Effects of inbreeding and selection in a closed line of hereford cattle
by Darrell Ian Nevins

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University

Abstract:
The objectives of this study were to estimate the effect of inbreeding on birth weight, weaning weight and yearling weight in a closed line of Hereford cattle and to evaluate the selection index in use in this line. The Havre Line 4 has been closed since 1976. Mean inbreeding was .15 and .14 for calves and dams, respectively. Inbreeding of calf was increasing at a rate of .005 per year. Estimates of the effect of inbreeding of calf and dam on birth weight were very small and not biologically significant. Inbreeding of calf had no effect on weaning weight of male calves and a -.84 kg/% of calf inbreeding effect on female calf weaning weight. Inbreeding of dam had no effect on weaning weight of female calves and a -.64 kg/% of dam inbreeding effect on male calf weaning weight. Estimates of the effect of inbreeding on yearling weight were very small and not biologically significant. Selection in the Havre Line 4 is based on the index, I = Yearling Weight -3.2 Birth Weight. The purpose of the index is to achieve an acceptable increase in yearling weight while minimizing the correlated increase in birth weight. Genetic trends were estimated by use of frozen semen from sires born in 1975 and 1976 (group 1) and sires born in 1980 and 1981 (group 2) in a common tester herd. Estimates were -.2, 2.3 and 2.8 kg/yr for birth weight, weaning weight and yearling weight, respectively. The index is effectively reducing the trend for larger birth weight but is not increasing yearling weight at the expected rate.

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APPROVAL

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Darrell Ian Nevins

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliograghic style, and consistency, and is ready for submission to the College of Graduate Studies.

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TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF TABLES

LIST OF TABLES - Continued

LIST OF TABLES - Continued

LIST OF FIGURES

ABSTRACT

The objectives of this study were to estimate the effect of inbreeding on birth weight, weaning weight and yearling weight in a closed line of Hereford cattle and to evaluate the selection index in use in this line. The Havre Line 4 has been closed since 1976. Mean inbreeding was .15 and .14 for calves and dams, respectively. Inbreeding of calf was increasing at a rate of .005 per year. Estimates of the effect of inbreeding of calf and dam on birth weight were very small and not biologically significant. Inbreeding of calf had no effect on weaning weight of male calves and a -.84 kg/% of calf inbreeding effect on female calf weaning weight. Inbreeding of dam had no effect on weaning weight of female calves and a -.64 kg/% of dam inbreeding effect on male calf weaning weight. Estimates ofthe effect of inbreeding on yearling weight were very small and not biologically significant. Selection in the Havre Line 4 is based on the index, I = Yearling Weight - 3.2 Birth Weight. The purpose of the index is to achieve an acceptable increase in yearling weight while minimizing the correlated increase in birth weight. Genetic trends were estimated by use of frozen semen from sires born in 1975 and 1976 (group 1) and sires born in 1980 and 1981 (group 2) in a common tester herd. Estimates were -.2, 2.3 and 2.8 kg/yr for birth weight, weaning weight and yearling weight, respectively. The index is effectively reducing the trend for larger birth weight but is not increasing yearling weight at the expected rate.

INTRODUCTION

Animal Breeding is the science of improving the genetics of domestic livestock. Two procedures result in changes in the genetic properties of a population, selection of parents and control of the way in which parents are mated. Control of mating may result in inbreeding (Falconer, 1981).

Inbreeding is the mating together of individuals that are related to each other by ancestry (Falconer, 1981). The primary effect of inbreeding is to increase the probability that the two alleles at a particular locus in an individual are identical by descent. This causes an increase in the proportion of homozygous loci in the inbred individual (Brinks and Knapp, 1975).

Increased homozygosity is associated with a decline in performance traits such as reproduction, survival and growth rate (Brinks and Knapp, 1975). The measure of inbreeding is the coefficient of inbreeding (Fx) developed by Wright, (1922). The coefficient of inbreeding is the probability that the two genes at any locus in an individual are identical by descent (Falconer, 1981).

Growth traits, from birth to weaning in beef cattle, are affected by both the genotype of the offspring and the maternal environment provided by the dam (uterine environment, lactation, and other less well-known factors)

(Brinks and Knapp, 1975).

Yearling weight is affected by the genotype of the individual and there is the possibility that inbreeding of dam could have a carryover effect on yearling weight of offspring. Therefore, growth traits may be concurrently affected by both the inbreeding of the dam and the inbreeding of the offspring.

Under dominance theory the relationship between inbreeding (homozygosity) and the level of performance for a trait such as weaning weight should be linear. A non-linear relationship would indicate an epistatic interaction between loci (Falconer, 1981). Analyzing inbreeding as both a linear and a quadratic effect provides some indication whether dominance theory explains the effects of inbreeding.

Artificial selection is the process resulting from the choice of parents. Only the selected parents produce offspring. The response to selection is measured by the change in the population mean, the difference between the offspring of selected parents and the parental generation (Falconer, 1981).

Many early studies of selection were not designed to allow separation of genetic changes from the phenotypic changes (Dalton and Baker, 1979). Techniques of evaluating the genetic trends in beef cattle include maintaining a random bred control population, repeat matings, intra-year comparisons of sire or dam progeny groups and semen storage with evaluations on a common tester herd (Koch et al., 1982).

Selection for higher growth rate has been advocated to increase efficiency in beef production (Barlow, 1979). Dickerson et al. (1974) studied selection criteria including carcass composition, meat quality, optimum economic weight at slaughter of calves, mature size, milk production and calving difficulty of cows to improve efficiency of beef production. An index (I) of I = Yearling Weight - 3.2 Birth Weight was suggested.

Dickerson et al. (1974) predicted the index should result in 56% less increase in birth weight while reducing increase in yearling weight 10% as compared to selection for yearling weight alone. This should be possible since the genetic correlation between birth weight and yearling weight is about .6 (Woldehawariat et al., 1977).

Selection for faster growth (among bulls) will increase birth weights of calves before it increases cow size (Dickerson et al., 1974). Birth weight is the most important factor affecting calving difficulty (Bellows et al., 1971). Two-year-old-dams that experience dystocia wean fewer calves and as 3-yr-olds wean fewer and lighter calves than 2-yr-old dams that do not experience dystocia (Brinks et al., 1973).

The data for this study are from the Havre Line 4 Herefords. The Havre Line 4 is a closed line and herd sires are selected by the index, I = Yearling Weight -3.2 Birth Weight. Therefore, genetic change in this line may be affected by both inbreeding and selection.

The objectives of this study are to estimate the effect of inbreeding on birth weight, weaning weight and yearling weight in the Havre Line 4 and to evaluate the effect of selection based on the selection index on birth weight, weaning weight and yearling weight. To evaluate the selection index a progeny test was performed through the use of frozen semen in a common tester herd.

PART I

THE EFFECT OF INBREEDING ON BIRTH WEIGHT, WEANING WEIGHT AND YEARLING WEIGHT

LITERATURE REVIEW

This section of literature review focuses on the effects of inbreeding of calf (Fx) and inbreeding of dam (Fd) on birth weight, weaning weight and yearling weight in beef cattle.

The Effect of Inbreeding on Birth Weight

Swiger et al. (1961) pooled 283 records from two Hereford lines, one Angus line and one Shorthorn line. Mean inbreeding coefficients were .13 for calves and .10 for dams. Partial regression values of birth weight on inbreeding in kilograms per percent inbreeding were -.17 for Fx and -.01 for Fd. At a separate location 677 records from ten Hereford lines and two Angus lines were pooled. The mean inbreeding coefficient of calves was .05 and the mean inbreeding coefficient of dams was .03. Partial regression values were -.03 kg/% Fx and .06 kg/% Fd for birth weight on inbreeding. Significance levels were not reported for either analysis.

Swiger et al. (1962) pooled 647 records from Hereford Angus and Shorthorn lines. Mean inbreeding coefficients of calves and dams were .09 and .08, respectively. Partial regression values of birth weight on inbreeding were -.03 kg/% Fx and .06 kg% Fd. Significance levels were not reported.

Nelms and Sratton (1967) analyzed 302 records from one Hereford line. Mean inbreeding coefficients were .11 for calves and .05 for dams. Partial regression values of birth weight on inbreeding were -.02 kg/% Fx and -.03 kg/% Fd. Neither Fx or Fd were significant sources of variation in birth weight.

Sutherland and Lush (1962) analyzed 1008 records from a line of Holsteins. Mean inbreeding of calves was .10. Mean inbreeding of dams was not reported. Simple regression values of birth weight on inbreeding of calf were -.10 kg/% Fx of male calves and -.14 kg/% Fx for female calves. Simple regression values of birth weight on inbreeding of dam were -.12 kg/% Fd for male calves and -.13 kg/% Fd for female calves.

Brinks et al. (1965) analyzed 2027 Miles City Line 1 Hereford records. Mean inbreeding of calf and dam were .16 and .12, respectively. Partial regression values for inbreeding of calf on birth weight were -.06kg/% Fx in males and -.18 kg/% Fx in females. Values for inbreeding of dam on birth weight were .004 kg/% Fd and .04 kg/% Fd for males and females, respectively. Significance levels were not reported.

Anderson (1966) analyzed 640 records from three Hereford lines. Mean inbreeding of calf and dam were .15 and .09, respectively. Partial regression values were .01 kg/% Fx for males and -.03 kg/% Fx for females when birth weight was regressed on inbreeding of calf. Values for birth weight on inbreeding of dam were .17 kg/% Fd for males and .06 kg/% Fd for females. Only Fd for males was a significant source of variation in birth weight.

Brinks and Knapp (1975) pooled records from 48 inbred lines in the western United States. Mean inbreeding of calves was .19 and mean inbreeding of dams was .12. When only the linear effect of inbreeding was considered the partial regression coefficients of birth weight on inbreeding were -.04 kg/% Fx and -.10 kg/% Fd for males and -.03 kg/% Fx and .001 kg/% Fd for females. Fx for both males and females were significant sources of variation in birth weight. When both linear and quadratic effects of inbreeding were fitted no partial regressions of inbreeding of calf or dam were significant sources of variation in birth weight.

Table 1. The effect of inbreeding on birth weight.

	b (kg/% Fx)		b (kg/% Fd)	
Swiger et al. (1961)	-.17		-.01	
Swiger et al. (1961)	-.03		.06	
Swiger et al. (1962)	-.09		-.03	
Nelms and Stratton (1967)	-.02		-.03	
	male	female	male	female
Brinks (1965)	-.06	-.18	.004	.04
Anderson (1966)	.01	-.03	.17	.06
Brinks and Knapp (1975)	-.04	-.03	-.10	.001

b (kg/% Fx) = partial regression of birth weight on inbreeding of calf

b (kg/% Fd) = partial regression of birth weight on inbreeding of dam

The Effect of Inbreeding on Weaning Weight

Koch (1951) analyzed 745 records from a line of Herefords. Mean inbreeding of calf was .12 and mean inbreeding of dam was .06. Partial regression values of weaning weight on inbreeding were -.22 kg/% Fx and -1.15 kg/% Fd. Significance levels were not reported.

Burgess et al. (1954) pooled 546 records from several Hereford lines. Mean inbreeding of calf and dam were .12 and .06, respectively. Partial regression values of weaning weight on inbreeding were -.81 kg/% Fx and -.52/kg% Fd. Both Fx and Fd were significant sources of variation in weaning weight.

McCleery and Blackwell (1954) analysed 1455 records from one line of Herefords. Calf inbreeding ranged from 0 to .25 and dam inbreeding ranged from 0 to .16. Partial regression values of weaning weight on inbreeding were -.54 kg/% Fx and .43 kg/% Fd. Fx and Fd were both significant sources of variation in weaning weight.

In the study of Swiger et al. (1961) partial regression values of weaning weight on inbreeding were -.65 kg/% Fx and -.02 kg/% Fx at two locations. Values for weaning weight regressed on inbreeding of dam were -.07 kg/% Fd and .02 kg/% Fd. Significance levels were not reported.

Anderson (1966) found partial regression values of weaning weight on inbreeding of -.12 kg/% Fx for males and -.05 kg/% Fx for females. Values for weaning weight on inbreeding of dam were -.78 kg/% Fd for males and -.07 kg/% Fd for females. Only Fd of males was significant.

The study of Nelms and Stratton (1967) found partial regression values of -.47 kg/% Fx and .27 kg/% Fd for weaning weight on inbreeding. Only Fx was a significant source of variation in weaning weight.

Brinks et al. (1965) found partial regression values for weaning weight on inbreeding of calf of -.21 kg/% Fx for males and -.77 kg/% Fx for females. Values for weaning weight on inbreeding of dam were -.85 kg/% Fd for males and -.20 kg/% Fd for females. Significance levels were not reported. Inbreeding of calf had a larger effect on weaning weight of females. Inbreeding of dam had a larger effect on weaning weight of males. Brinks et al. (1963) hypothesized that males have a greater growth potential and therefore are affected less by inbreeding of calf. Conversely, inbreeding of dam is associated with decreased milk production and males having greater growth potential are affected more by inbreeding of dam.

Dinkel et al. (1968) analyzed 860 records from four Hereford lines. Mean inbreeding of calf was .20 and mean inbreeding of dam was .09. Partial regression values of weaning weight on inbreeding were -.61 kg/% Fx for males and -.36 kg/% Fx for females. Values for inbreeding of dam were -.23 kg/% Fd for males and -.73 kg/% Fd for females. Only Fx of males and Fd of females were significant sources of variation in weaning weight. These results disagree with the hypothesis of Brinks et al. (1963). In a separate analysis, inbreeding was fitted as both a linear and a quadratic effect. Only Fx as a quadratic effect for males and Fd as a linear effect for females were significant sources of variation in weaning weight.

Brinks and Knapp (1975) found partial regression values of weaning weight on inbreeding of -.29 kg/% Fx and -.40 kg/% Fd for males and -.31 kg/% Fx and -.24 kg/% Fd for females. Each of the partial regressions was a significant source of variation in weaning weight. When both linear and quadratic effects of inbreeding were fitted only Fd as a quadratic effect was a significant source of variation in weaning weight.

Table 2. The effect of inbreeding on weaning weight.

	b (kg/% Fx)		b (kg/% Fd)	
Koch (1951)	-1.20		-.22	
Burgess et al. (1954)	-.81		-.52	
McCleery and Blackwell (1954)	-.54		.43	
Swiger et al. (1961)	-.65		-.07	
Swiger et al. (1961)	-.02		.02	
Nelms and Stratton (1967)	-.47		.27	
	male	female	male	female
Anderson (1966)	-.12	-.05	-.78	-.07
Brinks et al. (1965)	-.21	-.77	-.85	-.20
Dinkel et al. (1968)	-.61	-.36	-.23	-.73
Brinks and Knapp (1975)	-.29	-.31	-.40	-.24

b (kg/% Fx) = partial regression of birthweight on inbreeding of calf

b (kg/% Fd) = partial regression of birthweight on inbreeding of dam

The Effect of Inbreeding on Yearling Weight

Several researchers have studied the effect of inbreeding on final weight off postweaning gain test. Final weight may be a different trait in males and females since they are managed separately and fed to gain at different rates.

Brinks et al. (1965) analyzed final weight off postweaning gain test of males and 12-mo weight of females. Partial regression values for final weight of males on inbreeding were -1.04 kg/% Fx and -.39 kg/% Fd. Values for 12-mo weight of females on inbreeding were -1.38 kg/% Fx and -.10 kg/% Fd. Significance levels were not reported.

Nelms and Stratton (1967) analyzed final weight off postweaning gain test of males and females. Partial regression values for final weight on inbreeding were -.15 kg/% Fx and .50 kg/% Fd. Neither Fx or Fd were significant sources of variation in final weight.

Dinkel et al. (1967) analyzed final weight off postweaning gain test. Partial regression values for final weight on inbreeding were -1.09 kg/% Fx and -.004 kg/% Fd for males and -.53 kg/% Fx and -.61 kg/% Fd for females. Fx and Fd for males and Fd for females were significant sources of variation in final weight. When both the linear and quadratic effects of inbreeding were fitted only Fd of females as both a linear and quadratic were significant sources of variation in final weight.

Anderson (1966) found partial regression values for final weight on inbreeding of -.61 kg/% Fx and -.65 kg/% Fd for males and -.17 kg/% Fx and -.19 kg/% Fd for females. None of the regressions were significant sources of variation in final weight.

Brinks and Knapp (1975) found partial regression values for final weight on inbreeding of -.44 kg/% Fx and -.31 kg/% Fd for males and -.25 kg/% Fx and .13 kg/% Fd for females. Only Fx of males was a significant source of variation in final weight. When both linear and quadratic effects of inbreeding were fitted only Fd of males as a quadratic was a significant source of variation in final weight.

Table 3. The effect of inbreeding on yearling weight.

	b (kg/% Fx)		b (kg/% Fd)	
Nelms and Stratton (1967)	-.15		.50	
	male	female	male	female
Brinks et al. (1965)	-1.04	-1.38[a]	-.39	-.10[a]
Dinkel et al. (1967)	-1.09	-.53	-.004	-.61
Anderson (1966)	-.61	-.17	-.65	-.19
Brinks and Knapp (1975)	-.44	-.25	-.31	.13

b (kg/% Fx) = partial regression of yearling weight on inbreeding of calf
b (kg/% Fd) = partial regression of yearling weight on inbreeding of dam
[a] 12-mo weight

Summary

Inbreeding of calf and dam have little effect on birth weight. Inbreeding of calf has a fairly large (approximately -.5 kg/% Fx) detrimental effect on weaning weight. The effect of inbreeding of dam on weaning weight is usually detrimental and varies greatly with line. Inbreeding of calf has a fairly large (approximately -.6 kg/% Fx) detrimental effect on yearling weight. Inbreeding of dam has a smaller (approximately -.14 kg/% Fd) detrimental effect on yearling weight. The response to increased inbreeding varies greatly between inbred lines of beef cattle. Growth traits of a particular line may be greatly affected by inbreeding in a positive or negative manner or may not be affected. The explanation for sex differences in response to inbreeding is not known. There is no strong evidence for a quadratic growth response to inbreeding (Brinks and Knapp, 1975).

MATERIALS AND METHODS

The data for this part of the study were collected at the Northern Agricultural Research Center (NARC) near Havre, Montana from 1976 to 1983.

Site Description

NARC is located 13 km SW of Havre. The area is rolling plains with an approximate elevation of 819 m. Annual precipitation averaged 297 mm from 1951 to 1980 (USDC, 1980). The pastures at NARC are mixed praire grasslands containing *Agropyron desertorum*, *Stipa comata* and *Bouteloa gracilis* (crested wheatgrass, needle and thread and blue grama) as the major forage species.

Experimental Animals

Data were collected on 594 Havre Line 4 Horned Hereford calves. The Havre Line 4 is a subline of the Miles City Line 1. Foundation cows were purchased from the Livestock and Range Research Station at Fort Keogh in 1962 and 1963. The Havre Line 4 consists of approximately 100 cows. The line was closed in 1976.

Selection and Mating System

Each year two sires are selected within the line by utilizing the following index, I = Yearling Weight - 3.2

Birth Weight. Yearling weight and birth weight are corrected for age of dam and yearling weight is corrected to 365 d of age. Correction factors are calculated from within herd data. Sires are used for breeding as yearlings and 2-yr-olds. As yearlings, sires are randomly mated with replacement heifers and cows. Two-yr-old sires are repeat-mated to half the dams that produced their offspring the preceding year. To limit the rate of increase in inbreeding half-sib and son-dam matings are excluded and the two sires selected each year cannot be half-sibs.

All yearling heifers are exposed to breeding and those becoming pregnant are retained in the herd. Dams are culled on Most Probable Producing Ability for preweaning gain of calves. Cows which are not pregnant in the fall are culled.

Management

Breeding is by natural service for 45 d beginning June 1. After the breeding season the four sire groups are pastured together on improved pastures for the rest of the year. Winter feed for the cow herd consists of grass hay and corn silage.

Weaning occurs on Oct. 1. After a 2-wk warmup period bull calves go on a 168-d gain test. The ration consists of corn silage, grass hay and an oat-barley concentrate mix. Average gain is 1.1 kg per d.

For 6-wk after weaning heifer calves are pastured on hay field aftermath and then go on a 140-d gain test. The ration consists of corn silage, second cutting alfalfa and barley. Average gain is .6 kg per d.

Data

The data collected on the 594 Havre Line 4 calves weaned from 1976 to 1983 included birth date, birth weight sex of calf, age of dam, sire of calf, weaning weight and final weight off postweaning gain test. Inbreeding was calculated by an algorithm developed by Quaas (1976).

Statistical Analysis

To estimate the effect of calf and dam inbreeding on birth weight, weaning weight and yearling weight the data were analyzed by fixed model least-squares procedures (Harvey, 1977). The effects of inbreeding of calf (Fx) and inbreeding of dam (Fd) were the variables of primary interest in the analysis. The other variables and interactions were fitted to account for known sources of variation and allow better estimates of the effects of inbreeding. The model used to analyze birth weight was as follows:

$$Y_{ijkl} = u + Yr_i + Sx_j + A_k + S_{l(i)} + Yr \times Sx_{ij} + Yr \times A_{ik} + Sx \times A_{jk} + B_{ijkl} + Fx_{ijkl} + Fd_{ijkl} + Sx_j \times Fx_{ijkl} + Sx_j \times Fd_{ijkl} + e_{ijkl}$$

where

Y_{ijkl} = an observation

u = the overall mean

Yr_i = the fixed effect of the ith year

Sx_j = the fixed effect of the jth sex

A_k = the fixed effect of the kth age of dam

$S_{l(i)}$ = the fixed effect of the lth sire nested within the ith year

$Yr \times Sx_{ij}$ = the interaction of the ith year and the jth sex

$Yr \times A_{ik}$ = the interaction of the ith year and the kth age of dam

$Sx \times A_{jk}$ = the interaction of the jth sex and the kth age of dam

B_{ijkl} = the effect of day of birth

Fx_{ijkl} = the effect of inbreeding of calf

Fd_{ijkl} = the effect of inbreeding of dam

$Sx_j \times Fx_{ijkl}$ = the interaction of the jth sex of calf and inbreeding of calf

$Sx_j \times Fd_{ijkl}$ = the interaction of the jth sex of calf and inbreeding of dam

e_{ijkl} = random error.

The same model with weaning weight as the dependent variable was used to analyze weaning weight. A similar model was used to analyze yearling weight. Final weight off postweaning gain test was the dependent variable and age at yearling weight was included as a covariate.

In preliminary analyses, inbreeding of calf and dam were fitted as both linear and quadratic covariates. Inbreeding of calf and dam as quadratic covariates were not significant sources of variation in any analysis and were not included in final models.

The two-way interactions of age of dam x inbreeding of calf and age of dam x inbreeding of dam were fitted in preliminary analyses. These interactions were not significant for any trait and were not included in final analyses.

RESULTS AND DISCUSSION

Inbreeding

Inbreeding of dam ranged from .06 to .31 with a mean of .14. Inbreeding of calf ranged from .08 to .39 with a mean of .15. Inbreeding of calf increased at a rate of .005 per year. The trend for inbreeding of calf is shown in Figure 1.

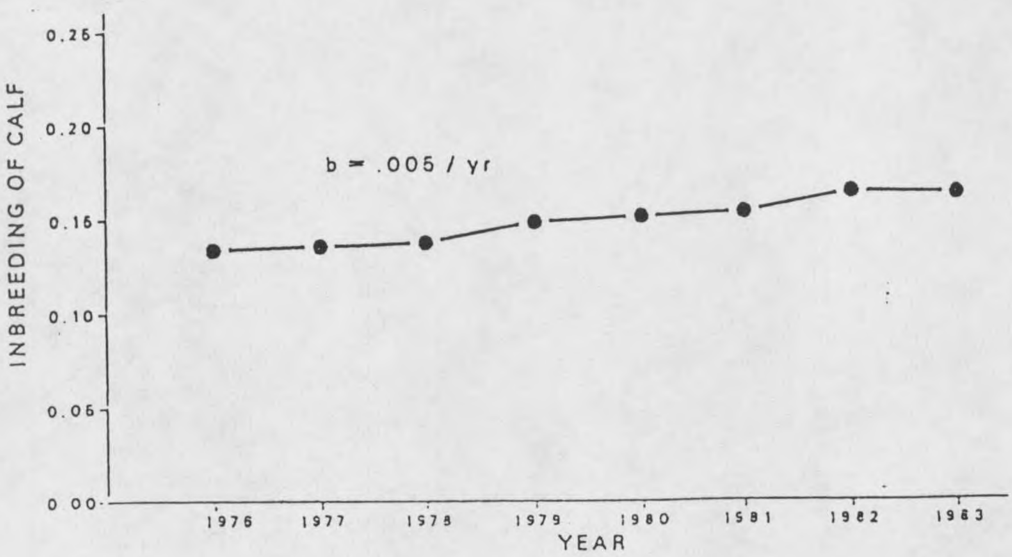

Figure 1. Trend in inbreeding of calves over years.

Birth Weight

The mean birth weight was 36.2 kg. Birth weight was significantly affected by all main effects except sire within year. The least-squares analysis of variance of birth weight is shown in Table 4 and the least-squares means for main effects are shown in Table 5.

Table 4. Least-squares analysis of variance for birth weight.

Source	df	Mean square (kg^2)
Year	7	70**
Sex	1	476**
Age of dam	3	392**
Sire/year	27	21
Year x sex	7	13
Year x age of dam	21	27**
Sex x age of dam	3	13
Regressions:		
Day of birth	1	2909**
Inbreeding of calf	1	34[a]
Sex x Inbreeding of calf	1	35
Inbreeding of dam	1	45*
Sex x Inbreeding of dam	1	29
Remainder	519	11
R^2		.49

** P<.01
* P<.05
a P=.08

Year was a significant source of variation in birth weight and means ranged from 34.3 kg in 1979 to 37.8 kg in 1983, a difference of 3.5 kg. This is in agreement with Burfening and Kress (1973) who found a significant year effect in a study at the same location.

Sex of calf was a significant source of variation in birth weight and mean male calf birth weight was 37.3 kg and mean female calf birth weight was 35.3 kg. Males were 2.0 kg heavier than females at birth. The sex difference is within the range given by Woldehawariat et al. (1977).

Table 5. Least-squares means for main effects affecting birth weight (kg).

Item	n	Mean	SE
u	594	36.3	±.16
Year			
1976	64	36.0	±.55
1977	69	36.4	±.45
1978	65	35.5	±.45
1979	68	34.3	±.47
1980	68	37.3	±.47
1981	77	37.2	±.44
1982	88	35.8	±.46
1983	95	37.8	±.40
Sex			
Male	302	37.3	±.22
Female	292	35.3	±.23
Age of dam			
2	140	33.6	±.35
3	127	36.2	±.33
4	83	37.3	±.40
5-10	244	38.2	±.25

Age of dam was a significant source of variation in birth weight and means were 33.6, 36.2, 37.3 and 38.2 kg for 2-yr-old, 3-yr-old, 4-yr-old and 5-10-yr-old dams, respectively. Birth weights were lightest for 2-yr-olds, increased with age to mature dams (5-10-yr-old). The effect of age of dam on birth weight is in agreement with Woldehawariat et al. (1977).

The two-way interaction year x age of dam was a significant source of variation in birth weight. Year means for age of dam subclasses changed erratically in rank and magnitude from year to year. The explanation of this interaction was not apparent.

Partial regression values are shown in Table 6. Day of birth as a covariate was a significant source of variation in birth weight. Birth weight increased .06 kg for each one day increase in the calving season. This agrees with Burfening and Kress (1973).

Table 6. Partial regression values of birth weight on inbreeding of calf, inbreeding of dam and day of birth.

Regression	b	SE
Inbreeding of calf (kg/% Fx)	-.0001	±.0001
Inbreeding of dam* (kg/% Fd)	-.0001	±.00004
Day of birth** (kg/d)	-.06	±.01

**P<.01
*P<.05

Inbreeding of calf approached significance as a source of variation in birth weight. Inbreeding of dam was significant. The partial regression values were -.0001 kg/% inbreeding of calf and -.0001 kg/% inbreeding of dam. These small values lack biological significance. Inbreeding had little effect on birth weight in this study. This is in agreement with several studies which have shown little effect of inbreeding of calf on birth weight (Swiger et al., 1962; Brinks et al., 1965 and Brinks and Knapp, 1975). This study agrees with most previous studies where inbreeding of dam has shown little effect on birth weight (Brinks and Knapp, 1975).

Weaning Weight

The mean weaning weight was 203.4 kg. Weaning weight was significantly affected by all main effects except sire within year. The least-squares analysis of variance for weaning weight is shown in Table 7 and the least-squares means for the main effects are shown in Table 8.

Table 7. Least-squares analysis of variance for weaning weight.

Source	df	Mean square (kg^2)
Year	7	5512**
Sex	1	12057**
Age of dam	3	24683**
Sire/year	27	375
Year x sex	7	396
Year x age of dam	21	934**
Sex x age of dam	3	691
Regressions:		
Day of birth	1	59262**
Inbreeding of calf	1	190
Sex x inbreeding	1	1678*
Inbreeding of dam	1	440
Sex x inbreeding of dam	1	1507*
Remainder	519	355
R^2		.67

**P<.01
* P<.05

Year was a significant source of variation in weaning weight and means for year ranged from 176.6 kg in 1978 to 216.8 kg in 1977. Many studies have shown a significant year effect on weaning weight. Anderson (1966) found a significant year effect of a similiar magnitude at the same location.

Sex of calf was a significant source of variation in weaning weight and mean weaning weight was 207.7 kg for males and 192.0 for females. The 15.7 kg difference due to sex is in agreement with Woldehawariat et al. (1977).

Table 8. Least-squares means for main effects affecting weaning weight (kg).

Item	n	Mean	SE
u	594	199.9	±1.3
Year			
1976	64	198.6	±4.6
1977	69	216.8	±3.5
1978	65	176.6	±3.4
1979	68	193.2	±3.0
1980	68	214.7	±3.1
1981	77	208.1	±3.7
1982	88	190.8	±4.5
1983	95	200.0	±3.0
Sex			
Male	302	207.7	±1.7
Female	292	192.0	±2.0
Age of dam			
2	140	176.6	±2.0
3	127	198.3	±1.8
4	83	210.3	±2.2
5-10	244	217.8	±1.4

Age of dam was a significant source of variation in weaning weight and means were 177, 198, 210 and 218 kg for 2-yr-old, 3-yr-old, 4-yr-old and 5-10-yr-old dams respectively. This effect of age of dam on weaning weight is in agreement with Woldehawariat et al., (1977).

The two-way interaction year x age of dam was an important source of variation in weaning weight. Weaning weights of calves from 2-yr-old dams were affected more by year than calves from mature dams as shown in Figure 2.

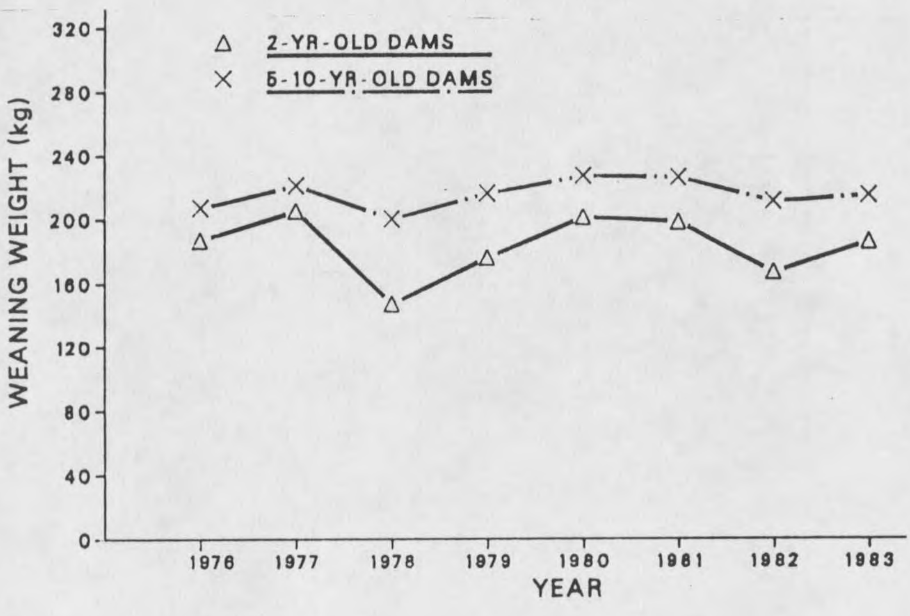

Figure 2. Year x age of dam interaction for weaning weight.

Day of birth as a covariate was a significant source of variation in weaning weight. Weaning weight increased .89 kg for each one day decrease in day of birth. This agrees closely with the study of Urick (1958) at the same location.

Inbreeding of calf and dam when pooled over sex were not significant sources of variation in weaning weight. However, the two-way interactions sex x inbreeding of calf and sex by inbreeding of dam were significant. Male weaning weight decreased .64 kg for each one percent increase in inbreeding of dam. Female weaning weight decreased .84 kg for each one percent increase in inbreeding of calf. Partial regression values are shown in Table 9.

Table 9. Partial regression values of weaning weight on sex x inbreeding of calf, sex x inbreeding of dam and day of birth.

Regression	b	SE
Inbreeding of calf (kg/% Fx)	-.22	±.30
Sex x inbreeding of calf* (kg/% Fx)		
Male	.39	±.46
Female	-.84	±.36
Inbreeding of dam (kg/% Fd)	-.22	±.20
Sex x inbreeding of dam* (kg/% Fd)		
Male	-.65	±.29
Female	.20	±.28
Day of birth** (kg/d)	-.89	±.07

** $P<.01$
* $P<.05$

Inbreeding of calf had a detrimental effect on weaning weight of females. Several studies have found a sizeable detrimental effect of inbreeding of calf on both sexes (Swiger et al., 1962; Dinkel et al., 1968, Brinks et al., 1965 and Brinks and Knapp, 1975). Inbreeding of dam had a detrimental effect on weaning weight of males. Studies have found a detrimental effect of inbreeding of dam on weaning weight of both sexes (Brinks et al., 1965; Anderson, 1966 and Dinkel et al., 1968), a positive effect (McCleery and Blackwell, 1954) and no effect (Nelms and Stratton, 1964). The response of weaning weight to increased inbreeding varies by line and selection criteria.

Weaning weight of males was more greatly affected by inbreeding of dam while weaning weight of females was more greatly affected by inbreeding of calf. This agrees with Brinks et al. (1963). This similarity is probably to be expected because Brinks et al., (1963) used Miles City Line 1 Hereford data and the Havre Line 4 is a subline of the Line 1.

Yearling Weight

The mean yearling weight was 350 kg. All main effects were significant sources of variation in yearling weight except sire within year. The least-squares analysis of variance is shown in Table 10 and the least-squares means for main effects are shown in Table 11.

Year was a significant source of variation in yearling weight and means for yearling weight ranged from 316 kg in 1978 to 381 kg in 1980. This 65 kg variation due to year agrees with Anderson (1966).

Sex of calf was a significant source of variation in yearling weight and mean yearling weight for males was 398 kg and mean yearling weight for females was 298 kg. The 100 kg difference due to sex is larger than the range given by Woldhawariat et al. (1977). Sex effect in this analysis is a combination of sex and environment. The two sexes are managed separately and males are fed to gain at a higher rate.

Table 10. Least-squares analysis of variance for yearling weight.

Source	df	Mean square (kg^2)
Year	7	15620**
Sex	1	1047412**
Age of dam	3	26626**
Sire/year	27	2020
Year x sex	7	3716**
Year x age of dam	21	726
Sex x age of dam	3	1650
Regressions:		
Age at yearling weight	1	96437**
Inbreeding of calf	1	6120**
Sex x inbreeding of calf	1	875
Inbreeding of dam	1	2016
Sex x inbreeding of dam	1	6196**
Remainder	493	841
R^2		.82

**P<.01

Age of dam was a significant source of variation in yearling weight and means were 332, 347, 357 and 359 kg for 2-yr-old, 3-yr-old, 4-yr-old and 5-10-yr-old dams. The weaning weight differences due to age of dam were maintained through yearling weight.

The two-way interaction year x sex was a significant source of variation in yearling weight. Male means were more varied than means for females. Males apparently respond differently to environmental differences of year than females.

Table 11. Least-squares means for main effects affecting yearling weight (kg).

Item	n	Mean	SE
u	568	347.7	±1.4
Year			
1976	62	335.5	±4.9
1977	67	344.4	±4.0
1978	56	316.2	±4.3
1979	65	345.8	±4.2
1980	68	381.1	±4.1
1981	75	355.1	±3.9
1982	83	345.5	±4.1
1983	92	357.9	±3.5
Sex			
Male	284	397.7	±2.0
Female	284	297.7	±2.0
Age of dam			
2	124	324.0	±3.2
3	124	345.7	±2.9
4	82	358.7	±3.5
5-10	238	362.3	±2.2

Age at yearling weight was a significant source of variation in yearling weight and the partial regression value was 1.2 kg/day. Each 1 day increase in age resulted in a 1.2 kg increase in yearling weight. Inbreeding of calf was a significant source of variation in yearling weight. The partial regression value is small, -.001 kg/% Fx, and lacks biological significance. A completely inbred individual would decrease only .1 kg in yearling weight. Regression values are shown in Table 12.

Table 12. Partial regression values of yearling weight on inbreeding of calf, sex x inbreeding of calf, inbreeding of dam, sex x inbreeding of dam and age yearling weight.

Regression	b	SE
Inbreeding of calf** (kg/% Fx)	-.001	±.0005
Sex x inbreeding of calf (kg/% Fx)		
Male	-.0008	±.0007
Female	-.001	±.0006
Inbreeding of dam (kg/% Fd)	-.0003	±.0003
Sex x inbreeding of dam** (kg/% Fd)		
Male	-.002	±.0006
Female	.0004	±.0004
Age at weaning weight** (kg/d)	1.2	±.1

** $P < .01$
* $P < .05$

The two-way interaction sex x inbreeding of dam was also significant. The partial regression values were -.0008 kg/% Fd and -.002 kg/% Fd for males and females, respectively. Again these small values lack biological significance. Selection for increased yearling weight in the Havre Line 4 may be masking the possible effect of inbreeding on yearling weight. Previous studies of the effect of inbreeding on yearling weight have generally found a detrimental effect (Brinks and Knapp, 1975).

Summary

The effect of inbreeding of calf and inbreeding of dam on birth weight, weaning weight and yearling weight were estimated in the Havre Line 4 Herefords. Inbreeding of calf and dam had little effect on birth weight. Inbreeding of calf caused a -.84 kg/% Fx decrease in female weaning weight. Inbreeding of dam caused a -.64 kg/% Fd decrease in male weaning weight. Inbreeding of calf and dam had little effect on yearling weight.

PART II

THE EFFECT OF SELECTION FOR AN INDEX ON BIRTH WEIGHT, WEANING WEIGHT AND YEARLING WEIGHT