

Factors affecting length of productive life in Swedish Dairy Cattle

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Abstract

The length of productive life of Swedish dairy cattle has been analyzed with survival analysis. After editing, the data set had information on 1 019 518 cows calving from 1988 to 1996 from the Swedish Official Milk Recording System and AI scheme. Four breeds: Swedish Red and White (SRB), Swedish Friesian (SLB), Swedish Polled Breed (SKB), and Jersey; and crossbreds (SRB x SLB), were included. Length of productive life was defined as days from first calving to culling (uncensored) or end of data collection (censored). A preliminary analysis included the effects: stage of lactation by parity number, peak yield deviation within herd-year, age at first calving, year, season, region, breed, and the random effect of herd. The proportion of censored records was 37%. All the effects were significant at $P < 0.001$. The effects with the greatest contribution to the likelihood function were stage of lactation by parity and peak yield deviation. The risk of culling increased within lactation and with parity number. Low producing cows were ten times more likely to be culled than average producing cows.

Introduction

The importance of functional longevity has grown during the last decade because of its increasing impact on production cost, and because of the need to improve functional longevity in dairy populations that have been selected only for production. The economic advantage of longevity lies primarily in retaining productive, healthy and trouble-free cows as long as possible.

The length of life of a cow is the result of a complex process where not only the biological traits of the cow are important but where also environmental factors play a role. Furthermore, all these factors are filtered through the decision making process of the farmer. It is necessary to have a better understanding of the culling process and the environmental factors, to be able to account for those in the genetic models. However longevity is a difficult trait to measure, mainly due to the presence of incomplete records; *i.e.* cows that are still alive when the study is carried out. Ducrocq (1987) defined functional herd life (FHL) as the ability of a cow to remain sound and healthy, after adjustment for production level; it refers to the ability to delay involuntary culling.

Survival Analysis, which deals with censoring in the analysis of time response, has been applied in the animal breeding context to estimate genetic parameters for longevity. It is the methodology applied for routine genetic evaluation for longevity in dairy cattle in many countries (Van der Linde and de Jong, 2003).

The objective was to study the systematic factors that influence the length of productive life of Swedish dairy cattle.

Materials and Methods

The data consisted of 1 019 518 cows calving from 1988 to 1996. Data was provided by the Swedish official milk recording system and AI scheme. Four breeds were included: Swedish Red and White (SRB) (562741 cows), Swedish Friesian (SLB) (422886), Swedish Polled Breed (SKB) (5448), Jersey (7152), and crossbreds (SRB x SLB) (21291).

Productive life (PL) was defined as the time from first calving to culling or end of data collection, measured in days. Records were considered to be censored if cows were still alive at the end of the studied period (31 December 1996).

The following Weibull model was fitted to analyze PL:

$$\lambda(t) = \lambda_0(t) \exp \{ z'(t) \beta \}$$

where,

$\lambda(t)$ is the hazard function of a cow t days after calving; $\lambda_0(t)$ is the baseline hazard function, $\lambda_0(t)^{p-1}$, assumed to follow a Weibull distribution with scale parameter λ and shape parameter p ; and β contains the covariates (time-dependent and time independent) affecting the hazard, with the corresponding design vector $z'(t)$.

The variables included in the model were:

Year = fixed time-dependent effect of year, changed at January 1st each year;

Season = fixed time-dependent effect of season. Six classes were considered: January-February, March-April, May-June, July-August, September-October, and November- December;

$P \times S$ = fixed time-dependent effect of parity number by stage of lactation (parities 1 to 6+ and stages of lactation with changes occurring each 30 days (0, 30, ..., 390 days of each lactation);

Peak = fixed time-dependent effect of the cow's peak test-day yield in a given lactation as a deviation from herdmates in that herd-year. Normalized deviations were calculated using the herd-year mean (m_{hy}) and the overall phenotypic standard deviation of test-day peak yield within herds ($s.d._{hy}$). The m_{hy} and $s.d._{hy}$ were calculated for first lactation and later lactations separately and for the different breed groups. SRB, SLB and Crossbred were grouped together. These normalized deviations were used to create 13 classes, the cut-off points were chosen such as the classes were expected to contain 4x 2.5%, 1x 5%, 7 x10 % and 1x 15% of the observations. Before the calculations, peak yields were adjusted for days in lactation up to day 60, based on a fourth degree polynomial estimated separately for first and later lactations in the same data. Cows with missing information on peak yield were set to average herd-year production (class 9, deviation 0);

Age at first calving = fixed time-independent effect of age at first calving (21 classes: 18-20, 21, 22, ..., 39, 40-42 months of age);

Breed = fixed time-independent effect of breed; 5 classes were considered: SRB, SLB, Crossbred, Jersey and SKB;

Region = fixed time-independent effect of region; 3 classes. Sweden was divided into 3 geographical regions: north, middle and south;

Herd = random time-dependent effect of herd, assumed to follow a gamma distribution with parameter γ , which was algebraically integrated out from the joint posterior density

The analysis was done with the Survival Kit (Ducrocq and Sölkner, 1998). Estimates were obtained for the parameters ρ and γ .

Results and Discussion

The proportion of right censored records was 37% (cows still alive when the data set was created). The mean observed failure time was 736 days and the mean censoring time was 635 days. The estimate of γ was 1.73. The estimate of ρ was below unity (0.85). Values greater than one were reported for other populations (Van der Linde and de Jong, 2003). Roxtröm (2001) reported $\rho = 0.79$ for Swedish SRB.

All the effects included in the model were significant at $P < 0.001$. The most important changes in log likelihood ($-2 \log L$) were observed after the inclusion of parity by stage of lactation and the effect of peak yield deviation.

Solutions of fixed effects are expressed as relative culling rate (RCR), defined as the ratio between the estimated risk of being culled under the influence of certain environmental or genetic effects and the risk for a chosen reference class. For example, if the RCR for a given class of a fixed effect is 2, it means that a cow in that class has twice as high risk of being culled compared with a cow in the reference class for that effect.

The effect of year (Figure 1a) showed a decreasing trend, with a higher risk of culling at the beginning of the period analyzed. A slightly increase of risk of culling was observed at the end of the period. The higher risk observed during 1989-1990, could be related to an substantial decrease in number of cows, as reported by the Swedish Dairy Association (1999). In Sweden the quota system started in 1995 and was therefore not expected to have had a large influence in the data.

The estimates for the season effect showed a higher risk of culling during the fall (September-October); this could be related to the fact that farmers have to sell the cows that they are not able to keep indoors during the winter (Figure 1b).

The risk of being culled increased with increasing age at first calving (Figure 1c). Although from 26 to 32 months of age, there was no difference in culling risk. Primiparous cows calving at older ages had a higher risk of being culled, for example, a cow calving at 38 month of age have a risk of being culled 45 % higher compared with a cow calving at 25 month of age.

Figure 1d shows the solutions for peak yield deviation. Low producing cows are at significant higher risk of being culled compared with an average herd-mate (class 9). On the other hand the risk of being culled of high producing cows was reduced, but only slightly. Peak yield describes the first part of the lactation, and is expected to be a better indicator of voluntary culling than the total lactation (Roxtröm, 2001).

The interaction of parity by stage of lactation with the baseline hazard is illustrated in Figure 1e, which shows the estimated hazard rate of an "average cow" assuming a calving interval of 400 days. The effects of parity and stage of lactation were treated jointly as an interaction. It seems appropriate because it reveals how the hazard rate changes within lactation for the different parity groups, and it avoids the problem of not being able to compare first lactation cows in the first stage of lactation with older cows at the same stage. The risk of being culled increased throughout the lactation, and the same trend was observed for all parities. The risk decreased from calving to day 30. This decrease is

related to p being < 1 . The same situation was reported by Roxtröm (2001) for SRB. In our study, when the effect of parity by stage of lactation was included in the model, p became below 1. The risk was almost flat from stage 270-300 to 330-360 days; around 270 days the culling could be related to mastitis. After 330-360 days the risk was significant increased until the end of the lactation; perhaps farmers wait until the very end of the lactation to cull non-pregnant cows. Such cows have a higher persistency, since the reducing effect of pregnancy on production never occurs. The hazard rate increased with time; thus older cows had a higher risk of being culled.

SLB cows had a slightly higher risk of being culled than SRB whereas SKB and Jersey (small breeds) had a higher risk of being culled (Figure 1f). Peak yield deviation was calculated within breed, to avoid comparing the level of production of different breeds in the same herd. Small breed cows usually are in the same herd together with SLB and/or SRB; there are very few herds with these small "pure" breeds.

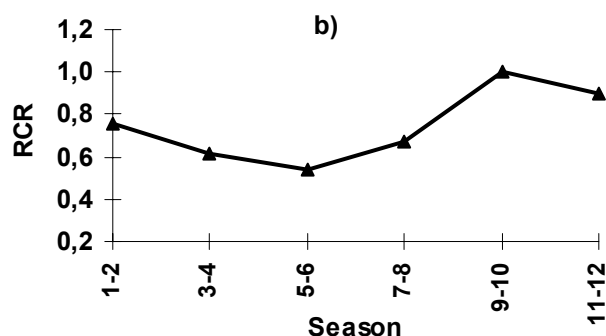
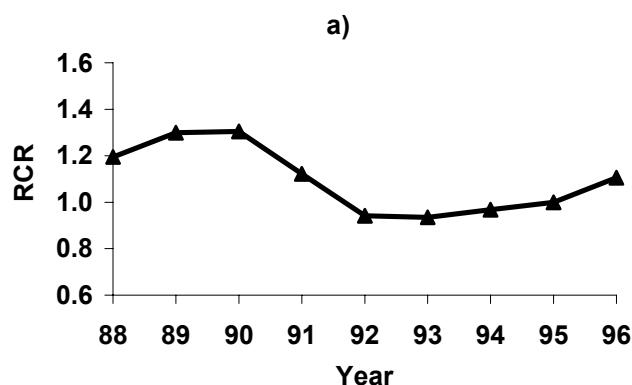
Cows in herds in the middle of Sweden had a lower risk of being culled compared to the other geographical regions, although the differences were small (North (RCR=1.03), Middle (RCR=0.91), south (RCR=1.0)).

Conclusion

Survival analysis was used to investigate the systematic factors that may influence the productive life in Swedish dairy cattle. The most important effects that influence the productive life were the effect of parity by stage of lactation and the effect of peak yield deviation. Solutions showed that the probability of being culled is higher at the end of the lactation for all parity groups, for cows producing below herd average and for heifers calving at older ages.

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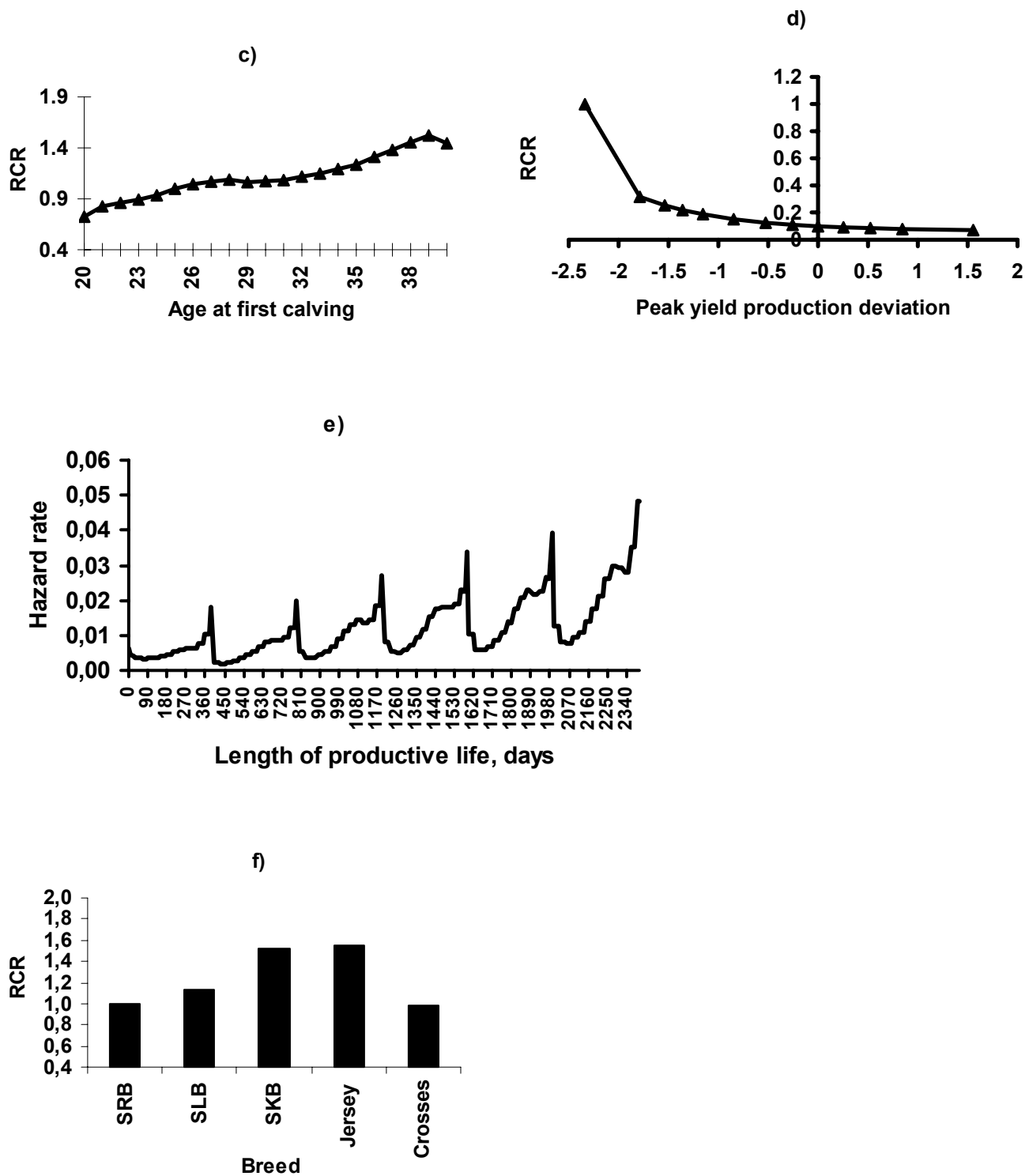


Figure 1: Estimates of relative risk of culling for productive life a) Effect of year ; b) Effect of season c) Effect of age at first calving; d) Effect of peak yield deviation; e) Estimated hazard for a cow with 400 day of calving interval; f) Effect of breed.