GENETIC AND ENVIRONMENTAL INFLUENCES ON DYSTOCIA AND SIRE EVALUATION FOR CALVING EASE AS A TRAIT OF THE CALF.

by

© Hilaire St-Arnaud.

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Suggested short title: Sire Evaluation, Calving Ease

Dedicated to: The dairymen who contribute to better and more complete sire evaluation by providing useful information from their on farm observations.

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ABSTRACT

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GENETIC AND ENVIRONMENTAL INFLUENCES ON DYSTOCIA
AND SIRE EVALUATION FOR CALVING EASE AS A TRAIT OF THE CALF

Two distinct studies were carried out in relation to calving ease as a trait of the calf. In the first, a total of 16653 calving records from Holstein cows in herds enrolled on the Quebec Dairy Herd Analysis Service, collected from September 1979 through March 1980, were used to examine the effect of changes in definition of calving performance on variance components estimation. A first definition (Definition I) was combining ease of calving and calf survival, the scoring procedure considering ease of calving first, with a secondary delineation on calf survival. The second definition (Definition II) was considering ease of calving only, malpresentation cases being excluded. Analyses were performed for three population subsets: first calf heifers (4254), second and later parity cows (12367) and all parity cows (16653). The model used included herd, sex of calf, parity (or age) and size of dam at calving, month of calving and the interaction age by sex as fixed effects, and sire and error as random effects. Both definitions yielded higher heritability estimates for heifers (0,11 and 0,08) than for older cows (0,03 and 0,02). For the three subpopulations, Definition I resulted in higher heritability estimates than Definition II (0,049, 0,111, and 0,030 with Def. I and 0,042, 0,085, and 0,021 with Def. II for all parity, heifers and older cows, respectively).

In the second study, a similar set of data from the same source was obtained, which included a total of 121848 calving records collected from September 1979 through May 1981, and was used to examine the effect of using records from either subpopulation already described on sire evaluation and recommendations for use on virgin heifers. Preliminary results indicated that heifers (22564) experienced more dystocia, with 40% of their calvings receiving some assistance, as compared to older cows (99284) who were assisted for 25% of their calvings. Higher calf mortality rate was observed from heifer calvings (7,5%) as compared to calvings from older cows (3,1%), with increasing mortality rate being associated with higher degree of difficulty. Chi-squares analysis with records from all parity cows indicated that sex of calf, parity, season of calving, size of dam and the interactions sex by parity, sex by size, parity by size and sex by size by parity were all significant sources of variation on calving performance. With records from the other two subpopulations, the significant factors were sex of calf, month or season of calving, and size of dam. With calving performance being defined as for Definition II of the first study, variance components were estimated according to MINQUE procedure. Heritability estimates were 0,035, 0,045, and 0,012 for all parity cows, first calf heifers, and second and later parity cows, respectively. Sires were ranked genetically for the calving ease of their calves based on records from each subpopulation. Rank correlations of 0,44 and 0,66 were obtained between sire rankings from first vs later parities and from first vs all parities, respectively. Sire evaluation from all parity records seems appropriate, but a second evaluation using records from heifers only should be obtained simultaneously to identify all sires representing some risks as to their use on virgin heifers.

RESUME

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ETUDE DES FACTEURS GENETIQUES ET DE L'ENVIRONNEMENT
SUR LES DYSTOCIES ET EVALUATION DES GENITEURS POUR
LA PERFORMANCE AU VELAGE CONSIDEREE COMME CARACTERE DU VEAU

Deux études distinctes sur la facilité au vêlage considérée comme caractère du veau ont été complétées. Dans le premier cas, les données sur le vêlage de 16653 vaches Holstein ont été obtenues de septembre 1979 à mars 1980 auprès des éleveurs inscrits au Programme d'Analyse des Troupeaux Laitiers du Québec. Ces données ont été utilisées pour étudier l'effet du changement de définition de la performance au vêlage sur l'estimation des composantes de variance. Une première définition (Définition I) considérait simultanément le type de vêlage et la survie du veau, tandis que la seconde (Définition II) était basée uniquement sur le type de vêlage, les cas de mauvaises présentations étant exclus. Les analyses ont été effectuées pour trois sous-populations: les taures (4254), les deuxièmes vêlages et vêlages subséquents (12367), et tous les vêlages considérés ensemble (16653). Le modèle d'analyse considérait les effets fixes attribuables au troupeau, au sexe du veau, au numéro de vêlage (ou âge au premier vêlage), à la taille de la mère au vêlage, au mois de vêlage, et à l'interaction de l'âge et du sexe. Les effets aléatoires comprenaient l'identité du géniteur et l'erreur. Pour les deux définitions, les estimations de l'héritabilité ont été plus élevées dans le cas des taures (0,11 et 0,08) que dans le cas des vaches à leur deuxième vêlage et subséquents (0,03 et 0,02). Pour les trois sous-populations, les esti-

mations de l'héritabilité étaient plus élevées en utilisant la Définition I comparativement à celles obtenues avec la Définition II.

Pour la seconde étude, un total de 121848 observations sur la performance au vêlage a été obtenu des mêmes sources, de septembre 1979 à mai 1981. L'analyse de ces données avait pour but d'étudier l'effet de l'utilisation des observations provenant de l'une ou l'autre des sous-populations déjà décrites sur l'évaluation des géniteurs pour la facilité de vêlage et sur les recommandations relatives à leur utilisation pour l'accouplement avec les taures. L'incidence des dystocies était plus élevées chez les taures (40% de leurs vêlages étant assistés à un degré quelconque) que chez les vaches à leur deuxième vêlage ou subséquents (25% des vêlages étant assistés dans cette sous-population). De même, le taux de mortalité était plus élevé (7,5%) chez les veaux nés de taures que chez ceux issus de vaches (3,1%). Lorsque tous les vêlages étaient considérés pour les analyses, le sexe du veau, le numéro de vêlage, la saison de vêlage, la taille de la mère, de même que les interactions sexe-numéro de vêlage, sexe-taille, taille-numéro de vêlage et sexe-taille-numéro de vêlage ont été identifiés comme sources significatives de variation de la performance au vêlage. Pour les deux autres sous-populations, les sources de variations significatives étaient le sexe du veau, la saison de vêlage, et la taille de la mère. La performance au vêlage étant définie telle qu'à la Définition II de la première étude, les composantes de la variance ont été estimées par la méthode MINQUE. L'héritabilité a été estimée à 0,035 pour tous les vêlages, à 0,045 pour les vêlages de taures, et à 0,012 pour les deuxièmes vêlages et subséquents. Les géniteurs ont été classés génétiquement pour la facilité au vêlage de leurs veaux, et une corrélation de rang de 0,44 a été obtenue entre le classement basé sur les premiers vêlages et le classement basé sur les deuxièmes vêlages et subséquents, alors que la corrélation entre le classement basé sur les premiers vêlages et le classement basé sur tous les vêlages était de 0,66. L'évaluation des géniteurs basée sur tous les vêlages semble adéquate, mais il faudrait aussi obtenir une seconde évaluation basée sur les premiers vêlages seulement de manière à identifier tous les taureaux représentant le moindre risque lorsqu'utilisés pour l'accouplement avec des taures.

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I. INTRODUCTION

Economic losses attributable to dystocia, or calving difficulty, have been reported for beef cattle, and more recently for dairy cattle in United States. Results from research projects which examined the economic impact of calving difficulties in Holstein heifers (McDaniel, 1981) indicated that the minimum cost per heifer requiring assistance at calving was $50 to $60, and that mating that would minimize calving difficulty in Holstein heifers could be economically justified. These authors noted the reduction in milk yield and poorer reproductive performance observed for heifers experiencing dystocia as compared to those who gave birth normally. In addition, it was found from the same study that stillbirths and other calf deaths through 48 hours postpartum were 8,2% and 10,1% from unassisted and slighty assisted births, as compared to 34,9%, 55,2% and 47,7% from births that were scored hard pull, jack needed, and veterinarian needed, respectively.

> "Reducing calf mortality by 1% in first parity and 0,5% in later parity cows would increase industry revenue by 8 millions dollars in United States." (Thompson et al., 1981).

Because of the association between dystocia and calf mortality, an important reduction in the latter would be obtained by decreasing the incidence of the former. Sire evaluation for calving ease of their progeny and subsequent recommendations as to the use of sires rated easy calving on virgin heifers has been proposed as a means of reducing the incidence of dystocia. Several artificial insemination organizations in United States and in Canada have initiated such programs for dairy sires.

This study, based on data from commercial dairy herds in Quebec and the Maritime provinces, was undertaken with the following objectives:

- to examine the frequencies of difficult calvings and calf losses in the Holstein population
- to examine the effects of factors such as sex of calf, parity or age at first calving of dam, size of dam at calving and month of calving, on calving performance of Holstein cows and heifers
- to investigate the effect of changes in the definition of calving performance on variance components estimation
- to examine the effect of using records from all cows versus first calf heifers on sire evaluation for calving ease and recommendations for use on virgin heifers.

The larger breeds of dairy cattle have been demonstrated to be more affected by dystocia (Monteiro, 1971; Thompson et al., 1981). This study, which is the first undertaken in Quebec, was restricted to the Holstein-Friesian breed. Dystocia in cattle may be considered as a trait of the calf (direct effect) or as a trait of the dam (maternal effect). In this study, the trait has been regarded only as a trait of the calf.

II. REVIEW OF LITERATURE

Definition of Dystocia and Stillbirth

Dystocia, or calving difficulty in cattle, may be defined as parturition that is markedly prolonged or becomes difficult or impossible for the dam without assistance (Brinks et al., 1973), which is to a large extent a consequence of an incompatilibity between the size of calf and the dam's pelvic opening (Bellows et al., 1971; Rice and Wiltbank, 1972; Menissier, 1975).

Most of the causes of dystocia are known to act in combination from the dam and her calf, and therefore from a genetic point of view, the trait must be referred to in relation to both these sources of genetic variance. The calf effect - or direct effect - refers to the effect of parentally transmitted genes on the birth prospects for their progeny. The dam effect - or maternal component - includes the direct effect of a dam's genes on the size of her calf along with what is called the pure maternal effect, i.e. the uterine influence of the dam on her calf's birth weight, and the influence of her own genotype on the pelvic opening, preparation for calving, etc.. (Philipsson et al., 1979).

In normal cases, parturition in cattle results in the birth of live calves. When a single calf born after a normal gestation period is dead at birth or dies within a certain period of time after birth (which may be called "post-partum allowance"), it is considered as stillborn. The post-partum allowance may vary, but is usually 24 hours following birth (e.g. Laster and Gregory, 1973; Cady et al., 1981). In some cases, the calf survival criteria is extended to a period of 48 hours after birth (e.g. Schaeffer and Wilton, 1976; McDaniel, 1981). Philipsson et al., (1979) indicated that in some countries, the limit is extended to a week or to the first occasion of milk recording after birth.

Dystocia Related to Early Calf Losses

Any variation in the course of parturition is of importance for the viability of the calf and many studies have revealed that dystocia was a major cause of calf losses at or near time of birth. Woodward and Clark (1959) reported that dystocia was the identified factor associated with stillbirth for 37% of the total number of calf losses, this figure being the largest among identified factors. Anderson and Bellows (1967) found that 79% of the calves lost at birth were anatomically normal and that the most common cause of death was injury resulting from difficult or delayed parturition. Laster and Gregory (1973) revealed that calf losses at or near time of birth were four times greater (20,4%) in calves experiencing dystocia than in those not experiencing dystocia (5,0%). Philipsson (1976a) demonstrated the association of stillbirth with type of calving in Swedish cattle breeds, with frequency of stillbirth varying between 1% and 5% at easy and normal calvings, while at difficult calvings, the frequency was about 25% for SLB and SRB populations, and reached 45% for the SKB population. Other results indicating a similar association between type of calving and calf losses were reported by Cady et al., (1981) and McDaniel (1981), among others.

Dystocia and Subsequent Productivity of the Cow

Losses other than those related to higher calf mortality may be due to difficult calvings. Several studies have revealed that dystocia may impair subsequent reproductive performances of the cows, calf crop weaned (beef cattle), and yield of milk and fat. All these factors result in higher culling rates. Brinks et al. (1973) reported that heifers experiencing calving difficulty as 2-year-olds weaned 11% fewer calves of those born the first year (which is attributable to higher calf losses) and 14% fewer calves per cow exposed the second year when compared to contemporaries that had no difficulty at first parturition. In addition, calves from 3-year-olds that had dystocia at 2 years of age were born an average of 13 days later and were 21 Kg lighter at weaning than calves from 3-year-old dams that had no dystocia at 2 years of age. Laster et al. (1973) reported that for all cows, dystocia resulted in a 15,6% lower conception rate to A.I. and a 15,9% lower overall conception rate, with problems being more serious among 2-year-old cows as compared to older cows.

Indication of impaired milk and fat production because of dystocia, as well as poorer subsequent reproductive performance, was reported by McDaniel (1981).

Factors Influencing Calving Performance

Factors influencing calving performance can be divided into components attributable either to the calf or to the dam, and in many cases, they may be combined. The causes may also be looked upon as either genetic or non-genetic. (Philipsson, 1976a).

Factors attributable to the calf

Calf sex and birth weight (or size) are the most important factors attributed to the calf which significantly affect dystocia. Results showing the effect of calf sex on dystocia have been reported by many authors (Bellows et al., 1969; Rice and Wiltbank, 1970; Bellows et al., 1971; Brinks et al., 1973; Laster et al., 1973; Laster, 1974; Pollak and Freeman, 1976; Tong et al., 1976; Philipsson, 1976b; Thompson et al., 1981; Fredeen et al., 1982; Makarechian and Berg, 1981). In all cases, female calves caused fewer problems at calving than male calves.

The sex difference in calving performance is largely due to differences in birth weight, male calves being heavier at birth than female calves (Nelson and Huber, 1971; Laster et al., 1973; Fisher and Williams, 1978; Makarechian and Berg, 1982), and birth weight being positively correlated to calving problems (Bellows et al., 1969; Rice and Wiltbank, 1970). Laster (1974) found that birth weight was the most important factor affecting dystocia, and Laster et al., (1973) reported that for each kilogram increase in birth weight, calving difficulty increased by 2,3% ± 0,21. However, it has been demonstrated that even when birth weight was held constant, effect of sex remained significant (Bellows et al., 1971; Pollak and Freeman, 1976). This suggests that difference in sex other than size or weight may exist, such as structure, conformation or homonal influences. Dufour et al. (1972) found that male calves required four times more assistance than females, for calves born from second parity cows.

Another important calf factor affecting calving performance is abnormal presentation, position or posture at birth, as indicated by Philipsson (1976a), who mentionned that according to some authors, approximately 5% of all calves are born posteriorly, with some authors reporting that such presentations accounted for 20% to 30% of the dystocia.

Factors attributable to the dam

Among factors attributed to the dam, parity is the most important single cause of variation on dystocia, with frequency of difficult calvings being two to four times higher among first calf heifers as compared to older cows (Philipsson, 1976a). Reports in the literature are consistent in indicating this effect of parity on calving performance, as indicated by Laster and Gregory (1973), Laster et al. (1973), Brinks et al. (1973), Pollak and Freeman (1976) Tong et al. (1976), Thompson et al. 1981), Makarechian and Berg (1981), among others. According to Thompson et al. (1981), the effect of parity is similar in all dairy breeds, except for the Brown Swiss.

Except for heifers, there is no great effect of age within parity, as mentionned by Philipsson (1976a) who also indicated that among first calf heifers, frequency of difficulties would be higher when heifers are very young (less than 24 month old) or very old (3 years or older). Results from the same study (Philipsson, 1976b) indicated that age at first calving significantly affected calving performance in two populations (SRB-north and SKB) while it was not significant in two other populations considered (SLB and SRB-south). Poor development as a result of unsuitable feeding related to the chosen calving age would be largely responsible for the higher frequency of difficult calvings among younger heifers, while greater fatness and a higher degree of ossification and stiffness of the pelvis would explain the greater problems observed among oldest heifers.

Condition, size or other body measurements of the dam at calving have been investigated as to their effect on calving performance. Bellows et al. (1969), Rice and Wiltbank (1970), Bellows et al. (1971) and Laster (1974) reported consistent results indicating that pelvic area of the dam was associated with ease of calving. Generally, a larger pelvic area was associated with less calving difficulty. Results of Laster (1974) indicated that heavier 2-year-old cows had larger pelvic openings, but had proportionately even larger calves with little indication of breed differences in these associations. Thus, pelvic size independent of cow weight may have a significant effect on dystocia but would not be a large source of variation. Price and Wiltbank (1978) found that pelvic area was the most highly correlated variable with dystocia score, while dam weight had a non-significant correlation. The latter observation is consistent with results of Sagebiel et al. (1969) who reported correlation coefficients between dystocia score and post-calving cow weight that were low, negative and generally non significant.

Factors attributable to both cow and calf

According to results reported by Bellows et al. (1971), disproportion between size of calf and size of birth canal seems to be the most common cause of difficult calving attributable to both cow and calf, especially for heifers. Other researchers found that an increase in the ratio of calf birth weight to weight of dam at calving was associated with an increase in dystocia (Sagebiel et al., 1969; Makarechian and Berg, 1981). These are consistent with findings of Bellows et al. (1971), since cow weight was found to be the largest source of variation associated with pelvic area (Laster, 1974).

The interaction of sex of calf with parity (or age) of dam was found to be a significant source of variation on dystocia in several studies (Brinks et al., 1973; Pollak and Freeman, 1976; Makarechian and Berg, 1981), due to smaller differences between dystocia scores for male and female calves with an increase in parity (age) of dam. Therefore, this interaction is likely to be important, at least when calvings from first and later parities are considered together.

Genetic factors

Numerous studies involving crossbreeding in beef cattle have indicated that breed of sire and breed of dam significantly affect dystocia. Investigations of different purebred populations have also demonstrated clear breed differences on the incidence of difficult calvings; Sagebiel et al. (1969) reported that Charolais - sired crossbred calves had significantly higher dystocia scores (i.e. more difficulties) than either Angus - or Hereford - sired crossbred calves. In addition, crossbred calves born to Angus cows had significantly larger dystocia scores than crossbred calves from Hereford and Charolais cows. Laster et al. (1973) found results leading to similar conclusion, with more breeds of sires represented (Hereford, Angus, Jersey, South Devon, Limousin, Simmental and Charolais). However, with Hereford and Angus as the two breeds represented on the dam's side, they observed that Hereford dams had more calving difficulty than Angus dams (P <.005).

Cady et al. (1981) reported that Holsteins required assistance in 37,5% of their calvings as compared to 11% for the other dairy breeds, according to the results from a survey of dairy purebred populations in Ontario (Can.). A survey involving five dairy breeds in U.S. by Thompson et al. (1981) indicated that larger breeds (such as Holstein) were more affected by dystocia as compared to smaller breeds. These observations are consistent with previous reports by Monteiro (1971), who observed calving difficulty percentages of 18,3%, 11,3%, and 8,2% for Friesian, Ayrshire and Jersey breeds, respectively. Philipsson (1976a) reported similar results.

The type of mating has also been considered in some experiments as to its effect on calving performance. On the one hand, crossbreeding could result in some heterosis effect on calving difficulty, while, on the other hand, inbreeding may also affect dystocia. Laster et al. (1973) examined the effect of crossbreeding, but found no significant heterosis effect in Hereford-Angus reciprocal cross calves on calving difficulty. Sagebiel et al. (1969) observed that births involving crossbred male Hereford, Angus and Charolais calves did not differ significantly in dystocia scores from straightbred calves, but that crossbred female calves had significantly more calving problems than straightbred female calves.

Brinks et al. (1973) examined the effect of inbreeding on dystocia. They reported that lower levels of calf inbreeding (1% to 30%) and dam inbreeding (1% to 15%) were associated with lower than average calving difficulties. Significant differences due to line of sire and sire within line have also been reported by Brinks et al. (1973).

Heritability and relationship of dystocia

Heritability of calving performance may be estimated as a trait of the calf or as a trait of the dam. Several estimates of these parameters are now available in the literature. Generally, the values for calving performance as a trait of the calf (direct effect) are of the order 0,03 to 0,18 when estimated with records from first calf heifers only. When records from second and later parity cows are considered, heritability estimates are found to be different than estimates from first parity records, with lower values (0,0 - 0,08). Pollak (1975) cited by Berger and Freeman (1978), Pollak and Freeman (1976) and Thompson et al. (1981) among others, have reported declining heritabilities with increasing parity.

According to Philipsson et al. (1979), this difference would be due, on the one hand, to the incidence of different biological phenomena involved for the trait in heifers versus cows, and on the other hand, to the effect of the mean frequency level of this category trait on its heritability estimates, the latter referring to the threshold model for binomial traits. Dystocia is measured in discrete categories, but there is assumed to be an underlying normal continuous distribution of liability and a threshold with animals affected by dystocia if the liability falls above this value (Falconer, 1960; Van Vleck, 1971; Hill, 1977). Some of the heritability estimates for calving performance as a trait of the calf found in the literature are presented in Table 1.

Along with the fact that heritability estimates are decreasing with increasing parity, it was reported by some researchers that changes in calving performance definition or scoring procedure result in changes on variance components estimation and therefore on heritability estimates (Tong et al., 1976; Philipsson, 1976c). Philipsson (1976c) indicated that heritability estimates are higher when calving performance is differentiated into three or more classes, in comparison with an all - or - none data presentation.

Despite the fairly low heritability estimates obtained in most studies, Philipsson et al. (1979) concluded that there is a rather large genetic variability that can be utilized in selection for both calf and dam effects in heifer calvings.

Correlations between dystocia or calving performance and other traits of the calf or of the dam have been examined in many studies, and some of these results are summarized in Table 2.

Relationships between dystocia in first with later parities, and between direct and maternal effects on dystocia have been examined in some studies. Bar-Anan et al. (1976) reported genetic correlations between heifer and cow performance for dystocia that were low to moderate (0,2 to 0,6). Other researchers (Cady, 1980; Pollak, 1975; Teixeira, 1978) cited by Thompson et al. (1981) calculated correlations of sire rankings from first with sire rankings from later parity data to be 0,50 to 0,60. According to those results, researchers (Bar-Anan et al., 1976;

Table 1. Heritability estimates for calving performance as a trait of the calf.

Study	Population considered	Heritability	Comment
Bar-Anan (1976)	First calf heifers 2nd and later parities	0,043 0,005	Average figures from alternative analyses with Israeli-Friesian cows.
Brinks *et al.* (1973)	2-year-old dams all parity cows	0,126 0,069	Study involving straight-bred Herefords.
Burfening *et al.* (1978)	All parity cows	0,34	From records on progeny calves of Simmental purebred bulls.
Cloppenburg (1966)	First calf heifers	0,04	Cited by Philipsson (1976a)
Philipsson (1976)	Skane heifers Halland heifers	0,03-0,05 0,12-0,19	h^2 estimated for 3 scoring procedures of calving performance
Pollak (1975)	First calf heifers 2nd parity cows ≥ 3rd parity cows	0,17 0,08 0,05	Study involving U.S. Holstein populations Cited by Berger and Freeman (1978)
Pollak and Freeman (1976)	First calf heifers (MW) 2nd parity cows (MW) ≥ 3rd parity cows (MW) All parity cows (MW) All parity cows (SS)	0,18 0,08 0,05 0,08 0,05	Study involving two Holstein populations in U.S. (records from Mid-West Coop and Select Sires Inc.).
Schlote *et al.* (1975)	Simmental heifers German Friesian heifers German R & W heifers	0,03-0,08 0,03-0,10 0,01-0,05	Cited by Philipsson (1976a)
Thompson *et al.* (1981)	First calf heifers ≥ 2nd parity cows	0,08 0,04	Study involving U.S. Holstein populations.
Tong *et al.* (1976)	≥ 3-year-old cows	0,064-0,10	Study involving Charolais - sired progeny records. Heritability estimated for 3 definitions of calving performance.
Voght-Rohlf & Lederer (1975)	First calf heifers	0,045	Cited by Philipsson(1976)

Table 2. Phenotypic and genetic correlations between dystocia and other traits of the calf or of the dam.

Study	Traits correlated with dystocia (or calving score)	Correlation	
		Phenotypic	Genetic
Bellows et al. (1969)	dam pelvic area	-0,18 to -0,22	----
	sex of calf	-0,26 to -0,47	----
	calf birth weight	0,48 to 0,54	
Burfening et al. (1978)	calf birth weight	0,31	0,33
	gestation length	0,04	0,21
Philipsson (1976c)	stillbirth	0,23 to 0,52	0,33 to 0,94
	birth weight	0,19 to 0,31	0,82 to 1,01
	gestation length	0,12 to 0,18	0,19 to 0,38
Pollak and Freeman (1976)	calf size	----	0,89 to 0,97
Rice and Wiltbank (1970)	dam pelvic area	-0,32 to -0,34	----
	birth weight	0,36 to 0,44	----
	calf sex	-0,39	----
Sagebiel et al. (1969)	calf birth weight	0,11	----
	cow weight	-0,24	----
	ratio calf birth weight to cow weight	0,24 to 0,40	----

Cady, 1980; Philipsson, 1976) have suggested that dystocia in first and later parities should be considered separate traits. However, a high positive genetic correlation of 0,84 was reported by Thompson et al. (1981), indicating that dystocia is affected by the same genes in all parities, thus allowing calving reports on older dams and heifers to be combined in predicting a bull's calving performance.

The genetic calf effect and dam effects are poorly correlated, and would even be antagonistic, according to results reported from studies examining this relationship. Among others, Philipsson (1976c) and Thompson et al. (1981) reported negative correlations of -0,19 and -0,38, respectively, for heifer populations. Thompson et al. (1981) also reported a correlation of -0,25 for the cow (second and later parities) population. Thus, bull evaluations for calf effects are of no use in predicting daughter group results.

Thompson et al. (1980) examined the correlated response expected for dystocia if bulls are selected for transmitting ability for production, type, or both. Genetic correlations between dystocia transmitting ability with Predicted Difference milk, fat test and dollars were small or zero, indicating that selection for production traits alone should not increase dystocia. Genetic correlations for transmitting ability of dystocia were -0,28 with a predicted type index and -0,23 with a type-production index, indicating that selection for type without emphasis on calving difficulty would increase dystocia. The increased size associated with high type classification was a major factor in the dystocia-type relationship.

Other factors

Gestation length has an indirect effect on dystocia through birth weight. Bellows et al. (1971) found significant positive correlations between gestation length and calf birth weight (0,34 for Hereford dams and 0,19 for Angus dams). Similarly, De Fries et al (1959) had indicated that calves carried one day less than average weighed 0,4 Kg less. Burfening et al. (1978) found that percent assisted birth increased by approximately 0,70% per day as gestation length increased. However, when both birth weight and gestation length were included in the model for dystocia, gestation length no longer affected the trait, while birth weight was a significant source of variation.

Season or month of calving is the most important pure environmental factor affecting dystocia. Results from previous studies (Philipsson, 1976b; Pollak and Freeman, 1976) indicated that more dystocia occurred in winter as compared to summer months.

Significant effects of year ($P < .01$) on calving difficulty was reported by Brinks et al. (1973), while Thompson et al. (1981) indicated that herd-year-season affected calving difficulty score in all dairy breeds.

Scoring Procedure for Dystocia and Stillbirth

Stillbirths occur when viability has sunk below a certain threshold level, and therefore, it is difficult to register calf liveability in any other way than categorically live or dead. However, a certain post-partum allowance must be included and a calf may be considered stillbirth if it is born dead or dies within a certain period of time shortly after birth. Therefore, certain variations may exist in scoring procedure for stillbirth. In most studies the scoring procedure with two liveability categories was used (Sagebiel et al., 1969; Laster an Gregory, 1973; Philipsson, 1976; Schaeffer and Wilton, 1976) with the post-partum allowance being 24 hours except for Schaeffer and Wilton (1976) who considered a limit of 48 hours. Scoring procedures considering three liveability categories that are found in the scoring schemes of the National Association of Animal Breeders (U.S.) and the Conception-to-Consumer (C-to-C) Charolais progeny test program were used by Thompson et al. (1981) and Tong et al. (1976), respectively. In these cases, the third category corresponds to the post-partum allowance.

As of ease of calving, it is clear that parturition may be more or less difficult, and without being measured on a continuous scale, several categories of difficulty can be considered. Number of categories for ease of calving differ, however, from one scoring scheme to the other. Laster (1974) considered two categories (either 0 - easy or 1 - difficult) with posterior presentations being recorded separately. In most studies, scoring procedures have used from three (Philipsson, 1976; Schaeffer and Wilton, 1976) to six categories (Brinks et al., 1973). The scoring procedure proposed by the Charolais C-to-C program and used by Tong et al. (1976) is different, with 8 categories of ease of calving. Four of these codes correspond to different types of malpresentations.

Since field records on calving performance are reported by farmers, it is important to propose simple scoring procedures for these traits. Philipsson et al. (1979) proposed the following classification (or coding) of type of calving:

1. No assistance required
2. Assistance of one person required; no mechanical aids
3. Assistance of more than one person required, or mechanical aids
4. Ceasarian section
5. Malpresentation

Most procedure used for field data collection correspond closely to such a classification. It is also important to use more than two codes, since the heritability estimates are generally higher when calving performance is differentiated into three or more classes in comparison with an all - or - none presentation.

Evaluation Methods

In order to evaluate sires for dystocia, only data from single births after normal gestation periods, and calves free from visible congenital defects, should be considered. A gestation period falling within $\pm$ 3σ of the population mean is considered normal. Since the phenotypic standard deviation of gestation length is about 5 days, only records from births occurring after 265 - 295 days should be kept. (Philipsson et al., 1979).

Methods of sire evaluation for calving ease have been examined in many studies. Schaeffer and Wilton (1976) indicated that the approach of Grizzle et al. (1969) can be extended to mixed models using Henderson's BLUP (Henderson, 1973) under the assumptions that the body of categorical data was sampled from one population, and that only one function of the categories is sufficient for interpretation of the results.

Hypothesis testing may be conducted which yield sums of squares which are distributed approximately as chi-squares under the assumption of large samples. These testing techniques should be used for categorical data, since usual analysis of variance are appropriate for normally distributed continuous data.

Berger and Freeman (1978) reported that the addition of relationships among sires in the model decreased prediction error of all bulls by 5%, with as much as a 30% decrease for some bulls. This decrease in prediction error was particularly beneficial to bulls with fewer actual progeny records.

Tong et al. (1976) examined the effect of different definitions of ease of calving on estimates of variance components. Three definitions were considered, with two of them combining ease of calving and calf survival, while a third definition was dealing strictly with ease of calving. Smaller sire variance and larger error to sire variance ratios were observed for the first two definitions, as compared to the third definition. According to their findings, selection for ease of calving based on ease of calving alone would result in more genetic progress than selection based on scores using calf liveability to aid in determining the extent of calving difficulty.

III. SOURCE AND CLASSIFICATION OF DATA

Source of Data

Data used in this study were field records on calving performance from herds in Quebec and the Maritime provinces enrolled on the Dairy Herd Analysis Service (DHAS). Collection of data on calving performance by DHAS started in September 1979.

Information required to examine calving performance as a trait of the calf included:

- herd number
- cow identification: breed, control number, Registration number or number and letter on National Identification Program (N.I.P.)
- birth date of the cow
- calving date of the cow
- lactation number initiated at calving
- cow weight: tape measurement at first test day following calving, in kilograms
- service sire identification: Registration number or identification number at Centre d'Insémination Artificielle du Québec (C.I.A.Q.)
- sex of calf: 1- male; 2- female; 3- multiple birth
- size of calf: 1- small; 2- medium; 3- large
- ease of calving: 1- easy, no assistance; 2- slight assistance; 3- difficult, hard pull; 4- surgical; 5- malpresentation
- calf survival: 1- alive; 2- dead at birth or within 24 hours postpartum.

Definition of Calving Performance

Ease of calving as a trait or calving performance is defined in different ways in the literature. Changes in the definition of ease of calving may have some effect on sire evaluation. To examine this, two definitions have been considered for the trait in Trial I. Even if a live calf is economically more important than a dead calf, the major criterion for scoring was ease of calving in both definitions, since the industry is mainly interested in evaluating sires for this single trait. In Definition I, a composite trait of ease of calving and calf survival was considered. The criterion for scoring in this case was primarily ease of calving with a secondary delineation on calf survival within ease of calving scores, thus creating five categories of calving performance. This approach was to examine if additionnal categories due to considering calf liveability, or the mere fact that calf liveability is considered along with type of calving could help identifying those sires with poorer calving performance as reflected by more calving problems and more calf losses resulting from their use.

The second definition (Definition II) was concerned with ease of calving only, malpresentation births being excluded. The reason for deleting malpresentations from the data was that no information was available as to the type of presentation or degree of difficulty from those births. Schaeffer and Wilton (1977) and Burfening <u>et al</u>. (1978) also deleted malpresentations.

In both definitions, code 1 (easy, no assistance) and code 2 (slight assistance) were combined because there is no way of establishing differences between these two categories. No assistance may have been because of the absence of observation of calving, and the dairyman might have provided slight assistance had he been present. An approach similar to that of Trial I was investigated by Tong et al. (1976).

For Trial II, the definition of calving performance considered was identical to Definition II of Trial I. The definitions considered are fully described in Table 3.

Table 3. Definitions of calving performance as a trait of the calf

Code reported on DHAS form		Type of calving		Score attributed
Ease of calving	Calf condition	Ease of calving	Calf condition	
		Definition I		
1 or 2	1	No assistance or slight assist	alive	100
1 or 2	2	No assistance or slight assist	dead	90
3 or 5	1	Hard pull or Malpresentation	alive	55
3 or 5	2	Hard pull or Malpresentation	dead	45
4	1 or 2	Surgical	alive or dead	0
		Definition II		
1 or 2	---	No assistance or slight assist	----	100
3	---	Difficult: hand pull	----	50
4	---	Surgical	----	0

Classification of Data

Trial I

Calving records with complete information as to the parameters already mentionned available from the DHAS file were used to create a data set in April 1980 which included calvings reported over a period of 7 months (September 1979 through March 1980). Fortran programs were used on IBM 370 Model 148 computer belonging to DHAS, to read and edit the data tapes.

Restrictions imposed for records to be kept were the following:

- calvings restricted to Holstein cows and Holstein service sires
- deletion of multiple births
- for second and later parity cows, cows with gestation length of over 296 days and less than 267 days (the mean ± 3σ) were deleted
- each service sire was required to have a minimum of 2 observations in 2 herds to avoid confounding of herd and sire effect.

Breeding dates were available from the DHAS file for second and later parity cows, but not for first calf heifers. Therefore, the restriction as to the gestation length was not imposed for the latter.

When calvings from all cows (first and later parities) were included, a total of 16653 observations were obtained fron 2914 herds. Subsets of the population were set up for analysis. First calf heifers and second and later parity cows were considered separately, and also combined as one set. Definition II excluded malpresentations, thus six subsets of data were prepared and are shown in Table 4, with observations classified according to sex of calf, month of calving, size of cow at calving (Table 4B) and parity or age at first calving (Table 4C).

Table 4. Trial I: Distribution of calving observations

A. By population subset, with number of herds and number of sires represented.

	Population subsets					
	All parity cows		First calf heifers		2nd and later parity cows	
	Def I	Def II	Def I	Def II	Def I	Def II
No. of observations	16653	16379	4254	4167	12367	12180
No. of herds	2914	2900	1537	1522	2736	2724
No. of sires	179	179	137	136	156	156

B. By sex of calf, month of calving and size of cow at calving.

		Population subsets					
		All parity cows		First calf heifers		2nd and later parity cows	
		Def I (16653)	Def II (16379)	Def I (4254)	Def II (4167)	Def I (12367)	Def II (12180)
Sex of calf							
Class	sex						
1	male	8127	7965	2087	2039	6023	5910
2	female	8526	8414	2167	2128	6344	6270
Month of calving							
Class	month						
1	Sept 79	401	396	152	148	249	248
2	Oct 79	1921	1890	704	687	1212	1198
3	Nov 79	2061	2023	658	645	1399	1374
4	Dec 79	3458	3406	943	926	2508	2472
5	Jan 80	3486	3411	927	905	2553	2501
6	Feb 80	1033	1020	257	253	774	765
7	Mar 80	4293	4233	613	603	3672	3622
Size of cow at calving							
Class	size (Kg)						
1	≤ 475	3844	3776	1400	1366	2431	2397
2	476-525	5385	5311	1746	1721	3627	3578
3	526-575	4211	4138	795	772	3407	3357
4	≥ 576	3213	3154	313	308	2902	2848

C. By parity, and age at first calving

		Number of observations	
		Definition I	Definition II
Parity of the dam		(16653)	(16379)
Class	parity		
1	1	4268	4182
2	2	3971	3915
3	3	2705	2666
4	4	2138	2099
5	≥ 5	3571	3517
Age at first calving (heifers)		(4254)	(4167)
Class	age at calving (month)		
1	< 24	436	424
2	24-27	1110	1094
3	27-30	912	887
4	30-33	1002	985
5	> 33	794	777

Trial II

Trial II examined the effect of using records from either all parity cows, first calf heifers or second and later parity cows on sire evaluation and recommendations as to their use on virgin heifers based on a new data set created in June 1981 which included all calving records with complete information for a period of 21 months (from September 1979 through May 1981). When calvings from all cows were considered, a total of 121 848 observations were obtained from 5987 herds. The three subsets of data corresponding to the subpopulations considered are shown in Table 5.

Classification of data and restrictions imposed for records to be kept were similar to those in Trial I. However, the restriction on the number of observations per service sire was imposed for variance components estimation and sire evaluation, but not for preliminary least squares analyses.

Since the 21 months period included cows with more than one calving reported in the DHAS files, only the first single birth calving with an identified service sire for a cow was retained.

Table 5: Trial II: Distribution of calving observations

A. By population subset, with number of herds represented.

	Population subsets		
	All parity cows	First calf heifers	Second and later parity cows
No. of observations	121848	22564	99284
No. of herds	5987	3535	5955

B. By sex of calf, month of calving and size of cow at calving.

		Population subsets		
		All parity cows (121848)	First calf heifers (22564)	Second and later parity cows (99284)
Sex of calf				
Class	sex			
1	male	60570	10933	49637
2	female	61278	11631	49647
Month of calving				
Class	month			
1	Sept 79	443	152	291
2	Oct 79	2167	743	1424
3	Nov 79	2366	687	1679
4	Dec 79	4001	994	3007
5	Jan 80	4094	977	3117
6	Feb 80	3787	691	3096
7	Mar 80	7497	550	6947
8	Apr 80	6003	427	5576
9	May 80	4341	344	3997
10	June 80	3786	298	3488
11	Jul 80	4012	406	3606
12	Aug 80	5581	1209	4372
13	Sept 80	7777	2457	5320
14	Oct 80	8820	2546	6274
15	Nov 80	8784	2265	6519
16	Dec 80	8478	1924	6554
17	Jan 81	8797	2068	6729
18	Feb 81	8159	1629	6530
19	Mar 81	12101	1204	10897

		Population subsets		
		All parity cows (121848)	First calf heifers (22564)	Second and later parity cows (99284)
Month of calving (cont'd)				
Class	month			
20	Apr 81	8620	752	7868
21	May 81	2234	241	1993
Size of cow at calving				
Class	size (Kg)			
1	≤ 420	4706	1166	3540
2	421-430	2283	568	1715
3	431-440	2232	601	1631
4	441-450	5911	1548	4363
5	451-460	4080	1129	2951
6	461-470	4952	1438	3514
7	471-480	6523	1907	4616
8	481-490	5717	1656	4061
9	491-500	12382	3116	9266
10	501-510	5785	1315	4470
11	511-520	7590	1500	6090
12	521-530	6080	1158	4922
13	531-540	7917	1262	6655
14	541-550	7345	1086	6259
15	551-560	5511	677	4834
16	561-570	4780	522	4258
17	571-580	4745	479	4266
18	581-590	4190	369	3821
19	591-600	4402	366	4036
20	≥ 601	14717	701	14016

C. By parity and age at first calving

Parity of the dam		No. of records
Class	Parity	(121848)
1	1	22564
2	2	29599
3	3	21130
4	4	16610
5	≥ 5	31945

Age at first calving (first calf heifers)		
Class	Age at 1st calving (months)	(22564)
1	< 21	160
2	21	144
3	22	481
4	23	1315
5	24	2078
6	25	2063
7	26	1995
8	27	1882
9	28	1894
10	29	1956
11	30	1901
12	31	1571
13	32	1320
14	33	951
15	34	791
16	35	626
17	≥ 36	1436

The number of observations in the variance components estimation and sire evaluation analyses were reduced for each subset of data because of the restriction on the minimum number of observations per sire. The description of these three subsets of data are given in Table 6.

Table 6. Trial II: Distribution of calving observations, number of herds represented and number of sires represented in the population subsets for variance components estimation and sire evaluation.

	Population subsets		
	All parity cows	First calf heifers	Second and later parity cows
No. of observations	98300	21081	76891
No. of herds	5706	3443	5616
No. of sires represented[1]	425	296	380

[1] Service sires with at least 2 observations (calvings) in 2 herds.

IV. METHODS OF ANALYSIS

Similar analysis procedures were used for the Trial I and Trial II data sets on calving performance. The Fortran programs used for the main statistical analysis were written by B.W. Kennedy and A.K.W. Tong.

Trial I

Least Squares Analysis

Fixed effects due to herd, sex of calf, parity (or age at first calving) of the dam, month of calving, size of cow at calving, plus the interaction sex by parity were examined according to the following linear model:

$$Y_{ijklmn} = \mu + H_i + X_j + P_k + M_l + T_m + XP_{jk} + e_{ijklmn}$$

where Y_{ijklmn} is the observed calving performance at birth of the n^{th} calf.

μ is the population mean

H_i is the fixed effect of the i^{th} herd

X_j is the fixed effect of the j^{th} sex of the calf

P_k is the fixed effect of the k^{th} parity (or age at first calving of heifers), with parity classified into four subclasses for second and later parity cows (2,3,4, and $\geq$ 5), five subclasses for all parity cows (1,2,3,4, and $>$ 5), and into five subclasses of age at first calving for heifers ($<$24, 24-27, 27-30, 30-33 and $>$33).

M_l is the fixed effect of the l^{th} month of calving with seven subclasses (September 1979 to March 1980).

T_m is the fixed effect of the m^{th} size of the dam at calving, with size classified into four subclasses ($\leq$475, 476-525, 526-575, $\geq$576).

XP_{jk} is the interaction between parity (or age at first calving) of the dam and sex of the calf.

e_{ijklmn} is the random error associated with the ijklmnth observation.

The classification and distribution of observations were as presented in Table 3, Section III. Herd equations were absorbed in the analyses. Results of the Least Squares analysis are presented in the Appendix Table 2 to 4.

Variance Components Estimation

An iterative MINQUE (Minimum Norm Quadratic Unbiased Estimation) (Rao, 1971) procedure was used to simultaneously estimate fixed effects and variance components, using Henderson's mixed model equations (Henderson, 1975). It may be noted that MINQUE estimation of sire and error variance components is a statistically valid procedure for a trait such as calving ease, since it does not depend on any distributional assumptions.

General Mixed Linear Model

The following general mixed linear model was used:

$$y = Xb + Zu + e$$

where y is a vector of observations of order n x 1, for n = total number of observations

X is an incidence matrix describing the association of the observations with the fixed effects listed above

b is a vector of unknown fixed effects of order p x 1

Z is an incidence matrix describing the association of the observations with the random sires u is a vector on random sire effects of order q x 1 ~(0, σ_s^2 I); sires were assumed unrelated

e is a vector of random error of order n x 1

Additionnaly u and e are assumed to be uncorrelated

The mixed model equations were:

$$\begin{pmatrix} X'X & X'Z \\ Z'X & Z'Z + D \end{pmatrix} \begin{pmatrix} \hat{b} \\ \hat{u} \end{pmatrix} = \begin{pmatrix} X'y \\ Z'y \end{pmatrix}$$

where: $D = \frac{\sigma_e^2}{\sigma_s^2} I$, assuming σ_e^2 and σ_s^2 are known.

Procedure

In partitioned form, the mixed model equations are:

$$\begin{pmatrix} X'X \\ Z'X \end{pmatrix} \begin{pmatrix} X'Z \ldots \\ Z'Z + \tilde{\sigma}_e^2 / \tilde{\sigma}_s^2 I \end{pmatrix} \begin{pmatrix} \hat{b} \\ \hat{u} \end{pmatrix} = \begin{pmatrix} X'y \\ Z'y \end{pmatrix}$$

where $\tilde{\sigma}_e^2$ and $\tilde{\sigma}_s^2$ are prior estimates of σ_e^2 and σ_s^2.

Let T be a symmetric generalized inverse of the coefficient matrix:

$$\begin{pmatrix} X'X & X'Z \\ Z'X & Z'Z + D \end{pmatrix}^{-} = T = \begin{pmatrix} T_{bb} & T_{bs} \\ T'_{bs} & T_{ss} \end{pmatrix}$$

Then sums of squares are computed:

$$t_o = y'y - \hat{b}'X'y - \hat{u}\, Z'y - \hat{u}'\hat{u}\hat{\sigma}_e^2 / \hat{\sigma}_s^2$$

$$t_s = \hat{u}'\hat{u}\, (\hat{\sigma}_e^2 / \hat{\sigma}_s^2)^2$$

and coefficients

$$P_{oo} = n - r - q + \sum_{i=1}^{s} \sum_{j=1}^{s} \mathrm{tr}\, T_{ss} T'_{ss} \frac{\tilde{\sigma}_e^2}{\tilde{\sigma}_i^2} \frac{\tilde{\sigma}_e^2}{\tilde{\sigma}_j^2},$$

where r = rank of X

$$P_{os} = \left(\frac{\tilde{\sigma}_e^2}{\tilde{\sigma}_s^2}\right)^2 \left(tr\ T_{1i} - \sum_{j=1}^{s} tr\ T_{ss}\ T'_{ss}\ \frac{\tilde{\sigma}_e^2}{\tilde{\sigma}_s^2}\right)$$

$$P_{ss} = \left(\frac{\tilde{\sigma}_e^2}{\tilde{\sigma}_s^2}\right)^2 \left(q_s - 2\ tr\ T_{ss}\ \frac{\tilde{\sigma}_e^2}{\tilde{\sigma}_s^2} + tr\ (T_{ss})^2 \left(\frac{\tilde{\sigma}_e^2}{\tilde{\sigma}_s^2}\right)^2\right)$$

Defining

$$P = \begin{pmatrix} P_{oo} & P_{os} \\ P'_{os} & P_{ss} \end{pmatrix}, \quad t = \begin{pmatrix} t_o \\ t_s \end{pmatrix} \quad \text{and} \quad \sigma_s^2 = \begin{pmatrix} \sigma_e^2 \\ \sigma_s^2 \end{pmatrix}$$

then MINQUE of σ^2 is

$$\sigma^2 = P^{-1}\ t$$

and var $(\hat{\sigma}^2) = 2\ P^{-1}\ \hat{\sigma}_e^4$

This process can be repeated iteratively until convergence such that $\tilde{\sigma}^2 \simeq \hat{\sigma}^2$.

Prior estimates and iteration

These solutions require a starting point or prior estimates of σ_e^2 / σ_s^2. The starting ratio can be estimated by techniques given by Schaeffer and Burnside (1974). Since heritability estimates for calving ease as a discrete trait have been demonstrated to decline with increasing parity, (Pollak, 1975), different starting ratios have been used according to the population considered:

Let $r = \sigma_e^2 / \sigma_s^2$

If heritability estimated by the Paternal Half Sib method is defined as

$$h^2 = \frac{4\,\sigma_s^2}{\sigma_s^2 + \sigma_e^2}$$

then $h^2 = 4/(1 + r)$

Therefore, h^2 estimates for calving ease as a discrete trait reported from previous studies can be used to provide some knowledge of the starting ratio (σ_e^2 / σ_s^2). The first estimates of σ_e^2 / σ_s^2 produced the first set of solutions and estimates of variance components. These results were then substituted and the new equations formed and solved. Repeated rounds of iteration were run until the difference between error to sire variance ratios in two successive rounds were < /.01/.

Input ratios and ratios in successive rounds of iteration are found in Appendix Tables 5, 6 and 7.

Mixed Model Analysis

Service sire was included as a random effect in the following model:

$$Y_{ijklmno} = \mu + H_i + X_j + P_k + M_l + T_m + XP_{jk} + S_n + e_{ijklmno}$$

where $Y_{ijklmno}$, μ, H_i, X_j, P_k, M_l, T_m and XP_{jk} are as already described and where:

S_n is the random effect associated with the n^{th} sire $\sim (0, \sigma_s^2)$

$e_{ijklmno}$ is the random error associated with the $ijklmno^{th}$ record.

This model was analyzed according to MINQUE procedures for the two definitions and for the three subpopulations considered. This provided estimates of the variance components, best linear unbiased estimates of fixed effects (BLUE) and best linear unbiased predictors (BLUP) of random effects.

Heritability estimation

Heritability may be defined as the fraction of total phenotypic variation attributable to genetic difference. In this study, the heritability was estimated by the Paternal Half Sib (PHS) method, assuming that sires are unrelated.

$$h^2 = \frac{4\ \hat{\sigma}_s^2}{\hat{\sigma}_p^2} = \frac{4\ \hat{\sigma}_s^2}{\hat{\sigma}_s^2 + \hat{\sigma}_e^2}$$

where $\hat{\sigma}_s^2$ is the estimate of the sire variance

$\hat{\sigma}_e^2$ is the estimate of the error variance

$\hat{\sigma}_p^2$ is therefore the estimate of the phenotypic variance.

These estimates do not necessarily yield the true heritability of the trait - calving ease - since heritabilities from discrete variable commonly are adjusted upward. However, these h^2 estimates reflect the error to sire variance ratio for BLUP since we are dealing with the discrete trait and not the underlying normal distribution that can be assumed.

Hypothesis testing

Categorized traits such as ease of calving are not distributed normally but may have an underlying normal distribution. Conventional tests of hypothesis may therefore be inappropriate for such traits. In this study, hypothesis testing has been conducted which yield sums of squares which are distributed approximately as chi-squares under the assumption of large samples. This can be achieved by multiplying the sums of squares obtained from generalized least squares by a scaling factor (t). These testing techniques have been proposed and are fully explained by Schaeffer and Wilton (1976).

Scaling factors for this study are presented in Appendix Table 1.

Trial II

Least Squares Analysis

The observations in the data sets created for this part of the study are classified and distributed as given in Table 5 of Section III. A first least squares analysis was run to determine if some subclasses of the effects considered (month, size, parity or age at calving) could be grouped.

For this, the following model was used:

$$Y_{ijklmn} = \mu + H_i + X_j + P_k + M_l + T_m + e_{ijklmn}$$

where: Y_{ijklmn} is the observed calving performance at birth of the n^{th} calf.

μ is the population mean

H_i is the fixed effect of the i^{th} herd

X_j is the fixed effect of the j^{th} sex of calf

P_k is the fixed effect of the k^{th} parity of the dam (or age at first calving of heifers), with parity classified into four classes for second and later parity cows (2,3,4 and ≥ 5), five subclasses for all parity cows (1,2,3,4, ≥ 5) and seventeen subclasses of age at first calving of heifers (from <21 to ≥ 36 months).

M_l is the fixed effect of the l^{th} month of calving, classified into twenty-one subclasses (from Sept '79 through May '81)

T_m is the fixed effect of the m^{th} size of dam at calving, classified into twenty subclasses (from ≤ 420 Kg to ≥ 601Kg).

$e_{ijklmno}$ is the random error term associated with the $ijklmno^{th}$ observation.

Herd effects were absorbed in the analysis. Results of these preliminary analyses are presented in Appendix Tables 8, 9 and 10 for all parity cows, first calf heifers, and second and later parity cows, respectively. According to these results, the classification for the effects of month of calving, size of dam at calving, and parity (or age at first calving) was modified as follows:

	Population subsets		
	All parity cows	First calf heifers	Second and later parity cows
	Season of Calving		
Class			
1	Sept. 79 - Mar. 80	Sept. 79 - Feb. 80	Classification unchanged
2	Apr. 80 - Sept. 80	Mar. 80 - Sept. 80	(21 months subclasses)
3	Oct. 80 - Feb. 81	Oct, 80 - Feb. 81	
4	Mar. 81 - May 81	Mar. 81 - May 81	
	Size of dam at calving		
Class			
1	< 480 Kg	Cov. 1 (body weight)	< 440 Kg
2	≥ 480 Kg	Cov. 2 (body weight squared)	≥ 440 Kg
	Parity (or age at 1st calving)		
Class			
1	1	< 25 months	2
2	≥ 2	25 - 34 months	3
3	--	>34 months	4
4	--	--	≥ 5

With the classification of data modified as mentionned above, a new series of least squares analyses was performed, to determine the effects of the identified factors and some of their interactions on calving performance. The model used for all parity cows and second and later parity cows was as follows:

$$Y_{ijklmn} = \mu + H_i + X_j + P_k + M_l + T_m + XP_{jk} + XT_{jm} + PT_{km} + XPT_{jkm} + e_{ijklmn}$$

where: Y_{ijklmn} is the observed calving performance at birth of the n^{th} calf

μ is the population mean

H_i is the fixed effect of the i^{th} herd

X_j is the fixed effect of the j^{th} sex of calf

P_k is the fixed effect of the k^{th} parity of dam, with parity classified into two subclasses for all parity cows, and four subclasses for second and later parity cows.

M_l is the fixed effect of the l^{th} season of calving, with season classified into four subclasses for all parity cows, and twenty-one subclasses for second and later parity cows

T_m is the fixed effect of the m^{th} size of cow at calving, with size classified into two subclasses

XP_{jk} is the fixed effect due to the interaction between sex of calf and parity

XT_{jm} is the fixed effect due to the interaction between sex of the calf and size of dam

PT_{km} is the fixed effect due to the interaction between parity and size

XPT_{jkm} is the fixed effect due to the interaction between sex of calf, parity and size of dam

e_{ijklmn} is the random error associated with the $ijklmn^{th}$ observation.

For first calf heifers, a similar model was used, except that size at calving was included as covariates for linear and quadratic effects of body weight in kilograms. The interactions with size were not in the model, which was as follows:

$$Y_{ijklmn} = \mu + H_i + X_j + P_k + M_l + b_1 O_{ijklm} + b_2 O^2_{ijklm} + XP_{jk} + e_{ijklmn}$$

where Y_{ijklmn}, μ, H_i, X_j and e_{ijklmn} are as already described

P_k is the fixed effect of the k^{th} age at first calving, classified into three subclasses

M_l is the fixed effect of season of calving, classified into four subclasses

O is the covariate body weight in Kg

O^2 is the covariate body weight squared

XP_{jk} is the interaction between sex of calf and age at first calving.

None of the interactions tested were significant in the case of first calf heifers or second and later parities. For all parity cows, all main effects and interactions tested were highly significant ($P < .01$) except the interaction between parity and size which was significant ($P < .05$). (See Appendix Tables 11 to 13).

Mixed Model Analysis

The service sire was included as a random effect in the three models set up for the three subpopulations considered. These models were as follows:

(1) All parity cows:

$$Y_{ijklmno} = \mu + H_i + X_j + P_k + M_l + T_m + XP_{jk} + XT_{jm} + PT_{km} + XPT_{jkm} + S_n + e_{ijklmno}$$

(2) Second and later parity cows:

$$Y_{ijklmno} = \mu + H_i + X_j + P_k + M_l + T_m + S_n + e_{ijklmno}$$

(3) First calf heifers:

$$Y_{ijklmno} = \mu + H_i + X_j + P_k + M_l + b_1 O_{ijklm} + b_2 O^2_{ijklm} + S_n + e_{ijklmno}$$

where $Y_{ijklmno}$, μ, H_i, X_j, P_k, M_l, T_m, O and O^2 are as previously described, according to the subpopulation considered, and

S_n is the random effect associated with the n^{th} sire $\sim (0, \sigma^2_s)$

$e_{ijklmno}$ is the random error associated with the $ijklmno^{th}$ observation.

These models were analyzed according to MINQUE procedure to obtain estimates of variance components, BLUE of fixed effects and BLUP of random effects. Considerations on general mixed linear model and procedure have already been explained in this section.

Rank Correlations

Correlations for sire rankings from the different population subsets used were calculated according to Kendall's rank correlation coefficient of two variables (Siegel, 1956).

V. RESULTS AND DISCUSSION

Frequencies of Dystocia and Calf Mortality

Frequencies of calvings falling into each category as reported by dairymen on DHAS forms have been analysed in both parts of this study (Trial I and Trial II), and these are presented in Table 7, for the three subpopulations. Looking at the whole population (all parity cows), it appears that 29% of calvings in Holsteins required some degree of assistance (codes $\geqslant 2$), assuming that malpresentation cases reported were assisted.

Something that already was suspected is observed when looking at figures from the other two subpopulations: first calf heifers experienced much more calving problems than older cows, with 40% (40,3% in Trial I and 39,9% in Trial II) of their calvings receiving some degree of assistance (code $\geqslant 2$), as compared to 25-26% for calvings from older cows. This trend is in agreement with other studies with Holstein cows (McDaniel, 1981; Cady et al., 1981). Percentage of assisted births among first calf heifers is higher in this study than the figures reported by Pollak and Freeman (1976) who found that 29% and 34,1% of births from heifers required assistance, in a study which examined the same trait in two Holstein populations in United States.

The association of calf losses at or near the time of birth with type of calving (or, degree of difficulty) is illustrated in Table 8, with values obtained from the larger data set (Trial II). Percent calf mortality represented 3,9% of calves delivered among the whole population (all parities). This result is slightly lower than figures repor-

Table 7. Frequency of calvings in each category as reported by Holstein Breeders, for each population subset.

Code	Type of calving	Population subsets					
		All parity cows		First calf heifers		Second and later parity cows	
		Trial I (%)	Trial II (%)	Trial I (%)	Trial II (%)	Trial I (%)	Trial II (%)
1	Easy, no assist.	70,8	71,3	59,7	60,1	74,6	73,8
2	Slight assist.	21,8	22,5	25,4	26,8	20,6	21,5
3	Difficult: hard pull	5,3	4,6	11,5	10,4	3,1	3,2
4	Surgical	0,5	0,3	1,3	0,8	0,2	0,3
5	Malpresentation	1,6	1,3	2,1	1,9	1,5	1,2
	TOTAL	100	100	100	100	100	100
No. of observations		16653	121848	4254	22564	12367	99284

Table 8. Calf losses at or near time of birth associated with type of calving, for each population subset.

Code	Type of calving	Population subsets					
		All parity cows		First calf heifers		Second and later parity cows	
		%	No.	%	No.	%	No.
1	No assist.	2,4	2085	3,9	529	2,1	1539
2	Slight assist	3,0	822	4,6	279	2,5	534
3	Hard pull	22,4	1255	27,6	648	18,4	584
4	Surgical	40,0	146	40,5	73	40,0	119
5	Malpresentation	29,5	467	39,0	167	26,0	310
	Overall	3,9	4775	7,5	1696	3,1	3086

ted by Thompson et al. (1981) who found a calf mortality rate of 5% in a population of the same breed in the U.S. The proportion of calves reported dead at or near time of birth was more than twice as high for calvings from heifers as compared to those from older cows (7,5% vs 3,1%, respectively). Depending on the subpopulation considered, percent calf losses within code 3 (hard pull) was 6 to 9 times greater than mortality associated with unassisted births. Percent mortality within code 2 (slight assist) was close to the corresponding figures for code 1 (unassisted) suggesting that these two categories can be attributed almost equal economic weightings as far as calf losses in concerned, but with some difference due to a few extra labor expanded for calvings of code 2, As expected, the more severe calf losses were associated with surgical calvings, with 40% of calves born this way reported dead at or near time of birth, regardless of the population considered.

The association of calf losses with type of calving has been reported from several studies. Laster and Gregory (1973) indicated that losses at or near time of birth were four times greater in calves experiencing dystocia than in those from normal births. Other researchers reported figures in agreement with these (Laster et al., 1973; Brinks et al., 1973; Philipsson, 1976a; McDaniel, 1981). These figures of calf losses associated with type of calving suggest that reducing the incidence of dystocia would result in important reduction in calf losses.

Calving Performance Scores

According to the code reported on DHAS form and to the definition adopted for calving performance, a score was attributed for any given observation. Mean calving ease scores and frequencies of calvings falling in each new category created appear in Tables 9, 10, and 11 for Definition I, Definition II (Trial I) and for the scoring procedure adopted in Trial II (which is similar to Def II), respectively. Tong et al. (1976) used scoring procedures similar to those used in this study, and the data used by these authors were from Charolais c-to-c program, which includes only cows at least 3 year old. When comparing the frequencies from their study with frequencies from older cows in this study, one can observe that frequency of surgical calvings is similar in both populations, while other degrees of difficulty show larger differences. For example, calvings scored 100 in this study represented 93% and 96% of the observations for Definition I and Definition II respectively, as compared to 88% and 93% of the observations from Charolais population for the corresponding scoring procedures. These differences are not surprising, since it is known that more frequent calving problems were experienced with the use of Charolais sires in beef cattle populations.

Table 9. Trial I: Frequency of observations in each category of calving performance and mean calving ease scores by population subsets, for Definition I.

		Population subsets		
		All parity cows (16653)	First calf heifers (4254)	Second and later parity cows (12367)
Performance	Score	Frequency (%)		
No assist or slight assist Calf alive	100	90,4	81,8	93,4
No assist or slight assist Calf dead	90	2,2	3,4	1,8
Hard Pull or M.P. Calf alive	55	5,3	9,4	3,9
Hard Pull or M.P. Calf dead	45	1,6	4,1	0,7
Surgical Calf alive or dead	0	0,5	1,3	0,2
Mean Calving Ease Score		96,02	91,86	97,47

Table 10. Trial I: Frequency of observations in each category of calving performance and mean calving ease score by population subset, for Definition II.

		Population subsets		
		All parity cows (16379)	First calf heifers (4167)	Second and later parity cows (12180)
Performance	Score	Frequency (%)		
No assist or slight assist	100	94,2	86,9	96,7
Hard Pull	50	5,4	11,8	3,1
Surgical	0	0,5	1,3	0,2
Mean calving ease score		96,83	92,79	98,22

Table 11. Trial II: Frequency of observations in each category of calving performance and mean calving ease score by population subset.

		Population subsets		
		All parity cows	First calf heifers	Second and later parity cows
Performance	Score	Frequency (%)		
No assist or slight assist	100	95,0	88,6	96,5
Hard Pull	50	4,7	10,6	3,2
Surgical	0	0,3	0,8	0,3
Mean calving ease score		97,33	93,90	98,12
Standard deviation		11,87	17,57	10,15

Fixed Effects

Fixed effects included in the models to account for known source of variation were sex of calf, parity (or age at first calving), month (or season) of calving, and size of dam at calving. The significance level of these effects appears in Appendix Tables 2 to 4 for analyses in Trial I, and in Appendix Tables 8 to 13 for analyses in Trial II.

In Trial I, results from least squares analyses were similar for both Definition I and Definition II. For all parity cows, sex of calf, parity and the interaction sex by parity were highly significant, while month of calving and size of dam were not significant source of variation. For first calf heifers and second and later parity cows, sex of calf was the only significant source of variation on calving performance ($P < .01$).

According to the results from analyses with the larger data sets (Trial II), the least squares estimated differences (LSE) of main effects on calving ease score appear in Figures 1 to 9. Each subclass of an effect is expressed as a deviation from the last subclass which is set to zero. These illustrate the results from analyses before modifications of the initial classification. The significance of these effects appear in Appendix Tables 8, 9 and 10, for all parity cows, first calf heifers, and second and later parity cows, respectively.

Sex of Calf

As expected, male calves consistently experienced more dystocia than female calves, this effect being a significant source of variation ($P < .01$) on calving ease score in all analyses and for all population subsets considered. However, the difference between calving ease scores for male and female calves were smaller in second and later parity population as compared to first calf heifer population (see Figure 1). This suggests that the interaction sex by parity is likely to be important when all parities are considered for analysis. The sex by parity interaction was significant only in the analyses which included all parity cows, and is illustrated in Figure 10a. This result regarding parity by sex interaction is supported by Pollak and Freeman (1976).

The higher frequency of dystocia observed at birth of male calves may be due to heavier birth weights of males. However, Pollak and Freeman (1976) found that sex of calf remained significant ($P < ,05$) with calf size in the model, indicating that differences in sex other than size, such as structure or hormonal differences, may exist.

Sex of calf has been reported as a significant source of variation on calving ease from many previous studies (Bellows et al., 1969; Rice and Wiltbank, 1970; Bellows et al., 1971; Brinks et al., 1973; Laster et al., 1973; Pollak and Freeman, 1976; Philipsson, 1976; Tong et al., 1976; Burfening et al., 1978, and others).

Distribution of observations for Trial II in Section III indicates that the sex ratio (M : F) was as follows, for calvings from all parity cows, first calf heifers, and second and later parity cows, respectively:

49,7 : 50,3; 48,4 : 51,5; 50,0 : 50,0.

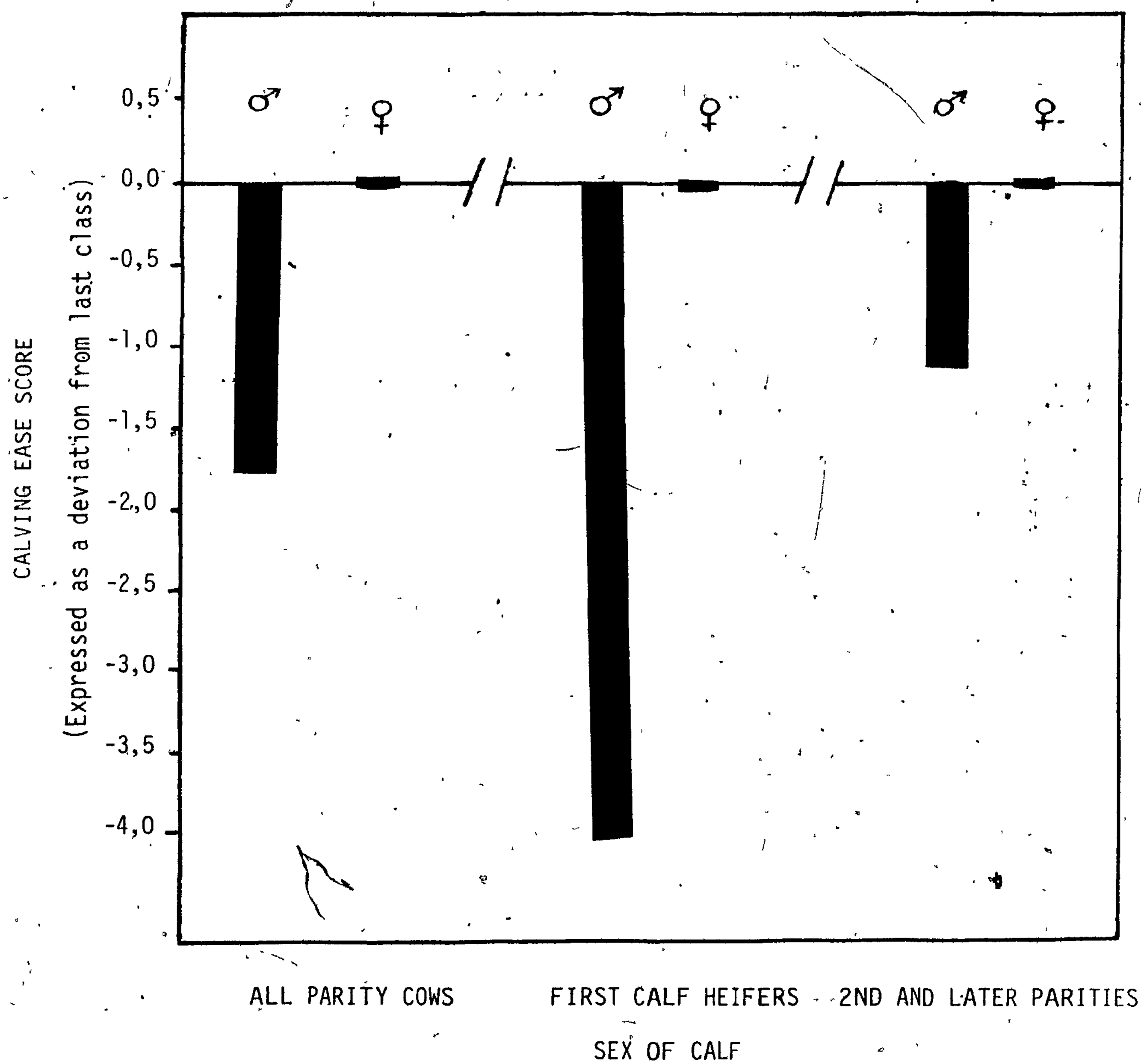

Figure 1. Least squares estimated differences for the effect of sex of calf on calving ease score.

Parity

Effect of parity on calving ease score was highly significant (P < .01) when all parity cows were considered. This is consistent with many previous studies (Laster and Gregory, 1973; Brinks et al., 1973; Pollak and Freeman, 1976; Philipsson, 1976a, and others). Calves born from first calf heifers experienced much more problem than those born from cows at their second and later calvings, as illustrated in Figure 2. The difference in calving ease score was pronunced only between first parity and later parities, while differences between second and later parities were very small.

Therefore, data were classified into two subclasses regarding parity - first vs second and greater - for further analyses with all parity cows. Though effect of parity was not significant with second and later parity cows, the effect of parity was included with four subclasses (2, 3, 4 and ≥ 5) in the model for analyses of the second and later parity population subset.

According to Van Dieten (cited by Philipsson, 1976b) it is the mere fact that the process of parturition takes place for the first time that causes the difference between heifers and cows, rather than age. Growth and skeletal development after first calving and a more favorable relation between calf and cow weight for cows are other explanations for such a difference, despite the fact that calf weight is greater at later parities.

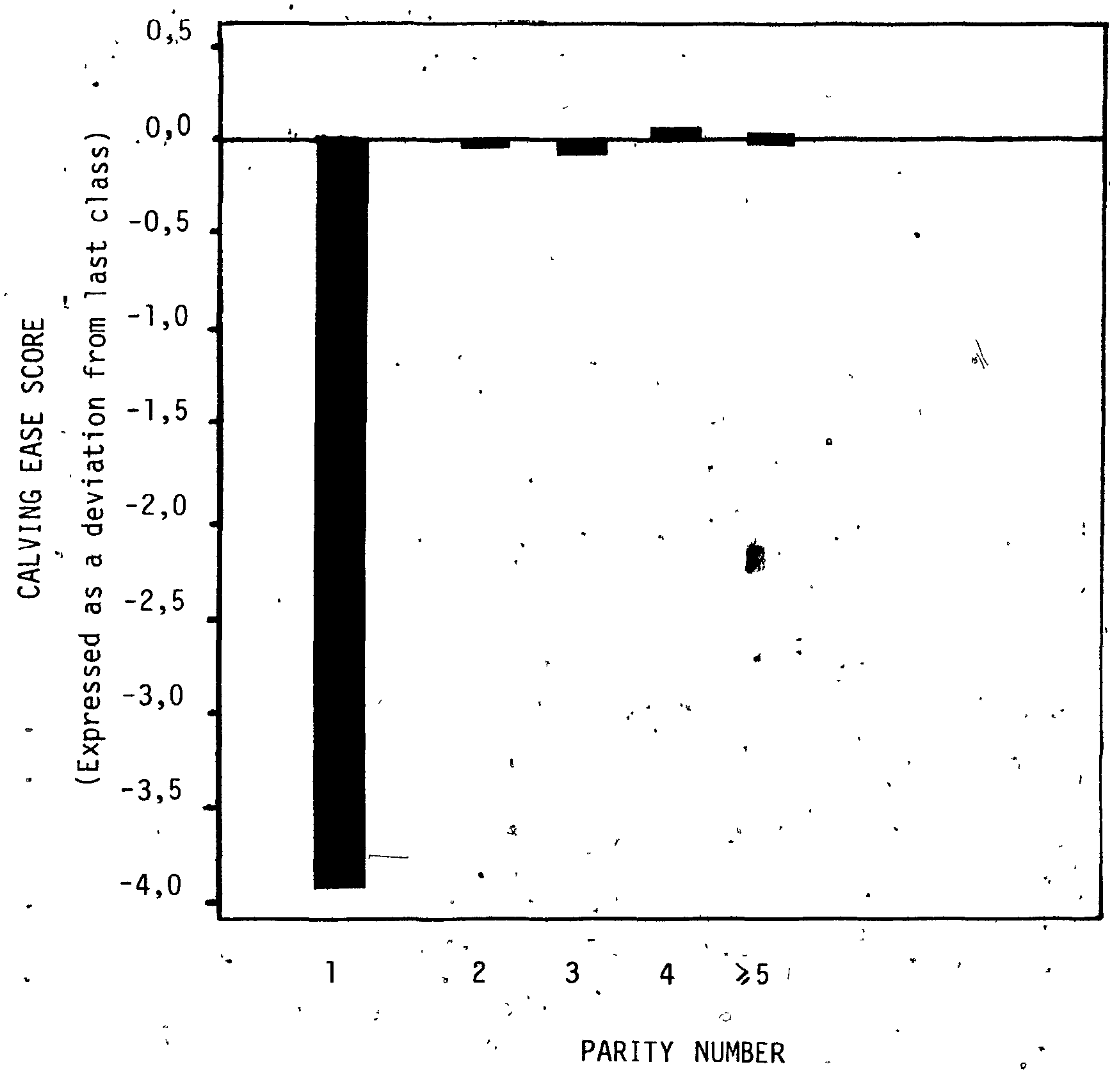

Figure 2. Least squares estimated differences for the effect of parity on calving ease score.

Age at first calving

The age at first calving effect was included in the model which considered only first calf heifers. Age at calving was classified into 17 subclasses for preliminary analysis in Trial II (from < 21 month to ≥ 36 month old, by increment of 1 month). As seen in Appendix Table 9, age at calving was not a significant source of variation on calving ease score. Philipsson (1976b) also examined age at first calving, and reported it to be significant in some populations, while it was not for other populations. In all cases, he observed that calving difficulty tended to be least at intermediate age. Least squares estimated differences for age at first calving are illustrated in Figure 3. With the exception of the subclass 21 month old, calves born from heifers younger than 25 months experienced more difficulties than those born from older heifers. Calves born from heifers in the 9 subclasses from 25 to 33 month old (inclusively) were those experiencing the less difficulties, while calvings from heifers ≥ 34 month old tended to be more difficult again. Poorer performance of older heifers vs those at intermediate age may be due to greater fatness with fat depots in the birth canal, along with a higher degree of ossification and stiffness of the pelvis.

For further analyses, classification with respect to age at first calving was modified, with only three groups of age being created (< 25 month, 25-34 month, and > 34 month old). Distribution of the data (Table 5c, Section III) indicates that 18,5% of heifers calved at age less than 25 month, as compared to 72% calving from 25 to 34 month old, and 9% calving at 35 months and older.

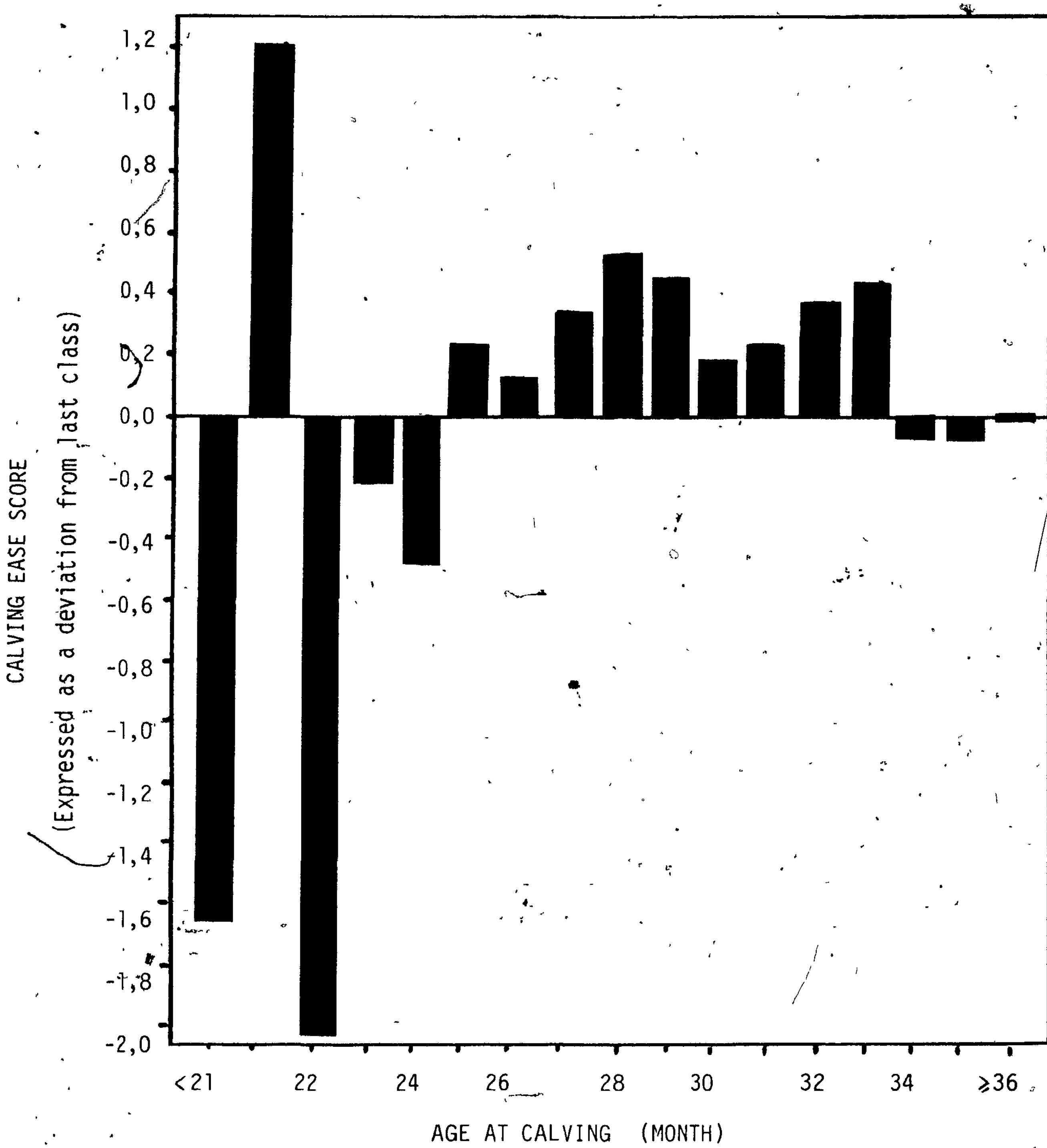

Figure 3. Least squares estimated differences for the effect of age at first calving of heifers on calving ease score.

Though the effect of age at first calving on calving ease appears to be small, still some 38% of first calf heifers were calving at 30 month and older. Late calvings from heifers have been shown to represent a net loss of income for producers.

Month of calving

The month of calving effect, with 21 subclasses in the analyses for Trial II (from Sept 79 through May 81), was a highly significant ($P < .01$) source of variation on calving ease score for the three subpopulations considered (Appendix Tables 8, 9 and 10). In the analyses for Trial I, effect of month was found to be non significant, but this may be explained by the fact that the period covered in Trial I corresponds closely to one season (winter), as defined in a previous study (Pollak and Freeman, 1976).

Least squares estimated differences in Figures 4,5 and 6 illustrate effect of month of calving on calving ease score for all parity cows, first calf heifers, and second and later parity cows, respectively. These indicate that more dystocia is experienced in winter months than during summer months, which is consistent with results from previous studies (Pollak and Freeman, 1976; Philipsson, 1976b). Season delimitation does not appear constant from one year to the other (which would be a year effect), or from one subpopulation to the other. In the analyses for all parity cows and first calf heifers, classification of month of calving was modified according to the trends from the LSE, as previously indicated in Section IV. For second and later parity cows, seasonal trends were not apparent, although the effect of month was found to be significant.

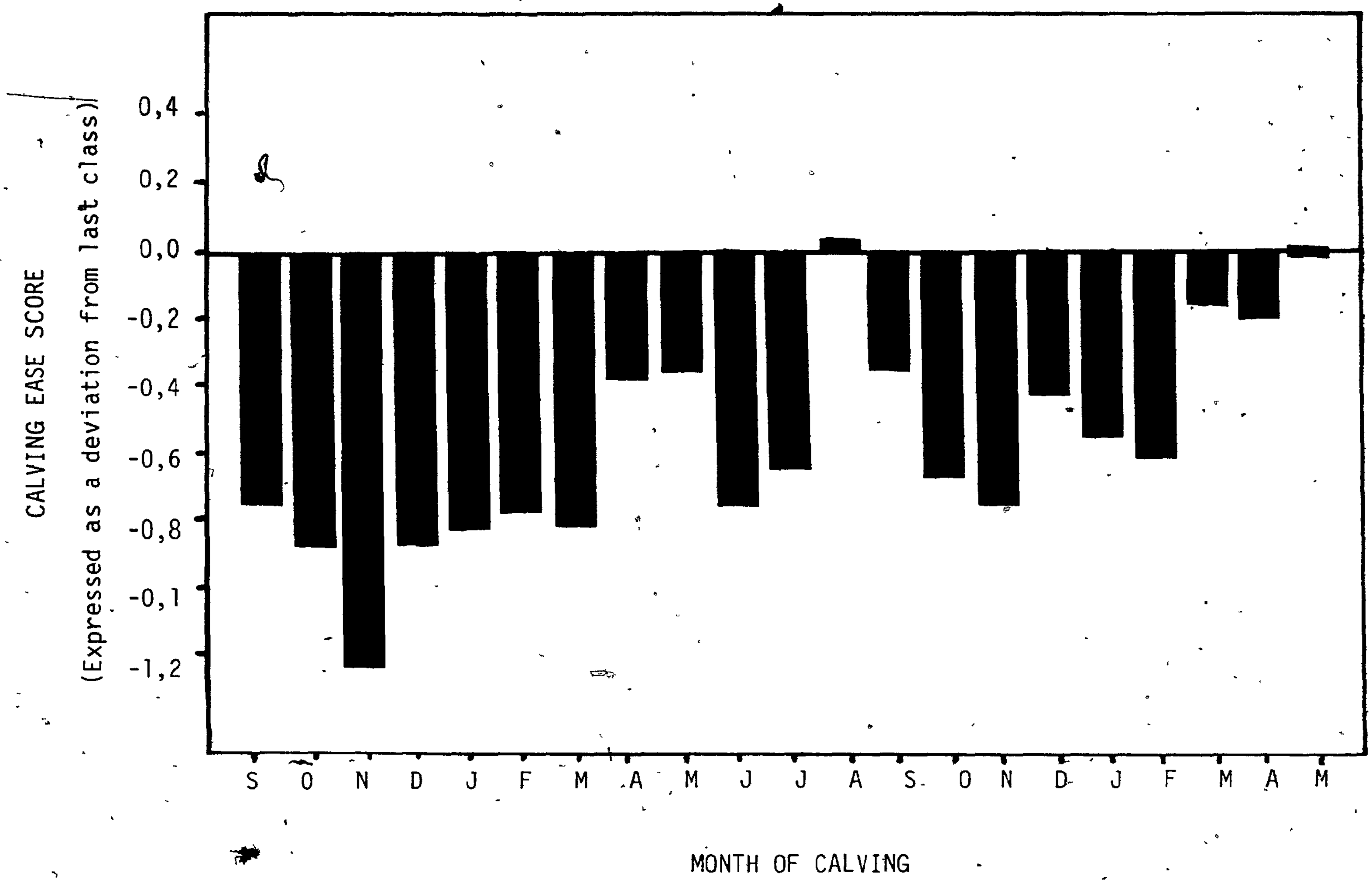

Figure 4. Least squares estimated difference for the effect of month of calving on calving ease score, all parity cows.

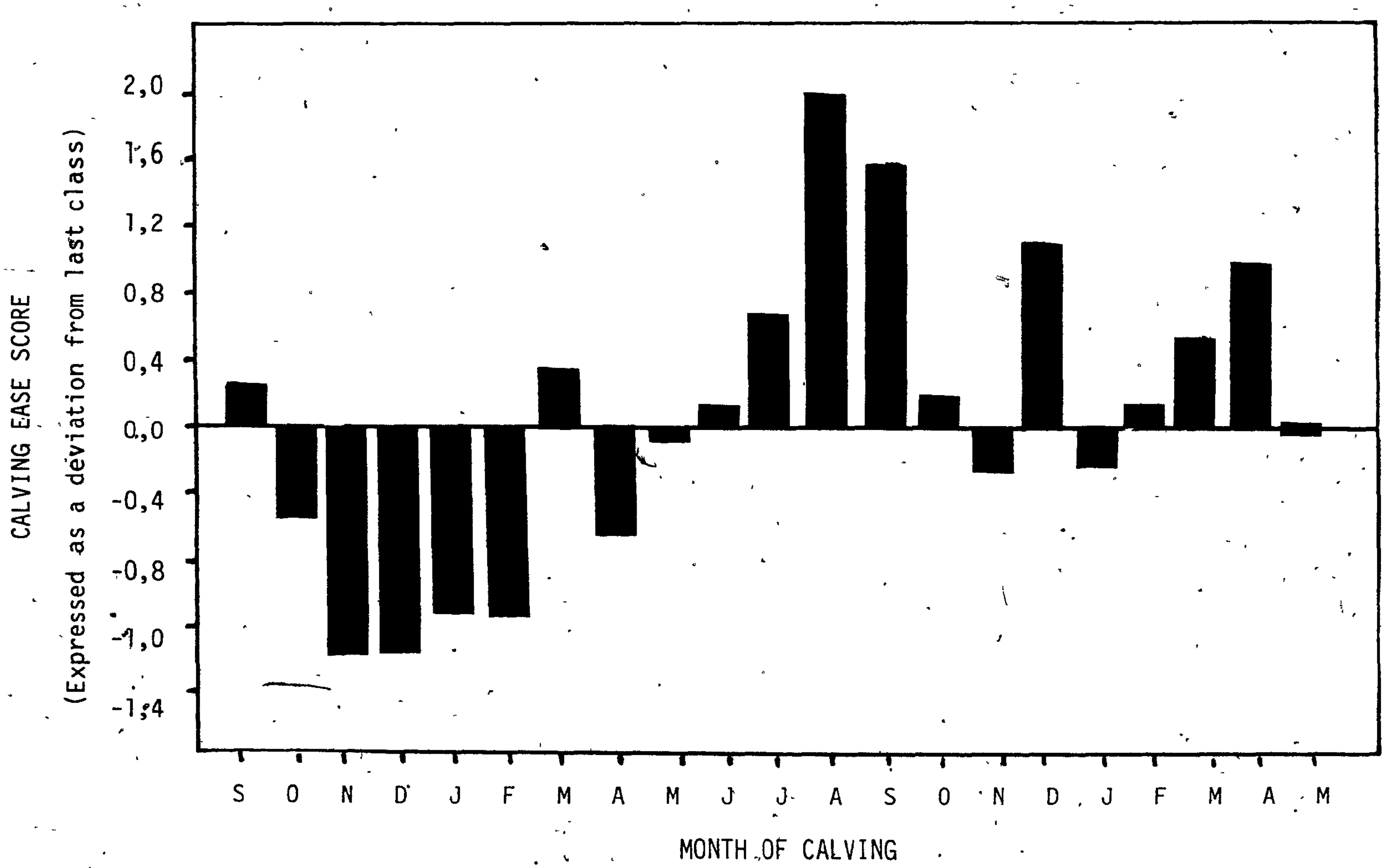

Figure 5. Least squares estimated differences for the effect of month of calving on calving ease score, first calf heifers.

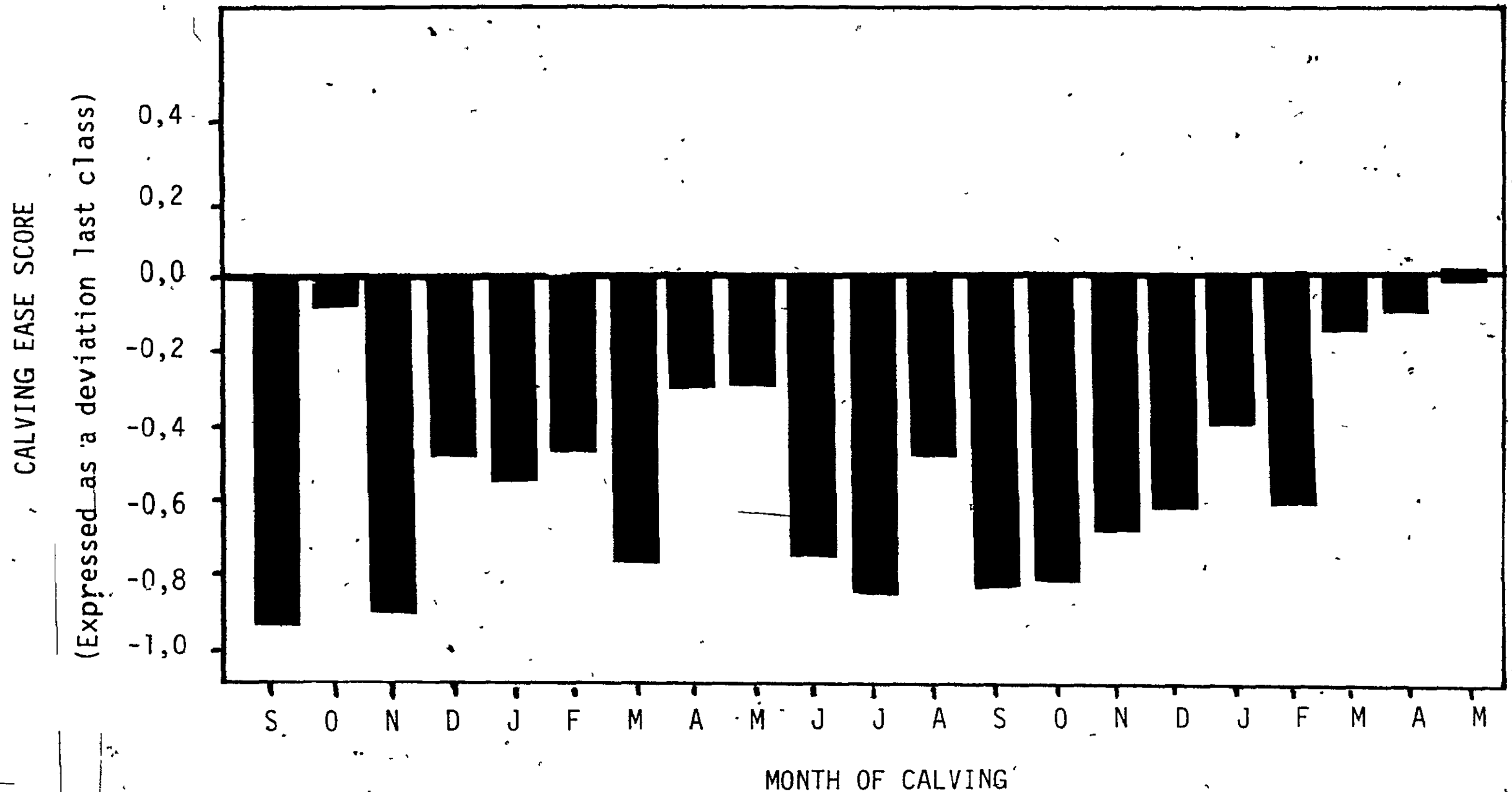

Figure 6. Least squares estimated differences for the effect of month of calving on calving ease score, second and later parity cows.

Classification of month was not modified for the second and later parity subset.

Hypothesis explaining this seasonal effect may be, first, cows calving in summer may be in better physical condition to calve. Secondly, dairymen may have more time in winter to witness and aid in delivery of calves. Some effect of the daylight on calving performance could also be suspected, since the frequency of difficult calving is on the decrease a few months before the cows go out to pasture. Seasonal effects on gestation length and birth weight have been reported (Philipsson, 1976b; Fisher and Williams, 1978) with gestation length being shorter in spring and summer, and the lowest birth weights registered in the same period. It could then be suggested that seasonal effect on calving performance is associated with gestation length and calf size. However, Philipsson (1976b) found that adjustment for these two factors did not noticeably alter the effect of month on calving performance.

Calving ease data was collected for the first time in the DHAS population in October 1979. Trial I covered a period of seven months. Trial II extended over a period of 21 months including the 7 months of Trial I. Figure 5 shows that in each of the first nine months the average index was lower than in the corresponding month in the second year of data collection. In the first trial second and later parities, 4,8 percent of calvings (- 1 in 20) resulted in difficult, surgical or malpresentation problems. In first calf heifers 14,9 percent (1 in 6,7) of these calving difficulties occurred. The initiation of a data collection program would tend to make dairymen more alert to the problem of calving difficulties. Most dairymen are aware of a higher incidence of calving difficulties with virgin heifers. Artificial insemination catalogues did not carry calving ease scores but some bulls carried descriptions suggesting potential calving difficulties.

The distribution of calving ease scoring as used for analysis from Trial I and for data collected following Trial I is presented in Table 12 for first calf heifers. A chi-square test of independence indicates that the distribution of these two groups are different. This would indicate that following the initiation of calving ease data collection, dairymen increased the frequency of matings to avoid calving difficulties.

A second possible explanation is that in the introductory period of data collection dairymen with the more severe calving problems might be the first to participate. This would have led to a gradual reduction in the frequency of difficulties in the first trial period. There is no evidence of this in Figure 5.

Table 12. Distribution of calving ease observations by class and for the Trial I period and post Trial I period.

	Distribution of calvings			
	Trial I		Post Trial I	
Class[1]	No.	%	No.	%
1	3620	86,94	15988	88,96
2	489	11,74	1858	10,34
3	55	1,32	126	0.70
Total	4164	100,0	17972	100,0

[1] 1 = Easy or slight assist; 2 = Difficult; 3 = Surgical.

Size of dam

In the preliminary analysis of Trial II, size of dam at calving was classified into 20 subclasses, from ≤ 420 Kg to ≥ 601 Kg, by increments of 10 Kg. Chi-squares analysis (Appendix Tables 8, 9 and 10) indicated that this factor significantly affected calving ease score ($P < .01$) for all parity cows, but was not significant in the other two subpopulations.

Figures 7, 8 and 9 illustrate the effect of size of dam on calving ease score for the three subpopulations considered in Trial II. For all parity cows, it appears that calves born from cows less than 480 Kg experienced more problems as compared to those born from cows over 480 Kg. Calving ease score increased progressively from the smallest subclass (≤ 420 Kg) up to the subclass 470-480 Kg, the other groups (> 480 Kg) forming a plateau. A similar pattern was observed for second and later parity cows (Figure 8) but with a truncation at 440 Kg. Based on these trends for the two subpopulations mentionned, classification of size at calving was modified (two groups) as indicated in Section IV.

For first parity cows, LSE (Figure 9) showed a progressive increase in calving ease score (i.e. a decrease in incidence of dystocia) from the lowest weight group (≤ 420 Kg) to the highest weight group (≥ 601 Kg), suggesting that a curvilinear-type relationship would exist between size and calving ease score. Consequently, covariates for body weight (Kg) and body weight squared were included in the model for further analyses with first calf heifers in Trial II.

Most researchers who examined the effect of size of cow at calving reported it to be non-significant (Sagebiel et al., 1969; Laster, 1974; Pollak and Freeman, 1975), but indicated that size of cow significantly affected calf size.

Interactions of size of cows with parity and size of cow with sex of calf were both significant ($P < .05$ and $P < .01$, respectively) in the population of all parity cows, and are illustrated in Figure 10. These interactions size of cow x parity tested with the other two subpopulations were not significant and were not considered in the final models for these subpopulations.

Estimates of Variance Components

Convergence of variance components under the MINQUE procedure was very fast because of a close approximation, in most cases, of the starting variance ratios (see Appendix Table 5 to 7 for convergence in Trial I). Final estimates of sire and error variance components and the ratios of error to sire variance are shown in Table 13 for Trial I and in Table 14 for Trial II. Heritability estimates for the trait are also presented in these Tables.

Trial I

In Trial I, where two definitions of calving performance were compared as to their effect on variance components estimation, the sire variance was higher for Definition I than for Definition II. These results are in contrast with those reported by Tong et al. (1976) who found highest sire variance for the definition which dealt strictly with ease of calving (i.e. Definition III in their study). On the other hand, error variance

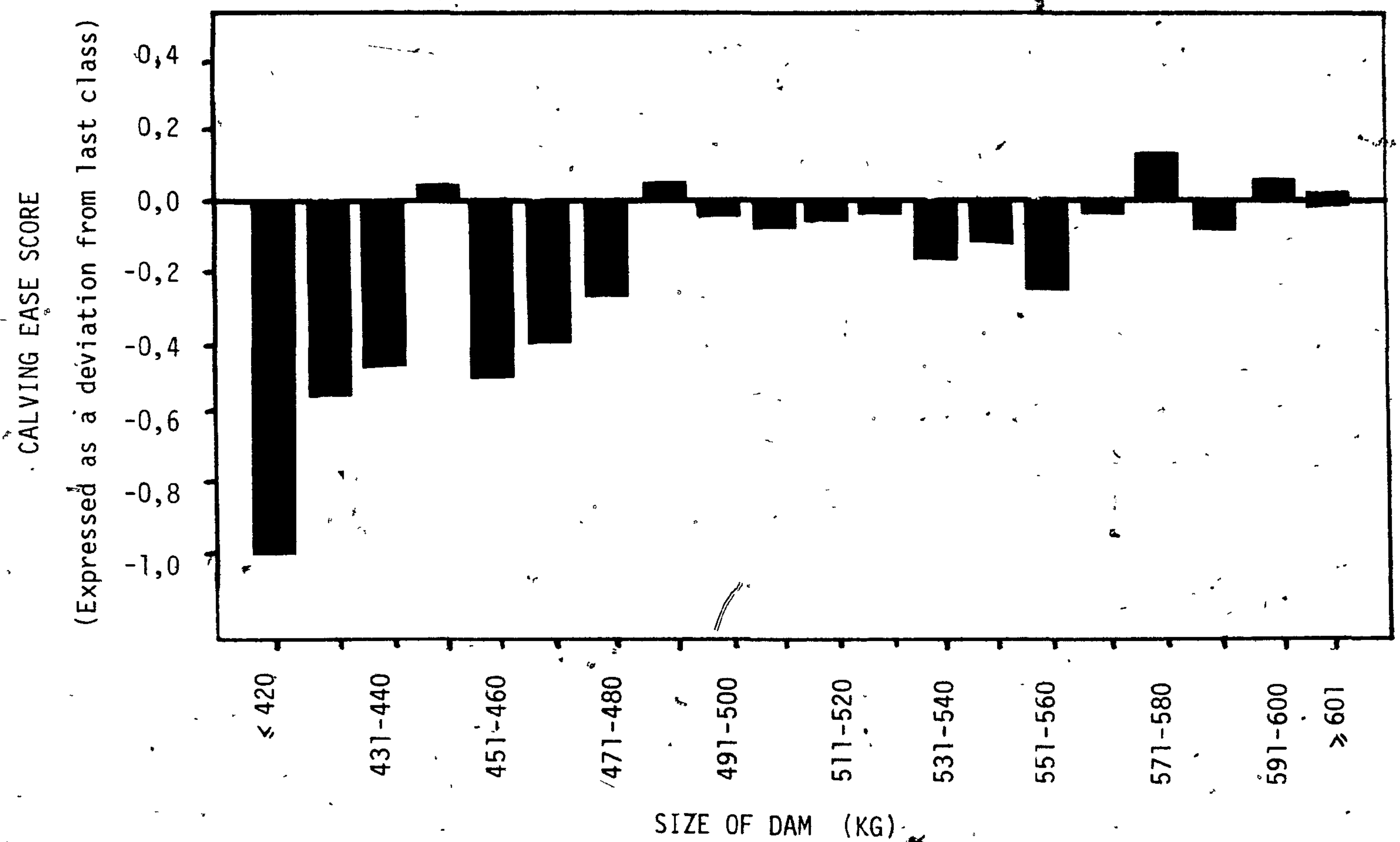

Figure 7. Least squares estimated differences for the effect of size of dam on calving ease score, all parity cows.

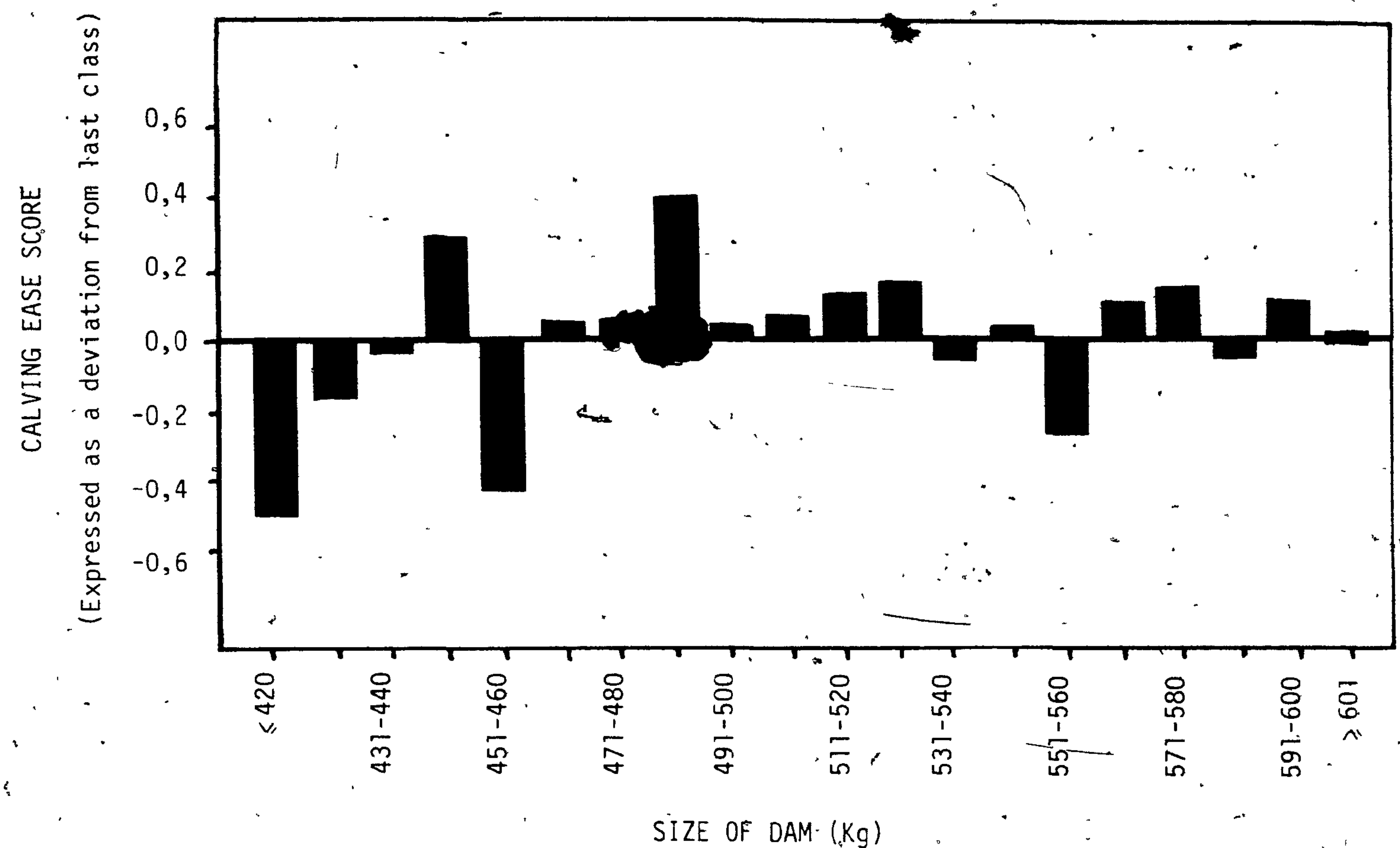

Figure 8. Least squares estimated differences for the effect of size of dam on calving ease score, second and later parity cows.

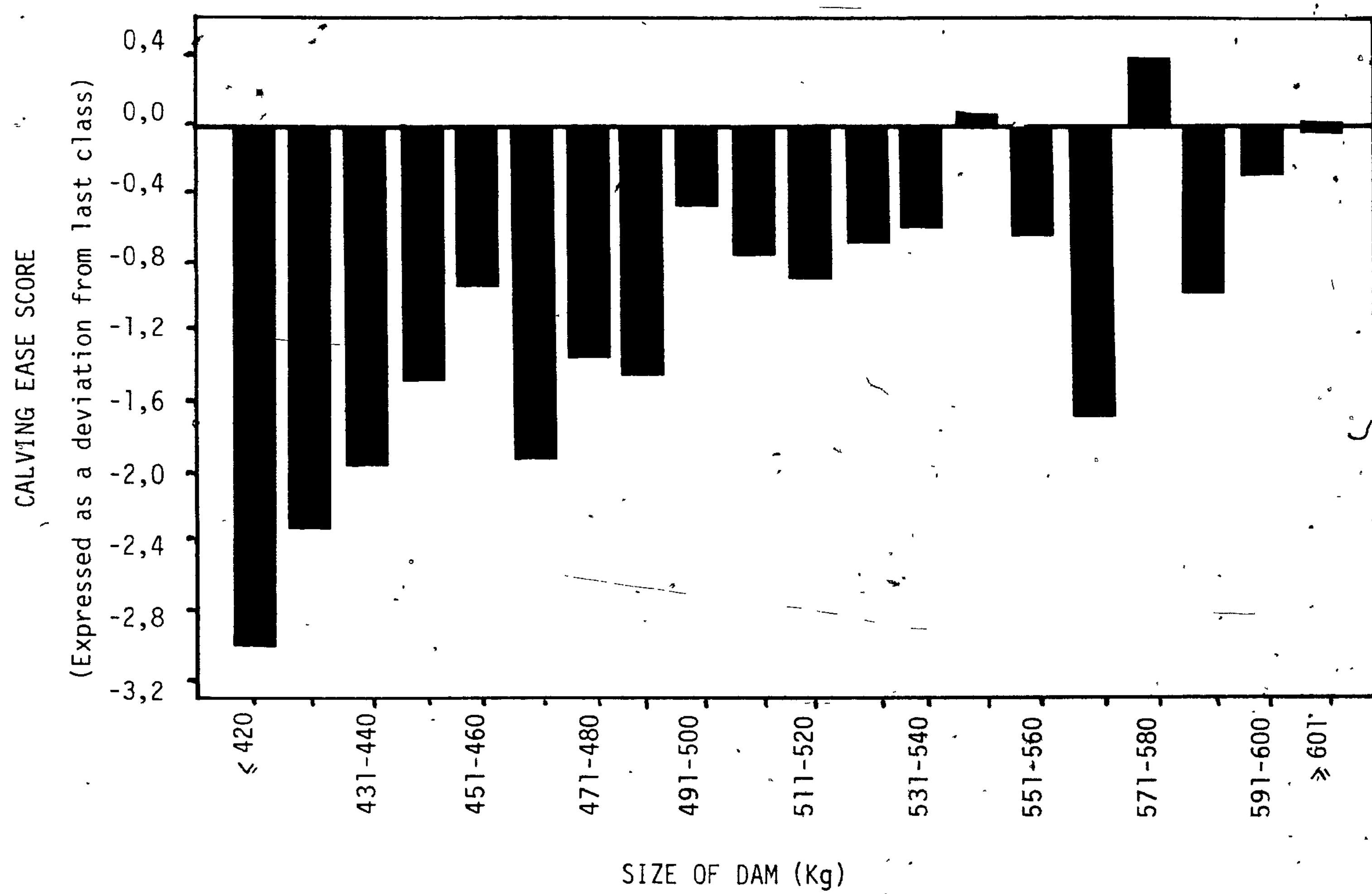

Figure 9. Least squares estimated differences for the effect of size of dam on calving ease score, first calf heifers.

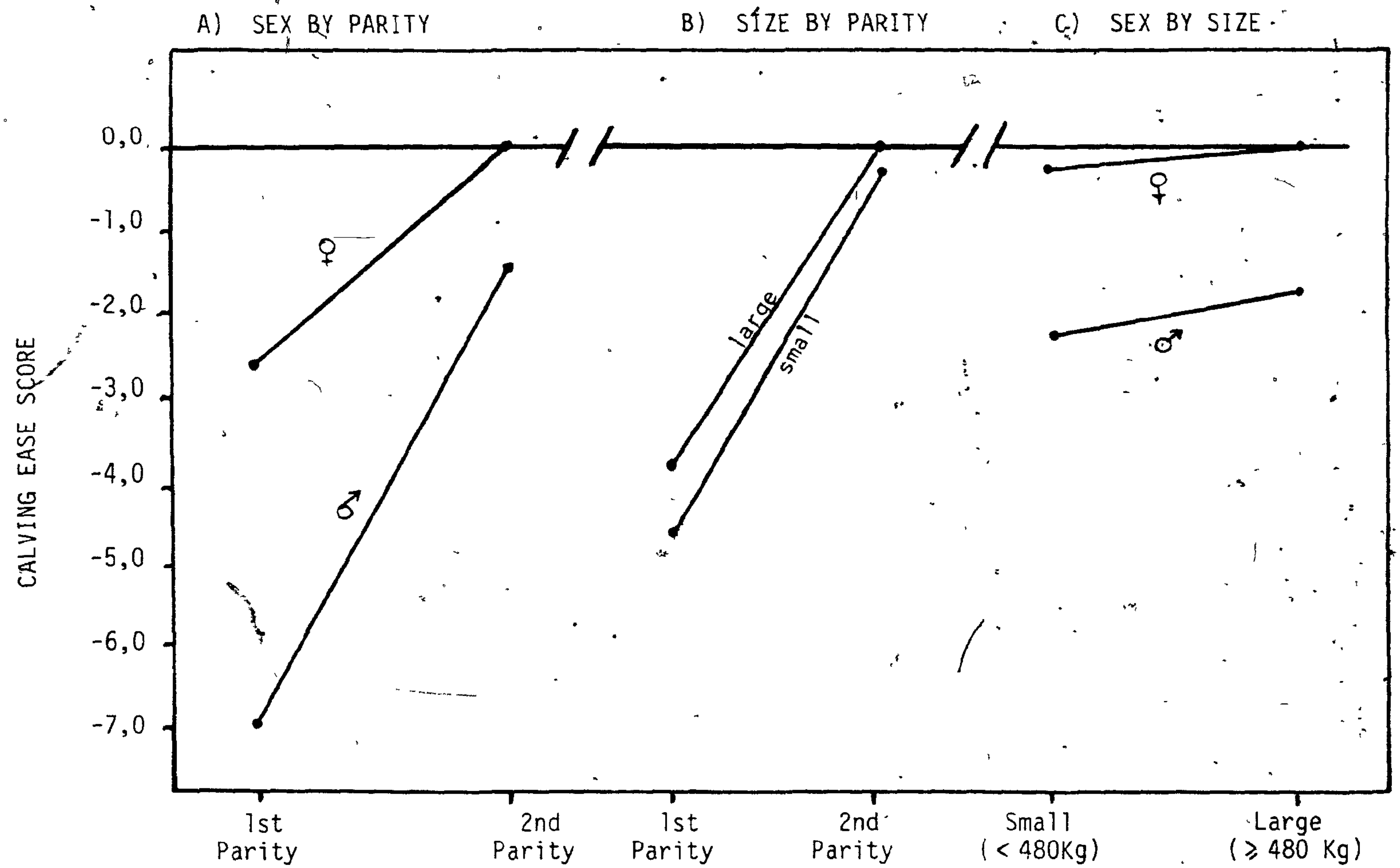

Figure 10. Least squares estimated differences for the effects of interactions a) sex by parity; b) size of dam by parity; c) sex by size of dam on calving ease score (all parity cows).

was lower with Definition II, which is consistent in both studies.

Results from this study would suggest that additionnal categories in Definition I, mainly due to considering calf liveability, contributed some additive genetic variance, as reflected by a higher sire variance. This suggest that more genetic progress in calving performance would result by considering calf liveability when evaluating sires.

Research has indicated that very little additive genetic variation can be attributed to liveability characteristics (Philipsson, 1976c). Therefore a much higher additive genetic variance should not be expected by including liveability with calving ease. The deletion of malpresentations from the data set in Definition II resulted in a lower frequency of calvings that represent serious problems, assuming all malpresentations are very difficult births. This, along with a different scoring of observations, may be partly responsible for the smaller sire variance in Definition II, since the observed heritability estimates for calving ease (a categorical trait) are dependent upon the frequency of difficult calvings.

The changes in definition (and scoring) of calving performance seems to have had an effect on variance components estimation. For this reason it becomes important to examine different definitions and to adopt the most appropriate. With respect to ease of calving, an appropriate definition dealing strictly with this trait is more attractive to the industry. As for improvement of calf liveability, some positive effect should result from reducing the incidence of dystocia. Separate evaluation of sires for liveability could also be proposed, but improved herd care and management would appear to be more effective than selection.

Table 13. Trial I: Final estimates of variance components and heritability for two definitions of calving performance as a trait of the calf, by population subset.

Population subset	Definition	Estimates			
		Sire Variance	Error Variance	r $(\sigma_e^2 / \sigma_s^2)$	h^2 $(4 / (1 + r))$
All parity cows	I	2,197	177,760	80,903	0,049 ± 0,014
	II	1,701	160,730	94,472	0,042 ± 0,013
First calf heifers	I	10,078	351,511	34,880	0,111 ± 0,043
	II	7,483	345,919	46,230	0,085 ± 0,038
2nd and later parity cows	I	0,855	112,251	131,304	0,030 ± 0,012
	II	0,487	92,226	189,201	0,021 ± 0,010

Table 14. Trial II: Final estimates of variance components and heritability for calving ease score, by population subset.

Population subset	No of calvings	Estimates			
		Sire Variance	Error Variance	r $(\sigma_e^2 / \sigma_s^2)$	h^2 $(4 / (1 + r))$
All parity cows	98300	1,233	138,755	112,525	0,035 ± 0,006
First calf heifers	21081	3,146	279,365	88,812	0,045 ± 0,011
2nd and later parity cows	76891	0,291	96,203	330,683	0,012 ± 0,003

Trial II

Variance components obtained by Minimum Norm Quadratic Unbiased Estimation (MINQUE) methods were used to estimate heritability of calving ease score for the three population subsets considered in Trial II. These estimates were lower than most of the estimates reported in the literature. For all parity cows, h^2 estimate obtained in this study (0,035) is less than half the value (0,08) reported from a previous study with the Holstein breed in the U.S. (Pollak and Freeman, 1976). However, it is known that variance components derived from categorical data are specific to the definition of the trait and the population considered. With these traits, the observed estimates of heritability are dependent upon the frequency of each category. When the frequency in either class approaches zero, the actually observed variance becomes very small (Robertson and Lerner, 1949). This relationship may also be responsible for the difference in heritability estimates from first calf heifers (0,045) versus second and later parity cows (0,012). The largest drop in the heritability estimate from Trial I to Trial II was for first calf heifers (0,085 to 0,045). An increased use of selective matings to avoid calving difficulties with first calf heifers nine months after data collection started would be expected to reduce the sire variance and consequently heritability estimates. According to the definition used in this study, the difficult calvings (hard pull and surgical) represent 11,4% of the observations from first calf heifers, versus 3,5% of those from second and later parity cows (see Table 11). The difference in heritability estimates from first calf heifers versus second and later parity cows is in agreement with previous reports (Smidt and Cloppenburg, 1967; Pollak and Freeman, 1976; Thompson et al, 1981) and some researchers (Philipsson, 1976, Bar-Anan et al, 1976) have suggested that dystocia in first and later parities should be considered different traits, assuming different biological phenomena are involved for these traits in heifers versus cows. The literature is not unanimous in these interpretations, but recently, Thompson et al (1980) estimated a genetic correlation of 0,84 for dystocia in first and later parities, indicating that the same genes are affecting the trait in both populations.

Sire Evaluation and ranking

Sires with a repeatability proof of at least 0,55 were ranked according to the BLUP estimates obtained from MINQUE analysis for the three subpopulations considered. The 0,55 level for repeatability is the Canadian standard to warrant publication of any proof for individual bulls. For BLUP proofs, repeatability is calculated from the standard error of prediction (S.E.P.) and the sire variance (σ_s^2) according to the following formula:

$$\text{Repeatability} = 1 - \frac{SEP^2}{\sigma_s^2}$$

The number of sires proven, mean proofs (and their standard deviation) and range of the proofs are presented in Table 15. A total of 65, 33 and 39 sires were proven (with Repeatability $\geq$ 0,55) from all parity cows, first calf heifers and second and later parity cows, respectively. A complete listing of proven sires from each subpopulation is presented in Appendix Tables 14 to 16. The low heritability estimates obtained for the trait resulted in a small proportion of the sires represented in the study to be proven (e.g. 65 out of 425 from all parity cows, and 33 out of 296 from first calf heifers). In addition to this the range of the proofs in each population is small. For evaluations from all parity cows, the proofs ranged from 1,69 to -2,26; for evaluations from first calf heifers, the range was from 3,06 to -2,61. The narrowest range was observed for proofs from second and later parity cows (0,64 to -1,33). These ranges indicate that the gap between two proven sires may be very small. Despite these observations, a certain genetic variability still exists that can be utilized in selection for calving ease. Assuming that a large number of observations on calvings are made available, service sires may be identified as to the calving performance of their progeny (calves to be born).

Table 15. Mean, standard deviation and range of the proofs for sires proven with records from each population subset.

Population subset	No of sires proven	Mean proof	Standard deviation (σ)	Range of the proofs
All parity cows	65	0,050	0,737	1,69 to -2,26
First calf heifers	33	0,124	1,405	3,06 to -2,61
2nd and later parity cows	39	-0,033	0,452	0,64 to -1,33

Because of the very small gap between two proven sires, it seems practical to classify bulls into three groups, with the separation between groups being made according to the deviation of the breeding values, in σ units, from the population mean. The "EASY" category would group those sires with proof values greater than $\mu + \sigma$ (approximately 16% of the sires should fall into this group); the "DIFFICULT" category would group sires with proof values of less than $\mu - \sigma$ (approx. 16% of proven sires); sires with proof value in between ($\simeq$ 68%) would be considered "AVERAGE" with respect to calving ease. Table 16 summarizes the resulting distribution of sires by these calving ease categories.

Table 16. Distribution of proven sires by calving ease category, for evaluation from each population subset.

Population subset	Calving ease category			Total proven
	EASY	AVERAGE	DIFFICULT	
All parity cows	9	47	9	65
First calf heifers	5	22	6	33
2nd and later parity cows	3	29	7	39

Despite the fact that the heritability estimate was lower for all parity cows as compared to the estimate for first calf heifers, the much larger number of observations available with all parity cows allowed twice as many sires to be proven. Due to the contradictions still existing in the literature as to considering dystocia as different traits in first versus later parities, it is important to determine if any given sire would fall in the same group regardless of the parities included in an evaluation. The 33 sires proven from first calf heifer subpopulation were all represented among the 65 sires proven from all parity population. The upper and lower 10 of these 33 sires appear in Table 17, listed according to their rank based on the evaluation from first calf heifers. Their

Table 17. The upper and lower 10 of 33 sires ranked for ease of calving from first calf heifers, with their rank for the same trait from all parity cows.

	Population subsets							
	First calf heifers				All parity cows			
Sire No. (CIAQ code)	BLUP proof	Rep. (%)	Rank	Group[1]	BLUP proof	Rep. (%)	Rank	Group[1]
H-175	3,06	68	1	E	0,89	90	5	E
H-106	2,58	74	2	E	1,69	86	1	E
H-145	1,83	91	3	E	1,02	97	2	E
H-211	1,67	66	4	E	0,88	92	6	E
H-126	1,61	58	5	E	0,99	85	3	E
H-179	1,50	76	6	A	0,90	56	4	E
H-184	1,45	61	7	A	0,44	85	10	A
H-138	1,38	76	8	A	0,69	92	8	E
H-110	1,34	68	9	A	0,16	91	17	A
H-194	1,26	68	10	A	0,06	87	18	A
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H-163	-0,84	59	24	A	-1,05	90	31	D
H-123	-0,93	57	27	A	-0,77	87	27	A
H-208	-1,09	73	26	A	-0,80	93	28	A
H-168	-1,18	56	27	A	0,25	90	13	A
H-144	-1,45	81	28	D	-0,06	96	23	A
H-162	-1,50	74	29	D	-0,49	77	24	A
H-164	-1,73	89	30	D	-1,20	97	32	D
H-153	-1,83	59	31	D	-0,95	89	29	D
H-186	-2,02	87	32	D	-0,96	97	30	D
H-177	-2,61	73	33	D	-0,64	94	26	A

[1] E = EASY; A = AVERAGE; D = DIFFICULT.

corresponding rank based on evaluation from all parity cows is also given on the same Table. All 5 sires falling in the EASY category according to the evaluation from first parity were in the same recommendation group when records from all parity cows were included in the evaluation. Four other sires were listed in the EASY group when records from all parities were included in the analysis. One of these sires (H-400) did not get a proof with records from first calf heifers because of insufficient calving. The other three (H-179, H-174 and H-138) were AVERAGE when only first calf heifer records were used. These three sires were at least above the mean, with two of them (H-179 and H-138) very close in rank to the EASY group in the first calf heifer subpopulation. Therefore, no problem should be expected by recommending their use on virgin heifers, particularly if it is assumed that proof accuracy is higher for evaluation with records from all parity cows. Along with recommendations on sires to use on virgin heifers, it is more important to warn dairymen against the use of DIFFICULT sires particularly on virgin heifers. The evaluation based on records from all parity cows resulted in 9 sires that would be in the DIFFICULT group, as compared to 6 when the evaluation was based on records from first calf heifers. A careful approach would be to warn against more sires for use on heifers, thus favoring the evaluation from all parities. Three sires (H-144, H-162 and H-177) were DIFFICULT when evaluated from the first calf heifer population but AVERAGE when evaluated from all parity cows. If recommendations are based on an evaluation with records from all parity cows, these sires would not be included, while they may represent some risk when used on heifers, according to the first calf heifer evaluation.

Rank correlations

Thirty-three sires were represented in each of the three sets of evaluation. Correlations of sire rankings were calculated according to Kendall rank correlation procedure. Results are shown in Table 18. Correlations of sire rankings from first with sire rankings from later parity data have been reported previously by researchers (Bar-Anan et al, 1976; Cady, 1980, Pollak, 1975, Teixeira, 1978), and ranged from 0,50 to 0,60. Considering the means and variance in dystocia score for each population, some of these researchers have suggested that dystocia in first and later parity should be considered separate traits. In this study, correlation of sire rankings from first with rankings from later parities was lower than those reported previously, at 0,44, but was consistent in indicating that sires could be misranked for use in the heifer population if calvings from later parities would be included to evaluate sires. According to Calo et al (1973), these correlations underestimate the genetic relationship between the traits considered, and the genetic correlation between dystocia as a separate trait in first and later parity births should measure this relationship. The large genetic correlation reported by Thompson et al. (1981) indicates that the same genes influence dystocia in all parities. This would allow inclusion of data from later parity cows for improved accuracy in evaluating sires for use on virgin heifers.

Table 18. Kendall rank correlations for A.I. sires[1] evaluated with records from first calf heifers, from second and later parity cows, and from all parity cows.

Correlation between	Rank correlation
First calf heifers and 2nd and later	0,44
First calf heifers and all parity cows	0,66
2nd and later and all parity cows	0,69

1 33 sires with proof repeatability ≥ 0,55 represented in the three sets of evaluation.

VI. SUMMARY AND CONCLUSIONS

In the first part of this study, two definitions of calving performance with different scoring procedures were compared as to their effect on variance components estimation. The first definition (Definition I) was combining ease of calving and calf survival, the scoring procedure considering ease of calving first with a secondary delineation on calf survival. The second definition (Definition II) considered ease of calving only, malpresentation births being excluded. For the three subpopulations considered in the analysis (all parity cows, first calf heifers and second and later parity cows), Definition I resulted in higher heritability estimates than Definition II, suggesting that considering calf liveability contributed some additive genetic variance. These results are in contradiction with previous reports. Deletion of malpresentations from the data set in Definition II, resulted in a lower frequency of difficult calving, and may be partially responsible for the change in variance components estimation, since these estimates are dependent upon the frequency of difficult calvings.

Preliminary analysis of data in Trial II revealed that in the Quebec Holstein population studied 29% of all cows required some degree of assistance, with a large difference between first calf heifers (40%) and older cows (26%). Increased calf losses at or near the time of birth was associated with an increase in the degree of difficulty at calving. Reducing the incidence of dystocia could then result in a reduction in calf losses.

Fixed effects considered in the models for least squares analyses included herd, sex of calf, parity (or age at first calving), month of calving, and size of cow at calving. Different interactions between some of these effects were also tested. Analyses were performed for three population subsets: first calf heifers, second and later parity cows, and all parity cows.

In the analysis using records from all parity cows, least squares analysis indicated that all main effects considered plus the interactions sex by parity, sex by size, parity by size by sex were all highly significant ($P < .01$) sources of variation on calving ease score. The interaction parity by size was significant at the $P < .05$ level. Major observations from the study indicated that male calves experienced more problems at birth than females; calves born from first calf heifers experienced considerably more problems, but between the other parities, differences were very small; calves born during summer months had less problems, as compared to those born during winter; and those born from larger cows (> 480 Kg) experienced less dystocia than those born from smaller dams.

In the analysis of records from second and later parity ~~cows,~~ the least squares analyses produced similar trends, but to a lesser extent, for the effects of sex of calf ($P < .01$) and size of dam ($P < .05$); month of calving was also significant ($P < .01$). No seasonal trend was established. Parity was not significant when first calf heifers were not included. The interaction parity x sex was not significant and probably should be ignored unless first calf heifers data is combined with second and later calvings in an analysis.

In the analysis of first calf heifers data, the effects of sex of calf and month of calving were highly significant and similar to the results from all parity cows. The significant effect of the size of dam included as covariates for linear (P < .01) and quadratic (P < .05) effect of body weight (Kg) stresses the importance of an adequate development of replacement heifers. The age at first calving had a small non significant effect, on calving performance, however, heifers calving at intermediate ages were the ones experiencing the least problems. This would indicate that as long as heifers are well developped, there is no advantage in delaying the age of first calving

Variance components were obtained by MINQUE procedure. Heritability estimates for calving ease score in Trial II were 0,035, 0,045, and 0,012 for all parity cows, first calf heifers, and second and later parity cows, respectively. These low values, regardless of the population considered, indicate that a large number of calving records is required in order to get adequate proofs of sires for the trait. The reduction in heritability from Trial I to Trial II suggests that the introduction of a data collection procedure can have an effect on subsequent mating practice with respect to the calving ease trait.

Using records from each subpopulation considered, sires were evaluated and ranked according to their BLUP proofs. A total of 65 sires were proven with repeatability ⩾ 0,55 when using records from all parity cows, as compared to 33 and 39 sires proven with records from first calf heifers and from second and later parity cows, respectively. Rank correlation of sire rankings from first with sire rankings from later parity records was low (0,44) suggesting that sires could be misranked for use in heifer population if later parities are included in a calving ease evaluation. A closer look at differences in rankings lead to the conclusion that in order to make recommendations to dairymen as to the use of sires on heifers in order to reduce the incidence of dystocia, the most careful approach would be to evaluate sires simultaneously with records from all parity cows and with those from first calf heifers only. The first evaluation seems appropriate and presents the advantage of allowing more sires to be proven because of a much larger number of observations available and despite a lower heritability. The second evaluation (with records from first calf heifers) would allow one to identify sires that fall into the "difficult" category when used on heifers. The dairymen then could be provided with a list of sires that fall in the "difficult" category in either of the two analysis. This would be done with the idea that he would avoid these sires for virgin heifer matings.

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Appendix Table 1. Scaling factors calculated to transform sums of squares into chi-squares, for each population subset.

Population subset	Trial I Definition I	Trial I Definition II	Trial II
All parity cows	0,00522	0,00532	0,00695
First calf heifers	0,00262	0,00267	0,00324
Second and later parity cows	0,00843	0,00981	0,00972

Appendix Table 2. Trial I: Chi-squares analysis of fixed effects for calving performance, all parity cows.

	Definition I		Definition II	
Source	d.f.	X^2	d.f.	X^2
Sex of calf	1	123,68 **	1	110,72 **
Parity	2	327,14 **	2	305,71 **
Month of calving	6	2,46	6	2,57
Size of dam	3	0,990	3	2,23
Sex x Parity	2	54,77 **	2	58,45 **
Error	13725	12735,49	13465	11510,62

** Significant at the 0,01 level.

Appendix Table 3. Trial I: Chi-squares analysis of fixed effects for calving performance, first calf heifers.

	Definition I		Definition II	
Source	d.f.	χ^2	d.f.	χ^2
Sex of calf	1	48,74**	1	50,04**
Age at 1st calving	4	1,34	4	1,18
Month of calving	6	2,65	6	1,09
Size of dam	3	1,24	3	1,09
Sex x Age	4	2,91	4	2,52
Error	2699	2485,00	2627	2426,31

** Significant at the 0,01 level.

Appendix Table 4. Trial I: Chi-squares analysis of fixed effects for calving performance, second and later parity cows.

	Definition I		Definition II	
Source	d.f.	χ^2	d.f.	χ^2
Sex of calf	1	48,48**	1	42,59**
Parity	3	1,44	3	1,86
Month of calving	6	2,34	6	2,63
Size of dam	3	0,53	3	2,99
Sex x Parity	3	1,53	3	2,68
Error	9615	9102,99	9440	8541,37

** Significant at the 0,01 level.

Appendix Table 5. Trial I: Estimates of variance components and heritability for two definitions of calving performance, all parity cows.

Round of Iteration	Definition	σ_s^2	σ_e^2	$r = \sigma_e^2 / \sigma_s^2$	$h^2 = 4/(1 + r)$
0	I			80,500	
	II			85,500	
1	I	2,197	177,760	80,899	0,0488
	II	1,733	160,720	92,728	0,0426
2	I	2,1972	177,760	80,903	0,0488
	II	1,7065	160,730	94,183	0,0420
3	I	2,1972	177,760	80,903	0,0488
	II	1,7013	160,730	94,472	0,0419
4	I	--	--	--	
	II	1,7013	160,730	94,472	0,0419

Appendix Table 6. Trial I: Estimates of variance components and heritability for two definitions of calving performance, first calf heifers.

Round of Iteration	Definition	σ_s^2	σ_e^2	$r = \sigma_e^2 / \sigma_s^2$	$h^2 = 4/(1 + r)$
0	I			34,500	
	II			45,500	
1	I	10,088	351,506	34,844	0,112
	II	7,483	345,919	46,227	0,085
2	I	10,078	351,510	34,879	0,111
	II	7,483	345,919	46,227	0,0847
3	I	10,078	351,511	34,879	0,111
	II	7,483	345,919	46,227	0,085

Appendix Table 7. Trial I: Estimates of variance components and heritability for two definitions of calving performance, second and later parity cows.

Round of Iteration	Definition	σ_s^2	σ_e^2	$r = \sigma_e^2 / \sigma_s^2$	$h^2 = 4/(1+r)$
0	I			85,00	
	II			85,00	
1	I	0,857	112,250	130,985	0,030
	II	0,488	92,226	188,830	0,021
2	I	0,855	112,251	131,299	0,030
	II	0,487	92,226	189,208	0,021
3	I	0,855	112,251	131,304	0,030
	II	0,487	92,226	189,201	0,021

Appendix Table 8. Trial II: Chi-squares analysis of fixed effects for calving performance, all parity cows (preliminary).

Source	d.f.	χ^2
Sex of calf	1	661,58 **
Parity	4	1567,91 **
Month of calving	20	58,90 **
Size of dam	19	40,17 **
Error	115817	109351,90

** Significant at the 0,01 level.

Appendix Table 9. Trial II. Chi-squares analysis of fixed effects for calving performance, first calf heifers (preliminary).

Source	d.f.	χ^2
Sex of calf	1	263,149 **
Age at 1st calving	16	10,94
Month of calving	20	46,00 **
Size of dam	19	29,85
Error	18973	17403,01

** Significant at the 0,01 level.

Appendix Table 10. Trial II. Chi-squares analysis of fixed effects for calving performance, second and later parity cows (preliminary).

Source	d.f.	χ^2
Sex of calf	1	355,61 **
Parity	3	0,71
Month of calving	20	58,48 **
Size of dam	19	29,68
Error	93286	90035,30

** Significant at the 0,01 level.

Appendix Table 11. Trial II: Chi-squares analysis of fixed effects for calving performance, all parity cows (final).

Source	d.f.	χ^2
Sex of calf	1	661,89 **
Parity	1	1667,67 **
Season of calving	3	42,36 **
Size of dam	1	14,95 **
Sex x Parity	1	255,46 **
Sex x Size	1	11,88 **
Parity x Size	1	5,55 *
Sex x Parity x Size	1	33,80 **
Error	115851	109123,91

* Significant at the 0,05 level.

** Significant at the 0,01 level.

Appendix Table 12. Trial II. Chi-squares analysis of fixed effects for calving performance, first calf heifers (final).

Source	d.f.	χ^2
Sex of calf	1	238,11 **
Age at 1st calving	2	5,51
Season of calving	3	27,01 **
Covariate 1 (body weight)	1	6,73 **
Covariate 2 (body weight squared)	1	5,13 *
Error	17630	15957,66

* Significant at the 0,05 level.

** Significant at the 0,01 level.

Appendix Table 13. Trial II, Chi-squares analysis of fixed effects for calving performance, second and later parity cows (final).

Source	d.f.	χ^2
Sex of calf	1	273,93 **
Parity	3	0,72
Month of calving	20	38,65 **
Size of dam	1	5,84 *
Error	71250	66625,36

* Significant at the 0,05 level.

** Significant at the 0,01 level.

Appendix Table 14. Sire proofs for calving ease as a trait of the calf based on records from first calf heifers.

Sire registration number	Sire Name	Semen Code	Number of Herds	Number of calvings	Code	Rep.	Proof
327907	Ronbeth Telmatt	73H00175	193	236	Easy	68	3,06
307368	A Lime Hollow Burkgov Excellence	73H00106	275	412	Easy	74	2,58
322678	Laflam Astronaut	73H00145	872	1731	Easy	91	1,83
333860	Aquarius Elevator	73H00211	189	247	Easy	66	1,67
315487	Ingholm Klondike	73H00126	114	156	Easy	58	1,61
329544	Wykholme Portrait	73H00179	267	419	Average	76	1,50
329150	Craftland Monarch	73H00184	155	193	Average	61	1,45
318077	Mountholm Imperial	73H00138	296	473	Average	76	1,38
305376	Sunnylodge Rockman Lad Duke	73H00110	203	284	Average	68	1,34
335192	A Doorco Elevation Major	73H00194	201	250	Average	68	1,26
324865	Fleuve Apollo Chieftain	73H00150	140	188	Average	61	0,80
314774	Mountholm Mountaineer	73H00128	218	312	Average	67	0,72
336701	A Leblanc Vibration	73H00209	608	1051	Average	87	0,65
329313	A Robthom Veematt Pennant	73H00165	338	486	Average	79	0,56
324254	Harlaka Marock	73H00149	127	158	Average	56	0,53
328149	Cherry Lane Aquarius	73H00174	153	193	Average	63	0,45
323509	Maridon Madison	73H00154	166	209	Average	63	0,13
332453	A Stardell Longlasting	73H00178	181	215	Average	64	0,08
327638	Roybrook Regal	73H00172	121	165	Average	56	-0,25
329029	Sunnylodge Jester	73H00173	520	993	Average	86	-0,26
327584	Medway Mandrake	73H00171	389	591	Average	81	-0,42
332725	Elmside View Dean	73H00197	174	250	Average	62	-0,58
333968	A J-L-Kinglea Valor	73H00183	407	579	Average	81	-0,81
325229	Langview Pacific	73H00163	138	175	Average	59	-0,84
314236	Maska Skipper Seven Up	73H00123	143	190	Average	57	-0,93

Appendix Table 14. Sire proofs for calving ease as a trait of the calf based on records from first calf heifers. (cont'd)

Sire registration number	Sire Name	Semen Code	Number of Herds	Number of calvings	Code	Rep.	Proof
333391	Deslacs Rockman Lynmack	73H00208	246	332	Average	73	-1,09
326838	Mount Hope Flavius	73H00168	119	149	Average	56	-1,18
322128	A Lime Hollow Admiral	73H00144	406	551	Difficult	81	-1,45
325144	Myrewood Esteem	73H00162	273	366	Difficult	74	-1,50
326314	Inglwae Make Rite	73H00164	679	1146	Difficult	89	-1,73
323281	Ocala Corvette	73H00153	127	162	Difficult	59	-1,83
333063	A Robthom Elevation Gaylord	73H00186	587	887	Difficult	87	-2,02
330643	Roybrook Tempo	73H00177	235	323	Difficult	73	-2,61

Appendix Table 15. Sire proofs for calving ease as a trait of the calf based on records from second and later parity cows.

Sire registration number	Sire Name	Semen Code	Number of Herds	Number of calvings	Code	Rep.	Proof
322678	Laflam Astronaut	73H00145	1868	3894	Easy	89	0,64
333860	Aquarius Elevator	73H00211	1273	2328	Easy	82	0,63
329029	Sunnylodge Jester	73H00173	709	1033	Easy	72	0,48
327907	Ronbeth Telmatt	73H00175	907	1525	Average	79	0,40
315487	Ingholm Klondike	73H00126	389	605	Average	61	0,39
326838	Mount Hope Flavius	73H00168	703	1089	Average	73	0,37
328149	Cherry Lane Aquarius	73H00174	412	591	Average	59	0,36
321217	Sunnyville Perfection	73H00142	447	666	Average	62	0,35
329544	Wykholme Portrait	73H00179	610	917	Average	70	0,34
324254	Harlaka Marock	73H00149	508	842	Average	66	0,29
322128	A Lime Hollow Admiral	73H00144	1684	3435	Average	88	0,27
333968	A J-L-Kinglea Valor	73H00183	1553	3093	Average	87	0,24
318077	Mountholm Imperial	73H00138	785	1295	Average	75	0,23
332453	A Stardell Longlasting	73H00178	1008	1587	Average	79	0,23
327638	Roybrook Regal	73H00172	385	556	Average	57	0,21
329398	Gladibrae Stan	73H00182	482	676	Average	63	0,16
330925	Briarwood Commodore	73H00180	357	512	Average	56	0,12
329313	A Robthom Veematt Pennant	73H00165	1023	1657	Average	80	0,12
324865	Fleuve Apollo Chieftain	73H00150	634	987	Average	71	0,11
332046	Howes Noble Majorman	73H00189	365	496	Average	56	0,10
323509	Maridon Madison	73H00154	741	1172	Average	74	0,07
329150	Craftland Monarch	73H00184	407	559	Average	58	0,01
336701	A Leblanc Vibration	73H00209	1748	3790	Average	83	-0,02
305376	Sunnylodge Rockman Lad Duke	73H00110	741	1272	Average	74	-0,06
321975	Ingholm Yukon	73H00141	368	545	Average	57	-0,07

Appendix Table 15. Sire proofs for calving ease as a trait of the calf based on records from second and later parity cows. (cont'd)

Sire registration number	Sire Name	Semen Code	Number of Herds	Number of calvings	Code	Rep	Proof
324426	A Ravenglen Astronaut Saturn	73H00143	399	582	Average	59	-0,07
335192	A Doorco Elevation Major	73H00194	560	831	Average	67	-0,09
325144	Myrewood Esteem	73H00162	1098	1889	Average	81	-0,20
330643	Roybrook Tempo	73H00177	1005	1876	Average	82	-0,16
325250	Werrcroft Model Telstar	73H00160	404	545	Average	58	-0,34
314236	Maska Skipper Seven Up	73H00123	504	798	Average	65	-0,46
323281	Ocala Corvette	73H00153	604	949	Average	71	-0,46
333391	Deslacs Rockman Lynmack	73H00208	1068	1839	Difficult	81	-0,53
327584	Medway Mandrake	73H00171	1826	4354	Difficult	90	-0,54
333063	A Robthom Elevation Gaylord	73H00186	2193	4660	Difficult	90	-0,64
325229	Langview Pacific	73H00163	710	1104	Difficult	73	-0,70
303326	Sunnyville Citation Master	73H00102	506	769	Difficult	66	-0,89
326314	Inglwae Make Rite	73H00164	2573	7187	Difficult	93	-0,93
320124	Green Poplar Kennedy	73H00137	479	727	Difficult	65	-1,33

Appendix Table 16. Sire proofs for calving ease as a trait of the calf based on records from all parity cows.

Sire registration number	Sire Name	Semen Code	Number of Herds	Number of calvings	Code	Rep.	Proof
307368	A Lime Hollow Burkgov Excellence	73H00106	543	850	Easy	86	1,69
322678	Laflam Astronaut	73H00145	2250	5649	Easy	97	1,02
315487	Ingholm Klondike	73H00126	451	763	Easy	85	0,99
353403	A Robthom Marathon	73H00400	128	156	Easy	56	0,98
329544	Wykholme Portrait	73H00179	789	1337	Easy	90	0,90
327907	Ronbeth Telmatt	73H00175	1011	1763	Easy	92	0,89
333860	Aquarius Elevator	73H00211	1359	2576	Easy	93	0,88
328149	Cherry Lane Aquarius	73H00174	527	786	Easy	85	0,74
318077	Moutholm Imperial	73H00138	967	1770	Easy	92	0,69
324467	Madawaska Maple	73H00156	131	183	Average	59	0,58
331738	Romandale Dividend Patriot	73H00185	267	368	Average	74	0,58
324415	Little River Mardi Gras	89H00097	92	280	Average	61	0,53
314774	Mountholm Mountaineer	73H00128	385	577	Average	81	0,52
329398	Gladibrae Stan	73H00182	552	796	Average	86	0,47
329150	Craftland Monarch	73H00184	526	755	Average	85	0,44
321217	Sunnyville Perfection	73H00142	522	799	Average	85	0,42
324254	Harlaka Marock	73H00149	593	1002	Average	87	0,36
304016	Shorelea Citation	89H00070	117	394	Average	65	0,29
329313	A Robthom Veematt Pennant	73H00165	1204	2145	Average	93	0,27
326838	Mount Hope Flavius	73H00168	773	1238	Average	90	0,25
353218	A Exranco Troubadour	73H00380	111	158	Average	57	0,23
330925	Briarwood Commodore	73H00180	403	579	Average	81	0,21
329029	Sunnylodge Jester	73H00173	1070	2033	Average	93	0,20
324865	Fleuve Apollo Chieftain	73H00150	710	1175	Average	89	0,20
323509	Maridon Madison	73H00154	833	1383	Average	90	0,16

Appendix Table 16. Sire proofs for calving ease as a trait of the calf based on records from all parity cows. (cont'd)

Sire registration number	Sire Name	Semen Code	Number of Herds	Number of calvings	Code	Rep.	Proof
305376	Sunnylodge Rockman Lad Duke	73H00110	859	1558	Average	91	0,16
332710	High Point Clipper Jac	73H00196	204	261	Average	67	0,15
334498	Ronbeth Persistent	73H00218	262	339	Average	72	0,14
307133	Chacook Rock Burke Cavalier	73H00201	175	256	Average	66	0,12
324426	A Ravenglen Astronaut Saturn	73H00143	453	673	Average	83	0,07
335192	A Doorco Elevation Major	73H00194	690	1082	Average	87	0,06
333968	A J-L-Kinglea Valor	73H00183	1728	3678	Average	95	0,05
336701	A Leblanc Vibration	73H00209	2027	4846	Average	96	0,04
332453	A Stardell Longlasting	73H00178	1092	1802	Average	92	0,02
332046	Howes Noble Majorman	73H00189	424	591	Average	82	-0,02
327638	Roybrook Regal	73H00172	473	722	Average	84	-0,02
325250	Werrcroft Model Telstar	73H00160	455	643	Average	63	-0,04
322128	A Lime Hollow Admiral	73H00144	1838	3990	Average	96	-0,06
355341	A Nor-Lene Emil	73H00410	124	154	Average	56	-0,09
349800	Catinale Roystar	73H00390	137	189	Average	61	-0,09
317031	Rainbow Valley Supreme Dana	89H00088	138	453	Average	70	-0,09
312069	North-Leeds Majestic President	89H00082	93	239	Average	56	-0,20
321384	A Lime Hollow Standout Roeland	73H00139	169	208	Average	62	-0,24
309702	Maridon Citation Champion	73H00115	328	522	Average	79	-0,32
308045	Briarwood Chieftain	73H00120	279	375	Average	74	-0,39
352120	Evesville Don	73H00392	116	147	Average	55	-0,40
321975	Ingholm Yukon	73H00141	415	639	Average	82	-0,41
315674	Shepody Majestic Prince	73H00130	218	295	Average	69	-0,46
325144	Myrewood Esteem	73H00162	1240	2256	Average	77	-0,49
322781	Almerson Emperor Lyndon	89H00095	83	226	Average	56	-0,59

Appendix Table 16. Sire proofs for calving ease as a trait of the calf based on records from all parity cows. (cont'd)

Sire registration number	Sire Name	Semen Code	Number of Herds	Number of calvings	Code	Rep.	Proof
327584	Medway Mandrake	73H00171	1930	4948	Average	96	-0,59
330643	Roybrook Tempo	73H00177	1101	2202	Average	94	-0,64
354744	A Winter-Place Hijack	73H00404	133	169	Average	58	-0,65
320248	Elmwold David	73H00147	213	276	Average	68	-0,66
314236	Maska Skipper Seven Up	73H00123	612	989	Average	87	-0,77
333391	Deslacs Rockman Lynmack	73H00208	1191	2172	Average	93	-0,80
323281	Ocala Corvette	73H00153	673	1113	Difficult	89	-0,95
333063	A Robthom Elevation Gaylord	73H00186	2397	5552	Difficult	97	-0,96
325229	Langview Pacific	73H00163	789	1280	Difficult	90	-1,05
326314	Inglwae Make Rite	73H00164	2692	8339	Difficult	97	-1,20
332725	Elmside View Dean	73H00197	300	454	Difficult	77	-1,30
303326	Sunnyville Citation Master	73H00102	555	852	Difficult	66	-1,38
320124	Green Poplar Kennedy	73H00137	514	818	Difficult	86	-2,08
347710	Laflam Pontiac	73H09985	97	218	Difficult	62	-2,15
353404	A Buggs Tornado	73H00381	118	162	Difficult	57	-2,26