), fixed time-dependent with 15 classes, changed at 0, 10, 20 . . . 140 d after each farrowing;
2. Parity number (PAR), fixed time-dependent with 9 classes, changed at each farrowing date up to parity 9 (greater parities were grouped with parity 9);
3. Combination of herd and year (HY), fixed time-dependent with 63 classes, changed at January 1 each year;
4. Total number of piglets born in the litter (PB), fixed time-dependent with 7 classes (\( \leq 7, 8 \) to 9, 10 to 11, 12 to 13, 14 to 15, 16 to 17, \( \geq 18 \)), changed at each farrowing date;

Figure 1. Graphical test of the Weibull assumption. Linear regression of \( \ln[-\ln S(t)] \) on \( \ln(t) \) for productive life (PL), reproductive disorder-determined length of PL (RPL), udder problem-determined length of PL (UPL), lameness-determined length of PL (LPL), and mortality-determined length of PL (MPL) in Swedish commercial herds. \( S(t) = \) Kaplan-Meier estimates of the survivor function at time \( t \).
5. Number of days between weaning and next farrowing (WF_INT), fixed time-dependent (weaning to service interval + gestation length + nonproductive days) with 5 classes (≤119 d, 120 to 122 d, 123 to 136 d, 137 to 157 d, ≥158 d; parity 1 sows were included in class 120 to 122 d), changed at each farrowing date;
6. Farrowing month (F_MO), fixed time-dependent with 12 classes, changed the first day of every calendar month;
7. Age at first farrowing (AFF), fixed time-independent with 5 classes (≤10, 11, 12, 13, ≥14 yr);
8. Combination of PAR and PB (PAR×PB), fixed time-dependent with 63 classes; and
9. Combination of PAR and DAF (PAR×DAF), fixed time-dependent with 135 classes.

Using models 1 and 2 to analyze PL, we estimated the shape parameter \( \rho \) at 1.6, whereas using model 3, we estimated \( \rho \) at 1.4. Using model 1 in the competing risk analyses, we estimated the shape parameter \( \rho \) at 2.5 for RPL, 2.2 for UPL, 1.2 for LPL, and 0.9 for MPL.

The solution for a fixed factor is expressed as a hazard ratio. Hazard ratio is defined as the ratio between the estimated hazard for being removed under the influence of certain environmental or genetic factors and the estimated hazard for a single reference class. Thus, the hazard ratio is a ratio describing the relative risk of removal. The reference classes selected were as follows: 12 mo of age at first farrowing; farrowing month July; first parity; 30 d after farrowing; 120- to 122-d interval between weaning and next farrowing; and 12 to 13 piglets in litter size. The order of the factors’ influence on the removal risk for the 5 traits was measured by their contribution to the likelihood function (\( R^2 \) of Maddala) of the full model. Results on herd × year combinations are not shown because this factor was included in the analyses only to take its variation into account and not to evaluate the individual herds.

**RESULTS AND DISCUSSION**

In this study, mean PL length in Swedish crossbred sows was found to be 579 d from first farrowing. This is approximately the same as estimates based on purebred sows, 535 to 617 d (Yazdi et al., 2000a; Yazdi et al., 2000b; Tarrés et al., 2006).

**Overall Risk Analysis for Sow Removal (PL)**

The 6 time-dependent factors (days after farrowing, parity, herd × year combination, total number of piglets born, days between weaning and next farrowing, and farrowing month) included in model 1 were highly significant (\( P < 0.001 \)), and the time-independent factor age at first farrowing was significant (\( P = 0.005 \)). The effect of the most important factor in the overall risk analysis, days after farrowing, is shown in Figure 2a. The hazard for removal was greater (\( P < 0.001 \)) 30 to 40 d after farrowing than it was in other periods of the reproductive cycle. The pattern of overall removal during the reproductive cycle showed that herdsmen perform most of the removals within a short period after weaning (planned culling), presumably to keep the number of nonproductive days as low as possible. Other studies also have shown that most animals are removed shortly after weaning (Brandt et al., 1999) and that the risk for removal is greatest after weaning (Tarrés et al., 2006).

The second most important factor for overall removal risk was parity. Compared with sows in parity 1, sows in parities 2 to 7 had a lower (\( P < 0.001 \)) hazard for removal, whereas sows in parity 8 and above had a greater (\( P < 0.001 \)) removal hazard (Figure 2b). The high removal risk for first-parity sows indicates that sows that cannot cope with the production system were sorted out. The greater risk found in older parities agrees with recent results of Tarrés et al. (2006). However, it is obvious that all sows eventually will be removed, resulting in a high removal hazard for the last parities.

The third most important factor in the overall analysis, the herd × year combination, showed that different management and housing systems have a large impact on sow removal. Data in the current study were not investigated further because the small number of herds (21) did not permit detailed analysis of factors at the herd level (data not shown).

The fourth most important factor for overall removal risk was the total number of piglets born. Sows with a litter size of 9 piglets or fewer had a 24 to 60% greater (\( P < 0.001 \)) hazard for removal than those with litters of 12 to 13 piglets (Figure 2c). The increased removal hazard for sows with a small litter found in the current study agrees with similar previous studies (Brandt et al., 1999; Yazdi et al., 2000a; Guo et al., 2001). In the current study, large litters did not give an increased hazard for removal. The reason for this may be that cross-fostering was practiced in the herds (sows giving birth to large litters were less challenged because some piglets were moved to, and nursed by, other sows).

The fifth most important factor in the overall analysis was days between weaning and next farrowing. Intervals of 120 to 122 d between weaning and next farrowing resulted in a lower (\( P < 0.001 \)) hazard for removal than shorter or longer intervals (Figure 2d). Sows with a 120- to 122-d interval showed estrus, were inseminated within 5 to 7 d after weaning, and became pregnant at this first mating. Intervals longer than 137 d, indicating at least one return to estrus, resulted in at least a 50% greater (\( P < 0.001 \)) hazard for removal than that found for 120- to 122-d intervals. This high level of risk for removal is probably the effect of the batchwise production system practiced in all the herds investigated. In batchwise production, sows returning to estrus are difficult to fit into another batch, especially
in herds with long intervals between batches. In a previous study of this material, return to estrus accounted for almost 20% of overall removal (Engblom et al., 2007).

In the current study, the sixth most important factor for overall removal risk was farrowing month. Compared with July (reference month), the hazard for removal was greater ($P < 0.05$) in January and September, but it was less in March and December (Figure 2e). The low hazard for sow removal in December was probably because the slaughter plants prioritize fattening pigs over sows during that month. Instead, these sows were slaughtered the month after, which explains the greater hazard in January. For the rest of the year, variations in hazard for removal between months are not clear.

This low fluctuation could be due to several factors. For example, a limited number of replacement gilts available might result in a reduced possibility for planned removal during periods of high unplanned removal. This speculation is supported by a previous study, which indicated that the risk for removal attributable to lameness was reduced during periods when removal attributable to reproductive disorders was high (Anil et al., 2005). Furthermore, Guo et al. (2001) did not find any special pattern across season for overall removal risk.

The factor with the lowest impact in the overall analysis among those tested in the current study was age at first farrowing. Sows of 14 mo or older at their first

Figure 2. Overall risk analysis of sow removal in Swedish commercial herds. Estimates of hazard ratio for length of productive life using model 1: a) effect of days after farrowing; b) effect of parity; c) effect of total number of piglets born; d) effect of days between weaning and next farrowing; e) effect of farrowing month; f) effect of age at first farrowing.
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Figure 3. Overall risk analysis of sow removal in Swedish commercial herds. The combined effect of parity and total number of piglets born using model 2 is presented.

Farrowing had a 16% greater ($P < 0.001$) hazard for removal than sows that were 12 mo at their first farrowing (Figure 2f). This finding agrees with other studies (Koketsu et al., 1999; Yazdi et al., 2000b).

Model 2 was applied to investigate whether the effect of litter size was similar in different parities. This model included the combined effect of parity and total number of piglets born, with the main factors parity and total number of piglets born excluded. The effect of days after farrowing, the combination of parity and total number of piglets born, the herd × year combination, days between weaning and next farrowing, and farrowing month were highly significant ($P < 0.001$), and age at first farrowing was significant ($P = 0.007$). The hazard for removal was, in all parities above 1, greater for small litters (≤9) than it was in the reference class (12 to 13 piglets). The greater hazard for small litters was accentuated in greater parities (Figure 3). This indicates that herdsmen were less tolerant of the small litters of older sows. Moreover, descriptive statistics relating to the present material showed that most of the planned removal (removal attributable to low production) occurred in greater parities (Engblom et al., 2007). This also agrees with other studies (Boyle et al., 1998; Lucia et al., 2000). Also in parity 1, the hazard was greater for sows with small litters (≤7) than it was for the reference class (12 to 13 piglets). The greater hazard for small litters was found for litter sizes with at least 18 piglets. Sows with 18 to 24 piglets in their first litter had a 42% greater ($P = 0.04$) removal hazard than the reference class, but because there were only 35 informative failures in this class, the results can only be interpreted as an indication that an excessively large litter in young sows might have a negative impact on the survival of the sow.

Model 3 was applied to investigate whether the effect of days after farrowing was similar in different parities. The model included the combined effect of parity and days after farrowing, with the main factors parity and days after farrowing (Figure 4). This pattern was repeated over parities, with an increasing peak for greater parities. This indicates that the proportion of planned removal increased with greater parity number, which is in accordance with previous studies (Boyle et al., 1998; Lucia et al., 2000; Engblom et al., 2007).

RPL

Removal attributable to reproductive disorders accounted for 27% of all removals, and mean RPL length in Swedish crossbred sows was 445 d. All 7 factors (days after farrowing, parity, herd × year combination, total number of piglets born, days between weaning and next farrowing, farrowing month, and age at first farrowing) included in model 1 were highly significant ($P < 0.001$). The effect of the most important factor in the analysis of RPL, parity, is shown in Figure 5b. The hazard for removal was greater ($P < 0.001$) in first parity than it was in greater parities. This agrees with earlier studies showing that most removals attributable to reproductive disorders occur in low parity numbers (Boyle et al., 1998; Lucia et al., 2000), and it was also confirmed by the descriptive data on sows in the present study. The second most important factor was the herd × year combination (data not shown). This shows that different management (breeding routines, different limits for the number of repeated breedings accepted) and housing systems are important for the length of RPL.

Farrowing month was the third most important factor in the analysis of RPL. Compared with July, the
Figure 4. Overall risk analysis of sow removal in Swedish commercial herds. The combined effect of parity and days after farrowing using model 3 is presented. The interval between 2 subsequent farrowings was set at 150 d. The sow was with the litter until 30 to 40 d after farrowing, and the removal hazard was greatest shortly after weaning for all parities.

hazard for removal was greater \( (P < 0.05) \) in January, February, September, and October (Figure 5e). The greater hazard in September and October reflects the problems of reproduction that occur in some Swedish herds during early autumn (Tummaruk et al., 2000). The fourth most important factor was age at first farrowing. Sows of 14 mo or older at their first farrowing had a 21% greater \( (P < 0.01) \) hazard for removal than those in the reference class, 12 mo at first farrowing (Figure 5f). Older age at first farrowing indicates that these sows, as gilts, had impaired reproductive capacity (late puberty, return to estrus, or both). This agrees with a study by Sterning et al. (1998) showing that reproductive problems among gilts were likely to recur after the first parity. The fifth most important factor was days after farrowing. The hazard was lower \( (P < 0.001) \) at 0 to 30 d and was greater \( (P < 0.001) \) at 60 to 130 d and at 140 to 150 d after farrowing than it was 30 to 40 d after farrowing (Figure 5a). The hazard for removal attributable to reproductive disorders was greatest at 70 to 100 d after farrowing. This is in accordance with another study in which sows removed because of reproductive disorders were found to cluster after 10 wk (Stein et al., 1990). Sow removal during this period generates a high number of nonproductive days. Obviously, this is economically undesirable, but it also makes it more difficult to control the batchwise system practiced in most Swedish herds.

The sixth most important factor in the analysis of RPL was the total number of piglets born. Sows with litters of 7 piglets or less had a 21% greater \( (P < 0.001) \) hazard for removal than those with litters of 12 to 13 piglets (Figure 5c). The factor with the least importance among the ones tested in the analysis of RPL was days between weaning and next farrowing. An interval longer than 137 d between weaning and next farrowing resulted in a greater \( (P < 0.001) \) hazard for removal than was found for the 120- to 122-d interval (Figure 5d). These intervals, corresponding to at least one return to estrus, gave a 60 to 100% greater hazard for removal attributable to reproductive disorders than did the optimal 120- to 122-d interval. The increase in hazard of removal for RPL was expected for these long intervals and shows that removal reasons coding in the herds were correct.

UPL

Removal attributable to udder problems accounted for 18% of all removals, and mean UPL length in Swedish crossbred sows was 517 d. The effects of days after farrowing, the herd × year combination, parity, and farrowing month were highly significant \( (P < 0.001) \), days between weaning and next farrowing were significant \( (P = 0.004) \), and the total number of piglets born was also significant \( (P = 0.02) \). The effect of the most important factor in the analysis of UPL, days after farrowing, is shown in Figure 5a. The hazard for removal was greater \( (P < 0.001) \) 30 to 40 d after farrowing than it was in the other intervals. The reason for the UPL peak may be that chronic granulomatous mastitis often is diagnosed at the time of weaning (Persson, 1997). The second most important factor for UPL was the herd × year combination. This shows that different housing systems and management influenced the UPL.

The third most important factor in the analysis of UPL was parity. The hazard for removal was greater \( (P < 0.001) \) in first parity than it was in greater parities (Figure 5b). The pattern found in this study is contradictory to descriptive statistics on parts of this material (Engblom et al., 2007), which showed that most removal attributable to udder problems occurred in the medium parity numbers. In addition, Hultén et al. (2003) showed that a high parity number is a risk factor for
mastitis, and that the proportion of sows with granulomatous mastitis increases with increasing parity number. Therefore, results from the current study regarding the influence of parity on removal because of udder problems should perhaps be interpreted with caution. In the current study, farrowing month was the fourth most important factor. Compared with July, the hazard for removal was lower \( (P < 0.01) \) in December (Figure

**Figure 5.** Competing risk analyses of sow removal in Swedish commercial herds. Estimates of hazard ratio for reproductive disorders- (RPL), udder problems- (UPL), lameness- (LPL), and mortality- (MPL) determined length of productive life using model 1: a) effect of days after farrowing; b) effect of parity; c) effect of total number of piglets born; d) effect of days between weaning and next farrowing; e) effect of farrowing month; f) effect of age at first farrowing.
5e). Just as for PL, this may be because the slaughter plants during that month prioritize fattening pigs over sows. The fifth most important factor was days between weaning and next farrowing. The hazard for removal was greater ($P < 0.001$) in intervals between weaning and next farrowing of $\leq 119$ d and from 123 to 136 d than it was in the 120- to 122-d interval (Figure 5d).

Finally, the sixth most important factor among the ones tested in the analysis of UPL was the total number of piglets born. Sows with litters of 9 piglets or less had more than a 20% greater ($P < 0.01$) hazard for removal compared with those with litters of 12 to 13 piglets (Figure 5c).

**LPL**

Removal attributable to lameness accounted for 9% of all removals, and mean LPL length in Swedish crossbred sows was 401 d. The effects of days after farrowing, parity, and the herd × year combination were highly significant ($P < 0.001$), and days between weaning and next farrowing was significant ($P = 0.007$). The effect of the most important factor in the analysis of LPL, days after farrowing, is shown in Figure 5a. The hazard for removal was greater ($P < 0.001$) 30 to 40 d after farrowing than it was in the other intervals. The greater hazard during this period may be an effect of herdsmen keeping sows with tolerable lameness until the litter is weaned. Furthermore, in the current study, sows were grouped after weaning, and lameness was probably more apparent to the herdsmen when the sows were in groups (in larger pens) than in individual farrowing pens. The second most important factor was the herd × year combination. The explanation for this may be different housing systems. The third most important factor was parity. The hazard for removal was greater ($P < 0.01$) in first parity than it was in greater parities (Figure 5b). The reason for this is probably that herdsmen remove young sows with bad legs and for the subsequent parities there are only sows with good legs remaining. Finally, the fourth most important factor in the analysis of LPL was days between weaning and next farrowing. The hazard for removal was greater ($P < 0.001$) in intervals between weaning and next farrowing of 137 to 157 d than it was in the 120- to 122-d interval (Figure 5d).

**MPL**

Removal attributable to sow mortality accounted for 4% of all removals, and mean MPL length in Swedish crossbred sows was 458 d. The effects of days after farrowing, parity, the herd × year combination, and farrowing month were highly significant ($P < 0.001$), and the total number of piglets born was significant ($P = 0.003$). The most important factor in the analysis of MPL was the herd × year combination. This indicates that variation in housing and management routines may influence the level of sow mortality. The second most important factor was days after farrowing. The hazard for removal was 45% greater ($P = 0.01$) at 0 to 10 d, and lower ($P < 0.01$) at 10 to 30 and at 40 to 150 d, after farrowing than it was at 30 to 40 d after farrowing (Figure 5a). The hazard for removal was greatest just after farrowing. This agrees with previous studies (Madec, 1984; Deen et al., 2000) and indicates that the farrowing process places physical strain on the sow.

The third most important factor in the analysis of MPL was parity. The hazard increased with greater parities and was greater ($P < 0.001$) in parities from 8 than it was in parity 1 (Figure 5b). There were only 27 informative failures in this class, but this trend was supported by another study that found the greatest hazard for sow mortality in greater parity numbers (Koketsu, 2000). The fourth most important factor was farrowing month. Compared with July, the hazard for removal was lower ($P < 0.05$) in January to April, June, September, October, and December (Figure 5e). The greater hazard for mortality during the summer months of July and August was probably due to the greater ambient temperature. This is in agreement with several other studies that have shown an increased risk for sow mortality during the summer months (D’Allaire et al., 1996; Deen et al., 2000; Koketsu, 2000). Finally, the fifth most important factor in the analysis of MPL was the total number of piglets born. Sows with litters of 7 piglets or less had an 82% greater ($P < 0.001$) hazard for removal than those with litters of 12 to 13 piglets (Figure 5c). The greater hazard for mortality among sows with small litters found in the current study might be caused by dystocia or, alternatively, might indicate inferior body condition in the sow at farrowing. However, it should be kept in mind that the proportions of censored records in the competing risk analyses were high, especially in the analyses of MPL (97%), and some of the estimates should be interpreted with caution.

**Main Findings**

Days after farrowing was the main risk factor for sow removal among the factors tested, followed by parity and the herd × year combination. Overall, the hazard for removal was greatest shortly after weaning, and the same pattern was found for removal attributable to lameness and udder problems. However, the hazard for sow mortality was greatest around farrowing, and for removal attributable to reproductive disorders, the hazard was greatest at 70 to 100 d after farrowing. Hazard for removal was low in the medium parity numbers. Overall, the influence of farrowing month was not clear, but for sow mortality the hazard was greater during July and August. Furthermore, old age at first farrowing, small litters, and long intervals between weaning and next farrowing resulted in high removal hazard.
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LITERATURE CITED


