An Evaluation Of The Parameters Influencing The Weight Of Beef Cows

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Abstract

The body weight of beef cows (cow weights) on nine ranches and farms located in the province of British Columbia were recorded each fall and spring for three years. Cow weights were also recorded on two additional occasions during the winter in the largest of these herds. The cows in these herds were all straightbred Hereford or Angus cows, or crossbreds of one or other of these breeds. During the summer five of the herds used rangeland, and four used pasture. Each herd calved in the spring after overwintering on conserved forage.

The influence of breedtype, year, age, season and herd on the spring and fall weight records were determined by a least-squares analysis as outlined by Harvey (1975).

Season was found to have a major influence on cow weight. Each weight change (considered as a percentage of the mean weight during the period) was included as a dependent variable in separate analyses. In addition to the parameters already mentioned, calf sex, calf age, calf weaning weight, previous weight change and the interval from calving to weighing in the spring were included where appropriate in the models for these analyses.

The two mid-winter weights were included in a similar statistical analysis to determine the influence of pregnancy *per se* on cow weight in this herd. The parameters fitted in this model were age, year, age x year, days pregnant (DP), DP^2 and DP^3.

Age, season and herd were found to be significant sources

of variation in the cow weight records; but, within each herd, genetically different breedtypes normally had similar weights. The cows on summer rangeland were on average 119.0 lb. lighter than those on summer pasture. The increase in weight over age and the seasonal fluctuations around this mean growth curve also varied significantly between herds. However, in all but one of the herds there was a weight loss each winter and a weight gain each summer. The mean spring/fall weight difference was 114.2 lb. The mean mature age of the cows was six, and the mean mature weight was 1083.9 lb.

The summer change in weight of a cow depended on age and herd, but not on breedtype. Younger cows gained more weight through the summer than older cows; the influence of herd on cow weight was not correlated with any single factor. Summer weight change was not influenced by the calf the cow suckled during the summer, but cows which lost the most weight during the previous winter gained the most the following summer.

The winter weight change of a cow was not the same for all ages and breedtypes, but differed from herd to herd according to the level of winter feeding in each herd. Again there was a close correlation between this weight change and that in the previous period. The winter weight loss was found to continue through the interval from calving to weighing. The average weight loss during this period was around 0.7 lb. per day.

A mean weight increase of 101.4 lb. was recorded between the 90th and 260th days of pregnancy. There was then a 6.8 lb. weight loss in the remaining 25 days through to parturition. The weight loss at parturition was 80.0 lb. or 7.3% of the cow's pre-partum weight.

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CHAPTER 1

Introduction

Genetic differences between and within breeds in the rate and efficiency of gain are related to differences between animals in their mature body weight (Klosterman, 1972; Brown, 1970) and rate of maturing (Fitzhugh and Taylor, 1971). In the beef industry such differences are exploited through the male side of a breeding program. A bull which has a high breeding value for growth will tend to have a relatively heavy mature weight. His female offspring which enter a breeding herd will, owing to the high heritability of mature body weight (Brinks *et al.*, 1964; Bennyshek and Marlowe, 1973; Francois *et al.*, 1973), also tend to be relatively heavy.

Previous research indicates that the nutrient requirement of a beef cow is related to her weight. As fifty to sixty percent of the total feed energy required to raise a beef animal from conception to slaughter is used by its dam for maintenance and production (Klosterman, 1972; Thiessen, 1976), the extra cost of keeping heavier cows is likely to be significant. In British Columbia the beef industry is based on a cow-calf system; in this type of production system the proportion consumed by the dam *per se* is considerably higher, and the extra cost is correspondingly greater. This increased feed cost will, however, be offset in part by the faster growth which a genetically heavier cow will pass on to its calf, together with a maternal environmental advantage *in utero*.

Weight, however, is a dynamic rather than a static trait. Consequently, a classification of the productivity of a cow simply in terms of a single weight can be misleading (Bowman, 1972). In slaughter animals considerable information is available on the environmental parameters which influence the phenotypic expression of an animal's genetic ability to grow in early life. However, their influence through maturity in a breeding female is not well documented.

The objective of this research was thus to rectify this deficiency by evaluating the parameters influencing the growth, up to and beyond maturity, of beef cows on certain farms and ranches in the southern half of the province of British Columbia.

The criteria which have been used to define mature weight in previous studies are not identical. In this study mature body weight is defined as the weight of an animal to which no further significant annual increments are added. This is equivalent to the definition of mature weight used by Brinks et al. (1962), Fitzhugh (1965) and Fitzhugh and Taylor (1971). It is similar to the asymptote of a fitted growth curve which was the criterion used to define mature weight by Joandet and Cartwright (1969).

CHAPTER 2

Review Of Literature

Mature 'size' is a phenotypic and genetic characteristic generally attributable to a breed of beef cattle (Mason, 1971; Adams, Garret and Elings, 1973). The 'size' of a cow has been variously described by a single measurement or by an index of several (Jeffrey and Berg, 1972; Biaglo and Meragalli, 1972; O'Mary, Brown, and Ensminger, 1972; Tanner, Cooper and Kruse, 1956; Simpson *et al.*, 1972, Brown *et al.*, 1956 a & b). Variation in the level of nutrition has less effect on skeletal measurements than on body weights, especially as a cow approaches maturity. Consequently the former is a more stable estimate of cow size (Brown *et al.*, 1956 a & b). Skeletal measurements, however, are affected by stance, and also require precise location of anatomical points for accurate measurement. Consequently, Taylor (1963) reports a ten-fold change from trial to trial in the accuracy of body measurements of monozygous twins, and Johansson and Hildman (1954) report that the error incurred in taking body measurements is almost three times greater than that incurred in weighing. Other workers, Brookes and Harrington (1961) and Fisher (1975), also mention this problem of poor repeatability, especially in beef cattle, which tend to be more difficult to handle than dairy cattle.

Mean mature weight of females of beef breeds is reported to vary from 750 lb. in Dexters (Thiessen, 1976) to 2240 lb. in Maine-Anjou (Mason, 1973). Most research studies on the body weight of beef cows have included Hereford cattle. Within this breed mature weight is reported to vary from 997 lb. (Koger and Knox, 1951) to 1280 lb. (Guilbert and Gregory, 1952), with many intermediate values (Vacarro and Dillard, 1966; Clark et al., 1958; Brinks et al., 1962; Urick et al., 1971; Joandet and Cartwright, 1969; Fitzhugh, 1965; Fitzhugh, Cartwright and Temple, 1967; Edwards and Bailey, 1975; Brown, Brown and Butts, 1972). Reports vary on the age at which Hereford cows reach mature weight. Bennyshek and Marlowe (1973) and Guilbert and Gregory (1952) found that it occurred at five years of age; others report that cows could be twice this age before reaching their mature weight (Urick et al., 1971; Fitzhugh, 1965; Fitzhugh et al., 1967; Clark et al., 1958; Kilkenny and Stollard, 1973; Joandet and Cartwright, 1969). The body weight of Hereford cows has also been found to decline after eight (Knox and Koger, 1945), nine (Clark et al., 1958; Brinks et al., 1962) and fourteen (Bennyshek and Marlowe, 1973) years of age.

There are fewer reports on the age and weight at maturity of other breeds. Urick et al. (1971) report that Angus and Charolais cows reach mature weights of 1160 lb. and 1290 lb. respectively at five years of age. Brown et al. (1956a) and Brown et al. (1972) report a similar age for Angus cattle of 1065 lb. and 970 lb. mature weight respectively. However, Fitzhugh (1965) and Fitzhugh et al. (1967) report that Angus cows reach mature weights from 840 lb. to 1135 lb. at around nine years of age. Brahman cows in this study were mature at between 840 lb. and 1135 lb., and Santa Gertrudis between 950 lb. and 1120 lb., at unreported ages. Crossbred cows (seven-eighths Brahman:one-eighth Hereford) reached mature weights of 1080 lb. at four years of age in a study by Joandet and Cartwright (1969).

These reports on age and weight at maturity indicate a variation between breeds and cows in their pattern of growth. This variation is the result of environmental and genetic factors and their interactions. Table 1 lists the most frequently reported of these.

Herd

The Herd Effect on the mean body weight of cows of the same breed in different herds reported by Fitzhugh (1965) and Fitzhugh *et al*. (1967) was considerably greater than the Breed Effect on the weight of cows in the same herd. These authors do not mention the grazing conditions for each herd. However, Edwards and Bailey (1975) report a difference between the mature weights of Hereford cows grazing summer range (1010 lb.) and those grazing entirely on irrigated pasture (1170 lb.). The herd differences reported by Fitzhugh (1965) and Fitzhugh *et al*. (1967) are presumably a product of such environmental differences, together with genetic differences between the herds. Such factors are inevitably included in the Herd Effect.

Year

The Year Effect was reported to be significant by most of the authors listed in Table 1. The environmental differences between years did not normally show any trend.

Season

The weight of a spring-calving cow is normally lighter post-partum than it is in the fall at weaning (Fitzhugh, 1965;

TABLE 1

Some Parameters Influencing the Weight of a Beef Cow

	AGE	BREED	HERD	YEAR	SEASON	PREG STATUS	SIRE
Bennyshek & Marlowe (1973)	sig		ns	ns			
Anderson *et al* (1973)	**			**	sig		**
Clark *et al* (1958)	**			**	sig	sig	
Holloway & Totusek (1973)	***	***					
Joandet & Cartwright (1969)	sig	sig					
Kilkenny & Stollard (1973)	sig	sig	sig				
Urick *et al* (1971)	**	**		**		**	
Fitzhugh (1965)	**	**	**	**	**	**	**
Fitzhugh *et al* (1967)	**	**	**	**	**	**	**
Brown *et al* (1972)	sig	***		**			**
Brown (1970)	*	sig					*

Interactions

Bennyshek & Marlowe (1973)	year x age
Kilkenny & Stollard (1973)	breed x herd
Urick *et al* (1971)	age x breed year x age

key

* = p≤0.1
** = p≤0.05
*** = p≤0.005
sig = level of significance not given
ns = variable not significant

Fitzhugh *et al.*, 1967; Vacarro and Dillard, 1966; Jeffrey and Berg, 1971). However, Singh *et al.* (1970) and Joandet and Cartwright (1969) report that cows lost weight during the period of lactation. When a cow is weighed pre-partum in the spring, Clark *et al.* (1958) and Anderson *et al.* (1973) report only a slight gain in weight during this summer period - 11 lb. and 9 lb. respectively. Brinks *et al.* (1962) report that cows under five years of age gain weight from pre-partum to weaning, while older cows lose weight. Ewing *et al.* (1962) and Vacarro and Dillard (1966) report that there is initially a loss in weight after calving. The latter authors report a mean weight loss of 33 lb. during a sixty-day period after parturition. Ewing *et al.* (1962) report that, prior to increasing in weight with the spring grass, cows lost 17% of their weight the previous fall. Included in this overall loss was a 13% loss in weight at parturition (119 lb.). They made no mention, however, of what proportion of the remaining 4% was lost post-partum.

Most workers report a loss in weight through the winter. Naturally, when the cow is weighed pre-partum the weight loss reported is considerably smaller (Anderson *et al.*, 1973) than that recorded for cows weighed post-partum (Jeffrey and Berg, 1971; Fitzhugh, 1965; Fitzhugh *et al.*, 1967). However, Clark *et al.* (1958) report a slight gain (7 lb.) from fall to spring (pre-partum), whilst Brinks *et al.* (1962) report Year Effects, indicating both gains and losses during pregnancy from fall to spring (pre-partum), with the slight gain occurring more often.

Pregnancy status

This Seasonal Effect has been reported to differ between cows suckling a calf and those which are dry. The latter have a significantly greater increase in weight through the summer and can be as much as 150 lb. heavier than the former in the fall (Clark *et al*., 1958; Urick *et al*., 1971). Fitzhugh (1965) and Fitzhugh *et al*. (1967) also report that a cow's weight is influenced by whether she weaned or gave birth to a calf in the previous year.

Year of birth

Brown (1970) and Brown *et al*. (1976) found that the year of birth of a cow was a significant factor in influencing her weight. However, Brown (1970) mentions that the effect is likely to be confounded with the influence of her sire if he was used only in a single year. Holloway and Totusek (1973) and Joandet and Cartwright (1969) did not find this Year of Birth Effect to be significant.

Age at first calving

Brown (1970) used five non-linear models to describe the growth of Jersey and Hereford cows. Those parameters in the models for Jersey cows which reflected the rate of growth to maturity were significantly influenced by the age of the cow at first calving. It did not affect mature weight. Anderson (1973), Brown and Franks (1964) and Fitzhugh (1965) report that age at first calving significantly influenced the weight of three-year-old cows.

Month of calving

Fitzhugh (1965) and Fitzhugh *et al*. (1967) report that cows calving at different times of the year have different spring and fall weights. However, this Month of Calving Effect varied across the ten herds in the study and was partially confounded with a varying interval from parturition to weighing.

Condition

As expected, a cow's condition is reported to have an effect on her weight (Bennyshek and Marlowe, 1973). For example, Lowman (1975) showed that cows with a subjective condition score of one, weighed on average 150 lb. more than those with a condition score of five. Meat and Livestock Commission (1975) and Barton (1967) discuss condition-scoring of cattle and report a poor repeatability between and within untrained observers. Brewis (1974) reports mean intra- and inter-operator correlations in condition-scoring of 0.83 (range 0.66 to 0.95) and 0.70 (range 0.68 to 0.72) respectively. The five operators in this study varied considerably in their experience. As Taylor (1963) mentions, it is to be expected, and has been confirmed in trials, that measurements that are intrinsically most variable (such as those reflecting condition) invariably have the poorest repeatability.

Genotype

Negative correlations have been reported between the degree of inbreeding of an animal and its growth in early life. (Dinkel, Bush and Minyard, 1968; Moore, Stonaker and Riddle, 1961; Alexander and Bogart, 1961). Anderson et al. (1973) found a significant effect of inbreeding on cow weight at breeding time, but not in the fall or pre-partum. Weight at breeding time was recorded shortly after the cows had been trailed for three days, and the authors suggest that the inability of the inbred cows to cope with this stress resulted in their lower weights.

They also report a difference in fall weight between the three selected lines of cows in their study. Fitzhugh (1965), Fitzhugh et al. (1967), Brown et al. (1971) and Brown (1970) report a similar Sire Effect.

Studies of summer and winter changes in weight as dependent variables are listed in Table 2. The increase in weight and decrease in weight respectively which normally occur during these periods were discussed above.

Age

Vacarro and Dillard (1966), Fitzhugh (1965) and Fitzhugh et al. (1967) report that younger cows put on more weight through the summer than older cows. As mentioned previously, Brinks et al. (1962) report that while older cows lose weight through the summer, younger cows gain weight. However, this finding is not in conflict with other work, since this study used pre-partum spring weights. If a correction were made for parturition weight loss all these cows would have been found to gain weight through the summer, with younger cows gaining more than older ones. Among the weight losses through the summer reported by Singh et al. (1970) the younger cows lost more than the older ones. This anomalous result is presumably a product of the availability of feed. When it is plentiful younger cows can overcome the stress of lactation and express their genetic requirement to grow. When it is insufficient, lactation stress has a greater effect on the younger cows, causing them to lose more weight than their older contemporaries. However, age does not always influence weight change during this suckling period (England et al., 1961).

TABLE 2

Some Parameters Influencing the Weight Change of a Beef Cow

	AGE	BREED	HERD	YEAR	WEANING WEIGHT
Vacarro & Dillard (1966)	sig		sig		*
Carpenter *et al* (1972)				sig	
Brinks *et al* (1962)	sig			sig	
England *et al* (1961)	ns			sig	sig
Fitzhugh *et al* (1967)	sig	sig	sig		
Fitzhugh (1965)	sig	sig	sig		
Singh *et al* (1970)	*				*

key

* $=p \leq 0.05$

sig = level of significance not given

ns = variable not significant

Brinks *et al*. (1962) report that when related to a pre-partum spring weight younger cows tend to increase in weight through the winter more than older cows. Fitzhugh (1965) and Fitzhugh *et al*. (1967) report that when related to post-partum spring weight, winter weight loss is greatest in older cows. This age difference is again linked to the younger cows' greater inherent requirement to grow.

Breed

Reports of variation between breeds in weight changes during summer and winter periods are limited and inconsistent. Fitzhugh (1965) and Fitzhugh *et al*. (1967) found that Angus averaged less weight gain or more weight loss through the summer than Herefords. Brinks *et al*. (1962) found the opposite in their study.

Mean body weight

Mean body weight has been found to influence weight change (Carpenter *et al*., 1972). In this study the animals were maintained at an equal degree of fatness. To achieve this the larger cows were fed less, and naturally tended to gain less, than the smaller cows. This result was, therefore, the result of the feeding regime. Brown (1970) also reported that weight change was correlated with mean body weight. However, when weight change was expressed as a percentage of mean body weight the relationship was not significant.

Calf weaning weight

A number of studies have found a significant relationship between cow weight change and calf weaning weight; the cause-and-effect relationship between these two factors will be considered in the discussion. Meanwhile previous research on this is described. Vacarro and Dillard (1966) and Singh et al. (1970) report a negative correlation. On the other hand, England et al. (1961) found a positive correlation, in each of six 28-day periods, from which they concluded that good pasture conditions affect cow and calf weights similarly within periods. The correlation between these factors in different periods was, however, negative. The authors attributed this to cows which increased in weight in the earlier periods subsequently having poor milk production. Brinks et al. (1962) and Jeffrey and Berg (1971) found no significant relationship between cow and calf changes in weight during the summer period.

Sex of calf

It has been reported that the sex of a calf has an influence on the milk production of its dam. Rutledge et al. (1971) report that dams nursing female calves produce significantly more milk than those nursing males. Pope et al. (1968) found that cows nursing male calves had superior milk production. However, no reports exist on whether this differential sex effect on milk production influences a cow's weight change during the suckling period.

It is apparent from this literature that a cow's weight is determined by a number of major factors. These are her age, her herd, her condition, her history of pregnancy and lactation, and the time of year at which she is weighed. Certain other factors seem to be of lesser importance, viz. her age at first calving, month of calving and line of breeding. In addition, year of birth and degree of inbreeding have been reported to influence a cow's weight, but their importance is likely to be relatively minor.

There are fewer reports on the factors affecting a cow's weight change. Her age and the season through which the change takes place influences the magnitude and direction of the change, but her breed and body weight are not important. Reports on the influence of the calf on a cow's weight change through the summer are inconsistent.

All these significant genetic and environmental factors and their interactions will affect a cow's pattern of growth. Fitzhugh (1965), Fitzhugh et al. (1967) and Brown et al. (1972) found a considerable oscillation in the weight of cows around their mean growth curve. Joandet and Cartwright (1969) report that the body weight of one five-year-old cow, which had a mean weight of 1120 lb., varied by as much as 40% in a period of eight months. As a consequence of this, they question the rationale of comparing the weights of cows taken at constant ages, unless the effects of the environment have been established. Taylor (1965) also remarks that differences in nutrition and environment can be relatively so great that the unqualified use of liveweight in comparing breeds within a species or individuals within a breed becomes worthless.

The work which has been covered in this review gives an indication of the nature and significance of the environmental and genetic influences on cow body weight. Most of the data, however, were obtained from cow herds maintained at experimental stations, many of which are in the southern United States. There are no data from commercial herds and from cattle in northern latitudes.

CHAPTER 3

Materials and Methods

In this study growth patterns are defined by changes in body weight. The reasons for the use of body weight are as follows:

1) The measurement of body weight is more precise than that of skeletal parameters. Consequently, the lack of repeatabity of skeletal parameters, which was reported in the previous chapter, precludes their use as valid alternative or additional measures of growth.

2) Growth rate, a factor of major importance in a beef production system, is closely correlated with body weight.

3) Body weight is the major determinant of a cow's nutrient requirement and is thus important *per se*.

4) Body weight, in contrast to skeletal measurements, responds quickly to the environment and can be used effectively for the evaluation of both genetic and environmental factors affecting growth patterns.

The decision to use field data was based on the rationale that the large sample of animals included in a field study is likely to be more representative of the population of cows than the smaller sample which could be included in a controlled experiment. Thus the results obtained from a field study are more likely to reflect the situation as it exists in the total population of cows. However, field research has some disadvantages:

1) Certain parameters cannot be investigated because specific treatments cannot be imposed on the animals.

2) The parameters which can be investigated cannot be controlled.

4) Cows are culled from the herds and new ones are introduced.

5) Herd owners may stop co-operating.

6) Fewer data can be collected than in a controlled experiment.

These disadvantages were not, however, considered sufficient to preclude the field approach.

The data were collected from ranches and farms in the province of British Columbia during the period from the fall of 1973 to the spring of 1976. The initial approach to beef producers was by a letter in which the objectives of the study were explained and the individual was asked whether he would be interested in co-operating. These were mailed to:

1) All producers who were enrolled on the federal Record of Performance (Beef) Program.

2) All beef producers who had used the services of the major, local artificial insemination service during the previous five years.

Positive replies were received from 45 of the approximately 135 individuals who were contacted. A full-time technician was then employed to visit each of these producers to discuss their participation in the study. For a producer to participate, his operation had to satisfy the following four prerequisites:

1) There was a scale on which to weigh the cows accurately.

2) The cows were all identified with a unique ear-tag, or other equivalent mark.

3) The dates of birth of the cows (at least year and season) were known.

4) The calves were identified and their date of birth, sex and dams identity were recorded.

Additionally the producer was required to commit himself to the following procedures, for three years.

1) To weigh his cows each spring as soon as possible post-partum.

2) To weigh cows and calves each fall at weaning time.

3) To record the birth date, weaning date and sex of the calves.

4) To mail all these data to the author.

The technician also asked the producers he visited, and the local agricultural officers of the provincial government, for names of other producers in the area whose operations satisfied the criteria mentioned above. Any such producers were also asked to co-operate in the study.

As a result of the work of the technician from September to December 1973, approximately twenty-five producers agreed to co-operate. A small number of these were able to weigh at weaning time in the fall of 1973. Most of the calf weaning weights recorded at this and subsequent fall weighings were also included in the federal Record of Performance (Beef) Program. They were, therefore, recorded under the supervision of the local agricultural officer of the provincial government.

During the winter of 1973/74 personal approaches were made by the author and Dr. John Hodges to enlist the co-operation of a ranch with 650 cows which satisfied the first three of the four prerequisites mentioned above. As the study progressed the producer decided to identify the calves and record their dates of birth, thus satisfying the fourth prerequisite. Additional co-operation was enlisted from this ranch to enable the cows to be weighed on two additional occasions during the winter.

Contact with producers who had agreed to co-operate, was re-established by a visit from a full-time field technician during the late winter and spring of 1974. At the same time further potential co-operators were contacted. Spring-weight data were obtained from most of the herds which had been weighed the previous fall and from a number of new herds. The technician during this period also extracted background data about each cow's history (such as the age and breed or cross of each cow being weighed and its pregnancy status in 1973) from the breeding records for each herd.

Subsequent to the spring of 1974 the author maintained contact with co-operating producers by letters, phone and personal visits. However, as these individuals were widely distributed over an area which extended 650 miles to the north of Vancouver,B.C. and 550 miles to the east, personal visits were limited by the time available and the large distances to be travelled. Nevertheless, most of the co-operators were visited at least twice between the summer of 1974 and the spring of 1976. On these occasions the management practices of each herd were recorded and it was ascertained that such practices were standard for all the animals in the herd.

Further sets of data were collected in the fall of 1974, the spring and fall of 1975, and the spring of 1976. The age and breed or cross of any new cows were recorded when they were first weighed. The author was personally involved in the recording of cow weights at the 650-cow ranch. Here, in addition to the regular spring and fall weighings, the cows were weighed in January of 1974, 1975 and 1976 and in February of 1975 and 1976.

The accuracy of the scale at this ranch was checked by the author prior to each weighing session. On the other operations the accuracy of the scale was checked by the local agricultural officer of the provincial government when he was present to weigh the calves each fall.

When the data were finally collated it became apparent that there were nine herds which had been weighed regularly enough during this three-year period to allow them to be included in an analysis of consecutive weight records. A general description of each follows.

Herd 1

Breedtype;- Hereford (grade)

Number of cows:- 135

Summer grazing:- range

Farm/ranch latitude:- 50° 40' North

Farm/ranch elevation:- 1200ft.

General location in British Columbia:- Southern Interior Region

Herd 2

Breedtype:- Hereford (grade)
Hereford x Shorthorn
Hereford x Angus

Number of cows:- 650

Summer grazing:- range

Farm/ranch latitude:- 50° 30' North

Farm/ranch elevation:- 1600ft.

General location in British Columbia:- Southern Interior Region

Herd 3

Breedtype:- Hereford (grade)

Number of cows:- 150

Summer grazing:- range

Farm/ranch latitude:- 52° 0' North

Farm/ranch elevation:- 2900ft.

General location in British Columbia:- Chilcotin/Cariboo Region

Herd 4

Breedtype:- Hereford (grade and purebred)
British breed crosses
Limousin crosses (≤50% Limousin)
Simmental crosses (<50% Simmental)
Charolais crosses (<50% Charolais)
Chianina crosses (<50% Chianina)

Number of cows:- 150

Summer grazing:- range

Farm/ranch latitude:- 50° 30' North

Farm/ranch elevation:- 2800ft.

General location in British Columbia:- Kootenay Region

Herd 5

Breedtype:- Hereford (grade)

Limousin crosses (≤50% Limousin)

Charolais crosses (≤50% Charolais)

Number of cows:- 60

Summer grazing:- grass pasture - no irrigation

Farm/ranch latitude:- 50° 10' North

Farm/ranch elevation:- 1800ft.

General location in British Columbia:- Kootenay Region

Herd 6

Breedtype:- Aberdeen Angus (purebred)

Number of cows:- 20

Summer grazing:- grass pasture - no irrigation

Farm/ranch latitude:- 49° 20' North

Farm/ranch elevation:- 300ft.

General location in British Columbia:- Lower Mainland Region

Herd 7

Breedtype:- Hereford (purebred)

Number of cows:- 45

Summer grazing:- grass and alfalfa pasture - partially irrigated

Farm/ranch latitude:- 51° 0' North

Farm/ranch elevation:- 2200ft.

General location in British Columbia:- Southern Interior Region

Herd 8

Breedtype:- Hereford (grade and purebred)

Hereford x Angus

Number of cows:- 120

Summer grazing:- range

Farm/ranch latitude:- 54° 0' North

Farm/ranch elevation:- 2300ft.

General location in British Columbia:- Central Region

<u>Herd 9</u>

Breedtype:- Hereford (grade)

Simmental crosses (≤50% Simmental)

Charolais crosses (≤50% Charolais)

Number of cows:- 35

Summer grazing:- grass and alfalfa pasture - partially irrigated

Farm/ranch latitude:- 49° 40' North

Farm/ranch elevation:- 2700ft.

General location in British Columbia:- Kootenay Region

Management practices were the same for each herd, i.e. spring calving, summer grazing, fall weaning and winter feeding on silage and/or hay. The winter feeding period normally extended from October/December until April/May and was determined by the latitude and elevation of the summer grazing. The major difference between the herds was that five of them (as mentioned above) utilized summer rangeland while four used summer pasture - two of which were partially irrigated. The quality of summer range was observed by the author to vary between ranches, but no attempt was made to quantify these differences. With the exception of some of the older cows in herd 7, all the cows were spring-born and calved for the first time at two years of age.

All the cows in a herd were subject to the same management practices. Apart from minor adjustments in response to financial and climatic factors, these were the same from one year to the next. Such minor 'within herd, between year' management differences, and any minor differences between herds, will be described as they become relevant in the Discussion.

CHAPTER 4

Statistical Analysis

A basic precept of accurate statistical analysis is the formulation of precise and complete mathematical models. To enable efficient and valid estimates of the effects to be calculated, all significant sources of variation should be included in a model.

In this research separate models will be formulated for the following dependent variables:

1) Cow weight in the spring (post-partum) and fall (at weaning).

2) Changes in cow weight a) during the summer, b) during the winter. The change in weight will be considered as a percentage of the mean weight during the period under consideration.

3) Cow weight in one herd in the fall and on two occasions during the winter (winter analysis).

The independent analyses for the weight changes are considered necessary for the following reasons:

1) The ability to include additional parameters in these analyses which are specific to one or other of the weight changes.

2) The physiological effect of, for example, a 100 lb. change in weight is likely to differ between a small and a large cow. By considering each change on a percentage basis such a difference can be included in the analysis.

Previous research has shown that the following parameters or independent variables might affect the above dependent variables, (* = anticipated as being potentially significant and biologically meaningful if significant).

	Cow Weight	Winter Weight	Change in Weight Summer	Change in Weight Winter
Breedtype of the cow	*	*	*	*
Age of cow	*	*	*	*
Herd of the cow	*	*	*	*
Year of recording	*	*	*	*
Date of recording	*	*		
Spring interval	*		*	*
Age at first calving	*	*		
Genotype of the cow	*	*	*	*
Pregnancy and lactation status in the year of record	*	*	*	*
Pregnancy and lactation status in the previous year	*	*	*	*
Birth year of the cow	*	*		
Season of birth of the cow	*	*		
Condition of the cow	*	*	*	*
Body weight			*	*
Previous change in weight			*	*
Calf age at weaning	*	*	*	*
Calf weaning weight	*	*	*	*
Sex of calf	*	*	*	*
Days pregnant		*		

Where they are relevant, these factors should, therefore, be considered for inclusion in the models for the analysis of the dependent variables. The rationale for including them in or excluding them from the models for the present analyses is discussed below.

Age

A cow will (despite seasonal fluctuations) increase in weight until she reaches maturity. Age is, therefore, included in the models for the analyses of absolute body weight (weight) and seasonal weight change (weight change).

Breedtype

The mature weight and age of a cow are dependent on her breed, or, for a crossbred cow, her breed composition. In herds of more than one breedtype, this effect is included in the models for the analyses of weight and weight change. In a herd of a single breedtype it is confounded with the Herd Effect. The breedtype of each individual cow in the largest herd in this study is not known. The omission of this effect inevitably increases the residual error in the analysis. However, it was felt that the inclusion of the large number of cows from this herd would more than offset this disadvantage.

Herd

The feeding management, breeding management, range management and other factors unique to a herd will only affect the weight and weight change of the cows in that herd. In this study the cows in any herd are all treated alike, each herd is therefore considered as a single unit. The Herd Effect, which is included in the model for each analysis, also includes the following factors:

1) Location - in respect of climate, range/pasture quality, winter feed quality.

2) In herds of a single breed, the Breedtype Effect.

Year of recording

In a herd the environmental effect, e.g. climate, feed quality and management practices, might vary between years. A Year Effect is, therefore, included in the models for the analyses of weight and weight change.

Date of recording

The availability of feed, the climatic conditions and the pregnancy and lactation status of a cow will affect her weight and weight change. The effect of these is dependent on the time of year (date) at which she is weighed. It is, therefore, included in the model for the analysis of cow weight as a Season Effect. In the winter weight analysis the observations are classified by the number of days the cow is pregnant at the date of recording. They are thus independent of this factor.

Spring interval

The interval between calving and weighing in the spring is more variable than the interval from weaning to weighing in the fall. If cows lose or gain weight during this interval in the spring, the weight at the time of recording is a poor estimate of her weight immediately post-partum. A Spring Interval Effect cannot, however, be included as an independent variable in the analysis for the absolute weights. In the analysis for summer weight change it is confounded with the Previous Weight Change Effect (see later) and also cannot be included. It is, however, included in the analysis for winter weight change. As there is known to be no correlation between age and spring interval (r=0.07), it will not be fitted independently in each age subclass. Data which have a spring interval long enough to have a significant effect on winter weight change in a preliminary, individual herd analysis are removed from all subsequent analyses.

Age at first calving

The stress of pregnancy and lactation might cause a cow which first calves at two years of age to be lighter than one which was older at first calving. In eight of the nine herds in this study the cows first calved at two years of age. In the other herd a number of cows over six years of age calved for the first time in the spring at two and a half years of age. For these fall-born cows the Age of First Calving and Season of Birth (see later) Effects are, therefore, confounded. They are included in the model for the weight analysis of this herd as an Age of First Calving Effect.

Genotype

The weight and, possibly, weight change of a cow is influenced by the gametes contributed by her sire and dam, i.e. by their genotypes. However, a lack of breeding records prevents their inclusion in the models for the present analyses.

Pregnancy and lactation status in the year of record

A cow without a calf can direct all the feed she consumes to her body tissue, instead of to milk production and/or the foetus. Such a cow will, thus, have a different weight and weight change in comparison to a suckling and/or pregnant cow.

This research is concerned with the weight and weight change of the pregnant beef cow. Therefore, the spring and fall weight records of cows which were not pregnant and the fall weight records of cows which gave birth to a calf but did not wean it are excluded from the analyses.

Pregnancy and lactation in the previous year

The effect described immediately above can have a carry-over effect from one year to the next. Therefore, once a cow does not wean a calf (including those not weaning a calf in 1973), all her subsequent records are excluded from the analysis.

A lack of calving records in the largest herd in this study prevented any exclusion of these cows on the basis of past or present pregnancy and lactation status. Their inclusion inevitably increases the residual error in the analysis. However, it was felt that the inclusion of the large number of cows from this herd would more than offset this disadvantage.

Year of birth

Genetic or environmental factors unique to the year of birth of a cow might have an influence on her weight. Previously quoted research has shown this effect to be relatively small. Therefore, it is here assumed to be random and is allowed to contribute to the residual variance.

Season of birth

In all but one of the herds in this research study the cows were born in the spring. In the other herd some of the older cows were born in the fall and calved for the first time at two and a half years of age. As previously mentioned, this joint

Season of Birth /Age at First Calving Effect is included in the model for the analysis of weight in this herd.

Condition

Previous research has shown that this affects the weight of a cow. It could also affect the weight change of a cow - a 'fatter' cow might be expected to have a greater weight loss, or less weight gain, than a 'thinner' cow. Condition is a subjective character and the problem of classifying it was reported previously. The problem of recording the intrinsically more variable body measurements which reflect body condition was also mentioned. The advantage which might be gained from including one or other of these estimates of condition in the present analysis is considered to be insufficient to offset the risk of the increase in the error factor which could result from their inclusion. It is not, therefore, included in the models for the present analyses.

Body weight

If body weight reflects condition i.e. a 'fat' cow is a heavy one, and vice versa, the body weight of a cow could influence her weight change. However, the correlation which exists between the age of a cow and her body weight prevents the inclusion of this factor in the models for the weight change analyses.

Previous change in weight

A cow will have a characteristic mean weight which will be dependent on her age, breedtype, herd etc. If short-term environmental factors cause her actual weight to deviate from this, a subsequent compensation is likely to occur to cause it to return towards its expected or true mean. Thus, a change in weight in one period is influenced by the weight change in the previous period. This compensatory growth is, however, likely to differ between age subclasses. In a younger cow a weight gain reflects a growth of muscle and, to a lesser extent, skeletal tissue, and such weight gain is not easily lost. In older cows weight changes reflect changes in condition and thus weight can be gained and lost relatively easily. Therefore, this previous change in weight parameter will be fitted independently in each age subclass in the models for the analyses of weight change.

Weaning weight

A heavy calf weaning weight is partially a product of a high milk production by its dam. In comparison with a less productive contemporary, a cow with a heavy calf might direct more of the feed she consumes to milk production. In the less productive animal it is more likely to accumulate in her body tissue. This difference in 'lactation stress' might be reflected in a cow's fall weight. In the analysis of the spring and fall weights it is confounded with the Season Effect and in the analysis of winter change in weight it is confounded with the previous weight change. A lack of weaning weight data prevents its inclusion in the model for the winter analysis. Therefore, a Weaning Weight Effect will only be included in the model for the summer weight-change analysis.

Calf age at weaning

A cow which has a relatively old calf is likely to be producing less milk than one with a younger calf. This is a product of the fact that:

1) She is at a later stage in her lactation.

2) The calf is suckling her less.

A cow with an older calf at weaning will, therefore, have had more time to overcome the 'lactation stress' mentioned above than a contemporary with a younger calf. Her fall weight might reflect this. As with weaning weight, this Calf Age Effect will only be included in the model for the summer weight-change analysis.

Sex of calf

A differential effect of the sex of a calf on the milk production of its dam was mentioned previously. This might, owing to a differential 'lactation stress', influence the weight change of a cow. Sex of calf will, therefore, be included in the model for the analysis of summer weight change.

Days pregnant

The weight of a cow during pregnancy will reflect the increase in the weight of the foetus and its associated tissues and fluids. At the time of weighing in the spring a cow is empty, in the fall the weight of the foetus etc. will be minimal. It is, therefore, considered to be of insufficient importance to warrant its inclusion in the models for the analysis of spring and fall weights and weight change. However, in the winter weight analysis its influence is likely to be significant. The increase in weight of the conceptus is not linear over time, therefore, the number of days a cow is pregnant and its squared and cubed values are included in the winter analysis. The date of conception for a cow is calculated by subtracting 285 days, the mean length of pregnancy for

British beef breeds quoted by Preston and Willis (1960), from her calving date. Days pregnant is then the interval in days between this date and that of weighing.

The first order interactions amongst the independent variables to be considered are also included in the models for the analyses. Higher order interactions are considered as having insufficient biological meaning to warrant consideration.

Once the parameters to be included have been decided, the next step is to define the nature of the models which are to be analysed. Eisenhart (1947) defines two 'types' of models; the 'type' of model is dependent on the class of variables to be analysed.

Type 1 Model - in which 'the estimation is of a fixed, relationship among means of sub-sets of the universe of objects concerned'.

Type 2 Model - in which 'the estimation is of components of (random) variation associated with a composite population.......from the population of possible individuals'.

These he classified as 'fixed effects' and 'random effects' models respectively. The initial computational procedures and the mechanics of the tests of significance are the same for the Analysis of Variance (ANOVA) for each model. Interpretation of the ANOVA, however, depends on the type of model. Eisenhart (1947) also mentions the 'mixed' model, in which there are both fixed and random effects. This model and methods for handling its analysis are discussed in more detail by Henderson (1953) and Searle and Henderson (1961).

Eisenhart (1947) defines a fixed effect as being composed of distinct sub-sets, he also states that any conclusions from a fixed effect analysis must be confined to the specific effects included in it. In this analysis herd, year, season, breedtype and sex of calf satisfy these criteria. They are thus fixed effects and the model used for their analysis is Eisenhart's Type 1.

It could be argued, however, that the herds, years, genotypes and ages, especially the last, were a random selection from the populations of these effects. This view would require use of a Type 2 model. However, in this study these effects are viewed in Eisenhart's terminology as being the 'universe' about which direct conclusions are drawn. They are also composed of distinct sub-sets, amongst which comparisons are to be made. For these reasons they are considered as fixed effects.

The remaining independent variables, viz. previous weight change, spring interval, days pregnant, calf age and weaning weight, are considered as random effects. Their influence on the dependent variable is removed by the use of covariance. This allows the fixed effects to be measured with greater precision.

Since Fisher (1925) first formulated the analysis of variance, many modifications have been devised to increase the scope of its application. These have included its application to data with unequal subclass frequencies (Harvey, 1975). The confounding of effects which results from such non-orthogonal data can be overcome by considering all the effects simultaneously. Least-squares methods of analysis allow this to be done, and are used here.

Yates (1934) proposed a method of analysing fixed effects by 'fitting constants', analagous to the method of regression when the independent variables assume the values of 0 or 1. Harvey (1975) describes in detail the use of this method. For a fixed effects model this provides for the computation of means, regression coefficients, standard errors, tests of significance, orthogonal polynomials and the sum of squares of differences between components of an effect. A general outline of the analysis described by Harvey (1975) follows:

1) The formulation of least square equations.
2) The reduction of these equations by imposing the appropriate restrictions - normally that the sum of the constants within a given set equal zero.
3) The solution of these n equations in n unknowns. This is done by inverting the variance/covariance matrix. Each constant is then equal to the sum of the products of the inverse elements of the variance/covariance matrix for a constant and its Right Hand Member (R.H.M., the numerical value of its equation).
4) The computation of total sum of squares (total S.S.), reduction S.S. (from the sum of products of the constants and their R.H.M.) and the residual S.S. (by difference).
5) Computation of the sums of squares of differences between components of a set. These are obtained from the product of the constant estimates for a given set and their corresponding inverse segment of the variance/covariance matrix.

6) The computation of the standard errors of the constants. These are obtained from the product of the residual mean square and the inverse diagonal element of the variance/covariance matrix for the constant.

7) The computation of the required comparisons.

The least squares analysis used in this research is a modified version of the above. It was carried out using a generalised least squares subroutine, developed by Peterson (1974). The analysis package was written in Fortran IV and was used on a I.B.M. system/370, model 168, computer. A general outline of this analysis follows:

1) The formulation of the least squares equations - with the sum of the constants of a given set equalling zero.

2) Computation of the sum of squares and cross-product matrix - from 1) by absorbing μ row and column.

3) The computation of the variance/covariance matrix - from 2) by dividing by the total degrees of freedom.

4) The computation of the correlation matrix - from 3) by dividing by the geometric mean of the variance.

5) The computation of the inverse of the correlation matrix.

6) The computation of the inverse of the variance/covariance matrix, in which the ijth element (C_{ij}) is obtained as follows:-

$$C_{ij}^{-1} = R_{ij}^{-1} \times (1/(V^{ii})^{.5}) \times (1/(V^{jj})^{.5}) \times (1/W^{11}-1)$$

where

R_{ij}^{-1} = the ijth element of the inverse of the correlation matrix.

V^{ii} = the variance of the ith effect which are the diagonal elements of the variance covariance matrix.

W^{11} = the total number of observations.

7) The computation of the total S.S, the reduction S.S and, by difference, the residual S.S. The reduction S.S is calculated as fcllows:

Reduction S.S. = Total S.S. x R-square complete model (R_n^2)

where

$$R_n^2 = \Sigma\, b'_{ni.j} \times r^{in}$$

($b'_{ni.j}$ = the standard partial regression coefficient of the ith independent vaiable holding all other independent variables constant and r^{in} = the correlation between the ith independent variable and the nth dependent variable, from the correlation matrix).

8) The computation of constants - from the product of the standardised partial regression coefficient and the ratio of the standard deviations of the dependent and independent variable being considered.

9) The computation of their standard errors - as in Harvey (1975).

10) The computation of constants and standard errors for the absorbed independent variables.

11) The computation of the sums of squares of differences between means - as in Harvey (1975).

The maximum number of degrees of freedom which can be fitted in a model is limited by the precision of the inversion of the correlation matrix. This is a product of the rounding errors which occur in this inversion. Previous experience has shown that the upper limit is approximately one hundred and fifty degrees of freedom.

As a result of the above rationale, the following models are used in the analyses.

1) Cow weight in the spring and fall

$Y_{ijklmn} = \mu + B_i + A_j + H_k + R_l + S_m$ + (interactions) + e_{ijklmn}

in which

Y_{ijklmn} = the record of a cow's weight on a particular occasion of weighing.

μ = the overall mean-common to all cows when the sum of each set of discrete variables in zero.

B_i = the effect of the ith breedtype.

A_j = the effect of the jth age.

H_k = the effect of the kth herd.

R_l = the effect of the lth year.

S_m = the effect of the mth season.

(interactions) = the first order interactions amongst these discrete independent variables.

e_{ijklmn} = the random error associated with the Y_{ijklmn}th record

2a) Change in cow weight during the summer

$Y_{ijklmn} = \mu + B_i + A_j + H_k + R_l + S_m$ + (interactions) + $b_1(W_{ijklmn} - \bar{W}) + b_2(C_{ijklmn} - \bar{C}) + b_3(P_{ijklmn} - \bar{P}) + e_{ijklmn}$

in which

Y_{ijklmn} = the summer weight change record.

μ = the overall mean.

B_i = the effect of the ith breedtype.

A_j = the effect of the jth age.

H_k = the effect of the kth herd.

R_l = the effect of the lth year.

S_m = the effect of the mth sex of calf.

(interactions) = the first order interactions amongst these discrete independent variables.

b_1 = the regression of the dependent variable on the weaning weight of the calf.

b_2 = the regression of the dependent variable on the age of the calf.

b_3 = the regression of the dependent variable on the previous weight change of the cow.

e_{ijklmn} = the random error associated with the Y_{ijklmn}th record.

2b) <u>change in cow weight during the winter</u>

$Y_{ijklm} = \mu + B_i + A_j + M_k + R_l +$ (interactions) $+ b_1(S_{ijklm} - \bar{S})$
$+ b_2(P_{ijklm} - \bar{P}) + e_{ijklm}$

in which

Y_{ijklm} = the winter weight change record.

μ = the overall mean.

B_i = the effect of the ith breedtype.

A_j = the effect of the jth age.

H_k = the effect of the kth herd.

R_l = the effect of the lth year.

(interactions) = the first order interactions amongst these discrete independent variables.

b_1 = the regression of the dependent variable on spring interval.

b_2 = the regression of the dependent variable on the previous weight change of the cow.

e_{ijklm} = the random error associated with the Y_{ijklm}th record.

3) Cow weight during the winter

$Y_{ijk} = \mu + R_i + A_j +$ (interactions) $+ b_1(DP_{ijk} - \overline{DP}) + b_2(DP^2{}_{ijk} - \overline{DP^2}) + b_3(DP^3{}_{ijk} - \overline{DP^3}) + e_{ijk}$

in which

Y_{ijk} = the record of a cow's weight on a particular occasion during the winter.

μ = the overall mean.

R_i = the effect of the jth year.

A_j = the effect of the kth age.

(interactions) = the first order interactions amongst these discrete independent variables.

b_1 = the regression of the dependent variable on the number of days pregnant(D.P.).

b_2 = the regression of the dependent variable on $(D.P)^2$.

b_3 = the regression of the dependent variable on $(D.P.)^3$.

e_{ijk} = the random error associated with the Y_{ijk} th record.

The analyses using these models was first carried out on a within herd basis. The sums of squares accounted for by the effects fitted in each herd were noted. The final formulation of the models for the combined analyses was based on these results.

In order to test the statistical validity of combining the data from the herds into such combined analyses, Bartlett's test for homogeneity of variance was applied to the Residual Mean Squares from the within herd analyses. The decision to include or exclude a herd from a combined analysis was made from the results of this test, together with the biological interpretation of the within herd analyses.

The results of these analyses are given in the following chapter. The influence of a parameter in an analysis is considered significant if $P \leq 0.05$.

CHAPTER 5

Results

Spring and Fall weight

The model for this analysis can be fitted to the spring and fall weight records from all nine herds. However, for the following reasons herd 9 is excluded from the combined herd analysis:

1) The variance in this herd (20042) is distinctly different from the variances of the other herds - their arithmetic mean is 9384(±1589).

2) In the analyses of individual herds the Breedtype Effect is significant only in this herd.

The remaining eight herds do not have homogeneous variances when tested with Bartlett's test. However, the magnitude of the differences between them were not excessive when considered in biological terms. They are, therefore, all included in a combined analysis.

Since the Breedtype Effect was not significant when fitted in the individual analyses for herds, it is not included in the model for the combined analysis. Similarly the Age at First Calving/Season of Birth Effect required for the weight records of herd 7 is also excluded.

The ANOVA of the records from these eight herds is shown in table 3. The least squares estimates of the means of the subclasses in the analysis are shown in table 4, the least squares constants from which they are calculated are in appendix 1.

The Herd Effect is significant and the means of each herd are shown in fig 1. The following single degree of freedom comparisons were carried out (the herd numbers are shown in parentheses).

Comparison	F-value	R-square	
pasture(5-7).v.range(1-4+8)	266.5	0.080	sig.
Herd 3.v.other range herds	926.9	0.068	sig.
Range herd comparisons (excluding herd 3)			
crossbred (2+4+8) .v. straightbred(1)	30.2	0.002	sig.
Exotic crossbred(4) .v. British crossbred(2+8)	2.6	0.000	N.S.
Pasture herd comparisons			
crossbred (5) .v. straightbred (6+7)	24.86	0.002	sig.
Hereford(7).v. Angus (6)	0.24	0.000	N.S.

Thus, cows in pasture herds (weighted mean = 1090.5 lb.) are significantly heavier than those in range herds (weighted mean = 971.5 lb.). Herd 3 is significantly lighter than the other range herds and is not included in the other comparisons between range herds. The mean weight of cows in the crossbred range herds (980.2 lb.) is significantly less than that of the cows in the straightbred range herd (1030.5 lb.). However, amongst the pasture herds the cows in the crossbred herd are significantly heavier (1104.4 lb.) than those in the

TABLE 3

Analysis of Variance

Spring and Fall Body Weights

Source	d.f.	Mean Square	F-value	R-square
Herd	7	1606284	186.86*	0.096
Age	9	1332069	154.96*	0.103
Year	2	8219	0.96	0.000
Season	1	3869523	450.15*	0.033
Herd x Year	14	124576	14.49*	0.015
Herd x Sn.	7	854873	99.45*	0.051
Herd x Age	59	59994	6.98*	0.033
Age x Year	18	22337	2.60*	0.004
Age x Season	8	119543	13.90*	0.008
Yr x Season	2	226917	26.40*	0.004
Residual	5187	8596		0.382

(* = effect significant)

Total S.S. = 0.1168061E+9

Reduction S.S.= 0.7221858E+8 R-square = 0.618

% of Total S.S. assigned to parameters = 34.4

TABLE 4

Least Squares Estimates for

Spring and Fall Weights

subclass	L.S. estimate	subclass	L.S. estimate
Herd 1	1030.5 (672)*	Age 1	847.3 (134)
2	971.2 (2612)	2	870.9 (685)
3	865.1 (654)	3	950.6 (759)
4	995.4 (493)	4	1020.2 (706)
5	1104.4 (223)	5	1057.7 (597)
6	1075.4 (88)	6	1083.9 (508)
7	1083.3 (247)	7	1075.9 (327)
8	1029.6 (326)	8	1090.9 (268)
		9	1109.7 (268)
		10+	1086.5 (783)
Year 1	1016.5 (1299)	Fall	1076.5 (2752)
2	1024.2 (2179)	Spring	962.2 (2563)
3	1017.4 (1837)		

Age x Year

Year Age	1	2	3
2	871.6	863.2	877.8
3	946.9	972.4	932.3
4	1030.7	1020.4	1009.7
5	1051.6	1065.7	1055.9
6	1064.7	1093.3	1093.6
7	1064.2	1078.7	1084.7
8	1093.0	1094.6	1085.2
9	1108.7	1110.6	1109.8
10+	1077.2	1095.8	1086.3

Herd x Year

Year Herd	1	2	3
1	973.5	1066.3	1051.8
2	986.4	949.3	978.0
3	841.5	872.2	881.6
4	1017.3	1001.0	967.8
5	1126.4	1103.3	1083.7
6	1039.9	1093.4	1092.7
7	1105.4	1085.5	1059.1
8	1041.2	1023.1	1024.5

Herd x Age

Herd Age	1	2	3	4
2	928.8	775.4	793.9	871.4
3	947.8	865.6	794.6	943.3

(* =number of observations shown in parentheses)

TABLE 4 ccnt

4	1027.2	972.8	868.4	1032.5
5	1067.8	998.5	899.0	1060.7
6	1096.2	1018.5	916.7	1061.5
7	1091.3	1050.2	924.4	1068.2
8	1074.8	1079.2	913.3	1050.5
9	1087.1	1081.6	920.7	1042.0
10+	1106.3	1071.2	926.4	1012.0

Herd Age	5	6	7	8
2	936.9	970.3	779.9	910.6
3	1045.3	1082.5	984.1	941.3
4	1099.4	1078.3	1075.5	1007.9
5	1147.2	1126.3	1104.1	1058.3
6	1190.3	1178.8	1135.0	1075.0
7	1147.0	1063.9	1166.1	1096.0
8	1135.3		1209.2	1118.1
9	1202.5	1181.7	1228.0	1097.5
10+	1135.6	1062.8	1227.0	1079.0

Age x Season

Season Age	Spring	Fall
2	801.4	940.4
3	863.3	1037.8
4	952.0	1088.3
5	1001.9	1113.6
6	1036.9	1130.8
7	1027.2	1124.6
8	1036.3	1145.5
9	1064.8	1154.6
10+	1048.4	1124.6

Herd x Season

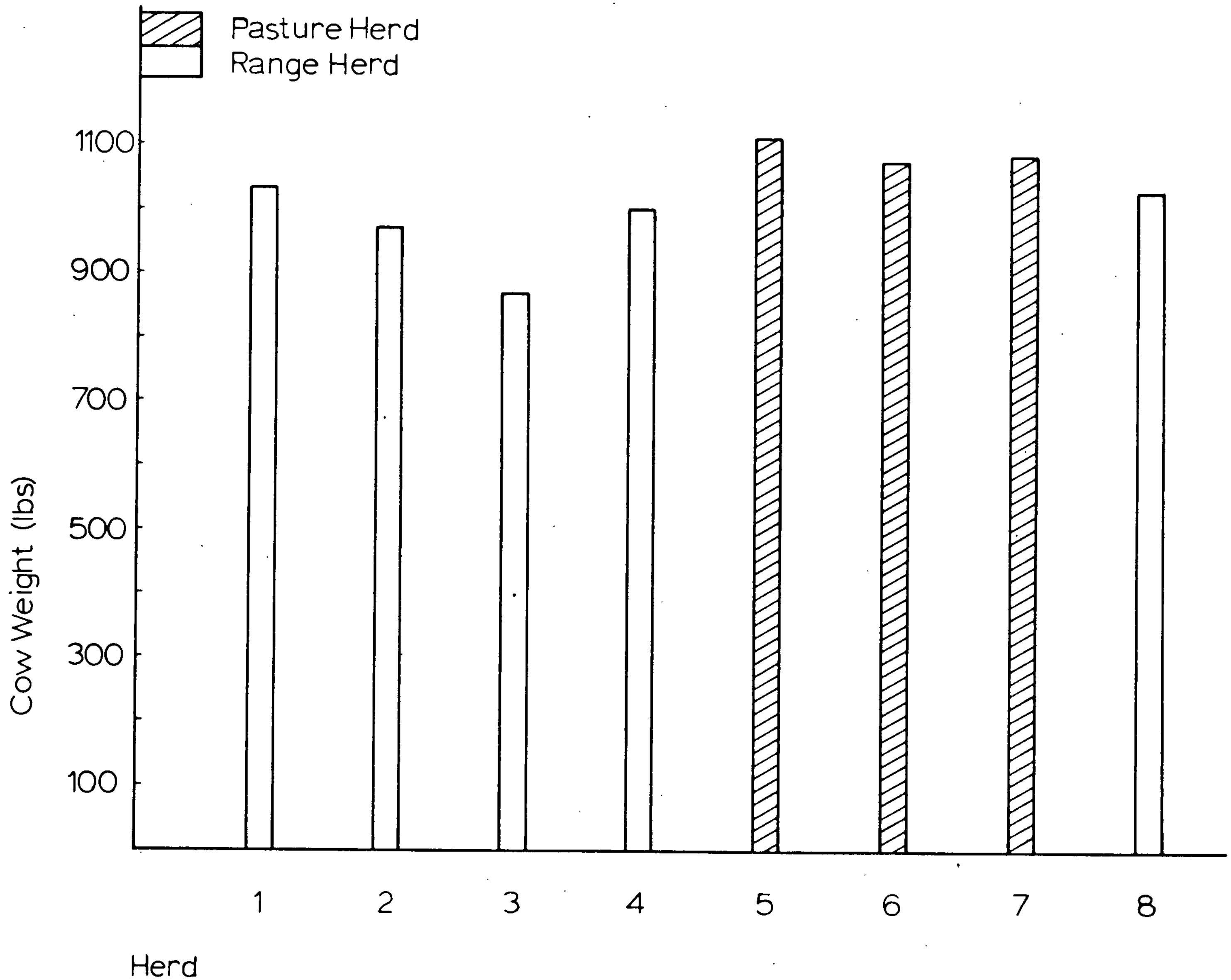
Season Herd	Fall	Spring
1	1009.5	1051.6
2	988.9	953.6
3	991.2	739.1
4	1060.8	930.1
5	1191.3	1017.3
6	1101.6	1049.0
7	1131.3	1035.3
8	1137.0	926.2

Year x Season

Season Year	Fall	Spring
1	1051.9	981.0
2	1085.6	962.8
3	1091.9	942.9

Figure 1

The weight of the cows in each herd.


Pasture Herd
Range Herd
1100
900
700
500
300
100
Cow Weight (lbs)
1
2
3
4
5
6
7
8
Herd

straightbred herd (1081.6 lb.). These straightbred pasture herds consist of one Hereford herd and one Angus herd. The cows in the former (1083.3 lb.) are not significantly different in weight from those in the latter(1075.3 lb.). Amongst the crossbred range herds the mean weight of cows in the herd containing exotic crossbreds (995.4 lb.) is not significantly different from the mean weight of cows in the herds which have only crossbreds of British breeds (977.7 lb.). Although these comparisons have been classified by the breedtypes or range/pasture type of the herds, they also reflect all the other components of the Herd Effect which were mentioned in Chapter 5.

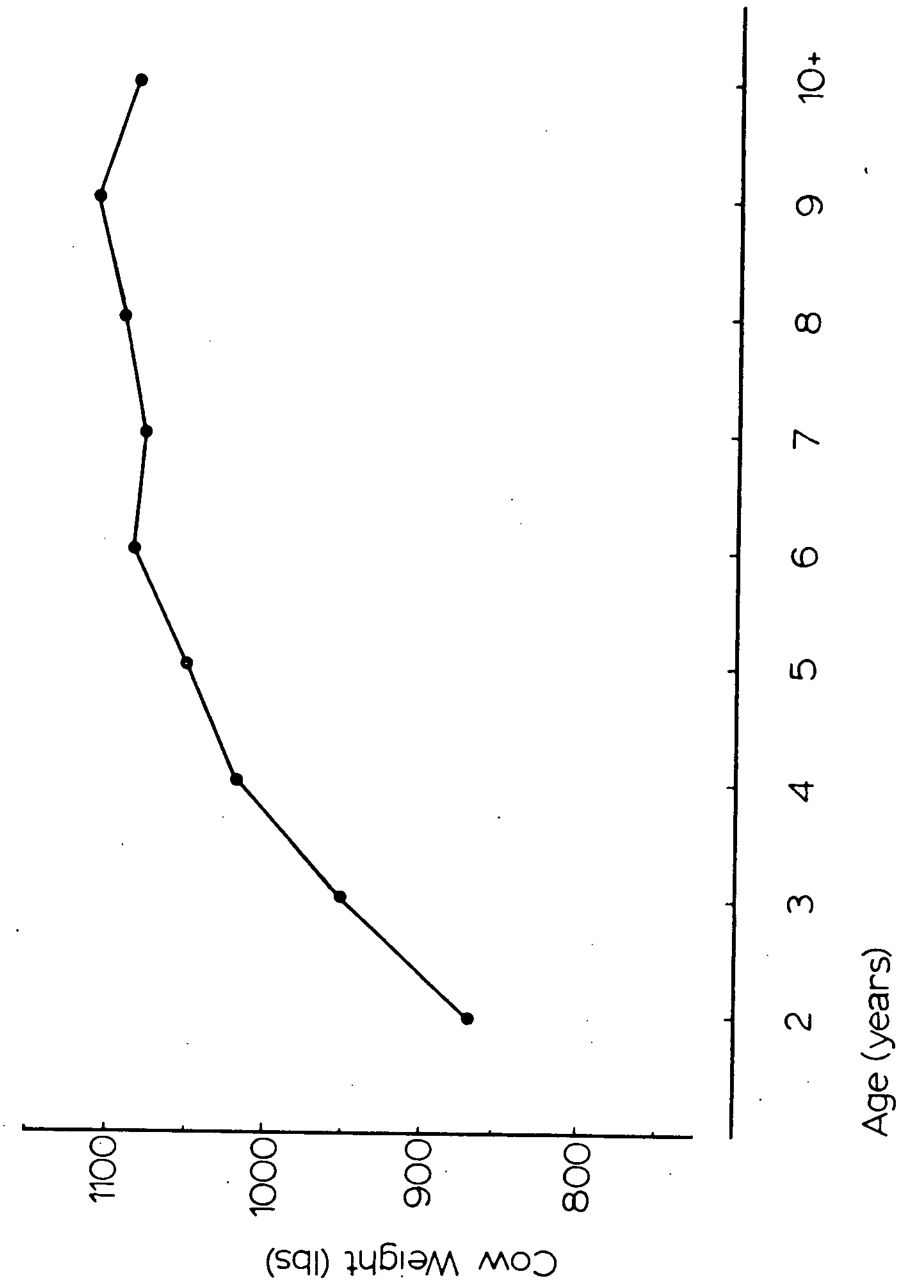
The Age Effect in the ANOVA is significant. The pattern of the increase in weight over age is shown in fig 2. Both the linear (R^2=0.001) and quadratic (R^2=0.019) components of this increase in weight are significant. From a weight of 870.9 lb. at two years of age, the weight of a cow initially increases rapidly. The rate of increase then slows, but continues through to 9 years of age. The increase in weight from the mean of ages six and seven to nine is significant, but the difference in weight between nine-year-old cows (1109.7 lb.) and ten-year-old (1086.5 lb.) cows is not.

The Year Effect is not significant, the largest difference between the years being only 7.7 lb. However, within each year, the Season Effect is significant. Cows are on average 114.2 lb. heavier in the fall than in the spring.

The Age/Year and Age/Season interactions are significant statistically, but their R^2-values show that their biological significance is minimal. The mean summer and winter weight

Figure 2

The increase in weight over age.


Cow Weight (lbs)
1100
1000
900
800
Age (years)
2
3
4
5
6
7
8
9
10+

changes which can be calculated from the Age/Season interaction subclass means are shown in table 5. The difference between the mean winter weight loss of these estimates and the main seasonal effect is an inevitable product of the least squares analysis. The difference between the outer two weight estimates(two-year-olds in the spring and ten+-year-olds in the fall) is absorbed into the winter change in weight estimates. These seasonal fluctuations around the mean pattern of growth are shown in fig 3. In comparison to the summer weight changes, the values of the winter weight change are more similar across ages. The summer weight gain is greatest in younger cows (ages 2 to 5). Amongst these younger cows, the weight gain of three-year-old cows (174.5 lb.) is 27% greater than the mean gain of two and four-year-old cows (137.8 lb.).

The Year/Season interaction is also significant statistically, but again its biological importance is small. The mean summer and winter weight changes in each year are shown in table 6. As explained above, the difference between the mean summer weight gain of these estimates and the main seasonal effect is an inevitable product of the least squares analysis. The two summer weight gains are equivalent to each other, as are the two later winter weight losses. The smaller weight loss in the winter of 1973/74 is mostly a product of the herds which were recorded over this period.

The Herd/Year interaction is statistically significant and accounts for considerably more of the variation amongst the weight records than the interactions mentioned previously. However, only three of the interaction deviation constants are

TABLE 5

Seasonal Weight Changes(lb) in each Age Subclass

Age	Summer Weight Change	Winter Weight Change
2	139.0	-77.1
3	174.5	-85.8
4	136.6	-86.7
5	111.7	-76.7
6	93.9	-103.6
7	97.4	-88.3
8	109.2	-80.7
9	89.8	-106.2
10+	76.2	

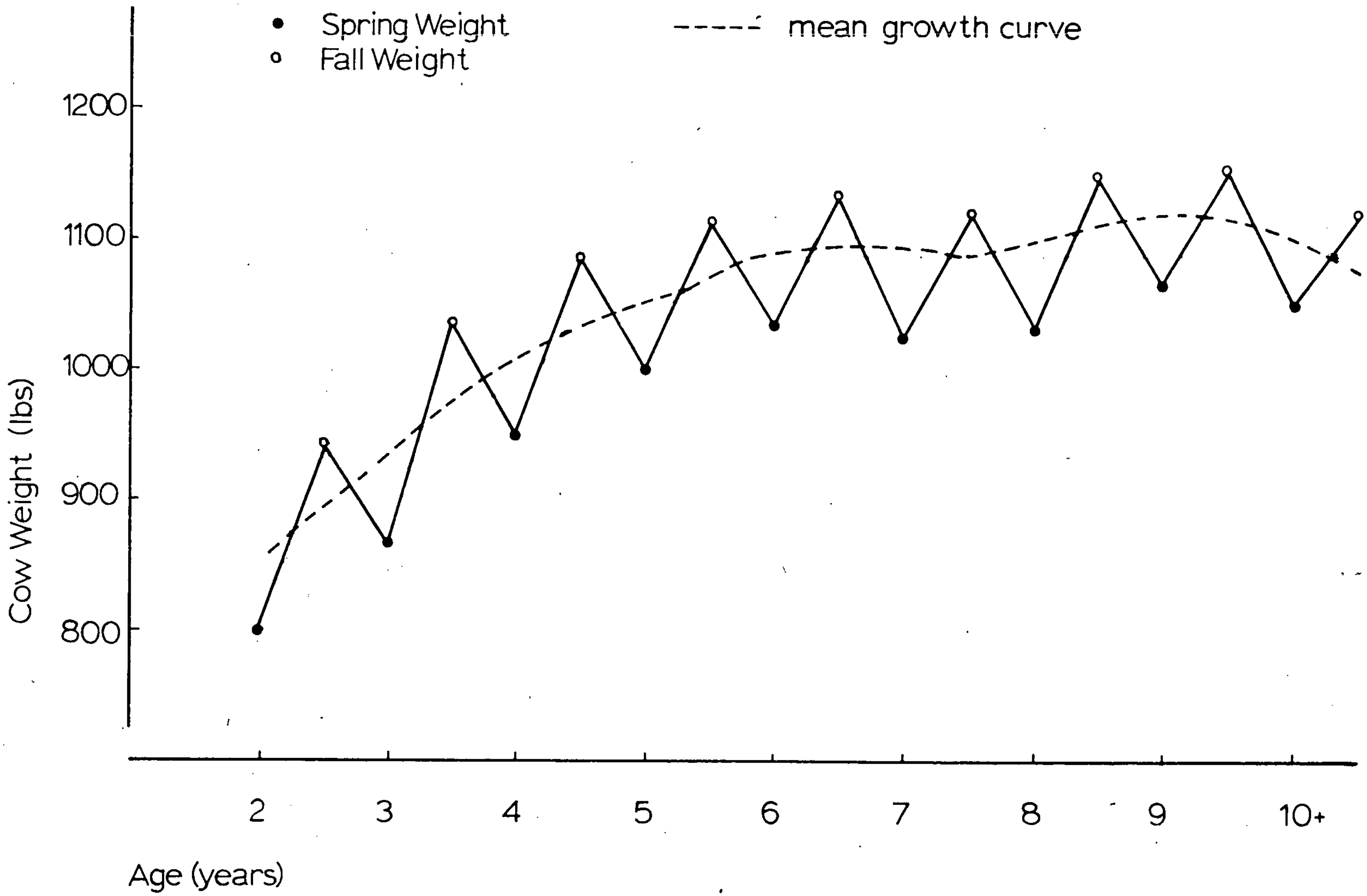
TABLE 6

Seasonal Weight Changes(lb) in each Year

Winter Year 1	-70.9
Summer Year 1	104.6
Winter Year 2	-122.8
Summer Year 2	129.1
Winter Year 3	-149.0

Figure 3

The seasonal fluctuations in weight around the mean growth curve.


Spring Weight
Fall Weight
mean growth curve
1200
1100
1000
900
800
Cow Weight (lbs)
2
3
4
5
6
7
8
9
10+
Age (years)

greater than 30 lb., two of these being in herd 1. In this herd there was a mean weight increase of 92.8 lb. betweeen year 1 and 2, with 14.6 lb. of this being lost in year 3. This point will be discussed later. When the means for the other herds are compared over years, two of the herds were lightest in year 1, two were lightest in year 2 and three in year 3. Thus, excluding herd 1, the year of record appears to be and is considered as a random variable.

The Herd/Season interaction is also significant. The proportion of the variance accounted for by this interaction exceeds expectation to a greater extent than in any of the other interactions. The subclass means for this interaction provide an estimate of the mean fall and subsequent spring weights in each herd. They are shown in fig 4. The estimates, however, are not calculated independently of any Herd/Year interaction. But, as each winter change in weight occurs within any one year, the difference between these means is a reliable estimate of the mean winter change in weight in each herd. These are shown in table 7. In herds where there is no significant Herd/Year interaction (i.e. mean weight is constant over years) the mean summer change in weight is equal and opposite to that during the winter. In herds where there is a significant Herd/Year interaction, the fact that the summer change in weight crosses the interface between two adjacent years, results in a confounding of summer change in weight with any change in the mean weight of the herd. As most of the herds do have a variation in mean weight over years, no true estimates of summer weight change, can therefore be obtained from this analysis.

Figure 4

The spring and fall weights in each herd.

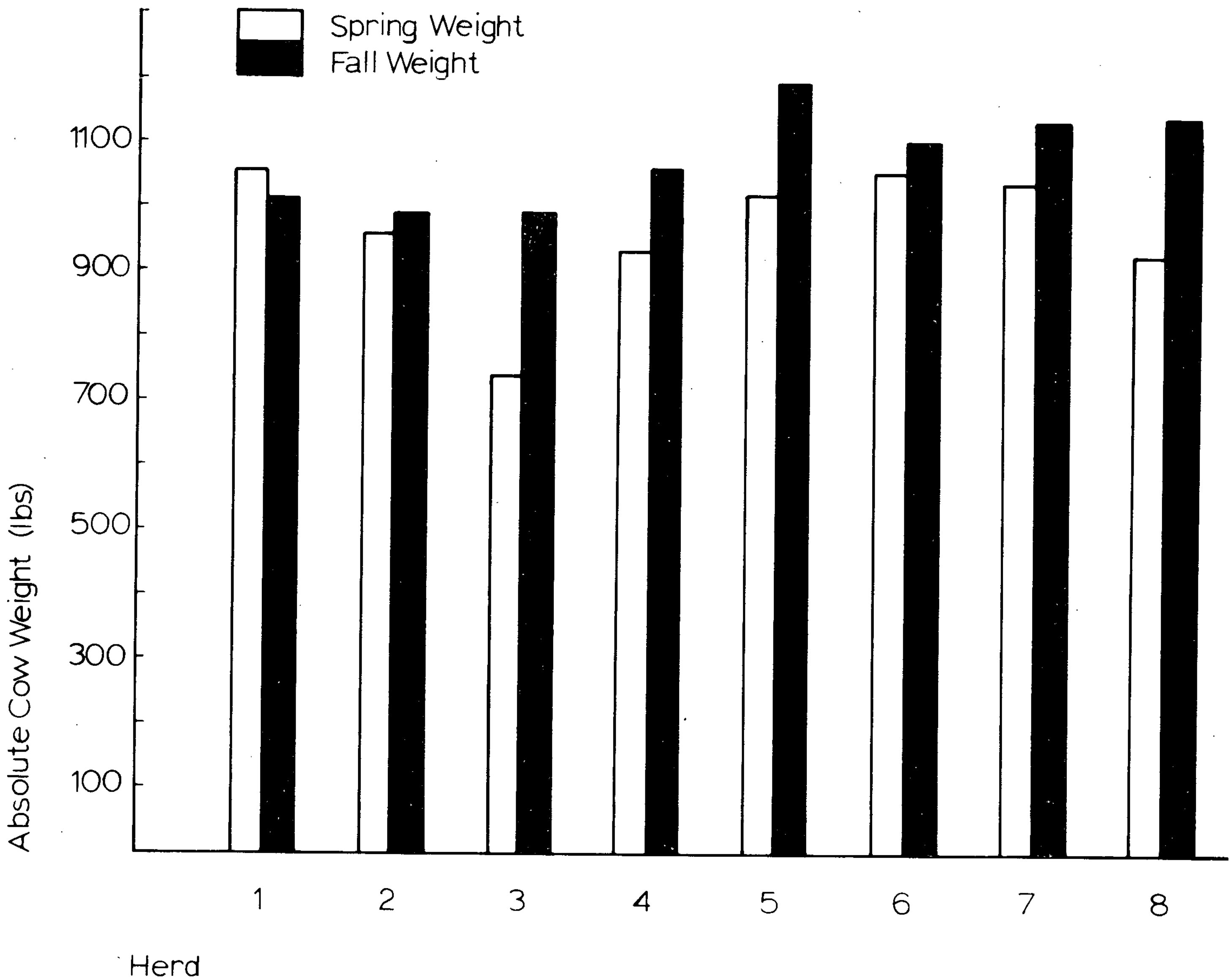

Spring Weight
Fall Weight
Absolute Cow Weight (lbs)
1100
900
700
500
300
100
1
2
3
4
5
6
7
8
Herd

TABLE 7

Winter Weight Change (lb) in each Herd

Herd 1	+42.0	Herd 5	-174.1
2	-35.3	6	-52.7
3	-252.2	7	-96.1
4	-130.8	8	-210.9

The Herd/Age interaction is significant, but the amount of variation it accounts for exceeds expectation less than that due to the herd/season interaction. The patterns of growth of the cows in each herd are shown in fig 5. The deviation in each herd from the mean growth pattern can be summarized as follows:

(1= interaction deviation >20lb<35lb, 2 = >35<50lb, 3 = <50lb)

Herd 1 - two-year-old cows heavy (2), older cows (ages 8+9) light (1)

Herd 2 - younger cows (ages 2+3) light (2), older cows (ages 7-10+) heavy (2).

Herd 3 - two-year-old cows heavy (2), older cows (ages 8+9) light (1). The deviation of the two-year-old cows is such that there is no increase in weight from two to three years of age.

Herd 4 - younger cows (ages 2,4+5) heavy (1), older cows (ages 9+10+) light (3).

Herd 5 - older cows (ages 8,10+) light (2).

Herd 6 - the small number of records in this herd (88) results in poor estimates for the age subclasses. The deviations are all large (3) and inconsistent.

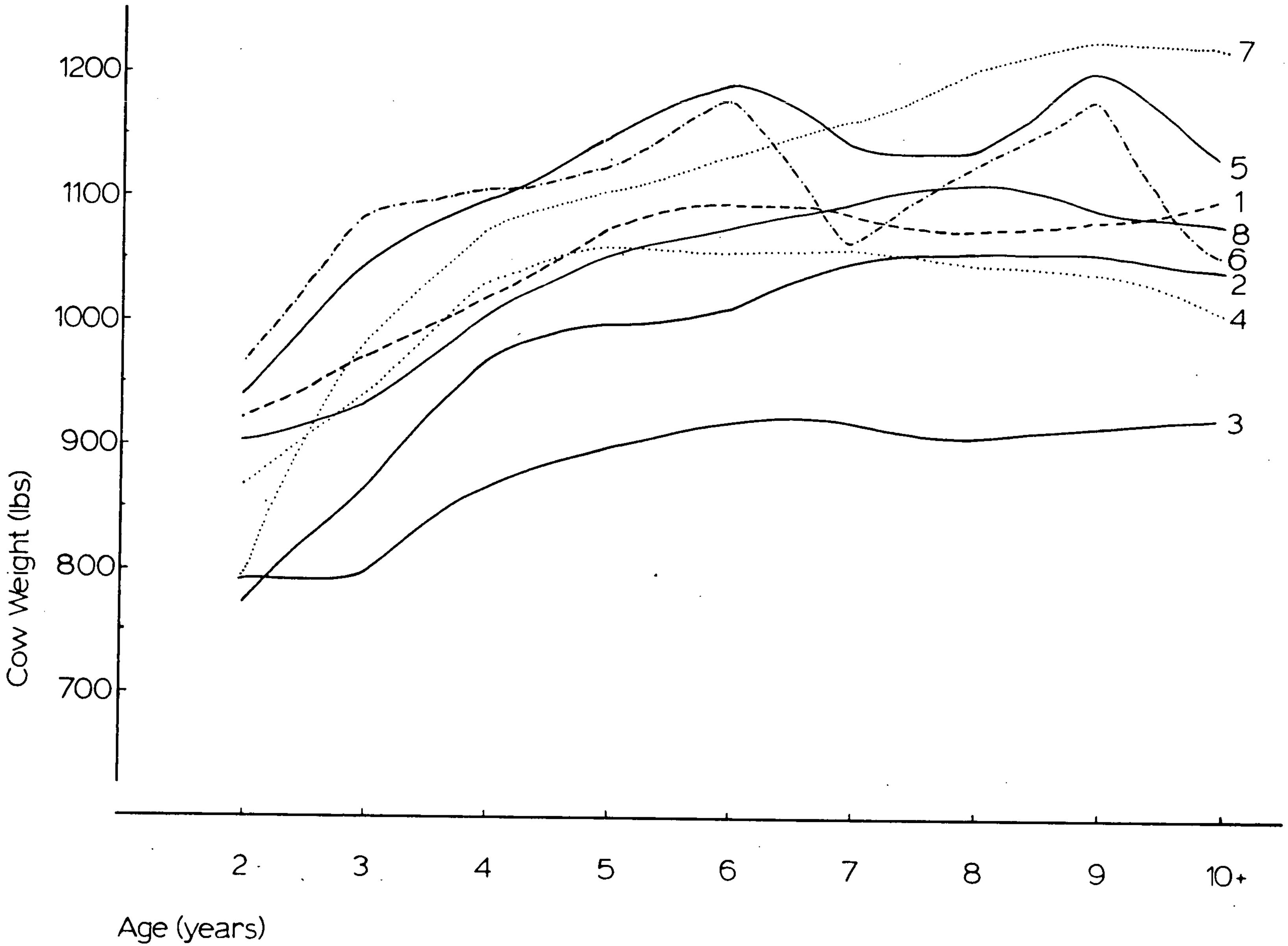
Herd 7 - younger cows (ages 2+3) light (2), older cows (ages 8-10+) heavy (3).

Herd 8 - younger cows (ages 1+2) heavy (1).

Thus, the cows in herds 1,3,5 and 6 reach their maximum weight at six years of age. Those in herd 4 reach this weight at five years of age, while in herds 2 and 8 this is delayed until eight and in herd 7 until nine years of age. In herds 2 and 8

Figure 5

The growth curve in each herd.


Cow Weight (lbs)
1200
1100
1000
900
800
700
Age (years)
2
3
4
5
6
7
8
9
10+
7
5
1
8
6
2
4
3

the weight increase betweeen six and eight years of age is 60.7 lb. and 43.1 lb. respectively, in herd 7 there is a 93.0 lb. increase after six years of age.

In certain herds the mean weight of the age subclasses decreases amongst older cows. There is a 48.7 lb. decrease in weight after age five in herd 4 and a 39.1 lb. decrease in weight after age eight in herd 8. In herd 5 the nine-year-old subclass estimate is a product of a small number of records(4), the loss in weight from age six to the mean of ages eight and ten+ is 54.9 lb. Owing to the small number of records from herd 6 all the estimates from this herd are a little inconsistent. But there is a decrease of 60.1 lb. between the weighted mean of five to nine-year-old cows (13 records) and the mean of cows over nine years of age (13 records).

<u>Summer change in weight - Analysis 1</u>

The model for this analysis can be fitted to the summer weight change records in all the herds except herd 8. However, the number of records from herd 6 (33) and herd 9 (27) are considered to be insufficient to give reliable estimates. Therefore these herds are not included in the combined analysis. Amongst the remaining herds, herd 7 is the only herd in which male calves are raised as bulls. The use of records from this herd would necessitate the addition of a third 'sex' subclass in the analysis. Consequently, the inclusion of these records from cows with bull calves (38 in total) would considerably decrease the balance of the data, without greatly increasing the total number of records. Therefore, they are not included in the analysis. The remaining records from this herd (from thirty-two cows with heifer claves) are considered to be insufficient in number and are also excluded from the analysis.

The variances of the herds to be included in the combined analysis (herds 1 to 5) are not homogeneous. However, the magnitude of the differences between them is not excessive when considered in biological terms. They are, therefore, all included in the combined analysis.

In this analysis all the records from herds 3,4 and 5 are from 1974, those from herd 2 are from 1975 and only the records from herd 1 are from both years. Thus the estimates for the Herd and Year Effects are confounded and cannot be considered independently. However, the remaining estimates are unconfounded. The results from analysis 2 of summer change in weight provide an unconfounded estimate of this Herd Effect.

Since preliminary,individual herd analyses showed that the breedtype of a cow does not significantly affect her weight change through the summer, this effect is omitted from the model for the combined analysis.

The ANOVA of the summer change in weight records shown is in table 8 and the least squares estimates of means of the subclasses in table 9. The least squares constants from which the latter are calculated are in appendix 1.

The Age Effect is significant, and the means of the age subclasses are shown in fig 6. The rate of decline in summer weight gain decreases over age and there is thus a significant quadratic effect amongst these values, but no linear component. Nine- and ten-year-olds have a significantly smaller weight

TABLE 8

Analysis of Variance

Summer Change in Weight for Two Years

Source	d.f.	Mean Square	F-value	R-square
Herd	4	644	23.14*	0.031
Year	1	4724	153.51*	0.051
Age	8	195	7.02*	0.019
Sex of Calf	1	38	1.37	0.000
Herd x Sex	4	31	1.13	0.001
Herd x Age	29	31	1.10	0.011
Year x Age	8	48	1.72	0.005
Year x Sex	8	10	0.37	0.001
Prev Ch Wt	9	710	25.50*	0.076
Calf Age	1	23	0.84	0.000
Weaning Wt	1	34	1.25	0.000
Residual	465	27		0.154

(* = effect significant)

Total S.S. = 84324

Reduction S.S.= 71376 R-square = 0.846

% of Total S.S. assigned to parameters = 19.4

Mean value of covariables

Previous Change in Weight(%) for Age 2 = 0.34±11.73
3 = -1.61± 9.05
4 = -3.02±10.13
5 = -1.73±11.06
6 = -5.02±10.32
7 = -5.52±11.85
8 = -2.69±14.76
9 = -1.82±13.90
10+= -1.75±12.71

Calf Age = 213±33 days
Weaning Weight = 430.0±74.3 lbs

TABLE 9

Least Squares Estimates

for Summer Change in Weight for Two Years

subclass	L.S. estimate	subclass	L.S. estimate
Herd 1	7.08 (200)*	Age 2	13.50 (50)
2	14.99 (155)	3	12.38 (94)
3	10.26 (101)	4	9.07 (77)
4	1.79 (38)	5	6.96 (44)
5	2.20 (46)	6	6.56 (57)
		7	6.95 (49)
Year 1	12.94 (290)	8	4.90 (41)
2	1.59 (250)	9	2.01 (52)
		10+	3.05 (76)
(1) Steer calf	7.65 (278)		
(2) Heifer calf	6.87 (267)		

Herd x Age

Herd Age	1	2	3	4	5
2		17.98	12.17		8.10
3	10.97	20.80	15.21	5.47	9.45
4	10.19	15.69	9.84	5.09	4.55
5	2.79	10.37	13.89		6.28
6	10.54	14.09	6.48	0.18	1.49
7	6.07	12.51	10.69	2.48	2.98
8	4.56	12.30	7.22	1.90	-1.48
9	3.94	15.45	3.98	-9.04	-4.30
10+	2.44	12.45	7.10	5.38	-1.39

Age x Year

Year Age	1	2
2	17.10	9.90
3	17.30	7.45
4	13.48	4.66
5	11.07	2.86
6	14.49	-1.37
7	11.73	2.16
8	11.39	-1.59
9	10.04	-6.03
10+	9.85	-3.76

(* =number of observations shown in parentheses)

TABLE 9 cont

Herd x Sex

Sex / Herd	1	2
1	7.30	6.85
2	14.67	15.31
3	10.81	9.71
4	3.62	-0.04
5	1.86	2.54

Age x Sex

Sex / Age	1	2
2	14.11	12.89
3	13.05	11.71
4	9.27	8.87
5	7.42	6.50
6	7.47	5.64
7	6.68	7.21
8	5.75	4.06
9	1.50	2.52
10+	3.64	2.45

Regression coefficients for covariables

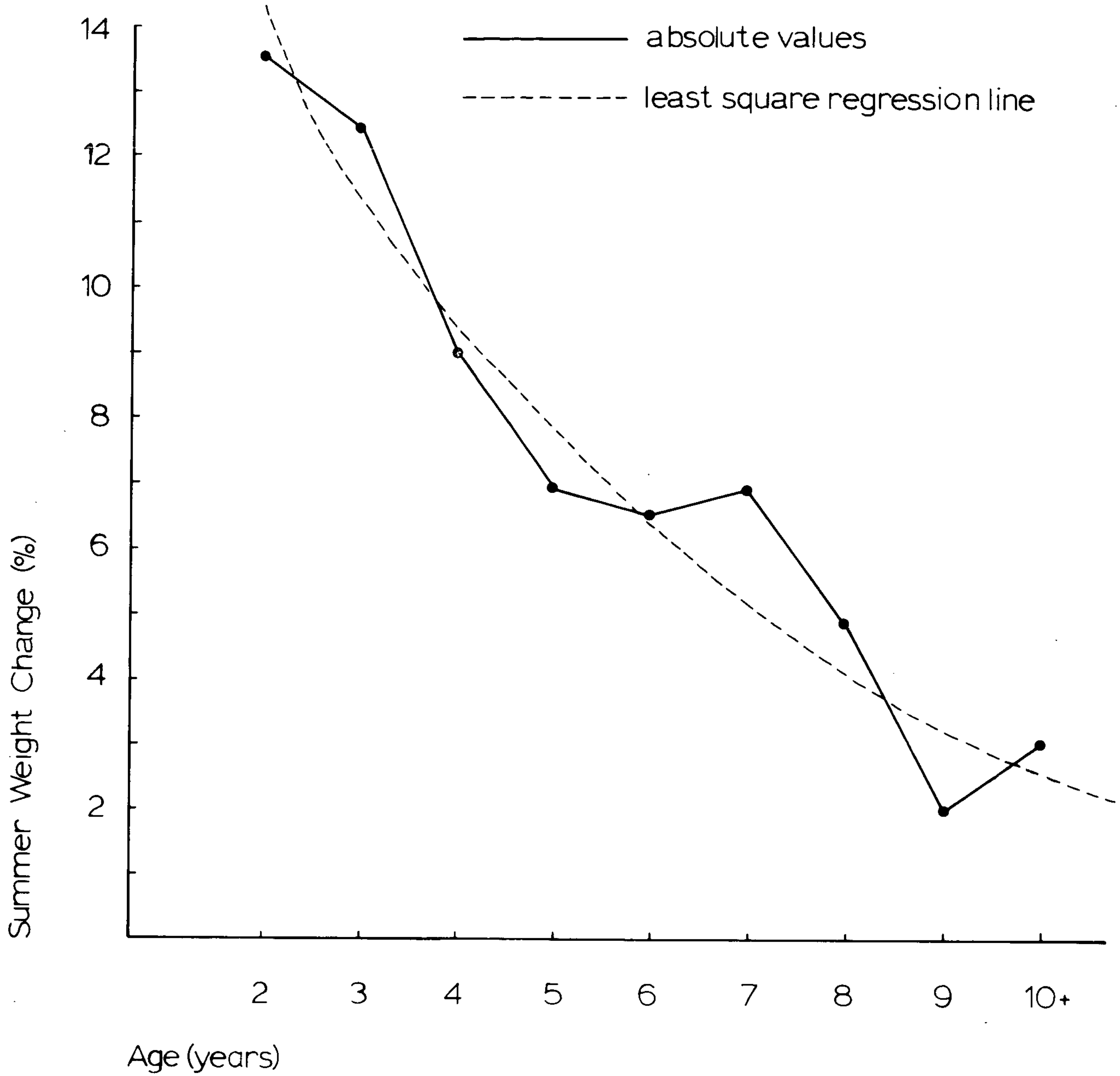
Previous Change in Weight for Age 2 = -0.7656 ± 0.0037
3 = -0.6498 ± 0.0135
4 = -0.9436 ± 0.0177
5 = -0.5133 ± 0.0046
6 = -0.6638 ± 0.0084
7 = -0.5638 ± 0.0065
8 = -0.7278 ± 0.0050
9 = -0.7732 ± 0.0104
10+= -0.5289 ± 0.0101

Weaning Weight = -0.0056 ± 0.0050

Calf Age = -0.0086 ± 0.0094

Figure 6

The summer weight change in each age subclass.



absolute values
least square regression line
Summer Weight Change (%)
14
12
10
8
6
4
2
2
3
4
5
6
7
8
9
10+
Age (years)

increase than cows aged four to eight. Two- and three-year-old cows have significantly larger increases in weight than these intermediate aged cows. There is no difference between the summer increase in weight of nine- and ten-year-old cows; nor between that of two- and three-year-old cows.

None of the interaction subclasses in this analysis are significant biologically or statistically.

The effect of a cow's previous change in weight (through the winter) has the highest R-square value of all the fitted effects in this analysis. The regression coefficient for each age subclass is significant and their values are shown in table 9. There is no trend across ages in the deviation of each coefficient from the overall mean of (-0.6811 ± 0.1380).

The effects associated with the calf a cow suckles through this period (calf sex, calf age, calf weaning weight) are far removed from statistical or biological significance.

Summer change in weight - Analysis 2

The model for this analysis does not include the previous change in weight covariable. The reason for its omission will be discussed in the following chapter. This analysis was carried out in order to obtain a non-confounded estimate of the Herd Effect. Thus only weight records from 1974 were included and this necessitated the exclusion of herds 2 and 9. Although this model could be fitted to weight records from the other seven herds, 6 and 7 are not included in the combined analysis. The rationale for this decision and the omission of the Breedtype Effect from the model is the same as for analysis 1.

The variances of the remaining five herds are homogeneous and their weight records are combined in the ANOVA shown in table 10. The least squares estimates of the means of the subclasses in this analysis are shown in table 11, and the least squares constants from which they are calculated are in appendix 1.

The Herd Effect in this analysis is a very large source of variance. The least squares estimates for each herd are shown in fig 7. Herd 1 has a significantly smaller weight gain than the other range herds (3,4 and 8) and the pasture herd (5) has a significantly smaller weight gain than the range herds, regardless of whether herd 1 is included or not.

The age effect is significant and has a significant linear pattern. The quadratic effect is not significant.

The age/herd interaction is significant, has a relatively large R-square value, but, due to the large number of degrees of freedom, has only an F-value of 1.7. The deviations for this interaction show no trend and they can only be attributed to the relatively small number of records in some of the subclasses (<10).

The other interactions and the effects associated with the calf a cow suckles through this period are far removed from statistical or biological significance.

Winter change in weight

The model for this analysis can be fitted only to the winter change in weight records from herds 1,2,6 and 7. Herd 6 is excluded from the combined analysis as the number of records

TABLE 10

Analysis of Variance

for Summer Change in Weight in 1974

Source	d.f.	Mean Square	F-value	R-square
Herd	4	4296	95.27*	0.321
Age	8	303	6.73*	0.045
Sex of Calf	1	2	0.05	0.000
Herd x Sex	4	36	0.79	0.002
Herd x Age	32	80	1.78*	0.047
Age x Sex	8	47	1.04	0.007
Calf Age	1	47	1.04	0.001
Weaning Wt	1	0	0.00	0.000
Residual	365	45		0.308

(* = effect significant)

Total S.S. =53522

Reduction S.S.=37061 R-square = 0.692

% Of Total S.S. assigned to parameters = 42.5

Mean value of covariables

Calf Age = 222±31 days

Weaning Weight = 479.2±84.5 lbs

TABLE 11

Least Squares Estimates for Summer Change in Weight in 1974

subclass	L.S. estimate	subclass	L.S. estimate
Herd 1	5.02 (104)*	Age 2	18.12 (78)
3	29.47 (102)	3	19.20 (53)
4	9.35 (93)	4	16.74 (41)
5	11.67 (50)	5	12.63 (59)
8	17.99 (75)	6	16.79 (40)
		7	14.14 (42)
		8	14.44 (36)
(1) Steer calf	14.79 (208)	9	10.01 (37)
(2) Heifer calf	14.61 (217)	10+	10.23 (39)

Herd x Age

Herd Age	1	3	4	5	8
2	8.62	31.21	10.09	15.29	25.39
3	12.15	35.3	14.23	13.66	20.66
4	4.94	36.60	11.86	15.35	14.96
5	0.97	26.66	6.92	13.49	15.12
6	15.06	27.64	9.78	15.69	15.79
7	3.93	24.55	7.14	10.97	24.11
8	0.11	29.47	13.61	10.63	18.61
9	0.46	29.39	1.25	4.38	15.49
10+	0.09	21.05	0.48	17.75	11.78

Herd x Sex

Herd Sex	1	3	4	5	8
1	6.10	29.82	9.73	11.14	17.16
2	3.94	29.12	8.97	12.21	18.82

Age x Sex

Sex Age	1	2
2	17.35	18.89
3	20.24	18.16
4	15.39	18.09
5	13.70	11.56
6	18.61	14.97
7	13.83	14.45
8	15.23	13.65
9	7.99	12.03
10+	10.74	9.73

(* =number of observations shown in parentheses)

TABLE 11 cont

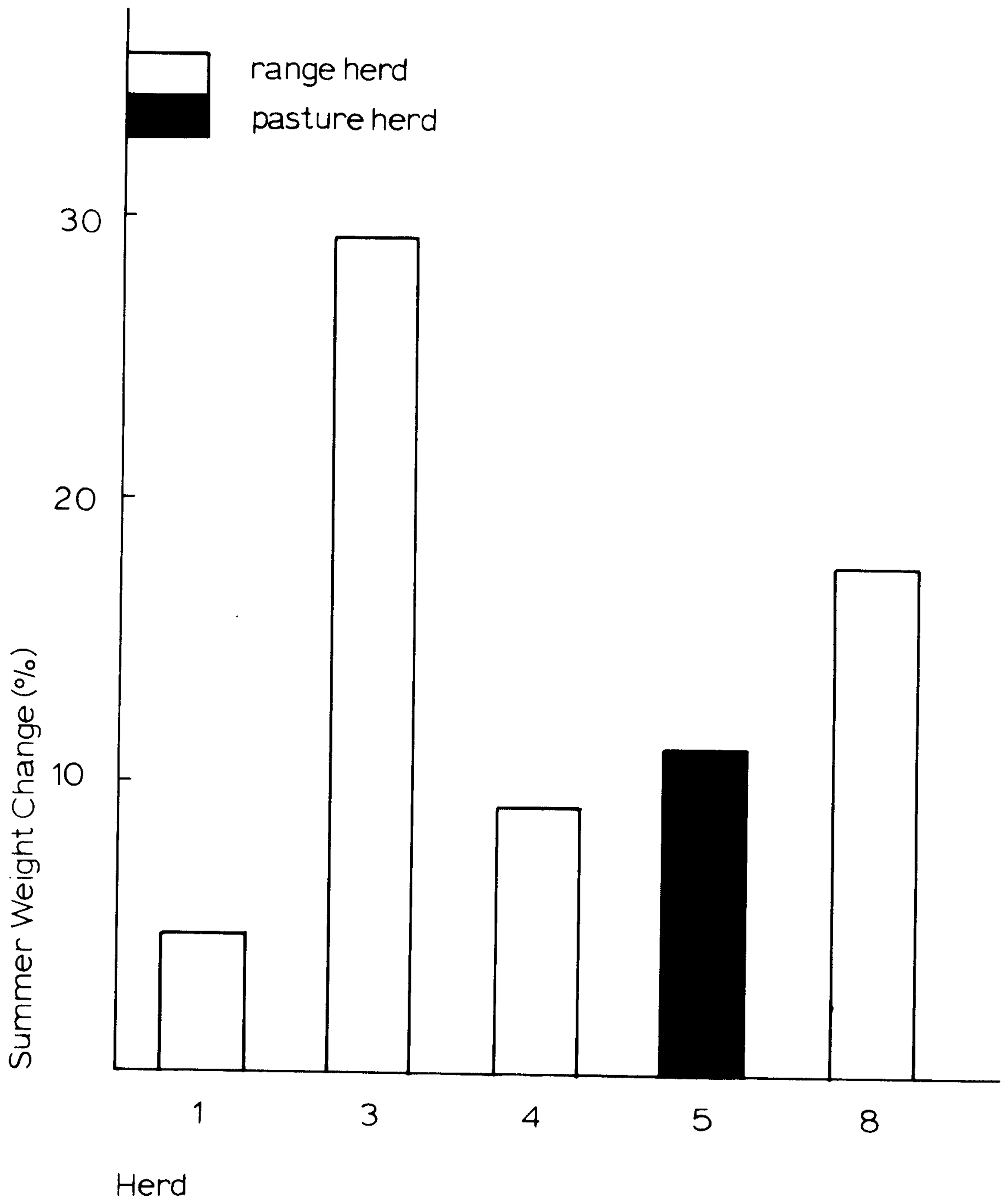
Regression coefficients for covariables

Weaning Weight = -0.0001±0.0074

Calf Age = -0.0210±0.0205

Figure 7

The summer weight change in each herd.


range herd
pasture herd
30
20
10
Summer Weight Change (%)
1
3
4
5
8
Herd

(21) is considered insufficient to give reliable estimates. Homogeneity of variance allows the records from the other three herds to be put together in a combined analysis. Herd 2 is predominately a Hereford herd; some of the cows are Hereford/Shorthorn crosses and a few are Hereford/Angus crosses, but the exact breedtype of each is not known. In herds 1 and 7 the cows are all 100% Hereford. Therefore, breedtype is not included in the model for the analysis.

The ANOVA of these records is shown in table 12. The least squares estimates of the means of the subclasses in the analysis are in table 13 and the least squares constants from which they are calculated are in appendix 1.

The Herd Effect is a significant source of variation, but the Year and Age Effects are not. The pattern of the winter weight change amongst the age subclasses is shown in fig. 8. The rate of decline of winter weight change decreases with age. After the age of eight the pattern is reversed and there is a less negative winter change in weight. There is thus a significant quadratic effect amongst these values. The winter weight change of two-year old cows is significantly greater than that of cows over four years old. However, the weight change of three-year-old cows is not significantly different from older or two-year-old cows. The estimates for cows over eight years old are not significantly different form that of four to eight-year-old cows.

The mean winter changes in weight in herds 2 and 7 are negative and are significantly different from the winter increase in weight in herd 1. They are not, however,

TABLE 12

Analysis of Variance

for Winter Change in Weight

Source	d.f.	Mean Square	F-value	R-square
Herd	2	263	11.57*	0.018
Year	1	18	0.80	0.000
Age	8	44	1.94	0.013
Herd x Year	2	789	34.74*	0.057
Herd x Age	16	75	3.28*	0.043
Age x Year	8	45	1.96*	0.013
Sp Interval	1	239	10.51*	0.009
Prev Ch Wt	9	596	26.25*	0.193
Residual	544	23		0.444

(* = effect significant)

Total S.S. = 27832

Reduction S.S.= 15483 R-square = 0.556

% of Total S.S. assigned to parameters = 34.6

Mean value of covariables

Spring Interval = 26±14 days
Previous Change in Weight(%) for Age 2 = 2.95±6.98
3 = 12.90±6.93
4 = 7.11±8.44
5 = 2.36±6.61
6 = 4.25±7.66
7 = 5.11±6.63
8 = -1.94±8.37
9 = 1.50±6.50
10+= 2.92±7.61

TABLE 13

Least Squares Estimates for Winter Change in Weight

subclass		L.S. estimate	subclass		L.S. estimate
Herd	1	1.55 (161)*	Age	2	2.63 (46)
	2	-0.49 (391)		3	0.73 (107)
	7	-3.02 (40)		4	-1.71 (92)
				5	-0.59 (60)
				6	-2.04 (60)
				7	-2.54 (46)
Year	1	-0.60 (180)		8	-3.12 (43)
	2	-1.35 (412)		9	-1.55 (48)
				10+	-0.58 (90)

Herd x Year

Herd / Year	1	2	7
1	5.04	-5.39	-3.01
2	-1.94	-0.65	-3.04

Herd x Age

Herd / Age	1	2	7
2	-2.06	3.38	7.51
3	3.47	2.50	-2.81
4	4.01	-0.19	-7.99
5	3.55	1.04	-5.39
6	-0.47	0.27	-4.95
7	0.57	-3.51	-3.72
8	0.78	-3.41	-5.76
9	1.67	-2.25	-3.11
10+	2.47	-2.27	-0.98

Age x Year

Year / Age	1	2
2	2.54	2.71
3	1.03	0.43
4	-0.20	-3.23
5	-1.86	0.68
6	-2.94	-1.14
7	-2.47	-2.60
8	-2.24	-3.99
9	-0.56	-2.54
10+	1.33	-2.49

(* =number of observations shown in parentheses)

TABLE 13 cont

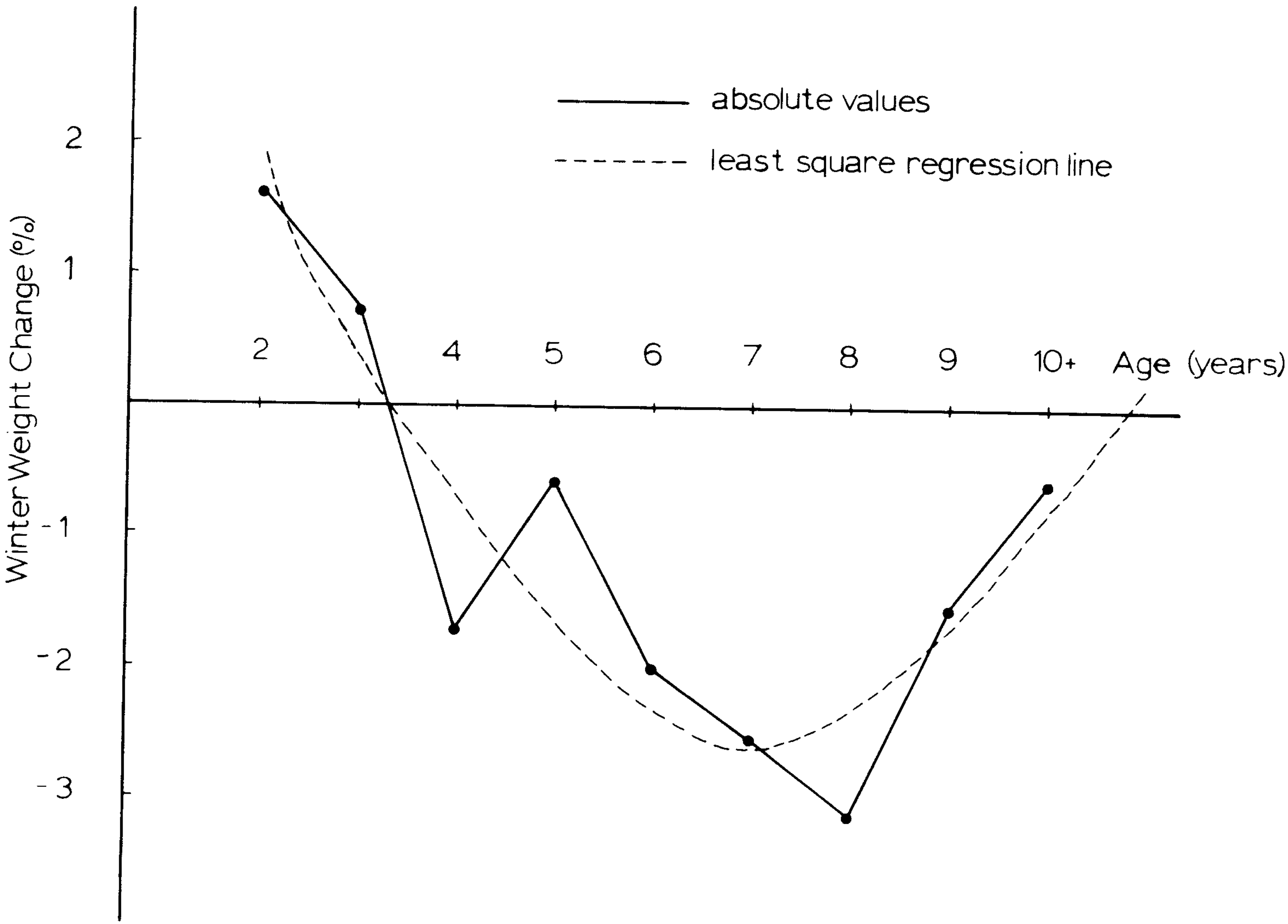
Regression coefficients for covariables

Previous Change in Weight for Age	2 =	-0.4020±0.1432
	3 =	-0.4367±0.0732
	4 =	-0.4756±0.0702
	5 =	-0.5257±0.1086
	6 =	-0.5314±0.0854
	7 =	-0.4956±0.1121
	8 =	-0.6495±0.0969
	9 =	-0.6360±0.1319
	10+=	-0.5216±0.0735

Spring interval = -0.0650±0.0200

Figure 8

The winter weight change in each age subclass.


absolute values
least square regression line
Winter Weight Change (%)
2
1
-1
-2
-3
2
4
5
6
7
8
9
10+
Age (years)

significantly different from each other.

The two interactions which include the Herd Effect are significant and have relatively high R^2-values. The least squares estimates for each interaction subclass are shown in figs. 9 and 10. From these it can be seen that these effects are biologically significant. They will be discussed in the following chapter. The Age x Year interaction is statistically significant, but its biological significance is relatively small. Only two of the interaction sublcass constants have values which are greater than 1.5% (approximately 15 lb.).

The Spring Interval Effect is significant, but its biological significance is also relatively small. The cows initially lose weight post-partum. The weight loss is 0.07% (0.7 lb.) per day.

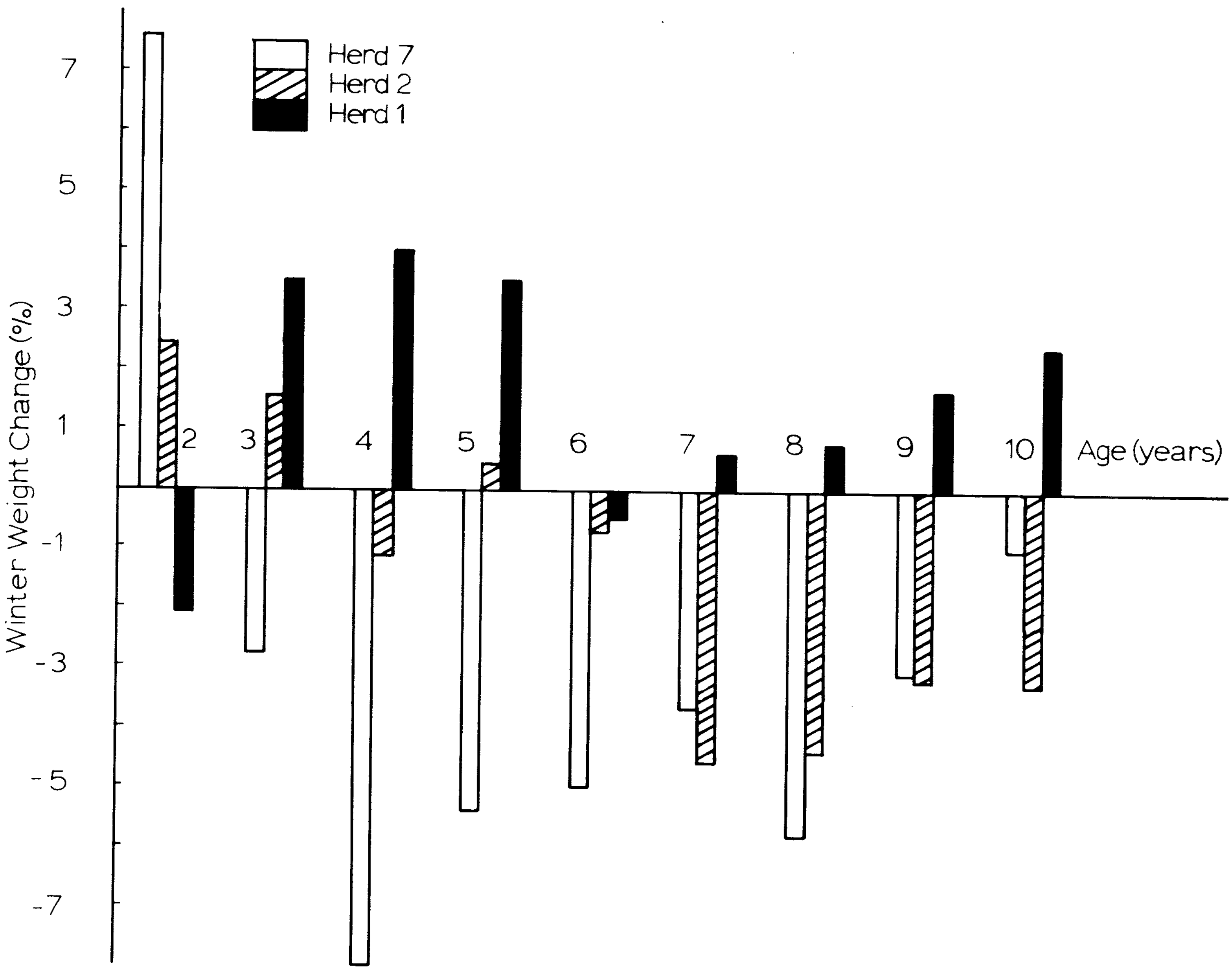
The overall Previous Change in Weight Effect is significant and has the highest R^2-value of all the fitted effects in this analysis. The values of the regression coefficients for the Previous Change in Weight Effect vary across ages, with a tendancy for those of older cows (ages 8-10, mean b = -0.6024) to be greater than those for younger cows (ages 2-4, mean b = -0.4381). The effect of this covariable is significant in all the age subclasses except age two. Table 10 shows the considerable differences which exist between the mean value of the previous change in weight in each age subclass.

<u>Winter analysis in Herd 2.</u>

The ANOVA of the fall, January and February weight records from herd 2 is shown in table 14. The least squares estimates of

Figure 9

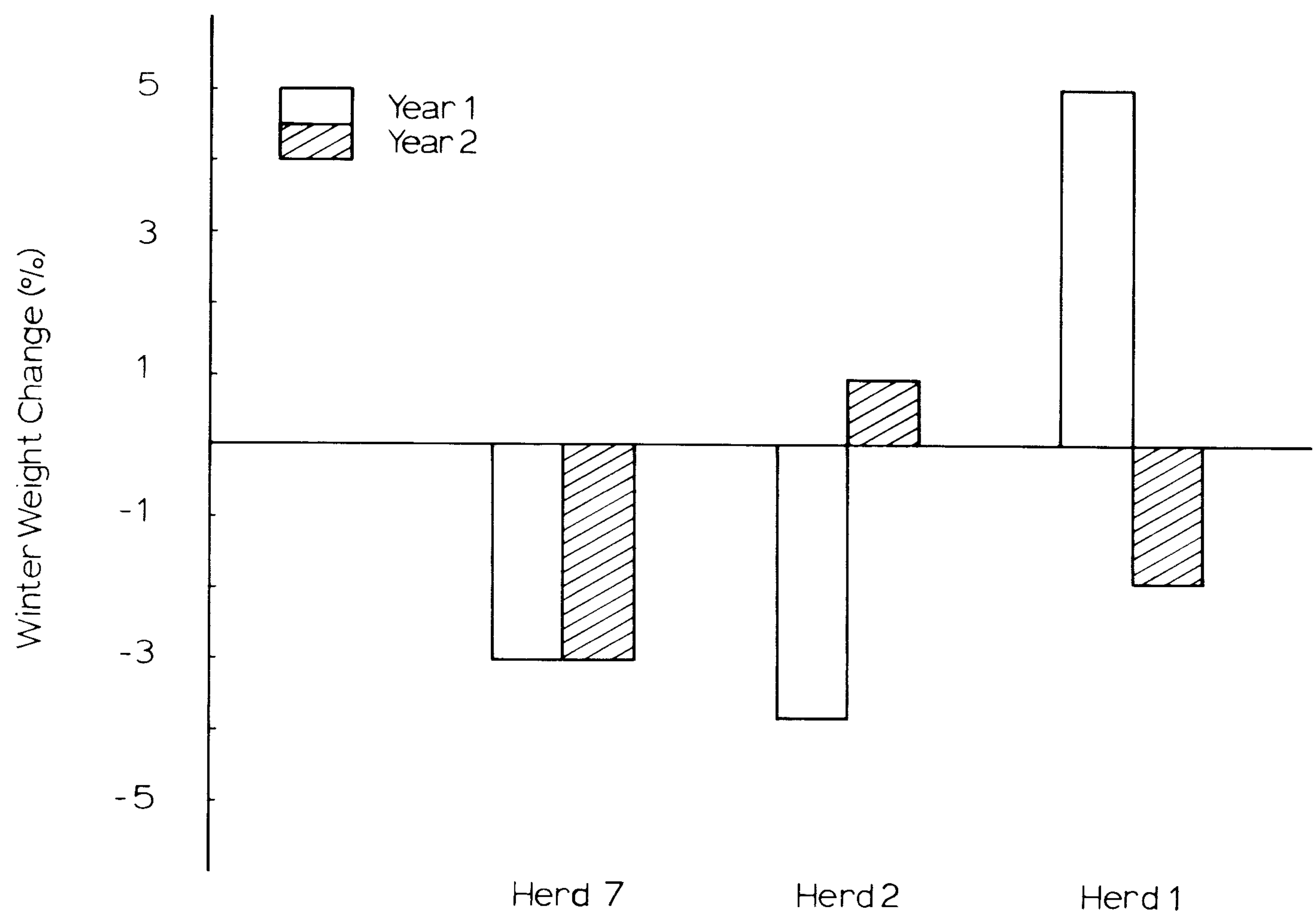
The winter weight change in each herd/age subclass.



Herd 7
Herd 2
Herd 1
Winter Weight Change (%)
7
5
3
1
-1
-3
-5
-7
2
3
4
5
6
7
8
9
10
Age (years)

Figure 10

The winter weight change in each herd/year subclass.


Winter Weight Change (%)
5
3
1
-1
-3
-5
Year 1
Year 2
Herd 7
Herd 2
Herd 1

the means of the subclasses in the analysis are in table 15 and the least squares constants from which they were calculated are in appendix 1.

A major source of variance in the data is the Age Effect. The Year Effect is also significant statistically, but the R^2-value associated with it is relatively small. The interaction between these effects is statistically significant but its biological significance, is negligable - only three age/year subclasses have an interaction deviation of more than 10 lb.

The regression coefficients for days pregnant (DP), DP^2, DP^3 are also shown in table 15. The analysis which included all three covariables together had a significantly larger reduction S.S. than those with DP + DP^2 or DP alone. The combined effect of the covariables was significant statistically and biologically (R^2=0.076). Each covariable was also independently significant. The reduction S.S. was not increased significantly by fitting these three covariables independently within each age subclass, their effect did not, therefore, vary between ages.

The effect of these covariables on cow weight in the range of DP included in the data (90 to 285 days) is shown in fig 11. From a mean weight of 1004.2 lb. at 90 days pregnant, the weight of a cow initially increases rapidly. The rate of increase then peaks at a mean of 1105.6 lb. at 260 days pregnant. There is then a slight decrease in weight, so at 285 days pregnant, the day on which parturition is assumed to occur, the mean weight is 1098.8 lb. This is an increase of 94.6 lb. during the last two-thirds of pregnancy. This weight change and that occurring immediately post-partum are discussed in the

TABLE 14

Analysis of Variance for Winter Weights from Herd 2

Source	d.f.	Mean Square	F-value	R-square
Year	1	720390	102.71*	0.022
Age	10	1182420	168.59*	0.355
Year x Age	9	17381	2.48*	0.005
Days Preg	3	839228	119.66*	0.076
Residual	1946	7014		0.410

(* = effect significant)

Total S.S. = 0.333245E+8

Reduction S.S.= 0.196762E+8 R-square = 0.590

% of Total S.S. assigned to parameters = 45.7

Mean value of covariables		R-square
Days pregnant =	194	0.001
(Days pregnant)^2 =	40298	0.002
(Days pregnant)^3 =	8812268	0.003

TABLE 15

Least Squares Estimates for Winter Anlysis For Herd 2

subclass	L.S. estimate	subclass	L.S. estimate
Age 2	841.3 (160)*	Age 3 x Year 1	944.7
3	967.5 (444)	3 2	990.3
4	1032.0 (240)	4 1	1002.9
5	1060.0 (165)	4 2	1061.2
6	1064.9 (220)	5 1	1051.3
7	1087.9 (130)	5 2	1070.2
8	1150.6 (124)	6 1	1033.1
9	1117.4 (126)	6 2	1096.8
10	1123.8 (118)	7 1	1060.5
11	1137.8 (89)	7 2	1115.3
12+	1134.5 (154)	8 1	1123.6
		8 2	1177.7
		9 1	1061.7
		9 2	1173.0
		10 1	1108.8
Year 1	1039.4 (1055)	10 2	1138.8
2	1091.3 (915)	11 1	1106.6
		11 2	1141.0
		12+ 1	1110.5
		12+ 2	1158.5

Regression coefficients for covariables

Days pregnant = -3.127 ± 1.210

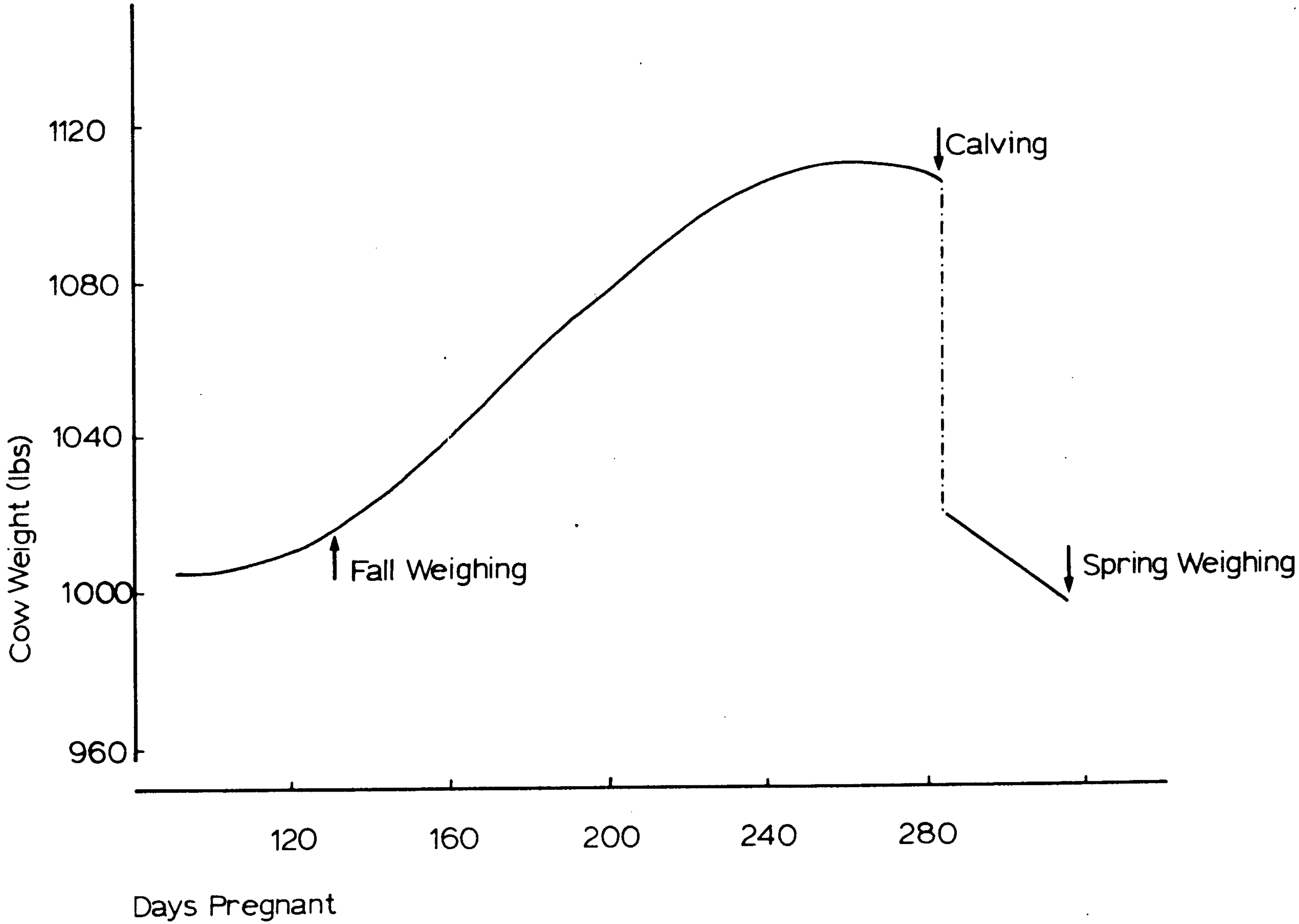
$(\text{Days pregnant})^2 = 0.02267 \pm 0.00678$

$(\text{Days pregnant})^3 = -0.424\text{E-}4 \pm 0.122\text{E-}4$

(* =number of observations shown in parentheses)

Figure 11

The changes in weight through pregnancy and parturition in herd 2.


1120
1080
1040
1000
960
Cow Weight (lbs)
Calving
Fall Weighing
Spring Weighing
120
160
200
240
280
Days Pregnant

following chapter in relation to the results of the cther analyses.

Chapter 6

Discussion

This discussion is divided into three sections. Initially the results are discussed in relation to i) the analytical procedures used, ii) the inter-relationship between the analyses, iii) the variance which can be explained by the management practices of the operations. This is then followed by a discussion of the influence of the parameters *per se* on cow weight and weight change. The chapter is terminated by a discussion of the salient points from this research.

Section 1 - Discussion of the Analyses

Weight analysis

The model for this analysis accounts for 61.8% of the total variance in the weight records. The following factors will be included in the remaining error variance:

1) The varying interval from calving to weighing. As mentioned in chapter 5, the effect of this was minimized by excluding records with an excessively long interval.

2) The slightly different set of cows which were weighed on consecutive occasions.

3) The inclusion of some non-pregnant cows from herd 2.

4) Any variation between animals in their ability to obtain feed. This is likely to be of greatest significance in the winter and is discussed in relation to the weight change in this period.

5) The other parameters mentioned in Chapter 5 which were not included in the model, e.g. genotype.

6) Any variation in the weight of stomach contents at weighing.

7) Any errors in weighing.

However, only 34.4% of the total S.S. was assigned to specific effects. This limitation in partitioning the reduction S.S. is due to the imbalance of the data and the lack of orthogonality amongst the fitted effects. Nevertheless, certain parameters are significant.

Herd

The mean weight of a herd will be dependent on the following two factors and their interaction:

1) The genotype(s) of the cows in the herd - a result of the breeding management, conscious or otherwise, of the herd operators.

2) The environmental parameters influencing the herd, e.g. availability of nutrients, climate.

Thus, the winter feed management in herd 1 is known to be liberal (see later); the cows in this herd were the only ones in this study to gain weight overwinter. This above average level of winter feeding is at least part of the reason why the mean weight of this herd is significantly heavier than that of the crossbred range herds.

In contrast, the sub-optimal winter feeding in herd 3 (see later) causes the cows in this herd to be relatively light and have very large seasonal changes in weight. Joandet and Cartwright (1969) and Fitzhugh et al. (1967) assumed that the similar, but smaller, seasonal variation which they observed, was occurring around the expected or 'true mean weight' of each cow. However, in the present research this assumption does not hold for herd 3. The extremely poor winter feeding in this herd results in an excessive winter weight loss (252.1 lb.) and the occasional death of cows. Each summer a cow has to regain this large winter weight loss, as well as nursing a calf. Consequently, she only reaches a weight close to her 'true mean weight' before she is exposed to another winter of extremely poor nutrition. Her mean weight is, therefore, less than that which would be expected with an average winter nutrient supply. If the 'true mean weight' of the cows in this herd were assumed to be closer to the upper limit of their seasonal variation (around 991 lb.), their mean weight would be similar to the weighted mean of the cows in the other range herds in this study (971.5 lb.).

The information available about the management practices and summer grazing quality suggests that the mean weights of the cows in the other seven herds are close to their 'true mean weights'. This subjective assessment is considered to be true even for herd 8. The large seasonal change in weight in this herd (210.9 lb.) is more likely to be a product of the cows getting fat during the summer on good quality range than a product of poor winter nutrition.

The other herd comparisions, from which herd 3 was omitted, are discussed in section 2.

<u>Herd x Age</u>

Although the cows in herds 1, 3, 5 and 6 reach their maximum weight at six years of age, those in herds 2, 7 and 8 continue to increase in weight after this age, while the cows in herd 5 do not increase in weight after the age of five. There are also other between herd differences in the pattern of growth in early life.

This variation could be due to genetic and/or environmental factors. For example, genetic differences in the rate of maturing are known to cause variations in the pattern of growth (Fitzhugh and Taylor, 1971; Brown et al., 1972). Alternatively, the classical experiments of McMeekan (1940) show that the growth pattern of pigs can be influenced environmentally through the availability of feed. In the present research it is impossible to separate objectively such genetic and environmental influences. However, the feeding management in each herd is known to differ considerably and it can be speculated that this is a major reason for the between herd difference in growth patterns.

A similar conclusion can be made about the weight loss which occurs in the older cows in four of the herds. Although three of these herds (4, 5 and 8) are crossbred herds, there appears to be no reason why this genetic factor per se should account for the weight loss.

Herd x Season

The proportion of the variance accounted for by this interaction effect is considerably greater than that accounted for by any of the other interactions in the ANOVA. The reason why the mean summer weight changes in a herd cannot be calculated from the season subclass means for that herd was mentioned in the previous chapter.

The estimates of winter weight change, however, suffer from the limitation that the weight records included for a herd each fall and spring do not come from exactly the same set of cows. However, the estimates from the individual herd analyses for winter change in weight are calculated from the weight changes of individual animals, i.e. the same set of cows each fall and spring. On comparing these two sets of estimates of winter weight change, it is apparent that the limitation of the present analysis affects only the estimate from herd 5. Only one set of spring weight records was obtained from this herd and considerable culling was carried out during the course of this study. Consequently the winter weight loss (-174.1 lb.) estimate from the analysis is double the estimate of the weight loss of individual cows (approximately -85 lb.). This spurious result will not, therefore, be included in the discussion which follows.

The winter weight change estimates from the other herds reflect the weight changes of individual cows. These weight changes are the result of a number of inter-related factors. These will be discussed fully in relation to the analysis of winter change in weight later in the discussion. However, the main determinant of a cow's winter weight change is the winter feed management in the herd.

The information which the author has been able to collect about winter feed management is known to suffer from the following limitations:

1) Any estimate of the amount fed is relatively subjective.

2) It lacks an assessment of feed quality.

It is, however, considered to be useful and sufficient to aid the discussion of the winter weight changes recorded in this study.

Winter feeding in all the herds is based on conserved forage, and the amount available to the cows during the winter is controlled entirely by each operator. It is, therefore, not surprising that there is a correlation between the winter weight changes of the cows and the different management policies of these individuals.

The only cows which gain weight over the winter are those in herd 1. After returning from summer range, around the beginning of November, these animals are allowed to graze on some rough ground and adjacent hay meadows. 20-25 lb. of grass hay is normally fed per cow per day from mid- or late December until the first or second week in February. It is then replaced by 20 lb. alfalfa hay and 8-10 lb. corn silage and feeding is continued until the cows are turned out on summer range, normally in mid-April. This herd is owned by the provincial government and it is possible that factors other than commercial profit are included in the management objectives. Consequently, the winter feeding is relatively liberal and the cows gain weight (+42.0 lb.). The winter feed management in this herd is described in some detail because the rather atypical weight changes of the cows in this herd will be considered on several subsequent occasions in this discussion.

The smallest winter weight loss (-35.3 lb.) occurs in herd 2. The winter feeding in this herd is again relatively liberal, approximately 10 lb. of hay and 35-45 lb. of silage are fed per cow per day. A similar weight loss (-52.8 lb.) occurs in herd 6, a small herd of purebred Aberdeen Angus cows. Again winter feed management is relatively liberal, 20-25 lb. of grass hay is fed per cow per day and this is supplemented with an *ad-libitum* supply of corn silage from mid-February onwards.

The other herd which has a weight loss that is less than the mean is herd 7. This is a relatively small herd of registered Hereford cows in which the winter feeding policy is to provide as much grass hay as the cows will clean up. The result of this management, combined with a winter climate which is more severe than that for the three previously mentioned herds, is a 96.1 lb. loss in weight over winter.

The winter weight change estimate of the remaining pasture herd, herd 5, has been previously discussed and is considered to be spurious. There is some indication that the winter weight loss is similar to that of herd 7. This relatively small winter weight loss in herd 5 is the product of winter feeding based on equal quantities of corn silage and grass hay.

The winter feed management in herd 8 is to feed 20-25 lb. of alfalfa hay per cow per day. This is supplemented with a limited amount of proprietary concentrate feed or alfalfa cubes post-partum. In the summer the cows are on good quality summer range and return in the fall in excellent condition - as reflected in their heavy fall weights. Their large winter weight loss (-210.9 lb.) is thus a product of 1) winter feeding 2) an atypically large negative compensatory weight gain - a consequence of the cows being 'fat' in the fall. This latter point will be discussed in more detail in relation to the change in weight analyses.

In herd 4 winter feeding is similar to that in herd 8, without the supplementation post-partum. However, the weight loss in this herd (-130.8 lb.) is considerably less that that in herd 8. It appears that this difference is due to a smaller negative compensatory gain component in the winter weight loss in herd 4.

The excessive winter weight loss in herd 3 (-252.1 lb.) has already been mentioned. The winter feed management in this herd is based entirely on grass and alfalfa hay. The quality of the hay is known to be variable and quantity fed meagre, hence the large loss in weight and occasional death of cows previously mentioned.

Summer change in weight - Analysis 1

The reduction S.S. in this analysis accounts for 84.7% of the total variance in the summer change in weight records. With the exception that weight records from an identical set of cows are included in a spring and in the subsequent fall, all the other factors mentioned as being sources of error in the absolute weight analysis are included in the present error variance. In addition, the cows in three of the herds were not all weighed on the same occasion in a fall or spring. Although this reduces the length of the Spring Interval, it results in a variation in the length of the summer periods within these herds. This will, therefore, be an additional component of the error variance.

The imbalance of the data and the lack of orthogonality amongst the fitted effects allows only 19.4% of the total S.S. to be specifically assigned in the ANOVA despite this limitation, certain of the parameters in the model are significant.

Previous change in weight

The largest source of variation in the summer gain in weight is the effect of the change in weight of the cows in the previous winter. The regression coefficient for each of these covariables is negative and significant.

The effect of their inclusion in the analysis is to remove the variation in summer weight gain that is caused by the deviation of a cow's winter weight change from the mean of its age subclass. This allows the fixed effects which are included in the model to be estimated with greater precision. The biological interpretation of this 'covariable correction' is as follows.

A cow whose winter weight loss is greater than the mean for her age subclass will enter the summer period in relatively poor condition. Consequently, her summer weight gain will contain a positive compensatory gain component which is greater than that of a cow of the same age which has a mean winter weight loss. The inclusion of the covariable corrects for, i.e. removes, this extra weight gain. Conversely, a cow which loses less weight than the mean will be relatively fat and will have a smaller positive compensatory gain. If she gains weight through the winter her compensatory growth in the summer will be negative. The covariable in these cases adds a compensatory growth component to a summer weight change record to make this component of the weight change equal in all the records in the analysis.

The value of the regression coefficients for previous change in weight varies between -0.5133 (five-year-old subclass) and -0.9435 (four-year-old subclass), but there is no trend around the mean value of -0.6811. The variation which is present is due to non-random sampling variation and/or the limitation of the statistical analysis in calculating an estimate of the effect from amongst all the variance present in the data.

This latter limitation could be reflected in each subclass estimate for summer weight change. If it is present, it would be most significant in the herd subclass means, which have the largest previous change in weight deviations. In the other subclasses the sum of the deviations is either zero (age), or the effects are far removed from significance. The importance of this limitation is thus minimal in these subclasses.

This possible spurious influence on the herd estimates was the reason for omitting the Previous Change in Weight Effect from the model for analysis 2 of the summer weight change records. In the present analysis the confounding of the Herd and Year Effects also precludes any meaningful comparisons amongst the herd and year estimates. Therefore, the Year Effect was also removed from the model for analysis 2.

<u>Age</u>

The estimates for this analysis are similar to the summer change in weight estimates from the absolute weight analysis, i.e. younger cows have significantly greater weight gains than older cows. The present estimates, however, have a significant quadratic trend over age, while those from the absolute weight analysis appear to have a more linear pattern. This difference is a product of the smaller sample of records included in this analysis.

<u>Summer change in weight - Analysis 2</u>

The R-square value for the reduction S.S. in this analysis (0.692) is 15.0% less than that in anlaysis 1. This difference is jointly due to the lack of the previous change in weight parameter and the different records included in each analysis. The variation due to the previous change in weight of the cow is now present in the error variance, together with all the other factors mentioned previously. The records in this analysis are considerably more balanced than those in analysis 1 of summer weight change and consequently the proportion of the total S.S. specifically assigned to effects in the ANOVA has increased to 42.52%.

<u>Herd</u>

The mean summer change in weight estimates for each herd in this analysis are not confounded and are not influenced by the previous change in weight covariable. Even though the estimates are from only one summer (1974), they are similar in magnitude, but opposite in sign, to the winter weight loss estimates for these herds from the absolute weight analysis. The exceptions to this are herds 1 and 5. The magnitude of the estimate for herd 5 is further evidence to indicate the previously mentioned winter weight loss anomaly for this herd. The estimate for herd 1 will be discussed later in this section of the discussion.

Each herd mean contains both a compensatory gain and a 'new weight gain' component. It is, however, impossible to separate them quantitatively. It would appear, however, that although the summer weight gain must reflect the productivity of the summer grazing for each herd, the influence of the human controlled winter weight loss is a major factor determining its magnitude. Hence, as a consequence of liberal winter feeding, herd 1 has a small summer weight gain, while poor winter feeding in herd 3 results in a very large summer weight gain. Consequently the large amount of variation accounted for by this herd effect (R-square = 0.321) is very much a product of the differing winter management policies of the herd operators.

In the absolute weight analysis the pasture herds were found to be heavier than the range herds. It is apparent from this analysis that the heavy cows in herd 5 (which was the heaviest of the pasture herds) do not put on more weight in the summer than the cows in the range herds. The reason for the heavier cows in this herd, and probably in the other pasture herds as well, is therefore to do with the availability of nutrients in both summer and winter. The cows are fed at an above average level in the winter, thus a greater proportion of the summer weight increase is 'new weight gain' and the cows are relatively heavy.

<u>Age</u>

The large summer weight gain of three-year-old cows and the linear decline in weight gain over age which were apparent in the absolute weight analysis are also present in this analysis. The difference between these estimates and those of analysis 1 is a product of the different records included in each analysis.

Winter change in weight analysis

The reduction S.S. in this analysis accounts for 55.6% of the total variation in the winter change in weight records. Of the factors mentioned in relation to the error variance of the summer change in weight analysis 1, the varying interval from calving to weighing is the only one not included in the present error variance. This Spring Interval Effect is included as an independent variable in the analysis.

It can be speculated that the relatively large error variance in this analysis is associated with the varying ability of cows to compete for the limited amount of winter feed. The more aggressive cows obtain a better quality and quantity of winter feed and consequently have smaller weight losses (or greater weight gains).

Owing to the relatively balanced data for winter weight change, a large proportion (62.2%) of the reduction S.S. is specifically assigned to parameters in the ANOVA, i.e. 34.6% of the total S.S.

The possible inadequacies of a covariable correction were discussed in relation to the summer change in weight analysis 1. The winter weight change estimates might also be affected by this limitation. However, owing to the very much smaller magnitude of the deviations of the previous weight change in each herd (maximum deviation from the mean = 2.9%) and the small influence of the spring interval deviations (b=-0.0650) any such limitation in this analysis is likely to be small. Consequently, a discussion of all the effects can be based on the estimates which were reported in chapter 6.

Previous change in weight

The change in weight of the cow in the previous summer has a major influence on her winter weight change. The effect of the inclusion of this covariable is exactly the same as in the summer change in weight analysis 1. It removes the variation in winter weight change which is due to the deviation of a cow's previous summer gain in weight from the mean value for her age subclass. It thus allows the fixed effects to be estimated with greater precision.

The rationale for fitting this covariable independently in each age subclass is substantiated by the lack of significance of this covariable in two-year-old cows and by the large variation in the mean value for each covariable. The reason for this non-significance of the covariable in two-year-old cows and the trend in the magnitude of the coefficients over age will be discussed in the following section.

Herd

The herd estimates are expressed as a percentage of a cow's mean body weight and are corrected for the previous change in weight. Nevertheless, they are ranked in the same order as in the absolute weight analysis. The difference (when expressed in absolute terms) between these two sets of estimates is a product of the covariable corrections and the different records included in each analysis.

Age

The relatively liberal winter feeding in the herds included in this analysis is especially apparent in the age subclass estimates. Whereas all the age groups in the absolute weight analysis have equivalent winter weight losses (mean=-88 lb.), the younger cows in this analysis tend to gain weight and the older cows have only small weight losses. However, the difference between the age subclasses is not significant overall, which confirms the conclusions made about the equivalent absolute weight estimates.

Age x Herd

The quadratic pattern of weight change over age is not the same in each herd. In herd 1 liberal feeding during rearing and extra feeding in the winter period prior to first calving results in relatively heavy two-year-old cows (see absolute weight analysis). Consequently, although most of the age subclasses in this herd gain weight, two-year-old cows lose weight over winter. The other large deviation in this herd (+3.19% for four-year-old cows) is not associated with an unusual absolute weight and lacks an apparent biological explanation.

The relatively small two-year-old cows in herd 7 have an atypically large winter weight gain (interaction deviation = +6.93%). However, there are only two observations in this subclass and the estimate is totally unreliable. The other large interaction deviations, in four (-4.23%) and five-year-old cows (2.75%), are not related to unusual absolute weights and they again lack any apparent biological explanation.

Herd x Year

Although the overall Year Effect in this analysis is not significant, the winter weight changes in herds 1 and 2 do vary significantly between years. In herd 2 the 2.92% (approximately 29 lb.) difference between years appears to be associated with a milder winter in year 2, rather than any difference in winter feeding. The difference between years is most pronounced in herd 1. In year 1 the cows gain weight (5.04%), while in year 2 they lose weight (-1.94%) - a between year difference of approximately 71 lb. The anomalous weight changes in this herd have already been mentioned several times. They will now be integrated and discussed.

The weight changes in herd 1

The weight changes in this herd are best discussed as absolute, uncorrected weight changes. The most comprehensive estimates of these changes are obtained from the preliminary, individual herd analysis of the weight records: they are as follows.

Year	Season	Weight (lb.)	Weight Change
1	fall	943.5	
			+58.1
1	spring	1001.6	
			+44.8
2	fall	1046.4	
			+43.7
2	spring	1090.1	
			-42.7
3	fall	1047.4	
			+16.2
3	spring	1063.6	

The cows in this herd have a steady increase in weight between the fall of year 1 (1973) and the spring of year 2 (1975). The 44.8 lb. summer weight gain is smaller, but in the same direction as the weight changes in the other herds in this study. The winter weight gains, however, are distinctly different from the winter losses in all these other herds.

It has already been mentioned that the winter weight change in a herd must inevitably reflect the winter feeding policy of each operator. Therefore, in order to aid this discussion, the winter feeding policy of herd 1 has previously been described in some detail. However, although such a subjective assessment can be made, a quantitative assessment of nutrient intake would be necessary to definitely resolve the present anomaly. But, from the information available, it appears that the winter feeding in this herd is liberal and could result in a weight gain over this period.

It might be speculated from the consistent eighteen month weight increase that the cows were in relatively poor condition at the outset of the study. Enquiries by the author, however, have not produced any information to substantiate this. Nevetheless, the cows must have been in good condition in the spring of year 2 and it would have been biologically possible for the cows to lose 42.7 lb. during the following summer. The author has been unable, however, to find any management or other environmental factor which might have brought this about.

The small increase in weight (+16.2 lb.) in the winter following this summer weight loss indicates the following:

1) As a different scale was used for the fall and spring weighings, the weights recorded on the former occasion are not

light merely because of an inaccuracy of the scale used.

2) Even though winter feeding was liberal there was no large positive compensatory gain. The cows were thus still in reasonable condition in the fall after their summer weight loss; consequently they must have been fat the previous spring.

It can be concluded from these results that human influences are a major factor controlling the weight changes in a cow, i.e. winter feed management. However, the extent to which cow weight can be manipulated by man has biological limitations. Hence the anomalous summer weight loss.

Winter analysis in herd 2

The reduction S.S. in this analysis accounts for 59.0% of the total variance present in the weight records. The factors included in the error variance are inevitably the same as those listed in the absolute weight analysis. However, the effect of social interaction during feeding, which was discussed in relation to the winter change in weight analysis, will be more important as a component of error in this analysis.

The proportion of the total S.S. assigned in this analysis (45.7%) is greater than that assigned in any of the other analyses. This is the result of the more balanced data from this single herd.

The significant Year Effect is due to the following factors:

1) The cows were brought in off range a month earlier in year 2, and thus they entered the winter in better condition.

2) The winter in year 2 was considerably milder than that in

year 1.

The subclass estimates for age have the same pattern as those in the absolute weight analysis, i.e. an increase in weight up to eight years of age, and a relatively stable weight after this point.

In fig 11 the weight estimates from this analysis are integrated with those from other analyses carried out on the records from this herd. The rationale for this integration is as follows.

1) The mean spring weight from the individual herd analysis is 996.6 lb. The mean spring interval between parturition and this occasion of weighing is 31 days and the mean weight loss is -0.07% of a cow's mean weight per day. The mean weight loss is thus 22.2 lb. and mean cow weight immediately post-partum is 1018.8 lb.

2) The fall weight estimate from the individual herd analysis is 1040.0 lb. Thus there is a mean loss of 21.2 lb. Between the fall weight and that immediately post-parturition

3) The mean weight immediately pre-partum is 1098.0 lb. the mean weight loss due to parturition is 80.0 lb. or 7.3% of the pre-partum weight.

Although the mean birth weight of calves in this herd is unknown, it would appear that this estimate of parturition weight loss is rather small. This is partly a product of a few unidentifiable non-pregnant cows which were weighed through this winter period. As they do not have an increase in weight similar to that of pregnant cows, their inclusion inevitably lowers the overall estimate of the weight gain due to pregnancy.

Section 2 - The Influence of the Parameters

The parameters influencing the weight of beef cows are numerous and varied. Those which were investigated in this research are now discussed. The Seasonal Effect was found to have a major influence on cow weight and separate analyses were carried out to determine the parameters influencing the seasonal weight change *per se*. The results from these analyses are included in the discussion of this effect.

Breedtype

The confounding of the genetic and environmental parameters influencing cow weight in this research limits independent consideration of the genetic components.

However, the lack of significance of the Breedtype Effect when it is included in the individual analyses for herds 4, 5 and 8 indicates that, within these herds, cows of genetically different breeds and crosses have a similar mean weight. As the breedtypes in herd 8 are British breeds, or crosses of British breeds, and the cows are managed as one unit, the result in this herd is reasonable. In herds 4 and 5 approximately thirty percent of the cows are crossbreds of exotic breeds, but most of these breedtypes are at least fifty percent composed of British breeds. The genetic influence of the larger exotic breeds (Mason, 1971; Adams *et al.*, 1973) in these cows is not, however, sufficient to cause them to be significantly heavier than their straightbred, British-breedtype contemporaries.

In herd 9, however, exotic crossbred cows are significantly heavier than their British breedtype contemporaries. This difference could be due to more generous feed management in this small herd. In these circumstances the exotic crossbred cows exhibit a greater growth potential.

Herd 2 is composed of Hereford, Hereford x Shorthorn and a few Hereford x Angus cows. The lack of significance of the Breedtype Effect indicates that the inclusion of this herd without specifying the breedtype of each individual is not adding significantly to the error term in the analyses. The net result of their use is thus advantageous, and the decision to include them without specifying the breedtype is thus vindicated.

Fitzhugh et al. (1967) and Fitzhugh (1965) report weight differences between breedtypes within ten state and federal experimental station herds in the southern United States. The cows in their study were of Hereford, Angus, Brahman and Santa Gertrudis breeding, but the authors do not mention the breedtype composition of the crossbred cows or the level of significance of the differences.

Herd

It is apparent from the outline description of the herds that a heterogeneous sample of herds is included in this research. It is not, therefore, suprising that the Herd Effect accounts for a large proportion of the variance of the weight records. Fitzhugh (1965) and Fitzhugh et al. (1967) also found this effect to be a major factor determining the weight of a beef cow. These authors report that the between herd, within breed weight differences were larger than those between breeds within herds

The environmental and genetic parameters included in this

Herd Effect were mentioned in Chapter 5, but it is impossible to assess objectively their relative importance. It is likely, however, that a large portion of the between herd variance is due to environmental factors. Thus, the major reason why the cows in the pasture herds are 119 lb. heavier than those in the range herds is that more nutrients were available to the cows in the pasture herds in both summer and winter. Edwards and Bailey (1975) also report that cows grazing summer pasture are heavier than those grazing summer range. They report a 160 lb. difference between herd types but make no mention of winter feeding.

Similarly, the inconsistent difference between the mean weight of straightbred and crossbred herds on range and pasture is likely to be a product of environmental rather than genetic factors. This herd x environment interaction is similar to the breedtype x environment interaction reported by Kilkenny and Stollard (1973). These British workers found that the mean weight of a breedtype depended on whether it was located in a lowland, upland or hill herd. In this study, however, the only relationship between weight and location is the range/pasture difference.

Age

As expected, the rapid increase in weight of younger cows declines with age. Thus at two years of age a cow weighs 78% of her maximum weight, but during the following four years of her life her weight only increases each year by approximately 8%, 6%, 3% and 3% respectively. In this study a cow's weight is stable at six and seven years of age and then increases again through the following two years. Although the 25.8 lb. increase in weight between six- and nine-year-old cows is significant statistically it would not appear to be so biologically. There is certainly no apparent biological explanation for such a delayed period of growth.

The definition of the mature weight of a cow was discussed in chapter 1. In this study it is defined as that weight to which no further significant annual increments are added. Therefore, the cows in this research reach their mature weight at six years of age, at which time their mean weight is 1083.9 lb. However, it is apparent that there is a considerable between herd variation in this pattern of growth. If the anomalous estimates of the mean weights in herd 3 are excluded, mature weight and age varied between 1068.2 lb. at five years of age (in herd 4) and 1228.0 lb. at nine years of age (in herd 7). As discussed in Section 1, this variation is probably due to environmental differences between herds.

Fitzhugh (1965) and Fitzhugh _et al_. (1967) report a similar variation in mature age (6-12years) but a considerably greater variation in mature weight (maximum difference 313 lb.) amongst the ten herds in their study. These herds, however, contained a more diverse selection of breedtypes than those found in the herds in the present study.

The decline in the weight of older cows reported by Knox and Koger (1949), Clark _et al_. (1958) and Brinks _et al_. (1962) was not apparent in the overall age estimates in this study. However, environmental factors in herds 4, 5, 6 and 8 did cause the cows in these herds to lose weight after maturity.

Year

The year of record dces not influence the overall mean or the age subclass mean weights in this study. However, within this non-significant Year Effect each herd does have a variation in its mean annual weight. A similar random variation across herds was reported by Fitzhugh (1965) and Fitzhugh et al. (1967). In all herds except herd 1, the between year variations in weight are relatively small and presumably reflect minor environmental variations within each herd. Similar variations in response to environmental factors were found by Clark et al. (1958), Brown and Franks (1964) and Urick et al. (1971). The factors associated with the weight changes in herd 1 have already been discussed.

Season

The season of weighing is a major parameter influencing the weight of the cows in this study. The mean increase in weight of 114.2 lb. between spring and fall is a product of the following factors:

1) The superior nutrition available to cows during the summer.

2) The stress due to pregnancy, parturition and early lactation influencing spring but not fall weight.

3) The possibility of the weight of the foetus and its associated tissues and fluids being a component of a cow's fall weight.

However, Salisbury and Van Demark (1961) report that the weight of the foetus and its associated tissues and fluids is likely to be relatively small in the fall (see later). The influence of early lactation stress is minimized in this research by eliminating weight records which have a spring interval of more than seventy days. Consequently, the other factors mentioned above are the main reasons for this seasonal weight change.

The only previous study which has reported a seasonal weight change of similar magnitude is that of Jeffrey and Berg (1971). The cows in their study had a summer weight gain and winter weight loss of 150 lb. and 133 lb. respectively. In comparison, Vacarro and Dillard (1966) report a 180-day summer weight gain of 32 lb., and Fitzhugh (1965) and Fitzhugh et al. (1967) report a mean seasonal weight difference of only 19 lb. A summer weight loss of 61 lb. was reported by Singh et al. (1970).

Amongst the other studies mentioned in Chapter 2, the report by Joandet and Cartwright (1969) contains no quantitative estimate, while that recorded by Ewing et al. (1965) is not comparable. The studies of Brinks et al. (1962), Clark et al. (1958) and Anderson et al. (1973) are concerned with pre-partum spring weights. The unknown weight of the foetus and associated tissues included in this weight precludes any reliable comparison of the seasonal weight changes in these studies with the present estimate.

The difference between the comparable reports of seasonal weight change is likely to be the result of the interaction of the following two factors:

1) These other studies have involved research herds. In comparison with most of the herds in the present study, the winter feed management in such herds is likely to be relatively

liberal. Thus, the cows calve in good condition in the spring and have only a small (or zero) need to increase in weight through the summer. In contrast, the cows in this study calve in relatively poor condition and have larger summer weight gains.

2) The studies of Vacarro and Dillard (1966), Fitzhugh (1965), Fitzhugh *et al.* (1967) and Singh *et al.* (1970) were carried out in the southern half of the United States. The present study and that of Jeffrey and Berg (1971) were carried out north of the 49th parallel of latitude. The more severe winters in Canada could be another reason for the larger seasonal fluctuations in weight.

A variation in seasonal weight change has also been recorded within the present study. The parameters which influence the magnitude of these changes in weight will now be discussed. Those which can be directly related to absolute weight, i.e. spring interval and the parameters associated with the calf, will, however, be discussed *per se* later in this section of the discussion.

Breedtype - this factor was never significant in any of the individual analyses for herds with more than one breedtype. It is thus apparent that, within a herd, the variation in seasonal weight change occurs independently of genetic, breedtype differences. As in the absolute weight analysis, this result vindicates the decision to include the records from herd 2 without specifying the breedtype of each cow.

Previous change in weight- as mentioned in section 1, this parameter has a major influence on the seasonal weight changes recorded in this study. The regression coefficients for all the previous change in weight covariables are negative. Thus, as would be expected, there is a positive compensatory gain in the summer in response to a winter weight loss, and a negative compensatory gain in the winter in response to a summer weight increase.

The negative compensatory winter gain is, however, not significant in two-year-old cows. At this age the summer weight gain undoubtedly reflects growth of muscle and, to a lesser extent, skeletal tissue. The weight gain due to such growth is not easily lost, and the effect of the covariable is not significant. The relatively small regression coefficients in the three- and four-year-old subclasses also reflect similar summer growth (mean b=-0.4561). In older cows a summer weight gain reflects a change in condition, which is more easily lost in a subsequent winter. Hence, the greater relationship between the weight changes (mean b = -0.6024).

Conversely, the winter weight loss in each age subclass is mostly a loss in condition. Thus there is no biological reason why the subsequent compensatory gain should vary across ages. This is reflected in the more equivalent values for the covariable across ages in the summer change in weight analysis.

It is apparent that the positive compensatory gain in the summer (mean b = -0.6811) is greater than the negative gain during the winter (mean b = -0.5194). Again this is a product of the tissue changes involved. As the negative winter gain is relatively small and the larger positive compensatory gain occurs on relatively inexpensive summer range/pasture, this biological relationship is an asset to a farmer or rancher.

Herd - the other parameter which has a major influence on these seasonal weight changes is the Herd Effect. As mentioned in section 1, this parameter will be discussed by considering the herd estimates which include the compensatory growth component. The reasons for the between herd differences in weight change could be both genetic and environmental. However, it appears that both the summer and winter weight changes in a herd are very much dependent on the winter feed management in that herd. A herd which is relatively well fed in the winter, e.g. herd 1, has a small weight gain in the winter. Its subsequent compensatory gain is thus negative and its summer weight gain is small. The opposite occurs in herd 3. Its winter feeding is very poor and this results in a very large winter weight loss, a subsequent large positive compensatory gain and thus a large total summer weight gain.

Thus, if the herds are ranked according to their weight changes, the order of ranking is the same for both summer and winter weight, even though the former is expressed as a percentage of body weight.

The cows in the pasture herds in this study (herds 5, 6 and 7) are significantly heavier than those in range herds. Their heavier weights could be a result of either a smaller winter weight loss or a greater summer weight gain, or both. There is some indication that the former is occurring in this study. As a result of this, there is less compensatory growth in the summer and the summer weight gain consists of a relatively large proportion of 'new weight increase'. Thus, even though these cows do not have especially large summer weight gains, the net result is that they are relatively heavy.

In the present research seven of the eight herds studied lost weight over the winter. Fitzhugh (1965) and Fitzhugh *et al.* (1967) also found that in all but one of the six herds for which they could estimate seasonal weight change there was a winter weight loss. The winter weight changes reported by these authors varied between a weight loss of 50 lb. and the one weight gain of 62 lb. Vacarro and Dillard (1966) also report a small difference in summer weight gain between the two herds in their study. Differences can also be found between the single-herd studies using pre-partum spring weights which were described in chapter 2.

Age - the influence of this parameter varies between the summer and winter weight changes. The winter feed management and the stress of pregnancy, parturition and lactation causes each age subclass to lose a similar amount of weight over the winter. These factors are thus sufficient to inhibit completely a young cow's inherent need to grow. In the summer the availability of feed is not limited by the intervention of man. Thus, younger cows are able to express their inherent need to grow, and their weight gains are significantly greater than those of older cows. Thus the cows in this study are increasing in weight over age as a product of larger summer weight gains in younger animals, and not as a result of any differences between ages in winter weight changes.

The relationship between summer weight gain and age does show minor differences between herds, but the general pattern is the same in each herd. In the herds where winter feeding was more liberal, i.e. those included in the winter change in weight analysis, two- and three-year-old cows tend to have a smaller weight loss, or even a gain in weight, during the winter. But overall, age is still not a significant source of variation amongst the weight change records.

Similarly, the year of record did not influence this pattern of seasonal weight change over age.

Vacarro and Dillard (1966), Fitzhugh (1965), Fitzhugh et al. (1967) and Brinks et al. (1962) also recorded a similar differential summer weight gain over age, while England et al. (1961) found that summer weight gain is not associated with age. However, no reascn for this exception is apparent in the report on the last of these studies.

During the winter Fitzhugh (1965) and Fitzhugh et al. (1967) recorded a greater weight loss from fall to post-partum weighing in clder cows. Brinks et al. (1962) found greater weight gains from fall to pre-partum weighing in younger cows. The winter feed management in research herds such as those in these studies has previously been discussed and is considered to be more liberal than that in most of the herds in the present study. It seems likely that these reports of an Age Effect on winter weight change are a product of this winter feeding.

Year - overall the year of record did not influence these seasonal weight changes. Nevertheless, environmental differences between years did cause minor annual variation in weight change in some herds, e.g. winter weight change in herd 2. The one exception to this is herd 1; the anomalous weight changes in this herd have already been discussed. The comprehensive investigation of this between herd variance was, however, limited by the nature of the data.

Spring interval

After parturition a cow is lactating to provide nutrients for her calf; the peak of her lactation curve occurs soon after parturition. During this spring interval period (mean length 26 days ± 14days) the cows in this study lose 0.7 lb. per day. It would thus appear that the weight of a cow is influenced by her milk production during this spring interval. However, the weight of a cow can only be related to time, any relationship of weight with the level of milk production cannot be estimated.

Vacarro and Dillard (1966) also recorded a loss in weight during the first sixty-day period post-partum. After this point there was a summer weight gain. The mean weight loss in this study, however, was approximately 0.3 lb. per day. These workers found that in older cows this weight loss had a significant negative correlation with calf weight gains; an indication that, at least in older cows, weight loss is associated with milk production (Koch, 1972).

Amir and Kali (1974) report that in early lactation dairy cows are frequently unable to eat sufficient to meet the energy cost of lactation and they consequently mobilize body reserves. A weight loss immediately post-partum is thus a common and accepted phenomenon in dairy cows.

Calf age, Calf sex, Calf weaning weight

In this study none of the parameters associated with the calf being suckled through the summer period influence the cow's weight change. Thus any effect which the sex of a calf might have on its dam's milk production (Rutledge *et al.*, 1971; Pope *et al.*, 1968) is not sufficient to influence her weight. Similarly, the lactation stress described in chapter 5 which might be associated with the age of a calf does not influence cow weight. The lack of significance of weaning weight indicates that the influence of lactation on cow weight, which was apparent immediately post-partum, does not last through the summer.

The relationship between the dam and its calf during the summer is a reciprocal one. Thus the converse interpretation of previous studies in which the weight change of the dam is considered in relation to its influence on calf weaning weight are equally valid. The conclusion of Jeffrey and Berg (1971) is therefore the same as that of the present research. However, the conclusions of Vacarro and Dillard (1966) and Singh *et al.* (1970) do not agree with the present research.

The differing results in these studies can be associated with the magnitude of the summer weight changes recorded in them. As mentioned previously, a 150 lb. summer weight gain was reported by Jeffrey and Berg, (1971) while Vacarro and Dillard (1966) recorded only a 32 lb. weight gain and Singh *et al.* (1970) actually report a summer weight loss. Thus, if the cows have a small or negative weight gain, a significant relationship is apparent between the cow and calf weights. However, when the summer weight gain is large, the influence of the calf is relatively small and weaning weight does not significantly affect cow weight.

Pregnancy and parturition

As expected, a cow's stage of pregnancy is a significant parameter influencing her weight. The mean weight of the cows in herd 2 used in this study, increases by 101.4 lb. between the 90th and 260th day of pregnancy. After this point there is a mean weight loss of 6.8 lb. prior to parturition. A weight loss in the last days of pregnancy has also been observed in dairy cattle (Hodges, 1976), but a physiological explanation for this loss has not been documented. It can be speculated that it is due to one or both of the following factors:

1) A change in the amount of digesta present in the rumen during this period.

2) If the cow is having to metabolize her body reserves pre-partum to support the calf and its associated tissues, her own weight loss is masked through most of pregnancy by the increasing weight of the conceptus. However, after the 260th day of pregnancy the rate of weight increase is relatively small and the net result is a weight loss.

The mean weight loss at parturition is 80.0 lb. or 7.2.% of the cows pre-partum weight. This estimate is less than the 131.6 lb. weight loss reported by Ewing *et al*. (1972). In their study this weight loss was 13.1% of the pre-partum weight of the cow. The reason for this relatively small weight loss estimate in the present study was discussed in Section 1. The weight loss during the last ninety days of pregnancy, including parturition weight loss, is 50.7 lb. This weight loss is, however, similar to the 68.0 lb. loss during the same period reported by Vacarro and Dillard (1966).

There is also a weight loss from the fall through to parturition. This 21.2 lb. loss could partly be due to the influence of pregnancy in the fall, when the cows are on average 129 days pregnant (Salisbury and Van Demark, 1961). It is likely, however, that this difference is also due to a change in the weight of the cow per se.

Section 3 - Conclusions

The discussion is concluded by synthesizing the most salient points which arise from this research. Although such conclusions apply only to the herds included in this research, most of them also have implications which extend outside this 'universe'. These conclusions are as follows:

1) A herd operator exerts a major influence over the weights of the cows in his herd. This human influence is present in the large Season, Herd, and Herd x Season Effects.

2) The weight changes of the cows in herd 1 show the biological upper limit of this human influence. Overfeeding of these cows led to an atypical summer weight loss.

3) The season of weighing has a major influence on cow weight. Normally there is a loss in weight during the winter and in the initial period post-partum. This is followed by an increase in weight through the summer.

4) Each seasonal change in weight consists of a compensatory weight change, which can be either positive (in the summer) or negative (in the winter), and a 'new weight change'. The compensatory gain is dependent on the weight change in the previous period, while the 'new weight change' is more directly

related to the availability of nutrients during the period of change. Thus the winter feed management of an operator has an influence over both the summer and winter weight changes in his herd.

5) This seasonal variation in cow weight does not necessarily occur around the animal's expected or true mean weight.

6) Within a herd, genetically different breedtypes have the same seasonal weight changes.

7) The seasonal weight change recorded in this research is considerably greater than that reported in most previous studies. This is considered to be a consequence of,

i) the location of the studies,

ii) better winter feeding in the research herds included in these previous studies.

8) A significant portion of the between herd differences in weight is likely to be related to the availability of nutrients (both in summer and winter) in each herd. Thus, the weight of a cow is dependent on her herd environment.

9) Within a herd there is normally no difference between the mean weights of genetically different breedtypes. There is some indication, however, that where the feed supply is more liberal such a difference does exist. However, to confirm this, further research would be necessary.

10) The mean age at maturity is six years. The mean growth curve up to and beyond this point has a significant linear and quadratic component. Environmental differences between herds cause a variation in the age at maturity and the shape of the growth curve.

11) During the summer younger cows increase in weight more than older cows, but during the winter all ages lose equivalent amounts of weight. Thus cows are increasing in weight over age owing to larger summer weight gains, and not to any differences in winter weight change.

12) The calf being suckled by a cow through the summer period has no influence on her summer weight gain.

This research has described and evaluated many of the environmental parameters which Taylor (1965) and Joandet and Cartwright (1969) mentioned as being potentially important influences on the growth pattern of a cow. In the environments included in this research it is apparent that these parameters have a major influence on the phenotypic expression of a cow's genotype for growth. The nature of the available data has, however, limited the evaluation of the possible genetic parameters influencing growth to maturity.

The difficulty in separating the influence of these environmental and genetic parameters is reflected in the limited published data on the latter aspect of growth in beef cows. Further research to investigate the genetic component would require the inclusion of breeding records, and would have to be carried out over several generations of breeding. The present research emphasizes that such studies would be meaningless without some specification or control of environmental conditions.

The large seasonal weight changes recorded in this research suggest an interesting management option for a beef producer. If he allows his cows to lose weight through the winter and then regain it during the following summer, he can reduce his winter feed costs. The limitation of such a management practice, however, is its effect on the cow's productivity, as reflected in her ability to raise a good sized calf each year. In dairy cattle it has been found (Hodges & Hiley, unpublished) that the magnitude of the weight loss is not the most important factor affecting fertility, i.e. the ablility to produce a calf each year. If the body weight of a cow is increasing during the breeding period, this will offset the decreased fertility which might result from a weight loss. Thus, as the cows in herds 3 and 8 were presumably increasing in weight during breeding, the large weight loss in these herds might not have had a detrimental influence on fertility. A study of conception rates in these herds, or others which have a similar seasonal weight loss, could usefully be carried out to investigate these relationships in beef cattle.

However, if a large winter weight loss causes a cow to raise a relatively small calf in the subsequent fall, a policy of allowing a large winter weight loss would, perhaps, not be expedient. Research to investigate these factors is currently being carried out.

It is also apparent from the present results that large weight gains, of both cows and calves, occured during summer grazing of rangeland. Although the summer weight gain in a herd varied according to the magnitude of the winter weight loss, it would also have been dependent on factors such as the quality of the summer grazing, stocking rate and the amount of precipitation. Also there could have been genetic differences in growth rate between the herds. A study to ascertain the range type/plant species which were associated with large weight gains, as well as the other environmental differences responsible for the between herd variation in summer weight gain, would yield usefull information for future range management policy decisions in this province. However,such a study over the extensive area of rangeland included in this research would be a large task. It was thus considered to be outside the scope of the present research.

The weight loss which was observed immediately post-partum is similar to that observed in dairy cows. Although it is impossible for a high yielding dairy cow to consume sufficient feed to prevent this loss (without disturbing the required roughage- concentrate ratio), an increased level of feeding could possibly prevent it in beef cows. It might also increase milk yield and calf weight gains. However, if the calf is too young in the first few weeks post-partum to utilize a more plentiful supply of milk, and especially if it results in their developing calf scours, this would not be a benificial management policy. But if the weight loss continues through a longer period, such as the sixty days considered by Vacarro & Dillard (1966), additional feeding at some stage might be advantageous. A study involving more frequent weighing and controlled feeding immediately post partum is required to resolve this uncertainty.

These practical implications indicate that the pattern of weight change in beef cows is a potentially important factor in a cow/calf operation. Thus the comment of Bowman (1972), that a classification of the productivity of a cow simply in terms of a single weight can be misleading, is especially true on farms and ranches in northen latitudes.

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APPENDIX 1

Least squares constants for each degree of freedom fitted in the analysis for Spring and Fall weights

Subclass	L.S. Constant	S.E.
Herd 1	11.2	4.7
2	-48.1	3.6
3	-154.2	4.8
4	-24.0	7.0
5	64.0	9.4
6	56.0	13.0
7	64.0	6.8
7	10.2	6.7
Age 2	-148.5	5.5
3	-68.8	5.2
4	0.9	5.8
5	38.4	6.3
6	64.5	7.9
7	56.5	9.3
8	71.6	6.5
9	90.3	9.9
Year 1	-2.9	4.0
2	4.9	3.5
Spring	-57.1	2.7
Hd. 1 Yr. 1	-54.1	5.8
2 1	18.1	6.6
3 1	-20.7	6.2
4 1	24.9	8.9
5 1	24.9	10.4
6 1	-32.5	17.8
7 1	24.9	8.9
1 2	30.9	5.5
2 2	-26.8	4.7
3 2	2.2	6.7
4 2	0.7	7.1
5 2	-6.2	9.5
6 2	13.2	13.5
7 2	-2.7	8.3

Hd. 1	Sn. 1	78.1	4.2
2	1	39.5	4.0
3	1	-68.9	4.8
4	1	-8.3	7.4
5	1	-29.9	8.9
6	1	30.8	11.3
7	1	9.1	6.1
Hd. 1	Age 2	46.7	9.5
2	2	-47.3	8.2
3	2	77.3	10.8
4	2	24.5	9.9
5	2	-19.0	15.3
6	2	43.4	21.2
7	2	-155.0	15.3
1	3	-13.9	9.7
2	3	-36.9	7.4
3	3	-1.7	12.0
4	3	16.7	10.2
5	3	9.8	13.9
6	3	75.9	20.4
7	3	-30.4	15.8
1	4	-4.2	10.6
2	4	0.7	7.5
3	4	2.4	12.1
4	4	36.3	13.2
5	4	-5.9	14.1
6	4	2.1	27.8
7	4	-8.7	14.1
1	5	-1.1	11.9
2	5	-11.1	8.0
3	5	-4.5	12.3
4	5	26.9	13.8
5	5	4.5	15.4
6	5	12.6	32.3
7	5	-17.6	13.6
1	6	1.5	13.6
2	6	-17.2	9.9
3	6	-13.0	12.2
4	6	1.6	15.0
5	6	21.5	19.7
6	6	37.9	43.7
7	6	-12.9	16.5
1	7	4.2	14.5
2	7	22.5	11.0
3	7	2.8	12.9
4	7	16.3	17.6
5	7	-13.9	21.3
6	7	-68.0	20.7

1 8	-27.3	11.5
2 8	36.4	9.1
3 8	-23.4	10.9
4 8	-16.4	19.3
5 8	-40.6	18.6
7 8	54.3	17.7
1 9	-33.7	14.1
2 9	20.1	11.7
3 9	-34.8	14.0
4 9	-43.7	16.9
5 9	7.8	26.8
6 9	16.0	53.1
7 9	67.6	23.6
Age 2 Yr. 1	3.6	6.8
3 1	-0.7	7.1
4 1	13.3	6.4
5 1	-3.2	6.3
6 1	-16.3	7.6
7 1	-8.8	7.8
8 1	4.9	7.3
9 1	1.9	8.1
1 2	9.2	11.8
2 2	-12.5	6.3
3 2	17.0	5.2
4 2	-4.8	5.2
5 2	3.1	5.8
6 2	4.6	5.9
7 2	-2.0	6.5
8 2	-1.2	6.9
9 2	-3.9	6.7
Age 2 Sn. 1	-12.4	4.9
3 1	-30.1	3.9
4 1	-11.2	3.7
5 1	1.3	4.3
6 1	10.2	4.3
7 1	8.4	4.7
8 1	2.5	4.9
9 1	12.2	5.0
Yr. 1 Sn. 1	21.7	3.6
2 1	-4.3	2.7

<u>Overall Means For Dependent Variable</u>

Least-Square = 1019.4

Arithmetic = 1004.5

Least squares constants for each freedom fitted in the analysis for summer change in weight in 1974 & 1975

Subclass	L.S. Constant	S.E.
Herd 1	-0.19	0.95
2	7.72	1.02
3	3.00	1.05
4	-5.47	1.56
Age 2	6.24	1.94
3	5.12	1.10
4	1.81	1.31
5	-0.30	1.08
6	-0.71	1.26
7	-0.32	1.70
8	-2.36	1.83
9	-5.26	1.34
Year 1	5.68	0.46
(1) steer calf	0.39	0.33
Hd. 1 Sex 1	-0.16	0.45
2 1	-0.71	0.49
3 1	0.16	0.60
4 1	1.44	0.86
Hd. 2 Age 2	1.21	2.63
3 2	-1.14	3.01
1 3	-1.22	1.52
2 3	0.70	1.94
3 3	-0.17	2.59
4 3	-1.44	1.73
1 4	1.31	2.15
2 4	-1.11	2.01
3 4	-2.24	2.67
4 4	-1.49	2.51
1 5	-3.98	1.91
2 5	-4.32	2.37
3 5	3.93	2.51

1	6	4.17	2.28
2	6	-0.19	2.44
3	6	-3.08	2.39
4	6	-0.90	2.09
1	7	-0.69	2.30
2	7	-2.16	3.30
3	7	0.75	2.30
4	7	1.01	4.02
1	8	-0.15	3.24
2	8	-0.33	3.42
3	8	-0.69	3.19
4	8	2.47	4.17
1	9	2.12	2.39
2	9	5.73	2.34
3	9	-1.03	2.81
4	9	-5.58	2.30
Age 2	Yr. 1	-2.07	1.01
3	1	-0.75	0.94
4	1	-1.27	1.06
5	1	-1.57	1.19
6	1	2.25	1.56
7	1	-0.89	1.91
8	1	0.82	1.22
9	1	2.36	0.78
Age 2	Sex 1	0.22	0.78
3	1	0.28	0.57
4	1	-0.19	0.63
5	1	0.07	0.83
6	1	0.52	0.79
7	1	-0.66	0.77
8	1	0.45	0.92
9	1	-0.90	0.79

Overall Means For Dependent Variable

Least-Square = 7.26

Arithmetic = 9.85

Least squares constants for each degree of freedom fitted in the analysis for summer change in weight for 74 only

Subclass	L.S. Constant	S.E.
Herd 1	-9.68	0.91
3	14.77	0.98
4	-5.35	0.95
8	3.29	1.08
Age 2	3.42	1.24
3	4.50	0.98
4	2.04	1.09
5	-2.07	0.98
6	2.09	1.27
7	-0.56	1.31
8	-0.26	1.54
9	-4.69	1.76
(1) steer calf	0.09	0 40
Hd. 1 Age 2	0.18	1.79
3 2	-1.68	1.74
4 2	-2.69	1.65
8 2	3.98	2.26
1 3	2.63	1.60
3 3	1.33	2.23
4 3	0.38	1.82
8 3	-1.83	2.03
1 4	-2.12	1.88
3 4	5.09	2.11
4 4	0.47	2.48
8 4	-5.07	2.47
1 5	-1.98	1.88
3 5	-0.74	2.24
4 5	-0.36	2.19
8 5	-0.80	1.65
1 6	7.95	2.64
3 6	-3.92	1.99
4 6	-1.66	2.15
8 6	-4.29	2.01

1	7	-0.53	1.94
3	7	-4.36	1.77
4	7	-1.65	2.58
8	7	6.68	3.11
1	8	-4.87	2.14
3	8	0.26	2.16
4	8	4.52	5.03
8	8	0.88	2.41
1	9	-0.79	2.23
3	9	4.61	2.76
4	9	-3.41	2.38
8	9	2.19	5.08
Age 2	Sex 1	-0.85	0.85
3	1	0.95	0.92
4	1	-1.44	1.18
5	1	0.99	0.94
6	1	1.74	1.20
7	1	-0.39	1.04
8	1	0.70	1.11
9	1	-2.11	1.33
Hd. 1	Sex 1	0.99	0.68
3	1	0.26	0.71
4	1	0.29	0.74
8	1	-0.92	0.79

<u>Overall Means For Dependent Variable</u>

Least-Square = 14.70

Arithmetic = 14.68

Least squares constants for each degree of freedom fitted in the analysis for winter weight change

Subclass	L.S. Constant	S.E.
Herd 2	-0.48	0.48
7	-2.05	0.74
Year 1	0.38	0.42
Age 2	3.60	1.25
3	1.70	1.37
4	-0.74	0.88
5	0.39	0.82
6	-1.06	1.15
7	-1.56	1.01
8	-2.14	1.24
9	-0.58	1.11
Hd. 2 Yr. 1	-0.36	0.79
7 1	-2.75	0.54
Hd. 2 Age 2	0.28	1.81
7 2	6.93	2.32
2 3	1.29	1.34
7 3	-1.49	2.15
2 4	1.04	1.01
7 4	-4.23	1.55
2 5	1.14	0.91
7 5	-2.76	1.37
2 6	1.83	1.05
7 6	-0.86	1.44
2 7	-1.45	1.35
7 7	0.87	1.52
2 8	-0.77	1.34
7 8	-0.59	2.39
2 9	-1.18	1.42
7 9	0.48	2.14

Age 2 Yr. 1	-0.46	1.06
3 1	-0.08	0.82
4 1	1.14	0.71
5 1	-1.65	0.65
6 1	-1.28	1.06
7 1	-0.31	1.16
8 1	0.50	0.74
9 1	0.61	0.86

<u>Overall Means For Dependent Variable</u>

Least-Square = -0.97

Arithmetic = 0.25

Least Squares Constants For Each Degree Of Freedom Fitted In Analysis For Weights Considered As Days Pregnant

Subclass	L.S. const	S.E.
Age 2	-224.1	7.2
3	-97.8	4.5
4	-33.3	7.4
5	-4.5	6.4
6	-0.4	6.3
7	22.6	10.7
8	85.3	7.2
9	52.0	8.1
10	58.5	8.4
11	72.5	8.4
Year 1	-26.0	2.6
Age 3 Yr. 1	-3.1	4.6
4 1	3.2	7.3
5 1	-16.5	6.4
6 1	5.9	6.3
7 1	1.4	10.6
8 1	1.1	7.2
9 1	29.7	8.1
10 1	-10.9	8.3
11 1	-8.8	8.4

Overall Mean For Dependent Variable

Least-Square = 1131.8

Arithmetic = 1051.4

Appendix 2

Weighing Dates

Herd	1973 Fall	1974 Spring	1974 Fall	1975 Spring	1975 Fall	1976 Spring
1	15/11	19/3 28/3 1/4 18/4	14/11	25/3 3/4 8/4 23/4	13/11 4/12	17/3 25/3
2		14/5 17/5	18/11 21/11 27/11	5/5 7/5 8/5	30/9 9/10 28/10 30/10	3/5 4/5 5/5
3	27/10	4/5 1/6	2/11 9/11		2/11	8/5
4	1/11	4/5	17/10		26/10	
5	17/12	26/4	30/11		31/12	
6		at birth	1/10	at birth	17/10	20/4
7	20/10	11/6 15/6	30/10	12/6 17/5	10/12	9/5
8		27/4 28/4 29/4	8/11		9/11	1/5
9	30/10		13/10	31/3 20/4 13/4	18/10	17/4