Comparison of Relative Net Income with and without the application of Opportunity cost.

by

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Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Dairy Science

in

Dairy Science

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June 26, 1991

Blacksburg, Virginia

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(ABSTRACT)

This study used DHI records of 1,023,827 Holstein cows to determine the impact of adjusting measures of profit for opportunity cost and for evaluating the impact of herd-year variables and registry status on measures of profit. Relative Net Income (RNI) and RNI including opportunity cost (RNIOC), the revenue forfeited that could have been generated by a replacement heifer, were calculated for 48 month, 60 month, 72 month, and all lactations herdlife period. Application of opportunity cost caused a decreased value for length of herdlife. Number of lactations initiated prior to the various herdlife periods was the criteria for deciding how much information was included in each of the herdlife periods.

Opportunity cost per day (OCPD), the revenue forfeited that could be earned by replacement, was calculated by regressing herd-year means for RNI and days of productive life (DPL) on overall herd means based on the number of animals in herd-years, and dividing the regressed mean for RNI by the regressed mean for DPL. RNIOC for each herdlife period (i) was calculated as RNI(i) - (OCPD(i) * DPL(i)) for each cow in a herd-year.

Application of OCPD removed all of the variation due to herd and year for RNIOC. Standard deviations and means were smaller for RNIOC than for RNI. This was because there were fewer animals with extremely large values for RNIOC than for RNI. These differences increased as herdlife period advanced.

The correlation of RNI and RNIOC to 72 mo herdlife was .95. This was caused by a lower correlation with DPL for RNIOC than RNI (.73 vs. .84). First lactation yield had similar correlations with both measures.

Regression analysis showed all of the year within herd variance for profit measures and no error variance could be explained by herd management variables, with average first lactation milk dominating. Grade cows were lower than registered cows for profit measures within herd, and differences increased as herdlife period advanced.

Acknowledgements

I always think that these things sound very plastic and manufactured, two things I hate. How do you begin to say thank you to people for all that they have done for you over the past, well may ıs well call it, three years?

I would like to thank Dr. Bennet G. Cassell for putting up with me even when I was, as Winona would put it, "cutting my nose off to spite my face". To Dr. Ron Pearson, I thank you for all of the academic and personal support you have given me while at Virginia Tech. You always went the second mile. To Drs. Mike McGilliard, Bob James, and Bill Vinson, thank you for serving on my committee.

To all of the gang in the Management Lab, thank you for the laughs and the friendship that each of you gave me. I am sure that I will miss you. Maybe, now you will have a quieter, cleaner atmosphere where the words to songs have not been changed.

To Alan and Cindy, thanks for everything you did to help me both, on my project and socially.

To all of the secretaries, I would like to thank you for your friendship and support. Thanks for all of your concern.

I would also like to thank my parents, Bruce and Winona, for their love and support, my brother, Stephen, for making me laugh, and my sister, Lisa, for her bright outlook. I would also like to thank Jack and Claudie Wheeler for their friendship and opportunity to work with them over the years.

I wish all of you the best of luck. May God Bless You, and a sincere thank God its OVER!!!

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Introduction

Breeding programs and management strategies aim at increasing the profitability of the dairy farm. Definition of an appropriate profit function may aid in determining such practices.

Current selection strategies have stressed increasing income by improved first lactation yield. Past studies of profitability in field data have shown herdlife to be the dominating variable in predicting profit (8,41). Traits used in selection should be traits that have moderate to high heritabilties and are expressed early in life. Herdlife has neither one of these qualities.

Previous studies calculated profit on the assumption that the animal would not be replaced when the animal left the herd. Van Arendonk (58) included opportunity cost, the revenue forfeited by keeping a cow each day of productive life that could have been generated by a replacement heifer, in his calculation of lifetime profitability in simulated data. Application of opportunity cost to profit measures caused herdlife to be advantageous if animals were more profitable than the opportunity cost in additional days of life.

The extent to which profitablity is controlled by management practices is not known. What herd management practices should receive the greatest attention is also not known. Management practices leading to longer yield and longer herdlife would be assumed to increase herd profitability.

Registered cows have been shown to have advantages in milk production and herdlife. Dentine (20,21) suggested that differences between grade and registered herds may be in herds attempting to increase the portion registered. These differences have been assumed to be caused by differences in the way grades and registered cows are managed, and very little by genetics.

Objectives of this study were:

1. To determine the impact of including opportunity cost in profit measures given different lengths of herdlife opportunity.

2. To determine the impact of herd-year management variables in explaining changes in profit measures within herd.

3. To compare grade and registered cattle within herd for profit measures within three categories of herd-year registry status.

Review of Literature.

The goal of dairy cattle breeding and management is to increase profitability. Definition of an appropriate profit function would aid in determination of breeding goals and management practices.

Profit is some combination of income and expenses (32,42). Sales from milk yield are the primary source of income in most dairy farms. Current selection practices heavily emphasize increasing income by improving yields. Selection of sires is the primary pathway of genetic improvement (45). Bull evaluations are based heavily on the standardized ME first lactation yield records of bulls' daughters. This practice appears to be warranted because (a) milk is the primary source of income to dairy farms, (b) yield in first lactation has a moderate heritability (.15 to .40 (37)), and (c) yield in first lactation has a high genetic correlation with yield in later lactations (.7 to .95 (37)).

Differences in the rate of maturity of progeny groups (14,54), a decreasing genetic trend for herdlife (26,40), and negative correlations of first lactation yield with fitness traits (10,11) cast doubt on the use of first lactation to improve overall profitability. Dairymen often complain that daughters of bulls with high genetic evaluations last for only a few lactations. Inclusion of traits that reduce expenses are popular with dairymen. Dairymen select for improved type, whether or not any income is received from the sale of animals for breeding stock, in belief that improved workability and increased longevity will result. Selection on type traits to improve longevity could be very beneficial because selection on type traits would allow for a quicker generation interval than direct selection for longevity. However, research has not shown strong relationships of type with longevity (19,21,25,59).

Longevity is a very desirable trait in dairy cattle for animals with adequate revenue generating ability. Many feel that improvement in longevity has the potential to have greater impact on profitability than increased yield (46,57). Longevity is an important trait for total herd profit because it allows for : (a) decreased rearing expenses, (b) increased opportunity to cull for voluntary reasons (production), (c) a higher percentage of animals in the herd would be milking in more profitable later lactations, and (d) lower percentages of resources allocated to non-producing females (46).

Researchers have measured longevity as (a) age at disposal, (b) number of lactations, (c) age at last calving, (d) days of productive life, and (e) survival to various ages and lengths of productive life. Length of productive life, the time from first freshening until disposal, is of more importance economically (60). Two animals may live to be the same age, but the animal that first calved at an earlier age would have had more time in production within a herd. Stayability, the ability to survive to various ages or lengths of productive life, has been the most commonly reported measure of longevity in recent years. Everett (26) first introduced stayability as the ability of progeny groups of bulls to survive to 36, 48, 60, 72, and 84 months of age. Van Doormaal (60), in a Canadian study, measured stayability to 42, 54, 66, and 78 months of total life and 17, 30, 43, and 55 months of productive life. Van Doormaal (60) chose these lengths of total life and herdlife because they more closely related to the times following periods of heavy culling in the lives of animals.

Stayability has the advantage over other measures of longevity in that information can be gathered at various intervals before all daughters of the bull are deceased. The value of early measures of stayability, e. g. 48 month stayability, is dependent upon how closely correlated early measures of stayability are with later measures. The degree to which traits in early life are correlated with traits in later life is dependent upon the relationship of traits contributing to survival in early life and traits

Table 1. Phenotypic and genetic correlations of stayability traits, Everett, et. al. (25) [1, 2]

	Trait							
	1	2	3	4	5	6	7	8
(1) Milk		.85	.27	.41	.55	.51	.51	-.32
(2) Fat	.85		.20	.32	.45	.43	.47	-.34
(3) 36-mo stayability	.18	.13		.94	.82	.62	.58	-.11
(4) 48-mo stayability	.25	.21	.61		1.0	.99	.86	-.14
(5) 60-mo stayability	.36	.29	.53	.76		1.0	1.0	-.15
(6) 72-mo stayability	.32	.27	.39	.63	.82		1.0	-.11
(7) 84-mo stayability	.31	.29	.37	.54	.71	.85		-.09
(8) PDT	-.28	-.30	-.09	-.10	-.11	-.08	-.06	
(9) % 1st cull	-.20	-.12	-.27	-.16	-.06	-.05	-.14	.08

[1] Genetic correlations above the diagonal and phenotypic below.

[2] Genetic correlations ranging from 1.13 to 1.36 were entered as 1.0

Table 2. Estimates of heritability, genetic correlations, phenotypic correlations for stayability to lengths of total life. [1] **Van Doormaal, et al. (60).**

	Months of total life			
	42	54	66	78
42	.051	.726	..288	.219
54	.582	.040	.880	.744
66	.474	.705	..045	1.10
78	.453	.625	.786	.059

[1] heritabilities on diagonals, genetic correlations above diagonals, and phenotypic correlations above diagonals.

Table 3. Estimates of heritability, genetic correlations, phenotypic correlations for stayability to lengths of productive life. [1] **Van Doormaal, et al. (60).**

	Months of productive life			
	17	30	43	55
17	.025	.983	.952	.911
30	.624	.040	.983	1.0
43	.457	.719	.039	1.04
55	.357	.657	.766	.033

[1] heritabilities on diagonals, genetic correlations above diagonals, and phenotypic correlations above diagonals.

affecting later survival. Everett (25) found 36 month stayability had genetic correlations of .94, .82 ,.62, and .58 with 48, 60, 72, and 84 month stayabilities, respectively. (Table 1.)Van Doormaal (60) found 42 month stayabilities had lower genetic correlations with later measures of .73, .29, and .22 with 54, 66, and 78 months of total life, respectively, (Table 2), but the earliest measure of productive life, 17 month productive life, had higher genetic correlations of .98, .95, and .91 with 30, 43, and 55 months of productive life, respectively (Table 3).

These results showed that culling decisions may be more dependent on stage of productive life rather age.

Everett (25) suggested 48 month stayability and Van Doormaal (60) suggested 17 month productive life as possible traits to be incorporated into selection programs. These traits were chosen because of their high correlations with later stayabilities traits and they could be measured earlier to allow for a shorter generation interval.

Inclusion of any measure of longevity in selection programs is greatly limited by the low heritabilities. Van Doormaal et al. (60) found heritabilities of .05, of .05, 04, .05, and .06 for 42, 54, 66, and 78 months of total life. DeLorenzo (18) used logistic transformation on stayability data to model an underlying threshhold culling model and found higher heritabilities than on the linear scale (.20 vs. .10).

The ability of an animal to survive within its environment is influenced by the ability of the animal to avoid (1) culling for health reasons such as mastitis and reproduction, commonly referred to as involutary culling, and (2) culling on producing ability; voluntary culling, and (3) random accidents caused by such things as lightening, farm machinery, tractor-trailer trucks, etc. Everett (25) showed first lactation milk yield to have genetic correlations of .27, .41, .55, .51, and ,.51 with stayabilities to 36, 48, 60, 72, and 84 months, respectively. Van Doormaal (60) found first lactation milk yield to have correlations of .39, .39, .34, and .29 with stayabilities to 17, 30, 43, and 55 months of productive life. These results suggest slight differences in the trend of importance of evaluations for yield in predicting stayability as opportunity length increased, but they both suggest that bulls with higher evaluations for milk yield have daughters that last longer. Results by DeLorenzo (19) suggest that increasing yield beyond a certain level may be of little benefit in increasing stayability. His study showed that milk yield had little value in predicting stayability in the top 25 % of bulls in A.I. through 1980. The correlation of milk yield with stayability may be caused by low survival rates of daughters of bulls with poor transmiting abilities for yield.

Smith (52) argued that the sizeable correlation of survival with milk yield in first lactation suggested that selection for increased milk yield should lead to improvement in survival. Selection experiments in other species suggest that selection on a primary trait will lead to negative responses in survival (15). A negative correlated response in longevity from selecting primarily on milk yield is a common reason for evaluating longevity in dairy cattle.

Evaluation of the fitness of an animal to survive would require a model that adjusts survival ability for the yield ability of the animal(22,23,24,33). Hudson and Van Vleck (33) adjusted the variance components of stayability for the correlation with milk yield and found heritability to be reduced by 35 %. Ducrocq (22,23,24) suggested the use of two measures of stayability : (a) "true" stayability, which is the same as other measures of stayability, and (b) functional stayability, which is the ability of the animal to avoid involuntary culling. Functional stayability was measured by adding to the model of "true" stayability, which included herd by year, stage of lactation by lactation number, and a random sire effect, an effect for within herd by level of milk production. Adjustment for milk production helped remove the effects of voluntary culling so that a clearer estimate of involuntary culling could be extracted. Ducrocq (23,24) found a rank correlation of .73 between his estimates of "true" and functional stayabilities. The heritabilities of both measures were approximately .085.

Ducrocq (23,24) discussed which of these measures should be used. He stated that "true" stayability is more indicative of how long animals stayed in the herd and was probably more indicative of overall profitability, whereas functional stayability may be more indicative of the animals ability to avoid expenses such as mastitis, reproductive costs, etc. The measure of stayabilty that should be added should be the trait that adds the most after evaluations for production in determining overall profitability.

PROFIT FUNCTIONS

Profit functions have been applied to field data primarily to evaluate the importance of traits measured early in life in predicting lifetime profit. Pearson (43) concluded that studies involving profit functions differ mainly in method of estimation and completeness of items affecting profitability. The primary measures of profitability have been total profit and profit per unit time.

Andrus and McGilliard (4) evaluated the impact of traits on profit per year using lifetime data of 111 cows in the Michigan State research herd that were disposed of prior to 1974. Standard partial regression coefficients for milk, mastitis, fat test, live freshenings, herd life, body weight, and milking time, were used to predict profit per year. Milk yield was the most important variable predicting profit per year with a standard partial regression coefficient of .64. Mastitis and fat test followed milk; each with approximately half the predictive value of milk. Live freshenings was also significant with about one third the predictive value of milk. Herdlife, body weight, and milking time were not significant in predicting profit per year. The insignificance of herdlife in this study may be from its covariance with other traits in the model.

Gill and Allaire (29,30,31) and Lin and Allaire (34,35) at Ohio State University examined additional facets of profit functions. Some data (29,30,31) were from 933 Holstein cows first calving between 1955 and 1969, sired by 93 bulls, producing in 8 institutional herds. The remaining data (34,35) were from 1806 Holstein cows sired by 457 bulls, calving in 38 California herds for the first time in 1968 and 1969. Both of these data sets were limited to animals that had at least two natural calvings, and did not include information from terminal records. This was done so that reproductive parameters could be investigated. This may have biased the data to some extent because some selection for milk yield in first lactation likely occurred.

Profitability studies by Allaire and co-workers used the following profit equation (28,29,30,33,34):

Profit = (7.00 + (.08) (Fat % - 3.5) (Milk;kg) / 45.4

+ 75 (Number of Calvings) + 390

-.045 (Est. Net Energy for Maintenance, Growth, Pregenancy, and Lactation)

- 15 (Number breeding services)

- Rearing Cost

- (.6945 + .00022(Rearing Cost))(Days of Herdlife)

where Rearing Cost = 535 + .67(Age at first freshening - 730).

These studies primarily focused on: (a) the importance of first lactation performance variables in predicting profitability and performance variables to 48 months of age, 72 months of age, and lifetime, (b) the relationship among different lifetime variables, and (c) the relative efficiency of using milk records in first lactation to 305 days of lactation, a completed first lactation, and milk produced to 41 months of life in improving yield for lifetime. Both total profit and profit per day measures were used. Results of these studies concerning the impact of various traits on lifetime performance and profitability will be discussed later.

Balaine and Pearson (5) later applied four measures of profitability to the rather detailed information of lifetime data through three lactations of 182 cows in the Beltsville research herd. Cows in this study were not subjected to voluntary culling which may have slightly affected interpretation of results. The profit functions used in this study were:

Total Profit(TP) = Income - Expense

Profit Per Day(PPD) = Income - Expense / Days of Herdlife

Profit Per Unit Investment (I/E) = Income / Expense

Cost per Unit of Production (E/I) = Expense / Income

Harris (32) suggested that the profit function chosen should reflect from whose viewpoint profit should be maximized, the individual or the national viewpoint. Measures of efficiency become relatively more important than actual margin when the national viewpoint is considered. Balaine and Pearson (5) found strong correlations in all four measures. The two measures of efficiency, I/E and E/I, as expected, approached a correlation of -1. The correlation of I/E with PPD was larger than the correlation of I/E with TP (.99 vs. .92). Correlations of TP, PPD, and I/E with lifetime variables indicated that TP had a stronger relationship with milk yield and herdlife than did PPD and I/E, while the effects of mastitis were more important in determining PPD and I/E than TP.

Balaine et al (6) also calculated the cumulative and noncumulative repeatability of TP, PPD, and I/E. Cumulative measures were measures of the total profit produced to various points in life, where noncumulative measures considered only single lactations.

Cumulative measures included salvage value at the end of the lactation while noncumulative measures did not include rearing cost or salvage value. The repeatabilities of cummulative measures were higher than noncummulative measures. Cumulative measures of profit were more repeatable because the part to whole nature of cummulative measures. Cumulative measures of PPD and I/E were more repeatable than cumulative TP. Noncumulative measures of profitability showed the opposite trend in the order of increasing repeatability, with TP having a higher repeatability than PPD and I/E. Both Balaine et al. (6) and Bertrand et al. (11) found noncumulative measures of profitability to be less repeatable than individual lactation milk yield.

Norman et al. (41) applied the profit function, Relative Net Income (RNI) to 10,139 Jersey cows first calving between 1967 and 1972 in 1014 herd-years. All cows were required to have opportunity to produce in the same herd for at least 72 months. Information of milk yield was through the first 305 days of lactation, therefore estimates of actual lifetime milk yield and revenues were slightly underestimated. RNI was calculated in the following manner:

RNI = (lifetime value of product * net percentage)

+ (number of lactations * net value of calf)

+ salvage value - value at first calving

- feed cost for growth after first calving

- (days of productive life)(daily cost of maintenance, fixed, and operating expense)

The primary focus of this study was to determine the relative importance of type traits in predicting profitability. The individual type trait most related to lifetime performance in Jerseys was dairy character. Dairy character had little impact, however, when milk yield in first lactation was added to the model indicating the strong correlation of milk yield and dairy character. This study also demonstrated the strong correlation of different measures of lifetime performance and total profit-

Table 4. Phenotypic correlations between lifetime traits calculated within herd-year of calving. Norman, et. al. (41).

	Trait								
	1	2	3	4	5	6	7	8	9
(1)Number of lactations	1								
(2)Total days in milk (DIM)	.99	1							
(3)Days of productive live (DPL)	.98	.99	1						
(4)Lifetime actual milk	.95	.97	.96	1					
(5)Lifetime actual fat	.96	.97	.97	.99	1				
(6)Lifetime value of product	.96	.97	.97	1	1	1			
(7)Lifetime relative net income	.84	.87	.83	.95	.94	.95	1		
(8)Value of product per DPL	.25	.30	.23	.42	.41	.41	.60	1	
(9)Relative net income per DPL	.63	.67	.63	.69	.69	.69	.69	.54	1

ability (Table 4). All of the measures of lifetime performce such as number of lactations, total days in milk, days of productive life, lifetime actual milk, lifetime actual fat, and lifetime value of product, had extremely high correlations (> .95). The high correlations of RNI with lifetime variables indicated animals that lived the longest and produced more total product were the most profitable. The correlation of RNI was higher for total lifetime production variables than length of productive life variables which indicated that it was more important for an animal to be productive than to live a long time. Tigges and Pearson (55) used the same data set as Balaine (5,6) to test the accuracy of RNI in predicting actual profitability (TP and TP/DPL). RNI explained 95% of the variation in TP, and RNI/DPL explained 85% of the variation in TP/DPL. The standard deviation of TP was smaller than the standard deviation of RNI (589 vs. 650). These workers concluded that the larger standard deviation of RNI was caused by cows with greater profitability also having greater mastitis costs which were not accounted for in RNI. This study also showed that cumulative milk value explained 75 % of the variation in total profit, while adding days of herdlife increased R^2 to .94. The results of Tigges et al. (55) suggested that variables other than milk yield were important in determining profit and profit could be estimated with a high degree of accuracy from the RNI function. The lower accuracy of predicting PPD from RNI/DPL than TP from RNI may be due to the greater importance of mastitis costs in determining PPD, as suggested by Balaine (5,6).

A major question impacting use of profit functions is how relationships of traits change if different relative prices are applied. This subject was addressed to some degree by both Balaine et al.(5) and Tigges et al. (55). A more extensive study of the effects of price changes was conducted by Beaudry et al.(8). They calculated RNI and RNI/DPL with eleven different combinations of milk, feed, and fixed costs and compared the correlations and means. Means of RNI changed dramatically with changes in prices. Correlations of the RNIs with different combinations of prices were extremely high, generally exceeding .90, with the exception of extreme combinations of milk price and feed cost. The correlation of the different price combinations applied to RNI/DPL were even less sensitive to price changes, with most of the correlations above .99. These results indicated that the application of different prices to profit functions had very little impact on the rank of cows within a herd.

Profit functions have also been used to determine the impact of sire selection on profitability. Bertrand et al. (11) et al. demonstrated that cows sired by bulls with high predicted difference milk had more mastitis, reproductive, and general health costs but yet higher profitability than cows sired by bulls with average predicted difference. Beaudry et al (9) predicted individual daughter and daughter average for deviated RNI and RNI/DPl from sire evaluations from different lactations. This study showed a small, yet significant, R^2 of .001 to .009 for predicting individual daughter RNI and RNI/DPl from combinations of proofs for first, later, and all lactations. Progeny group averages of deviated measures of profitability could be predicted with more accuracy than individual daughter deviated measures of profitability with R^2 ranging from .097 to .360. More variation in daughter average deviated RNI than daughter average deviated RNI/DPL could be explained by different combinations of sire evaluations based upon different combinations of lactations. Sire evaluations based on records after first were most useful in predicting average daughter deviated RNI.

Cassell et al. (13) also studied the utility of sire proofs for PD Dollars (PD$) and type traits in the prediction of sire proofs for discounted RNI (DRNI) calculated in grade and registered populations. The discount rate used was 3% and income and expenses were discounted back to date of birth. Discounting would favor cows with greater income producing ability early in life. The use of a 3% discounting rate probably had minimal effects on ranking of cows. Cassell et. al. found a genetic correlation of .99 between DRNI and RNI. PD$ had the strongest correlation with evaluations of DRNI in both grade and registered populations. Models containing only PD$ had R^2 of .47 and .59. in grade and registered populations, respectively. Rogers et al. (50) found less predictive value for PD$ for 54 month stayability in grade and registered data with R^2 of .229 and .090, respectively. Udder depth was the type trait that increased R^2 after PD$ was included in the model in both grade and registered cows (50). Partial correlations adjusted for PD$ indicated that body traits, such as stature and body depth, were positively related to DRNI in registered cows and negatively in grades.

The differences in importance of traits in predicting lifetime profit for grades and registered cows suggest grades and registered cows may be treated differently.

Importance of traits in predicting lifetime profit

Several studies to date have examined the impact of production and type traits on measures of profitability. Traits impact profitability in two ways : (a) direct economic impact on the profit function, and (b) the covariance with other traits in the profit equation (42). Traits chosen for study in profit functions should be traits that have the maximum impact on profitability. If a prediction equation or selection index is desired, addition of traits should be weighted by their increase in variation explained in the profit functions. Many traits can be eliminated because they have minimal impact on profitability and/or they covary with other traits in the profit function. Addition of traits from field data is also limited by the availability of accurate information. The traits that have been studied primarily are age at first freshening, milk yield in first lactation, reproductive efficiency (% days open, number of services, and first calving interval), and days of productive life.

Age at first calving

Age at first calving has been studied most extensively by Ohio State workers (29,30,31,34,35). Their suggestion was that an earlier age at first calving would be economically beneficial. The primary reasons for decreasing age at first calving would be to decrease rearing costs, and return more quickly on investment (35). DRNI stresses age at first freshening more than RNI. For example, if two cows have equal calving intervals, number of lactations, and revenue produced in each of the lactations, and the only difference between the two animals was age at first freshening, the animal with the earlier age at first freshening would have a greater value for DRNI than the animal with a later age at first freshening because of lower rearing costs and less discounting on the revenue generated.

Allaire et al. (29) stated that the optimal age at first calving would depend upon a balance of maximizing milk per day and percent days of life in milk. They (29) found phenotypic correlations of age at first freshening with milk per day of first lactation and milk per day of herdlife of .16 and .05 respectively. Herdlife had both negative genetic (-.08) and phenotypic (-.10) correlations with age at first calving, but relationships were not strong. This study also showed age at first calving to have a positive genetic and phenotypic correlation with first calving interval suggesting that fertility in heifers was related to fertility as a cow. Age at first calving had negative correlations both genetically and phenotypcially with total profit and profit per day. Phenotypic correlations of age at first calving and total profit and profit per day were -.16 and -.24, respectively.

Lin et al. (36) conducted an experiment to determine the effects of breeding heifers after 350 days of age and 462 days of age on performance variables to 61 months of age and three parities. Animals bred after 350 days of age were superior to those bred after 462 days of age for days of productive life (730 vs. 623), total milk yield (10,693 vs. 9,218 kg), and milk /day of life (6.8 vs 5.9 kg)to 61 months of age. However, the 350d breeding age group had less milk per day of productive life (14.2 vs. 15.1 kg) than animals in the 462 day breeding group to 61 months of age. Lin and Allaire (34) found similar results with age at first calving having phenotypic correlations with total milk produced to 48 months, 72 months, and lifetime of -.36, -.15, and -.10, respectively. These results suggest that calving animals at earlier ages would be advantageous, especially for performance to earlier fixed periods.

The results of Allaire and co-workers suggested (29) that it may be advantageous to include age at first calving in selection indexes. Selection on traits of first lactation indicated that profit per day of first lactation was 24% more efficient than selection on milk per day of first lactation in predicting total profit. The addition of age at first calving to milk per day of first lactation gave equal prediction as profit per day of first lactation. Much of the value of age at first calving was due to the high heritability of age at first calving ($h^2 = .51$) and the genetic correlation of age at first calving with milk yield in later life. These workers later showed this estimate to be biased by use of sire during certain times of the year.

Gil and Allaire (30) used multiple regression to predict optimal age at first calving for total profit and profit per day of between 22.5 and 23.5 months. Research suggests that calving animals at earlier ages from current industry averages would be beneficial. Optimum age at first calving in a herd may be dependent upon the nutritional management of heifers and the culling policies of the herd (53). Animals calving earlier with poor heifer nutritional management may be culled more heavily because of poor production.

Reproduction performance

Reproduction is an important trait in determining profitability in dairy cattle. Regular calving is critical to maintain adequate production to cover costs. Reproductive performance has been cited as being the primary reason for culling in 38% of cows (30).

Optimum calving interval for a particular cow may be dependent upon several characteristics of the cow such as milk production, persistency of production, energy balance, and lactation number. The goal of optimum reproductive performance is to maximize milk per day over the lifetime of the animal. Animals with higher than average production and persistency may be more profitable with a longer calving interval because of the advantage of having a higher % days in milk.

Studies involving the impact of reproductive measures on profitability have been conducted by Gil, Lin, and Allaire (29,30,31,32,33). Lin and Allaire calculated phenotypic correlations of first calving interval with total milk yield to 48 months, 72 months, and lifetime of .42, .29, and .17, respectively. A possible reason for these correlations is that animals with longer first calving intervals were also higher producers in first lactation. Gill and Allaire (30) also used regression to show that % days open explained 6.6 and 8.1 % of the variation in total profit and profit per day. The optimum percent days dry for maximizing profit and profit per day were 32.5 and 31.0 %, respectively. The optimum percent days dry in this study corresponded with cows conceiving after approximately 125 days into lactation and calving interval of 400 days. The results of this study suggested that shorter than optimum % days open may be more detrimental than a greater than optimum % days open. Reproductive efficiency may be more critical for profit/day than total profit.

Inclusion of reproductive traits into selection practices has been limited in breeding programs because measures of reproductive performance have very low heritabilities(10). Fischer's theorem (27) states that traits of fitness, such as reproduction, should have heritabilities of near 0 because natural selection has decreased the additive genetic variance of the trait. Much of the variation in reproductive traits may be due to environmental factors, such as efficiency of heat detection and breeding techniques. Therefore, changing reproductive efficiency by selection is very limited and inclusion of reproductive traits into selection indexes is limited. Management efforts should focus on improving reproductive efficiency in order to avoid involuntary culling from infertile cows.

First lactation milk

Milk yield in first lactation has been involved in most profit studies. Milk yield in first lactation should be studied for its impact on profitability because of its prevalence in current selection practices and its obvious role in economic prosperity on the dairy farm. Milk yield is the largest and most variable source of revenues in dairy cattle. It has a repeatability of (.5) and heritability (.25) (37), and much of the voluntary culling in dairy cattle is based on first lactation yields (2,48). Therefore, the impact of milk yield in first lactation is of primary interest in studies of profitability.

Milk yields are generally reported to a fixed length of 305 days. Comparisons of milk yield to a fixed period of time allows for comparisons in rate of milk produced. Yield in first lactation has been shown to be useful for prediction of total profit and profit/day (8,29,31,35). However, profit per day has consistently been more closely correlated with milk yield in first lactation and milk per day of first lactation than total profit. Beaudry et al. (8) calculated correlations of .64 and .50 for milk yield through 305 days of lactation with RNI/DPL and RNI, respectively. Norman et al. (41) found a slightly stronger relationship of standardized ME first lactation yield with RNI and RNI/DPL in Jerseys. Gil and Allaire (31) found milk per day of first lactation to explain 31.4% of the variation in profit per day vs. 11.4% for total profit. This is due to the greater emphasis of rate of production in profit per day.

Gil and Allaire (31) suggested that the optimum milk per day of first lactation for maximizing total profit was lower than the milk per day for optimizing profit per day. This difference was due to declining herdlife for cows in the highest class of milk production. These results demonstrate the greater emphasis of herdlife in predicting total profit.

Length of Productive Life

Length of productive life or days of productive life (DPL) has consistently been the variable most highly correlated with measures of total profitabilty (8,29,30). Beaudry (8) found days of productive life to be quite variable, ranging from 7 to 4,221 days. Animals with longer length of productive life have greater opportunity to accumulate profit. Further, long productive lives spread rearing cost over more productive days. An extra day of productive life adds to total profit as long as the value of production in that day is greater than variable cost. The direct benefit of an extra day of productive life in per day measures of profitability is from the reduction in rearing costs per day.

The value of DPL in predicting both measures of total profit and profit per day is dependent upon the extent to which cows that are more profitable per day are kept in the herd. Balaine et al (5) had lower correlations for days of productive life with both TP and PPD than did Beaudry (8) for analogous measures. The animals in the study of Balaine were not subject to voluntary culling and the number of lactations available was limited to three which may have reduced correlations of profitability measures with DPL.

Current national average age suggests that keeping dairy cows longer would increase profits (40). Heritabilities of longevity is lowly heritable, (24) therefore management should make efforts to reduce the amount of culling, especially in first lactation. Gil and Allaire (30) showed TP to increase linearly with herdlife, but PPD increased at a decreasing rate with increasing herdlife. Thus optimum herdlife may depend upon the definition of profitability used.

Sources of variation in lifetime profit functions

Little is known about the genetic and environmental control of profitability. Cassell et al (12) found Discounted RNI and RNI to have heritabilities of approximately 10%. Gil and Allaire (29) calculated heritabilities of total profit and profit/day of .26 and .31, respectively. Heritability for total profit was very similar to the heritability of herdlife. for profit per day was more similar to the heritability of milk per day of life because of the high genetic correlation of milk per per day of life and profit per day. Estimates of heritabilities for profit per day by Gil and Allaire (29) may have been influenced by removing cows with only one calving.

Heritabilities of measures of total profit like measures of longevity are largely influenced by many traits which have low heritabilities. Herd management has the potential to have large impact on measures of profitability. Average life in a herd is directly determined by culling percentage if the herd is of stable size and if culling percentage does not fluctuate greatly (46). Therefore, herds that cull 33% of all cows each year should have an average herdlife of three years. Sattler and Dentine (51) found the correlation of herd average age and turnover rate to be -.51. The importance of herd life in predicting profitability suggests that herds that have longer average herdlife should also have greater average profitability.

Several studies have examined the impact of herd management policies on herdlife of cows. Andrus and McGilliard (3) found cows in herds that were quickly going off test within the next year had younger average ages than cow in herds that remained on test. Batra et al. (7) showed that herds decreasing in size culled a higher percentage of cows than did herds remaining constant in herd size and increasing in herd size. These early studies showed that changes in herd management could impact how long cows are kept in a herd.

Sattler and Dentine (51) studied the impact of changes in herd management characteristics on herd average age, percentage culled in first lactation, and turnover rate adjusted for herd size. This study used data from 376 DHI herds and 747 owner-sampler herds on test between 1969 and 1984 in Wisconsin. The model used adjusted for herd and year effects. Results indicated that significant variation in herd average age could be explained by herd characteristics after adjustment for herd and year effects. Herd and year accounted for approximately 53% of the variation in herd average age. Addition of herd characteristics increased the variation explained to 70%. In DHI herds, herds with older cows had lower averages for production, shorter first calving intervals, longer later calving intervals, larger herd sizes, lower percentages of grade cattle, older ages at first calving, and higher ratios of production of cows culled to herd average production. This study showed that changes in management variables explained significant variation in average age after the removal of sizeable effects of herd and year.

Environmental effects on measures of profitability are large. Culling rate largely influences the environment for producing profit. The amount of variation explained by herd depends upon how herds differ in profit producing ability and similarity of cows within the herd. Environment for producing maximum profit per day may stress a higher herd average for production and a shorter calving interval. Also a herd by sire interaction may be large in measures of profit because of preferential treatment for daughters of a particular bull. Some producers may retain daughters of a bull for longer if the bull is perceived to be of superior merit.

Grade or Registered Status

The differences between grade and registered cows have received considerable attention in recent years. The impact of registry status can be viewed from the perspective of the overall herd, year within herd, and the individual cow within the herd-year. Powell et al. (44) compared grades and registered cows both across and within herd. The difference (registered minus grade) for two-year old production was 274 kg overall and 118 kg within herd. This demonstrates that registered cows were in herds with higher two-year old production and registered cows also milk more within herd. Powell (44) also found registered cows had a 95 kg advantage over their grade paternal sisters within herd. These results suggest that registered cows receive better treatment within herd or are out of better dams Differences in treatment of cows on the basis of registry status resulted in a grouping system based partially on registry status in the USDA animal model genetic evaluation program (61).

Grade cows are culled more heavily for mastitis and udder problems and sold less frequently for dairy purposes than registered cows in first lactation (20,21). Dentine (20) found the per cent of animals surviving to a second lactation was 70.8 % for registered cows and 68% for grades. Similar results were shown by Nieuwhof et al. (40). Milk production has usually been considered the reason for higher culling in grades. The results of Powell et al. (44) confirm this possibility as the grade cows are less inferior to registered cows in second and third lactations, and grade cows eventually surpassed registered cows in milk production in advanced lactations.

Another factor contributing to differences between registered and grade animals could be differences in calving intervals . Nieuwhof (39) found that grade animals had shorter calving intervals, especially as older animals. This could indicate differences in reproductive criteria for culling. Real genetic differences in reproductive efficiency in grade and registered cows are unlikely, therefore the observed difference is probably a result of different culling criteria for grade cows for reproduction.

The result of more intense culling of grades for both production and reproduction is a reduced herdlife. Nieuwhof et al. (40) reported grades to have 2.4 months shorter herdlife than registered cows.

Dentine et al. (20) reported that grades were 3.06 months younger at age of disposal than registered cows. Dairymen appear to treat their registered animals better and cull them later in life than grade animals. Dentine (21) implied that heaviest culling of grades may occur in herds of mixed registry status attempting to become all registered. Registered cows are often valued more by dairymen because they perceive them to be of greater resale value than grades.

Replacement policy and Opportunity cost

Computer simulation (43, 47, 48, 49, 56, 57, 58, 59) has been used to determine the optimum management strategies to maximize profits under different economic and biological conditions. The benefits received from these studies is dependent upon how well different parameters are estimated and to what extent meaningful biological and managerial relationships and interactions are incorporated. Such studies can give guidelines for optimum management practices.

Pearson and Freeman (43) used a simulation and compared economic impact of selection on estimated breeding value (EBV) at birth, EBV on all the cows′ own records, for younger cows, and EBV based on first lactation. Selection on the cows′ EBV based on all records was generally the most advantageous because it allowed for greater selection for permanent environmental effects. Selection on EBV at birth was the best selection method under high rearing costs because of the reduced expense of rearing heifers because rearing cost per day within the herd was more important than the added revenue per day relative to the system where selection was on EBV of the cows own records.

Congleton (16) and Congleton and King (16,17) also used simulation to estimate optimum average herdlife. The simulation model used determined culling decisions on the basis of the ratio of income to expenses in the ending lactation as cows went dry. Different lengths of average herdlife were determined by changing the minimum ratio of income to expense in order for an animal to be retained. Congleton (17) predicted an average of 4.96 lactations to maximize discounted income. The optimum length of herdlife was obtained through a reduction in replacement cost and increased income in first lactation, despite decreased average milk yield, increased health cost, and reduced cull cow income. Congleton also suggested that over a range of from 4 to 5.5 lactations that income was relatively constant.

Much of the simulation work on optimum herd management and culling policies have been conducted in the Netherlands. Renkema and Stelwagen (47) used simulation to make culling decisions by comparing the marginal earned income of a cow presently in the herd with the average earned income of a replacement heifer. Calculation of each estimate was compared on an average yearly basis and included probabilities of disposal. Cows were kept in the herd until of the marginal earned income of a cow was less than the average earned income of a replacement heifer. They (47) concluded that increasing the average number of lactations from 3.3 to 5.3 would increase earned income by approximately 20%.

Van Arendonk (56,57,58,59) expanded the work of Renkema and Stelwagen (47) and applied dynamic programing to test the impact in different pricing and involuntary culling asssumptions to determine optimum culling policies. Rogers et al. (48,49) further applied Van Arendonk's dynamic programming model to economic conditions in the United States.

The model used by Van Arendonk and Rogers (48,49,56,57,58,59) would make the optimum decisions of which cows to retain to maximize profits for the herd. The model assumed constant herd size . Therefore, the primary decision to be made is whether to retain a cow currently in the herd or replace her with a heifer. The model used a 20 year planning horizon. Optimization started at the end of the planning horizon by setting the value of cows equal to their salvage value. The model then preceded backwards making the decision of whether to retain or replace a cow on the basis of which animal would be more profitable to the end of the planning horizon, the current animal or a replacement heifer. Cows in the model were described by several state variables such as lactation number, stage of lactation, and milk production in the previous and present lactation. Probabilities of survival were also incorporporated into the model.

Rogers (48,49) used this model to determine the impact of different pricing assumptions on optimum culling policies in the United States. Culling rates under the base assumptions of prices determined optimal culling percentages to be 16.5 % involuntary culling, 8.6 % voluntary culling, and an overall culling percentage of 25.1. The base level price for replacement heifers was $1100. Decreasing the replacement cost to $1000 increased overall culling to 28 % with 16 % involuntary culling and 12% voluntary culling. Increasing replacement cost by $100 decreased culling %, but to a lesser degree than a $100 decrease in replacement cost. Changes in replacement cost greatly affected culling rates in the model because replacement costs had to be paid as a heifer entered the herd. Price assumptions for other variables such as milk price and feed costs were of smaller impact and opposite than what is often seen in the dairy industry. These price assumptions did however have a large impact on profitability. Increases in milk prices and decreases in feed cost caused an increase in the voluntary and overall culling rate. This was caused by the relative dilution of replacement costs compared to the total income and expense in the life of an animal. Rogers (48) also reported that a 20% decline in the probability of involuntary culling increased overall income by $22 per year. This added revenue was attributed to a lower replacement cost, decreased frequency of low yielding cows, and increased productive life of high yielding cows. Over 50 % of the advantage of decreasing involuntary culling was due to the latter two reasons. The advantage of a decrease in involuntary culling was insensitive to changes of herd average milk production and the assumption of a strong relationship of production and involuntary culling. These results suggest that decreasing involuntary culling will be economically advantageous even if herdlife is not increased.

Van Arendonk (58) used this same model to compare cows on total profit(PRTOT), profit per day of herdlife(PPD), and profit considering opportunity cost(PROFOP). He (58) criticized previous profitability studies for neglecting to include the cost of sacrificing the profit that a replacement heifer could have generated.

Profitability measures used by Van Arendonk (58) were calculated in the following manner. Opportunity cost (OPCOST) was calculated as average PRTOT/ average HERDLIFE.

PRTOT = REVENUES - COSTS

PPD = PRTOT/HERDLIFE

PROFOP = PRTOT - HERDLIFE * OPCOST

Therefore, OPCOST was greater than average PPD because more profitable cows had longer herdlife. Average PROFOP equalled 0, and more than half of the cows had negative values for PROFOP. Inclusion of OPCOST in calculating PROFOP makes this measure equivalent to the cummulative deviation of PPD from an average day's profitability. The inclusion of OPCOST changes the relative importance of traits for PRTOT and PROFOP. The most striking difference in the two measures is that herdlife has a greatly reduced importance in predicting PROFOP than in predicting PRTOT (58). Van Arendonk (58) demonstrated that the more that culling was based on yields the higher the correlation of DPL with PROFOP. In the calculation of PROFOP, an extra day of herdlife is beneficial only if the extra day is greater than the OPCOST. This can be due to superior revenue producing ability , or below average replacement cost per day. Van Arendonk estimated that the prediction value of herdlife was overestimated by 260% when OPCOST were not included. Regression coefficients for first lactation milk were the same under PROFOP and PRTOT, and first lactation milk had a greater predictive value relative to herdlife in the calculation of PROFOP vs. PRTOT.

Use of PROFOP may be more closely related to PPD because of the greater relative emphasis of milk production. PROFOP may also be a measure that more accurately evaluates the importance of traits in order to maximize profits within a herd with fixed resources. Application of such field data must take into account the profitability differences between herds, and emphasis of traits may be different within herds. The value of herdlife in predicting profit measures including opportunity cost under field conditions is not known. impact of traits under field conditions is currently unknown. The most similar situation to PROFOP to be applied to field data was the use of higher maintenance costs per day. This pricing assumption also found a reduction in the predictive value of herdlife.

Materials and Methods

The data set used in this study consisted of lifetime production files of approximately 3.77 million cows with 10.1 million records in 388,000 herd-years. Data used were an approximate one-third sample of the herds on test. This was done by including animals with DHI herd codes ending in 2, 4, and 7. The lifetime file of each cow consisted of a fixed record length portion, which contained such information as identification of cow, sire and dam, birth date, herdcode and number of lactations, and a variable portion which contained information on each lactation of the cow. Information on each lactation included lactation number, calving date, number of days (up to 305 days) in milk, days milked 3X, days carried calf, termination code, and actual milk and fat produced to 305 days of lactation. Standardized yields were not available.

Several edits were applied to the data to ensure that cows with valid information were used for calculating the various measures of profitability. The original unedited data set was used for the calculation of herd characteristics. Unedited data, rather than the edited data, were used for calculating herd parameters because the impact of edits on the "true" herd characteristics was not known and our goal was to get as accurate a representation of the herd management characteristics as possible. Calculation and use of herd characteristics will be discussed later. The following edits were applied to the data:

1. All cows were required to have first calved between January 1, 1966 and September 1, 1987.

2. All cows were required to have both sire and dam designated as Holsteins.

3. All cows were requried to have made all of their records in herds that were on test for at least 48 consecutive months.

4. All cows were required to have been born at least 48 months before the herd stopped official DHI testing or termination of the data (Fall of 1988). i.e. 48 month herdlife opportunity.

5. All animals were required to have first calved between 548 and 1096 days of age.

6. Animals with only one lactation were deleted if they had less than 100 days in milk in first lactation.

7. Animals were deleted if any of their calving intervals were less than 270 days or greater than 730 days.

8. Animals were required to have made all records present in the lifetime file within the same herd.

9. Animals were required to have been milked in herds where at least one animal that had 48 month herdlife opportunity freshened for the first time each year while the herd was on test.

10. All animals were required to have been milked in herds that did not have any animals that had been milked 3X.

11. All animals were required to have been milked in herds that had a minimum average of 5 animals calving per year with 72 month herdlife opportunity.

Profit Functions

This study calculated five different cumulative measures of profitability, Relative Net Income (RNI), RNI per day (PPD), Discounted RNI (DRNI), RNI considering opportunity cost (RNIOC), and DRNI considering discounted opporunity cost (DRNIOC), to four lengths of herdlife. The cu(DRNIOC), to four lengths of herdlife. The cumulative measures of profitability considered the entire lactation of those initiated prior to 48 months of age (RNI1), 60 months of age (RNI2), 72 months of age (RNI3), and all records provided the animal had a minimum of 72 month herdlife opportunity (RNI4). Therefore, cumulative profit measures often included income and expenses incurred after the cutoff points. For example, an animal that initiated a 305 day lactation at 47 months of age would have all of the information from this lactation included in 48 month (Period 1) cumulative measures of profitability. The purpose of evaluating profitability measures to the different herdlife periods was to evaluate how indicative partial measures of lifetime profitability are in predicting total lifetime profitability. Edits applied for cumulative measures were slightly different for each of the four herdlife periods. For example, an animal that had 55 month herdlife opportunity, would have profitability measures calculated through 48 months of age (period 1), but would not have sufficient opportunity to calculate cumulative measures for periods 2, 3, and 4. Therefore, requiring longer herdlife opportunity for calculation of later cumulative profitability measures reduced the number of cows available for longer herdlife periods (Table 5). Consecutive measures of profitability differed only if lactations had been initiated between the two periods. Therefore, if an animal had records initiated at 24, 35, 47, and 61 months of age ;48 month and 60 month measures of profitability would be equal and would include records initiated at 24, 35, and 47 months of age, but the 72 month measure and all lactations measure would also include information from the lactation initiated at 61 months of age and would be equal, provided the animal had a minimum herdlife opportunity of 72 months.

Table 5. Number surviving to different herdlife periods.

Herdlife length	Number of cows	Number of herd-years
48 month herdlife	1,023,827	73,868
60 month herdlife	928,539	68,763
72 month herdlife	831,315	63,481
All records [1]	831,315	63,81

[1] a minimum of 72 month herdlife period opportunity was required.

Cumulative measures of profitability considered the animal to have been culled at the last day in milk of the last lactation to the various herdlife periods, therefore the animal received credit for its salvage value at this time. This was done so that all animals could be evaluated on an equivalent basis. Also the cost of maintenance from the last day in milk of the last lactation of a herdlife period until any later freshenings was not subtracted from the first cumulative profit measure in question, but was subtracted in the later herdlife period. For example, an animal that initiated a 305 day record at 40 months of age, had a period of two months not in milk, and calved again at 52 months of age, would not have the cost of maintenance for the two month period not in milk between records subtracted from 48 month measures, but this cost would be subtracted from 60 month measures. This was done to treat animals culled at the end of a herdlife period the same as those that were not.

Relative Net Income (RNI)

RNI is an estimate of the profit producing ability of an animal has been used by researchers to estimate the relative importance of traits within herd. RNI was calculated similarly to Beaudry (8,9). Slight modifications were made in the calculation of rearing expenses (which was similar to the costing method used by Foster(29)) and different costs per day of maintenance were applied for a day designated as being in milk versus a day that was not. The difference in maintenance cost was so that animals with longer calving intervals would not be doubley penalized by having the cost of milking labor subtracted during dry periods, and not crediting such animals with with production after 305 days in milk. Prices used to calculate RNI and other measures of profitability are in Table 6. RNI's for the different herdlife lengths (i) were calculated as follows:

Table 6. Prices used in profit functions.

VARIABLE	PRICES	
Milk $ / 100 kg (3.5%)	26.46	
Milk $ /kg with 0.0% fat	.172	
Fat $ / kg	2.65	
$ .1 % fat /100 kg	.26	
Feed / $ MCAL	.06	
Quanity of discarded milk (%)	3.0	
Net Efficiency (%) milk value remaining after feed costs for production	73.0	
Rearing cost/day		
Maintenance	Milking	Non-milking
feed for maintenance	.91	.91
milking labor	.79	.00
vet cost	.09	.09
facilities	.43	.22
interest	.20	.20
feeding labor	.28	.28
Total	2.70	1.70
Net Value of Calf		
Average value of calf	175.00	
- probability of mortality (10%)	17.50	
- insemination cost	30.00	
- feed cost for gestation	12.00	
Net value	110.00	
Salvage value of cow		
carcass value wt. [1]	550.00	
value of heifer calf	250.00	
Salvage Value	300.00	

[1] All animals were assumed to survive to slaughter.

RNI_i = (lifetime product $value_i$ × net efficiency %).

+ (number of $lactations_i$ × net value per calf)

− (rearing cost)

− (days life in $milk_i$ × daily maintenance feed, milking labor, fixed cost and operating cost)

− (days not in $milk_i$ × daily maintenance feed, fixed cost and operating cost).

+ 300(Salvage)

Where:

i = herdlife period (48, 60, 72, and all lactations)

Rearing cost = ((AGEFF(days) - 790) * .99) + 1130

AGEFF = date of first freshening - date of birth

Net efficiency % = net percentage of milk income after feed costs for production and discarded milk have been subtracted

Discounted RNI(DRNI)

DRNI was calculated with the same prices as RNI and calculated in a similar manner as Cassell et. al. (13), with slight modifications in points in time where daily maintenance costs were discounted back to date of birth. DRNI was calculated in the following manner with an inflation adjusted discounting rate of (i = .05%).

$$DRNI_i = \sum_{j=1}^{n} \frac{1}{(1+d)^{a_j}} \times \text{Value of product}_j \times \text{adjustment for feed cost of production and discarded milk}$$

$$+ \sum_{j=1}^{n} \frac{1}{(1+d)^{b_j}} * \text{net value of calf}$$

$$+ \frac{1}{(1+d)^{c}} \times (\text{salvage value})$$

$$- \frac{1}{(1+d)^{g}} \times (\text{heifer calf value + rearing cost})$$

$$- \sum_{j=1} \frac{1}{(1+d)^{e_j}} \times (\text{maintenance per day of productive life in milk} * \text{days in milk}_j)$$

$$- \sum_{j=1}^{n} \frac{1}{(1+d)^{f_j}} \times (\text{maintenance per day of productive life not in milk} * \text{days not in milk}_j)$$

Income from product revenue and calves, and expenses from maintenance was summed over lactations used in each of the four herdlife periods. Income and expenses were discounted back to the date of birth of the animal. Lengths of time for which discounting were applied were based on the midpoint of aquisition of income or expenses. The points in time used for discounting in the formula for DRNI were:

$j =$ lactation

$a =$ age at $\text{calving}_j + (.33 \times \text{days in milk})$

$b =$ age at calving_j

$c =$ age at calving for the terminal record to the ith herdlife period + days in milk in terminal record_i

$g = \text{AGEFF} / 2$

$e =$ age at $\text{calving}_j + (\text{days in milk}_j/2)$

$f =$ age at $\text{calving}_j + \text{days in milk}_j + .5(\text{age at calving}_{j+1} - (\text{age at calving}_j + \text{days in milk}_j))$

$n =$ number of lactations to the ith herdlife period

$d =$ discount rate $(i = .05)$

All discounting points were in fractions of years.

Overall herd means, and number of animals and means within herd-year of first freshening were calculated for measures of RNI, DRNI, and days of productive life(DPL) for each of the four herdlife periods. Means and herd-year numbers will be discussed later in the calculation of opportunity cost.

RNI per day

RNI per day of productive life or profit per day (PPD) was included because of its prevalence in past profitability studies. This measure indicates the rate of profit producing ability. Both discounted (DPPD) and non-discounted (PPD) were calculated in the following manner:

$$PPD_i = \frac{RNI_i}{DPL_i}$$

$$DPPD_i = \frac{DRNI_i}{DPL_i}$$

Where :

i = herdlife opportunity length (48, 60, 72 month and ALL)

DPL_i = (age at calving of terminal $record_i$ – age at first freshening) + days in milk of terminal $record_i$

RNI with Opportunity Cost

Both non-discounted (RNIOC) and discounted (DRNIOC) measures of profitability were calculated with the inclusion of opportunity cost (OC and DOC, respectively). The application of opportunity cost to profit functions to the four herdlife periods was done similarly to the method suggested by Van Arendonk(58). The basic formulas for the calculation of RNIOC and DRNIOC were:

$$RNIOC_{iklm} = RNI_{iklm} - (DPL_{iklm} \times OC_{ikl.})$$

$$DRNIOC_{iklm} = DRNI_{iklm} - (DPL_{iklm} \times DOC_{ikl})$$

for the ith herdlife opportunity length (48, 60, and 72 mo. and all), calculated for the mth animal freshening for the first time in the lth year in the kth herd. OCikl and DOCikl are estimates of opportunity cost for the lth year in the kth herd. Opportunity cost, as defined by Van Arendonk (58), was the profit forfeited by retaining an animal each day of the animals′ life. The income forfeited by retaining an animal each day should be equal to the income that could have been generated by a replacement heifer. The goal in calculating an opportunity cost was to reflect the average profit produced by an animal under the same herd management conditions as the animal in question. Therefore, opportunity costs were calculated by regressing herd-year means on herd means for RNI, DRNI, and DPL for the four herdlife periods, and dividing regressed herd-year means for profitability by regressed herd-year means for DPL for the corresponding herdlife period. Herd-year means were regressed on overall herd means in a method similar to that used by Meland et. al.(38). The regression employed was a function of the number of animals first freshening in a given herd and year and the ratio of error variance to the year within herd variance obtained from nested analysis including herd, year/herd, and error. Table 7 includes these ratios. This allowed for opportunity cost used for a herd-year to be reflective of characteristics of the herd, and the trends

Table 7. Ratios of error variance to year within herd variance used in calculation of Relative Net Income with opportunity cost (RNIOC) and Discounted Relative Net with opportunity cost (DRNIOC).

Herdlife length	RNI(i)	DRNI(i)	DPL(i)
48 month herdlife	6.5	6.2	30.0
60 month herdlife	10.0	9.5	34.0
72 month herdlife	14.5	13.0	34.5
All records [1]	24.5	21.5	21.5

[1] a minimum of 72 month herdlife opportunity was required.

within the herd based upon herd-year numbers. The OC and DOC for a herd-year were calculated in the following manner:

$$OC_{ikl} = \frac{rHYRNI_{ikl}}{rHYDPL_{ikl}}$$

$$DOC_{ikl} = \frac{rHYDRNI_{ikl}}{rHYDPL_{ikl}}$$

Where regressed means for herd-year RNI, DRNI, and DPL ($rHYRNI_{ikl}$, $rHYDRI_{ikl}$, and$rHYDPL_{ikl}$, respectively) were calculated in the following manner:

$$rHYRNI_{ikl} = HRNI_{ik} + \frac{n_{ikl}}{n_{ikl} + \frac{\sigma_e^2}{\sigma_{y/h}^2}} \times (HYRNI_{ikl} - HRNI_{ik})$$

$$rHYDRNI_{ik} = HDRNI_{ik} + \frac{n_{ikl}}{n_{ikl} + \frac{\sigma_e^2}{\sigma_{y/h}^2}} \times (HYDRNI_{ikl} - HDRNI_{ik})$$

$$rHYDPL_{ik} = HDPL_{ik} + \frac{n_{ikl}}{n_{ikl} + \frac{\sigma_e^2}{\sigma_{y/h}^2}} \times (HYDPL_{ikl} - HDPL_{ik})$$

Where:

$HRNI_{ik}$ = mean for RNI in the kth herd for the ith herdlife period

$HYRNI_{ikl}$ = mean for RNI in the lth year in the kth herd forthe ith herdlife period

$HDRNI_{ik}$ = mean for DRNI of the kth herd for the ith herdlife period

$HYDRNI_{ikl}$ = mean for DRNI in the lth year in the kth herdfor the ith herdlife period

$HDPL_{ik}$ = mean for DPL in the kth herd for the ith herdlife period

$HYDPL_{ikl}$ = mean for DPL in the lth year in the kth herd for the ith herdlife period

$\sigma_e^=$error variance for trait

$\sigma^2_{y/h}$ = variance of year within herd for trait

n_{ikl} = number of animals first freshening withinthe lth year within the kth

herd and summing for the ith herdlife period

Regression Models

Regression models were used to predict different lifetime profit functions. Three regression models were used in this study to determine: [1] the importance of various traits of the cow, [2] the predictive value of herd management characteristics and [3] the importance of registry status based on three classes of percent grade. The four definitions of profit to the four herdlife periods examined allowed for comparison of the relative importance of traits over progressively longer periods for expression of lifetime performance , and the relative importance of traits to different definitions of profit.

Regression model [1], along with a nested analysis of variance and covariance, aided in the determination of the importance of cow traits to the various profitability measures. The nested analysis can be written as follows:

$$Y = u + herd_k + year_{kl} + e_{klm}$$

Where:

Y = profit measure or cow characteristic

$herd_k$ = the effect of the kth herd

$year_{kl}$ = the effect of the lth year in the kth herd

e_{klm} = error associated with the mth individual in the lth year in the kth herd

The nested analysis gave : (a) the proportion of variance attributable to herd, year within herd and error, (b) the correlations of the different measures of profitability across herds and within herd-year, and (c) the correlations of various cow characteristics with the different profitability measures. The regression model including cow traits absorbed herd and year within herd and used linear and quadratic forms of age at first freshening (AGEFF), milk actual in first lactation to 305 days (MLK1), and days of productive life for the ith herdlife period (DPL(i)). A second model included linear and quadratic effects for first calving interval (CINT1) in addition to the traits in the basic model to predict profit measures. Requiring a first calving interval, therefore restricted the data set to animals with at least two calvings. The initial regression model used was:

$$\text{Profit}_{ijklm} = \alpha_{ij} + \text{herd}_{ijk} + \text{year}_{ijkl} + b_{1ij}(\text{AFEFF}_{klm}) + b_{2ij}(\text{AGEFF}^2_{klm})$$

$$+ b_{3ij}(\text{MLK1}_{klm}) + b_{4ij}(\text{MLK1}^2_{klm}) + b_{5ij}(\text{DPL}_{iklm}) + b_{6ij}(\text{DPL}^2_{iklm}) + e_{ijklm}[1]$$

Where:

i = herdlife opportunity length (48, 60, 72)month and All

j = measure of profitability (RNI, DRNI, RNIOC, and PPD)

k = herd

l = year within kth herd

m = individual within the klth herd-year

Profit_{ijklm} = the jth measure of profit in the ith herdlife

of the mth individual in the lth year in the kth herd

α_{ij} = intercept for the jth measure of profit to the ith herdlife period

herd_{ijk} = the effect of the kth herd on the jth profit measure to the ith herdlife period

$year_{ijkl}$ = the effect of the lth year within the kth herd

for the jth profit measure in the ith herdlife period

b_{1ij} = linear regression coefficient for profit on $AGEFF_{klm}$

b_{2ij} = quadratic regression coefficient for profit on $AGEFF_{klm}$

b_{3ij} = linear regression coefficient for profit on $AGEFF_{klm}$

b_{4ij} = quadratic regression coefficient for profit on $MLK1_{klm}$

b_{5ij} = linear regression coefficient for profit on DPL_{iklm}

b_{6ij} = quadratic regression coefficient for profit on DPL_{iklm}

e_{ijklm} = error associated with the jth profit measure in

the ith herdlife period of the mth cow in the lth year of the kth herd

The second regression model added linear and quadratic terms for the model including first calving interval (b_{7ij} and b_{8ij}, respectively).

Herd Characteristics

The impact of herd management characteristics on the various measures of profitability were also examined. The herd characteristics used for predicting profitability measures were statistics calculated from all of the animals calving within the herd-year from the unedited data set. Herd characteristics from the edited data set used to calculate profit functions were also determined to examine the impact of edits on herd characteristics. The unedited data were used because it was expected to be more indicative of the herd characteristics in the herd-year.

A one-fifth random sample of the edited data set was used for this portion of the study to reduce computing expenses. The model used absorbed herd, and focused on the impact of changes over years in herd-year characteristics on profitability. The maximum amount of variation that could be explained by herd characteristics was the proportion of variance attributable to herd and year within herd, because no characteristics of the individual cows were used. Linear and quadratic effects of herd-year characteristics were examined in the following model:

$$\text{Profit}_{ijklm} = \alpha_{ij} + \text{herd}_{ijk} + \sum_{n=1}^{11}(b_{1ijn}x_{kln} + b_{2ijn}x_{kln}^2) + e_{ijklm}[2]$$

Where:

Profit_{ijklm} = profit estimated for the ith herdlife period by the jth method on the mth cow in the lth year of first freshening in the kth herd.

α_{ij} = intercept for the jth profit measure in the ith herdlife period

herd_{ijk} = effect of the kth herd (absorbed)

b_{1ijn} = linear regression coefficientof the jth profit measure to the ith herdlife on

the nth herd-year characteristic in the lth year in the kth herd

x_{kln} = the nth herd-year characteristic in the lth year in the kth herd

b_{2ijn} = quadratic regression coefficient of the jth profit measure in the ith herdlife period

on the nth herd-yearcharacteristic in the

e_{ijklm} = error associated with the jth profit measuure to the ith herdlife period in the

lth year in in the kth herd on the mth cow

The following herd characteristics were computed for both the edited and unedited data sets and were used in the prediction models:

TOTCOW - the total number of calvings within a herd-year

P2YR(%) - the percent of all calvings within a herd-year by animals less than 1096 days of age and with the record designated as a first lactation

AGEFF - average age of animals calving for first time and less than 1096 days of age

AMLK2YR - average actual milk of animals calving for first time and less than 1096 days of age

AVGINT - average first calving interval of animals first calving within a herd-year provided the animal was less than 1096 days of age

PSFD(%) - percent of animals calving within a herd-year with a termination code of being sold for dairy purposes

PTERM(%) - percent of animals with termination codes as being being sold for dairy or terminated

AGEGO - average age of animals terminated or sold for dairy

PGRADE(%) - percent of calvings within a herd-year by grade grade animals

CPGRADE(%) - change in percent grade within a herd three years later

$$CPGRADE = PGRADE_{i+3} - PGRADE_i$$

RTSZ(%) - the percent change in TOTCOW within a herd three years later

$$RTSZ = ((\frac{TOTCOW_{i+3}}{TOTCOW_i}) \times 100) - 100$$

Registry status within herd

The impact of registry status within three different herd registry categories on the measures of profitability was also examined using the one-fifth sample of data used to examine herd characteristics. The model examined was used on three data sets defined by proportion grade in each herd-year, and included registry status of the individual in addition to linear and quadratic effects of AGEFF, MLK1, and DPL(i) within herd and year. This model primarily was studied to determine if registry status was significant in predicting the different definitions of profit for herds with and without variation in registry status. The three categories for herd registry status were all grade herds (> 94 % grade), all registered herds (< 6 % grade), and mixed herds (between 6 % and 94 % grade). The following regression model was used:

$$Profit_{ijklmn} = \alpha_{ij} + herd_{ijk} + year_{ijkl} + b_{1ij}(AGEFF_{klm}) ..... + b_{6ij}(DPL^2_{iklm}) + b_{7ij}R_{kln} + e_{ijklnm} [3]$$

Where all of the terms in the regression model above were the same as in model (1) except:

b_{7ij} = linear regression coefficient of the jth profit measure on the nth registry status of the mth cow

R_{klm} = registry status of the mth cow in the lth year of first freshening in the kth herd (grade = 1, registered = 2)

e_{ijklnm} = error associated with the jth profit measure to the ith herdlife period of the mth cow of the nth registry status in the lth year in the kth herd.

Results and Discussion

The results of this study will be presented in three sections. The first section will deal with comparisons of the various methods of measuring profitability to the four herdlife periods. Differences in means, standard deviations, and the variance structure for the various profit measures are compared in Section 1. The importance of traits of individuals. predicting profit measure will be discussed in this section. The second section deals with the impact of various management variables for a herd-year in explaining changes in profit measures from year to year within herd. The third section compares means of grades and registered cows for the various measures of profitability within three categories of percent grade for a herd year.

Section 1

Calculation of the different profit measures used in this study, RNI, DRNI, RNIOC, DRNIOC, and PPD, to 48, 60, and 72 month and all lactations herdlife periods allowed for the two following questions to be addressed:

(1) How and why do the various methods of measuring lifetime profit differ?

(2) What is the impact of herdlife opportunity on the different measures of lifetime profit?

The various methods of measuring profitability differed primarily in the credit received as herdlife increased. Herdlife has been shown to be the dominating variable in predicting lifetime profit in previous studies using field data (2,8,9,29,30,31,55). The primary objective of this study was to determine the impact of differences in the way revenue was credited on : (a) which cows were considered to be most profitable, and (b) the importance of traits under the different definitions of profitability.

The use of the various herdlife periods allowed for the two following types of comparisons to be made: (a) comparisons of correlations of shorter herdlife periods with longer herdlife periods within the same measure, e.g., RNI1 with RNI4, and (b) across method comparisons to see if early measures for one profit measure are more highly correlated with later measures for the same profit measure than for alternative profit definitions, e.g. correlation of RNI1 with RNI4 compared to the correlation of RNIOC1 with RNIOC4. The correlation of earlier measures of profitability with later measures may be helpful in determining how early in the animals life accurate predictions of total profit can be obtained. This question will help to demonstrate how much herdlife opportunity is needed in order to express adequate variation in herdlife and consequently in the various measures of profitability. Knowledge of how accurate early methods of profitability are in predicting later measures could be beneficial in making both breeding and management decisions.

The criteria for determing how much information was included in the three time limited herdlife periods, 48, 60, and 72 month herlife opportunities, was dependent upon the number of lactations present in the lifetime production files that were initiated prior to the respective herdlife period cutoff points. The number of lactations that went into each of these three herdlife periods was restricted by the edits of : (a) a minimum age at first freshening of 18 months (548 days), and (b) a

Table 8. Distribution of number of cows by year of first freshening.

YEAR	# OF ANIMALS	%
1966	20,421	2.0
1967	23,590	2.3
1968	26,551	2.6
1969	29,273	2.9
1970	32,233	3.1
1971	33,567	3.3
1972	35,223	3.4
1973	36,459	3.6
1974	37,880	3.7
1975	39,300	3.8
1976	41,533	4.1
1977	46,543	4.5
1978	48,821	4.8
1979	55,710	5.4
1980	61,514	6.0
1981	67,354	6.6
1982	71,128	6.9
1983	77,223	7.5
1984	74,426	7.3
1985	78,736	7.7
1986	72,692	7.1
1987	13,650	1.3

minimum calving interval of 270 days. Therefore, the maximum number of lactations to 48, 60, and 72 month herdlife was 4, 5, and 7 lactations, respectively. The maximum number of lactations used in the fourth herdlife opportunity group, or all lactations, was 10. The number of animals that survived to later lactations in the fourth herdlife period was biased downward because many animals did not get adequate herdlife opportunity to express later lactations since data collection ended in 1988. Table 8 contains the distribution of the number and percent of animals by year of first freshening. Over 50 percent of the data are from animals first freshening after 1980. Very few of these animals would have had opportunity to have had eighth, ninth, and tenth calvings.

One of the focuses of this study was to determine how much impact herdlife opportunity had on an animals' ability to express variation in each of the methods of measuring profit used in this study. New variability introduced into a profit measure by the additional income generated in lactations initiated after the preceding period's cutoff. Table 9 contains a distribution of number of animals that survived to each lactation to 48, 60, and 72 months and all lactation herdlife periods. The number of animals that survived to each of the first three herdlife periods were not equal because 95,288 and 97,224 cows did not pass the edits for 60 and 72 month herdlife opportunity, respectively. However, interpretation of the percentage of animals that survived to each lactation over the four herdlife periods may aid in demonstrating how the distribution of the percent of animals surviving to each lactation changed as herdlife period increased.

The number of animals that survived to the various lactations in the first herdlife period (Table 9) indicated that no animal in the data set had initiated the theoretical maximum possible number of 4 lactations. Only a small percentage of the animals (4.5%) had initiated a third calving. No cows in all three of the limited herdlife periods reached the theoretical maximum number of lactations. The animals that survived to three lactations in the 48 month herdlife period were animals that were more likely to have been younger at first calving, and have had shorter average calving intervals than animals with fewer lactations. The number of lactations to 48 month herdlife was more dependent upon age at first freshening and calving intervals than later herdlife periods because fewer animals had yet been disposed.

Table 9. Distribution of total number of lactations to four herdlife periods

	48 MONTH		60 MONTH		72 MONTH		ALL LACT.	
# lactations	number	%	number	%	number	%	number	%
1	246,436	24.1	174,521	18.7	153,695	18.5	153,695	18.5
2	731,169	71.4	268,827	30.0	180,301	21.7	179,690	21.6
3	46,222	4.5	457,785	49.3	211,021	25.4	152,124	18.3
4			27,406	3.0	270,778	32.5	135,020	16.2
5					15,520	1.8	96,572	11.6
6							57,671	6.9
7							30,987	3.7
8							15,110	1.8
9							6,549	.8
10							3,897	.5

The average number of lactations to 48, 60, and 72 month and all lactation herdlife periods was 1.80, 2.39, 2.77, and 3.33 lactations, respectively. The average number of lactations to the fourth herdlife period, 3.33, was higher than the average of 3.13 reported by Beaudry (9). This was due to a lower percent of animals with only one lactation because of the requirement that animals with only one calving have a minimum of 100 days in milk. The cows that caused the increase in average lactation number from one herdlife period to the next were animals that had had more lactations in the previous herdlife period. The distribution of lactation number to the three limited herdlife periods were slightly skewed to the left. The distribution of lactation number to the fourth herdlife period was skewed slightly to the right.

The percentage of animals with only one lactation was fairly constant for the second, third, and fourth herdlife periods at approximately 18.5 percent. The slightly higher percentage of animals with only one lactation to the first herdlife period was probably caused by animals that were older at first calving that had not yet calved for a second calving. The percentage of animals with only two lactations was approximately equal in the third and fourth herdlife periods. The change in the distribution of lactation number over herdlife periods was through animals increasing in lactations with advancing herdlife periods. This demonstrated that some animals did not have adequate opportunity to express herdlife because of truncating the data at certain points.

The variability in the number of lactations that went into each of the three limited herdlife periods was dependent upon the ages at calving for the various lactations of the animal. Table 10 contains the averages, ranges and standard deviations for ages at the various calvings and calving intervals for all animals in the data set regardless of herdlife opportunity. Age at first calving averaged 857 days, or 28.2 months, with a standard deviation of 104 days (3.4 months). The 826,323 animals that calved a second time had an average age of 1,254 days (41.3 months) with a standard deviation of 125 days (4.1 months). These animals had an average calving interval of 397 days (13.1 months) with a standard deviation of 66 days (2.2 months). The increase in the standard deviation in age at calving from first to second calving was due to variability caused by reproductive performance. Standard deviations and ranges for ages at calving for the various lactations tended to increase with

Table 10. Ages at calving and calving intervals for various lactations.

Lactation	Number	Age at calving (da) Mean	SD	Min.	Max.	Calving interval (da) Mean	SD
1	1,023,827	857	104	548	1,096	397	66
2	826,323	1,253	125	853	1,824	395	62
3	572,584	1,643	144	1,151	2,496	397	62
4	360,723	2,035	163	1,536	3,063	400	64
5	210,694	2,427	181	1,880	3,484	403	65
6	114,214	2,818	200	2,203	4,119	406	67
7	56,543	3,208	216	2,610	4,510	409	68
8	25,556	3,597	231	2,979	4,807	411	69
9	10,446	3981	244	3,358	5,200	412	70
10	3,897	4,358	254	3,779	5,450	---	---

lactation number due to the cumulative variability in calving intervals. Age at second calving was greater than age at third calving minus second calving interval which suggested that animals older at second calving had a lower probability of having a third calving than animals younger at second calving. This trend increased as lactation number increased. Calving intervals past second showed an increasing trend which suggested a decline in reproductive performance as lactation number increased. Standard deviation for calving interval showed a similar trend. First calving interval had a higher ratio of standard deviation to mean which suggested that poor reproductive performance may be more tolerated in first lactation. Nieuwhof (39) reported similar trends for ages at calvings and calving intervals, such as increasing standard deviation in age at calving with increasing lactation number, etc., for the ones shown in this study. The ages at calving in Table 10 indicate that the "average" cow could have had 2, 3, and 4 calvings by 48, 60,and 72 month herdlife opportunity.

Increase in profitability from one herdlife period to the next was also influenced by milk production as animals approached maturity. Table 11 contains averages and standard deviations for days in milk, and actual milk and fat production. First lactation milk production averaged 5,958 kg with a standard deviation of 1,518 kg. Average first lactation milk production was slightly higher than the average first lactation milk production reported by Beaudry (9) because of the edit for a minimum of 100 days in milk if only one lactation applied to these data. Average production in later lactations was slightly lower than in the study reported by Beaudry (9). Average milk production increased fairly dramatically from first to second lactation. This was due to maturity and culling on production that occurred in first lactation. Milk production continued to rise through the fourth lactation. The standard deviation in milk production continued to increase through the seventh lactation likely because of a increase in the portion of animals with terminal records. An increased standard deviation of days in milk supports this contention. Maximum lactation length was 305 days, so only shorter lactations could increase the standard deviation for days in milk. Changes in averages and standard deviations for fat production as lactation number increased were less dramatic than trends in milk production, but showed similar trends.

Table 11. Days in milk, milk, and fat for various lactations.

Lact.	#	Days in milk		Actual Milk (kg) Yield				Actual Fat (kg) Yield			
		Mean	S.D.	Mean.	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
1	1,023,827	289	39	5,958	1,518	54	15,835	218	56	2	698
2	826,323	277	56	6,727	2,007	54	18,157	245	74	2	797
3	572,584	269	68	7,024	2,248	54	18,897	256	83	2	845
4	360,723	265	71	7,105	2,362	54	17,967	259	87	2	774
5	210,694	262	75	7,048	2,435	50	16,942	257	90	2	708
6	114,214	257	78	6,874	2,475	64	15,763	250	91	3	662
7	56,543	253	81	6,641	2,508	59	16,320	242	92	3	588
8	25,556	248	83	6,389	2,494	86	14,588	237	92	4	588
9	10,446	244	85	6,139	2,492	109	14,402	224	92	4	545
10	3,897	239	87	5,876	2,458	149	12,619	213	90	5	510

The methods differed primarily in credit given to revenue as herdlife increased. RNI, the most commonly used of the measures in previous studies, had no reduction of the value of revenue as herdlife increased. RNI can be considered a type of control to examine the impact of different methods of the the way revenue was credited. DRNI, because of the discounting, reduced the net percentage of value for revenue received as herdlife increased. RNIOC, the first application of Van Arendonk's (58) concept of opportunity cost applied to field data, applied a constant charge to each day of productive life. DRNIOC combined discounting and opportunity cost and may not be technically correct because of differences in the amount of discounting that the animal in question and the opportunity cost consider. Results are presented, however, to aid in interpretation of impact of discounting and consideration of opportunity cost.

Opportunity cost should reflect income that is sacrificed by keeping an animal that could have been generated by a replacement heifer under similar conditions. The regression procedure used to determine OCPD (discussed earlier) protected against dramatic fluctuations in profitability caused by low cow numbers within a herd-year. This method, however, could be insensitive to dramatic fluctuations in profit producing ability within a herd over time, especially for animals that were outliers for days of productive life within a herd-year. This would result in cows having an opportunity cost that was not truly indicative of the profit producing ability environment of the animal. The magnitude of this potential problem should be less for shorter herdlife period groups.

The OCPD that was subtracted from each cow reflected the average profit that would be produced in an average day by animals first calving within the herd-year, not the average profit per day of all animals first calving within a herd-year. Therefore, the opportunity cost should be a weighted average of profit per day within a herd-year where each individual's PPD is weighted by its DPL to the various herdlife periods. This can be written as:

$$OCPD_{iklj} = \Sigma PPD_{ikljp} \times DPL_{ikljp}$$

i = herdlife period (1,2,3,4)

k = profit measure (.non-.discounted or discounted)

l = herd

j = year within herd

p = individual within herd-year

OCPD can also be viewed conceptually as the total income minus total costs generated by animals within a herd-year divided by the total DPL by all animals within a herd-year to the various herdlife periods. Which can be written as:

$$OCPD_{iklj} = \frac{\text{Total Revenue}_{iklj} - \text{Total Cost}_{iklj}}{\text{Total DPL}_{iklj}}$$

This equation can be further broken down into the proportion of the OCPD that came from the income generated after animals entered production and the costs of rearing animals. This can be written as:

$$OCPD_{iklj} = \frac{\text{Tot. Net Inc. after first calving}_{iklj}}{\text{Total DPL}_{iklj}} - \frac{\text{Total Rearing Cost}_{iklj}}{\text{Total DPL}_{iklj}}$$

The different ways of viewing opportunity cost help to understand the characteristics of opportunity cost and how it affects RNIOC. Many of the characteristics of opportunity cost are driven by the way the rearing cost portion of opportunity cost is calculated. Opportunity cost for a herdlife period is generally greater than the average profit per day to the same herdlife period within a herd-year. This is because the regressed average of rearing cost per day by the DPL of the animals within a herd-year should have been less than the average rearing cost per DPL. Less rearing cost means higher opportunity cost. Also opportunity cost increases with later herdlife periods. As animals have more days of productive life and lower rearing cost per day as herdlife periods increase, the reduced rearing cost also receives more weight causing an increased opportunity cost.

A better understanding of opportunity cost helps to explain the direct impact of traits, namely herdlife, on the various profit functions. An additional day of herdlife will be advantageous for RNI as long as the revenue generated in the additional day is greater than the variable cost. DRNI behaves similarly, but enough revenue must also be generated to cover the reduction of the credit received for salvage value because of discounting. RNIOC might best be understood as an added expense per day. This can be written simply as:

$$RNIOC_{ikljp} = RNI_{ikljp} - (OCPD_{iklj} \times DPL_{ikljp})$$

Therefore, in order for an animal to have positive values for RNIOC, that animal has to have a greater PPD than the OCPD cost within the herd-year. RNIOC can be viewed as a cummulative deviation of PPD from OCPD which can be written as:

$$RNIOC_{ikljp} = DPL_{ikljp} \times (PPD_{ikljp} - OCPD_{iklj})$$

The PPD of an animal can be further broken down into the average income per day minus the rearing cost per day of the animal. Therefore, an animal could have PPD greater than OCPD, either by having greater revenue per day or by having lower rearing cost per day than those of the OCPD. RNIOC can also be written as:

$$RNIOC_{ikljp} = DPL_{ikljp}(REVPD_{ikljp} - OCREVPD_{iklj}) - DPL_{ikljp}(REARCPD_{ikljp} - OCREARPD_{iklj})$$

where:

REVPD = the average revenue per day of the individual

OCREVPD = the revenue portion of the opportunity cost

REARCPD = the rearing cost per day of the individual:

OCREARPD = the rearing cost portion of the opportunity cost

All the measures of profit include rearing cost. An animal must have paid rearing cost in order to have had a positive value for RNIOC. RNIOC is slightly different though, in that, animals can also be viewed as being credited with the rearing cost portion of opportunity cost each day the animal was in the herd. This was the primary direct financial advantage of having a longer herdlife under this definition of profitability. This can be viewed as the benefit of not having to raise a heifer gained by a cow maintaining a slot in the herd. Rearing cost, like daily maintenance cost, largely cancelled out in the RNIOC equation because a replacement would also incur these costs.

The differences in means, standard deviations, and ranges for the various measures of profitability to the four herdlife periods can be seen in Tables 13-16. (definitions of abbreviations Table 12) Animals with shorter herdlives are less affected by the application of discounting and opportunity cost to RNI than animals with longer, more profitable herdlives. This can be shown by comparing two example cows, Cow 1, who had only one lactation, and Cow 2, who had eight lactations. Constant positive revenue production per lactation was asssumed to simplify matters. Cow 1 would have equal values over the four herdlife periods for RNI, PPD, DPPD, DPL and DRNI. Cow 2 would be increasing in values for the same measures. The impact of discounting for Cow 1 would be constant and small over the four herdlife periods because there was little revenue to be discounted and the revenue produced was discounted less because of a shorter period of time. The difference in RNI and DRNI was larger as herdlife periods advanced for Cow 2 because of the cumulative effects of discounting and the net percent received for revenue decreased as lactations in-

Table 12. Definitions of profit measures and various traits of cows.

VARIABLE	Definitions
(i)	indicates the herdlife period where 1 = 48 month herdlife period where 2 = 60 month herdlife period where 3 = 72 month herdlife period where 4 = all lactations herdlife period
RNI(i)	Relative Net Income to the ith herdlife period
DRNI(i)	Discounted RNI to the ith herdlife period
RNIOC(i)	RNI with the application of opportunity cost to the ith herdlife period
DRNI0C(i)	Discounted RNI with the application of discounted opportunity cost to the ith herdlife period
PPD(i)	RNI per day of productive life (DPL) to the ith herdlife period
DPPD(i)	Discounted PPD to the ith herdlife period
PDOC(i)	PPD with the application of opportunity cost to the ith herdlife period
DPDOC(i)	DPPD with the application of discounted opportunity cost to the ith herdlife period
OCPD(i)	opportunity cost per day to the ith herdlife period
DOCPD(i)	discounted OCPD to the ith herdlife period
TOC(i)	total opportunity cost to the ith herdlife period (OCPD(i) * DPL(i))
DPL(i)	days of productive life to the ith herdlife period
AGEFF	age at first freshening
DAGE(i)	DPL(i) + AGEFF
TMLK(i)	total milk to the ith herdlife period
TFAT(i)	total fat to the ith herdlife period
TDASM(i)	total days in milk to the ith herdlife period
MLK1	actual milk production (kg) in first lactation
Q	addition of q to MLK1,AGEFF, and DPL(i) denotes the quadratic form

*For definitions refer to Table 4.

Table 13. Means of lifetime variables and profit measures to 48 months from 1,023,827 cows,

VARIABLE	MEAN	SD	MIN	MAX
RNI1($)	61.65	567.20	-1,773.62	4,219.31
DRNI1($)	-51.48	482.76	-1,624.34	3,481.13
RNIOC1($)	-8.73	428.22	-1,707.61	2,984.48
DRNI0C1($)	-7.74	387.42	-1,411.33	2,536.20
PPD1($)	-.29	1.51	-125.34	5.99
DPPD1($)	-.47	1.41	-120.00	4.90
PPDOC1($)	-.39	1.37	-124.64	4.45
DPPOC1($)	-.37	1.29	-119.17	3.78
OCPD1($)	.10	.55	-2.42	2.92
DOCPD1($)	-.10	.48	-2.41	2.32
TOC1($)	70.39	336.61	-2,110.31	2,289.48
DPL1	583	208	8	1,200
DAGE1(d)	1439	208	659	1765
TMLK1(kg)	11,353	4,601	104	37,272
TFAT1(kg)	414	168	4	1,474
TDASM1(d)	511	165	8	915

* For definitions of profit measures refer to Table 12.

Table 14. Means of lifetime variables and profit measures to 60 months herdlife period from 928,539 cows.

VARIABLE	MEAN	SD	MIN	MAX
RNI2($)	389.24	835.26	-1,895.90	6,921.50
DRNI2($)	201.30	688.65	-1,738.91	5,490.86
RNIOC2($)	-11.76	568.76	-2,338.48	4,163.46
DRNI0C2($)	-10.17	500.18	-1,965.13	3,530.80
PPD2($)	-.01	1.56	-10.58	5.99
DPPD2($)	-.21	1.44	-10.09	4.90
PDOC2($)	-.50	1.44	-11.40	3.87
DPDOC2($)	-.46	1.35	-10.64	3.28
OCPD2($)	.49	.50	-2.01	3.01
DOCPD2($)	.25	.43	-1.93	2.38
TOC2($)	401.00	336.61	-2,110.31	2,289.48
DPL2	796	35	100	1,571
DAGE2(d)	1,653	336	659	2,130
TMLK2(kg)	15,293	7,300	467	49,016
TFAT2(kg)	558	267	15	2,102
TDASM2(d)	667	264	66	1,220

*For definitions of profit measures refer to Table 12.

Table 15. Means of lifetime variables and profit measures to 72 months herdlife period from 831,315 cows.

VARIABLE	MEAN	SD	MIN	MAX
RNI3($)	630.86	1,080.56	-1,992.30	7,849.82
DRNI3($)	377.79	865.78	-1,791.46	6,270.91
RNIOC3($)	-13.20	687.53	-3,498.56	5,248.27
DRNI0C3($)	-11.55	590.18	-2,777.22	4,353.76
PPD3($)	.07	1.60	-10.58	5.99
DPPD3($)	-.14	1.47	-10.09	4.90
PPDOC3($)	-.58	1.50	-11.63	3.55
DPPDOC3($)	-.53	1.39	-10.82	2.94
OCPD3($)	.66	.47	-2.01	2.93
DOCPD3($)	.40	.40	-1.94	2.38
TOC3($)	644.06	602.34	-2,028.17	4,391.54
DPL3	953	464	100	1,943
DAGE3(d)	1,810	467	659	2,496
TMLK3(kg)	18,187	9,916	467	62,913
TFAT3(kg)	664	362	15	2,258
TDASM2(d)	782	360	66	1,525

*For definitions of profit measures refer to Table 12.

Table 16. Means of lifetime variables and profit measures for > 72 month herdlife period with all lactations for 831,315 cows.

VARIABLE	MEAN	SD	MIN	MAX
RNI4($)	902.75	1569.11	-2,637.36	14,946.20
DRNI4($)	603.84	1,175.17	-2,172.00	10,436.33
RNIOC4($)	-11.36	912.67	-3,829.21	8,980.07
DRNI0C4($)	-10.20	716.55	-3,050.67	6,525.79
PPD4($)	.03	1.72	-11.48	5.88
DPPD4($)	-.11	1.48	-10.09	4.90
PPDOC4($)	-.74	1.64	-12.70	3.24
DPPDOC4($)	-.62	1.42	-10.95	2.76
OCPD4($)	.77	.46	-2.14	2.70
DOCPD4($)	.51	.37	-1.94	2.14
TOC4($)	914.11	882.60	-2,818.82	9,971.42
DPL4	1,161	763	100	4,708
DAGE4(d)	2,018	767	659	5,739
TMLK4(kg)	22,069	15,494	467	121,296
TFAT4(kg)	805	567	15	4,709
TDASM4(d)	927	569	66	3,050

* For definitions of profit measures refer to Table 12.

creased. RNIOC was the only measure of profit that could change as herdlife increased for Cow 1 because of changes in opportunity cost. The difference for RNI and RNIOC for Cow 2 would increase as herdlife increased because of more DPL to multiply by OCPD. If it were assumed that Cow 2 had a constant amount of revenue produced per day, RNI would have a constant increase per day, DRNI would have a decreasing increase each day, and RNIOC would have a constant scaling relative to the revenue produced per day for RNI. The impact of discounting per day could be greater than opportunity cost per day depending upon the opportunity cost, the discounting rate, the revenue produced and the age of the animal when generating the revenue.

The differences in the way that profit measures were calculated was shown in the differences in the means, standard deviations, and ranges of the various profit measures to the four herdlife periods. Comparison of the means of the four cummulative profit measures, RNI, DRNI, RNIOC, and DRNIOC, showed RNI to have the highest value to all four herdlife periods, generally followed by DRNI, RNIOC, and DRNIOC. The only exception to this order of decreasing means for profitability was in the first herdlife period, where RNIOC was greater than DRNI. Comparison of the means of DRNI, RNIOC, and DRNIOC to RNI over the four herdlife periods showed impact of different methods revenue was credited. Therefore, it can be concluded that the effect of discounting was greater on average than opportunity cost to the first herdlife period.

The most obvious impact of discounting was, as expected, that the differences in RNI and DRNI became greater as herdlife period increased. The ratio of the increase in DRNI from one herdlife period to the next to the increase in RNI over the same change in herdlife period became smaller as herdlife periods increased.

The ratio of increase in DRNI to RNI going from the third herdlife period to the fourth herdlife period was smaller than the same ratio going from second to third herdlife periods. This was not technically possible. Originally, RNI4 was calculated incorrectly by subtracting discounted rearing cost (which used the mid-point between birth and age at first freshening as the discounting point) instead of the non-discounted rearing cost. In attempts to correct this problem, a discounted rearing cost was added back to RNI4 and the non-discounted rearing cost was subtracted. This time the discounted rearing cost used the age at first freshening as the discounting point. This caused a smaller value of discounted rearing cost to be added back into RNI4, therefore RNI4 was always slightly underestimated. This difference was greater for animals that were older at first freshening. Rearing cost for an animal with the average age at first calving of 857 days was underestimated by approximately $66.

The difference in RNI and RNIOC, total opportunity cost (TOC), was a function of the OCPD to a herdlife period within a herd-year and the DPL of the animal. More profitable animals with above average DPL within a herd-year with an highly positive OCPD would have a value considerably lower for RNIOC than for RNI. An animal with the same values for RNI and DPL within a herd-year with a highly negative OCPD would have a considerably higher value for RNIOC than RNI. The effects of opportunity cost were different from the effects of discounting in that: (a) opportunity cost varied from herd-year to herd-year, (b) opportunity cost varied from herdlife period to herdlife period within herd-year, (c) discounting had a greater impact on animals that produced more revenue per day, where OCPD was the same for all animals of equal DPL within a herd-year to a given herdlife period, and (d) discounting increased as a percentage over the herdlife of the animal, where opportunity did not change over time.

The average OCPD to 48 month herdlife (OCPD1) was $.10 with a standard deviation of $.55. OCPD1 ranged from -$2.42 to $2.92 (Table 13) The percent of animals with a negative OCPD1 and TOC1 to the first herdlife period was 43.1 percent. These animals would have values for RNIOC1 greater than RNI1. The percent of animals with negative OCPD and TOC was 16.3, 8.0, and .5 percent to the second, third, and fourth herdlife periods. The percent of animals with a negative opportunity cost declined over time primarily because the rearing cost per day portion of OCPD was diluted over more DPL due to increasing herdlife opportunity.

OCPD1 was greater than PPD1 at 48 month herdlife period ($.10 vs. -$.29). This was expected because cows with above average PPD within herds were expected to have above average DPL.

The positive relationship of DPL and PPD was somewhat automatic because rearing cost per day decreased as DPL increased. The difference in average OCPD and PPD became greater as herdlife period increased. PPD could only increase from one herdlife period to the next by individual animals increasing in PPD. OCPD could also increase by animals with higher PPD increasing in DPL and receiving more weight.

The standard deviation in OCPD decreased with increased herdlife period, compared to the standard deviation for PPD that increased with herdlife period. The standard deviation for PPD increased because animals that caused the increase in PPD over herdlife periods had values further from the mean for PPD for each herdlife period. The decrease in the standard deviation of OCPD may have been due to the differences in the degree to which herd-year means were regressed back to overall herd means for the various herdlife periods. The difference in the regression of OCPD may have been caused by differences in ratios of standard deviations and herd-year numbers.

The goal of computing OCPD to a herdlife period within a herd-year was to use an OCPD that represented the average PPD over all DPL of the animals within the herd-year. Summing the deviation of PPD from OCPD for a cow multiplied by the cow's DPL within a herd-year should, therefore, in theory equal 0. This would extend to all of the data. Van Arendonk's (58) profit measure that included opportunity cost averaged 0. RNIOC to all four herdlife perioids should have also averaged 0. The average RNIOC was slightly negative to all four herdlife periods. The exact reason for this slight discrepancy is not known.

The difference in average RNI and average RNIOC for a herdlife period should be equal to the average TOC to a herdlife period. The TOC (total opportunity cost) was slightly greater than the average RNI to each herdlife period. The standard deviation of TOC was $336.61, $469.85, $602.34, and $882.60 to the first, second, third and fourth herdlife periods, respectively. The increase in variability in TOC as herdlife period increased was due largely to the : (a) increased variability in DPL as herdlife period increased, and (b) increased average OCPD as herdlife period increased. The increased variability in TOC indicated that there was increased shuffling of RNIOC relative to RNI.

The distributions of RNIOC and RNI to 72 month herdlife opportunity are in Table 17 and Figure 1. The most notable changes in the distribution of RNIOC3 from RNI3 from the application of opportunity cost were: (a) a much larger percent of observations were negative for RNIOC3 (57.0% vs. 35.5%), (b) a considerably higher percent of observations with values greater than $2,000 for RNI3 than for RNIOC3 (12.3% vs. .6%), and (c) RNIOC3 is less variable than RNI3, i.e. the height of the curve is much greater for RNIOC3 than for RNI3. The reduction of the number of animals with higher values for RNIOC relative to RNI became more pronounced as herdlife period advanced.

The lower values for DRNI and RNIOC relative to RNI caused smaller deviations for these measures relative to the standard deviations for the RNI measures. The standard deviations (Tables 13-16) show similar trends in size as the means, with RNI having the greatest standard deviation, followed by DRNI, followed by RNIOC. RNI to each of the four herdlife periods had the greatest standard deviation, followed by DRNI, RNIOC, and DRNIOC. The ratio of the standard deviations of DRNI, RNIOC, and DRNIOC to the standard deviation of RNI became smaller as herdlife period advanced. The standard deviations of RNI, DRNI, RNIOC, and DRNIOC, all increased over time. The ratio of the standard deviations of RNI2 to the standard deviation of RNI1 was larger than the analagous ratios for DRNI, RNIOC, and DRNIOC. The ratios of standard deviations of later measures of RNI to the standard deviation of RNI1 became increasingly larger than analagous ratios for other measures of profit as herdlife increased. This showed that the variance of RNI increased proportionately more as herdlife period increased than did other methods of measuring profit. The reason for the difference can be seen in the differences in the maximum values for the various measures and the comparison of the various profit measures in the fourth herdlife period for the example animal with longer herdlife (Table 16).

Table 1. Distribution of Relative Net Income (RNI), RNI adjusted for opportunity cost (RNIOC), and total opportunity cost (TOC) to 72 month herdlife period (TOC3).

Ranges	RNI3		RNIOC3		TOC3	
	#	%	#	%	#	%
< -1,500	95	0	551	.1	27	0
-1,500 < x < -1,000	3,724	.4	15,454	1.9	595	.1
-1,000 < x < -500	115,743	13.9	228,639	27.5	4,994	.6
-500 < x < 0	195,481	21.1	229,329	27.6	60,448	7.3
0 < x < 500	137,414	16.5	169,660	20.4	341,315	41.1
500 < x < 1,000	119,456	14.4	111,638	13.4	217,439	26.2
1,000 < x < 1,500	100,699	12.1	52,489	6.3	124,760	15.0
1,500 < x < 2,000	76,293	9.2	17,851	2.1	56,584	6.8
2,000 < x < 2,500	50,311	6.1	4,530	.5	19,507	2.3
2,500 < x < 3,000	28,494	3.4	948	.1	4,648	.6
3,000 < x < 3,500	14,323	1.7	194	0	889	.1
3,500 < x < 4,000	6,072	.7	23	0	92	0
> 4,000	3,211	.4	9	0	17	0

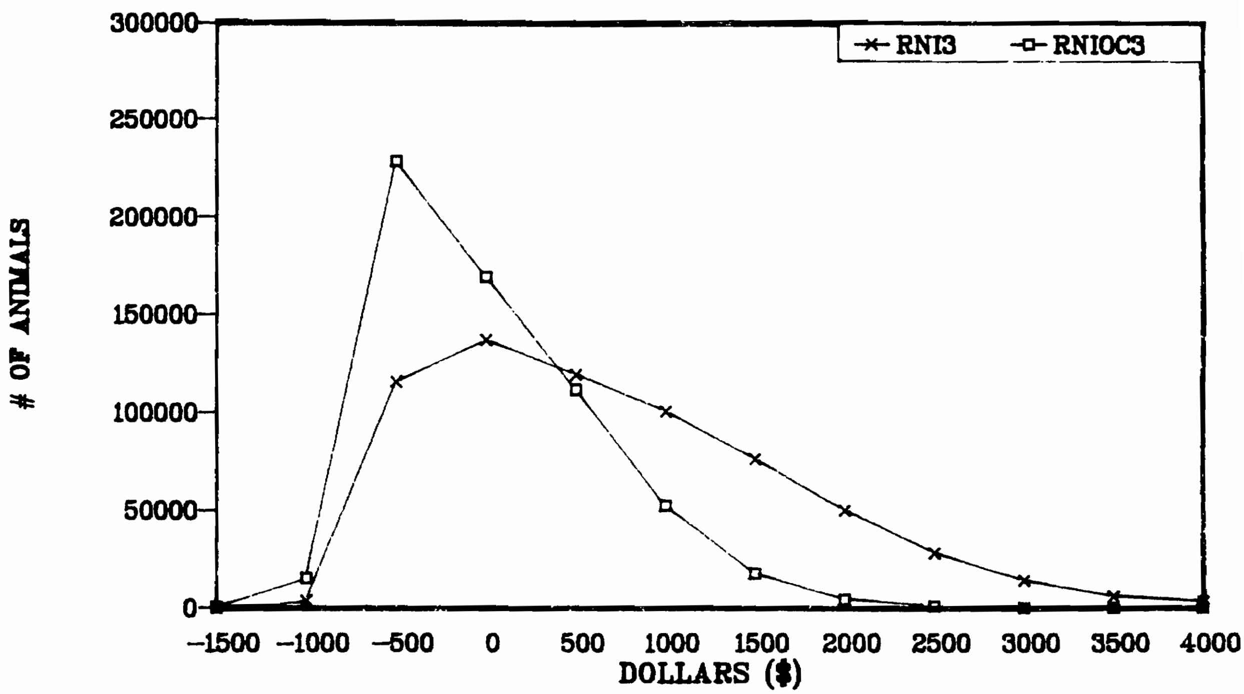

Figure 1. Distribution of Relative Net Income (RNI) and Discounted RNI (DRNI) to 72 month herdlife period.

Table 18. Analysis of variance for measures of profitability and DPL.

VARIABLE	HERD	YEAR	ERROR
	Percent of variation due to:		
AGEFF	23.1	15.2	61.7
MLK1	18.6	12.7	68.7
RNI1	22.3	10.5	67.3
DRNI1	23.1	10.8	66.1
RNIOC1	0.0	0.0	100.0
DRNI0C1	0.0	0.0	100.0
DPL1	2.7	3.0	94.4
RNI2	18.0	7.4	74.6
DRNI2	18.9	7.9	73.2
RNIOC2	0.0	0.0	100.0
DRNIOC2	0.0	0.0	100
DPL2	2.9	2.6	94.6
RNI3	15.1	5.6	79.4
DRNI3	16.1	6.0	77.9
RNIOC3	0.0	0.0	100.0
DRNIOC3	0.0	0.0	100.0
DPL3	3.4	2.7	93.9
DOC3PD	.7	0.0	99.3
PPD3	8.2	4.2	87.6
DPPD3	7.3	3.9	88.8
OC3PD	.7	0.0	99.3
RNI4	11.4	3.6	85.
DRNI4	12.6	3.9	83.4
RNIOC4	0.0	0.0	100.0
DRNIOC4	0.0	0.0	100.0
DPL4	4.5	4.9	90.5

*For definitions of profit measures refer to Table 12.

Table 19. Analysis of variance of profit functions and selected variables when at least two calvings were required.

	Percent of variation due to:		
VARIABLE	HERD	YEAR	ERROR
AGEFF	23.7	15.3	61.0
MLK1	26.6	18.5	55.0
RNI1	30.2	14.8	55.0
DRNI1	30.8	15.0	54.1
RNIOC1	.8	0.0	99.2
DRNI0C1	1.0	0.0	99.0
DPL1	4.7	4.6	90.7
RNI2	25.5	11.2	63.3
DRNI2	26.5	11.7	61.8
RNIOC2	.3	0.0	99.7
DRNIOC2	.5	0.0	99.5
DPL2	2.6	2.7	94.7
RNI3	20.9	8.2	70.9
DRNI3	22.3	8.8	69.0
RNIOC3	0.0	.1	99.9
DRNIOC3	.1	0.0	99.9
DPL3	2.9	2.6	94.5
DOC3PD	0.0	0.0	100
PPD3	24.1	10.5	65.4
DPPD3	23.5	10.3	66.2
OC3PD	0.0	0.0	100.0
RNI4	14.6	4.4	81.0
DRNI4	16.5	4.9	78.6
RNIOC4	0.0	.2	99.8
DRNIOC4	0.0	.2	99.8
DPL4	4.6	5.8	89.6

*For definitions of profit measures refer to Table 12.

The standard deviations in Tables 13-16 included the overall herd effects, the year within herd effects, and error or the within herd variance for the various measures of profitability. The within herd variance or the error variance was the portion of variance that was of primary interest in this portion of the study because the correlations between various profit measures, correlations of various traits with the profit measures, and regression equations using the various traits to predict profit measures were done within herd-year of first freshening. Previous researchers have concluded that the use of RNI was accurate to rank cows within herd. Table 18 contains the percentage of variance for the various measures of profit and several of the traits used to predict profitability for all of the data. Table 19 contains the same information using only those data for which a second calving was available. ANOVAs for both the full data set and the data set only containing animals with at least two calvings allowed for comparisons across data sets.

The most notable difference in profit measures was that virtually all variance due to herd and year was removed from RNIOC and DRNIOC to all four herdlife periods. This was because of the application of the regressed opportunity cost within herd-year. The percent of the variance that was explained by herds depended on how the impact of management conditions specific to cows born in a herd were to lifetime profit of those cows. This same analogy could be made for years within herd. The application of the opportunity cost within herd-year should give an average value of 0. Therefore, there should be no differences in herds or herd-years for any measure that has had opportunity cost applied to it. This gives evidence that the application of opportunity cost used had successfully removed herd and year within herd efffects. The data set using only animals with at least a second calving had a small percent of the variance due to herd and year within herd. The reason for the slight increases in the percent of variance explained by non-error variance was the difference in the weighted average of profitability of the animals within herd-year for animals with at least a second calving and the opportunity cost that was applied.

The decline in the percent of the variance that could be explained by herd and year within herd, i.e. non-error variance, for RNI and DRNI as herdlife period increased was also evident. An increase in the error variance indicated that there was decreased control of profit measures by management as herdlife period increased. The reason for this decline was more than likely due to the increased relative importance of DPL, to other traits such as age at first freshening and first lactation milk production, in predicting RNI and DRNI as herdlife opportunity length increased. DPL to all four herdlife periods had a lower percentage of the variance due to herd and year within herd than did age at first freshening and first lactation milk production. The proportion of the variance in DPL that was due to herd and year within herd was small because there was generally great variablity within herds of when an animal left the herd. Culling policy specific to herd and year had small impact on DPL.

DRNI also had a larger portion of the variance due to herd and year within herd than did RNI to all four herdlife periods. The discrepancy became greater as herdlife increased. Age at first freshening (AGEFF) and first lactation milk production (MLK1), which had larger herd and year variance than the measures of DPL, had a larger impact on discounted measures versus non-discounted measures. Discounting placed more relative importance on earlier traits because the animals with more DPL and profit were discounted more to zero.

All measures of profitabilty had larger variance components for herd and year when the data set included only animals with at least two calvings. This indicates that the percent of animals culled in first lactation was not largely controlled by management. The measures that were most affected were PPD3 and DPPD3. The percent of error variance decreased from 87.6 percent to 65.3 percent when the animals with only one lactation were excluded. This was because the individuals with extremely low values for PPD3, due to extremely high rearing cost, contributed a great deal to error variance. Exclusion of the animals with only one lactation also reduced the variability in DPL1. This was expected because the variance of DPL1 was caused largely by the disposals that took place in first lactation plus those disposed of in second lactation. All profit measures increased percentage of the variance explained by herd and year within herd by excluding the animals with only one calving.

Table 20. Correlations between profitability measures within herd [1].

	1	2	3	4	5	6	7	8	9	10	11	12	13
(1)RNI1		.82	.70	.54	1	.83	.72	.58	.98	.84	.75	.62	.76
(2)RNI2	.88		.91	.74	.82	1	.92	.78	.81	.98	.91	.78	.91
(3)RNI3	.80	.94		.86	.70	.91	1	.89	.69	.88	.96	.87	.93
(4)RNI4	.66	.81	.89		.54	.74	.86	1	.53	.72	.82	.95	.79
(5)DRNI1	1	.88	.80	.66		.83	.72	.58	.98	.84	.75	.62	.76
(6)DRNI2	.89	1	.94	.80	.89		.92	.78	.82	.98	.91	.78	.91
(7)DRNI3	.82	.95	1	.89	.82	.95		.89	.72	.90	.97	.87	.94
(8)DRNI4	.70	.84	.92	1	.70	.84	.92		.57	.75	.85	.96	.82
(9)RNIOC1	.97	.86	.78	.65	.97	.87	.80	.68		.85	.75	.63	.76
(10)RNOC2	.87	.96	.90	.77	.87	.97	.91	.81	.89		.94	.80	.91
(11)RNIOC3	.80	.91	.95	.85	.80	.91	.96	.88	.81	.95		.89	.94
(12)RNIOC4	.68	.80	.87	.94	.68	.80	.87	.95	.70	.83	.91		.83
(13)PPD3	.75	.79	.77	.67	.75	.79	.79	.78	.69	.77	.77	.74	

[1]Correlations for data set requiring 2 calvings above diagonal, correlations in full data set below diagonal.

*For definitions of profit measures refer to Table 12.

The within herd-year correlations of RNI, DRNI, and RNIOC to all four herdlife periods and PPD3 for the whole data set and the data set requiring a second calving are in Table 20. The use of the two data sets will demonstrate if the correlations of the various profit measures dependent on the data set used. The complete data set was more indicative of the total variance structure and will be discussed in more detail.

This study was designed to demonstrate how efficient early measures of profitability were in predicting later measures of profitability for the various methods of measuring profitability. RNI1 had within herd-year correlations of .88, .80, and .66 with RNI2, RNI3, and RNI4, respectively. DRNI1 had within herd-year correlations of .89, .82, and .70 with DRNI2, DRNI3, and DRNI4, respectively. RNIOC1 had within herd-year correlations of .89, .81, and .70 with RNIOC2, RNIOC3, and RNIOC4, respectively. The higher correlations of DRNI1 and RNIOC1 with later measures demonstrated that the use of these two methods of regressing measures to zero had caused higher correlations of early measures with later measures. RNI1 also had a slightly higher correlation with DRNI4 and RNIOC4 than with RNI4. This indicates that the revenue generated in later herdlife did not change the correlations of later measures with early measures as drastically when discounting or opportunity cost were considered.

Calculation of correlations of profit measures allowed between the comparison of the correlations of RNI, DRNI, and RNIOC to the four herdlife periods. DRNI had a correlation of 1.0 with RNI to all four herdlife periods. The within herd-year correlations of RNI and RNIOC to the same herdlife period were .97, .96, .95, and .94 for the first, second, third, and fourth herdlife periods, respectively. This indicated that: (1) there was only a small amount of change for rank in profit that occurred because of the application of discounting and opportunity cost to RNI, but less so for discounting than opportunity cost, and (2) the correlations in RNI and RNIOC decreased with increasing herdlife opportunity.

The restriction of the data set to animals with at least a second calving caused a few changes in the correlations of the various profit measures. The most noteworthy difference in the correlations seen in the two data sets was the smaller correlations of RNI1 with later measures of RNI for the data set that required a second calving compared to the data set without this restriction. For example, the correlation of RNI1 with RNI4 was .66 in the data set not requiring a second calving versus a .54 from the data set that required a second calving. The reasons could include : (a) the variance in the data set that required a second calving was smaller because all measures of profit had a reduction of the number of animals with low values in the data, and (b) the animals in the data set that required a second calving were also more likely to change in later measures of profit.

The correlation of both RNI1 and RNIOC1 with RNIOC4 from the two data sets did not differ as much as the correlation between RNI1 and RNI4. This indicated that RNIOC was less affected by herdlife opportunity length than was RNI. This data set without the requirement of at least two calvings did not include all of the variation in profit measures from extremely low values because animals in this data set with only one lactation and less than 100 days in milk were excluded. The higher correlations of earlier measures with later measures in the data set not requiring a second calving than in the data set requiring a second calving suggests that additional requirements for days of productive life would reduce the correlations of earlier measures with later measures.

The correlations of PPD3 with all cumulative measures of profit for the data set requiring a second calving interval were higher than the analogous measures in the data set without this requirement. Cumulative measures of profit were some function of days of productive life and PPD. The variance in PPD for the data set requiring a second calving was more of a function of the ability of animals to produce revenue after calving and less of a function of rearing cost per day than the data set without this requirement. The data set requiring a second calving also had less variation in days of productive life than the data set without this requirement. This caused an increased emphasis on the revenue producing ability of an animal, likely a more repeatable trait than herdlife. The most marked difference in the correlations of PPD with cumulative measures in the two data sets was the correlation of RNIOC4 with PPD3 of .74 in the data set not requiring a second calving compared to .83 in the data set that required that required a second calving. This difference indicated that PPD increased in importance relative to DPL in predicting RNIOC when there was less variance in DPL.

The correlations of various traits of the cow, AGEFF, MLK1, DPL(i), and total milk, TMLK(i), (where i denotes the DPL and TMLK to the same herdlife period as the profit measure in question) for the data set that did not require a second calving are in Table 21. Table 22 shows the correlations of traits with profit measures for the data set that required a second calving. Table 22 also contained the correlations of first calving interval (CI1), and can be used to compare the relative importance of traits for the difference in the data set restriction.

One of the objectives of this study was to determine if the different herdlife periods and definitions of profit changed the relative importance of DPL. The correlations of DPL(i) with profit measure(i), in both Tables 21 and 22, refers to the correlation of DPL for a certain herdlife period with the profit measure for the same herdlife period. DPL(i) had higher correlations with all profit measures to all herdlife periods than either MLK1 or AGEFF. TMLK(I) had higher correlations with all profit measures than DPL(i). The correlation of TMLK1 with RNI1 was greater for DPL1 with RNI1 (.92 vs. .72). The correlation of TMLK(i) with profit measures increased as herdlife period increased, but to a lesser degree than DPL(I).

The different methods of measuring profit differed in the increase in the correlation of DPL(i) as herdlife period advanced. RNI1 and RNIOC1 both had correlations of .72 with DPL1. The correlation of DRNI1 with DPL1 was slightly lower at .70. Therefore, discounting had a greater impact of deemphasizing herdlife than did the application of opportunity cost to the first herdlife period. The correlation of DRNI(i) with DPL(i) increased similarly to the correlation of RNI(i) with DPL(i) as herdlife period advanced. However, the correlation of DPL(i) with RNIOC(i) did not increase in the same manner. One reason for the similar correlations for DPL1 with RNI1 and RNIOC1 was that animals had not had time to express differences in opportunity cost. Therefore, the similarity of the correlation of DPL1 with the two measures was expected. By the fourth

Table 21. Correlations of age at first freshening AGEFF), first lactation milk (MLK1), days of productive life (DPL(i)), and total milk (TMLK(i)) for profit measures.

	AGEFF	DPL(i)	MLK1	TMLK(i)
RNI1	-.23	.72	.63	.92
RNI2	-.16	.80	.57	.94
RNI3	-.12	.84	.52	.96
RNI4	-.08	.89	.43	.97
DRNI1	-.25	.70	.63	.91
DRNI2	-.18	.79	.58	.94
DRNI3	-.14	.83	.53	.95
DRNI4	-.10	.87	.46	.96
RNIOC1	-.23	.72	.64	.91
RNIOC2	-.16	.72	.59	.89
RNIOC3	-.13	.73	.54	.88
RNIOC4	-.10	.78	.46	.88
DRNIOC1	-.26	.75	.63	.92
DRNIOC2	-.19	.75	.59	.90
DRNIOC3	-.15	.76	.55	.89
DRNIOC4	-.12	.77	.49	.88
PPD3	-.09	.79	.72	.81
DPPD3	-.10	.79	.72	.80
*AGEFF		-.09	.11	-.07
*DPL3			.42	.95
MLK1*				.51

For definitions refer to Table 12.
*TMLK3 used for correlations with non-profit traits.

Table 22. Correlations of age at first freshening (AGEFF), first lactation milk (MLK1), and days of productive life (DPL(i)), and total milk (TMLK(i)) with profit measures.

	AGEFF	DPL(i)	MLK1	TMLK(i)	CI1
RNI1	-.27	.55	.54	.91	-.18
RNI2	-.19	.70	.48	.93	-.13
RNI3	-.14	.79	.43	.95	-.08
RNI4	-.08	.87	.33	.96	-.04
DRNI1	-.30	.53	.55	.90	-.18
DRNI2	-.21	.68	.49	.92	-.14
DRNI3	-.16	.77	.44	.94	-.09
DRNI4	-.10	.85	.36	.95	-.06
RNIOC1	-.28	.54	.55	.89	-.19
RNIOC2	-.18	.60	.52	.88	-.17
RNIOC3	-.13	.66	.48	.87	-.13
RNIOC4	-.09	.74	.40	.87	-.09
DRNIOC1	-.32	.58	.53	.90	-.19
DRNIOC2	-.21	.62	.52	.88	-.16
DRNIOC3	-.16	.68	.48	.88	-.13
DRNIOC4	-.12	.72	.43	.86	-.10
PPD3	-.11	.72	.51	.88	-.08
DPPD3	-.14	.73	.50	.88	-.08
AGEFF		-.13	-.16	-.09	.02
DPL3			.17	.92	.09
MLK1				.36	.22
TMLK3					-.02

* For definitions profit measures refer to Table 12.
[1] The data set used were animals with at least two calvings.

herdlife opportunity period animals had had more opportunity to express differences in RNI4 and RNIOC4 because average OCPD4 was higher and DPL4 was longer with more variabilty. The differences in the correlation of DPL4 with RNI4 was .89 compared .78 for DPL4 with RNIOC4. This was similar to the reduced value of herdlife found by Beaudry (9) when a higher maintenance cost per day was used. Perhaps a lower correlation would have been found between DPL and RNIOC if health costs would have been included because an extra DPL would have been worth less.

The data set that required a second calving gave slightly lower correlations for DPL(i) with profit measures(i) to early herdlife periods. This result is likely due to elimination of cows with very few DPL which increased the correlation of DPL with profit measures. These cows evidently had a smaller impact on the correlations as herdlife period advanced.

One of the reasons that animals that lived longer were more profitable is that they had more opportunity to produce. The correlation of DPL3 with TMLK3 was very high at .96. Conversely, production in first lactation was not highly correlated with TMLK3. The data set containing all lactations found a correlation of .42 between MLK1 and DPL3. This indicated that MLK1 through 305 days in milk, which should be indicative of rate of production, had a relatively strong relationship with how long an animal stayed in the herd. The correlation of .17 for MLK1 with DPL3 from the data set that required animals to have at least two calvings suggested that much of the correlation for MLK1 with DPL3 from the full data set was caused by animals with low production in first lactation because of few days in first lactation.

Higher MLK1 was, therefore, advantageous in two ways: (a) directly from more revenue generated, and (b) indirectly through less voluntary culling. MLK1 had higher correlations with earlier measures of profitabilty because first lactation was a greater portion of the total revenue generated. Also, profit measures to early herdlife periods were less affected by DPL.

The correlations of MLK1 with RNI and with RNIOC were almost equal to the same herdlife period. The correlation of MLK1 with later herdlife period measures of RNIOC were slightly higher than analagous measures for RNI. This suggested that the rate of production may be slightly more important for RNIOC than RNI.

The correlations of AGEFF are also presented. The most noteworthy trends in correlations of AGEFF with profit measures were: (a) AGEFF was more critical for earlier herdlife period measures, and (b) AGEFF was slightly more important for discounted measures. An earlier AGEFF was more advantageous to earlier herdlife periods because: (a) it allowed for more total DPL because of an upper limit on maximum herdlife, and (b) rearing expenses were a larger part of total cost.

First calving interval, CI1, had the lowest correlations with profit measures of the traits used in this study. CI1 had small negative correlations with profit measures and reduced in importance as herdlife period advanced, similarly to AGEFF. The correlation of CI1 was slightly more important for RNIOC than RNI. Reproductive efficiency is beneficial to rate of production, therefore, the stronger relationship of CI1 with RNIOC was expected. The positive relationship of CI1 with MLK1 ($r = .22$) may have partially compensated for the added cost of maintenance after 305 days in milk. The use of CI1 as an indicator of reproductive efficiency was limited because reproductive traits have low repeatability and animals with poorest reproductive ability are removed in first lactation.

Regression was used to better understand the predictive value of DPL(i), AGEFF, MLK1, and CI1 in determining RNI, DRNI, RNIOC, and PPD to the four herdlife periods. Two basic models were run. One model included linear and quadratic terms for DPL(i), MLK1, and AGEFF to predict profit measures. The second model included CI1 which limited the data set to only animals with at least two calvings to be in the data set. Regression models predicting both RNI3 and RNIOC3 from various combinations of variables were also performed. All regression models removed the effects of herd and year.

Table 23. Variation in Relative Net Income (RNI3) and RNI adjusted for opportunity cost (RNIOC3) to 72 month herdlife period explained by various traits.

	Multiple Corr. Coef. (R^2)		
VARIABLES	RNI3[1]	RNI3 [2]	RNIOC3
1st milk actual(MLK1)	.47	.33	.33
Days of productive life(DPL3)	.79	,74	.57
Age at first freshening(AGEFF)	.28	.09	.07
MLK1, DPL3	.84	.79	.67
MLK1, AGEFF	.49	.21	.37
DPL3, AGEFF	.79	.36	.57
AGEFF, MLK1, DPL3	.84	.80	.68
AGEFF, MLK1, DPL3, CI1[3]	.85	.81	.70

[1] R^2 for RNI3 include variance due to herd and year.

[2] R^2 for RNI3 adjusted for herd and year variance.

[3] Adding CI1 restricted the data to animals with at least two calvings.
For definitions of profit measures refer to Table 12.

The comparisons of the multiple correlation coefficient (R^2) for the various combinations of variables to predict RNI3 and RNIOC3 (Table 23) helped to show the benefit of adding traits to a model provided other traits are in the model. RNIOC3 had 0% of the variation due to herd and year within herd effects, compared to 20.7% of the variation for RNI3. The variation explained within herd-year is the criterion of interest, therefore, R^2 for RNI3 must be adjusted for herd and year variance to determine the variance explained within herd-year.

DPL3 had greater predictive value than MLK1 for RNI3 and RNIOC3. There was, however, a marked difference in the percent of the variation explained in RNI3 and RNIOC3 by DPL3. The total R^2 for the model predicting RNI3 from both linear and quadratic forms of DPL3 was .79. However, DPL explained 74% of the variation within herd and year. This was still considerably larger than R^2 of .57 from the prediction of RNIOC3 from DPL3 within herd and year. Results verify conclusions from correlations reported earlier for the relative importance of DPL3 in predicting RNI3 vs. RNIOC3, as they must. The greater predictive value of DPL3 for RNI3 was expected because the direct economic benefit of an extra DPL was greater for RNI3 than RNIOC3.

The percent of the variation adjusted for herd and year explained in RNI3 by MLK1 was almost identical to that of RNIOC3 at 33%. There was, however, a slight difference in the percent increased variation explained by adding MLK1 to the model after DPL3 was already in the model. $R:^2$ increased for RNIOC3 57.1% to 67.1% after MLK1 was added to the model already containing DPL3. Addition of MLK1 to the model already containing DPL3 increased the percent of variation within herd-year for RNIOC3 from 74% to 80%. MLK1 was more important in predicting RNIOC3 than RNI3 because the application of opportunity cost placed greater emphasis on rate of production. Also an extra DPL was not as likely to add to RNIOC3 as it was to RNI3.

Addition of AGEFF to the model already containing DPL3 and MLK1 only slightly increased the percent of variation explained for both RNI3 and RNIOC3. Addition of CI1 to the model containing AGEFF, MLK1, and DPL3 increased the variation within herd-year by 2% for RNIOC3. Addition of CI1 to the model already containig AGEFF, MLK1, and DPL3 actually decreased the percent of variation within herd-year by 1%. A different data set was required to study CI1, so comparison of R^2 between models across data sets must be made with caution.

The primary conclusions that can be reached from examination of R^2 comparing the combinations of variables predicting RNI3 and RNIOC3 are : (a) a larger percent of the within herd-year variance is explained by DPL3 for RNI3 than for RNIOC3, (2) MLK1 had approximately equal predictive value for both RNI3 and RNIOC3, (c) AGEFF and CI1 had very little predictive value, and (d) more within herd variation can be explained by traits of the cow for RNI3 than RNIOC3. Van Arendonk (58) reached similar conclusions.

Tables 24-27 contain the regression coefficients and R^2 for the models with and without linear forms for CI1. Using the data set not requiring a second calving, R^2 increases as herdlife period increased for RNI, RNIOC and DRNI. The increased R^2 and the smaller percent of variation due to herd and year as herdlife increased indicated that the percent of variation that was explained by traits of the cow increased as herdlife opportunity length increased. The R^2 for the model not including CI1 showed increasing trends as herdlife period increased for RNI and DRNI. The R^2 for RNIOC also increased as herdlife period increased after the second period in the data set not requiring a second calving. PPD showed no trend for R^2 in this data set. There were no evident patterns for R^2 of different profit measures as herdlife period increased in the data set requiring a second calving.

Interpretation of regression coefficients for the different models in Tables 24-27 is difficult because of covariance between the independent variables and the size of the regression coefficients themselves. The regression models were graphed in order to better understand the relationship of variables. The importance of standard deviation unit changes was examined by insertion of the means for other traits in the model and then the impact of a standard deviation units change was viewed. Means and standard deviations for DPL, AGEFF, and MLK1 are in Tables 13-16. This was done for measures of RNI and RNIOC to the four herdlife periods and are included in Figures 2-9. Regression coefficients are in Tables 24-27 for the data set not requiring a subsequent calving. The primary conclusions are that of MLK1 had nearly equal impact to DPL(i) in early herdlife and the

Table 24. Regression models predicting profit measures to 48 month herdlife opportunity.

Y VARIABLE	MLK1		DPL1		AGEFF		CI1		R^2
	linear	quad.	linear	quad.	linear	quad.	linear	quad.	
RNI1	.26*	$8.6x10^{-7}$*	-.21*	.0013*	.50*	-.0008*	-6.65*	-.0049*	.860
RNI1	-.07*	$2.1x10^{-5}$*	.44*	.0008*	-.14*	-.0004*	---	---	.824
RNIOC1	.12*	$1.7x10^{-7}$*	.45*	.0007*	.32*	-.0007*	-6.91*	.0053*	.745
RNIOC1	-.01*	$3.4x10^{-6}$*	.56*	.0006*	.46*	-.0008*	---	---	.717
DRNI1	.23*	$3.4x10^{-8}$*	-.23*	.0011*	.16*	-.0006*	-5.73*	.0042*	.864
DRNI1	-.06*	$1.8x10^{-5}$*	.36*	.0006*	-.39*	-.00038	---	---	.825
PPD1	.0005*	$-5.8x10^{-9}$*	.0074*	$-3.7x10^{-6}$*	.0002*	$-1.0x10^{-6}$*	-.0153*	$1.3x10^{-5}$*	.833
PPD1	.0010*	$-4.6x10^{-8}$*	.0101*	$-6.0x10^{-6}$*	-.0049*	$1.5x10^{-6}$*	---	---	.912

* Significant ($P < .01$)
Full models with and without inclusion of CI1
For definitions of profit measures refer to Table 12.

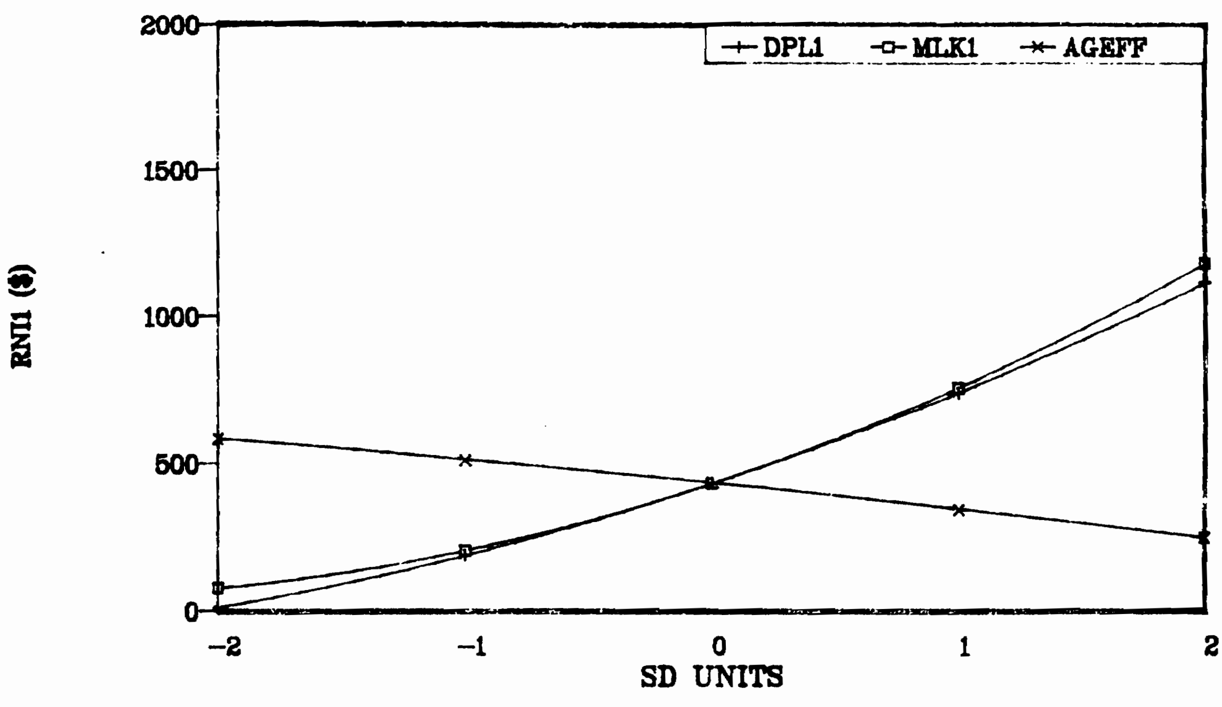

Figure 2. Graph of the impact of age at first freshening (AGEFF), first lactation milk yield (MLK1), and days of productive life (DPL1) on RNI1 to 48 month herdlife period.

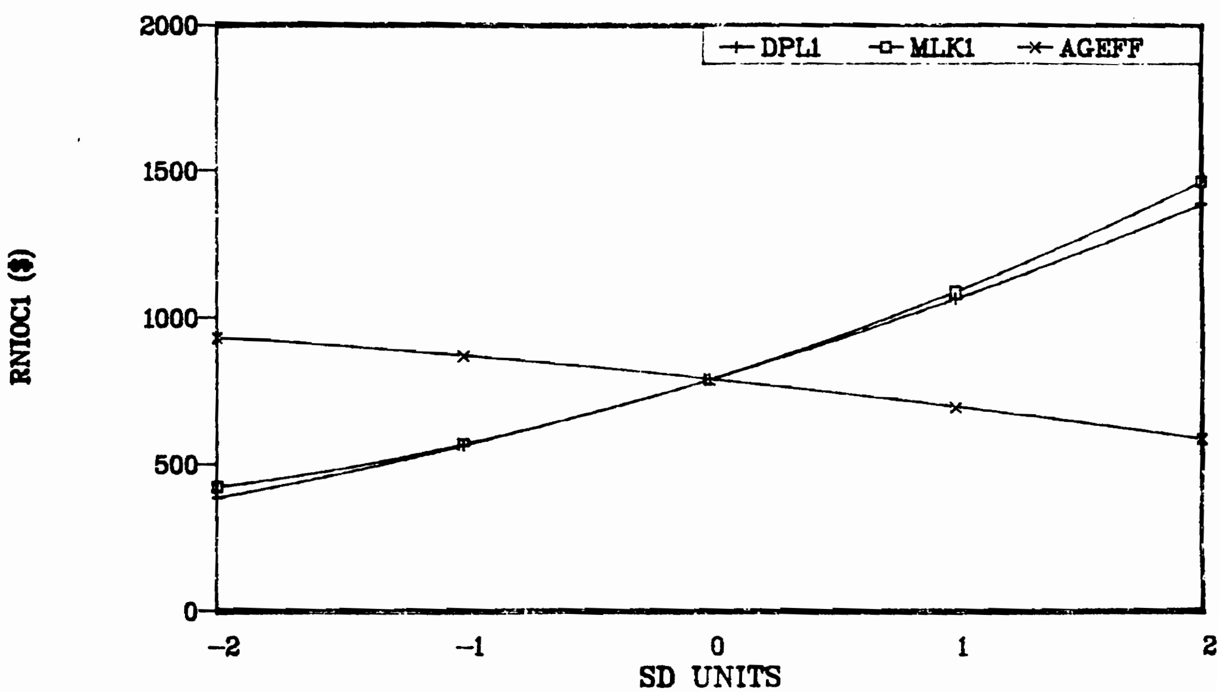

Figure 3. Graph of the impact of age at first freshening (AGEFF), first lactation milk yield (MLK1), and days of productive life (DPL1) on RNIOC1 to 48 month herdlife period.

Table 25. Regression models predicting profit measures to 60 month herdlife

Y VARIABLE	MLK1		DPL2		AGEFF		CI1		R^2
	linear	quad.	linear	quad.	linear	quad.	linear	quad.	
RNI2	.22*	$7.4x10^{-6}$*	1.81*	$1.3x10^{-5}$	-1.47*	.0003*	-3.26*	.0003*	.851
RNI2	-.13*	$2.9x10^{-5}$*	.22*	.0009*	.11	-.0005	---	---	.828
RNIOC2	.27*	$3.8x10^{-7}$*	1.49*	-.0001*	-1.09*	$7.3x10^{-5}$	-3.38*	.0005*	.716
RNIOC2	.05*	$2.1x10^{-5}$*	-.16*	.0008*	.59*	-.0008*	---	---	.678
DRNI2	.20*	$5.6x10^{-6}$*	1.56*	$-7.2x10^{-5}$*	-1.63*	.0004*	-2.89*	.0004*	.854
DRNI2	-.11*	$2.4x10^{-5}$*	.21*	.0007*	-.24*	-.0003*	---	---	.826
PPD2	.0004*	$-4.9x10^{-9}$*	.0051*	$-1.9x10^{-6}$*	-.0024*	$6.9x10^{-7}$*	-.0041*	$1.1x10^{-6}$*	.866
PPD2	.0012*	$-6.0x10^{-8}$*	.0072*	$-3.3x10^{-6}$*	-.0046*	$1.5x10^{-6}$*	---	---	.927

* Sig. ($P < .05$).

Full models predicting profit with and without inclusion of CI1.

For definitions of profit measures refer to Table 12.

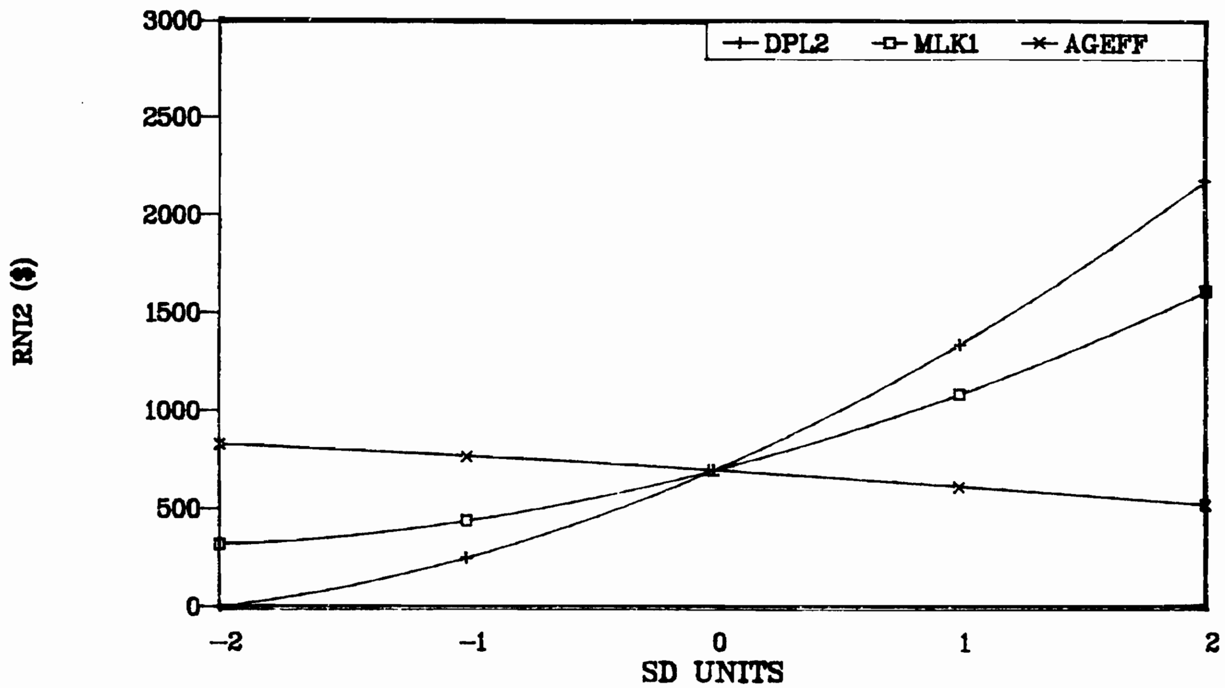

Figure 4. Graph of the impact of age at first freshening (AGEFF), first lactation milk (MLK1), days of productive life (DPL2) on RNI to 60 months.

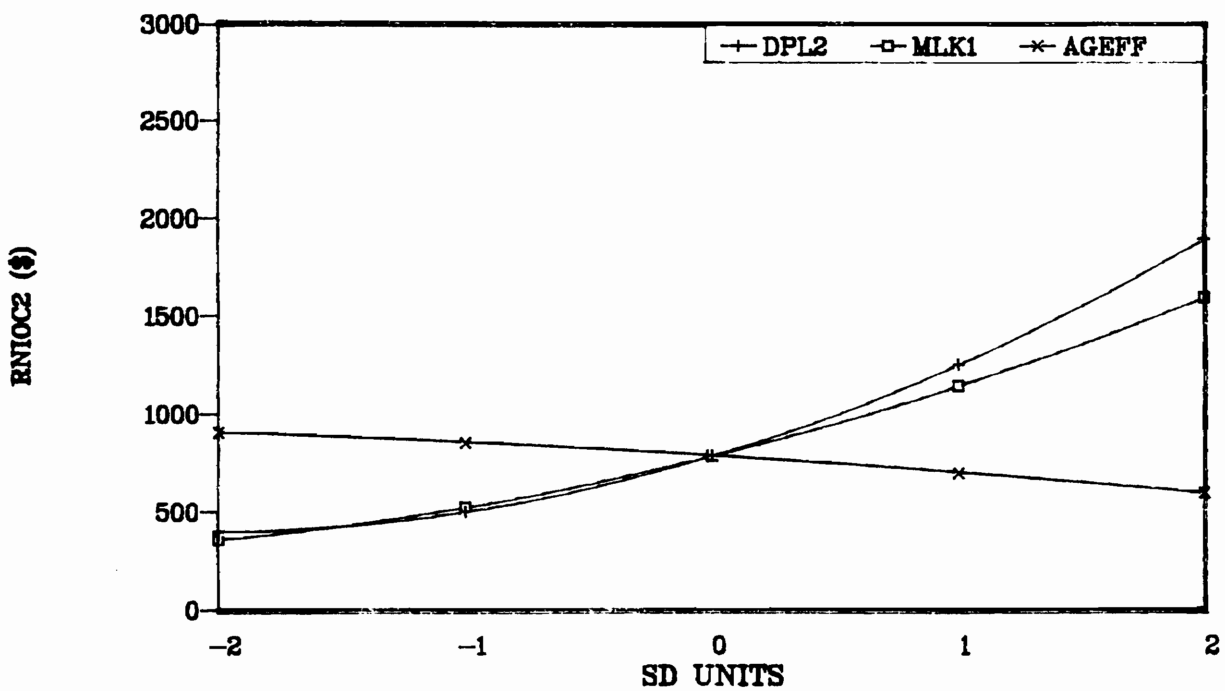

Figure 5. Graph of the impact of age at first freshening (AGEFF), first lactation milk (MLK1), days of productive life (DPL2) on RNIOC2 to 60 months

Table 26. Regression models predicting profit measures to 72 month herdlife opportunity.

Y VARIABLE	MLK1		DPL3		AGEFF		CI1		R^2
	linear	quad.	linear	quad.	linear	quad.	linear	quad.	
RNI3	.19*	$1.3x10^{-6}$*	1.18*	.0003*	-1.25*	.0002*	-3.80*	.0008*	.849
RNI3	.19*	$3.6x10^{-5}$*	.30*	.0007*	-.40*	-.0002*	---	---	.842
RNIOC3	.27*	$5.8x10^{-6}$*	.69*	.0002*	-1.02*	$1.2x10^{-5}$	-3.88*	.0009*	.702
RNIOC3	-.08*	$2.5x10^{-5}$*	-.24*	.0007*	-.04*	-.0004*	---	---	.679
DRNI3	.17*	$9.2x10^{-6}$*	1.06*	.0002*	-1.44*	.0002*	-.3.31*	.0008*	.851
DRNI3	-.15*	$2.9x10^{-5}$*	.30*	.0005*	-.66*	-.0001*	---	---	.839
PPD3	.0036*	$-1.9x10^{-9}$*	.0036*	$-1.1x10^{-6}$*	-.0018*	$4.0x10^{-7}$	-.0041*	$1.5*10^{-6}$	.862
PPD3	.0013*	$-7.2x10^{-8}$*	.0056*	$-9.9x10^{-6}$*	-.0036*	$9.0x10^{-7}$*	---	---	.925

*Sig. ($P < .05$)
Full models with and without inclusion of CI1.
For definitions of profit measures refer to Table 4.

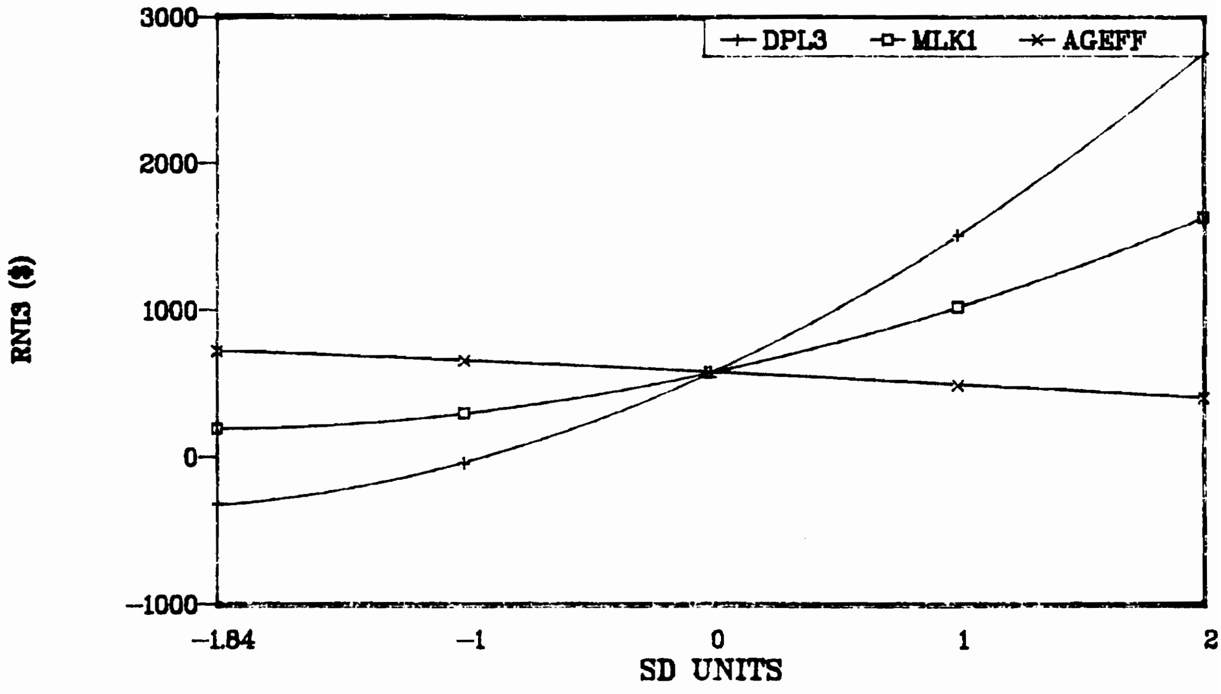

Figure 6. Graph of the impact of age at first freshening (AGEFF), first lactation milk (MLK1), days of productive life (DPL3) on RNI to 72 months.

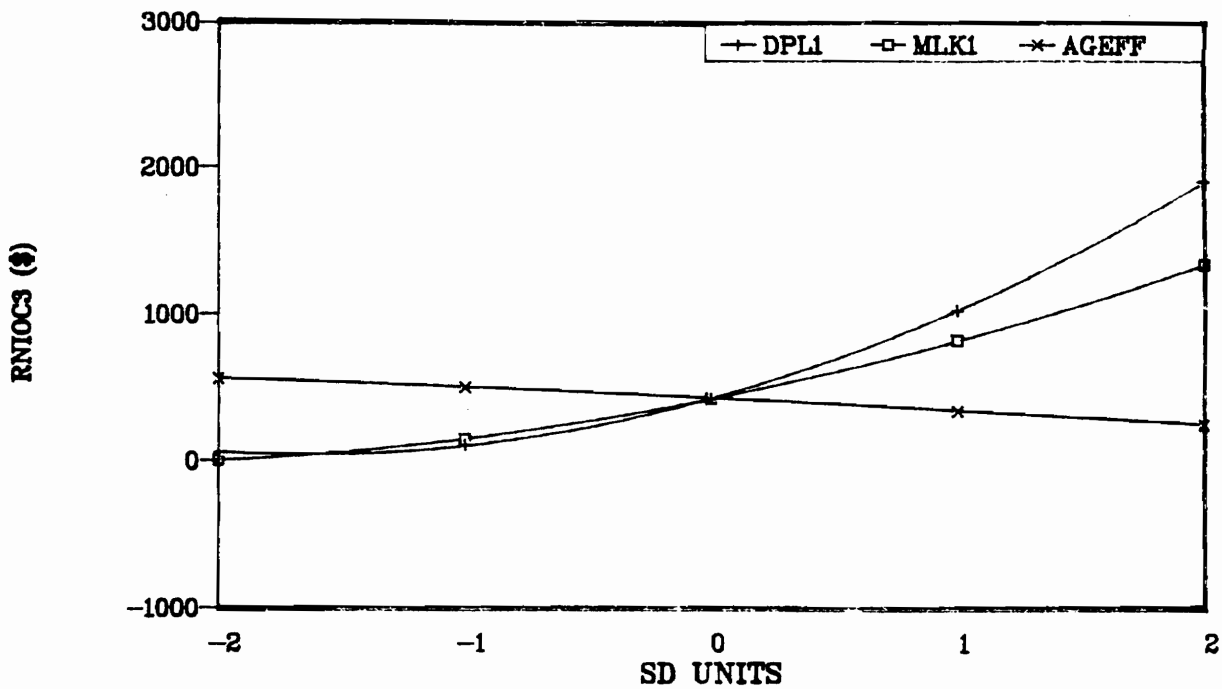

Figure 7. Graph of the impact of age at first freshening (AGEFF), first lactation milk (MLK1), days of productive life (DPL3) on RNIOC3 to 72 months

Table 27. Regression models predicting profit measures to > 72 month herdlife period including all lactations.

Y VARIABLE	MLK1		DPL4		AGEFF		CH		R^2
	linear	quad.	linear	quad.	linear	quad.	linear	quad.	
RNI4	.1479*	$1.7*10^{-5}$*	1.7983*	$-5.8*10^{-6}$*	-1.546*	.0001	-4.583*	.0015*	.866
RNI4	-.3546*	$4.8*10^{-5}$*	-1.4026*	.0001*	-.797*	-.0002*	---	---	.861
RNIOC4	.2698*	$7.2*10^{-6}$*	1.0357*.	$-1.6*10^{-5}$*	-1.513*	.0001	-4.600*	.0016*	.720
RNIOC4	-.2169*	$3.6*10^{-5}$	.6535	$8.1*10^{-5}$*	-.579*	-.0003*	---	---	.696
DRNI4	.1448*	$1.4*10^{-5}$*	1.5179*	$-7.6*10^{-5}$*	-1.597*	.0002*	-3.885*	.0012*	
DRNI4	-.2765*	$3.9*10^{-5}$*	1.1975*	$6.2*10^{-6}$*	-.934*	$-9.5*10^{-5}$*	---	---	.854
PPD4	.0037*	$-4.9*10^{-9}$*	.0019*	$-3.5*10^{-7}$*	-.0013*	$6.0*10^{-8}$	-.0034	$1.2*10^{-6}$*	.857
PPD4	.0018*	$-1.0*10^{-7}$*	.0030*	$-6.3*10^{-7}$*	-.0032*	$5.7*10^{-7}$*	---	---	.901

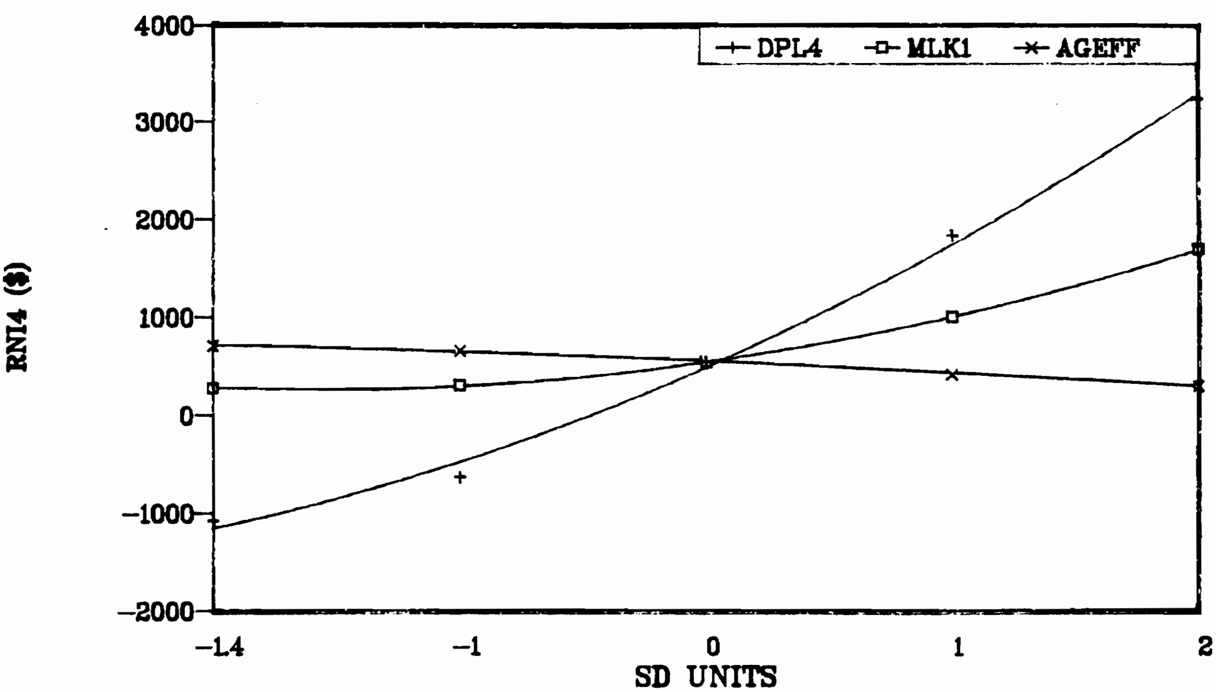

Figure 8. Graph of the impact of age at first freshening (AGEFF), first lactation milk (MLK1), days of productive life (DPL4) on RNI4 to all latations herdlife period.

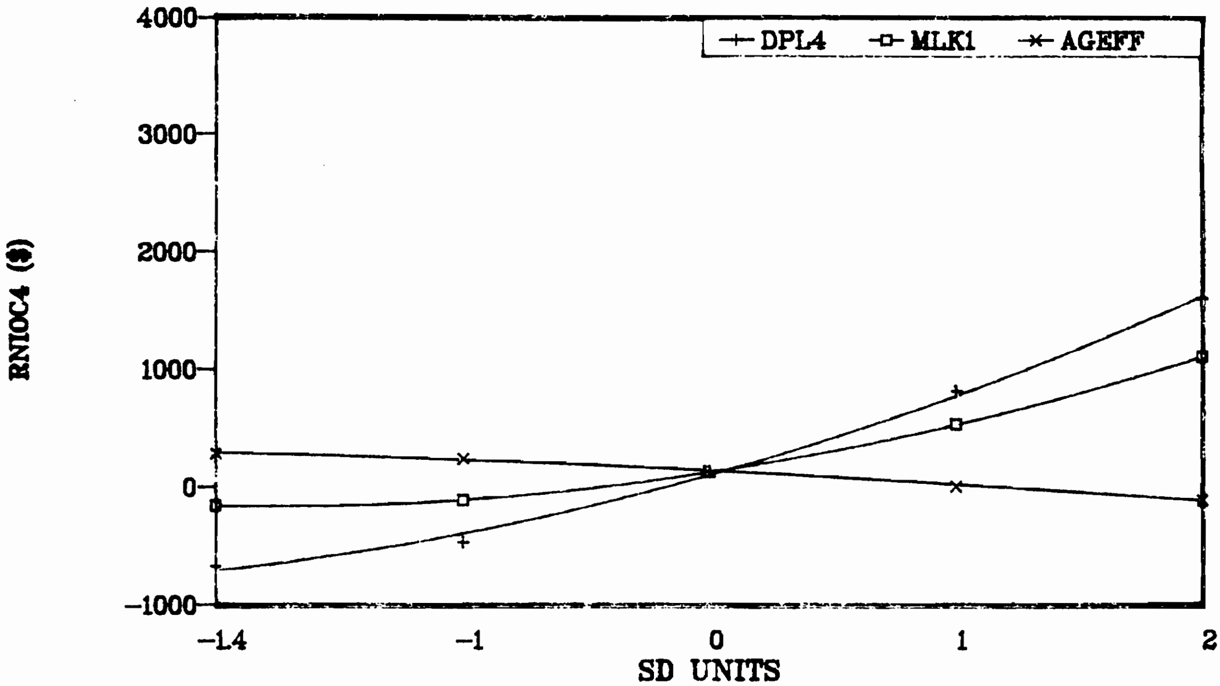

Figure 9. Graph of the impact of age at first freshening (AGEFF), first lactation milk (MLK1), days of productive life (DPL4) on RNIOC4 to all lactations herdlife period.

value of DPL(i) was greater for RNI(i) than RNIOC(i). Impact of AGEFF declined as herdlife period increased and the regression on profit appeared to be linear and constant.

The reduced importance of DPL4 on RNIOC4 relative to RNI4 is shown in Figure 10. Equations for this figure are from Table 27. Adjustment of profit equations for opportunity cost reduced differences between cows in profit arising from differences in DPL4. This result is as predicted by Van Arendonk (58).

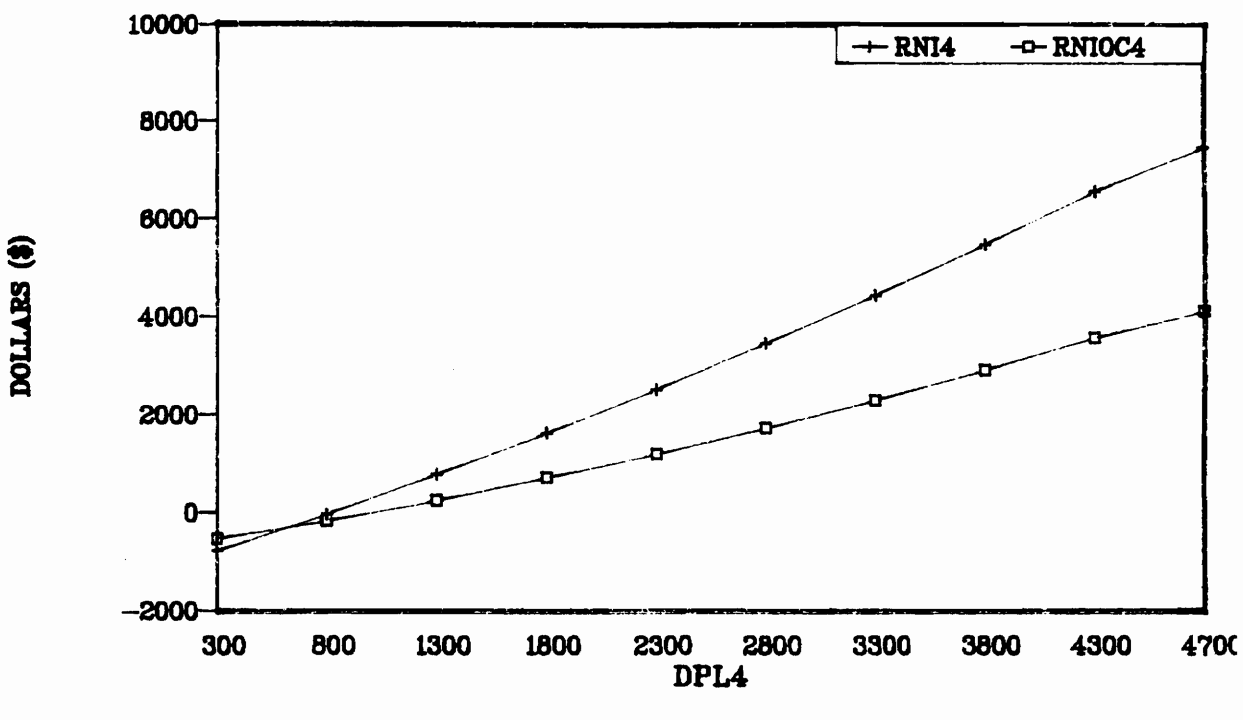

Figure 10. Graph of the impact of days of productive life on RNI4 and RNIOC4 to all lactations herdlife period.

Section 2

The goal of Section 2 was to determine the impact that selected management variables had on the various measures of profitability. The regression technique used in this part of the study absorbed herd effects and used linear and quadratic terms for the herd-year management variables and predicted the individual cows profit measures. Removal of herd effects ensured that the percent of the variation explained by the model would at least equal variation due to herd. The variation attributed to year (Table 14) decreased for RNI and DRNI as herdlife period advanced. The percent of variation in RNI attributable to year was 10.5%, 7.4%, 5.6%, and 3.6% to the first, second, third and fourth herdlife periods, respectively. The percent of variation in DRNI attributable to year was 10.8%, 7.9%, 6.0%, and 3.9% to the first, second, third, and fourth herdlife periods, respectively. RNIOC had no variation due to year. PPD3 is the only measure of PPD for which the variance due to year is known (4.2%). No traits of the individual animal were used, therefore, none of the within herd-year, or error, variance could be explained by the model. The goal of this part of the study was to determine how much of the variability in the profit measures of individuals was due to year to year changes in management variables within herd.

Definitions of herd-year characteristics are in Table 28. The means, standard deviations, minimums, and maximums for the herd-year variables used in this study are presented in Table 29. The correlation of the same variable from both the edited and unedited data sets are also in Table 29. Both data sets were analyzed for herd-year variables to see how much the edits placed on individual cows changed the original characteristics of the herds.

Herd-year variables used in this study were totals, means and percentages for several variables within the herd-year. Variables of the herd-year related to size (TOTCOW, RTSZ, P2YR), registry status (PGRADE, CPGRADE), disposal patterns (TERMP, PSFD, AGEGO), and biological traits (AGEFF, AMLK2YR, CINT1) were used to study yearly changes in profit within a herd. Linear and quadratic terms for these variables were used. Quadratic terms are denoted as the abbreviated name for these herd-year characteristics with (Q) added.

Table 28. Definitions of herd-year characteristics.

VARIABLES	DEFINITIONS
TOTCOW	total number of calvings within a herd-year
TOTCOWQ	quadratic term for TOTCOW
PGRADE	portion of calvings by grades within a herd-year
PGRADEQ	quadratic term for PGRADE
AGEFF	average age at first freshening for animal in a herd-year
AGEFFQ	quadratic term for AGEFF
AGEGO	average age at disposal for animals within a herd-year
AFEGOQ	quadratic term for AGEGO
TERMP	percent of animals termintated within a herd-year
TERMPQ	quadratic term for TERMP
AMLK2YR	average milk production of animals in first lactation within a herd-year
AMLK2YRQ	quadratic term for AMLK2YR
P2YR	portion of TOTCOW by animals if first lactation within a herd-year
P2YRQ	quadratic term for P2YR
PSFD	percent sold for dairy within a herd-year
PSFDQ	quadratic term for PSFD
CINT	average first calving interval of animals within a herd-year
CINTQ	quadratic term for CINT
CPGRADE	PGRADE three years later minus PGRADE of the herd-year in
CPGRADEQ	quadratic term for CPGRADE
RTSZ	percentage change in TOTCOW three years later
RTSZQ	quadratic term for RTSZ

Table 29. **Means and correlations of herd-year characteristics from original data set and the data set edited for 48 month herdlife.**

Variable	#	Original Data Mean	S.D.	Min.	Max.	#	48 mo Edited Data Mean	S.D.	Min.	Max.	Corr.
TOTCOW	73,868	58	58	1	2,283	73,868	41	40	1	1,454	.86
PGRADE(%)	73,868	46	41		100	73,868	44	42	0	100	.98
AGEFF	73,865	860	72	563	1,095	73,868	865	75	559	1,096	.78
AGEGO	71,874	1,741	436	578	5,478	67,435	1,595	458	550	4,709	.67
P2YR(%)	73,868	31	14	0	150	73,868	40	23	0	100	.57
TERMP(%)	73,868	18	9	0	98	73,868	16	10	0	96	.80
AMLK2YR	73,868	5,625	928	0	11,090	73,868	5,801	977	445	11,739	.91
PSFD(%)	73,868	1.92	5.38	0	97.83	73,868	1.22	4.37	0	96.43	.81
CINT	73,693	397	30	29	754	73,004	397	33	284	729	.85
CPGRADE(%)	65,311	0	11	-97	100	65,065	0	12	-100	100	.78
RTSZ(%)	65,311	40	227	-100	11,200	65,065	83	408	-100	59,700	.55

For definitions of herd characteristics refer to Table 28.

Most of the variables had relatively high (generally .7 or greater) correlations between the two data sets. The variable with the highest correlation (.98) was PGRADE, indicating that edits had little effect on this variable. The averages for PGRADE from both data sets were approximately equal at .45. The change in PGRADE three years later, CPGRADE, had a very low average value indicating that most herds did not change registry status drastically in the short term. The range and standard deviation for CPGRADE were relatively large indicating that some herds within the data set did have large changes in PGRADE.

The total number of cows calving within a herd-year, TOTCOW, was considerably higher for the unedited data set compared (58) to the edited data set (41). TOTCOW was lower in the edited data set because of edits on herdlife opportunity. Animals in second and later lactations when a herd initiated testing would not be included, and animals first calving in the last years a herd was on test would also not have been included in calculations of TOTCOW for the edited data set. The correlation of the TOTCOW between the two data sets was relatively high (.86).

The two variables that were least correlated in the two data sets were P2YR, portion of two-year olds, (.57) and RTSZ, ratio of change in herd size three years later, (.55). These variables probably had lower correlations than other variables because they were very sensitive to accurate measures of TOTCOW. The inaccuracy of measuring TOTCOW in end years of a herd could cause extreme values for RTSZ and P2YR in the edited data set. The maximum P2YR (1.5) from the unedited data set was higher than what was theoretically possible. There were only six such observations and many were caused by having one more two-year old than TOTCOW. The reason for this discrepancy is not known. The mean for P2YR from the edited data set was .31 versus .40 from the edited data set. This was consistent with the smaller average value for TOTCOW in the edited data set than in the unedited data set. The average RTSZ showed that the trend for increasing cow numbers was fairly strong in the herds in this data set.

Variables which were related to the rate at which animals left herds, TERMP and PSFD, had moderate correlations of .80 and .81 between estimates from original and unedited data. Both had similar ranges. Part of the reason for the similarities of these two variables was PSFD was part of TERMP. AGEGO was not as highly correlated in the two data sets at r = .67.

AGEFF, AMLK2YR, and CINT1 were herd-year variables that were influenced to some degree by biological traits of the animals first calving within a herd-year. These variables were examined on an individual basis within herd-year in Section 1. Considered as a herd-year variable, they can be interpreted as an indicator of management decisions relative to production and reproductive performance. AMLK2YR and CINT1 in a given year had higher correlations of estimates calculated in both data sets than AGEFF. The high correlation of AMLK2YR in both data sets indicated that the production level was consistent in both data sets. This study examined how much management's year to year changes of these traits impacted changes in herd-year average profitability.

The correlations of the eleven herd management variables with profit measures within herd to the four herdlife periods are in Tables 30-33. The variable with the strongest correlation with profit measures to all four herdlife periods was AMLK2YR. The correlation of AMLK2YR declined as herdlife opportunity period advanced for RNI and DRNI. The correlation of AMLK2YR with RNIOC and PPD was relatively more constant over time. AGEFF also had a higher correlation with RNI1 (-.11) than with later measures of RNI. Both of these traits were under a considerable amount of control by management and were of more importance to early herdlife periods. This may explain the higher portion of variance explained by herd and year within herd for earlier measures of RNI and DRNI.

The management variables not directly related to a biological trait generally had extremely low correlations with profit measures. TOTCOW had the highest correlation with RNI1 of any of the herd-year (.09) management variables not directly related to a biological trait. The correlation of TOTCOW with RNI measures declined as herdlife opport unity period advanced. The correlation of TOTCOW with RNI1 may be indirectly due to its correlation with AMLK2YR and may be influenced by the simultaneous trends for increased milk production and cow numbers within herd.

Table 30. Correlations within herd of herd-year characteristics and profit measures to the 48 month opportunity group.

Variable	RNI1	DRNI1	RNIOC1	PPD1
TOTCOW	.09	.09	.03	.04
PGRADE	-.04	-.04	-.02	-.03
AGEFF	-.11	-.12	-.04	-.09
AGEGO	.05	.05	.02	.07
TERMP	-.01	-.01	-.01	-.07
AMLK2YR	.29	.29	.11	.22
P2YR	-.02	-.02	.00	-.01
PSFD	.01	.01	.00	-.02
CINT	-.02	-.02	-.01	-.02
CPGRADE	-.01	-.01	.00	.00
RTSZ	-.05	-.05	-.02	-.01

For definitions of profit measures refer to Table 12.
For definitions of herd characteristics refer to Table 28.

Table 31. Correlations within herd of herd-year characteristics and profit measures to 60 month opportunity group.

Variable	RNI2	DRNI2	RNIOC2	PPD2
TOTCOW	.08	.07	.04	.03
PGRADE	-.03	-.03	-.02	-.02
AGEFF	-.07	-.08	-.03	-.05
AGEGO	.05	.05	.02	.08
TERMP	-.02	-.02	.00	-.08
AMLK2YR	.23	.24	.12	.21
P2YR	-.01	-.01	.00	-.01
PSFD	.01	.01	.00	-.02
CINT	-.02	-.02	-.01	-.01
CPGRADE	.00	.00	.00	.00
RTSZ	-.03	-.03	-.02	-.01

For definitions of profit measures refer to Table 12.
For definitions of herd characteristics refer to Table 28.

Table 32. Correlations within herd of herd-year characteristics and profit measures to the 72 month opportunity group.

Variable	RNI3	DRNI3	RNIOC3	PPD3
TOTCOW	.05	.06	.04	.03
PGRADE	-.03	-.03	-.02	-.02
AGEFF	-.05	-.06	-.03	-.04
AGEGO	.05	.05	.02	.08
TERMP	-.03	-.02	.00	-.08
AMLK2YR	.19	.20	.13	.20
P2YR	-.01	-.01	-.01	-.01
PSFD	.00	.00	.01	-.02
CINT	-.01	-.01	-.01	.00
CPGRADE	.00	.00	.00	.00
RTSZ	-.02	-.02	-.03	.00

For definitions of profit measures refer to Table 12.
For definitions of herd characteristics refer to Table 28.

Table 33. Correlations within herd of herd-year characteristics and profit measures to the all lactation opportunity group.

Variable	RNI4	DRNI4	RNIOC4	PPD4
TOTCOW	.00	.01	.03	.02
PGRADE	-.01	-.01	-.02	-.02
AGEFF	-.03	-.04	-.03	-.04
AGEGO	.04	.04	.03	.08
TERMP	-.04	-.04	-.01	-.09
AMLK2YR	.12	.14	.13	.18
P2YR	.00	.00	.00	-.01
PSFD	.00	.00	.01	-.02
CINT	-.01	-.01	-.01	.00
CPGRADE	.00	.00	.00	.01
RTSZ	.02	.01	-.01	.00

For definitions of profit measures refer to Table 12.
For definitions of herd characteristics refer to Table 28.

The variables related to the cow disposal practices of herd-years, TERMP, PSFD, and AGEGO, may be indicative of DPL. The correlations of these measures with profit measures were all smaller than the correlations of AMLK2YR with profit measures. AGEGO had a relatively small and constant positive correlation with profit measures as herdlife period advanced. TERMP was very small and negativly correlated with all profit measures and increased slightly with longer herdlife periods. PSFD was even less related to profit than TERMP and AGEGO. The small correlations of these measures with profit indicated that the prediction of herd-year variance by variables indicative of herdlife were very limited.

PGRADE was consistently small and negatively correlated with all definitions of profitability, as was CPGRADE. The correlations of these variables with profit indicated that herd-years with a higher PGRADE were less profitable, but the size of the correlation was too small to speculate about causes for this relationship. The impact of PGRADE in this study may have had a low correlation with profit measures because of low variability within herd.

The regression coefficients for both linear and quadratic terms for the eleven different management variables and R:^{2} predicting RNI, RNIOC, DRNI, and PPD to the four herdlife periods are in Tables 34-37. Interpretation of regression coefficients should be done with caution because of covariance of the variables in the model. The most noteworthy thing to show in the regression models was that all of the variation due to herd and year within herd was accounted for as in Table 18 in Section 1. This reemphasized that there was very little if any herd and year within herd variance for RNIOC to the four herdlife periods. The percent of variance explained by the management variables declined as herdlife period advanced, similar to the analysis in Table 18. The reason for the reduction in the herd and year within herd variance as herdlife opportunity increased was that DPL : (a) became more variable as herdlife period advanced, (b) became relatively more important for RNI and DRNI, and (c) had small herd and year within herd components of variance.

Regression coefficients are difficult to interpret but can be viewed as the change in the profit measure that would occur given a change in the variable in question given that the other variables

Table 34. Regression analysis using herd-year characteristics for profit measures to 48 month herdlife opportunity.

VARIABLES	RNI1	DRNI1	RNIOC1	PPD1
TOTCOW	1.73*	1.48*	.32*	.002*
TOTCOWQ	-.002*	-.001*	-.0003*	$1.8*10^{-6}$
PGRADE	-1.63*	-1.40*	-.56	-.0007
PGRADEQ	.004	.004	.0004	$-8.0x10^{-6}$
AGEFF	-2.65*	-2.38*	.90	.002*
AGEFFQ	.0006*	.0006*	-.0008	$-3.2*10^{-6}$
AGEGO	-.07*	-.06*	-.002	.0004*
AFEGOQ	$1.3*10^{-5}$*	$1.2*10^{-5}$*	$3*10^{-7}$*	$-7.1*10^{-8}$
TERMP	.015*	.015*	.004	-.0001*
TERMPQ	$3.0x10^{-7}$	$2.0x10^{-7}$	$1.0x10^{-7}$	$1.0x10^{-8}$*
AMLK2YR	.17*	.15*	.15*	.001*
AMLK2YRQ	$7.3*10^{-6}$	$6.3*10^{-6}$*	$-5.8*10^{-7}$*	$-2.0*10^{-8}$
P2YR	.29	.23	.56	.001
P2YRQ	-.007	-.006	-.0042	$-8.0x10^{-7}$
PSFD	6.35*	5.45*	2.00*	.02*
PSFDQ	-.09*	-.07	-.03*	-.0002*
CINT	1.26*	.99*	1.66*	.0065*
CINTQ	-.003*	-.003*	-.003*	$-1.2*10^{-6}$
CPGRADE	-.67*	-.58*	-.28	-.0006
CPGRADEQ	-.013*	-.010*	-.001	$-4.2x10^{-5}$*
RTSZ	.15*	.12*	-.02	.0007*
RTSZQ	$-1.7*10^{-5}$	$-1.1*10^{-5}$*	$1.8*10^{-5}$	$-3.2*10^{-7}$*
R SQUARED	.330	.342	.017	.180

* Significan (P < .01)
For definitions of herd characteristics refer to Table 28.
For definitions of profit measures refer to Table 12.

Table 35. Regression analysis for herd-year characteristics predicting profit measures to 60 month opportunity.

VARIABLES	RNI2	DRNI2	RNIOC2	PPD2
TOTCOW	2.46*	2.07*	.74*	.002*
TOTCOWQ	-.002*	-.002*	-.001*	-1.9*10-6*
PGRADE	-1.69*	-1.46*	-1.11*	$2.0x10^{-6}$
PGRADEQ	.0008	.0009	.0021	$-1.5x10^{-5}$
AGEFF	-.82	-.94	1.04	-.002
AGEFFQ	-.0005	-.0003	-.0009*	-2.4*10-7
AGEGO	-.05	-.05	-.04	.0005*
AFEGOQ	1.3*10-5	1.3*10-5	8.0*10-6	-7.8*10-8
TERMP	$-5.0x10^{-5}$	$-5.0x10^{-6}$	.0001	$-2.0x10^{-6}$*
TERMPQ	$2.0x10^{-6}$	$2.0x10^{-6}$	-.0001	$-2.0x10^{-6}$
AMLK2YR	.21*	.18*	.20*	.01*
AMLK2YRQ	$8.3x10^{-6}$*	$6.8x10^{-6}$*	$-7.3x10^{-6}$*	$2.5x10^{-8}$*
P2YR	.59	.46	.41	$1.1x10^{-5}$
P2YRQ	-.012	-.010	-.005	$3.0x10^{-6}$*
PSFD	8.93*	7.46*	3.06*	.02*
PSFDQ	-.12*	-.10*	-.046*	-.0003*
CINT	2.60*	2.05*	1.93*	.01*
CINTQ	-.006*	-.005*	-.003*	-1.2*10-5*
CPGRADE	-.82*	-.72*	-.48	$-4.0x10^{-6}$
CPGRADEQ	-.032	-.025*	-.0183*	$-6.0x10^{-5}$*
RTSZ	.58*	.46*	.04	.001*
RTSZQ	-.0002*	-.0002*	-1.4*10-5	-5.3*10-7
R SQUARED	.255	.269	.020	.151

* Significance (P > .01)
For definitions of herd-year characteristics refer to Table 28.
For definitions of profit measures refer to Table 12.

Table 36. Regression analysis for herd-year characteristics predicting profit measures to 72 month opportunity.

VARIABLES	RNI3	DRNI3	RNIOC3	PPD3
TOTCOW	2.95*	2.44*	1.27*	.002*
TOTCOWQ	-.003	-.002*	-.001*	$-2.1*10^{-6}$*
PGRADE	-1.78*	-1.52*	-1.60*	$5.0x10^{-6}$
PGRADEQ	.0002	.0005	.00352	$-1.7x10^{-5}$
AGEFF	-.10	-.40	.87	-.003
AGEFFQ	-.0009	-.0006	-.0009	$2.9*10^{-7}$*
AGEGO	-.007	-.02	-.06	.0005*
AFEGOQ	$9.8*10^{-6}$*	$1.0*10^{-5}$	$1.3*10^{-5}$	$-8.3*10^{-8}$*
TERMP	-.0004*	-.0002*	.0001	-2.2^{-6}*
TERMPQ	.07*	.06*	.009*	.0002*
AMLK2YR	.27*	.23*	.24*	.0008*
AMLK2YRQ	$4.9*10^{-6}$	$3.9*10^{-6}$	$-6.8*10^{-6}$*	$-3.1*10^{-8}$*
P2YR	.50	.36	.0003	$8.0x10^{-6}$
P2YRQ	-1.27	-1.03	-.24	$6.0x10^{-6}$
PSFD	11.22*	9.18*	4.35*	.017*
PSFDQ	-.18*	-.15*	-.07*	-.0003*
CINT	3.26*	2.52*	1.93*	.007*
CINTQ	-.006*	-.005*	-.0004	$-1.2*10^{-5}$*
CPGRADE	-1.11*	-.95*	-.76*	$-7.0x10^{-6}$
CPGRADEQ	-.0516*	-.0399*	-.0230	$6.8x10^{-5}$
RTSZ	1.01*	.80*	.19*	.001*
RTSZQ	-.0004*	-.0003*	$-8.3*10^{-5}$*	$-6.2*10^{-7}$*
R SQUARED	.205	.220	.023	.138

* Significant ($P < .01$)
For definitions of herd-year characteristics refer to Table 28.
For definitions of profit measures refer to Table 12.

Table 37. Regression analysis of herd-year characteristics predicting profit measures to the all lactations period.

VARIABLES	RNI4	DRNI4	RNIOC4	PPD4
TOTCOW	.36	.80*	1.24*	.0015*
TOTCOWQ	-.001*	-.001*	-.001*	$-1.8x10^{-6}$*
PGRADE	1.59	.62	-1.31	$1.1x10^{-5}$
PGRADEQ	-.002	-.001	$-4.9x10^{-4}$	$-2.2x10^{-5}$
AGEFF	-.69	-.70	.67	-.004
AGEFFQ	-.0005	-.0004	-.0009	$7.2*10^{-7}$
AGEGO	.09	.04	-.04	.0006*
AFEGOQ	$-3.9x10^{-6}$	$1.5x10^{-6}$	$1.3x10^{-5}$	$-9.8x10^{-8}$*
TERMP	-.13*	-.08*	-.02*	$-3.0x10^{-6}$*
TERMPQ	$2.2.0x10^{-5}$*	$1.4x10^{-5}$*	$5.0x10^{-6}$	$3.0x10^{-8}$*
AMLK2YR	.40*	.31*	.30*	.01*
AMLK2YRQ	$-5.8*10^{-6}$	$-3.4*10^{-7}$	$-8.3*10^{-6}$*	$-3.0x10^{-8}$*
P2YR	2.771	1.80	.68	.0013
P2YRQ	-.0365	-.0254.83	-.0112	$3.0x10^{-6}$
PSFD	16.55*	12.76*	7.63*	.02*
PSFDQ	-.30*	-.23*	-.13*	-.0003*
CINT	4.75*	3.50*	2.39*	.01*
CINTQ	-.008*	-.006*	-.005*	$-1.3*10^{-5}$
CPGRADE	-1.35	-1.11	-1.22*	$-6.0x10^{-6}$
CPGRADEQ	-.0613*	-.0468*	-.0295*	$-7.1x10^{-5}$*
RTSZ	1.51*	1.14*	.62*	.001*
RTSZQ	-.0007*	-.0005*	-.0003*	$-7.4*10^{-7}$*
R SQUARED	.146	.164	.020	.124

Signicicance (P > .01)
For definitions of herd-characteristics refer to Table 12.
For definition of profit measures refer to Table 28.

were at their mean. TOTCOW consistently had a positive linear regression coefficient and a negative quadratic term. This may indicate that animals that calved in herd-years with more animals may have been more profitable up to a certain point where further increases decreased profit. PGRADE was negative for the linear term and positive for the quadratic term for the first three herdlife periods. This relationship changed for the fourth herdlife period. Both linear and quadratic terms for PGRADE were negative indicating that increasing PGRADE within a herd was associated with a decrease in profit. TERMP was negative for the linear term to the second, third and fourth herdlife periods. This indicated that increasing the rate of disposal decreased profit within herd. PSFD was positive for the linear term indicating that increasing sales of animals for dairy purposes was associated with increased profitability. The linear term for AGEFF was consistently negative over the four herdlife periods. The linear term was positive for CINT1. This seemed to be opposite of what would be expected because longer calving intervals would be associated with lowered efficiency. The quadratic term, however, was negative. AMLK2YR was always positive for the linear term. The linear terms for AGEFF and AGEGO were both negative. Many of the signs of regression coefficients were expected.

Interpretation of regression coefficients is unclear because of the covariance of terms in the model. The variability of profit from year to year within herd was most influenced by AMLK2YR. This was particularly true of profit definitions based on shorter herdlife periods. Other herd variables had very small correlations with profit measures. Signs of the correlations may give an indication of the relationship of herd management variables with profit measures. Overall, however, the greatest opportunity for management to improve profit would be by adopting practices leading to higher yields in first calf heifers.

Section 3

The focus of this portion of the study was to determine if the differences existed in grade and registered cows for profit measures in mostly grade (> .94 PGRADE), mostly registered (< .06 PGRADE), and mixed herd-years. Basing the subsets on the PGRADE of the herd-year could result in animals from the same herd being in different data sets for different years. Subsetting was accomplished by splitting the data into three data sets based on the three categories for PGRADE listed above and including a term for registry status in addition to the linear and quadratic forms for AGEFF, MLK1, and DPL(i) after herd and year within herd effects were absorbed. Means for grades and registered cows were also compared within the three categories of PGRADE for the herd-year.

Table 38 shows the means for registered and grade cows in the three categories of herd-year PGRADE. The most obvious differences in the means for grade and registered cows in the three herd categories was: (a) that the grades were consistently lower than registered cows for measures of profit to the four herdlife periods, (b) differences for grade and registered cows increased within categories as herdlife opportunity period advanced, and (3) the difference in grade and registered cows was most in mostly registered herds , followed by mostly grade herds, and mixed herds. The differences in means for profit measures seemed to be directly related to the differences in DPL. This suggested that the differences in grade and registered cows within herd was related to less culling of registered cows. While grade cows were less profitable than registered cows within herd, increasing PGRADE was associated with more profitable herds.

The regression coefficients for registry status, (where grade = 1, and registered = 2), are presented in Table 39. Regression coefficients for other traits in the model and R^2 are not presented because they are similar in the three subsets. One of the most noteworthy things to notice is that the regression coefficients became larger with advancing herdlife period. The only exception to this is that

Table 38. Comparisons of means for grade and registered cows for profit measures within mostly grade, mostly registered, and mixed herds.

VARIABLE	< .06 PGRADE				> .94 PGRADE				MIXED			
	Reg.		Grade		Reg.		Grade		Reg.		Grade	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
RNI1	54,179	38	527	-101	300	115	42,782	36	46,417	79	44,669	43
DRNI1		-72		-187		-7		-74		-37		-67
RNIOC3		-3		-116		9		-9		3		-25
DPL1		581		499		588		581		593		568
RNI2	49,561	367	497	148	280	483	38,458	350	42,416	422	40,454	344
DRNI2		182		5		277		168		228		166
RNIOC2		-4		-137		-7		-12		7		-37
DPL2		799		665		837		787		817		763
RNI3	45,084	618	445	281	256	820	33,918	578	38,272	681	35,949	556
DRNI3		365		101		530		335		416		319
RNIOC3		-5		-173		4		-13		12		-47
DPL3		961		750		1,012		938		985		901
RNI4		925		389		1,156		790		998		770
DRNI4		614		217		801		523		672		508
RNIOC4		-3		-238		22		-12		27		-59
DPL4		1,196		870		1,254		1,108		1,220		1,070

For definitions refer to Table 12.

the regression coefficient for PPD became smaller as herdlife period advanced for the mostly registered subset. Registry status was also more likely to be significant (.01 significance level) for later herdlife periods and for RNIOC. The apparently larger impact of registry status as herdlife opportunity period advanced may have been due to cummulative preferential treatment and less stringent culling in registered cows.

Regression coefficients were also largest in the mostly grade subset. This suggested that registered cows are treated best relative to grade cows in herds where there are only a few registered cows in the herd. The regression coefficients for registry status were generally smaller in the mixed registry status herds than in the other data sets but were always significant and positive. The reason for this is that it took more difference in grade and registered cows in mostly grade or mostly registered herds to show significance. Fitting of MLK1, AGEFF, and DPL in the models may have reduced the regression coefficient for registry status because of differences between grade and registered cows for these variables.

Table 39. Regression coefficients and test of significance of registry status in a model including effects of herd, year , and age at first freshening, first lactation milk yield, days of productive life'.

VARIABLE	<.06 PGRADE	>.94 PGRADE	MIXED[1]
RNI1	17.90	8.79	7.30*
RNIOC1	20.00	-.75	8.72*
DRNI1	15.17	7.25	6.13*
PPD1	.019	.010	.013*
RNI2	23.23	55.94	15.43*
RNIOC2	35.20	45.61	18.39*
DRNI2	19.83	46.09	13.05*
PPD2	.001	.056	.018*
RNI3	49.37	72.07	22.53*
RNIOC3	57.20*	64.17	27.56*
DRNI3	40.69	58.63	18.82*
PPD3	.014	.079	.022*
RNI4	75.24	123.31*	40.23*
RNIOC4	77.42*	103.71*	51.69*
DRNI4	61.07*	95.07	32.34*
PPD4	-.049	.086	.015*

[1] Mixed herds were herds with PGRADE ≥ AND ≤.94.
* Significant at the .01 level of significance.
For definitions of profit measures refer to Table 28.

Summary and Conclusions

RNI, DRNI, RNIOC, DRNIOC, and PPD were calculated for herdlife periods of 48 month, 60 month, 72 month, and all lactations. The calculation of these measures to the different herdlife periods allowed for the comparison of the different profit functions as herdlife period advanced. The criteria for deciding the amount of information included in each herdlife period was the number of lactations initiated prior to the herdlife period cutoffs. RNIOC was the profit measure which represented the first application of opportunity cost to field data. The OCPD that was charged to an animal within a herd-year aimed at being representative of the average profit produced in a day by a replacement heifer. The OCPD was calculated by regressing herd-year means for RNI and DPL on overall herd means based on the number of animals in herd-years, and dividing the regressed mean for RNI by the regressed mean for DPL. Application of OCPD in this way resulted in 0% of the variation due to herd and year within herd, therefore almost all of the variance in RNIOC to all four herdlife periods was error variance. This was compared to 33%, 25%, 21%, and 15% of the variation due to herd and year within herd for RNI to the first, second, third, and fourth herdlife period, respectively.

Means and standard deviations were also smaller for RNIOC than RNI to each of the four herdlife periods. DRNI was intermediate between RNI and RNIOC, but more nearly followed RNI. Average RNI increased as herdlife period advanced at a declining rate because of increased disposals. Average RNIOC remained relatively constant over the four herdlife periods at approximately -$10. The average and standard deviation for TOC increased as herdlife period advanced. This indicated that the difference in RNI and RNIOC were increased as herdlife period advanced. The results of the application of opportunity cost was a distribution for RNIOC that had a larger percent of animals with negative values and a smaller percent of animals with extremely high, positive values.

The within herd correlation of RNI3 and RNIOC3 was .95. This indicated that very little had been done to change the ranking of cows within herd. The correlation of RNI1 and RNI4 in the data set not requiring a second calving was .66. The correlation of RNIOC1 and RNIOC4 was .70 in this data set. The correlation of RNI1 with RNI4 in the data set requiring a second calving was .54, and the correlation of RNI1 and RNIOC4 was .62. The correlation of RNIOC1 with RNIOC4 within the data set requiring a second calving was .63. These correlations indicated that RNIOC was less affected by herdlife opportunity length than RNI. This indicated that early measures more accurately predicted later measures for RNIOC than for RNI. The correlation of 48 month herdlife measures with a second calving required may be the correlation that would be of most interest when predicting later measures of profitability from type traits.

The reason for the higher correlation of RNIOC4 with RNI1 and RNIOC1 was RNIOC was less affected by herdlife. The correlation of DPL was higher for RNI4 (.89) than for RNIOC4 (.74). The correlation of MLK1 was slightly higher for RNIOC than for RNI to all herdlife periods, and declined as herdlife period advanced. The correlation of MLK1 and profit measures was greater in the data set not requiring a second calving than in the data set requiring a second calving. This may have been because of the greater covariance of MLK1 with DPL in this data set.

Regression analysis also showed DPL3 to be the most important variable in predicting RNIOC3 and RNI3, but DPL3 explained less of the within herd-year variation in RNIOC3 than in RNI3 (74% vs. 57%). Addition of MLK1 to the prediction of equation including DPL3 increased the variation explained for RNIOC3 more than for RNI3 (10% vs. 6%). AGEFF and CI1 added little when added to the prediction equation. Regression analysis also showed the relationship of MLK1 to DPL for RNIOC was more constant over time than for RNI. This was because an extra DPL for RNI was worth relatively more than for RNIOC.

Regression analysis using herd-year management characteristics to explain variation in profit measures showed that all of the year within herd variance could be explained by the linear and quadratic terms of the eleven variables used in this study. The portion of variance that could be explained for RNI and DRNI became smaller as herdlife period advanced. The prediction of herd-year variance for RNIOC was futile because there was little to no variance due to herd and year. The most important management variable predicting profit measures was AMLK2YR indicating that production was the management variable with the greatest impact on profit.

The comparison of grades and registered cows for profit measures within herd consistently showed registered cows to be more profitable than grades within the three categories of herd registry status. The difference in grade and registered cows became greater as herdlife period advanced. The higher DPL for registered cows as herdlife period advanced was probably the reason.

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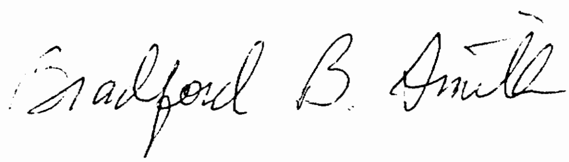
Vita



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