Effect of mastitis and fertility on culling in Swedish dairy cattle

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Abstract

The effect of mastitis and fertility on culling in Swedish dairy cattle was analyzed with Survival Analysis. The data had information on 980 705 cows calving from 1988 to 1996. Four breeds, Swedish Red and White (SRB), Swedish Friesian (SLB), Swedish Polled Breed, 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). The model (Weibull Proportional Hazard) included the fixed effects of mastitis by parity and lactation stage, fertility by parity and lactation stage, peak yield deviation within herd-year, age at first calving, year by season, region, breed, herd production level, and the random effect of herd. The effects of mastitis and fertility on culling were modeled as time-dependent covariates. Each lactation was divided in five stages in which mastitis and culling might occur. To evaluate fertility each lactation was divided in five stages in which the pregnancy status was known and culling could occur. Mastitis increased the risk of culling throughout the lactation. Sick cows were more likely to be culled than healthy cows. The risk of being culled was increased at the stage the disease was treated and it was higher in the following stage. The farmer's knowledge of the pregnancy status had a significant effect on culling. The risk of being culled of pregnant cows was highly reduced compared to a non-pregnant cow. Similar results were observed for all parities.

Introduction

Mastitis and impaired fertility are the most common reasons for culling in Swedish dairy cattle. Poor reproductive performance and mastitis (+ SCC) are the main reasons for culling (about 24% each) (Swedish Dairy Association, 2000). The main costs associated with low fertility are higher insemination costs, lower production per day and, especially, higher replacement costs owing to increased culling. Mastitis also has a negative impact on dairy farm profitability, through an increase of veterinary and treatment costs, reduced milk yield, discarded milk, reduction in milk price, and increased culling.

The length of life of a cow is the result of a complex process where not only biological traits are important but where also environmental factors play a role. Furthermore, all these factors are filtered through the decision making process of the farmer. When a farmer decides to cull a cow, he/she may consider the level of milk production, diseases, pregnancy status, stage of lactation, etc. 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.

When studying the effect of diseases on culling, an important aspect that has to be considered is the timing of the disease. The timing of a disease may influence the decision of when or whether to cull a cow. Timing has two aspects: the timing of disease occurrence and the time during lactation when culling actually occurs (Gröhn et al., 1997). Culling might occurs right after the disease or later during the lactation (Gröhn et al., 1998).

Another important aspect is how to model the impact of diseases. Beaudeau et al. (1995) suggested that survival analysis is more powerful than standard regression techniques to study the effect of diseases. Survival analysis can handle both censoring and time-dependent variables. If the effect of a disease is modeled as a time independent covariate, its effects on the outcome is the same, both before and after the occurrence of the disease, which does not make sense unless the disease occurs very early in lactation. In contrast if the disease is considered as a time dependent covariate its effects is different before and after the occurrence (Beaudeau et al., 1995). The effect may also vary over time if there is an interaction between the disease occurrence and the stage of lactation in which culling occurs. Mastitis is a disease that can occur at any point during the lactation and this fact can be accounted for in the analysis by considering different stages of disease occurrence (Rajala-Schultz and Gröhn, 1999a). This approach is also appropriate to evaluate the effect of pregnancy status. Cows can get pregnant at different stages during the lactation and this may have an impact on culling decisions.

The objective was to study the effect of mastitis and fertility on culling in Swedish dairy cattle.

Materials and Methods

The data consisted of 980 705 cows calving from 1988 to 1996. Data was provided by the Swedish official dairy cattle recording system and AI scheme. Four breeds were included: Swedish Red and White (SRB) (542176 cows), Swedish Friesian (SLB) (406348), Swedish Polled Breed (SKB) (5178), Jersey (6749), and crossbreds (SRB x SLB) (20254). The data had individual cow information on production, veterinary treatments of clinical mastitis (number of cases), and number of inseminations, together with temporal variables such as dates of calving, inseminations, and treatments as well as time and reasons for culling.

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:

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

where,

λ(t) is the hazard function of a cow t days after calving; λ_o *(t)* is the baseline hazard function, $\lambda\rho (\lambda t)^{\rho-1}$, assumed to follow a Weibull distribution with scale parameter λ and shape parameter ρ; 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 by season = fixed time-dependent effect of year by season (year 1988 to 1996 with changes occurring at January 1st and six seasons: January-February, March-April, May-June, July-August, September-October, and November-December);

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, Jersey, SKB and Crossbred;

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

Herd production level = fixed time-independent effect herd milk production level. Normalized deviations were calculated using the information on cow's peak test-day yield in first lactation. These deviations were used to create five classes, and the cut-off points were chosen such as the classes were expected to contain 25% of the observations (class1: low producing herds, class 5: high producing herds);

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;

Mastitis = fixed time-dependent effect of mastitis treatment, lactation stage and parity. It is a 3-way interaction term: period in which mastitis was treated, stage of lactation (when culling was observed) and parity (parities 1 to 6+)). Each lactation was divided in 5 stages (0-30, 31-60, 61-150, 151-240, > 240 days) where mastitis could have been treated and culling could occur. The first stage included cases of clinical mastitis that occurred 10 days before calving in first parity cows. The classes (*i,j*) were done considering the stage of lactation (*i*=1 to 5) and health status (*j*=0: healthy (no treatment of clinical mastitis reported); *j*≠ 0: sick (treatment reported) (Figure 1). For sick cows, *j* indicated at which stage the cow was treated for mastitis and she was considered to be sick from that stage to the end of the current lactation. As a result we had 6 different cases: 1) cows that were always healthy (diagonal, in Figure 1), 2) cows that were treated in the first stage; 2) cows that were treated in the 2nd stage (given that she was healthy in the first stage), and so on. For each lactation 20 classes were created;

Fertility = fixed time-dependent effect of pregnancy status, lactation stage and parity. Each lactation was divided in 5 stages (0-60, 61-150, 151-240, 241-305, > 305 days) in which the farmer knew if a cow had conceived or not and culling could occur. The knowledge of the pregnancy status could influence culling decisions depending in which part of the lactation the cow was in. It was considered as an interaction with parity number (parities 1 to 6+). We calculated the date in which the farmer knew when a cow was pregnant as the date of the last insemination plus 63 days (9 weeks). We applied different rules to calculate the time (T) when pregnancy status might have influenced the farmer's culling decision: 1) if the cow had a subsequent lactation: T = (next calving date – gestation length (279 d) + 63 days). For cows in their last lactation (in multiparous cows) the rules were done depending if the cow already finished her productive life (uncensored) or was still alive (censored). For cows that finished their productive life T was calculated as follow: 2) cows culled within 150 days after calving: were considered open during all that time; 3) cows culled later than 150 days after calving with the culling reason reported as non-pregnant: were considered open all that time; 4) cows culled later than 150 days after calving without the farmer stated non-pregnant as culling reason and without any insemination registered: she was considered open all that time; 5) cows culled later than 150 days after calving without the farmer stated non-pregnant as culling reason but with inseminations reported: if the interval between the last insemination and culling was ≥ 279 days, were considered open all that time; and 6) cows culled later than 150 days after calving without the farmer stated non-pregnant as culling reason and with inseminations reported: if the interval between the last insemination and culling was < 279 days; then T = (last insemination date + 63 days), and it was assumed that she conceived at the last insemination. For cows that were still alive (censored) the following rules were applied: 1) if she did not have any insemination, she was considered open; 2) if the she was inseminated and the interval between the last insemination and the censoring date was ≥ 279 days, she was considered open, and 3) if the she was inseminated and the interval between the last insemination and the censoring date was < 279 days, she was considered pregnant and T = (last insemination date + 63 days).

Classes (i,j) were done considering the stage of lactation (i=1 to 5) and the knowledge of pregnancy status (j=0: open; $j\neq 0$: pregnant) (Figure 2). For pregnant cows, j indicated at which stage the producer knew if the cow was pregnant. As a result we had 5 different cases: 1) cows open during the entire lactation, (diagonal, in Figure 2), 2) cows that the farmer knew that she was pregnant during the second stage of lactation; 3) cows that the farmer knew that she was pregnant during the 3rd stage of lactation (given that she was open in the previous stages), and so on. It was assumed that all cows were open during the first stage of lactation (0-60 days). For each lactation 15 classes were created.

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

Results

The proportion of right censored records was 37% (cows still alive when the data set was created). The mean observed failure time was 734 days and the mean censoring time was 626 days. The estimate of γ was 3.4 and the estimate of ρ was 1.08.

The interaction of year by season showed a decreasing trend, with a higher risk of culling at the beginning of the period analyzed. The higher risk observed during 1989-1990, could be related to a 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. A season effect was observed with 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. The risk of being culled increased with increasing age at first calving, although from 26 to 32 months of age, there was no difference in culling risk. Low producing cows were 10 times more likely to be culled than average herdmates.

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. 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 north and middle areas of Sweden had a lower risk of being culled compared to cows in herds in the south, although the differences were small (North and Middle (RCR=0.93), South (RCR=1.0). Regarding the herd production level effect, the risk of being culled of cows in low producing herds was reduced 40% compared to cows in high producing herds.

The effect of mastitis on culling is presented in Figure 3 and 4 for first and second lactation, respectively. In the graphs the interaction of mastitis treatment and stage of lactation with the baseline hazard is illustrated, which shows the estimated hazard rate of an "average cow" assuming a calving interval of 400 days. To compare hazards of a cow at different time points, the estimates of the time-dependent covariates should combined with the baseline hazard function at these points, otherwise erroneous conclusions could be drawn (Gröhn et al., 1997). The six cases for mastitis are shown in the figures: the hazard for cows that were healthy during the entire lactation, for cows that were treated during the 1st stage and so on.

The hazard rate of a sick cow was the same as for the healthy one until the disease was treated, and then the hazard rate for the sick cow was increased. In first lactation, for a healthy cow, the risk of being culled increased throughout the lactation, but the risk of being culled of sick cows was much higher and it varied according in which stage the cow was treated. During the first stage (0-30 days) the risk of being culled was considerably higher for a cow that was treated during this stage compared to the cows that were healthy at the very beginning of the lactation. The risk was higher in the following stage, but then culling was delayed until the end of the lactation. The risk of being culled of a cow that was treated during the second stage (31-60 days) was higher than the risk of a healthy cow, but not that marked as cows that were treated very early in lactation. However the risk of culling was markedly increased in the stage after the cow was treated. The same trend was observed for cows treated in the 3rd and 4th stage. A different trend in the last part of the lactation was observed for cows that were treated in the last stage (after 240 days); their risk of being culled was lower than the risk of a healthy cow.

In second parity (Figure 4) the trends were somehow different. The risk of a cow of being culled was increased during the stage she was treated compared to a healthy cow and it was higher in the following stage. Later the risk of being culled was reduced until the end of the lactation compared to first lactation where the risk was increased towards the end of the lactation. Cows that got sick in early lactation (from calving to 30 days in lactation) had a significant higher risk of being culled compared to healthy cows regardless the parity number. Lactation 3 to 6 showed similar trends to the second lactation (results not shown).

The effects of fertility (five cases) on culling in first and second lactation are shown in Figure 5 and 6, respectively. There was an increasing risk of being culled throughout the lactation for an open cow. The hazard rate of an open cow was the same as for the pregnant one, until the producer knew when she became pregnant and then the risk was dramatically reduced. The risk of a cow still open at the end of the lactation (> 305 days) was significant higher compared with cows pregnant at that stage. The same trend was observed for all parities.

Discussion

Mastitis had a significant effect on culling throughout the lactation. The risk of being culled was significant higher for sick cows compared to the healthy ones. Similar results were reported by Rajala-Schultz and Gröhn (1999a), Beaudeau et al. (1995), Gröhn et al. (1997, 1998), and Neerhof et al. (2000).

The results showed that there was an interaction between when mastitis was treated and the stage of lactation (when culling occurs). The effect of mastitis on culling was different according to parity number and when the cow was treated. When mastitis was treated in early lactation (< 30 days) the risk of culling was very high regardless the parity number. However the highest risk was observed in the stage following the treatment. This could be related that producers cannot sell cows that have been treated with antibiotics; they have to wait until the effect is washed out. Beaudeau et al. (1995) reported that mastitis occurring within the first 45 days of lactation and during the dry period was associated with an increased risk of culling regardless the lactation number in French Holsteins.

The difference between first and second parity is that the risk of culling was increased towards the end of the lactation in first parity, whereas in second and later parities the risk was more flat. The attitude of the producer might be different depending on the parity number, if cows get sick already in first lactation they might have fewer chances to be kept in the herd than older cows.

The reduced risk of culling of a cow treated after 240 days could be explained by the fact that farmers give an opportunity to cows that they get sick at the end of the lactation to see what will happen when they calve again. At this point of the lactation if it worth treating her, it worth keeping her. Rajala-Schultz and Gröhn (1999a) also reported that at the end of lactation mastitis seemed to have a protective effect against culling in Finnish Ayshires.

The farmer's knowledge of the pregnancy status of cows had a striking effect on culling in all parities. As soon as the producer knew the cow was pregnant her risk of being culled was sharply reduced. Similar results were found in other studies. Beaudeau (1995) found that reproductive performance had a high impact on the length of productive life in French Holsteins. Failure to conceive at first service and longer days open increased the risk of being culled regardless the lactation number. Gröhn et al. (1998) showed that once they had had conceived her risk of being culled dropped sharply.

We also evaluated two different models (results not shown): one included the "basic model" (year by season, peak, age at first calving, breed, region, herd production level, herd) and the effect of mastitis only, and the second included the basic model and the effect of fertility only. To compare the fit of these two models and our current model (basic model+mastitis+fertility), we checked the –2Log Likelihood values (9343555.18, 8636354.11, and 8610441.81, respectively). The inclusion of both effects mastitis and fertility in the model explained better the variation in culling.

Estimates (risk ratios) for fertility were slightly increased when mastitis was included in the model, although in first parity it was almost no change. On the other hand estimates for mastitis changed when fertility was considered in the model. The estimates of mastitis decreased in first parity; and in later parities were in general increased at the beginning of the lactation and reduced towards the end of the lactation. Rajala-Schultz and Gröhn (1999a) reported that the effect of diseases tended mainly to decrease when pregnancy status was considered in the model.

The effect of mastitis and fertility were modeled as time-dependent covariates. The results showed that there was an interaction between the time when mastitis was treated (or pregnancy status known) and the time when culling occurred. Previous studies (Beaudeau, 1995; Gröhn et al, 1997, 1998) agreed that this is the best approach to study the effect of diseases on culling.

Conclusion

Mastitis and fertility had an important effect on culling in Swedish dairy cattle. The effect of mastitis on culling varied according to when mastitis was treated and to parity number. The risk of being culled was highest in the stage after the one mastitis was treated. The risk of culling was significantly higher when mastitis was treated in early lactation compared to healthy cows, regardless the parity number. The knowledge of the pregnancy status had a striking effect on culling. As soon as the farmer knew a cow was pregnant her risk of culling was highly reduced. The same trend was observed for all parities.

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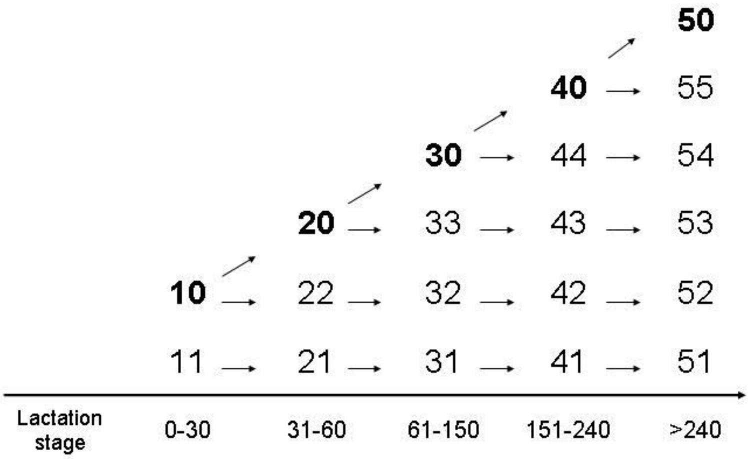

Figure 1. Classes (*i,j*) for the effect of mastitis. Stage of lactation (*i*=1 to 5); health status (*j*=0: healthy (no treatment of clinical mastitis reported); *j*≠ 0: sick (treatment reported). For sick cows, *j* indicated at which stage the cow was treated for mastitis and she was considered to be sick from that stage to the end of the current lactation.

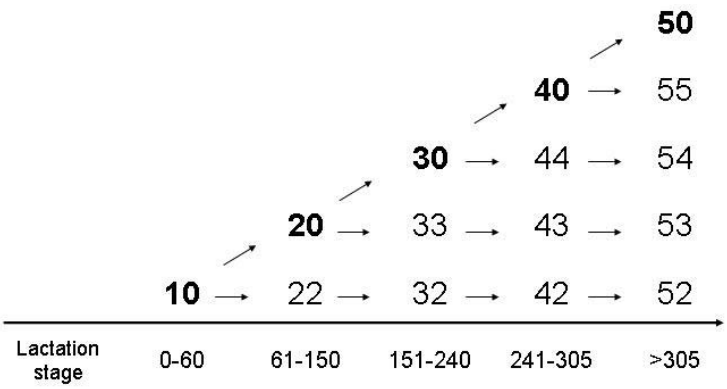

Figure 2. Classes (*i,j*) for the effect of fertility. Stage of lactation (*i*=1 to 5); knowledge of pregnancy status (*j*=0: open; *j*≠ 0: pregnant). For pregnant cows, *j* indicated at which stage the producer knew if the cow was pregnant

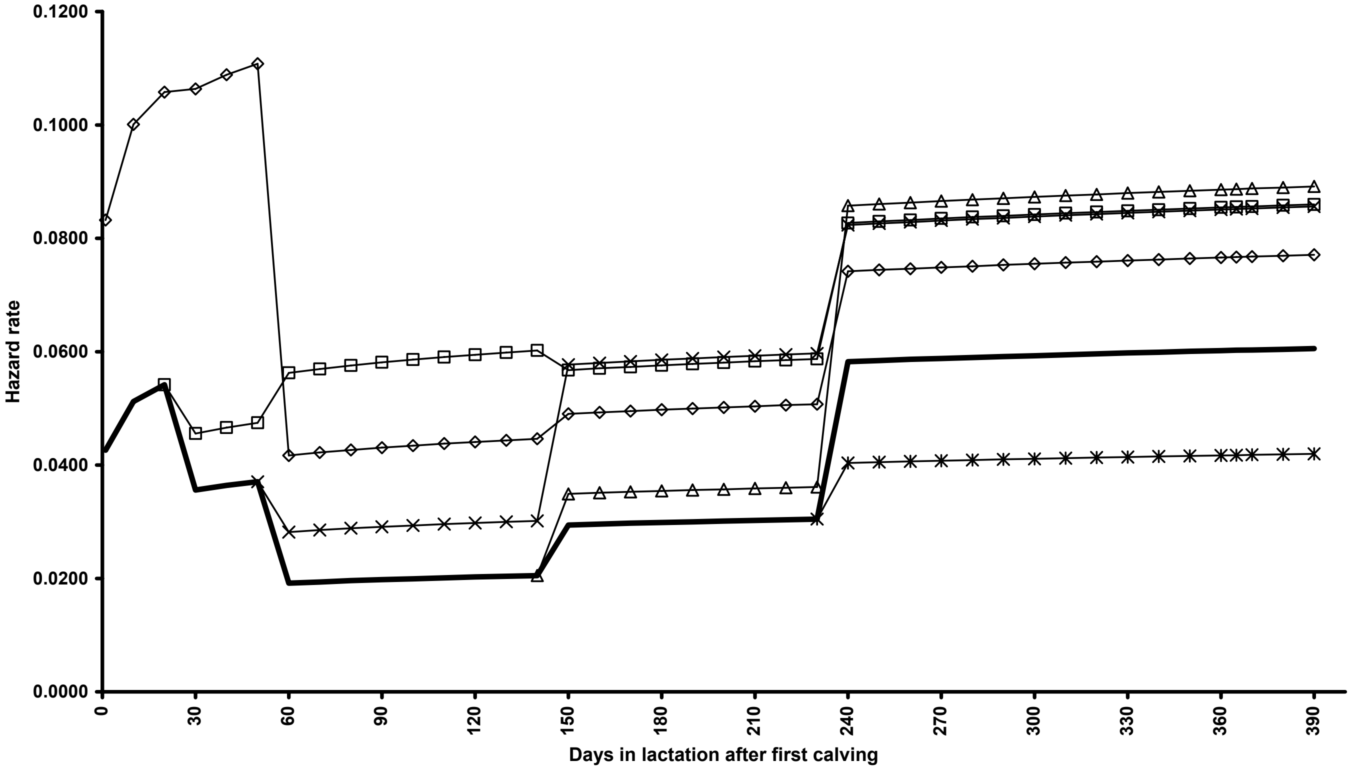

Figure 3. Estimated hazard rates of the effect of mastitis for a cow with 400 day of calving interval in first parity. (Bold line= healthy cow; stage when the cow was treated: ◊ = 1st, □ = 2nd , ×= 3rd, △ = 4th , ✳ = 5th).

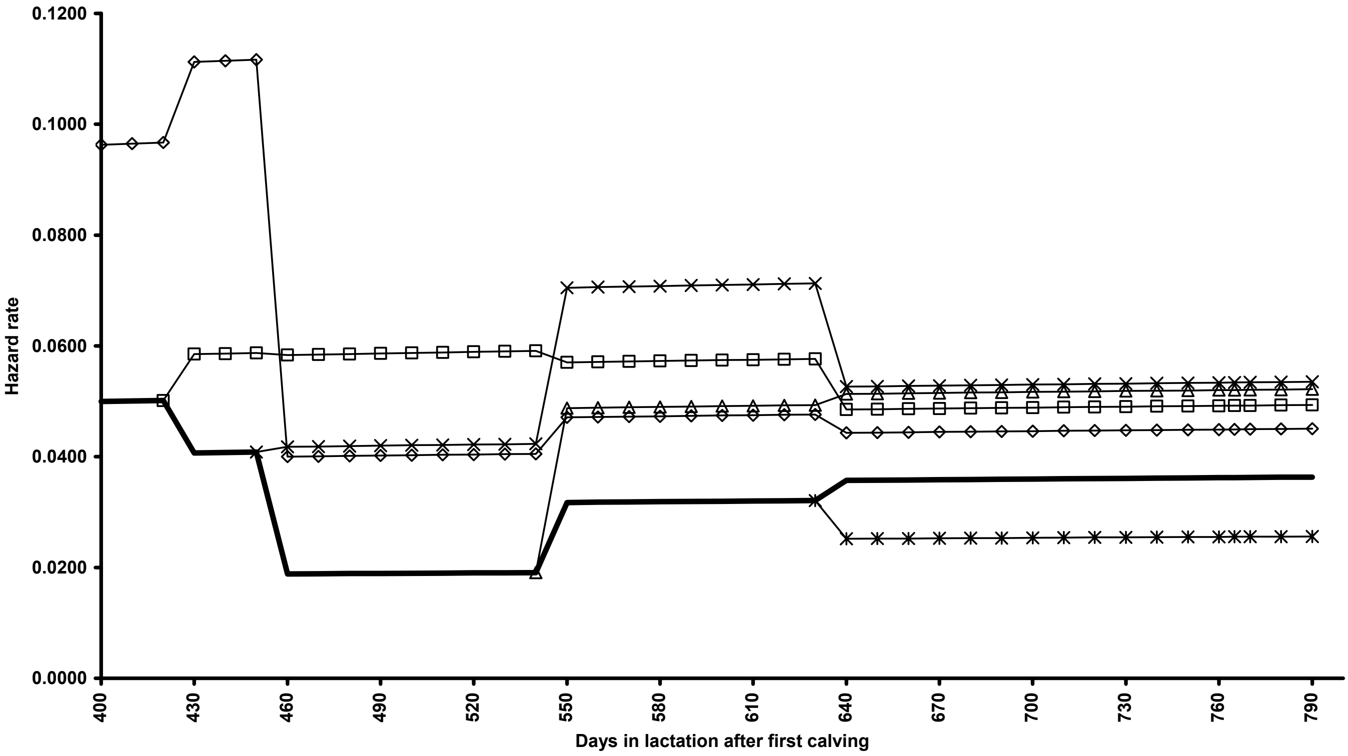

Figure 4. Estimated hazard rates of the effect of mastitis for a cow with 400 day of calving interval in second parity. (Bold line= healthy cow; stage when the cow was treated: ◊ = 1st, □ = 2nd , ×= 3rd, △ = 4th , ✳ = 5th).

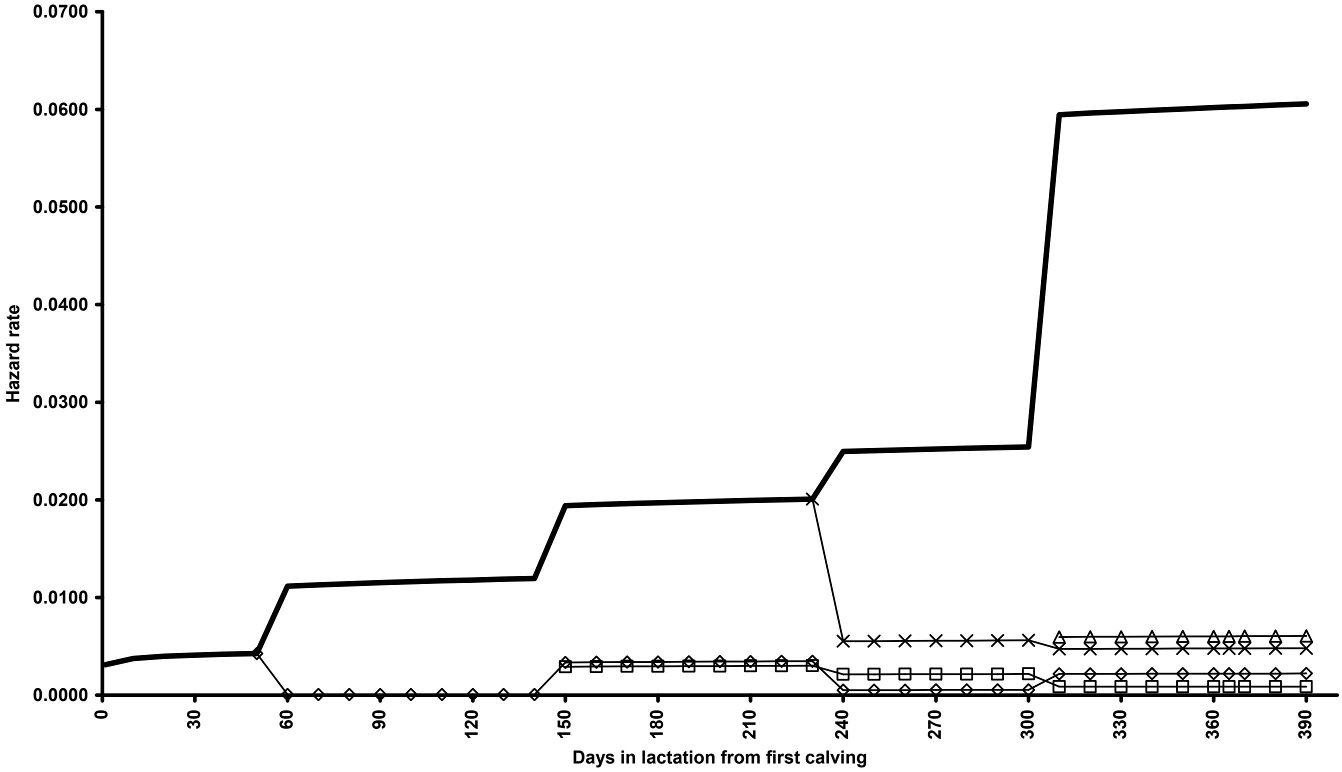

Figure 5: Estimated hazard rates of the effect of fertility for a cow with 400 day of calving interval in first parity. (Bold line= non pregnant; stage when the producer knew the cow was pregnant: ◊ = 2nd, □ = 3rd, ×= 4th, △ = 5th).

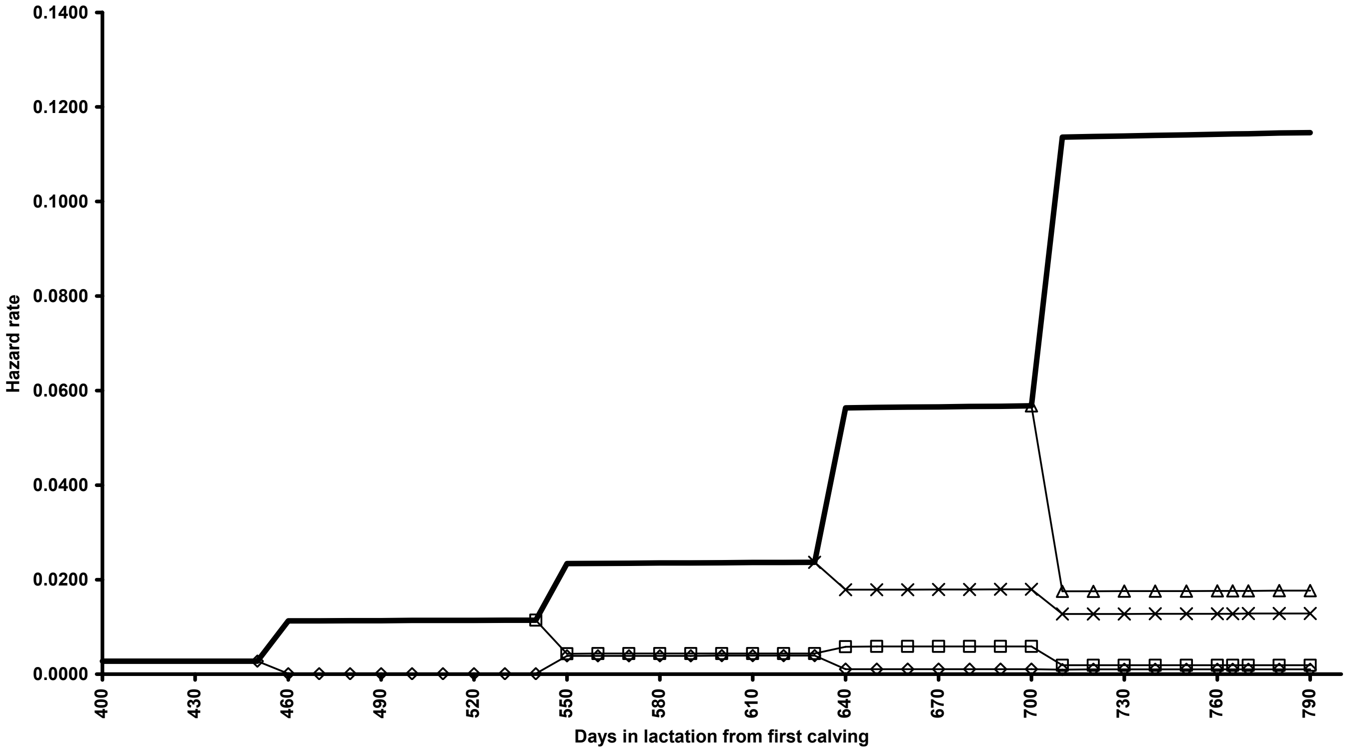

Figure 6: Estimated hazard rates of the effect of fertility for a cow with 400 day of calving interval in second parity. (Bold line= non pregnant; stage when the producer knew the cow was pregnant: ◊ = 2nd, □ = 3rd, ×= 4th, △ = 5th).