

# Influence of claw health on fertility and milk production in dairy cows

– An epidemiologic study from farms situated on the Åland Islands

*Carin Ekström*



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Klövhälsans inverkan på fertilitet och mjölkproduktion hos mjölkkor – En epidemiologisk studie från gårdar belägna på Åland

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**Credits:** 30 hp

**Level:** Advanced level, A2E

**Course title:** Självständigt arbete i husdjursvetenskap - masterarbete

**Course code:** EX0742

**Programme/education:** Agronom - husdjur

**Place of publication:** Alnarp

**Year of publication:** 2015

**Cover picture:** Carin Ekström

**Online publication:** <http://stud.epsilon.slu.se>

**Keywords:** claw health, lameness, claw lesions, dairy cow, milk production, milk yield, reproduction, fertility



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## Abstract

Lameness and claw lesions are frequent health problems observed among dairy cows and are a common reason for culling, reduced milk production and reproductive inefficiency. The present study investigated the association between claw health, reproduction and milk production of dairy cows at the Aland Islands in order to gain an understanding of the current situation. The study included data from 17 farms during the years 2013 and 2014 regarding claw health, reproduction, milk production and housing system. Five of the herds kept the cows in free stalls and 12 herds kept the cows in tie-stalls.

The recorded claw lesions were divided into infectious diseases and laminitis related diseases. Dermatitis, digital dermatitis, heel horn erosion, interdigital hyperplasia, wart growth, and interdigital phlegmone were considered as infectious diseases. Sole hemorrhage, sole ulcer, double sole, white line fissure, toe abscess, white line abscess and chronic laminitis, on the other hand, were considered as laminitis related diseases. Each disease was given a severity score depending on its clinical severity. The higher the total score a cow got the worse were the claw health. In the statistical analyses all trimming sessions for each cow were compared so that only the most severe score was used. This resulted in each cow having a maximum score for infectious diseases (maximum infectious point, MIP), a maximum score for laminitis related diseases (maximum laminitis point, MLP) and a maximum score for these two added together (maximum total point, MTP). Five parameters were studied in order to evaluate the effect of claw health on reproduction and milk production; number of services (inseminations), interval from first service to last service (IFLS), interval from calving to last service (ICLS), calving interval (CI) and mean ECM production.

Fifty per cent of the total number of trimmed cows during 2013 had no recorded claw lesions; the same number in 2014 was 52 %. No significant correlations between year of production and MIP, MLP and MTP could be observed. Laminitis related diseases were more common on all farms compared to infectious diseases and a difference in the prevalence of both laminitis related diseases and infectious diseases could be observed between farms. There were significantly more infectious diseases on farms with free stall systems compared to farms with tie-stalls during both years ( $P=0.000$  and  $P=0.016$ ). A significant difference in the occurrence of laminitis related diseases between the claw trimmers was found. There were no significant differences between tie-stalls and free stalls herds concerning number of services, IFLS, ICLS, CI and mean ECM production. Average ECM production was not affected by an increase in MTP, MIP or MLP and there were no tendencies for more services, longer ICLS or longer CI with increased MTP. There was however a tendency towards a positive correlation between IFLS and MTP.

The anecdotal evidence that dairy cows on the Aland Islands have better claw health than their counterparts in Sweden can neither be proved nor rejected based on the results from this study. The present study was an epidemiologic study, to draw conclusions about cause - effect relationships are therefore impossible. However, the results from this study can hopefully be a base in the future works towards a better claw health status at the Aland Island.

## Sammanfattning

Hältor och skador i klövarna är hälsoproblem som ofta uppmärksammas hos dagens mjölkkor. Studier i ämnet rapporterar om försämrad mjölkproduktion, försämrad reproduktiv förmåga samt ett ökat antal utslaktningar i samband med klövproblem. För att få en uppfattning om den nuvarande situationen på Åland undersökte den här studien sambandet mellan klövhälsa, mjölkproduktion och reproduktion hos 17 gårdar. Data hämtades från åren 2013 och 2014. Fem av gårdarna hade lösdrift med liggbås och 12 av gårdarna hade uppbundna kor.

För att underlätta de statistiska analyserna delades de registrerade klövsjukdomarna upp i två grupper; smittsamma klövsjukdomar och fångrelaterade klövsjukdomar. Dermatitis (lindrig), digital dermatit, klövröta, limax, vårta och klövspaltsinflammation ansågs vara smittsamma sjukdomar medan sulblödning, klövsulesår, dubbelsula, hålvägg/separation vita linjen, tåböld, sår/böld i vita linjen och fångbrytning ansågs vara fångrelaterade sjukdomar. Varje klövsjukdom tilldelades en poäng beroende på hur kliniskt allvarlig den var. Ju högre poäng en ko fick, desto sämre var klövhälsan. Poängen för varje klövverkningstillfälle jämfördes så att endast den högsta poängen för varje ko användes i de statistiska analyserna. Detta resulterade i att alla kor fick en maxpoäng för smittsamma sjukdomar (MIP) och en maxpoäng för fångrelaterade sjukdomar (MLP). Dessa två adderades så att alla kor också fick en total maxpoäng (MTP). För att undersöka om klövhälsan hade någon effekt på reproduktion och mjölkproduktion undersöktes fem parametrar; antal insemineringar, intervallet från första inseminering till den sista (IFLS), intervallet från kalvning till den sista insemineringen (ICLS), kalvningsintervall (CI) och den medelsnittliga ECM produktionen.

I studien var 50 % av alla kor friska och utan några rapporterade klövskador år 2013 och 2014 var siffran 52 %. Studien kunde inte finna någon signifikant korrelation mellan produktionsår och MIP, MLP och MTP. Fångrelaterade klövsjukdomar var generellt mer vanligt förekommande på gårdarna än smittsamma sjukdomar och det fanns en stor skillnad i förekomst av både smittsamma och fångrelaterade klövsjukdomar mellan gårdarna. Korna på gårdarna med lösdrift hade signifikant mer smittsamma klövsjukdomar båda åren ( $P=0.000$  och  $P=0.016$ ) jämfört med de gårdarna där korna stod uppbundna. Det fanns en signifikant skillnad i förekomst av fångrelaterade sjukdomar mellan de tre klövvårdarna som deltog i studien. Det fanns ingen skillnad i antal insemineringar, IFLS, ICLS, CI och medelsnittlig ECM produktion mellan gårdar med lösdrift och uppbundet. Den medelsnittliga ECM produktionen påverkades inte av ökade MIP, MLP eller MTP. Inte heller fanns det någon tendens för ett ökat antal insemineringar, längre ICLS eller längre CI då MTP ökade. Dock fanns det en tendens till en liten positiv korrelation mellan IFLS och MTP.

Uppgifter om att mjölkkor på Åland har bättre klövhälsa än deras motsvarigheter i Sverige kan varken bevisas eller förkastas på baserat på resultaten från denna studie. Detta var en epidemiologisk studie så det är inte möjligt att dra slutsatser om orsak och verkan. Dock kan studien förhoppningsvis fungera som stöd i det fortsatta arbetet för en förbättrad klövhälsa på Åland.

# 1. Introduction

The modernization and intensification of the agricultural industry has led to increased herd sizes and higher milk production (Campion et al., 2008; Tike, 2013; SCB, 2014) thereby putting high demands on the animals producing within the systems. One of the most pronounced differences nowadays compared to some decades ago is the new demands arising when transferring dairy cows from tie-stall barns to free stall systems. A major difference between the two housing systems is that cows in the free stall system have to move around in order to find feed and water and to be milked. This is, on the other hand, not necessary or possible in a tie-stall barn. The increased demand for mobility in combination with concrete floors and manure, affects the claw and leg health (Bergsten & Pettersson, 1992; Bergsten, 2001). Today, lameness and claw lesions have emerged as a frequent health problem among dairy cows (Warnick et al., 2001; Manske et al., 2002a; Campion et al., 2008) and are common reasons for culling (Sprecher et al., 1997; Rajala-Schultz & Gröhn, 1999).

Lameness is, according to Hedges et al. (2001), a disease that is associated with several risk factors such as nutrition, environment and management. Research suggests that a lame cow will produce less milk (Warnick et al., 2001; Green et al., 2002; Onyiro et al., 2008). In addition, oestrus detection is expected to become more difficult and lame cows are likely to experience reproductive inefficiency by having a longer interval between calving and conception and thus longer calving intervals (Lucey et al., 1986a; Collick et al., 1989; Sprecher et al., 1997). Even though claw problems are considered a major health concern research indicates that the occurrence of claw lesions can differ widely between herds (Barkema et al., 1994; Enting et al., 1997; Hedges et al., 2001; Manske et al., 2002a). This difference has also been noted by professional claw trimmers going to the Aland Islands and anecdotal evidence suggests that dairy cows on the Aland Islands have a superior claw health compared to their counterparts in Sweden.

## 1.1 Aim

The aim of this study is to analyze the claw health in association with reproduction and milk production of dairy cows at the Aland Islands in order to gain an understanding of the current situation.

## 1.2 Question formulation

What interactions exist between reproduction, milk production and claw health on dairy farms at the Aland Islands? Do dairy cows on the Aland Islands have better claw health than dairy cows in Sweden?

## 1.3 Hypothesis

The cows have in general good claw health, but cows with impaired claw health will have lower milk production and inferior reproduction results compared to cows with better claw health.

## 2. Literature review

### 2.1 Lameness and claw anatomy

It is important to have a general understanding of claw anatomy in order to realize why lameness and claw problems occur. Figure 1 shows the claw from below. The claw is surrounded by the wall, sole and bulb (heel) and their main function is to protect the foot from external stress when moving in different environments. When the cow is standing the weight of the body is mainly carried by the claw wall and not by the sole. The white line is located between the sole and the wall (see Figure 1). The white line consists of younger material than the wall and is therefore more vulnerable to external forces. Damage to the white line is especially common at the very back of the claw i.e., at the posterior wall. This is because the bulb is moving considerably when the cow is walking and this puts high pressure on the white line at the transition to the older wall material (Manske et al., 2002b).

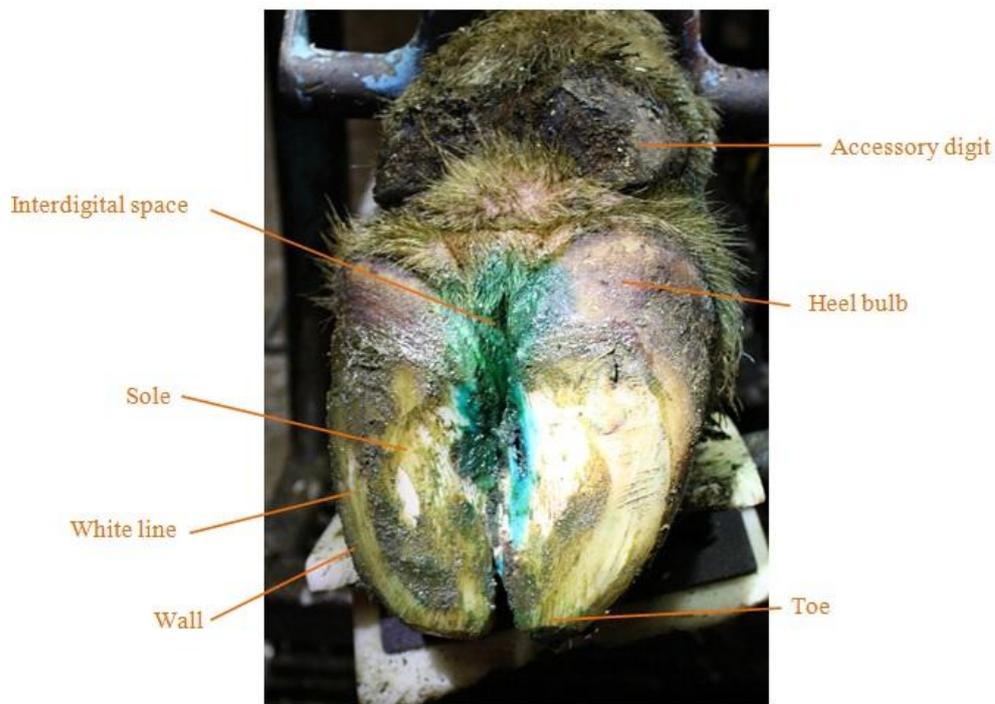


Figure 1: Anatomy of the claw. Photo: Carin Ekström.

The growth of the claw is a result of proliferation and keratinization of cells (MacCallum et al., 2002). The growth of the wall starts at the coronary band and is illustrated in Figure 2. The claw wall will grow about 4-6 mm/month (Offer et al., 2000; Manske et al., 2002b). The lamellar horn originates from the lamellar corium and can be recognized as the lamellar ring or white line. The sole and bulb also grows from their respective corium. The toe angle between the floor and the claw wall should be

45°-50° (see Figure 2) and the wear of the claw should ideally be equal to the growth of the claw (Manske et al., 2002b; Huxley et al., 2012). However, especially in free stall systems, the different characteristics of concrete floors influence the wear and this can result in an improper toe angle. The sole is often exposed to a moist environment making it softer and more sensitive to different kinds of trauma compared to the claw wall. Since the wall horn in the toe is harder than the bulb horn and the stress and the wear is greater at the bulb, the toe will be extended and the toe angle becomes shallower. The result is an overgrown claw, which is more sensitive to sole ulcers that can arise when the pedal bone pushes towards the sole (see Figure 2). Excessive wear of the wall can, on the other hand, result in the sole also becoming weight bearing and thereby creating pressure points that will increase the risk of injuries (Manske et al., 2002b; Telezhenko et al., 2009).

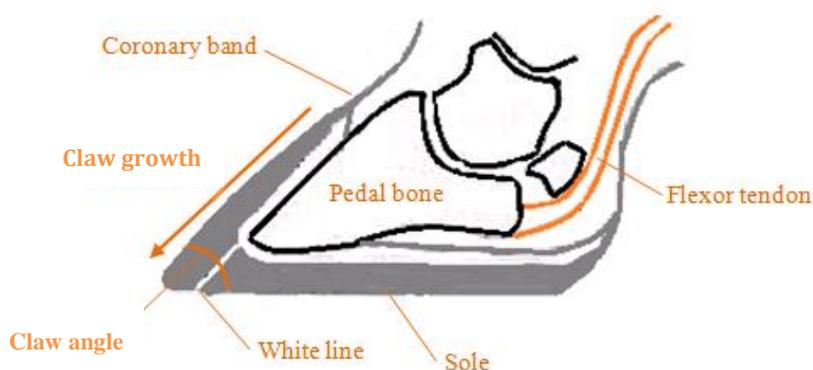


Figure 2: Illustration of the cross section of a claw. Modified from Hulsen (2011).

When the cow is walking she will carefully examine the ground in front of her in order to avoid placing the front feet on any obstacles. A cow with a normal gait will move with long strides and place the hind foot at the same spot as the front foot. The cow cannot see where she places the hind feet so this is a precautionary measure to avoid injuries. The cow will walk with a straight back and will have an even weight bearing between the left and right feet (O'Callaghan, 2002; Huxley et al., 2012). If a cow becomes lame the stride length will be shortened and the hind feet will no longer be placed in the same track as the forefeet (tracking up). The head will bob up and down and the back will be arched (Sprecher et al., 1997; Flower & Weary, 2009).

Bergsten (2001) defined lameness as an anomaly in the locomotor system while O'Callaghan (2002) in a similar way defined lameness as a condition which the animal exhibits by not being able to walk normally. The underlying cause may be a claw disorder or some kind of painful process in the limb (Murray et al., 1996; Bergsten et al., 2001). Studies have shown that the occurrence of lameness can differ greatly between farms. Warnick et al. (2001) reported that 40 and 52 % of the cows were treated for lameness at least once on the two farms included in the study. Barkema et al. (1994) demonstrated a significant difference in incidence of lameness between the participating farms ranging from 9.3 to 49.2 % while Enting et al. (1997) reported an average lameness incidence of 21 %. Green et al. (2002) reported that more than 70 % of the cows were diagnosed lame at least once during the study. Also, the lameness prevalence was 5.1 % in a study by Manske et al. (2002a). However, 72 % of the cows experienced a minimum of one claw lesion meaning that the majority of the claw lesions did not cause lameness.

Lameness is considered a multifactorial disease because there are many underlying factors that are contributing when a cow becomes lame (Vermunt, 2005). Manske et al. (2002a) and Capiion et al. (2008) therefore suggest that it may be advantageous to divide the underlying factors into cow-level and herd-level factors. One example of a cow-level factor is the individual milk production of each cow. There are evidence proving the existence of an unfavorable genetic correlation between health traits and production traits (Pryce et al., 1998) and this is also true for milk production since it is positively correlated to a high incidence of lameness (Hansen et al., 1979). This means that breeding

for higher milk production has brought about a higher incidence of lameness (Onyiro et al., 2008). However, the exterior of the cow is also of importance since studies have shown that for example sickled legs are related to poorer locomotion (Onyiro and Brotherstone, 2008).

Age and stage of lactation are other cow-level factors. Several studies have demonstrated that the highest lameness incidences were revealed during the first months of lactation (Collick et al., 1989; Barkema et al., 1994; Offer et al., 2000; Warnick et al., 2001; Green et al., 2002) and that older cows had a higher incidence and prevalence of lameness (Barkema et al., 1994; Warnick et al., 2001; Bicalho et al., 2007; Onyiro et al., 2008). Body weight is also considered to be a cow-level factor. Onyiro et al. (2008) demonstrated that cows with lower body weight had more locomotion problems. Also the body condition score (BCS) was correlated to locomotion problems and cows with a high BCS had higher locomotion scores (Onyiro et al., 2008).

Herd-level factors include factors such as season of the year, feeding and housing system. Onyiro et al. (2008) demonstrated that cows receiving a high concentrate/low forage ration and were housed throughout the year had higher lameness scores compared to cows receiving a low concentrate/high forage ration and that had access to pasture during the summer. Somers et al. (2003) and Onyiro and Brotherstone (2008) demonstrated in agreement with Onyiro et al. (2008) that cows having access to pasture and cows housed in straw yards suffered less from claw problems compared to cows housed on concrete floors. Pasture has also been shown to improve the gait of lame cows while the gait of cows housed on concrete floors tended to be stable or impaired (Hernandez-Mendo et al., 2007). However, a large proportion of today's dairy cows are housed on concrete floors. According to Bergsten (2001), the floors must not be too slippery, hard or dirty in order not to compromise the health of the claws and legs. Rubber floors can provide a better comfort and is preferred by the cows (Telezhenko et al., 2007).

Approximately 90 % of the lameness cases in cattle originate from claw lesions (Murray et al., 1996; O'Callaghan, 2002) and occur more often in the hind feet (Murray et al., 1996; O'Callaghan, 2002; Barkema et al., 2004). However, as mentioned earlier, claw lesions do not always result in lameness (Logue et al., 1994; Manske et al., 2002a). Globally, the most common causes for lameness are sole ulcer, white line disease, digital dermatitis, and foul-in-the-foot. However, the impact of these disorders varies between countries and management systems (Barkema et al., 2004; Huxley et al., 2012). Cows housed in a free stall system have to move around to find feed and water but this is not necessary in a tie-stall barn. This means that all claws of cows in a free stall system are exposed to the same environment. The claws of cows in a tie-stall system, on the other hand, are exposed to quite different environments (Sogstad et al., 2005). There is evidence that cows housed in free stalls suffer from a higher incidence of lameness and claw lesions compared to cows in a tie-stall housing system (Hultgren, 2002; Cramer et al., 2008).

## 2.2 Animal welfare

Changes in behavior are used in both research and in animal production practice as common signs of pain and discomfort in animals (O'Callaghan, 2002). Both Singh et al. (1993) and Hassall et al. (1993) could see that cows suffering from lameness changed their behavior. Therefore, and because of the high incidence and the pain associated with the disorder, lameness is considered to be an animal welfare issue (Hernandez et al., 2002). Singh et al. (1993) conducted a study in which the behaviors of lame and healthy cows were compared. The study included 10 lame and 10 healthy cows; 15 cows were housed in cubicles and five of the healthy cows were housed in a straw yard. The researchers observed the cows every 15 min for 24 hours and this procedure was repeated three times. The observed behaviors were total time spent for rumination, standing and lying. Eating time as well as the number of times the animal lied down and the maximum lying period, both for 24h, were included. Healthy cows housed in free stalls lay down significantly shorter than their herd mates in the straw yard system. Also, the healthy cows in cubicles lay down shorter than the lame cows. The lame cows were standing with arched backs and repetitively changed which leg they put weight on resulting in abnormal standing behaviors. The researchers concluded that the cows seemed to minimize pain by

changing posture. This suggests that lameness is a matter of serious concern from an animal welfare perspective (Singh et al., 1993). Juarez et al. (2003) reported that the percentage of cows lying down increased, that the cow stayed in a shorter distance of the pen exit and that the time taken to move from the milking parlor increased with increasing locomotion scores in their experiments. The results of the study by Hassall et al. (1993) showed that lame cows entered the milking parlor later, lay down for longer periods of time and grazed for shorter periods of time compared to healthy herd mates. The cows changed their behavior to such a great extent that Hassall et al. (1993), in agreement with Singh et al. (1993), wanted to emphasize that lameness truly is an animal welfare problem.

Cows are believed to hide the signs of pain and discomfort because this is a part of their natural behavior. However, this might result in the farmer having difficulties detecting lame cows (O'Callaghan, 2002). Wells et al. (1993) performed an epidemiologic study in which farmers were asked to estimate the prevalence of lameness on their farms. The researchers then scored the cows and this number was compared to the prevalence estimated by the farmers. The prevalence estimated by the farmers proved to be 2.5 times lower than the prevalence obtained by the investigators. Also Whay et al. (2002) performed a study in which the perception of lameness was evaluated in a similar manner. Whay et al. (2002) also concluded that the farmers underestimated the prevalence of clinical lameness on their farms; the farmers reported a prevalence of about 5 % while the observer found an average prevalence of about 22 %. The fact that farmers do not recognize most lameness cases poses a great risk that numerous cases of mild or moderate lameness remains undetected (Wells et al., 1993) and that lame cows therefore are less likely to get the treatments they need (Whay et al., 2002). However, research has found that cows change their feeding behavior two weeks before becoming lame and this may be used as a tool for monitoring lameness in the future (Norrington et al., 2014).

Culling is the fate of many lame cows. According to Rajala-Schultz and Gröhn (1999) culling caused by diseases can be categorized as involuntary culling while voluntary culling is the act of removing a cow from the herd because of for example a low milk yield or bad temper. Lame cows are more likely to be culled than non-lame cows (Rajala-Schultz and Gröhn, 1999) and this has been demonstrated by several studies. Rajala-Schultz and Gröhn (1999) reported that cows treated for foot and leg problems in the beginning of lactation had a six times greater risk of being culled than healthy cows. A cow had a 12 times higher risk of being culled if she was treated for foot and leg problems during the second month of lactation compared to a healthy cow. A study by Melendez et al. (2003) included one group of lame cows and one control group. The researchers reported that 30.8 % of the cows in the lame group left the herd whilst 5.4 % of the cows from the control group were culled before any reproductive event was recorded. Collick et al. (1989) found that almost 16 % of the lame cows were culled compared to about 5 % of the control cows while Sprecher et al. (1997) concluded that there is an 8.4 times higher risk of the cow being culled if she receives a lameness score  $>2$  compared to a cow receiving a lameness score of  $\leq 2$ .

## 2.3 Fertility

The effects of lameness on fertility have been studied for several decades. Weaver (1985) mentions infertility as a result of lameness as a plausible cause of economic loss for the British dairy farmers. According to Weaver (1985) a cow suffering from lameness will spend longer time lying and be less eager to mount other cows making estrus detection more difficult resulting in a longer interval between calving and conception.

Back in the 80's both Lucey et al. (1986a) and Collick et al. (1989) conducted studies in which the aim was to investigate the effect of lameness on fertility. The study by Lucey et al. (1986a) included 770 cows and 1491 lactations from calvings occurring between July 1977 and June 1982. Collick et al. (1989) on the other hand included 17 herds in the Somerset area during the housing period from October to April. Both studies included Friesian, Holstein and Ayrshire cows and cross breeds thereof. Lucey et al. (1986a) divided the lesions into four groups depending on where the affected areas were located: heel, wall/corony band, interdigital cleft and sole/white line. Also Collick et al. (1989)

divided the cause of lameness into groups. These groups were interdigital diseases, digital diseases and sole ulcers.

Both studies could demonstrate that the intervals between calving to first service and between calving and conception were affected by lameness. The calving to first service interval increased by seven (Lucey et al., 1986a) and four days (Collick et al., 1989). The interval between calving and conception increased by 11 (Lucey et al., 1986a) and 14 days (Collick et al., 1989) in cows diagnosed with lameness. The timing of when lameness struck and the type of lesion proved to be of importance. Lesions in the interdigital cleft arising 36 to 70 days postpartum resulted in a significantly longer calving to first service interval. Cows diagnosed with sole or white line lesions had a 17 days longer calving to first service interval and 30 days longer calving to conception interval when the lesion occurred in the same time period (36 to 70 d postpartum; Lucey et al., 1986a). Cows suffering from lameness needed more services per conception (2.14 vs. 1.72) and had a lower pregnancy rate at first service (45.9 vs. 56.3 %) compared to the control cows (Collick et al., 1989).

In a study by Sprecher et al. (1997) a five point lameness scoring system was introduced. In this system the best score (score one, normal) was given to a cow that walked with a normal gait and had a leveled back when standing still. The most severe score (score five, severely lame) was given to a cow that was reluctant to put weight on one or several feet. The study aimed at predicting the reproductive performance of the cows using this lameness scoring system. The study was conducted on one farm and included in total 66 cows. The researchers concluded that lameness increased the difficulty of estrus detection. Sprecher et al. (1997) demonstrated, in accordance with Lucey et al. (1986a) and Collick et al. (1989), that a cow with lameness score >2 were likely to have a prolonged interval between calving and first service and between calving and conception. As a result, the cow needed more services to enter gestation (Sprecher et al., 1997).

Also Barkema et al. (1994) investigated the effect of lameness on fertility and found similar results as reported by Lucey et al. (1986a), Collick et al. (1989) and Sprecher et al. (1997). The study included 13 commercial dairy farms with an average herd size of 64 cows. Information about milk production, reproduction, culling and lameness were collected by veterinarians and the farmers. The study included a control group of 1798 lactations from cows that were not lame and 637 lactations from cows reported lame. Compared to the control group, the interval from calving to first service was 2.9 and 4.6 days longer when the cow was lame in a hind- or fore leg respectively. However, despite the results, the researchers concluded unlike Lucey et al. (1986a), Collick et al. (1989) and Sprecher et al. (1997), that lameness only had a limited effect on reproduction (Barkema et al., 1994). Bicalho et al. (2007) also conducted a study investigating the calving to conception interval. Bicalho et al. (2007) concluded that the interval was significantly prolonged in cows suffering from lameness during the 70 first days of lactation.

The intervals between calving and first service and calving and conception is, however, not the only things to consider. Melendez et al. (2003) conducted an epidemiologic study in order to investigate the relationship between postpartum lameness and the occurrence of ovarian cysts. The researchers assumed that cows suffering from lameness postpartum would also suffer from an increased incidence of ovarian cysts compared to healthy cows. The study included in total 195 cows; 65 cows had been diagnosed with lameness within 30 days postpartum and 130 cows served as controls and had never been lame. The cows were housed on a commercial farm holding 3000 dairy cows with an average production of 10,500 kg per cow and year. Except for ovarian cysts, the study also examined the calving to first service interval, the pregnancy rate and conception rate at first service. The study found that the control cows were 4.22 times more likely to become pregnant after the first service compared to the lame cows. Also, the risk of a cow developing ovarian cysts before the first service was 2.63 times greater if she was lame 30 days postpartum. The authors concluded that lameness within 30 days after calving resulted in inferior fertility, that the cow was less likely to conceive and that the incidence of ovarian cysts increased compared to healthy cows (Melendez et al., 2003).

Garbarino et al. (2004) investigated the association between lameness and delayed ovarian cyclicity during 60 days postpartum and the number of days to first luteal phase. The study included 238 Holstein cows from a commercial dairy farm using estrus synchronization. The cows were reported as

lame, moderately lame or not lame according to the system introduced by Sprecher et al. (1997) with a few modifications. Garbarino et al. (2004) reported that delayed cyclicity was more common among cows that were lame (17 %) or moderately lame (14 %) compared to non-lame cows (6 %). The interval between calving and first luteal phase was longer among moderately lame and lame cows compared to cows that were not lame. The authors concluded that lameness do have a negative effect on the ovarian cyclicity, at least in Holstein cows during the first 60 days postpartum. If lameness had been prevented could the delay in ovarian cyclicity have been reduced by 71 % (Garbarino et al., 2004).

## 2.4 Milk production

The effect of lameness on milk production is of great interest and has consequently been studied by several researchers. The results of the studies are not, however, all in agreement with each other. As mentioned earlier, Barkema et al. (1994) also collected information about milk production. Barkema et al. (1994) concluded, in accordance with Hultgren et al. (2004), that milk production was not decreased by lameness. On the other hand, cows suffering from sole ulcers actually had a higher 100-day in milk (DIM) production (77 kg) and 270-DIM production (171 kg) compared to the control cows. No other lameness diagnoses resulted in any difference in milk production. However, Barkema et al. (1994) concluded that the study would benefit from daily measurement of milk production and calculations of the deviation from the lactation curve.

Also Dohoo and Martin (1984a) could find an effect of foot problems on milk production. The aim of the study was to estimate the effect of several diseases on milk production and reproduction by using a path model developed in Dohoo and Martin (1984b). The study included records from 2875 lactations from 2008 Holstein-Friesian cows. The researchers concluded that foot problems resulted in an increased milk production of 1.6 % per day of life. However, they could not explain what was causing this large positive effect on milk production due to the epidemiologic study design (Dohoo & Martin, 1984a).

There are however a greater number of studies demonstrating a negative effect of lameness on milk production. Lucey et al. (1986b) were able to demonstrate a significant decrease in milk yield (1.1 kg/day) one week before and after lameness was clinically diagnosed. Also, Green et al. (2002) could see a reduction in yield long before lameness was diagnosed. Green et al. (2002) conducted a study in which the objective was to investigate the relationship between lameness and milk production. The study included data from 900 Friesian/Holstein cows that were housed on five farms in the UK during 1997 to 1999. Test day-milk yields were recorded for each cow once every month and were included in the study. The farmers detected clinical lameness that was treated and diagnosed by veterinarians. The researchers reported that more than 70 % of the cows were lame at some point during the study period. A reduction in milk yield in cows identified as lame could be seen as early as four months before the lameness was even diagnosed. The study demonstrated that this reduction in milk yield could continue until five months after the cow had been treated.

Green et al. (2002) estimated that the total reduction in milk yield was 357 kg (range 160 to 550 kg) during a 305-day lactation if the cow became lame in the fifth month of lactation. However, in accordance with Barkema et al. (1994) and Hultgren et al. (2004) this study also identified cows with a higher yield than average to be more prone to develop lameness compared to cows with a lower milk yield. Green et al. (2002) believed that this was due to the fact that high yielding cows experienced a negative energy balance and must stand for long times in order to consume enough feed. The benefit of a high producing cow will be lost if she becomes lame because of the reduction in milk production. The farmer must therefore either take extra good care of high yielding cows or, if this is not possible, aim for a lower average production. The researchers concluded that the reduction in milk yield varied between farms, but that a clinically lame cow is likely to produce less milk than her potential (Green et al., 2002).

By using records from two commercial New York dairy farms Warnick et al. (2001) also investigated the effect of lameness on milk production. The participating farms housed mostly Holstein cows and

both farms used recombinant bST (growth hormone). On one farm lameness was identified as severe, moderate or mild and both diagnosed and treated by the farm staff. On the other farm claw lesions were diagnosed either by the farm staff or by a professional claw trimmer. The study included in total 2520 cows of which more than two-thirds were entering their first or second lactation. Milk production was recorded weekly as a total daily milk production. Of the cows included in the study, 52 % in the first herd and 40 % in the second herd received lameness treatment at least once during the study. The study revealed that lameness was significantly more prevalent in older cows and that lameness had a negative impact on milk production. Lameness resulted in a significant decrease in milk yield on both participating farms. The daily milk yield decreased by 1.5 kg/d during the second week and thereafter as from the lameness diagnosis on the first farm. On the second farm the reduction in milk yield of lame cows was slightly smaller, 0.8 kg/d during the first two weeks after diagnosis and 0.5 kg/d during the third week and thereafter. Different diagnoses affected the milk yield to various degrees. On the first farm sole ulcers and abscesses had a greater negative impact on the drop in milk production and its duration compared to cows diagnosed with foot warts (digital dermatitis), foot rot or healthy cows. A similar pattern was revealed on the second farm, however, sole ulcers and abscesses tended not to have as long and large effect on the milk yield as foot rot.

Rajala-Schultz et al. (1999) conducted a study in which the aim was to explore the effects of lameness as well as ketosis and milk fever on milk production. The study included 23,416 Finnish Ayrshire cows and test day milk production data was collected once every month. The researchers reported a decrease in milk yield among cows suffering from lameness. However, the magnitude of the effect of lameness on milk yield varied depending on lactation number. Cows in their first lactation experienced a significant decrease in milk production starting already two weeks before the cow actually was diagnosed as lame. The decrease in production continued throughout the entire lactation resulting in a loss of 1.0-1.6 kg/d during different stages of lactation. The study did identify a decrease in production during the second lactation; however, this decrease was not significant. During the third lactation the decrease was greatest 15-28 days after diagnosis, resulting in a significant decrease of 2.2 kg/d. Cows entering their fourth or later lactation also experienced a significant decrease two weeks before the cow was diagnosed with lameness. The significant reduction in milk yield continued for another six weeks and ranged between 1.7-2.8 kg/d. In conclusion, lameness had a detrimental effect on milk production in this study and cows in their first lactation were affected the most.

By using locomotion scores, based on the system introduced by Sprecher et al. (1997), Juarez et al. (2003) investigated how lameness influenced the behavior and milk production of multiparous Holstein cows. The study consisted of two experiments; experiment 1 and experiment 2 that were performed on two different farms. During experiment 1 milk production data was collected. The cows were housed in four pens, two close to the milking parlor (38 m) and two further away from the parlor (121 m). Behavioral data were collected and consisted of the return time from the parlor after milking, if the cow was standing, walking or lying in the pen and the cow location inside the pen (close to the exit or not). The second experiment was conducted in a similar way as the first experiment but was repeated two times. The cows were housed in three pens located 34, 64 and 94 m from the milking parlor. The researchers did not find a difference in milk production or protein and fat yields between locomotion scores and distance from the parlor in experiment 2. In experiment 1, on the other hand, there was a decrease in milk and protein production with increasing locomotion score. Juarez et al. (2003) recognized season and different feeding schedules as factors that could affect the results obtained in the study.

In a more recent study Onyiro et al. (2008) aimed at explaining the association between locomotion scores and milk production and how lameness influenced the shape of the lactation curve. The study included 248 cows that were divided into two management groups. One group was fed a low-forage, high-concentrate ration. The cows in the other group had the opportunity to graze for 7 months and their ration included at least 75 % DM forage. The system for locomotion scoring the cows was based on five scores. A cow given score one were considered normal and a cow given score five found it difficult to turn around. First lactation cows were considered to be one group and older cows (lactation 2, 3, 4 and 5) were one group when the analysis was performed. The researchers found that cows that become lame during the 60 first days of lactation had a higher milk production than healthy cows

during this period. However, the cows were not able to continue producing more milk during the rest of the lactation and the total milk yield did therefore not differ between healthy cows and cows being lame during the first two months of lactation. The healthy cows therefore had a more persistent lactation. Onyiro et al. (2008) explained that the increased milk yield among lame cows was due to the fact that high milk production was associated with higher locomotion scores and we should therefore not misinterpret these results and breed for inferior claw health to achieve higher milk production.

There are also studies that could not find any effect of lameness on milk yield. Cobo-Abreu et al. (1979) used a university herd to investigate the effect of several diseases on milk production as well as calving interval and culling. The study did find a small reduction in milk production among cows suffering from foot problems resulting in a lower than average life time milk yield. However, this reduction was not significant (Cobo-Abreu et al., 1979). Martin et al. (1982) included 18 farms holding purebred Holstein cows in a study in order to recognize diseases that increased the risk of culling. Even though the effect of the investigated diseases on milk production was not described in detail the researchers did not find a significant effect of foot problems on milk yield.

## 2.5 Economy

Diseases are considered to have a negative impact on farm economy. According to Kossaibati and Esslemont (1997) the costs for diseases could be divided into two different parts; direct and indirect costs. Costs involved with low milk yield, more working hours and medication are examples of direct costs. Longer calving intervals, extra services, greater risk for culling and other health problems are examples of indirect costs. It is important, according to Kossaibati and Esslemont (1997), to recognize the indirect costs and to realize that the total cost for a disease in reality can be higher than only the direct costs.

There are several studies investigating the impact of lameness on farm economy. Back in 1983 Whitaker et al. conducted a survey about incidence of lameness in dairy cattle. The study included 185 dairy farms and 21,000 cows from England and Wales. The researchers estimated that the cost for lameness was £1175 per year in a herd holding 100 cows. This indicated that the British dairy farmers lost £35 million in total due to lameness. Whitaker et al. (1983) realized that this was a rough estimate but concluded that lameness played a significant economic role. Kossaibati and Esslemont (1997) conducted a study in which the economic impact of some selected production diseases was estimated. The study was performed on 90 commercial dairy farms in England and was based on current prices for that time period. The researchers concluded that lameness contributed to the second largest health costs next to mastitis. The costs related to lameness were derived primarily from inferior fertility, that less milk was sold to the dairy plant and that more cows were culled. The study found the total cost for one case of lameness to be approximately £245. However, the total cost per affected cow was approximately £270 because a lame cow suffered an average of 1.4 cases.

Enting et al. (1997) used an epidemiologic study to investigate economic losses originating from clinical digital diseases. Data was collected by veterinarians from 21 Dutch farms and included in total 2183 cows. The collected data included information about milk production (yield, fat and protein), culling rate, calving interval and incidence of diseases. Enting et al. (1997) found in accordance with Kossaibati and Esslemont (1997) that lameness was one of the most costly diseases affecting the Dutch dairy cows. Only mastitis and fertility problems were considered more economically challenging. Enting et al. (1997) reported that each lame cow cost about NLG 230. In this study the researchers found similar underlying causes resulting in economic losses as reported by Kossaibati and Esslemont (1997). However, except reasons related to culling, milk production and fertility Enting et al. (1997) also found veterinary costs and extra labor associated with treating sick animals to be factors contributing to the total loss.

In a more recent study by Cha et al. (2010) a somewhat different approach was used. The objective was to help the farmer to manage lameness by calculating the cost for sole ulcer, digital dermatitis and foot rot on an individual cow level. The researchers created a model in order to evaluate if it was more profitable to replace a cow, keep a cow without inseminating her or inseminate her and thereby keep

the cow in the herd. This was implemented for all of the above mentioned disorders. Sole ulcer proved to be the most expensive cause of lameness. The average cost for one case of sole ulcer, digital dermatitis and foot rot was roughly 216, 130 and 120 US\$, respectively. Interestingly, the study found that the underlying costs differed depending on lameness diagnosis (Table 1).

Table 1. *The cost of sole ulcer, digital dermatitis and foot rot expressed as percentage of total cost for milk loss, decreased fertility and treatment. Modified from Cha et al. (2010)*

<b>Lameness diagnosis</b>	<b>Milk loss</b>	<b>Decreased fertility</b>	<b>Treatment cost</b>
<b>Sole ulcer</b>	38.4	33.3	28.3
<b>Digital dermatitis</b>	27	31	42
<b>Foot rot</b>	28	45	27

Milk loss accounts for the major cost per case of sole ulcer while treatment costs and decreased fertility constitutes the main costs of digital dermatitis and foot rot, respectively. Lactation number, pregnancy status and milk yield potential are also factors that affect the cost of lameness. For example, the cost of lameness was found to be less in older cows compared to younger cows because these cows have a shorter life expectancy (Cha et al., 2010).

Also Ettema and Østergaard (2006) wanted to assist decision making and lameness management. In this study, as in the study by Cha et al. (2010), a model was used in order to calculate the cost of lameness. The default herd was set to correspond to a typical Danish herd. The researchers concluded that each case of lameness resulted in an economic loss of €192 in the default herd. Barkema et al. (1994), on the other hand, did not agree with the earlier presented studies. In this study the effect of lameness on reproductive performance was investigated and the researchers did not conduct an economic analysis. Nevertheless, the study concluded that there was only a limited effect of lameness on reproduction and no effect on culling and production. Barkema et al. (1994) therefore anticipated that lameness should not have a major effect on farm economy.

### 3. Material and Method

The study was performed by collecting claw health protocols as well as data from the Finnish national cattle database from 17 dairy farms situated on the Aland Islands. Of the 1975 trimmed cows, 45 % (12 farms) were housed in tie-stalls and 55 % (5 farms) were housed in free stalls. At the time of the study three professional claw trimmers, all based in Sweden, were contracted to trim cows at farms on the Aland Islands. Claw health protocols were filled in by the claw trimmer when visiting the participating farms for scheduled trimming sessions during the years 2013 and 2014.

In Table 2 the mean milk production (kg) and the mean ECM production (kg) on the Aland Islands and in Finland during the years 2013 and 2014 are illustrated. The data is collected from farms that are part in the Finnish national cattle database. It is not mandatory to submit farm data to the national database meaning that the database does not comprise all farms in Finland. The Aland Islands have, compared to Finland, a higher average milk production. The difference between the Aland Islands and Finland was 539 kg milk and 930 kg ECM in 2013 and even greater in 2014 (883 kg milk and 1187 kg ECM) (Ålands Hushållningssällskap, 2013; Ålands Hushållningssällskap, 2014).

Table 2. Mean milk and ECM production on the Aland Islands compared to Finland in 2013 and 2014 (Ålands Hushållningssällskap, 2013; Ålands Hushållningssällskap, 2014)

Region	Milk 2013 (kg)	ECM 2013 (kg)	Milk 2014 (kg)	ECM 2014 (kg)
<b>Aland</b>	9497	10007	9995	10423
<b>Finland</b>	8958	9077	9112	9236

Threshold values for reproductive parameters are set in the Finnish national cattle database. The aim is to achieve a calving interval of 365-375 d., an interval from first service to last service of 0-20 d. and 1.0-1.6 services per calving. These parameters should not exceed 400 d., 30 d. and 2, respectively.

#### 3.1 Claw health protocols

The claw health protocol was divided into two sections. The herd number and claw trimmer identity as well as the date of the visit were specified in the first section. In the second section the trimmer recorded the identity number of the cow being trimmed and any claw problems detected during trimming. The severity of the problem (mild or severe) and if the trimmer decided to treat the claw in some way were also noted in the protocol. The protocol was filled in by hand during the trimming session by the claw trimmer since the claw trimmers that are currently working on the Aland Islands did not have the opportunity to use the Finnish computer software.

### 3.2 Animals and participating farms

Data concerning milk production and reproduction was collected from the Finnish national cattle database. The data included information about cow identity, date of birth, calving date, year of production, milk production (kg), energy corrected milk production (kg ECM), number of feed days, number of services, interval from calving to first service (ICFS; days), interval from first service to the last service (IFLS; days), calving interval (CI; days), recorded treatments as well as culling date and reason for culling. All the information was based on calendar year and not on lactation. From this data information about mean milk production (kg/d.) and mean ECM production (kg/d.) could be calculated by dividing milk production and ECM production with the number of feed days for each cow. Also, the interval from calving to last service (ICLS; days) could be calculated by adding the retrieved information about ICFS with the IFLS. All the participating farms were visited during August and September of 2014. During the visits information about housing system was collected (free stalls or tie-stalls).

At the time of the study there were 38 dairy farms at the Aland Islands. However, some farms were excluded from the study due to the lack of claw health data and data from the Finnish national cattle database. Therefore, the material included data from 17 farms, meaning that approximately 45 % of the total number of farms was included in the study. One farm was excluded in the 2014 dataset because no data from the Finnish national cattle database was available from that farm. Information concerning ICLS is missing from another farm in the 2014 dataset because information about ICFS and IFLS was missing in the national cattle database. In total 1298 individual cows were included in the study. However, each farm applied different claw trimming routines, meaning that the number of claw trimming sessions per year varied between the participating farms (range 1-3 times/year). The implication of this is that the number of cows trimmed was in total 1975 after adding all trimming sessions for each cow together for the years 2013 and 2014.

The recorded diseases were divided into two groups for analysis purposes; infectious diseases and laminitis related diseases. Dermatitis, digital dermatitis, heel horn erosion, interdigital hyperplasia, wart growth, and interdigital phlegmone were considered as infectious diseases while sole hemorrhage, sole ulcer, double sole, white line fissure, toe abscess, white line abscess and chronic laminitis were considered as laminitis related diseases. Only the most severely affected foot was used in the statistical analysis if a cow had several ulcers on different feet. A severity scoring system similar to the system adopted by Greenough & Vermunt (1991) and Bergsten & Herlin (1996) was used in the analysis. Each disease was then given a severity score depending on its clinical severity (Table 3 and 4). The scores of infectious diseases and laminitis related diseases were added together into a total score for each cow for each trimming session.

In the statistical analyses the scores given to a cow for infectious diseases, laminitis related diseases and the total score during each trimming session were compared so that only the most severe score from each of these parameters were used. This resulted in each cow having a maximum score for infectious diseases (maximum infectious point, MIP), a maximum score for laminitis related diseases (maximum laminitis point, MLP) and a maximum score for the total score (maximum total point, MTP). The conformation of the claw was not considered in the statistical analysis because this information was not always available. Other information that was not included in the study was information about treatments and additional comments made by the claw trimmers.

Table 3. *Severity scoring of infectious diseases*

<b>Infectious diseases</b>	<b>Points</b>
Dermatitis, mild case	1
Dermatitis, severe case	5
Heel horn erosion, mild case	1
Heel horn erosion, severe case	5
Interdigital hyperplasia	5
Wart growth	5
Digital dermatitis	5
Interdigital phlegmone	5

Table 4. *Severity scoring of laminitis related diseases*

<b>Laminitis related diseases</b>	<b>Points</b>
Sole hemorrhage, mild case	1
Sole hemorrhage, severe case	3
Sole ulcer, mild case	5
Sole ulcer, severe case	7
Double sole	3
White line fissure	3
Toe abscess	7
White line abscess	5
Laminitis	4

### 3.3 Statistical analysis

The data from the study were analyzed using Minitab Statistical Software (Minitab 16, Minitab Inc., State College, PA, USA). The statistical analyses were performed on herd level and on cow level. The herd level analyses were performed separately on mean values from year 2013 and 2014 but also on mean values from both years. The analyses on cow level included results from all trimmings for all cows and both years. On herd level descriptive statistics were calculated using the procedure descriptive statistics. The procedure two sample t-tests were used to determine if the means of the following parameters were different from each other: housing system and mean ECM production, housing system and number of services, housing system and IFLS, housing system and ICLS as well as housing system and CI. Variance analysis was performed in order to evaluate the effect of claw trimmer and housing system on MIP, MLP and MTP. The procedure used was General Linear Model and least square means. Pearson correlation coefficients was calculated using the procedure correlation between mean ECM production, number of services, IFLS, ICLS, CI, MIP, MLP and MTP. On the individual cow level boxplot diagrams were used to display the retrieved data. The means were considered to be statistically different in all analyses if  $P < 0.05$ . However, trends where  $P > 0.05$  was also noted.

## 4. Results

Fifty per cent of the total number of trimmed cows during 2013 and 52 % in 2014 had no recorded claw lesions and consequently a maximal severity score of zero. Table 5 shows the mean values of the parameters included in the statistical analyses.

Table 5. Mean values of the mean ECM production, number of services, interval from first service to last service (IFLS), interval from calving to last service (ICLS) and calving interval (CI) during the years 2013 and 2014

Year	Mean ECM prod. (kg/d.)	No of services	IFLS (d.)	ICLS (d.)	CI (d.)
2013	30.1	1.7	39	122	397
2014	29.5	2.1	41	124	402

### 4.1 Claw health

Figure 3 illustrates the prevalence of infectious and laminitis related diseases in the 17 participating farms.

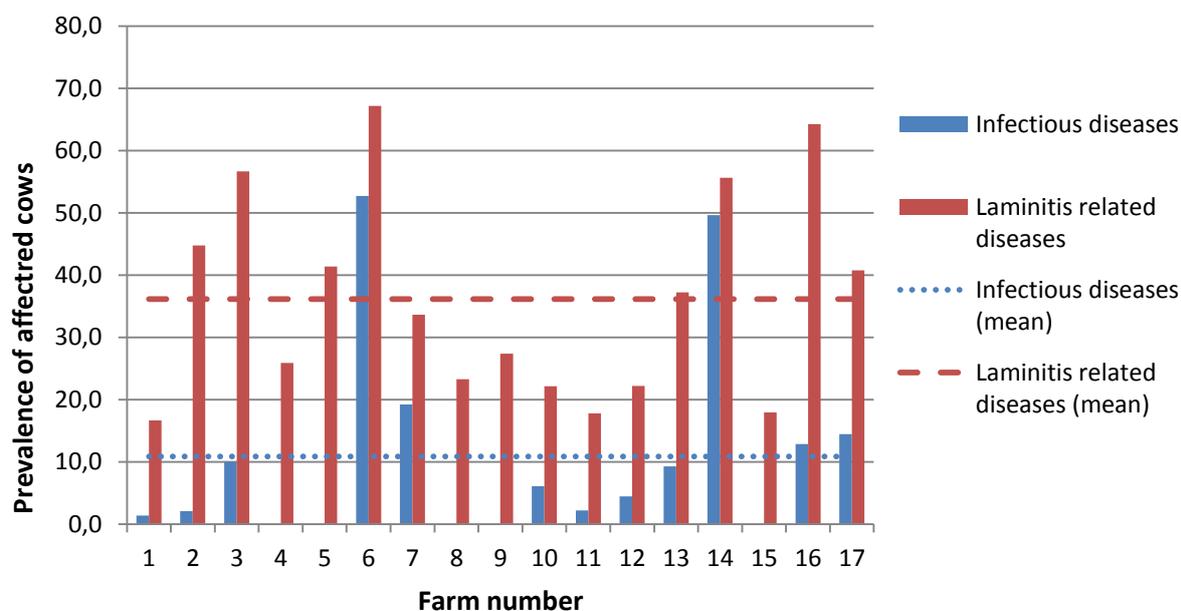


Figure 3. Prevalence of infectious and laminitis related diseases on the 17 participating farms.

Laminitis related diseases were more common on all farms compared to infectious diseases. There was a great difference in the prevalence of both laminitis related diseases (range 16.7 to 67.2 %) and infectious diseases (range 0.0 to 52.7 %) between farms (Figure 3).

There was no difference in the prevalence of infectious diseases between any of the years. There were, on the other hand, significantly more infectious diseases on farms with free stall systems compared to farms with tie-stalls during both years (P=0.000 and P=0.016). There were no significant differences in the prevalence of laminitis related diseases or MTP between tie-stalls and free stalls. There was a significant difference in the occurrence of laminitis related diseases (P-value: 0.024) and in MTP (P-value: 0.026) recorded by the three claw trimmers during the year 2013 but not during 2014 (P-value: 0.445).

Table 6 demonstrates the Pearson correlation coefficients between year of production, MIP, MLP and MTP in the combined 2013 and 2014 dataset. There were no significant correlations between year of production and MIP, MLP and MTP. It existed, on the other hand, significant positive correlations between MIP and MTP and between MLP and MTP. The correlation coefficient was however slightly lower in the first comparison (0.734 vs. 0.919).

Table 6. *Pearson correlation coefficients between year of production, maximum infectious points (MIP), maximum laminitis points (MLP) and maximum total points (MTP) in the 2013 and 2014 combined dataset. P-value within brackets*

2013 & 2014	Year of production	MIP	MLP
<b>MIP</b>	-0.068 NS		
<b>MLP</b>	0.202 NS	0.410 NS	
<b>MTP</b>	0.123 NS	0.734 (0.001)	0.919 (0.000)

## 4.2 Reproduction

There were no significant differences between tie-stalls and free stalls herds concerning any of the reproduction parameters. However, there was a tendency for a higher number of services in tie-stalls in the 2013 dataset (P-value: 0.060) and in the joined 2013 and 2014 datasets (P-value: 0.058).

Table 7 demonstrates the Pearson correlation coefficient between the above mentioned parameters and MIP, MLP and MTP in the 2013 dataset. There were no significant correlations between any of the reproductive parameters and MIP, MLP and MTP. However, there were significant positive correlations between IFLS and ICLS (0.799), IFLS and CI (0.045) and ICLS and CI (0.559).

Table 7. *Pearson correlation coefficient between number of services, interval from first service to last service (IFLS), interval from calving to last service (ICLS), calving interval (CI) and maximum infectious points (MIP), maximum laminitis points (MLP) and maximum total points (MTP) during year 2013. P-value within brackets*

2013	IFLS	ICLS	CI	MIP	MLP	MTP
<b>No. services</b>	0.127 NS	-0.180 NS	0.165 NS	-0.252 NS	-0.272 NS	-0.415 NS
<b>IFLS</b>		0.799 (0.000)	0.492 (0.045)	0.340 NS	0.375 NS	0.427 NS
<b>ICLS</b>			0.559 (0.020)	0.305 NS	0.183 NS	0.254 NS
<b>CI</b>				-0.065 NS	-0.452 NS	-0.415 NS

Table 8. Pearson correlation coefficient between number of services, interval from first service to last service (IFLS), interval from calving to last service (ICLS), calving interval (CI) and maximum infectious points (MIP), maximum laminitis points (MLP) and maximum total points (MTP) during year 2014. P-value within brackets

2014	IFLS	ICLS	CI	MIP	MLP	MTP
<b>No. services</b>	0.601 (0.018)	0.342 NS	0.449 NS	0.229 NS	0.275 NS	0.272 NS
<b>IFLS</b>		0.835 (0.000)	0.748 (0.001)	0.383 NS	0.509 (0.053)	0.487 NS
<b>ICLS</b>			0.834 (0.000)	0.234 NS	0.460 NS	0.383 NS
<b>CI</b>				0.098 NS	0.201 NS	0.161 NS

Table 8 and Table 9 demonstrate the Pearson correlation coefficients between the reproductive parameters and MIP, MLP and MTP for the 2014 and the joined 2013 and 2014 datasets, respectively. There were no significant correlations between the reproductive parameters and MIP, MLP and MTP. There were however, a tendency for a moderate positive correlation between IFLS and MLP (0.509, p-value: 0.053) in the 2014 dataset and between IFLS and MTP (0.467, p-value: 0.059) in the joined 2013 and 2014 dataset. There were moderate and strong significant positive correlations between IFLS and ICLS, IFLS and CI and between ICLS and CI in both the 2014 dataset and in the combined 2013 and 2014 dataset. In contrast to the 2013 dataset it existed a strong positive significant correlation between number of services and IFLS (0.601) in the 2014 dataset and a tendency for a moderate correlation (p-value: 0.055) in the joined 2013 and 2014 dataset.

Table 9. Pearson correlation coefficient between number of services, interval from first service to last service (IFLS), interval from calving to last service (ICLS), calving interval (CI) and maximum infectious points (MIP), maximum laminitis points (MLP) and maximum total points (MTP) in the combined 2013 and 2014 dataset. P-value within brackets

2013 & 2014	IFLS	ICLS	CI	MIP	MLP	MTP
<b>No. services</b>	0.473 (0.055)	0.151 NS	0.263 NS	0.009 NS	0.033 NS	0.035 NS
<b>IFLS</b>		0.819 (0.000)	0.561 (0.019)	0.413 NS	0.409 NS	0.467 (0.059)
<b>ICLS</b>			0.665 (0.004)	0.287 NS	0.254 NS	0.291 NS
<b>CI</b>				0.016 NS	-0.196 NS	-0.163 NS

Boxplot diagrams were produced on individual cow level in order to demonstrate the relationship between number of services, IFLS, ICLS, CI and MTP. Some MTP: s only occurred once in the dataset and this was reflected by the lack of a complete box in the diagram. There was no tendency for more services, longer ICLS or longer CI with higher MTP (see Figure 4, Figure 6 and Figure 7). There was however a tendency towards a small increase in IFLS with increasing MTP (see Figure 5).

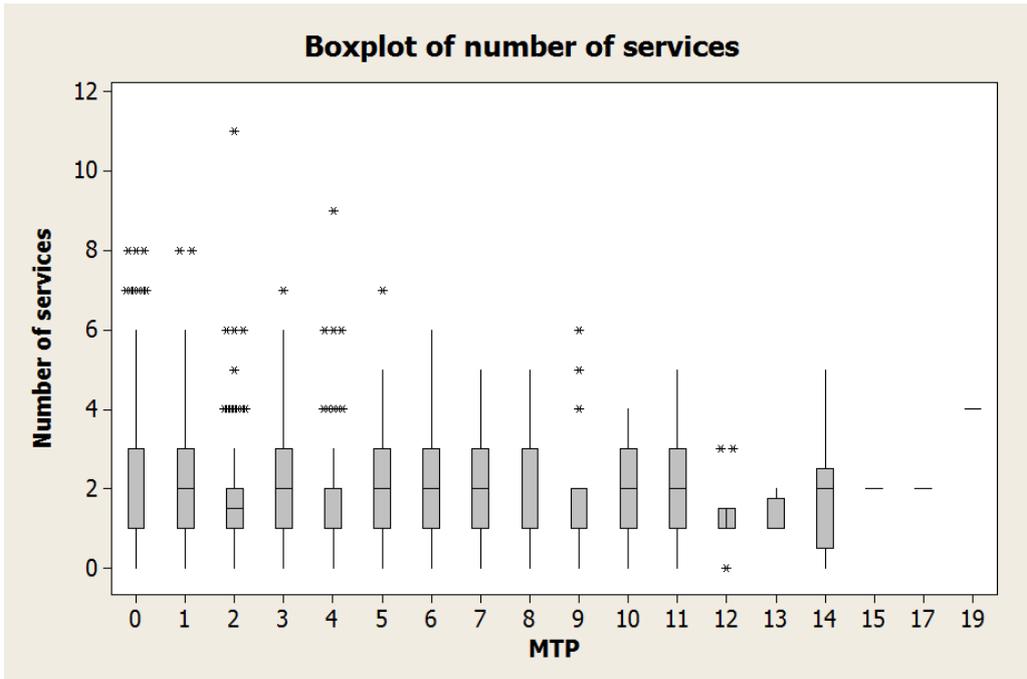


Figure 4: Boxplot of number of services compared to maximum total point (MTP) for all individual cows.

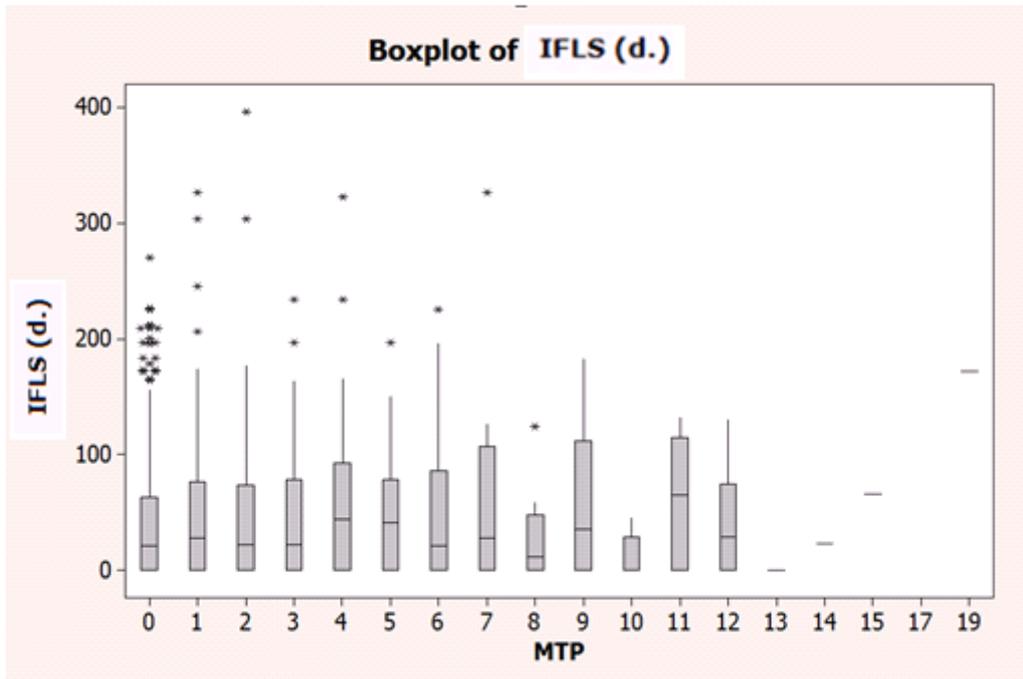


Figure 5: Boxplot of interval from first service to the last service (IFLS, d.) compared to maximum total points (MTP) for all individual cows.

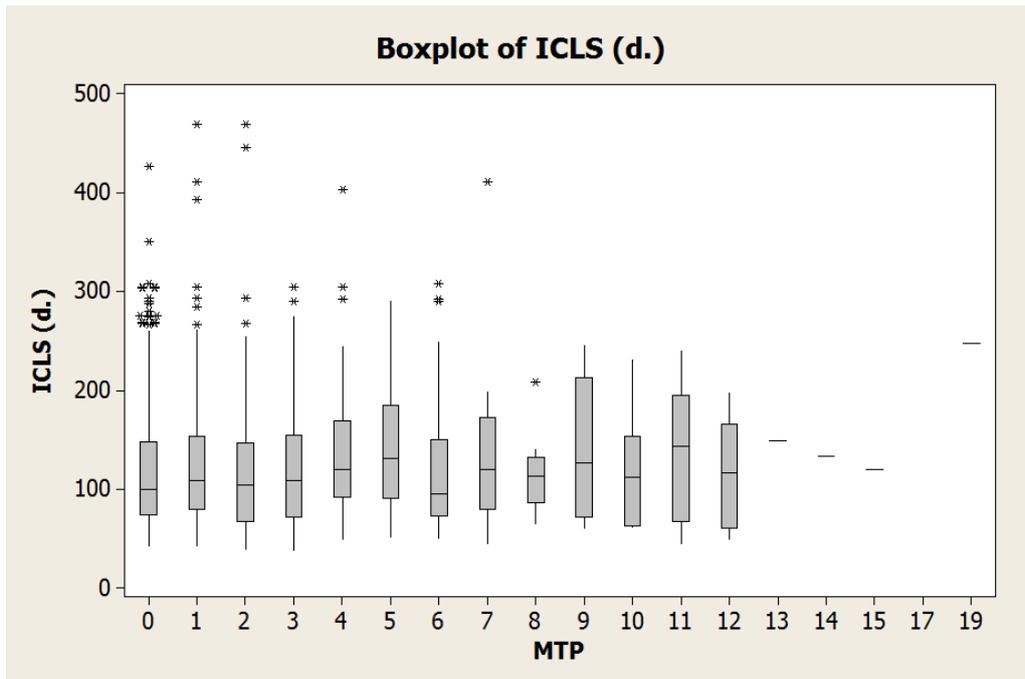


Figure 6: Boxplot of interval from calving to last service (ICLS, d.) compared to maximum total points (MTP) for all individual cows.

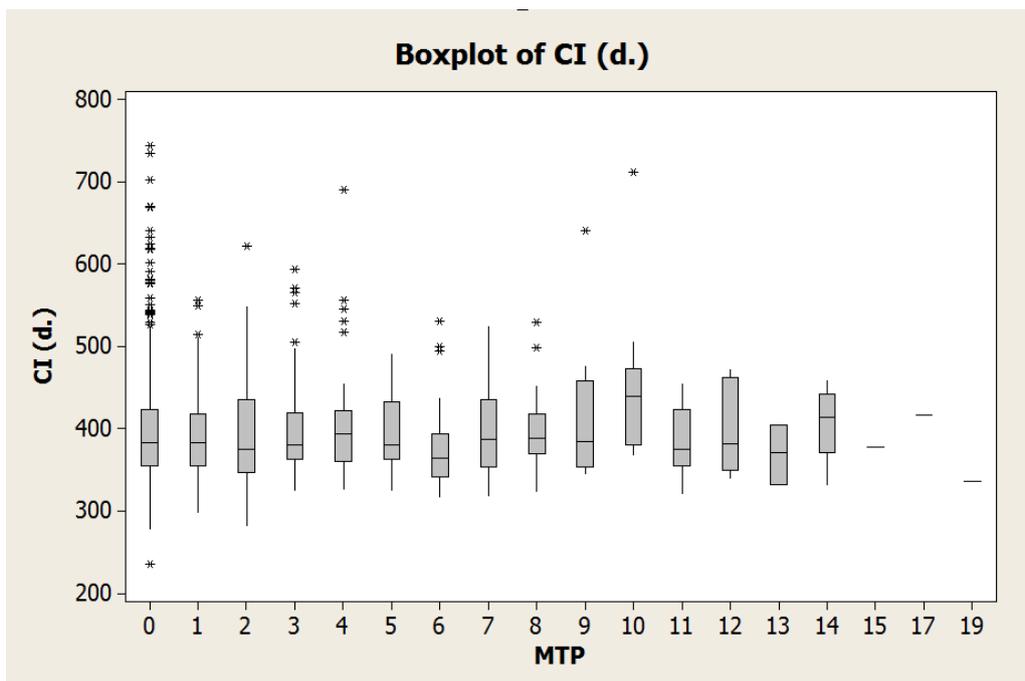


Figure 7: Boxplot of calving interval (CI, d.) compared to maximum total points (MTP) for all individual cows.

### 4.3 Milk production

There were no significant differences in mean ECM production between the different farm types (tie-stalls and free stalls). Figure 8 illustrates the average ECM production of all trimmed cows in relation to the MTP assigned to each cow during the trimming sessions performed during 2013 and 2014. Higher scores implied impaired claw health. The scores 15, 17 and 19 occurred only once in the

dataset explaining the lack of a complete box. The average ECM production was not affected by an increase in MTP, MIP or MLP (Figures 8, 9 and 10).

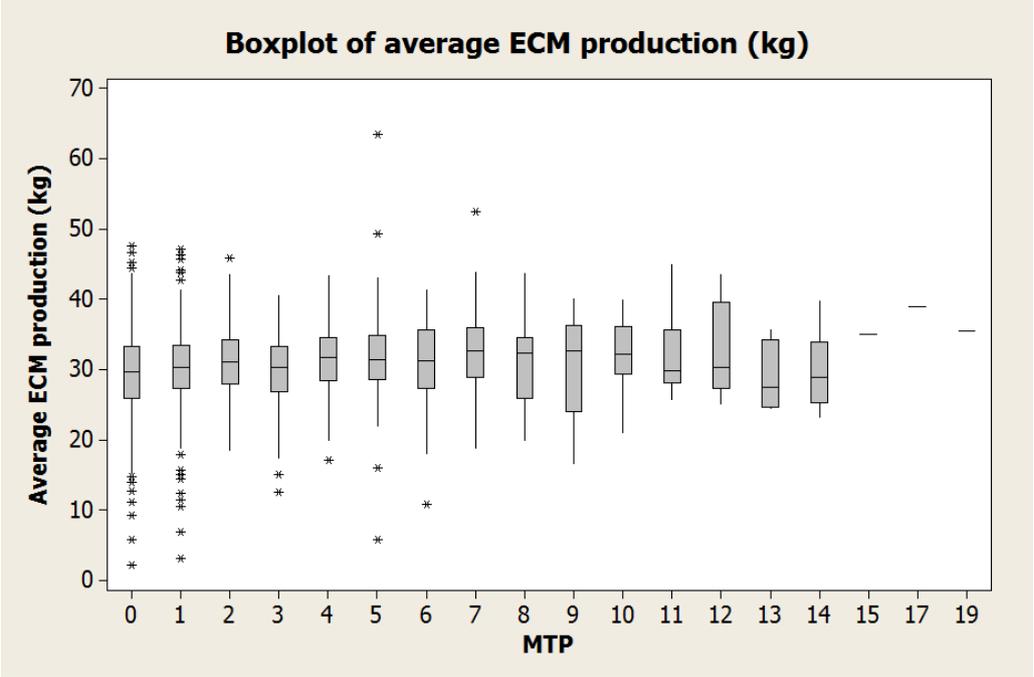


Figure 8: Boxplot of the average ECM production (kg/d.) compared to maximum total points (MTP) for all individual cows.

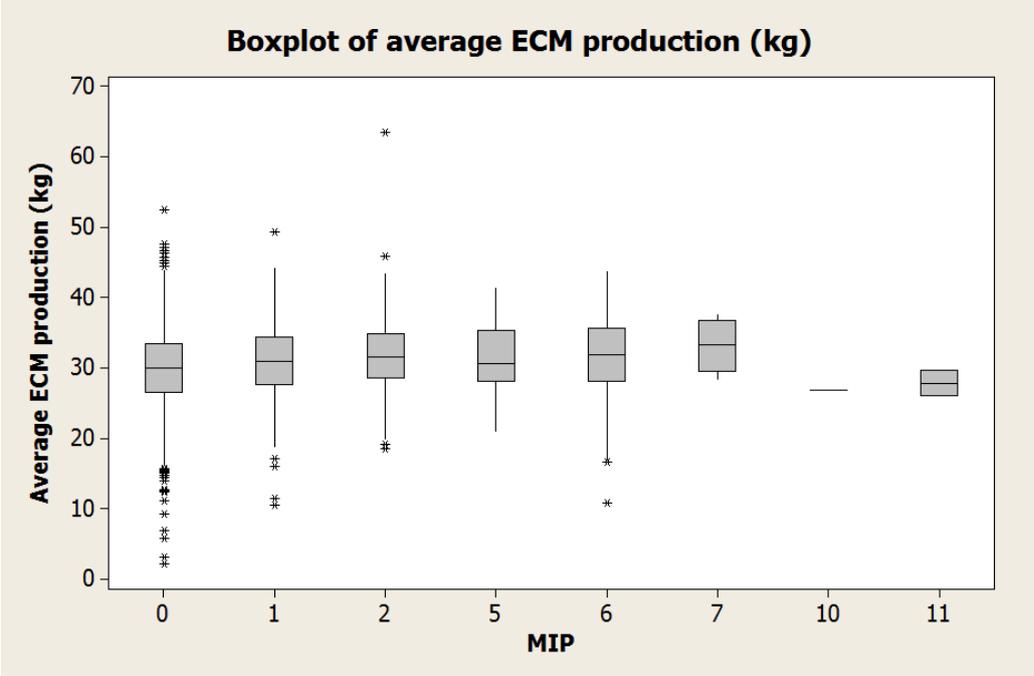


Figure 9: Boxplot of the average ECM production (kg/d.) compared to maximum infectious points (MIP) for all individual cows.

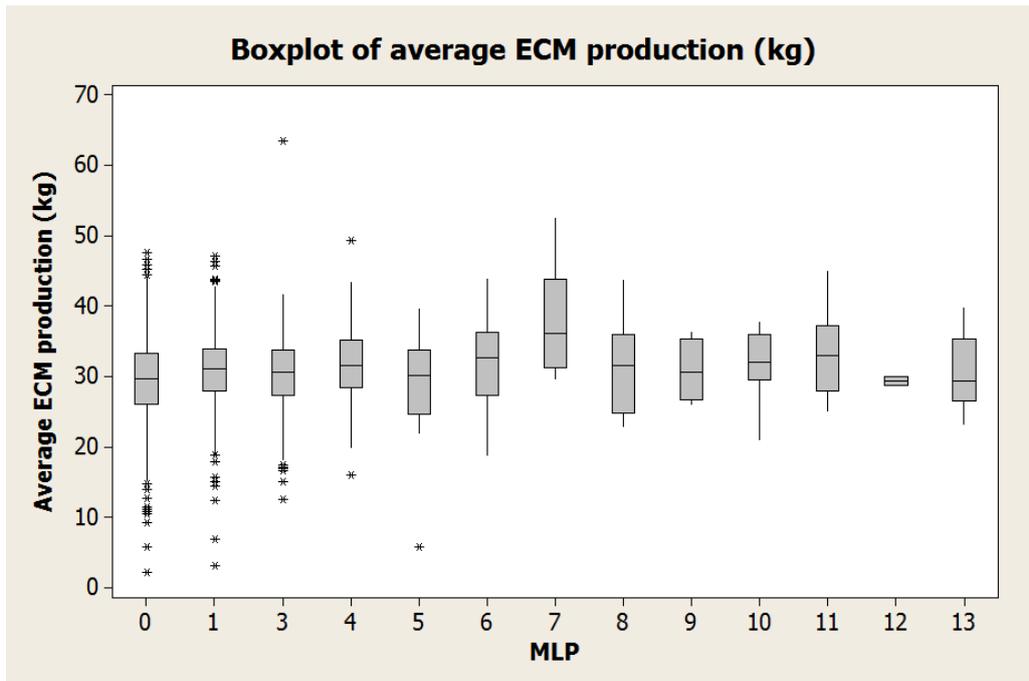


Figure 10: Boxplot of the average ECM production (kg/d.) compared to maximum laminitis points (MLP) for all individual cows.

## 5. Discussion

This kind of inventory of the claw health status and its effect on reproduction and production has not been performed on the Aland Islands before. The result from this study provides an idea of the current situation and can aid in the future work for a better claw health among the dairy cows on the Aland Islands. The results indicated that the claw health did not affect milk production or reproduction on the farms included in the study. There were no significant differences in milk production, number of services, IFLS, ICLS and CI between free stall and tie-stall systems. Nor did the Pearson correlation coefficients indicate any significant correlations between the above mentioned parameters and MIP, MLP and MTP. However, some tendencies towards significant correlations between IFLS and MLP and MTP could be detected. The results did however show that there were significantly more infectious claw diseases on farms with free stall systems and that there was a difference between the claw trimmers in the registration of laminitis related claw diseases.

Already in the 1980ies Lucey et al. (1986a) and Weaver (1985) considered lameness to be a major reason for disease and economic loss in the dairy industry. It is interesting and somewhat tragic to realize that this is still the case today, 30 years later. Many studies have been conducted in order to investigate the effect of lameness on milk production, reproduction and economy and the results are not always in agreement with each other. Many of previous studies used different ways to measure lameness and claw lesions and this may partly explain why different prevalence and incidence rates have been recorded (Warnick et al., 2001; Barkema et al., 1994; Enting et al., 1997; Green et al., 2002 and Manske et al., 2002a). Comparisons between this study and international studies are further complicated by the fact that lameness, instead of claw lesions, in many cases is used when investigating the effect on milk production, reproduction and economy. Lameness is however not the same thing as claw lesions that are registered during trimming. Maintenance claw trimming, regular trimming of all cows a few times per year, was implemented on the farms included in the present study. A positive aspect of maintenance claw trimming is that claw lesions are detected earlier compared to claw management methods that wait for signs of lameness or impaired locomotion before trimming is performed. The detected lesions are therefore treated immediately hopefully reducing the effect on reproduction, milk production, economy and improving animal welfare.

In the present study 50 % of the total number of trimmed cows during 2013 had no recorded claw lesions and the same number in 2014 was 52 %. Recent data from Sweden demonstrates similar figures; 57.5 and 55.6 % of the trimmed cows were healthy without remarks during the milk-recording years 2013/2014 and 2012/2013, respectively (Växa Sverige, 2014). These figures can be compared with results from the study by Manske et al. (2002a) in which 72 % of the cows experienced a minimum of one claw lesion. The claim that dairy cows on the Aland Islands have better claw health than their counterparts in Sweden can neither be proved nor rejected based on the results from this study. Approximately 45 % of the dairy farms on the Aland Islands were included in the present study which is similar to the proportion of farms included in the Swedish claw health statistics. Also the proportion of tied and loose housed herds on the Aland Islands corresponds to the proportion in Sweden. But, the claw health situation on the non-recorded farms in both countries is thereby unknown. The present study included only three claw trimmers which can be compared to Sweden where many more claw trimmers are active. A deviation in work methods among one of the three claw trimmers will consequently have a greater influence on the results in this study compared to if the

number were to be greater. Nevertheless, it is evident that the occurrence of claw lesions can vary greatly between farms, which have also been demonstrated in previous studies (Warnick et al., 2001; Barkema et al., 1994).

According to Rajala-Schultz et al. (1999) first lactation cows are most affected by lameness but Barkema et al. (1994), Warnick et al. (2001), Bicalho et al. (2007) and Onyiro et al. (2008) reported that lameness was most prevalent in older cows. However, no significant correlations between year of production and claw health could be found in the present study. There were, on the other hand, significantly more infectious diseases on farms with free stalls compared to farms with tie-stalls during both 2013 and 2014. This might be due to the fact that cows in free stall systems have to move around to find feed and water. This in combination with manure and concrete floors will facilitate the spread of infectious diseases and impair claw health (Bergsten & Pettersson, 1992; Bergsten, 2001). Furthermore, it is likely that cows in tie-stalls are not exposed to the same infectious pressure from other cows as they have their appointed space in the barn.

The present study also found that there was a significant difference in occurrence of laminitis related diseases and MTP between the claw trimmers in the year 2013. The same relationship did not exist in the year 2014. The reason for this is unknown. One explanation could be that the claw trimmers evaluated the laminitis related diseases differently in comparison to each other. Another explanation could be that the trimmers by coincidence worked on farms with different occurrence of laminitis related diseases. A significant difference between the trimmers might be facilitated if a claw trimmer that worked on farms with more laminitis related diseases is compared to a claw trimmer that worked on farms with very little laminitis related claw diseases. The significant difference in MTP between the claw trimmers in 2013 was probably an effect of the difference in laminitis related diseases and the fact that there were significant positive correlations between MIP and MTP and MLP and MTP where the correlation between MLP and MTP was the strongest.

## 5.1 Milk production

The hypothesis that the milk production decreased when the claw health deteriorated was not supported by this study. Similar results were reported by Cobo-Abreu et al. (1979) and Martin et al. (1982) who did not find significant effects of claw problems on milk yield. However, Lucey et al. (1986b), Rajala-Schultz et al. (1999), Warnick et al. (2001) and Green et al. (2002) all found that lameness had a detrimental effect on the milk production. There are also studies reporting a beneficial effect of lameness on milk yield. Dohoo & Martin (1984a), Barkema et al. (1994), Green et al. (2002) and Onyiro et al. (2008) all reported an increased milk yield from cows suffering from claw problems. However, not all claw lesions result in lameness (Manske et al., 2002a) which complicates the comparisons between these studies.

One explanation to the results in the present study is that the recorded hoof disorder simply did not affect the milk production since claw lesions can be subclinical. However, another explanation may perhaps be present. The dairy cows at the Åland Islands are the highest producing in Finland (Ålands Hushållningssällskap, 2013; Ålands Hushållningssällskap, 2014) and according to Barkema et al. (1994), Green et al. (2002), Hultgren et al. (2004) and Onyiro et al. (2008) are high yielding cows more prone to develop lameness. High producing cows are more likely to experience a large negative energy balance and have to remain standing by the feed bunk for longer periods in order to consume enough feed (Green et al., 2002). On the other hand, the negative energy balance could also be facilitated by a decreased feed intake resulting from the cow not standing at the feed bunk because of the pain associated with lameness and claw lesions. The difference in milk yield between lame and healthy cows is thereby reduced since the yield from high producing cows is decreased to the same level as the average but perhaps not below it. Lame cows may consequently not produce less milk than their healthy counterparts but will produce less milk than their potential and have a less persistent lactation (Green et al., 2002; Onyiro et al., 2008). In the future it would perhaps be better to measure the deviation from the milk curve as proposed by Barkema et al. (1994) and implemented by Bergsten et al. (2003) in order to quantify the difference between healthy and lame cows. There is also a risk,

according to Warnick et al. (2001), that cows with lameness and lower milk production are culled more often than lame cows with higher milk production. Cows with a higher milk production will remain in the herd and the risk of them suffering from lameness increases.

## 5.2 Reproduction

The effect of claw problems on fertility has been carefully studied. In previous studies have lameness and claw lesions resulted in an increased interval between calving and first service and calving and conception. Moreover, lameness is reported to increase the number of services, decrease the mounting activity making estrus detection more difficult and lead to an increased risk for developing ovarian cysts (Weaver, 1985; Lucey et al., 1986a; Collick et al., 1989; Sprecher et al., 1997; Melendez et al., 2003 and Bicalho et al., 2007). However, in contrast to earlier studies there were no significant correlations between claw health and the above mentioned fertility measurements in the present study. No significant differences between free stall and tie-stall herds were found in CI, ICLS, IFLS and number of services. The study did find moderate and strong significant positive correlations between IFLS, ICLS and CI. This is not surprising since both IFLS and ICLS will affect the CI. There were also a significant positive correlation between IFLS and number of inseminations in the 2014 dataset and a tendency for the same in the joined 2013 and 2014 dataset. This is reasonable because the IFLS should increase when the number of services increases. The boxplots did not supply any clear indications that the claw health deteriorated the fertility measures (see Figure 4, Figure 5, Figure 6 and Figure 7).

## 5.3 Study design

The facts that lameness is considered to be a multifactorial disease (Vermunt 2005) and that the present study is an epidemiologic study makes it impossible to draw conclusions about cause - effect relationships. The drawback of epidemiologic studies is that factors affecting the results cannot be controlled in the same manner as in intervention studies. Epidemiologic studies are also dependent on the quality of the input data since these cannot be controlled. This was evident in the present study since data from the Finnish national cattle database was missing from one farm and data about ICLS was missing from another farm in 2014. The lack of significant results can be explained by the small number of farms included in the study together with the large variation among them. A larger sample size is beneficial because it represents the average population better. This was however not possible because of lack of data from the Finnish national cattle database and claw trimming sessions.

All data from the national cattle database was based on calendar years instead of on lactation. A cow calving in January consequently had a much higher milk yield than a cow calving in December. The implication of this was that the mean ECM production had to be calculated by dividing the ECM production with the number of feed days. However, the number of feed days included the dry period and the maximum number of feed days was as a result 365 d. Since the lactation normally extends over 305 days, the calculated average daily ECM production will be lower than the true production when divided by 365 days. This procedure is not believed to have a significant effect on the results on the present study but should be remembered if the milk yields ever are to be compared to other studies. Another important factor that may affect the results is the time of the claw trimming sessions. The cows have to be outside on pasture during the summer and according to Hernandez-Mendo et al. (2007) and Onyiro et al. (2008) grazing will decrease the locomotion scores. It is possible that cows that were claw trimmed in autumn had better claw health than cows that were claw trimmed in late winter. This was however not investigated further in the present study and should be considered in future studies. The interval between calving and first service, known as the voluntary waiting period, was not included in the study because it depends largely on the farmers' attitude; the aim on some farms is to serve the cow the first time 60 d. after calving while others serve the cow as early as possible after calving.

The results from this study give rise to new questions. It would be interesting to investigate if different claw lesions affect the production and reproduction to different degrees as pointed out by Warnick et al. (2001). The effect of breed on the occurrence of different claw lesions could also be a future field of study. Another interesting aspect would be to check whether the difference between the claw trimmers was arbitrary or if they assessed claw lesions differently. There are records from every Swedish claw trimmer that would be possible to use for comparisons. A unified basis for assessment is important if claw health data are to be used in breeding in the future.

In the present study approximately 50 % of the cows experienced some kind of claw problem. Should this be considered as an acceptable figure since neither the production nor the fertility was affected? Murray et al. (1996) reported that sole ulcer, white line lesions, digital dermatitis, interdigital phlegmone, interdigital hyperplasia and interdigital dermatitis are claw lesions commonly associated with lameness. Lameness is considered to be an animal welfare problem associated with pain and changed behavior (Hassall et al., 1993; Singh et al., 1993; Hernandez et al., 2002 and O'Callaghan, 2002) as well as impaired economic results on farms (Whitaker et al., 1983; Kossaibati and Esslemont, 1997 and Enting et al., 1997). However, lameness was not recorded in the present study and many claw diseases are subclinical. Whether the cows in the present study experienced pain associated with lameness is therefore unknown. Finally, even if it would be considered acceptable that 50 % of the cows had some kind of claw lesion it would in any case be wise to minimize the prevalence of claw lesions on the farms. The present study indicates that free stall systems could benefit from controlling the claw health routines in order to decrease the occurrence of infectious diseases. It would however be important for all farms to decrease the amount of laminitis related diseases since these were the most common in the study. During these economically challenging times farmers might benefit from improving the claw health both from economic and animal welfare terms.

## 6. Conclusion

The aim of this study was to analyze the claw health, reproduction and milk production of dairy cows at the Aland Islands in order to gain an understanding of the current situation. The study found no significant differences in milk yield and fertility between the farms included in the study or with claw health records from Sweden. No detrimental correlations between milk production and claw health and between fertility and claw health could be reported. Laminitis related diseases were the most common claw problems on the farms but there were significantly more infectious diseases on farms with free stalls compared to tie-stalls. A significant difference in the occurrence of laminitis related diseases between the claw trimmers was found. The reason for this difference is unknown. The results of this study can aid in the future work towards better a claw health status among the dairy cows at the Aland Island.

## 7. References

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## Acknowledgements

First I want to thank my supervisor Professor Christer Bergsten for the guidance and advice that you have given me during this master thesis. Thanks also to Jan-Eric Englund for all the patience shown while helping me with the statistical analyses. I would like to say a big thank you to Kerstin Lundberg at Ålands Hushållningssällskap for all the time you have spent retrieving information that have made this master thesis possible. Thanks also to my family for all the support and for always believing in me, even when I did not believe in myself. Finally, I want to thank all the farmers that participated in the study. Without you and your participation this study would not have been possible.