PROTOCOL FOR THE COST-BENEFIT ANALYSIS
OF DAIRY CATTLE HEALTH MANAGEMENT

BY

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ABSTRACT

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This study establishes a protocol for the cost-benefit analysis of dairy cattle health management which will be utilized within the Food Animal Health Resource Management System (FAHRMX) at Michigan State University. The goal is for the data storage and processing capabilities of microcomputers to be exploited for the rigorous economic analysis of specific disease control procedures on individual commercial dairy farms. The data requirements and modeling difficulties that must be overcome for such analysis are discussed.

A single equation multivariate linear model of milk production, based on data available previous to FAHRMX, is used to demonstrate how inclusion of culled cows helps correct for the high positive parameter estimate expected for cystic ovaries. Future improvements depend on the identification of a set of simultaneous equations.

Results of a questionnaire concerning farm infrastructure as it relates to dairy cattle health care are also presented.

The cow is of the bovine ilk;
one end is moo, the other, milk.

The Cow, by Ogden Nash

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To all the dairy farmers and veterinarians that made my work realistic, exciting and possible I offer this thesis in hopes that they will one day be served by it.

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Chapter One

Introduction

A. The goal of efficient resource use.

Economically efficient use of resources occurs when each resource makes its maximum contribution to predetermined objectives. The goal of economically efficient employment of resources is obtainable only within the limits of known applications. Resource owners, dairy farmers for our purposes, make estimates of the expected return from investment of their resources in each known application (expected return = probability of payoff multiplied by the payoff). They weigh the expected return of each investment against the other known alternatives when deciding how to best utilize their time, money, and land. The dairy farmer's estimate of expected return may be more or less explicit depending on the amount of accounting information available.

1. Both monetary and non-monetary objectives are relevant.

The maximization of monetary profit is one common objective. However, there are non-monetary objectives relevant to dairy farming. Farmers may have favorite animals that receive care unjustifiable in terms of monetary gain alone. In some cases, their purchase of ever more expensive equipment, including new computer technology, may be primarily motivated by social status considerations (see Appendix 1). Investments made for non-monetary reasons have consequences that can be measured in dollar terms, however. In fact, all the decisions concerning resource use on the farm have consequences that can be given a dollar value.

2. More monetary accounting information helps with both monetary and non-monetary decision making.

When a dairy farmer invests in a given venture, the gain to be had from the next best alternative is sacrificed. When farmers' primary objective is monetary profit, they would like to know in what use their resources are likely to yield the highest monetary return. Presumably, farmers would also like to know the amount of money they forego when they utilize resources to meet non-monetary objectives. The fulfillment of both monetary and non-monetary objectives would be facilitated by more clearly delineating the monetary consequences of farm resource use. With monetary accounting information, objective weights can be given to subjective decisions. This means that fewer investment "mistakes" will be made when more monetary accounting information is available. Therefore, regardless of the farmers' objectives, they will benefit from knowing more precisely what the monetary value of their resources are in different applications.

B. Great potential gains to be had by improving animal health management are largely hidden from dairy farmers.

When a calf or cow dies, the farmer recognizes the loss of all the milk and offspring that would have been produced by the animal had it not died. Other losses of productive potential are not so obvious. For example, when productivity is impaired by subclinical mastitis or infertility, nothing that physically existed is taken away from the farmer. What is lost in these instances is potential. Because losses from subclinical mastitis and infertility are difficult to recognize and quantify, investment in mastitis and infertility control are among the farmer's least well-known alternatives. For these same reasons, many veterinary treatments for mastitis and infertility remain controversial.

The potential for profit through increased attention to dairy animal health management is evidenced by the enormous dollar losses attributed to mastitis and infertility. Blosser (1979) estimated that $1.3 billion was lost due to mastitis in U.S. dairy cattle in 1976. He attributed 69 percent of this loss to subclinical mastitis. Meyer (1953) reported that impaired fertility causes a total annual loss of $800 million in U.S. cattle. Adjusting only for inflation, this latter estimate would have to be more than tripled to bring it up to date.[1/] Although the validity

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[1/]All price adjustments for inflation made using the change in consumer price index for all items (Statistical Abstract of the United States, 1981).

of these estimates may be questioned, nonetheless they indicate the magnitude of these two health problems.

1. Detection of hidden losses requires careful monitoring of performance.

Detection of lost production potential, such as that caused by mastitis and infertility in dairy cattle, requires careful monitoring of a herd's performance. Health and production records must be combined and compared over time. The data requirements for such monitoring are significant. Computer technology has made the cost of extensive data storage and processing very low. A research project at Michigan State University called the Food Animal Health Resource Management System (FAHRMX) has demonstrated that detailed animal health management data can be collected and computerized with minimal farmer effort (see Appendix 2 for FAHRMX grant proposal).

2. FAHRMX is now developing a means to carefully monitor dairy herds' health management performance.

FAHRMX is an experiment initially involving 24 dairy farms served by 5 veterinary practices throughout Michigan. There are three stages of the system's function: data collection, data formatting, and data processing.

a. FAHRMX data collection.

Data currently being amassed by FAHRMX include records of all veterinarian and farmer delivered health care: vaccinations, disease treatments, calving dates, results of reproductive exams, etc. When participating farmers or veterinarians treat an animal, they record, in their own words: the date, the animal ID, and the action taken. The action taken may include the time spent in treatment, the dosage of drug administered, and any other details they deem pertinent. Their script is translated into codes and entered onto microcomputers by technicians at the five veterinary offices.

Other data are collected for FAHRMX through a questionnaire administered to each dairy farm concerning housing, milking, and health treatment facilities, among other things (see Appendix 3). These data will be most useful for interfarm comparisons of performance.

Communication between the five microcomputers and the mainframe computer at Michigan State University will allow for the aggregation of data from the five veterinary practices and make interfarm comparisons more meaningful. Such communication will also permit the exchange of information between the Dairy Herd Improvement Association (DHIA), which is a milk production monitoring service, and FAHRMX. Communication with DHIA will not only allow immediate access to milk production information but will also provide genetic data from DHIA's semiannual inventory reports. In conclusion, the total data collecting ability of FAHRMX encompasses farm infrastructure, animal health histories, labor and drug expense for health care, genetic information, and milk production.

b. FAHRMX data formatting.

There are a number of useful features of FAHRMX that simply involve organizing, or formatting, the data mentioned above. First, FAHRMX design allows for the easy retrieval of health, and eventually, milk production data on individual animals. This feature is important when, for example, an animal's health history must be considered before administering additional treatment. Second, FAHRMX software calculates whole-herd and whole-system statistics such as disease incidence figures. This provides some basis of comparison between herds, which will help farmers decide what their major animal health management problems are. Third, the existence of the data and the computer's quick searching ability are exploited by FAHRMX to raise "flags" or notices of upcoming necessary action like reproductive exams or vaccinations. The above three capabilities are also combined when, for example, the results from previous reproductive exams are displayed for all animals that are currently due for examinations.

c. FAHRMX data processing.

Although there are many benefits of merely reorganizing and aggregating FAHRMX's detailed animal health-related data, the most exciting opportunities presented by the data are their use for comparative medical purposes. It has never before been possible to measure, on a continuing basis, the effects of different disease control procedures on the milk producing potential of commercial dairy herds.

C. Comparative medicine and the farmer's resource-use decisions are equally well served by cost-benefit analysis.

Veterinarians and farmers alike are interested in which treatments and procedures are most effective in reducing cost and improving the productivity of their herds. The delineation of the costs and benefits of each health control technique would reveal the value of expenditure in each procedure to both farmers and veterinarians.

Such cost-benefit analysis would be new to veterinary medicine. Farmers could see the effectiveness of different health management procedures working within their own resource constraints. Many of the losses from health management problems would no longer be hidden. This would work to the veterinarians' advantage because they would no longer just have research herd results with which to convince a farmer of the benefits of a new technique. A discriminating cost-benefit analysis system for dairy herd health would also provide a check on the recommendations that veterinarians make.

The assumption was made earlier that further investment in dairy cattle health care merits consideration. A cost-benefit analysis system for animal health management would show where profitable investments exist within animal health management. Profitable investments in this area certainly exist. However, this does not mean that it is in the farmer's best interest to pour all available funds into animal health management. Even with a cost-benefit analysis system for dairy cattle health management, farmers would still have to decide if there are more profitable investments outside the scope of health management. For now, the development of a cost-benefit analysis system for dairy cattle health management is a big enough task. It is best to start where the greatest benefits are expected, but the need for economic decision aids for other aspects of dairy farming should be recognized. Once a cost-benefit analysis system is operational for dairy cattle health management, it could be expanded to include other farm enterprises.

D. Scope of Thesis

The purpose of this thesis is to develop a protocol for the cost-benefit analysis of dairy cattle health management. The economic analysis of dairy cattle health management has received much attention in the literature and has been frequently misunderstood, as evidenced in the literature review (Chapter 2). In all fairness, the rigor of previous studies has suffered from the lack of detailed health-related data, and the present study was undertaken in response to the new data capabilities outlined earlier. But the persistence of much used and very questionable estimates of losses due to disease problems is disturbing. If unsubstantiated estimates of economic losses caused by disease in dairy cattle are continually quoted because of a lack of understanding of economic analysis, then a clear presentation of the requirements for the economic analysis of dairy cattle health management is long overdue. Cost-benefit analysis is simply a form of economic analysis, or an economic model. A substantial part of this thesis is concerned with the method of cost-benefit analysis as it pertains to dairy cattle health management.

The accounting tool used for cost-benefit analysis is the partial budget. The standard partial budgeting procedure includes a list of factors which reduces profit (costs) by either increasing costs or reducing income, and a list of factors which increases profit (benefits) by either increasing income or reducing costs (Harsh et al., 1981). Creating an economic model for dairy cattle disease control consists primarily in identifying relevant costs and benefits, and organizing them as is done in Chapter 3.

Once it is clear how the costs and benefits will be used to aid in decision making, the next problem is estimating them. Estimating reduced lactating potential due to disease probably is most difficult because lactating potential is affected by many factors, and is itself difficult to estimate. Chapter 3 also contains a statistical model which is expected to estimate reduced lactating potential due to cystic ovaries and metritis (because these were the only diseases for which data were available retrospectively) better than has been done previously. However, questions about the specification of the model are raised, and suggestions are made as to how the model can be improved using current FAHRMX data.

Chapter Two

The Economic Evaluation of Dairy Cattle Health Management: A Review of the Literature

A. Introduction

A critical review of the available literature on dairy cattle health management reveals a growing interest, over the last two decades, in "economic" analysis. This is a function of the increasing importance given to less conspicuous effects of disease and lack of attention to animal health management. Such "hidden" effects include production losses due to subclinical mastitis and suboptimal breeding performance. The purpose of these "economic" studies has either been to stress the need for additional research expenditure or to "prove" the value of regular veterinary visits emphasizing reproductive herd health. Estimates of industry-wide losses due to mastitis and infertility are based on little more than guesses and should therefore be viewed with scepticism.

Measures of the value of regular veterinary visits or programmed herd health have suffered from the inability to isolate the most profitable features of these programs. Also, by comparing the farms' performance before and after the new program's inception, some investigators failed to correct for performance trends which were independent of the new program. In most cases, estimates of the effects of health management programs do not account for individual dairy farms' resource constraints. Despite these difficulties, the magnitude of the returns possible from increased attention to fertility and udder health have been demonstrated.

Progress in measuring the value of dairy cattle health care depends largely on understanding the relationship between health care, disease, and milk production. Recent evidence shows a positive correlation between milk production and some diseases. Whether this correlation is spurious or not remains to be proven. All previous studies on the economics of dairy cattle health management have been limited by lack of detailed data. Computer-facilitated data collection will allow for more rigorous analysis.

B. Estimating Losses Due to Mastitis

Numbers are often assumed to be magically endowed with objectivity. Once a numerical estimate is made, the subjective steps in making the estimate may be forgotten. In the case of estimating the cost of mastitis and infertility in dairy cattle, the tenuous nature of estimates made to date should be recognized.

In a 1979 article, Blosser reviewed the literature concerning economic loss due to mastitis in dairy cattle in the U.S. and other countries. His goal was to emphasize the need for further research by demonstrating the magnitude of loss due to mastitis. His estimate of $1.3 billion lost in the U.S. in 1976 ($2.6 billion in 1981 dollars) is based on an aggregate of estimates made by one person from each of 33 states whom he lets "represent" 86 percent of U.S. dairy cattle. The "representatives" were asked what the magnitude of losses was in their respective states, which collectively contained 86 percent of U.S. dairy cattle. Many of these statewide estimates were based indirectly on research which related reduced milk production to results of California Mastitis Test (CMT) scores (Janzen, 1970; Forster et al., 1967; Natzke et al., 1965; Philpot, 1967). This research attributed a percentage loss of milk production to a standardized mastitis test score. With some idea of the incidence and severity of mastitis (i.e., percent of dairy cattle showing CMT T, 1, 2, or 3), the investigator could estimate reduced milk production. Unfortunately, such incidence data is not yet available for large populations. Therefore, the estimates aggregated by Blosser are little more than impressions.

Research is now being carried out to relate CMT results to the Dairy Herd Improvement Association's (DHIA) method of counting somatic cells (Kirk, 1982). DHIA's Somatic Cell Count (SCC) is done electronically and requires minimal additional effort during monthly milk testing. If DHIA's SCC can be reliably associated with CMT scores, then DHIA's SCC can be used to estimate reduced milk production due to mastitis instead of CMT scores. Success in this area of research would mean that data concerning the incidence and severity of mastitis could be as widespread as DHIA's network.

C. Estimating Losses Due to Reproductive Health Management Problems

Tracing the origins of estimates of losses due to reproductive health management problems also proves difficult. In a 1964 article, Hershler and co-authors made reference to an estimated loss of $800 million (2.3 billion 1981 dollars) due to impaired fertility in all U.S. cattle. The reference is to a paper by Meyer (1953) in which he simply listed a figure given to him by a friend. It is difficult to have much confidence in this estimate when none of the details of its calculation are known.

In order to estimate the monetary benefit of reducing calving intervals through a herd health management program emphasizing reproductive efficiency, Hershler et al. (1964) used a figure from Haller (1957) of $1.66 lost for each day beyond a 12-month calving interval (CI). Assuming that a 12-month CI is optimal, Haller determined from a New York survey that, "each month's delay in rebreeding means a $45 to $50 loss in production and maintenance." He attributed $20/month for maintenance and the balance to lost production. Converting the $50 figure to days, this came out to $.66/day for maintenance and $1.00/day due to lost production. It is necessary to point out that the only real loss was due to unrealized milk production. The maintenance cost must have been paid regardless of whether the cow was pregnant or not. Assuming for simplicity that the maintenance cost was $.66 regardless of reproductive status, and that $1.00 worth of milk could be gained for each day that a CI was reduced (to a limit of 365 days), then for each day that a calving interval was extended beyond 365 days, only $1.00

was lost, not $1.66 as one might assume from reading Haller. In other words, $1.00 could not have been gained without losing $.66. If there is no way to have gained $1.66/day even with 365-day calving intervals, how could $1.66/day be lost when calving intervals were longer than 365 days?

Louca and Legates (1968) were aware of the tenuous nature of previous estimates of losses due to extended CIs, and cleared up much of the ambiguity. Louca and Legates rigorously studied the effect of "days open," defined as "the interval between parturition and successful mating," on milk production. They agreed that the length of CI provides much of the same information as days open. They found that days open are not uniformly expensive for all lactations. Each additional day open in first lactation Holstein cows was associated with an average of 1.16 kg. (2.6 lbs.) less milk per lactation period. For cows in their second and third lactations, the corresponding figures were 3.58 kg. (8.0 lbs.) and 3.68 kg. (8.2 lbs.), respectively. A reduction of 8.0 lbs. of milk represented a loss of $1.07 in 1982 (8 lbs. * $13.42/cwt. = $1.07). This estimate did not include adjustment for the reduced calving rate, with which Louca and Legates were also concerned. Estimating the cost due to a reduction in the number of calves born per year because of extended CI depends largely on the value of the calves that were not born. This rather complex problem is discussed in Chapter Three.

Louca and Legates' results also support previous evidence that gestation does not significantly affect milk production until after the first 210 days of lactation. This suggests that the lowered milk production brought about by delayed breeding only appears after day 210.

Louca and Legates concluded that lifetime milk production could be maximized by keeping days open to a minimum. They suggested a 13-month CI for first calvers and a CI as short as possible for older cows. They acknowledged that the limit on the minimum length of CI is the sum of a 280-day gestation period and the 26-80 days[2/] after calving required for insemination to be most successful.

Their research could be improved by accounting for the reasons for extended CI. Research by Erb et al. (1981) and results reported in this thesis show a positive association between cystic ovaries, which lengthens CI, and high production in cows. This suggests that cows with cystic ovaries make longer CIs look better because they raise the average production of cows with longer CIs. Without proper adjustment for the effects of the disease, the costs of lengthened CI, in terms of reduced production, may be misinterpreted.

D. Measuring the Value of Dairy Cattle Health Care

1. The Rise of Intensive Preventive Care

In the past 20 or 30 years, there has been a shift in veterinary medicine from strictly emergency service to intensive preventive care for dairy herds. By controlling the most detrimental contagious diseases and by overcoming area mineral deficiencies, veterinary science has been a crucial factor in the trend to greater herd size (Morris and Blood, 1969). With more intensive animal production, veterinary medicine has become more intensive. Greater emphasis has been put on management problems such as improving reproductive efficiency. A number of studies have encouraged the practice of intensive preventive veterinary medicine for dairy cattle by estimating high returns from its application. Although these studies show that preventive programs can be profitable, especially through improving reproductive performance, they could be further improved by more attention to detail.

A common feature of past studies is that they calculated the value of a whole program. This made it impossible to isolate the most profitable components of a

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[2/] 26-80 days is the range of estimates they cited from other researchers.

program. In some studies, the final calculations were not adjusted for performance trends that existed prior to a program's inception. This usually exaggerated the value of a new program. Finally, most of the evaluation procedures ignored the increased feed, labor, and equipment costs required to increase milk production. Associated with this problem was the need to take each farm's resource constraints into account. Because resources differ between farms, there is not one optimal health management procedure for all farms (Morris and Blood, 1969).

a. Hershler et al. (1964)

To measure the "economic impact" of a fertility control and herd management program on one U.S. dairy farm, Hershler et al. (1964) estimated the economic benefit of reducing average days open and reducing the age at first calving for heifers. The herd in this study was maintained at 55 Guernsey cows. It was visited monthly for reproductive examinations over a three-year period. Average calving intervals were reduced by four days in the first year (433 to 429), 40 days in the second year (429 to 389), and 3 more days by the end of the third year (389 to 386). Hershler multiplied the cumulative average reduction for each year by the number of animals (55) and added these numbers to get 220 + 2,420 + 2,585 = 5,225. This represents the total number of open days saved over the three-year period. Next, he multiplied by Haller's (1953) estimate of $1.66 saved per day that a calving interval is reduced (to a limit of 365 days) which yields $8,674. Hershler called $8,670 the "anticipated increase in income" from the control program. (For some unknown reason, $8,599 appeared in the summary instead of $8,670.) For reasons already stated, the relevant part of Haller's estimate was the production loss. Therefore, if Hershler used Haller's results for anticipating increase in gross income, he would obtain $5,225, not $8,670.

To calculate the actual three-year gain in income, Hershler began with the increase of 371,195 pounds of milk which was realized over the three years. At the

1964 price of \$5.17/cwt., this milk was worth \$19,200. Hershler added \$2,250 to this figure which he said represented the maintenance costs saved by breeding heifers younger. This \$2,250 addition was invalid. The increase in milk production accounted for all the improvements made in the herd, including the benefit of getting heifers bred younger. The only exception is that with shorter calving intervals more calves were produced per year. The increase in milk production did not account for the increased sales of replacement stock (herd maintained at 55 cows). When the average calving interval was 433 days, 46 calves were produced per year (365/433 * 55 = 46). With an average calving interval of 386 days, 52 calves per year were produced (365/386 * 55 = 52).

The inclusion of a non-existent reduction in maintenance costs exaggerated Hershler's estimate of returns. He acknowledged that his estimate did not include increased sales of replacements. Inclusion of this benefit (six more calves per year) suggests that returns exceeded \$19,200. But Hershler did not account for some important costs which were associated with increased milk production, such as increased feed, labor, and equipment expenses which vary among farms. Delineation of these costs required more detailed data than ~~was~~ were available.

Because Hershler used Haller's estimate, it is interesting to compare their results. Assuming that the increase in milk production could be attributed solely to reduction of days open, and that other costs and benefits balance out, then a total reduction of days open by 5,225 days was worth \$19,200. This made each day's reduction worth \$3.67 in 1964 or \$9.53 in 1982 (371,195 * \$13.42/cwt.) / 5,225 = \$9.53 . Single estimates of the potential production lost due to extended calving intervals are only meaningful over a given range. Each farm has a different average calving interval and can therefore expect different results from a fertility control program.

Referring to more of Hershler's data, it can be shown that each day's change in calving interval (days open) did not have a constant value. Comparing the information he gave about change in calving interval with the change in average annual milk production per cow, we have the following: (1) At the end of the first year of the program, milk production was 8,000 lbs. milk/cow/year and the average CI was 429 days. (2) The second year figures were 8,500 lbs. and 389 days. (3) The last year's figures were 10,000 lbs. and 386 days. This means that between the first and second years average milk production went up by 500 lbs./yr. (8,500 - 8,000) while the CI decreased by 40 days (429 - 389 = 40). If we assume that the reduced CI is solely responsible for the increase in milk production, then we find that each day's reduction in CI was worth 12.5 lbs. milk over this range (500 lbs./40 days = 12.5 lbs./day). In 1964, 12.5 lbs. milk was worth $.65 (12.5 lbs. * $5.17/cwt. = $.65), or $1.68 in 1982 (12.5 lbs. * $13.42/cwt. = $1.68).

Comparing the change between the second and third years, we find that a reduction in CI of three days (389 - 386 = 3) yielded a 1,500 lb. increase in annual milk production per cow (10,000 - 8,500 = 1,500). Again, assuming the reduced CI was totally responsible for the increased milk production, then each day's reduction in CI was worth 500 lbs. of milk over this range. In 1964, 500 lbs. of milk was worth $25.85 (500 lbs. * $5.17/cwt. = $25.85), or $67.10 in 1982 (500 lbs. * $13.42/cwt. = $67.10). These results are summarized in Table 1.

Table 1. Value of a Reduction in Calving Interval (CI) Over Different Ranges Assuming Reduction of CI Sole Cause of Production Increase

Source	Average Change in CI (Days)	Average Change in Production (Pounds)	Value/Day, 1964 ($5.17/cwt.)	Value/Day, 1982 ($13.42/cwt.)
Haller (1957)	?	?	$ 1.00	
Hershler et al. (1964), Year 2	40	500	$ .65	$ 1.68
Hershler et al. (1964), Year 3	3	500	$25.85	$67.10

With such a drastic difference in benefit from a day's reduction in CI, it is clearly misleading to average the benefit over a long period.

Hershler's study utilized only one farm. The lack of a control group means that increases in performance were not adjusted for trends which were independent of this new control program. Because only one farm was studied, generalization of the results is very dangerous. The comparison in Table 1 is meant for illustrative purposes only. The values in Table 1 should not be considered statistically significant.

b. Grunsell et al. (1969)

Grunsell and his colleagues (1969) took a different approach to determining the value of a preventive medicine scheme in England. Their sample consisted of 15 farms, not all of which were primarily dairy operations. The three-year project began with a visit to each farm by a farm management advisor. This was followed by a meeting on each farm of the farmer, his veterinarian, and an agricultural economist. After this introduction and initial appraisal, the farms received quarterly visits by veterinarians. The effectiveness of the scheme was rated according to the change in a number of performance indicators. These included yield per cow, milk sales per cow, concentrates per cow, margin over concentrates per cow, stocking rate, and margin over concentrates per acre. The farms were graded as showing "marked improvement" (7 farms), "some improvement" (5 farms), and "inconclusive" (3 farms).

Grunsell was concerned with the benefits of such a program to both the farmer and veterinarian. He included some interesting discussion about the reactions of the 15 farmers and 10 veterinarians involved with the project. The ability of the advisors to suggest management improvements depended largely on the existence of good farm records. Overall success hinged on the farmer's organizational ability and willingness to accept management advice. This suggests that management ability may be the resource which varies most between farms.

The grading procedure Grunsell used was so subjective it is difficult to argue with in detail. The main disadvantage of the approach is that it is impossible to generalize the results. In addition, performance trends that were independent of the program were not explicitly included in the analysis.

c. Barfoot et al. (1971)

Barfoot et al. (1971) made an economic appraisal of a preventive medicine program for dairy cattle health management in Canada. They compared the performance of 27 herds visited monthly by veterinarians to a control group which received only emergency veterinary service (VS). The control farms were chosen to "closely resemble the organizational patterns and characteristics" of the farms participating in the preventive program. The period of study was two years.

Five parameters related to herd health were monitored on all farms: milk production, days open, calf mortality, cow mortality, and culling rate due to health problems. In addition, the farms in the study were grouped according to expenditure on VS and drugs per cow. This cost ranged from $8.00/cow, for the group using only emergency service, to $35.00/cow, for the group with the highest "response" to the preventive program.

Probability density functions were determined for the five health-related parameters. These were programmed into a model with the intent to determine income per cow, over the cost of VS and drugs, given various milk and animal values. Their results showed that income over the cost of VS and drugs was significantly greater for the farms spending $25, $30, and $35 per head than for a group of "similar" farms spending only $8 per head.

This analysis does have the advantage of differentiating the health management program somewhat. In other words, by separating the herds into different expenditure groups, the authors were not really measuring the value of just one program. This was a step towards isolating the most profitable aspects of the preventive scheme. A control group was included which corrected for trends independent of the new veterinary program. This means that Barfoot et al. did not just credit the program with all the improvements observed.

The main disadvantage of this study was that the only cost measured was veterinary expense. Other costs incurred from increasing production were not included. Also, measuring health management by veterinary expenditure alone was misleading. The results imply that the more farmers spend on VS, the better off they will be. Low expenditure on VS may have been either a function of a farmer's ambivalence towards the value of veterinary care, or of the farmer's ability to administer health care independently. Finally, no mention was made of disease in Barfoot's work. A farmer's veterinary bill certainly depends on the degree of disease problems suffered by the herd. To measure the true value of a new program, some adjustment must be made for differences in disease prevalence. Perhaps this was corrected for in choice of a control group, but this was not explicitly stated.

d. Poterfield and Heider (1980)

In contrast to Barfoot's findings that veterinary expense was directly related to profitability, Poterfield and Heider (1980) reported that large production gains could be achieved through preventive medicine programs that actually reduced veterinary expense per animal. Poterfield and Heider's survey consisted of 67 Ohio dairy farms that received regular visits from their veterinarians over an average of five years. The emphasis of the program was on reproductive and udder health.

The average yearly increase in milk production for participating farms was 474 lbs./cow compared to an annual gain of 265 lbs./cow for all Ohio cows on test. The average veterinary expense before the 67 farms received regular visits was $21.33 per animal compared to $20.13 per animal afterwards. Average total herd veterinary expenses rose, but this could be attributed to increase in herd size over the five-year period. The average herd size increased from 55 to 76 cows.

Poterfield and Heider rightly compared the performance of the 67 herds on the program with their contemporaries. However, because they averaged all the results, there is no way of knowing which aspects of the regular programs were more successful than the others. For example, the authors said that 38 herds received monthly veterinary visits, 16 herds were visited twice a month, and 13 were visited weekly. Which scheme proved most beneficial to which herds? In addition, Poterfield and Heider's study suffers from the by now familiar problem of not accounting for the non-veterinary costs necessary to increase milk production. These include feed, labor, and equipment costs.

e. McCauley (1974)

McCauley's approach did account for the additional costs needed to increase milk production. His data were from 117 Minnesota dairy farms over a period of two years. McCauley's goal was not to demonstrate the value of a preventive medicine program, but to measure the contribution of VS in general to the income of dairy farms. The farms in his sample primarily used emergency VS. McCauley's goal was accomplished through a production function analysis which had dairy enterprise income above feed cost as a function of cow numbers, veterinary charges, drug expense, cows culled (for non-dairy purposes), and calves died. Cow numbers served as a proxy for all the capital and labor invested in the dairy enterprise. The calf mortality and cows culled figures were included to differentiate the severity of disease problems between herds.

For 35 farms, McCauley also included a disease problem proxy which was based on mastitis incidence data. This did not prove very valuable. The number of cows culled for non-dairy purposes was found to be positively associated with profit. This is probably because the culling figure included those cows culled for low production. To be more meaningful as a disease problem proxy, it should have encompassed only those animals sold because of a specific disease problem.

Whenever VS reduces disease problems, it is contributing positively to gross income. With a severe disease outbreak, farm income may decrease even though VS expense goes up. Without correcting for the severity of the disease problem, VS could be seen to have a negative correlation with income, when the increased expenditure on VS actually reduced the amount of income lost. This is why some distinction must be made between the severity of disease problems on individual farms.

McCauley found that an average increase in income over feed cost of $2.96 (6.55 in 1981 dollars) was associated with each dollar invested in veterinary service. Decreasing returns to size of veterinary expenditure were observed. Returns per dollar invested in VS were $8.03 (17.77 in 1981 dollars) for herds spending less than $6.00/cow (13.28 in 1981 dollars) compared to $1.82 (4.03 in 1981 dollars) for herds spending more than $12.00/cow (26.56 in 1981 dollars) for VS.

In conclusion, McCauley corrected for two deficiencies that he observed in previous studies. First, he corrected directly for feed cost and indirectly for all other production inputs by using cow numbers as a proxy. Second, he made some adjustment for differences in disease problems among herds. This latter correction is particularly important because he was dealing primarily with emergency VS, in which veterinary calls are more directly related to disease problems. However, McCauley's analysis would have been more powerful if more detail could have been provided about each herd's disease incidence. The advantages and disadvantages of these program evaluation studies are summarized in Table 2.

Table 2. Some Advantages and Disadvantages of the Herd Health Program Evaluation Studies

	Hershler et al. (1964)	Grunsell et al. (1969)	Barfoot et al. (1971)	Poterfield & Heider (1970)	McCauley (1974)
Account for Independent Trends?	no	no	yes	yes	?
Differentiate Factors of VS Program?	no	implicitly ?	somewhat	no	somewhat
Adjust for Additional Costs of Increased Production?	no	no	no	no	somewhat
Account for Severity of Disease Problems?	no	no	no	no	somewhat

2. The Relationship Between Veterinary Service (VS), Disease, and Milk Production

McCauley (1974) pointed out the need to adjust for the severity of each herd's disease problems in order to better estimate the value of VS. Over a broad range, we can expect additional investment in VS to decrease disease problems. It is also intuitively reasonable that the extent of disease problems influences expenditure on VS. This means that disease and VS influence one another, or:

$$\text{VS} \Leftrightarrow \text{Disease}$$

Previously mentioned mastitis and infertility research showed clearly that disease affects milk production. Veterinary service influences income (of which milk production is the major part) through disease, or:

$$\text{VS} \Leftrightarrow \text{Disease} \longrightarrow \text{Milk Production}$$

Evidence from Erb et al. (1981) demonstrated a positive correlation between milk production and one disease. Erb and her colleagues found that cows with cystic follicles produced an average of 655 pounds more mature equivalent milk than non-cystic cows. Similarly, Shanks et al. (1981) reported that the highest producing cows had the highest of selected health costs (drugs, veterinary costs, and some labor). These findings suggest the possibility that high milk production causes more disease in some cases. It is intuitively reasonable that the increased stress of high production makes cows more susceptible to disease. If this is the case, then the relationship between VS, disease, and milk production can be expressed:

$$\text{VS} \Leftrightarrow \text{Disease} \Leftrightarrow \text{Milk Production}$$

There are two other possible explanations for the positive association between disease and milk production. The second explanation is that better managers recognize and treat more cases of disease. Actual disease incidence may not vary between herds, but the number of recognized cases might. Because better managers have higher producing cows, the correlation between production and disease would be spurious in this instance. A third explanation is the farmer's tendency to tolerate more disease in high-producing cows. The extra income from high-producing cows makes it worthwhile to spend more for their maintenance. The total effect is probably a combination of the three factors.

These are some examples of the complicated relationships that may exist between dairy cattle health management and profit. The various effects will have to be sorted out in order to adequately understand the influence of specific health management practices on profit. The strength of previous studies has been limited by available data. Computer-facilitated collection has made more comprehensive dairy cattle health data recently available. Several such computerized systems are described in the next section, along with other computer applications.

E. Computer Applications to Dairy Cattle Health Management

The data storage and processing capabilities of the computer are just beginning to be exploited for applications in dairy cattle health management. Kirk (1981) developed several routines for programmable calculators which aid in delineating the costs and benefits of various mastitis control procedures. The expected gain from mastitis control was some fraction of the estimated milk production lost based on California Mastitis Test scores. The expected cost of control was simply a tally of the costs of towels, teat dip, and antibiotic treatments proposed.

The main limitation of Kirk's application is its reliance on CMT scores for estimating lost milk production. Because all cows are not tested using CMT on a regular basis, there is no consistent measure of mastitis prevalence. It may be argued that, because the costs of mastitis problems so greatly exceed the costs of prevention, there is little need to estimate mastitis losses more precisely than can be done using occasional CMT testing of a fraction of the herd, as Kirk suggests. Although it is obvious that mastitis can be very costly, some methods of controlling or preventing mastitis are still controversial. This means that the benefits of some mastitis control techniques do not obviously far exceed their costs. More rigorous monitoring of mastitis prevalence in response to different treatments on individual herds would help dispel this controversy. Kirk's own research relating CMT scores to DHIA Somatic Cell Counts will facilitate careful mastitis monitoring. This research was discussed earlier.

Kirk's technique for calculating the costs and benefits of mastitis control requires more detailed data to be powerful. The same is true for linear programming applications to dairy cattle health management. Carpenter and Howitt (1979) describe the use of linear programming (LP) for determining the most economical approach to the control of brucellosis. Linear programming is a mathematical formulation in which a series of linear equations are solved simultaneously via computer. An objective function, such as minimizing the cost of brucellosis control, is solved given a number of constraints. Linear programming is only effective when the parameters of the objective function and constraints are clearly defined. For example, in Carpenter and Howitt's objective function, they included the cost of vaccination, market surveillance, personnel, and the value of cattle lost due to brucellosis.[3/] Reliable estimates of these values must exist for their model to be of any use. For most diseases of dairy cattle, reliable cost data simply do not exist yet. The previously mentioned problems with making industry-wide estimates of mastitis and infertility losses serve witness to this fact.

The above examples show that more data are required to fully utilize the analytical power of the computer for dairy cattle health management.

[3/] All the elements of their tableau are not well explained. I have assumed that the large negative numbers in the objective function represent the value of cattle lost due to brucellosis.

Another question arises about the constraint they have put on percent vaccination for 1976. As given in their tableau, it must be greater than or equal to 35 _and_ less than or equal to 25--for which no feasible solutions exist.

Coincidentally, other advantages of computers, namely their speed and ease of data storage and retrieval, are making collection of these data possible.

The Dairy Herd Improvement program is primarily designed for recording milk production and for the genetic selection of cows (Crandall, 1975). Other computerized systems have been developed to improve herd's reproductive performance. Systems described by Britt and Ulberg (1970); Erb et al. (1975); Gould (1975); Kelly and Holman (1975); Lineweaver and Spessard (1975); and Meek et al. (1975) are resigned to the retrospective analysis of reproductive performance. Cannon et al. (1978), however, describe a computerized herd health reporting system which is designed "to identify cows which show evidence of abnormal performance or are in high risk groups so that they can be examined and corrective procedures taken early." This goal is accomplished primarily through the provision of timely management reports.

Separate computerized reporting systems are therefore available for milk production and reproductive herd health (including some non-reproductive disease reporting). The need to combine the two capabilities is recognized (Cannon et al., 1978). At best, however, this combination would still ignore farm infrastructure and labor and drug expense devoted to animal health care. A more comprehensive system, the Food Animal Health Resource Management System (FAHRMX), has been described earlier. The total data collecting ability of FAHRMX encompasses farm infrastructure, animal health histories, labor and drug expense for health care, genetic information, and milk production. All this is collected from individual commercial herds on a continuing basis. The balance of this report is spent discussing the potential application of these data in the cost-benefit analysis of dairy cattle health management.

Chapter Three

Data and Methods

A. Introduction

This chapter describes the sources of the new data available from the FAHRMX project, and potential applications of the data in cost-benefit analysis of dairy cattle health management. The first part of the chapter, Data Sources, contains:

1) A description of FAHRMX pilot herds using Dairy Herd Improvement Association (DHIA) indices. This serves the dual purpose of determining how representative the pilot herds are of all Michigan dairy farms, as well as demonstrating some of the limits of DHIA data.

2) A discussion of a questionnaire administered to some of the pilot herds, and its future uses.

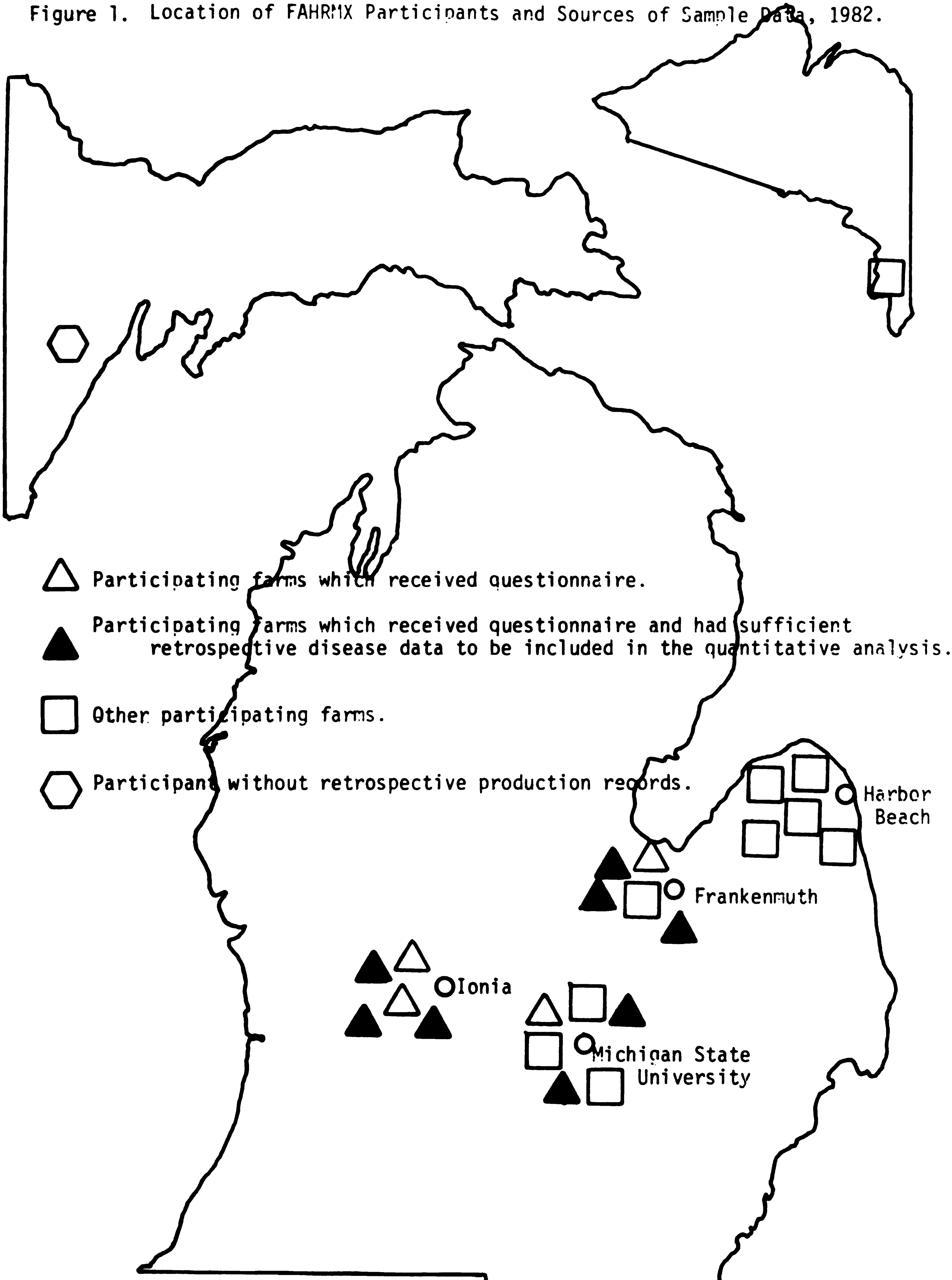
3) A description of the content of the retrospective[4/] data file entered onto mainframe computer.

The second part of the chapter deals with uses of the new data. General concepts of cost-benefit analysis, centering on the partial budget, are introduced. Disease control expenses are itemized, as are different impacts of disease control. The problems with estimating these expenses and impacts are discussed. Several examples are used with these expenses and impacts in a partial budgeting framework. Finally, a statistical model is outlined which estimates one particularly evasive impact of disease, reduced lactating potential.

Figure 1 shows the location of FAHRMX participants and sources of sample data, including the sources for both the questionnaire and disease data for the retrospective quantitative analysis. The purpose of the questionnaire was to obtain information about farm infrastructure and general disease control procedures. The retrospective quantitative analysis of disease and production records was a first attempt at estimating reduced lactating potential due to disease.

[4/] "Retrospective" refers to the current study which relies on pre-FAHRMX data, while "prospective" indicates current or future FAHRMX capabilities.

Figure 1. Location of FAHRMX Participants and Sources of Sample Data, 1982.



Twenty-three farms are currently in the FAHRMX project. One of these had no retrospective DHIA records, which excluded it from Table 3. Twelve farms had had the questionnaire administered to them by the end of the summer of 1982. Because of administrative problems, no other farms have been surveyed subsequently. Only eight of the twelve farms surveyed had good enough retrospective disease records to be included in the quantitative analysis of disease and production records.

It should be emphasized that any data that were utilized in this study were available previous to the existence of the FAHRMX project's growing data banks. Such retrospective analysis pointed out deficiencies in pre-FAHRMX data, and modeling difficulties, that need to be overcome if FAHRMX is to achieve its goals. The retrospective study also provided baseline data by which FAHRMX's success can be measured.

B. Data Sources

1. Description of Pilot Herds

Four progressive Michigan veterinary practices were asked to select clients whose record keeping and management abilities could be augmented by a computerized decision support system. Therefore, the pilot herds are not a random sample of Michigan herds, but are probably typical of Michigan's better herds. All participating herds are visited at least once a month for reproductive exams and preventive health care administered by their veterinarians. All participants are also members of the Dairy Herd Improvement Association (DHIA), a service which currently provides production and management reports for 37 percent of Michigan's dairy farmers who milk 47 percent of Michigan's dairy cows. A comparison of selected characteristics of FAHRMX and Michigan DHIA herds is presented in Table 3. The FAHRMX herds were an average of 25 percent larger (91 versus 73 cows), and their milk production was an average of 8.0 percent higher (16,941

Table ... Selected Characteristics of Holstein Herds in FAHRMX for the Year Prior to Study Initiation (1980)[a]

Herd	Cows	Age (months)	Milk Production[b] (lbs./year)	Services Per Conception	Calving Interval (days)	Days Dry	Days Open	Cull Rate (%)	Return Over Feed Cost ($)
1	65	58	17,366	1.2	396	46	199	30	1,571
2	46	47	15,615	NR	NR	40	189	NR	NR
3	111	49	19,441	2.3	397	40	117	24	1,724
4	78	47	16,032	2.1	414	53	134	16	1,651
5	172	45	15,879	1.0	360	48	124	22	1,238
6	124	50	17,392	NR	381	39	176	21	NR
7	65	53	11,957	1.0	369	47	182	24	835
8	111	62	16,777	3.1	373	54	94	31	NR
9	44	56	16,613	NR	420	46	207	17	NR
10	55	38	16,741	1.8	352	44	98	15	NR
11	115	41	19,819	NR	374	43	191	27	1,768
12	62	42	17,692	1.1	385	53	103	30	NR
13	121	51	16,900	2.4	396	41	99	24	1,478
14	54	46	14,811	2.3	378	57	121	18	NR
15	87	48	19,508	NR	378	48	179	24	NR
16	149	48	17,008	NR	358	42	186	28	NR
17	111	42	16,773	1.8	370	44	116	26	NR
18	35	48	14,945	1.9	389	49	156	29	1,259
19	86	52	15,003	1.9	380	46	117	20	1,211
20	157	53	17,537	1.5	390	43	127	17	1,833
21	116	42	16,807	2.8	393	53	109	33	1,514
22	40	50	17,108	2.7	439	46	130	20	NR
Average	91	48[c]	16,941[c]	1.5[c]	382[c]	48[c]	143[c]	24[c]	1,502[c]
Mi DHIA	73	51	15,674	1.9	391	48	145	23	1,187

a/From participants' DHIA records.

b/Milk produced per year for herd divided by the average number of cows (lactating plus dry).

c/Weighted average (adjusted for number of cows).

versus 15,674 lbs./cow/year) in 1980. The next to the last row of Table 3 consists of weighted averages, with the exception of the first column. This means that the averages were adjusted for the number of cows contributing to the average.

Some of the columns in Table 3 represent standard variables recorded for all herds on the DHIA program. Others, such as return over feed cost, are not required. This explains the missing values (NRs) in the last column. Most of the required features are reliable because they depend on, or are calculated from, data recorded by DHIA testers. These reliable variables include number of cows, age, milk production, calving interval, days dry, and culling rate. There are problems with the days open and services/conception calculations because these rely on the farmers' recollection of breeding dates and not all farmers keep reliable breeding records. If only the latest breedings are reported, then the services/conception ratio will equal one. If no breedings are reported, then the DHIA computer takes the full length of lactation as the open period. This is probably why some of the days open variables are very large.

DHIA presently does not separate those herds with complete reporting from those without. For their annual summaries, which are the source for the last line in Table 3, DHIA simply averages all the figures available from each herd, regardless of the fact that some herds have more complete information than the others (Thelan, 1982). This means that, for example, the number of herds contributing to the average of return over feed cost is less than the number contributing to the average of milk production. The lack of some performance indicators on some farms complicates interfarm comparison.

FAHRMX is attempting to ensure complete recording of animal events data by providing more direct incentives, and by making reporting easier. It should be stressed that DHIA and FAHRMX have, and will continue to have, independent functions. FAHRMX will serve to augment DHIA by permitting the long-awaited marriage of health and milk production information.

B. Data Sources

2. Questionnaire

a. Purpose and Description

The questionnaire, which can be found in Appendix 3, had several purposes. There was a need to introduce FAHRMX to the farmers and obtain permission to utilize their disease and production records. The questionnaire helped depict the size, management practices, and livestock facilities of the farms. It documented the farmers' methods of dealing with common disease problems. The questionnaire also helped determine the costs associated with disease control that would not be apparent to FAHRMX either through the veterinarians' bills or the farmers' treatment reports. Examples of these latter costs include special facilities and equipment that the farmer uses for health care. The questionnaire also keyed in on routine treatment costs and times, such as that spent for dry cow therapy, so that the farmer need not report labor and drug costs for routine treatments. Finally, the questionnaire determined the quality of disease records kept before FAHRMX was utilized. The quality of these retrospective records determined whether the farm could be included in the retrospective quantitative analysis.

A modified version of the questionnaire will be administered on an annual basis to update existing information and ensure that farmers need only report daily events. Data from the questionnaire will be entered onto FAHRMX software, and therefore will be available for the analysis of the effect of different physical facilities or general management practices on herd health.

b. Sample Size Limitations

At the least, veterinarians can use this infrastructure data to aid in their hunches about the cause of certain disease problems. They can, for example, easily compare type of bedding to mastitis incidence on all the farms in the project. However, in order for such differences between herds to be statistically significant, a specific number of herds must be participating with FAHRMX, depending on the variance of the parameter in question. The statistical criterion can be stated as follows:

> to be 100 (1-α) percent sure that the error x-n does not exceed "d" the required sample size is:

$$n = \left[\frac{Z_{\alpha/2}\,\sigma}{d}\right]^2$$

This condition requires that something be known about the variance, σ^2, of the parameter in question (Bhattacharyya and Johnson, 1977).

There are two types of error relevant to statistical testing. The condition above requires that α, or the probability of rejecting the null hypothesis when the null hypothesis is true, be specified. This is commonly referred to as "type I error." Type I error is usually considered the most serious. The null hypothesis is chosen so that the burden of proof falls on those who would consider rejecting it. The corollary to the null hypothesis in United States criminal law is "innocent." The alternative hypothesis is "guilty." In the correlation analyses that follow, the null hypothesis is that the parameters are not different than zero. Therefore, the parameter estimates will not be considered seriously unless the evidence against them being different than zero is overwhelming. Type II error is the probability of not rejecting the null hypothesis when the alternative hypothesis is true, which is usually represented by β (not to be confused with the parameter estimates). Given a fixed sample size, one type of error cannot be reduced without increasing the other. However, by increasing the sample size, both types of error can be reduced (Bhattacharyya and Johnson, 1977).

The statistical model of milk production, which is described subsequently, succeeds because milk production varies between individual cows. Even though only a small number of herds are included in the sample, there are enough cows in those herds to make the model statistically significant. In the model, all the variation between herds is assigned to one categorical variable per herd. The fact is that to detect statistically significant differences in factors that vary from herd to herd, instead of from animal to animal, many more herds are needed.

B. Data Sources

3. Retrospective Data File

The retrospective data file was developed to model the effect of disease on milk production. The resulting model is discussed in detail in a later section.

The quality of pre-FAHRMX disease records was highly variable. For some diseases, it was unclear whether they did not appear on records because they were consciously not recorded, or because there were no cases of the disease over the period of study. On those farms that kept disease records, metritis and cystic ovaries were usually well recorded because they were diagnosed by veterinarians, and were recorded by the farmers along with the veterinarians' instructions for treatment. Of the 12 farms that have received the questionnaire, 8 recorded all cases of metritis and cystic ovaries (see Table 12). These were the diseases chosen for study simply because these were the only diseases for which data were available.

The retrospective study was limited by the available disease data. Because FAHRMX is now building complete health histories of participating herds, this will not be a problem in future analysis.

The indices of genetic milk producing potential--sire predicted difference (PD), dam index, and cow index--were obtained from DHIA semi-annual inventory reports. Sire PD is the expected extra milk production capability per year that a sire passes on to his daughter (when compared to a daughter of a bull with a PD of zero). Cow index is similar to a sire's PD in that it is a measure of a cow's ability to transmit milk producing ability to her offspring. The cow index depends on the individual's pedigree as well as her actual milk production. The dam index is simply a dam's cow index (ABS, 1975).

Genetic indices were unobtainable for many cows because few farmers kept all their inventory forms. This is another problem unique to the retrospective analysis because the genetic information can and should be one of the first lines of data entered on new animals in the FAHRMX project because it may be very useful in estimating potential milk production.

Production data were obtained from DHIA monthly management reports filed at the DHIA office. These reports were photo-copied, and the pertinent data were copied by hand for entry onto mainframe computer. In future analyses, the transfer of DHIA production information will be done automatically via computer.

The retrospective data file contains the following information for each cow:

1. Herd Number
2. DHIA Four-Digit Cow Identification Number
3. Disease Code (0, for controls; 1, for cows reported as treated for metritis; 3, for cows reported as treated for cystic ovaries)
4. Date of First Treatment for Disease
5. Date of Onset of Lactation During Which Cow Was Recorded Sick
6. Lactation Number
7. Age at Calving (months)
8. Dry-Off Date (end of lactation)
9. Final Milk Production (pounds)
10. Final Butterfat Production (pounds)
11. Final Milk Production Adjusted to 305 Days
12. Date of Next Calving
13. Cull Code (Reason for Culling)
14. Cow Index of Genetic Potential
15. Dam Index of Genetic Potential
16. Sire PD (Sire's Index of Genetic Potential)
17. Total Days in Milk

18. Calving Interval (days)

19. Days in Milk at Date of First Treatment for Cystic Ovaries or Metritis

20. Season of Calving

21. Season of First Treatment for Cystic Ovaries or Metritis

22. Dollar Value of Production

and other variables derived from the above as needed (see Appendix 4 for the complete data file).

The file contains data roughly spanning the two-year period from 1979-1981. This span was chosen for several reasons. With a two-year span, the likelihood of obtaining matching production information for at least one calving interval was reasonably high. By just going two years back, the majority of the cows in the sample would still be in the herds. Finally, most farms that had pre-FAHRMX disease records had kept them reliably for about two years prior to receiving the questionnaire. This means that the retrospective data on most of the cows could be augmented by the prospective data currently being accumulated in FAHRMX data banks.

The above information was entered for each animal beginning and completing at least one lactation within the range of complete retrospective production and disease records for each herd. This range of complete records was quite restrictive in some cases. For example, in a herd for which the span of complete records was less than one year, the number of cows having complete lactations within that period was only a small percentage of the total herd (see Table 15).

In standard epidemiological jargon, diseased animals are called "cases" and non-diseased animals are called "controls." For the purposes of this study, case cows were those reported as having metritis or cystic ovaries during lactation. If the cow received more than one treatment for either of these two diseases during one lactation, only the date of first treatment was recorded. In the future, number of treatments for disease will add important information concerning the severity of each case.

If either a case or control were culled before drying-off, the reason for culling was noted (cull code), and the date of culling was entered as the dry-off date. The production data (final milk production, final butterfat, and 305-day adjusted milk production) at the date of culling were entered as the end-of-lactation figures, one difference being that the final 305-day adjusted production for culled cows was also mature equivalent adjusted. DHIA adjusts this variable so that farmers can judge the relative value of their culled cows. On Michigan DHIA management reports, mature equivalent production for other cows is only expressed as a deviation from the average mature equivalent production of herd mates. If either a case or control were dryed-off but culled before calving again, no second calving date could be entered.

C. Data Applications

1. General Concepts of Cost-Benefit Analysis

a. Introduction

At first, it may seem that organizing the costs and benefits of a disease control project and comparing them, such as is done in cost-benefit analysis, is a simple procedure. It is true that cost-benefit analysis would be greatly simplified if all costs and benefits were neatly timed, and if alternative resource uses need not be considered. However, it is a fact in animal production that the benefits of certain disease control procedures can accrue long after initial treatment. Likewise, the costs due to inadequate health care can be far-reaching. Therefore, calculating the present economic value of future benefits due to today's treatment requires discounting the future benefits. Furthermore, unless resources are valued in comparison to their best alternative use, cost-benefit analysis will not arrive at the economic value of the proposed project (Gittinger, 1981).

Of course, cost-benefit analysis is impossible without sufficient empirical knowledge of major costs and benefits. Even with the detailed data FAHRMX is collecting, estimation of at least one significant category, reduced lactating potential due to disease, presents a considerable challenge.

b. The Difference Between Financial and Economic Analysis

Financial analysis deals strictly with cash income and cash expenses. Financial accounting can be as straightforward as managing a checking account. Financial profit is simply the difference between money received and money paid out in a given period (depreciation and interest are usually deducted also). This calculation of profit can be thought of as the return to a farmer's unpaid labor and all other capital invested in the farm (Lipsey and Steiner, 1978).

Economic analysis includes the opportunity cost of resources invested. Opportunity cost is the value of the resource if used in the next best alternative. For example, if a farmer has the option to work as many hours as possible in an off-farm job for $8.00/hour, then the opportunity cost of an hour spent working on the farm is at least $8.00. If a farmer's capital can earn at most 12 percent in an off-farm investment, then this is the opportunity cost of capital invested in the farm. In economic analysis, these opportunity cost values appear explicitly among costs. An economic profit of zero means that the farmer makes just enough money to be content with farming. However, a financial profit of zero means that the farmer is getting no return on "unpaid" labor and capital, or that the farmer is paying for the privilege of farming (Lipsey and Steiner, 1978).

2. A Basic Tool of Cost-Benefit Analysis: The Partial Budget

The standard partial budgeting framework includes a list of factors which reduces profit and a list of factors which increases profit. Profit is reduced when costs are increased or income declines, and vice versa. Borrowing an example from Harsh et al. (1981), assume that a farmer is considering increasing soybean acreage by 40 acres and reducing corn acreage by 40 acres. The farmer expects $210/acre income from soybeans, compared to $262.50/acre from corn. But the soybeans cost less to grow. Cash expenses per acre are $54.66 for soybeans. In addition, soybeans require 4.7 hours labor/acre, which the farmer values at $4.25/hour. The corresponding corn expenses are $113.40/acre, and 4.1 hours labor/acre (also valued at $4.25/hour). The partial budget shapes up as follows.

Partial Budget: Should the farmer grow 40 additional acres of soybeans and 40 less of corn?

Step 1: Determine what increases profit of business.

1. Increased Income	1. Increased soybean income: (40 acres * $210.00 income/acre)	$8,400.00
2. Reduced Costs	2. Reduced corn costs:	
	(40 acres * $113.40 expenses/acre)	4,536.00
	(40 acres * 4.7 hours labor/acre * $4.25/hour)	799.00
3. Subtotal		$13,735.00

Step 2: Determine what decreases profit of business.

4. Reduced Income	4. Lost corn income: (40 acres * $262.50 income/acre)	$10,500.00
5. Increased Costs	5. Additional soybean costs:	
	(40 acres * $54.66 expenses/acre)	2,186.40
	(40 acres * 4.1 hours labor/acre * $4.25/hour)	697.00
6. Subtotal		$13,383.40

Step 3: Determine net change in profit (line 3 - 6) $351.60

It is clear from the above comparison that if the yield and price information used is reliable, then more money can be made if 40 acres of soybeans are grown instead of corn. However, the profit difference is small enough so that any risk involved in the shift might not make the shift worthwhile.

C. Data Applications

3. Itemizing the Costs and Benefits of Disease Control for Dairy Cattle

How can partial budgeting be used to evaluate disease control for dairy cattle? The first step is to determine relevant cost and benefit categories. It is helpful to view disease control as reducing the impact of disease. Therefore, disease control is the cost and reduced impact the benefit. The cost of disease control should not be confused with the cost of disease. There have been many articles discussing costs of disease such as lost milk production due to mastitis. The issue here is by what degree does disease control reduce the "costs of disease." Table 4 identifies 13 factors divided into two categories: expenditure for disease control and disease impact. The text following Table 4 discusses each item individually.

Table 4. Itemization of the Costs and Benefits of Disease Control for Dairy Cattle

Expenditure for Disease Control

1. Veterinarians' Service
2. Medicine
3. Farmers' Labor
4. Farmers' Special Health Care Facilities
5. Other

Disease Impact

6. Milk Contaminated by Somatic Cells or Antibiotic Residue
7. Change in Feed Consumption
8. Reduced Feed Utilization in Youngstock
9. Reduced Lactating Potential
10. Death Loss
11. Culling
12. Lengthened Calving Intervals
13. Other

The items listed under "disease impact" generally represent losses of income due to disease. However, disease affects the herd by reducing some costs. Therefore, factors which both decrease income and decrease costs are included among "disease impact."

Expenditure for Disease Control

1) Veterinarians' Service

Veterinarians' service is an obvious cost of disease control. It is defined here as the cost of veterinarians' labor and advice. Medicine is included in a separate category to account for both that administered by veterinarians and farmers. Charges for veterinary service are assigned to individual animals by FAHRMX veterinarians at the time of treatment.

2) Medicine

Each drug used in dairy practice has a code which is associated with a price per unit dosage in FAHRMX software. The cost of medicine, whether the veterinarians' or farmers', is automatically calculated by computer when farmers and veterinarians record treatments and dosages.

3 & 4) Farmers' Labor and Special Health Care Facilities

The extra labor requirements of sick animals is a commonly recognized cost, but until FAHRMX there has been no accounting for it on commercial farms. In general, little is known about the amount of health care which is administered by farmers acting alone. Animal health care expenses for farmers include the cost of their drugs, labor, and any health care facilities in which they have invested. The labor and facilities cost will be determined largely through data from the questionnaire mentioned earlier. The questionnaire can determine standard treatment times for farmer-treated diseases, as well as percentage use of special facilities (such as hoof-trimming tables) for each case of disease. Therefore, when most cases of disease are reported, the labor and facilities expense can be added automatically. For cases of disease with uncommon treatment times, farmers are expected to record the amount of their labor spent, and special facilities used when applicable, for each case of disease.

5) Other

The list provided is not intended to be comprehensive. There will most certainly be other expenses relevant to certain control programs.

Impact of Disease

6) Milk Contaminated by Somatic Cells or Antibiotic Residue

When codes for drugs which have milk withholding requirements are used, FAHRMX software automatically computes the number of pounds of milk withheld. Milk dumped because of high somatic cell count will also be recorded. Note should be made of alternative uses of contaminated milk, such as feeding to calves, and only the net loss considered.

7) Change in Feed Consumption

Change in feed consumption may be positive, negative, or insignificant given different diseases. Because feed consumption can both increase and decrease due to disease, this category can represent both an increase or decrease in profit. The problem is academic, however, because FAHRMX herds presently have no way of recording individual feed consumption. Electronic identification of farm animals, combined with automatic feeding equipment, may soon provide individually controlled rations on many farms (Nott, 1982). Until then, an a priori decision must be made as to the relative importance of this category for each disease control procedure being analyzed.

8) Reduced Feed Utilization in Youngstock

For cows, reduced feed utilization is measured in terms of reduced lactating potential. Weight gain might be an appropriate performance measure for youngstock (non-cows). Holstein heifers commonly begin cycling at 600 pounds regardless of age (Ax, 1981). If it is true that the average case of respiratory disease in calves causes a weight loss of 10-20 percent (AAPB Newsletter, 1979), then respiratory disease may cause a delay in getting heifers bred. Other diseases that inhibit weight gain should be charged with the delay in breeding that they cause. It is not likely that youngstock's feed intake will soon be monitored on a continuing basis on commercial farms. For this reason, the issue of reduced feed utilization due to disease in youngstock will probably have to be resolved on research farms.

9) Reduced Lactating Potential

Each cow has an optimal productive capability, or lactating potential, that can be impaired by disease. If lactating potential can be reliably estimated, then the difference between healthy potential production and the actual production of a diseased animal can be charged to disease. Several factors complicate such a calculation:

1) Production potential changes with age (see #10 & 11).
2) Disease can have long-term consequences, which may require lifetime disease and production information to detect.
3) Culling behavior as well as management practices influence the type of disease problems and the characteristics of the animals with the most disease problems.
4) There appears to be a joint influence between disease and milk production.

All these problems will have to be dealt with in a model to estimate reduced lactating potential. The model is of such complexity that it will be considered in a section of its own. The problems of estimating reduced lactating potential are introduced here because some of them touch on later categories, such as death loss and culling, and lengthened calving intervals.

In addition, with a reduction in lactating potential may come a reduction in certain costs as a result of having to handle less milk. These may include labor and equipment cost reductions.

10 & 11) Death Loss and Culling

Which animals die or are culled from the herd are determined by four factors:

1) Sale for dairy purposes;

2) Unpreventable circumstances such as natural disasters;

3) Preventable disease and accident problems; and

4) Selection by the farmer for genetic improvement of the herd.

Here the focus is on factors (3) and (4). The interest is in how losses due to preventable disease and accident problems limit a farmer's culling choices based on production potential alone. To illustrate how disease affects culling behavior, let us first assume a culling rate of 25 percent per year regardless of whether disease problems exist or not. The culling rate seems to be primarily determined by the number of replacements that can be raised (see Appendix 5). A culling rate of 25 percent per year is representative of FAHRMX pilot herds (see Results). Therefore, in the absence of disease, it may be possible to cull all 25 percent based only on production potential.

For example, consider a herd of 200 cows ranked by production potential[5]--cow #1 with the lowest potential and cow #200 with the highest--as in Figure 2. Then, without any disease problems severe enough in themselves to warrant culling, cows 1-50 may reasonably be culled.

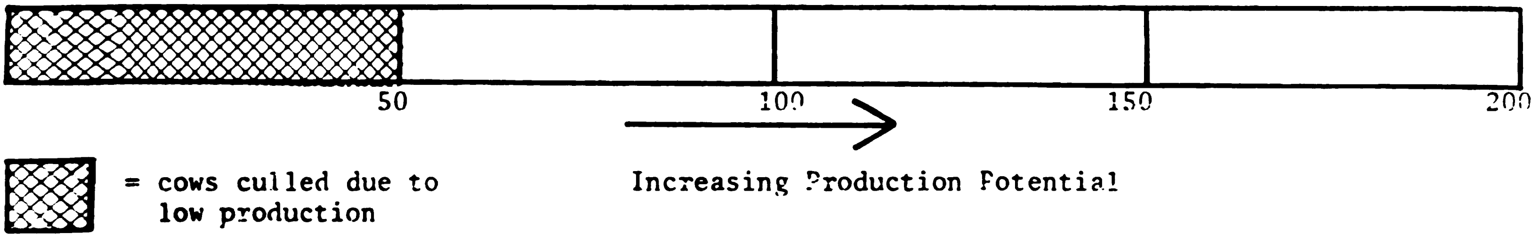


Figure 2. Culling Behavior in the Absence of Disease Problems Severe Enough to Warrant Culling

[5] Some problems with estimating production potential are discussed later.

Next, consider how disease would influence culling behavior. Data from FAHRMX pilot herds show that the probability of being culled due to disease problems is about 10 percent (see Appendix 6). These same data support the assumption that the chance of being culled is approximately random across production levels (see Appendix 7). Therefore, 10 percent of the 50 lowest producers, or 5 cows, and 10 percent of the 150 highest producers, or 15 cows, will be culled because of disease problems. However, the 5 of the 50 lowest producers would have been culled anyway. Disease has forced the culling of 15 cows that would have been kept in the herd had disease not existed. The net loss of replacement options due to the 10 percent probability of culling because of disease is therefore 10 percent of 75 percent, or 7.5 percent (10% * 150 = 15 cows), not the full 10 percent.

Figure 3 illustrates culling in the presence of disease. Every tenth cow must be culled due to disease--for a total of 20. This just leaves 30 that can be culled because of low production. The 30 chosen are 1-9, 11-19, 21-29, and 31-33. Comparing the with and without disease scenarios, 15 cows that would not have been culled for low production have to be culled because of disease. In this example, these 15 are represented by cows 60, 70, 80, ... 200.

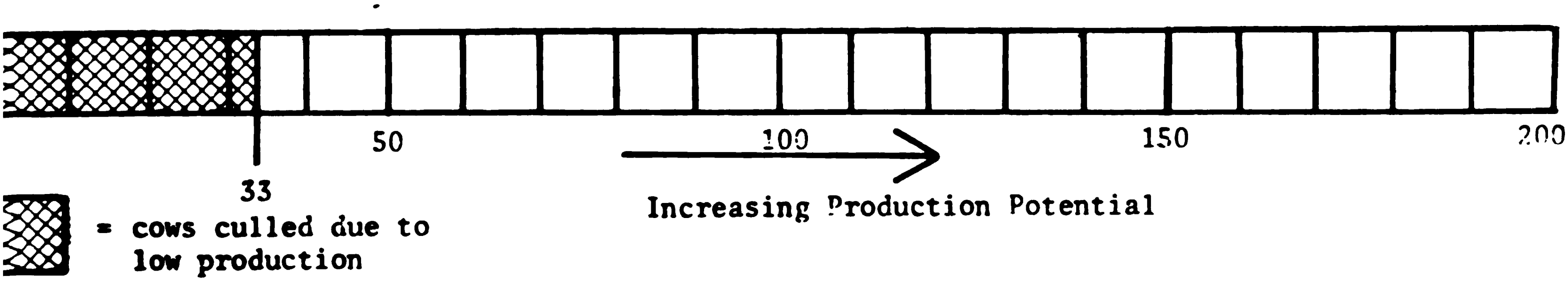


Figure 3. Culling in the Presence of Disease Problems Severe Enough to Warrant Culling: Assuming Every Tenth Cow Culled for Disease Reasons

Figure 4 illustrates how the loss of culling options lowers herd-producing potential. The assumptions on which Figure 4 are based are:

1) The herd consists of 20 cows;
2) 25 percent, or 5, will be culled;
3) In the presence of disease, 10 percent, or 2, will be culled for disease reasons; and
4) In this example, these two cows are #10 and #20.

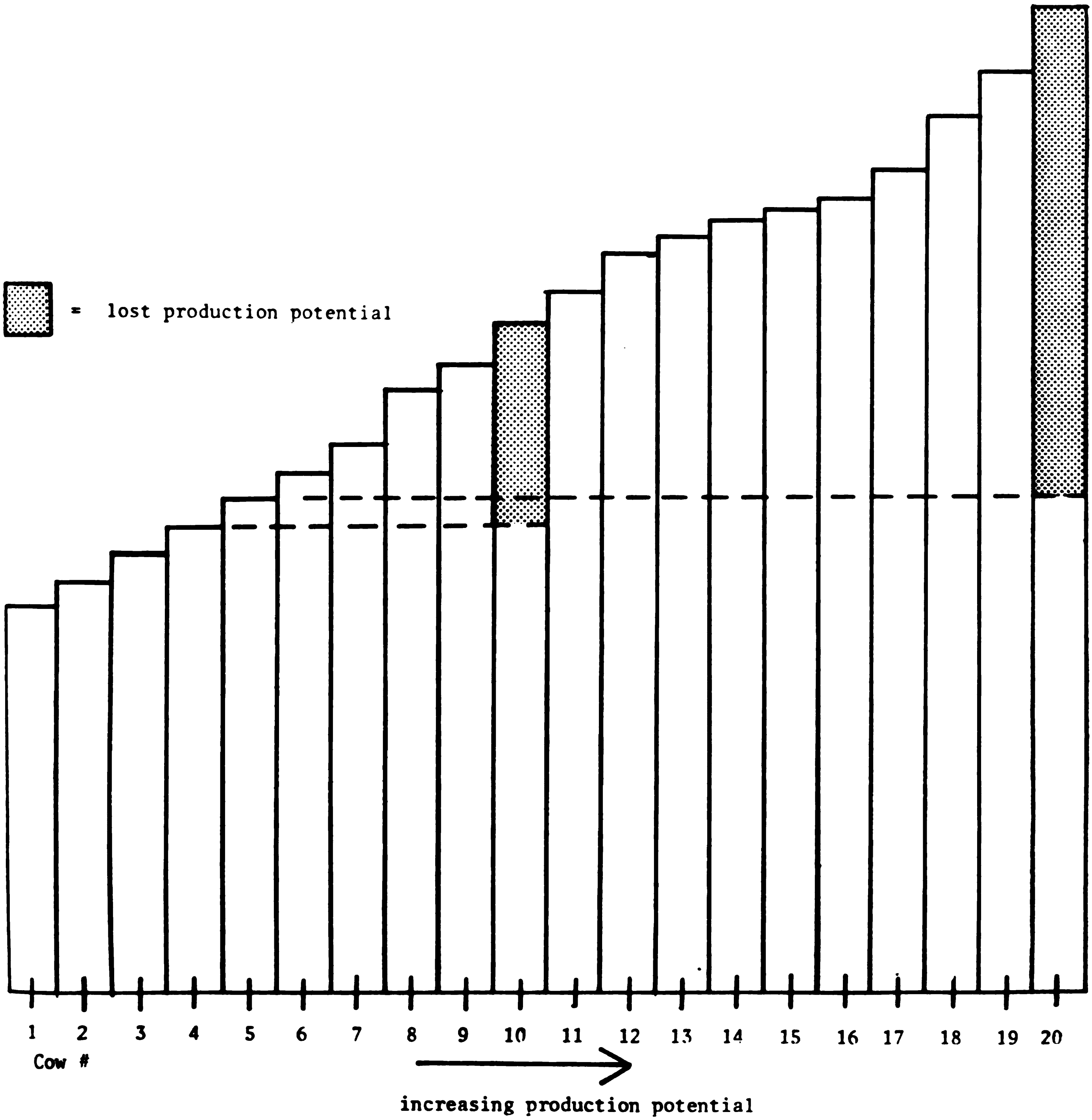
Without disease, cows 1-5 would be culled. With disease, cows 10 and 20 must be culled, and 1-3 will be culled because they are the lowest three producers. Therefore, cows 10 and 20 are culled in the place of 4 and 5 when disease is present. The production potential lost is the sum of 10 and 20's potential minus the sum of 4 and 5's potential, which is represented by the shaded area in Figure 4.

FAHRMX pilot herd owners are currently recording all reasons for death loss and culling. If a cow would not have been culled had she not been diseased, then her replacement cost should be considered as a cost of disease. But if she would have been culled because of low production anyway, then the disease should not be charged for her loss. Obviously, there is a need to be very precise about the reasons for removal. FAHRMX personnel should make this issue clear to farmers and ask them to ask themselves each time they report a cull, "Would I have culled her for low production anyway?" If the answer is "No," then her loss should be charged to the disease problem that caused her to be culled.

Identifying cows culled strictly due to disease problems, and not low production potential, first requires a definition of production potential. The goal is a scheme illustrated in Figure 4 in which all cows in all herds are ranked by production potential independent of preventable disease. Only then can farmers say which cows they would have culled had disease not limited their choices.

Figure 4

Loss of Production Potential Caused By
Loss of Culling Options



Estimation of production potential must adjust for the age of the cow. Younger cows' production should be mature equivalent adjusted. However, estimation of production potential independent of preventable disease is confounded by the positive correlation between age and disease. Because disease problems increase with age (Hlubik, 1979), it is debatable whether disease in older cows is always "preventable."[6] Increased age may make cows more susceptible to disease, in which case age causes disease to some degree. However, the positive correlation between age and disease also can be explained by the fact that older cows tend to be higher producers in which more disease is tolerated.

The model of reduced milk production potential, which is discussed later in this chapter, must deal comprehensively with the interrelationships between disease, milk production, age, culling behavior, and other factors. Here we have hypothesized that the true costs of disease cannot be estimated until reasons for culling are better documented. But the fact is that the improved information provided by FAHRMX, although not perfected at first, will make culling decisions more rational. Once culling decisions are better understood, the information regarding disease costs can be further improved, which will further refine culling decisions. . . and so on with an iterative process.

When the cows culled only for disease reasons, and not low production, can be identified, and when cows can be ranked by production potential independent of disease problems, then the loss of production potential caused by the loss of culling options can be easily calculated, as illustrated as in Figure 4. Other costs of replacement forced by preventable disease should also be considered. These costs include differences in breeding value not reflected in production potential.

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[6] Prevention, as discussed previously, is an economic concept. Almost every disease or accident could be prevented if enough money were spent. This may also apply to age-related disease to some degree. However, age-related disease eventually leads to death regardless of expenditure.

Furthermore, there may be different cost reductions involved with culling different animals. For example, if the maintenance cost of high producers is more than low producers, then losses in production potential by the forced culling of a high producer would be somewhat offset by a reduction in maintenance costs. Costs may also be reduced because less milk is being produced. Finally, any differences in salvage value between culled cows should be considered. For example, if a diseased cow cannot be sold for meat, then her salvage value is going to be less than that of a cow culled strictly for low production.

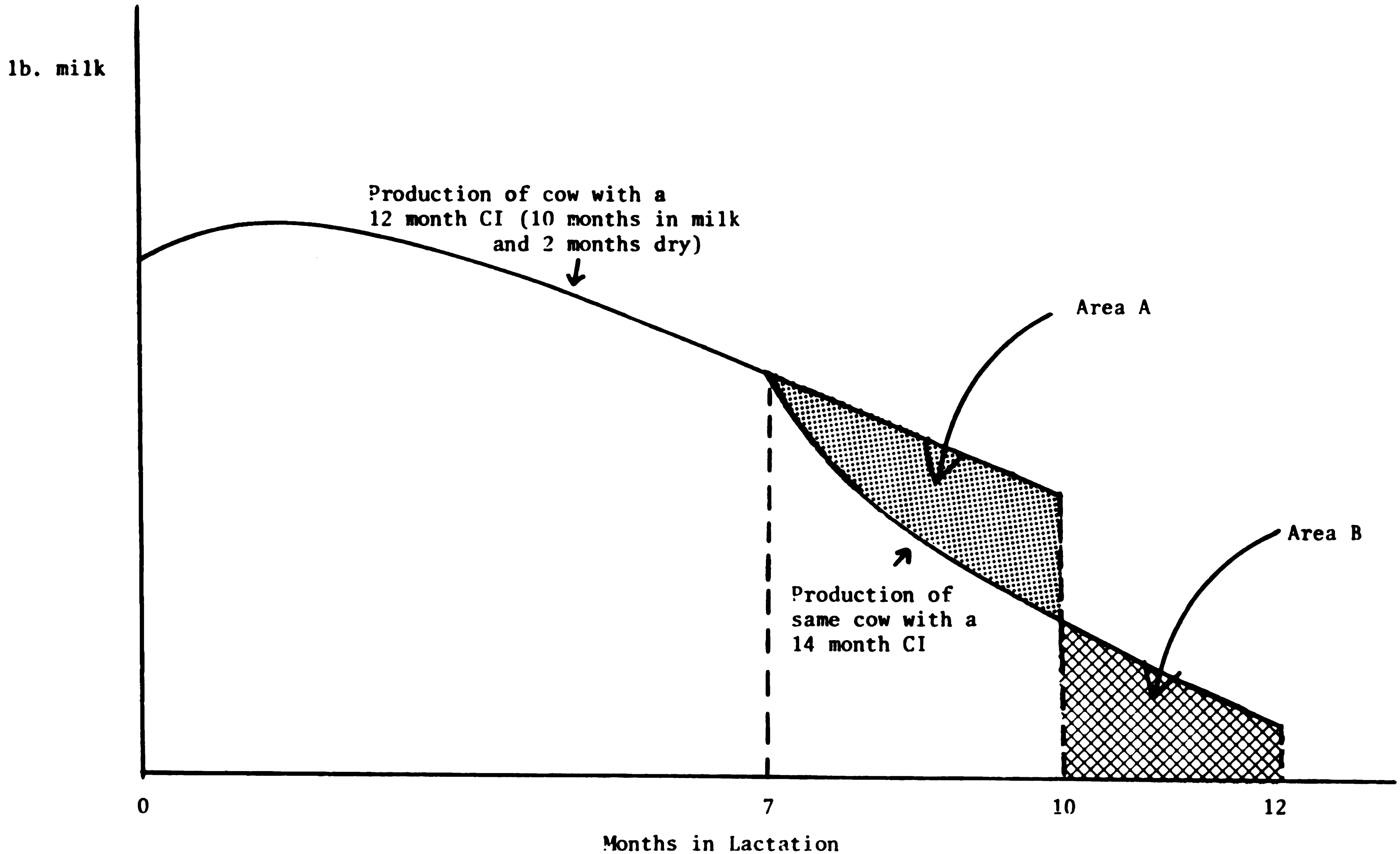
12) Lengthened Calving Intervals

As research by Louca and Legates (1968) shows, a calving interval drawn out by disease (or any other cause) reduces milk production below optimum. Their research also supports the conclusion that gestation does not significantly affect milk production until after the first seven months of lactation. Therefore, major differences in milk production between the cow bred at the optimal moment and the cow with more days open would appear only after seven months. Figure 5 illustrates what must be the case if 12 months is an optimal calving interval (with a 60-day dry period). Any additional production because of more days in milk (Area B) must be offset by less production before the first dry-off date (Area A); otherwise the shorter CI is not optimal.

This picture of the effect of more days open on lactation seems to be contradicted by evidence from Oltenacu et al. (1980) which supports the theory that delayed pregnancy frees more energy for milk production. Oltenacu and colleagues also provide evidence that there is a joint influence between milk production and days open, but they make no recommendations about optimal CIs for different production classes. Perhaps the association between high milk-producing cows and diseases which cause extended CIs is causing some of the confusion. The doubt raised by the Oltenacu data concerns the length of the

Figure 5

Definition of Optimal Calving Interval (CI) as per Louca and Legates (1968)



Area A must be greater than Area B for 12 month CI to be optimal.

optimal CI. The argument may continue over the shapes of the curves in Figure 5, but the definition of optimal CI will not change: additional production because of more days in milk must be offset by less production before the earlier dry-off date if the shorter CI is optimal.[7/]

Assuming that there is an optimal CI, and that some diseases cause reduced production potential by extending it, then this cost should be charged to disease. In order to do this, however, the optimal CI apart from disease must be defined.

In addition, longer CIs cause fewer calves to be born per unit of time. For example, assume there is a herd with an average of 70 cows milking. If the average CI is reduced from 13 to 12 months, then 5 more calves will be born each year (70/12) * 12 - (70/13) * 12 = 5. The CI may be lengthened due to disease or management problems. The cost of sub-optimal calf production can be easily computed for those calves that would not have been chosen to replace culled cows. The loss from these animals is simply their salvage value. However, because diseases which lengthen CIs seem to be associated with high-producing cows, more offspring are going to be "lost" from high producers. This means that many calves unborn due to extended calving intervals would have been likely replacement choices. Because of lost replacements, production potential is lost. Estimating the cost of losing these calves is therefore similar to estimating the loss of culling options caused by disease.

13) Other

The list provided is not intended to be comprehensive. There will most certainly be other impacts relevant to certain health management problems.

[7/] The only way that the longer CI could yield more milk in one lactation, and still be sub-optimal, is if it somehow causes a greater loss of milk in future lactations.

C. Data Applications

4. Examples of Partial Budgeting to Evaluate Disease Control Procedures

a. Introduction

The previous section pointed out many difficulties involved with estimating some of the items necessary to a partial budget evaluating disease control procedures. In some cases, a priori decisions must be made as to the relative importance of certain items because of the lack of empirical evidence about them. In this section, however, adequate knowledge of expenses and impacts is assumed so that the partial budget's application to disease control can be demonstrated. The values used in these examples are strictly imaginary.

Because the numbers appear neatly in the partial budgets, and the difference is easily calculated, there is a danger of endowing them with too much power. It should be clear by now that many separate human decisions may go into estimating certain values. For this ever to be a useful decision-making tool, the underlying assumptions behind the more tenuous estimates must be explained to farmers.

The variables in the examples represent the present values of the expected changes brought about by new disease control procedures. Present value calculations are made so that present and future income and expenses can be compared. Consider the timing of income and expenses in the apple business. Substantial expenses must be incurred to plant an orchard, and several years must pass before any income is generated. Comparing the value of the expenses paid now against the non-discounted income received in the future would make the investment appear more profitable than it really is. Similarly, delays in benefits are expected from disease control procedures. For example, perhaps the major benefits from using udder wipes to control mastitis only appear several years after their initial use because production potential rises due to a decrease in culling forced by mastitis. Assuming that our statistical models can estimate when the benefits come, and what they are worth in terms of milk production, then the present economic value of the benefits (and costs) must be calculated before they can be used in the partial budget (economic model).

For an example of the importance of making present value computations, suppose two different potential investments exist, both with the same initial investment and undiscounted income returned over a four-year period, but with the income stream timed differently. Project 1 and Project 2 both require a total investment of $750 paid immediately. Project 1 is expected to provide a steady income stream of $250 per year for four years. However, from Project 2, no return is expected until the fourth year, when $1,000 is expected. After four years, no other income is expected from either project. Table 5 compares the two projects at a discount rate of 12 percent. The discount rate is an estimate of the opportunity cost of capital, or the return that could be gained in the next best alternative investment. Although the two projects have identical undiscounted returns, because the timing of those returns is different, one is economically profitable while the other is not. If the discount rate accurately represents the opportunity cost of capital, then any project with a net present value greater than zero is worthwhile. Therefore, Project 1 is viable, and Project 2 is not (Gittinger, 1981).

Table 5. Example of the Importance of Using Present Values

Project 1

Year	Expenses	Income	Incremental Net Benefit	12% Discount Factor	Net Present Value
0	$750	0	$-750	0	$-750
1	0	$ 250	$ 250	.893	$ 223
2	0	$ 250	$ 250	.797	$ 199
3	0	$ 250	$ 250	.712	$ 178
4	0	$ 250	$ 250	.636	$ 159
Total	$750	$1,000	$ 250	3.038	$ 9

Project 2

Year	Expenses	Income	Incremental Net Benefit	12% Discount Factor	Net Present Value
0	$750	0	$ -750	0	$-750
1	0	0	0	.893	0
2	0	0	0	.797	0
3	0	0	0	.712	0
4	0	$1,000	$1,000	.636	$ 636
Total	$750	$1,000	$ 250	3.038	$-114

b. Examples

The first partial budgeting example considers using individual udder wipes as a preventive measure for mastitis. The only expenses are assumed to be the cost of the wipes and the farmer's labor. Let these figures represent the cost of using udder wipes for one year. The use of udder wipes for just one year may influence the herd over several years, by changing production potential through reduced culling because of mastitis, for example. In this example, the net present value of using udder wipes for one year is $40 ($200 - $160 = $40).

Example 1: Use of Individual Udder Wipes to Control Mastitis

			Present Value of Expected Change
Disease Control Expenses			
1)	Veterinarian's Service		0
2)	Medicine (udder wipes)		$-100
3)	Farmer's Labor		$ -60
4)	Farmer's Special Health Care Facilities		0
5)	Other		0
		Subtotal	$-160
Disease Impact			
6)	Contaminated Milk		$ +10
7)	Change in Feed Consumption		0
8)	Reduced Feed Utilization in Youngstock		0
9)	Reduced Lactating Potential		$ +90
10)	Death Loss		0
11)	Culling		$+100
12)	Lengthened Optimal Calving Interval		0
13)	Other		0
		Subtotal	$+200
		Total	$ +40

The second example considers the feeding of colostrum to calves in the first 12 hours of life. The only expense is assumed to be labor. The example assumes that from previous experience colostrum feeding has strengthened calves so that their feed utilization goes up (item 8), their mortality rate drops (item 10), and they eat more (item 7). The net present value of feeding colostrum for a set period is $250 in this herd ($300 - $50 = $250).

Example 2: The Effect of Feeding Colostrum to Calves Within 12 Hours of Birth

			Present Value of Expected Change
Disease Control Expenses			
1)	Veterinarian's Service		0
2)	Medicine (udder wipes)		$ 0
3)	Farmer's Labor		$ -50
4)	Farmer's Special Health Care Facilities		0
5)	Other		0
		Subtotal	$ -50
Disease Impact			
6)	Contaminated Milk		$ 0
7)	Change in Feed Consumption		$-100
8)	Reduced Feed Utilization in Youngstock		$+100
9)	Reduced Lactating Potential		0
10)	Death Loss		$+300
11)	Culling		0
12)	Lengthened Optimal Calving Interval		0
13)	Other		0
		Subtotal	$+300
		Total	$+250

C. Data Applications

5. A Model to Estimate Reduced Lactating Potential Due to Disease

Much effort has been spent earlier in this paper pointing out the deficiencies of the data used in other studies. The data used in this study also have many deficiencies, but that is because they rely on records which existed previous to FAHRMX. One of the purposes of this study is to direct FAHRMX to the information it should gather in order to meet its objectives. Although the retrospective data set used in this study is deficient for some purposes, it differs from most other data sources in two important respects. First, the disease data are from commercial farms, instead of from research herds. Second, culled cows are included in the sample. The importance of this second factor will become evident shortly. Another advantage of this study is that it has the prospective data capabilities to look forward to. Discussion of problems with the model can therefore take place at two levels. Some problems due to deficiencies in the retrospective data will be solved automatically by FAHRMX data, while others may be more lasting.

The model to estimate reduced production, using retrospective data, is outlined after the significant problem of measuring production is discussed. No model can accurately estimate reduced production if that reduced production cannot be detected by current measurement schemes.

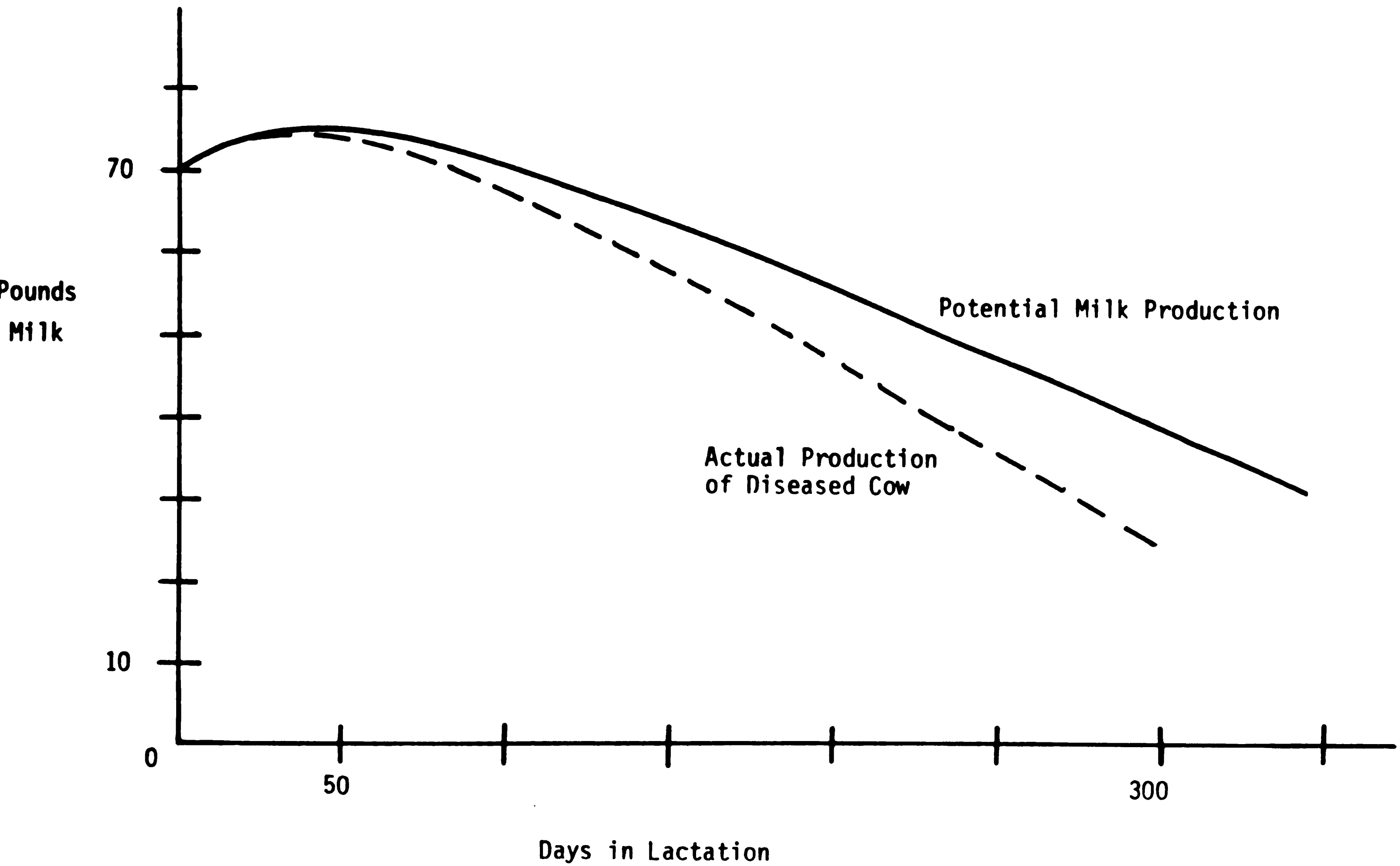
a. Measuring Production

Both the retrospective and prospective studies rely on DHIA for their production data. DHIA currently uses a monthly testing procedure which estimates the amount of milk produced by each cow. McDaniel et al. (1965) have calculated the correlation of DHIA's projections of 305-day milk production, made from one day's production measured monthly, to actual milk production measured at each milking. Early in lactation, the correlation is small but by the end of lactation (close to 305 days) the correlation is very high (.99). Therefore, DHIA estimates very well what a cow actually produces during her lactation by the end of her lactation.

It was initially proposed that 305-day projections, made before the onset of disease, be compared to later projections or end-of-lactation figures in order to detect production losses due to disease. However, metritis and cystic ovaries usually occur early in the lactation period (see Results) when projection factors are unreliable. Assuming that the magnitude of peak production influences production throughout lactation, the projection factors for cows with diseases that exert their influence before the peak would not reveal lowered potential if they stay below potential over the whole lactation period. Figure 6 demonstrates this phenomenon.

Figure 6

Possible Effect of Disease on Lactating Potential



In mid-lactation, DHIA averages monthly milk weights. If it is physiologically possible for a cow to recover suddenly from the stress of some disorders, then this practice of averaging monthly weights may miss "dips" in production between tests. Figure 7 shows the extreme case where a cow is stressed and recovers to her potential between DHIA test days. In this case, the monthly testing procedure would not detect any milk loss. However, DHIA's procedure will also overestimate milk lost in other instances (see Figure 8).

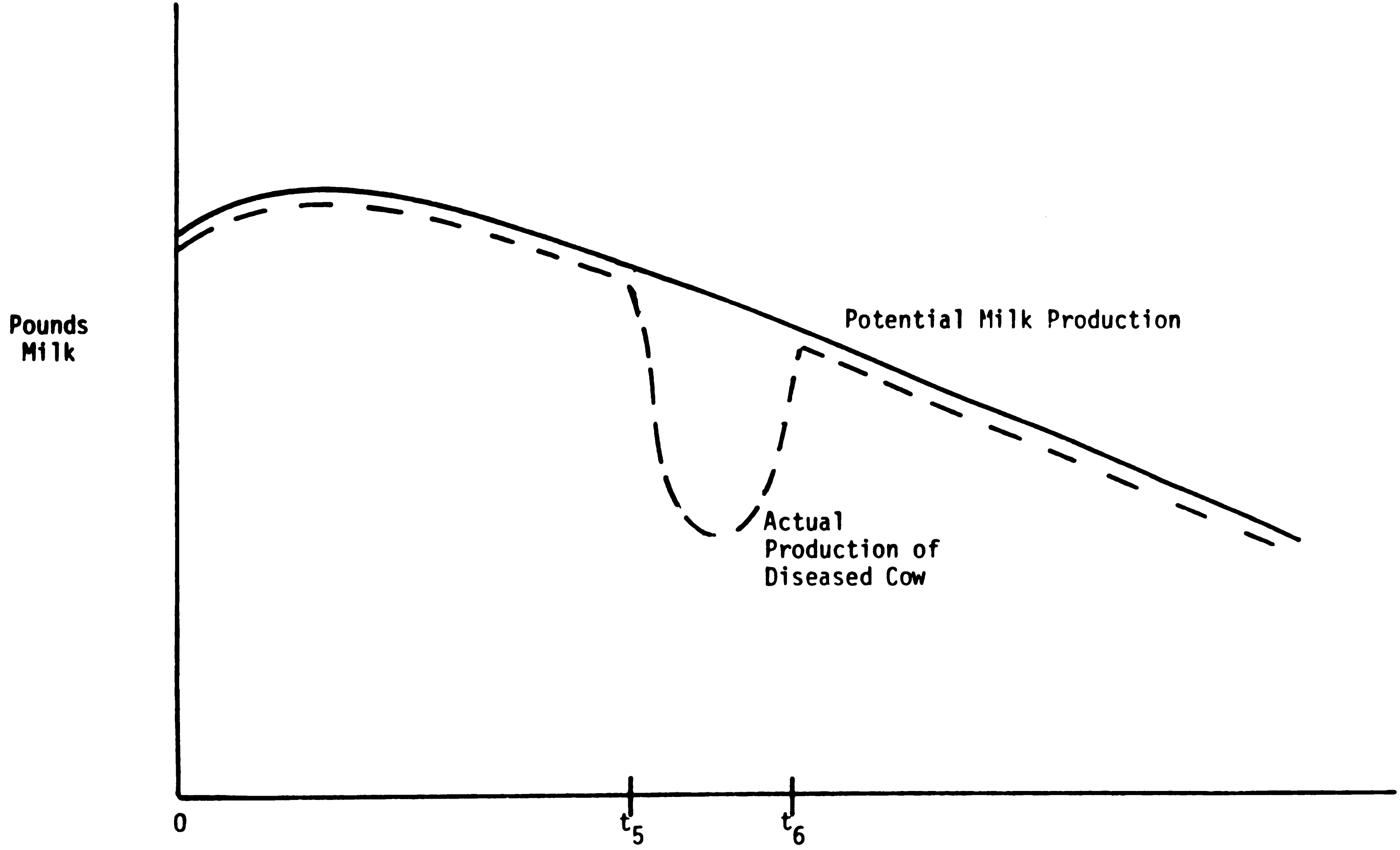
It is also possible that when a disease occurs in mid-lactation, the cow never completely recovers from the stress. In this instance, a difference in projection factors should be detectable. Figure 9 illustrates the case where a mid-lactation disease causes a detectable change in projection factors. At the fifth test day, the projected production can be represented by Area A. Assume that the cow is stressed immediately following the fifth test day; then, at the sixth test day, projected production could be represented by Area A minus Area B. A comparison of projections at t_5 and t_6 would show a net loss of Area B.

The advantage of using changes in projection factors is that cows can be used as their own controls. A disadvantage of projection factors is that they have not been determined independent of disease. Therefore, their use would probably underestimate the actual reduction due to disease. The fact that the retrospective data included only diseases which occur early in lactation (metritis and cystic ovaries) precluded the use of projection factors in the retrospective analysis. The only option left was to use end-of-lactation production figures. These are the most reliable and will account for production "dips" as well as any monthly testing scheme can.

The use of daily milk weights would circumvent many of the problems mentioned here. A few FAHRMX participants currently have the equipment to measure daily milk weights. Research is being done to use deviations in daily

Figure 7

"Dip" in Milk Production Undetected by Monthly Testing Procedures



t_5= fifth test day

t_6= sixth test day

Figure 8

"Dip" in Milk Production Overestimated by Monthly Testing Procedure

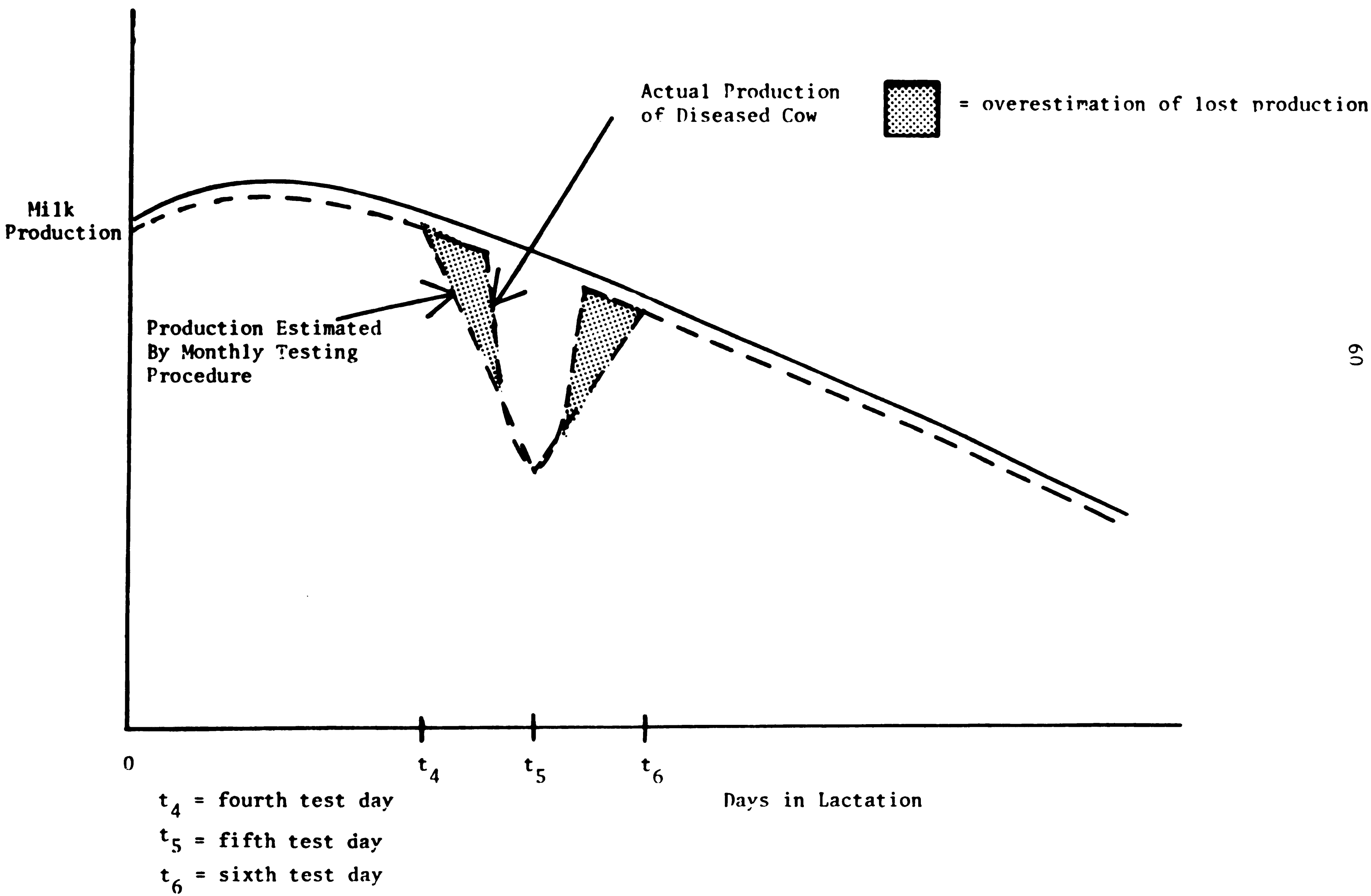
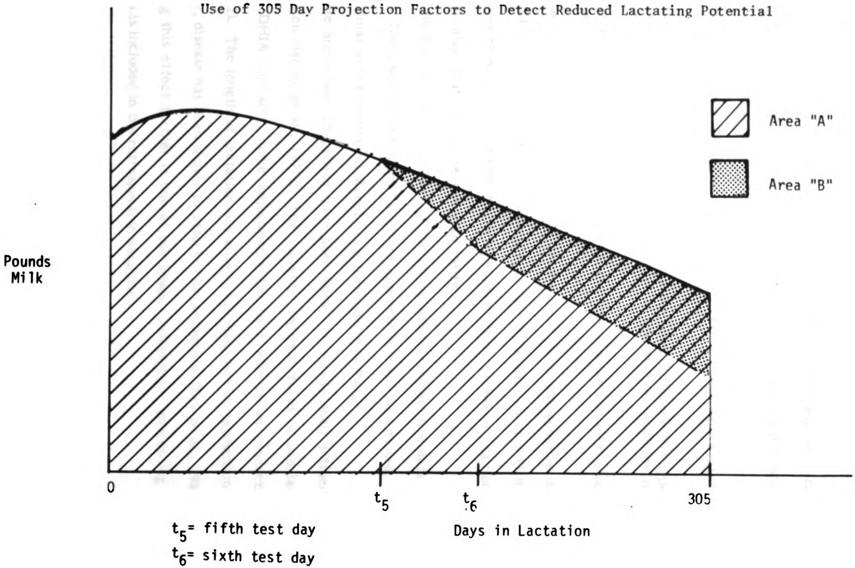


Figure 9

Use of 305 Day Projection Factors to Detect Reduced Lactating Potential



production as a diagnostic tool (Anderson, 1982). Combining daily milk weights with health histories on FAHRMX software would facilitate this research as well as remove doubts about how much milk a cow actually produced.

b. Scope of the Ideal Model

In a previous section, some problems were introduced that will have to be dealt with in a model to estimate reduced lactating potential caused by disease:

1) Production potential changes with age.

2) Disease can have long-term consequences, which may require lifetime disease and production information to detect.

3) Culling behavior as well as management practices influence the type of disease problems and the characteristics of the animals with the most disease problems.

4) There appears to be a joint influence between disease and milk production.

Some accounting of factors (1) and (3) can be made using retrospective data. Factor (2) will be accommodated automatically by the accumulation of FAHRMX health histories combined with DHIA production information. However, factor (4) presents difficulties that will not be solved so easily.

First, the format and capabilities of the model using retrospective data will be discussed. Then, some possibilities for future improvement will be outlined.

c. Format of the Statistical Model Using Retrospective Data

Both age and season of calving have been shown to significantly influence milk production (Miller et al., 1970). The variation between herds is also large enough that DHIA will soon make adjustments for herd effects on production (Thelan, 1982). The length of lactation has an obvious influence on production as well. Finally, disease has been shown to affect milk production (Erb et al., 1981), and exploring this effect further is one of our goals. Information concerning all these factors is included in the retrospective data file.

If it assumed that age, season of calving, herd, days in milk, and disease combine to determine milk production, then single-equation multiple-correlation analysis can be used to determine their various contributions.

To estimate reduced lactating potential, the goal is to attach a cost, in terms of milk production, to each case of a particular disease. Although correlation analysis cannot prove causality, it can be used to show the strength of association between two or more phenomena. With milk production chosen as the dependent variable, and age, season of calving, herd, days in milk, and disease chosen as explanatory variables, correlation analysis will estimate the (population) mean value of milk production in terms of the explanatory variables. If the model is specified correctly, then the disease parameter estimates (β's) will estimate the average change in production caused by each case of disease. The expectation is that disease parameter estimates must be negative in order to adequately represent the detrimental effects of disease (Gujarati, 1978).

The method of estimation used was ordinary least square (OLS). To obtain unbiased estimators using OLS, six assumptions must be valid:

Assumption 1: The conditional mean value of the population disturbance term u_i, conditional upon the given values of the explanatory variables (the X's), is zero.

Assumption 2: The conditional variance of u_i is constant, or homoscedastic.

Assumption 3: There is no autocorrelation in the disturbances.

Assumption 4: The explanatory variables are either nonstochastic (i.e., fixed in repeated sampling or, if stochastic, distributed independently of the disturbances, u_i.

Assumption 5: There is no multicollinearity among the explanatory variables, the X's.

Assumption 6: The u's are normally distributed with mean and variance given by Assumptions (1) and (2) (Gujarati, 1978).

With milk production as the dependent variable, and age, season of calving, herd, days in milk, and disease as explanatory variables, the equation looks like:

$$\text{Pounds Milk Production} = \beta_0 + \beta_1 \underset{\text{Calving}}{\text{Age}} \text{ at} +$$

β_2 (0,1 Variable for Spring Calving) +

β_3 (0,1 Variable for Summer Calving) +

β_4 (0,1 Variable for Fall Calving) +

β_5 (0,1 Variable for Herd 2) +

β_6 (0,1 Variable for Herd 3) + . . . +

β_{11} (0,1 Variable for Herd 8) +

β_{12} (Total Days in Milk) +

β_{13} $(\text{Total Days in Milk})^2$ +

β_{14} $(\text{Total Days in Milk})^3$ +

β_{15} (0,1 Variable for Metritis) +

β_{16} (0,1 Variable for Cystic Ovaries) +

unexplained error

Milk production was the total milk produced per lactation. Other researchers adjusted production to a standard 305 days. We felt some information might be lost by following this example. Time is accounted for in our model by the days in milk terms.

The season of calving, herd, and disease variables are all categorical variables, i.e., they can only take on the values zero or one. One less than the total number of each group of categorical variables is explicitly included in the model. For example, there are four seasons, but only three are explicitly included in the model. Production of a cow calving in winter, in herd 1, without either metritis or cystic ovaries, is estimated as a function of the intercept term, the age term, the days in milk terms, and the unexplained error. As its name implies, the error term accounts for all the variance not already "explained" by the explanatory variables.

In a model of similar specification (i.e., single-equation correlation analysis) Erb et al. (1981) found positive disease parameter estimates for cows with cystic ovaries. Cystic cows were found to produce an average of 655 pounds more mature equivalent milk than non-cystic cows. Using our previous interpretation of the model, this suggests that each case of cystic ovaries is "worth" about 655 pounds of milk, which could erroneously lead to the recommendation that farmers welcome the disease. There are obviously other factors as yet "hidden" from this model.

What Erb's evidence shows is a positive association between cystic ovaries and cows which produce a lot of milk. How else could this association be explained? One strong possibility is that farmers tolerate more disease in their high producing cows. As an example, suppose a herd is categorized into low, medium, and high producing groups as in Figure 10. Assume that one-third of the cows are culled each year. Also, suppose that cows can be categorized into those with no, modest, and significant disease problems. If the farmer were to follow a culling procedure that ignored disease, equal numbers of cows would be culled from each group as depicted in Figure 10a. Therefore, if an investigator were to sort cows into the three disease categories and examine the impact on milk production, an unbiased estimate of the impact would be obtained. In contrast, suppose the farmer takes disease into account in culling decisions, and that a higher lactating potential is required to retain a cow that has disease problems. The results would be similar to Figure 10b. Therefore, if cows were sorted into the three disease categories, milk production for the cows remaining in the herd would be seen to increase as disease increases. Biased estimators of the impact of disease on milk production would result because of the confounding effect of the farmer's culling procedure.

Erb's analysis effectively excluded culled cows because for her "regression analyses" she chose a subset of 810 animals with "complete records," a complete

Figure 10

Illustration of Culling Bias

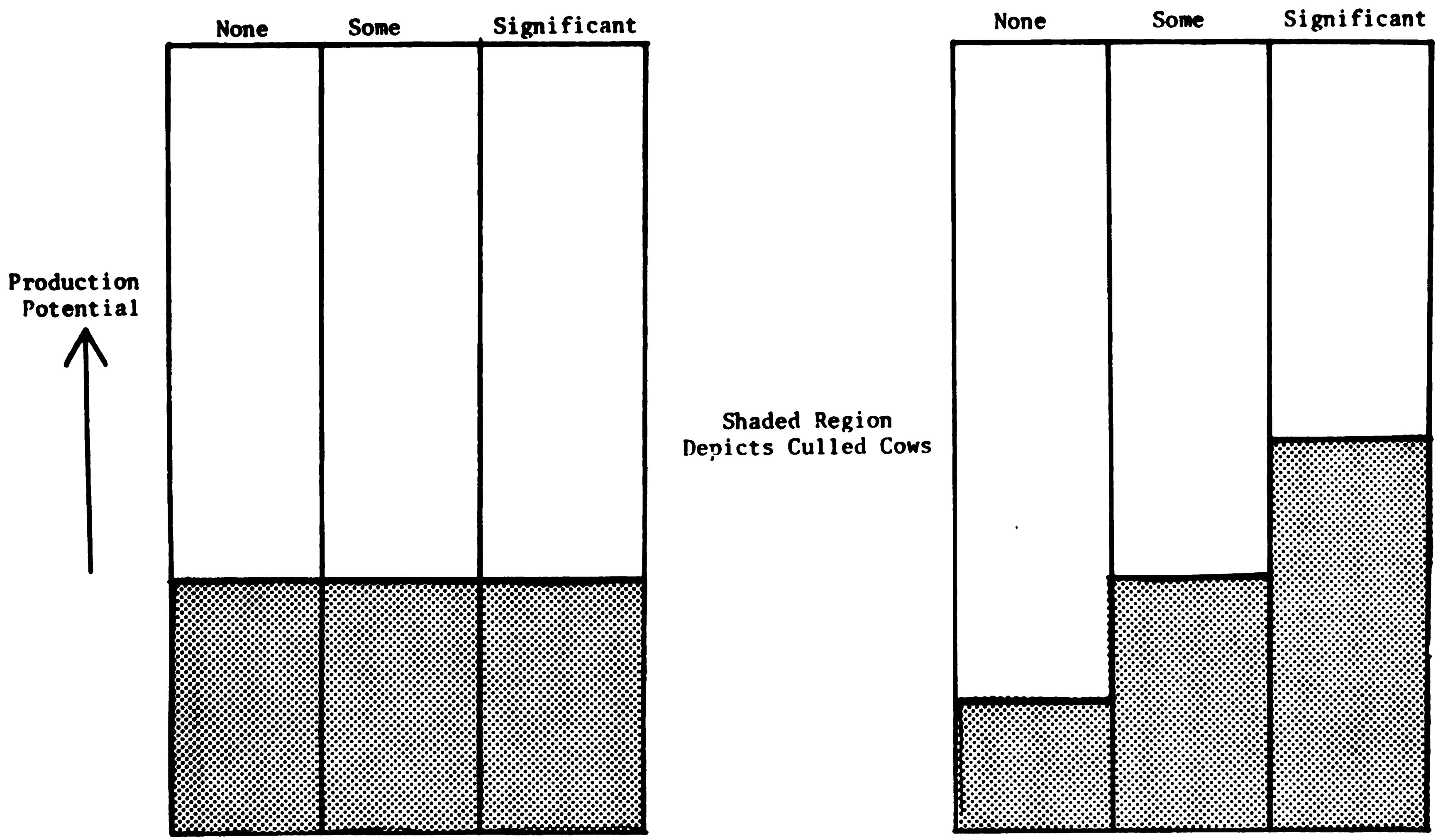


Figure 10a
Cows Culled Ignoring Disease

Figure 10b
Cows Culled Considering Disease

record being defined as the middle of three successive lactation periods. The inclusion of culled cows in our sample should help correct the bias by "saving" disease information about culled cows. We would expect that inclusion of culled cows will lower the cystic ovary parameter estimate (make it more negative). Although culled cows were included in our sample, we cannot be certain that the parameter estimate for cystic ovaries will be negative (representing its "true" value). This is because there are probably other significant factors creating the association between high milk production and disease for which our model does not yet account.

A further explanation may be that better managers recognize and treat more cases of disease. Actual disease incidence may not vary between herds, but the number of recognized cases might. Because better managers have higher producing cows, the correlation between production and disease would be spurious in this instance. This "reporting bias" is a "bug" that will be very difficult to remove.

A third possibility is that the stress of producing a lot of milk actually makes cows more susceptible to disease. If this is the case, then disease and milk production are jointly determined to some degree,[8/] and a single-equation model of milk production including disease is not legitimate because OLS assumption number four is contradicted. Rather, a set of simultaneous equations must be considered. Such a system of equations exceeds the limitations of the retrospective data. The simultaneous equations problem is discussed in the next section along with the prospective data probably required to solve it.

[8/]The vector linking the joint determination of days open and milk production, discovered by Oltenacu et al. (1980), may well be cystic ovaries. That is, cystic ovaries are jointly determined with milk production. Because cystic ovaries lengthen the open period, it may only <u>appear</u> as if milk production has a direct effect on the open period.

d. Possibilities for Future Improvement of the Model: Simultaneous Equations

In single-equation regression models, such as the one discussed previously, the dependent variable is listed as a function (linear in the parameters) of two or more explanatory variables. The fundamental assumption of this procedure is that causal relationships, if they exist, move only from the explanatory variables to the dependent variable. If the stress of producing large amounts of milk does make cows more susceptible to disease, then a single-equation model is no longer appropriate because disease and milk production are jointly determined. Here two different effects of disease must be distinguished: (1) disease as a result of poor management and (2) disease as an "inevitable" result of milking cows at maximum capacity. This latter problem involves developing a set of equations to be solved simultaneously. Another way to state the simultaneity problem is that if disease is correlated with the error term in a single-equation model of milk production, then there is no way to assess the separate influence of disease and the error term on milk production. This is a violation of OLS assumption number four (Gujarati, 1978).

The equations discussed previously had milk production as a function of age, season of calving, herd, days in milk, and two diseases, or:

Milk Production* = f (Age, Season of Calving, Herd, Days in Milk,

Disease 1*, Disease 2* + error)

where the asterisks (*) indicate jointly determined or endogenous variables. Each endogenous variable requires an equation which uniquely determines it (Gujarati, 1978).

With three endogenous variables, three equations are needed such as:

Milk Production* = f_1 (Age, Season of Calving, Herd, Days in Milk,

Disease 1*, Disease 2*, Genetic Potential + error")

Disease 1* = f_2 (Milk Production, Age, Season of Calving, Herd,

X_1 + error''')

Disease 2* = f_3 (Milk Production*, Age, Season of Calving, Herd,

X_2 + error'''')

where X_1 and X_2 are exogenous variables yet to be determined.

The unique determination of the equations is called identification. To identify the two disease equations, two exogenous, or predetermined, variables are needed:

X_1, which is correlated with Disease 1 in individual animals but not milk production, and

X_2, which is correlated with Disease 2 in individual animals but not milk production (Gujarati, 1978).

It is proposed to use lagged dependent variables for X_1 and X_2. Coleman's (1982) research on the recurrence of disease problems should be helpful in this regard. Because FAHRMX is currently amassing disease histories, it is possible that a lagged disease variable could be used in the prospective analysis. Both the rank and order conditions must be met for identification (Gujarati, 1978).

This segment on the model to estimate reduced lactating potential due to disease began with criticisms of monthly estimates of production. It concludes with a warning about what can be measured even with perfect knowledge of production.

e. A Point of Clarification: Measuring Reduced Lactating Potential in Animals Treated for Disease

In a strict sense, the foregone production due to lack of treatment for specific diseases in commercial herds cannot be measured. When a cow is diagnosed as ill, the animal is either treated, culled, or left untreated. Presumably, the decision to keep an untreated sick cow is based on the assumption that the disease is not very detrimental. This leaves a sample devoid of animals untreated for serious diseases. For those animals that either die or are culled due to disease, foregone production can be estimated as described earlier. Because veterinary treatment has already been justified for the surviving animals, the problem remains to calculate the value of treatment in cows that have already been treated. This is not a fair measure of the value of treatment. In fact, treatment may be very effective in preventing detrimental effects of disease, that is its purpose. What can be measured is the value of changes in treatment procedure.

f. Conclusion to Methods

To this point, it should be clear how the costs and benefits of disease control for dairy cattle can be compared once they are enumerated. A proposed model for enumerating lost production potential has been presented; however, difficulties with the model's specification are expected. The next chapter tests the model with data from FAHRMX herds that were available previous to FAHRMX. Chapter 4, therefore, contains much discussion about the representativeness of the sample data.

Chapter Four

Results

A. Introduction

This chapter is divided into five sections. The first lays out some results from the questionnaire which depict farm infrastructure and management factors pertaining to animal health care on the 12 farms surveyed. The second compares the sample disease data from 8 of these 12 herds to that of other studies. The third compares the characteristics of culled cows in the sample of eight farms to those in other culling studies. The fourth compares the results of the correlation analysis with and without culled cows. And, the fifth presents the results of a correlation analysis including genetic indices.

B. Questionnaire Results

The herd size of 22 FAHRMX participants was given in Table 3. Table 6 shows the size distribution of the 12 surveyed farms.

Table 6. Herd Size, 12 of 23 FAHRMX Participants, 1980

No. of Cows	< 50	51-75	76-125	126-157
No. of Farms	3	1	6	2

Source: DHIA Annual Herd Summaries, 1980.

Table 7 shows the milk production classes represented by the 12 farms.

Table 7. Milk Production Class, 12 of 23 FAHRMX Participants, 1980

Pounds Milk/Cow/Year	No. Farms
15,000 - 15,999	3
16,000 - 16,999	2
17,000 - 17,999	5
18,000 - 18,999	0
19,000 - 19,999	2

Source: DHIA Annual Herd Summaries for Holsteins, 1980.

Table 8 depicts the housing of lactating cows on the sample farms.

Table 8. Housing for Lactating Cows, 12 of 23 FAHRMX Participants, 1982

	Free Stall	Tie Stall	Tie Stall, Free Stall, and Pasture
No. of Farms	9	2	1

Table 9 shows the location of milking on the 12 farms. As might be expected, the nine farms with milking parlors coincide with the nine farms with free stalls in Table 8.

Table 9. Location of Milking, 12 of 23 FAHRMX Participants, 1982

	Milking Parlor	Stalls
No. of Farms	9	3

Table 10 shows how dry cows are housed on the sample farms. Three of the farms with free stalls for their lactating cows only provide loose housing for their dry cows (see Table 8).

Table 10. Housing for Dry Cows, 12 of 23 FAHRMX Participants, 1982

	Free Stalls	Loose
No. of Farms	6	6

The existence of special health care facilities should also be noted so that their influence on farm profitability or disease incidence may be studied. We received varied answers to the question, "Do you have a facility where you isolate or give special care to sick animals?" Many box stalls had multiple uses, some of which were not related to herd health. Some farms had nothing that could be classified as an isolation facility. Others had relatively elaborate facilities including hoof trimming tables, squeeze pens, catch pens, and head gates.

Table 11 shows the location of calving on the 12 farms.

Table 11. Location of Calving, 12 of 23 FAHRMX Participants, 1982

	Maternity Stalls	Own Stalls	Mostly Outside
No. of Farms	10	1	1

The low calf mortality reported by the 12 farmers, zero to 5 percent for females by the time of weaning, draws interest to calf care on the sample farms. The farms raise all their replacement animals. Age at weaning ranges from 4 to 12 weeks with an average of 7. Six farms have calf barns. Only one of these has a heated nursery. Five farms use calf hutches.

Table 12 addresses the degree of disease reporting on the sample farms before FAHRMX was used. For some diseases, it was unclear whether they did not appear on records because they were consciously not recorded, or because there were no cases of the disease over the period of study. The least common diseases among cows included pneumonia, hardware disease, diarrhea, pink eye, and bloat. The records consisted of date and treatment. They were either on MSU issue individual cow cards or cow folders, or were merely kept in a notebook. Cystic ovaries and metritis have the advantage of being primarily veterinarian diagnosed. This allows for consistency in diagnosis as well as reliable reporting. The common practice on these farms is for farmers to record the veterinarians' diagnoses at the time they make them. On the basis of these records, 8 of the 12 farms were chosen for the quantitative analysis of disease and production records.

Tables 13 and 14 reveal the degree of dependence of the farmers on their veterinarians. It is important to note the amount of health care that farmers perform themselves in order to calculate the total value of health care received by the herds. The degree of veterinary self-sufficiency may be an indicator of management prowess, or simply a function of proximity to the veterinarian's office. Tables 13 and 14 are based on the farmers' judgement of the percentage of self-treating that they do. The prospective data base includes empirical evidence of the amount of self-treating actually done.

All but one of the twelve sample farms dry treat all their cows for mastitis. Ten teat dip regularly. Two do not teat dip regularly. Five use the California Mastitis Test or the DHIA Somatic Cell Counting service. Seven farmers use only clinical signs to diagnose mastitis.

Table 12. Extent of Disease Recording Before the Utilization of FAHRMX, 12 of 23 FAHRMX Participants, 1979-1981

	Number of Farms That Recorded	
	All Cases	Fewer
Cystic Ovaries	10	2
Metritis	8	4
Displaced Abomasum	7	5
Milk Fever	5	7
Hardware Disease	5	7
Ketosis	5	7
Bloat	2	10
Mastitis	1	11
Pink Eye	1	11
Pneumonia	1	11
Lameness	1	11
Diarrhea	0	12

Table 13. Milk Fever, Percentage of Farmer Treatment, 12 of 23 FAHRMX Participants, 1982

	Percentage of Cases Self-Treated	
	None	90% or More
No. of Farms	6	6

Table 14. Retained Placenta, Percentage of Farmer Treatment, 12 of 23 FAHRMX Participants, 1982

	Percentage of Cases Self-Treated	
	None	90% or More
No. of Farms	4	8

C. Comparison of Sample Disease Data to That of Other Studies

Figures 11 and 12 show the distribution of days in milk at first treatment for metritis and cystic ovaries. The histograms support Shanks et al. (1981) conclusion that most of the treatment expense occurs in early lactation. In Figure 13, the incidence data for metritis and cystic ovaries have been combined in order to compare them with Shanks' et al. (1981) and Hansen's et al. (1979) reproductive disorders cost curves. Shanks included treatment costs for metritis, pyrometra, discharges, adhesions, cysts, retained placentas, tears in the reproductive tract, difficult calvings, as well as postpartum and other reproductive exams. Hansen excluded palpation labor and expense, but otherwise included the same disorders among reproductive costs. Shanks' data are from two research herds and cover about 1,000 lactations. Hansen's are from only one research herd but include about 2,500 lactations. It appears as if Hansen was more rigorous about recording the amount of farmer labor spent for animal health care. This might account for the difference between Hansen's and Shanks' reproductive cost curves.

From these comparisons, the importance of disease in the early stages of lactation is reaffirmed. The coincidence of total treatment expense and frequency of first treatment is probably not very surprising. The similarity across herds, however, is remarkable. It is important to stress that the costs tabulated by Shanks and Hansen were treatment costs. They omitted the major impact category of reduced milk producing potential.

D. Characteristics of Culled Cows

The inclusion of culled cows in the sample correlation analysis is expected to have an important effect. Therefore, it is crucial that culled cows included in the sample are representative of the whole population of culls. For some herds, the span of complete production and disease records was quite short. It was thought that particularly short spans would bias the sample in favor of culled cows because

Figure 11

Days in Milk at Time of First Treatment
for Metritis, Eight Pilot Herds

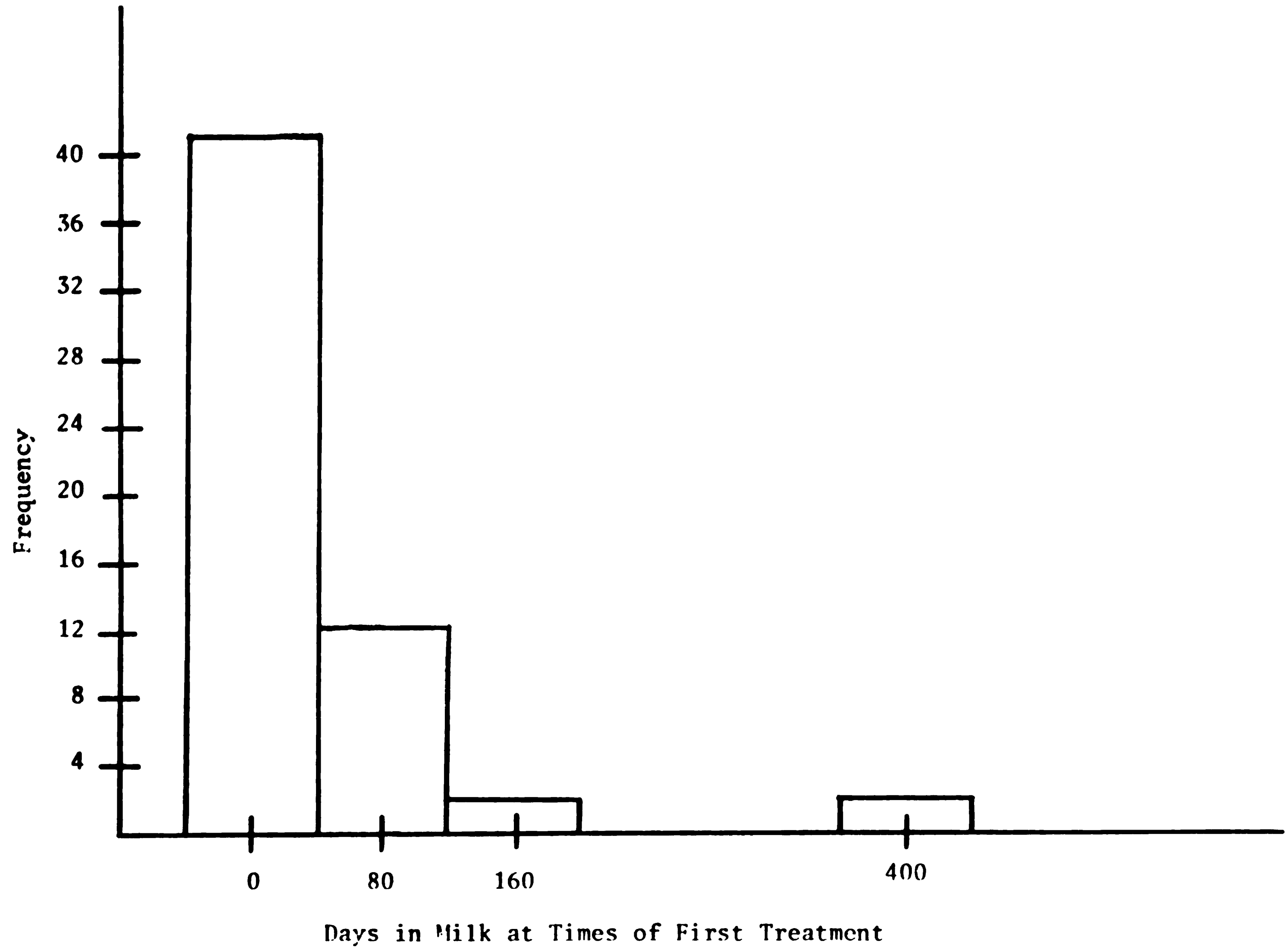


Figure 12

Days in Milk at Time of First Treatment for
Cystic Ovaries, Eight Pilot Herds

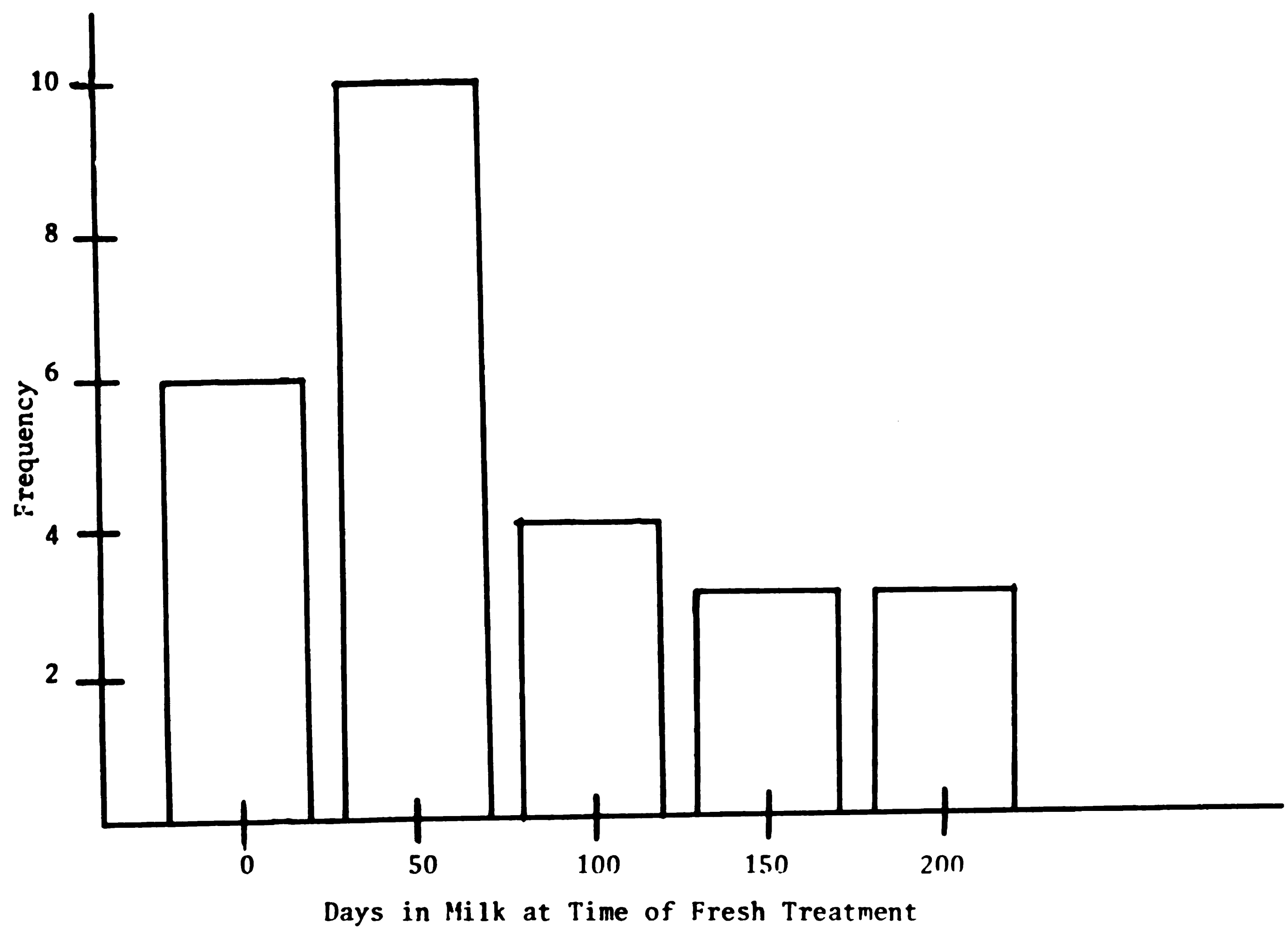
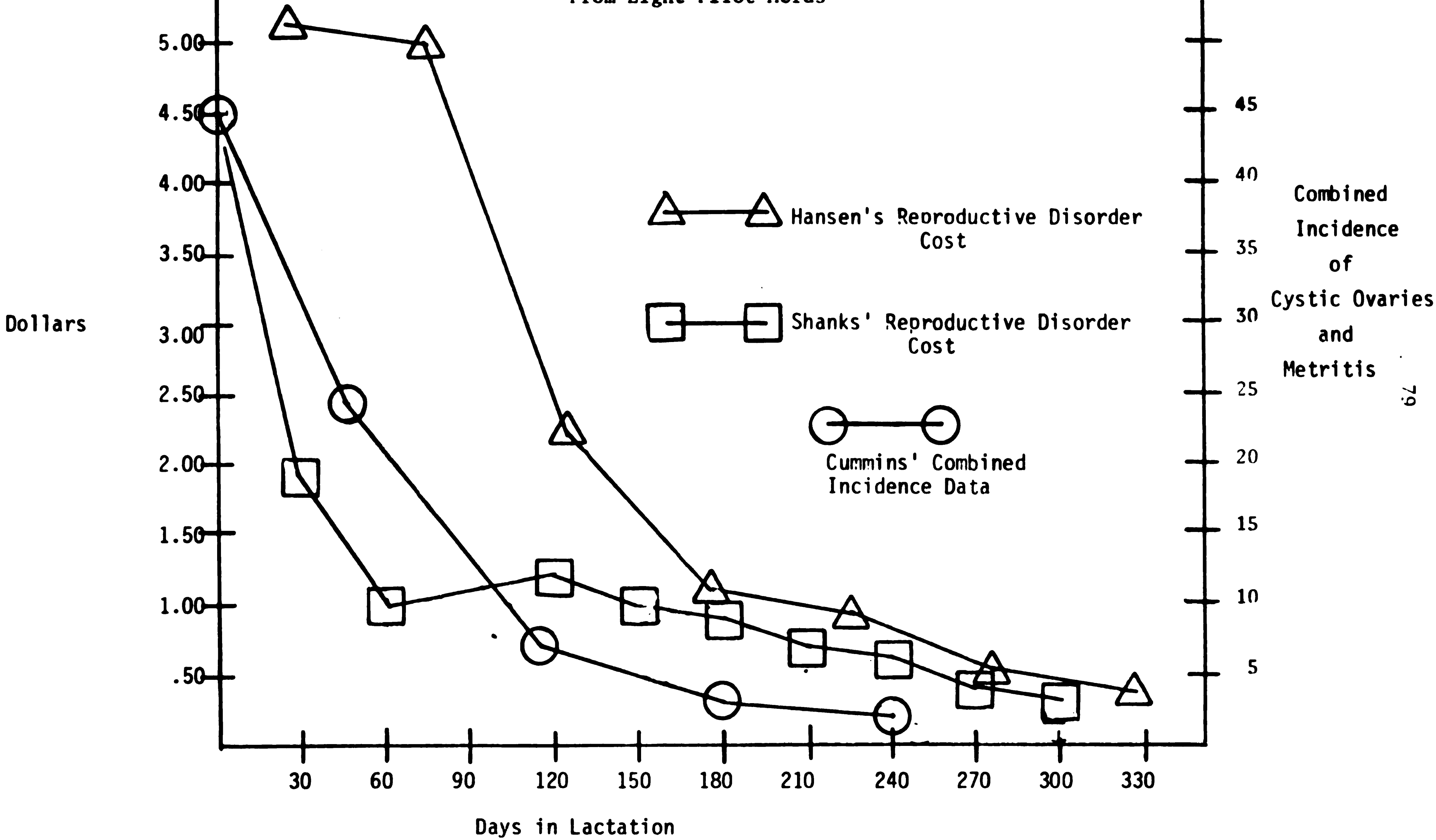


Figure 13

Comparison of Hansen's and Shanks Reproductive Disorder Cost Distribution to Cummins' Combined Incidence Data for Cystic Ovaries and Metritis From Eight Pilot Herds



their lactation periods tend to be shorter. However, the data presented in Table 15 dispel this fear. Although the sample culling percentages vary significantly from the percentages calculated by DHIA in 1980, the weighted mean culling percentages are both 24 percent (the last row in Table 15).

The information in Table 16 gives further evidence to the representativeness of the sample culls. Table 16 compares the reasons for culling in other samples to the data from eight pilot FAHRMX herds (last column in Table 16). Although the culling percentages in the Cummins' data are not necessarily annual figures, and some of the classifications of culls differ between studies, the similarity between the percentages from the various studies is evident. The data from which the last column in Table 16 was derived are contained in Table 17.

In Table 17, the mean mature equivalent production of those cows culled for dairy purposes is expectedly high. The magnitude of the production potential lost because of culling due to disease can be seen in the high mature equivalent production of cows culled for the following reasons: physical injury, mastitis, sterility, milk fever, illness, and leg problems. The low mean days in milk figures for those cows culled because of udder problems (89 DIM) suggests that the most severe udder problems occur early in lactation.

E. Correlation Analyses Compared: Sample With and Without Culled Cows

The results of the first regression excluding culled cows are contained in Table 18. The R-square value of .63 means that only 63 percent of the total variation in milk production is explained by the model. Given that all the OLS assumptions hold, it is evident that several parameter estimates are significant. The significance level represents the probability of rejecting the hypothesis that the true parameter value is zero when it is in fact equal to zero. Therefore, the smaller the significance level, the smaller the chances of falsely assuming that the parameters are different than zero. The parameter estimates represent the

Table 15

Percent Culling Per Year, Eight Pilot Herds in FAHRMX Retrospective Sample

Herd	Span of Complete Records[a]	Length of Span (Months)	Length of Span (Years)	Total Cows	Total Culls	Percent Culled Per Year[b]	Percent Culled Per Year In 1980 According to DHIA
1	9/27/79 - 6/1/81	20.0	1.66	63	13	12	30
2	1/15/80 - 6/16/81	17.0	1.42	51	21	29	16
3	5/23/80 - 1/21/82	20.0	1.66	116	35	18	31
4	3/25/80 - 8/23/81	17.0	1.42	18	11	43	24
5	1/3/80 - 6/16/81	17.5	1.46	118	45	26	28
6	4/17/80- 6/23/81	14.0	1.17	35	15	38	20
7	11/7/80 - 9/28/81	10.5	.875	15	7	53	17
8	10/2/79 - 7/23/81	21.5	1.79	42	10	13	20
	Weighted Mean					24[c]	24[d]

[a]The dates between which <u>both</u> retrospective disease and production records were available.

[b](Total Culls/Total Cows) ÷ Years of Complete Records

[c] $\sum_{i=1}^{8}$ (% cull $herd_i$ * # cows $herd_i$) / total # cows in all herds.

[d]From Table 3

Table [illegible]

Reasons for Dairy Cattle Replacement

O'Bleness &	Arnold &	White &	Curtis &

Table 16

Reasons for Dairy Cattle Replacement

Authors	O'Bleness & Van Vleck		Arnold & Beecher	White & Nichols	Gurtle & Smith	Dayton	Cummins
Location	New York	Netherlands	Florida	Pennsylvania	California	Michigan	Michigan
Date of Study	1962		1957-1958	1958-1963	1968-1969	1957-1962	1979-1980
# Cows	7,362		3,447	7,317	1,704	7,939 Holsteins	187 Holsteins
Annual Rate of Culling	25%[1]	22%	Not Given	Not Given	30.8%	Not Given	24%
Reason:[2]							
1) Reproduction		24.0	15.8		36		
2) Sterility	16.1			15.66		11.3	9.6[9]
3) Low Prod.	27.1	18.0	25.2	36.87	40	40.2	36.0
4) Dairy	14.2			9.65		11.2	16.0
5) Udder	6.1	18.0	19.8[4]	13.48	12		2.7
6) Mastitis	8.3			5.81		9.9	7.0
7) Legs and Feet	2.8	6.0					3.2
8) Type	2.0						
9) Behavior		1.0 - 2.0					0.5
10) Milk Ability	2.5	4.0				2.4	0.5
11) Other		9.0 - 10.0	2.3	9.79	5		
12) Unstated			9.7			.5	4.3
13) Died	10.1		14.2	2.86		4.9	2.1
14) Accident		2.0	2.5		5		
15) Disease	1.9[3]	8.0	3.0			3.9[7]	7.5
16) Injury	4.2			4.74	2[6]	12.2[8]	6.4
17) Age	3.6	9.0	4.7	0.6		1.8	3.7
Total	98.8%	100%	100%[5]	99.46[6]	100%		99.5%

[1] 25% culled if herds are registered; 33% if herds not registered.

[2] Reasons were not uniform across studies; some reasons cover the same subject as others (i.e., death = disease + accidents, sterility reproduction).

[3] Brucellosis & T.B. reactors.

[4] Udder & mastitis

[5] An additional 2.8% was a combination of reproduction and udder and low production.

[6] Hardware disease.

[7] Sold because of bangs & T.B.

[8] The high number in this category is probably because legs and feet and type were excluded as reasons.

[9] This column does not necessarily represent annual culling rates.

Source for all but Cummins data: Hlubik (1979).

Table 17

Culling Summary, Eight Pilot Herds in FAHRMX Retrospective Sample

DHIA Cull Code	Reason for Culling	# Culls	Mean Age At Calving (Months)	Mean Total Milk (Pounds)	Mean Mature Equivalent (Pounds)	Mean Days In Milk At Culling
30	Sold for dairy purposes	30	41 (25)sd[a]	8816 (5117)	16119 (2539)	192 (122)
31	Sold because of low production	67	52 (22)	11000 (5434)	15534 (3224)	222 (94)
32	Sold because of physical injury	12	75 (29)	10135 (6232)	18888 (4482)	181 (114)
33	Sold because of mastitis	13	47 (18)	9353 (6464)	17917 (4352)	146 (95)
35	Sold because of temperament	1	24	2218	10064	68
37	Sold because of sterility	18	98 (30)	14617 (5310)	16730 (3147)	241 (90)
38	Sold because of old age	7	134 (24)	12245 (4254)	15822 (1996)	228 (79)
39	Sold because of hardware disease	2	47 (28)	7859 (756)	16327 (4528)	147 (69)
40	Died because of milk fever	1	88	19734	19344	337
47	Died because of pneumonia	2	101 (52)	10280 (4159)	14201 (2476)	227 (161)
49	Died because of calving trouble	1	111	---	17882	352
50	Sold for unknown reason	8	53	13817 (4476)	15943 (3158)	255 (66)
52	Sold because of illness	3	81 (45)	15353 (3277)	18408 (6522)	192 (151)
53	Sold because of udder problems	5	41 (16)	5224 (2887)	15674 (1592)	89 (33)
54	Sold because of leg problems	6	94 (28)	13697 (2743)	19083 (1158)	189 (37)
55	Sold because slow milker	1	22	1907	14264	45
58	Sold because of displaced abomasum	4	69 (40)	10452 (8453)	15838 (3025)	188 (149)
61	Died because of unknown cause	4	100 (49)	15046 (7613)	18191 (3876)	336 (158)
62	Died because of mastitis	1	92	13659	19144	171
63	Died because of displaced abomasum	1	49	665	23057	15

[a]sd = one standard deviation.

Table 18

Single Equation Run Without Culled Cows

Dependent Variable = Pounds of Milk per Lactation
Degrees of Freedom = 272
F-Ratio = 28.54   Significance Level of F-Ratio = .0001
R-Square = .6267

Variable	Parameter Estimate	Standard Error	Significance Level[c]
Intercept	-479	2129	.8221
Age of Calving[a]	61	7.88	.0001
Spring Calving (0,1)[b]	-953	482	.0493
Summer Calving (0,1)	-1234	539	.0228
Fall Calving (0,1)	722	567	.2033
Herd 2 (0,1)	-400	733	.5850
Herd 3 (0,1)	-576	564	.3080
Herd 4 (0,1)	4960	1265	.0001
Herd 5 (0,1)	889	616	.1500
Herd 6 (0,1)	-1876	827	.0242
Herd 7 (0,1)	-1614	1193	.1771
Herd 8 (0,1)	638	687	.3541
Total Days in Milk	50	31	.1124
$(\text{Total Days in Milk})^2$	.0025	0.133	.9849
$(\text{Total Days in Milk})^3$	-0.000048	0.00016	.7686
Metritis (0,1)	-221	546	.6866
Cystic Ovaries (0,1)	1073	743	.1494

[a]Age in months.

[b](0,1) indicates a zero-one categorical variable. The model must explicitly include one less than the total number of categorical variables in each category.

[c]The larger the number is in this column, the lower the signficance level.

average change in each variable holding all others constant. With a low significance level, the parameter estimates can be accepted with a high degree of confidence. Assuming that OLS assumptions hold, the parameter estimates for age of calving and herd 4 can be accepted with 99.99 percent confidence. Age at calving has been shown to have an important influence on milk production (Miller et al., 1970). The herd variables account for variation in milk production between herds. Given the vast differences in the quality of management and animals which exist between herds, it is not surprising to see such differences in herd parameter estimates. Season of calving has also been shown to be a significant source of variation among milk production records (Miller et al., 1970). Miller et al. (1970) found that summer calving was associated with lower milk production, especially among older cows. The negative parameter estimate for summer calving in Table 18 supports this conclusion. If the model is specified correctly, it can be accepted with 98 percent confidence. Hansen et al. (1979) found that health costs were highest during the summer and that these costs were primarily associated with mammary and respiratory disorders. This provides some evidence that the lower milk production records associated with summer calvings may be caused by disease.

Of the two disease variables, only the parameter estimate for cystic ovaries is relatively significant. As expected, it is a high positive number, which apparently contradicts the notion that cystic ovaries is detrimental. As explained in Chapter 3, the data set excluding culled cows probably lacks explanatory power. Perhaps the inclusion of culled cows will lower the cystic ovary parameter estimate and more accurately represent the detrimental effects of the disease.

Table 19 shows the results of the regression including culled cows. The parameter estimate for cystic ovaries has decreased from 1,073 to 940. Because the significance levels are both relatively high (about 85 percent), this reduction of

Table 19

Single Equation Run With Culled Cows Included

Dependent Variable = Pounds of Milk per Lactation
Degrees of Freedom = 418
F-Ratio = 63.12   Significance Level of F-Ratio = .0001
R-Square = .7073

Variable	Parameter Estimate	Standard Error	Significance Level[c]
Intercept	1114	1296	.3906
Age of Calving[a]	45	5.43	.0001
Spring Calving (0,1)[b]	-358	401	.3711
Summer Calving (0,1)	-1511	433	.0005
Fall Calving (0,1)	535	487	.2726
Herd 2 (0,1)	-765	611	.2112
Herd 3 (0,1)	-741	508	.1455
Herd 4 (0,1)	1524	882	.0846
Herd 5 (0,1)	-538	532	.3120
Herd 6 (0,1)	-2704	675	.0001
Herd 7 (0,1)	-1323	925	.1535
Herd 8 (0,1)	-167	627	.7900
Total Days in Milk	18	19	.3258
$(\text{Total Days in Milk})^2$	0.19	0.079	.0161
$(\text{Total Days in Milk})^3$	-0.00033	0.0001	.0010
Metritis (0,1)	127	471	.7872
Cystic Ovaries (0,1)	940	657	.1537

[a]Age in months.

[b](0,1) indicates a zero-one categorical variable. The model just explicitly include one less than the total number of cateogrical variables in each category.

[c]The larger the number is in this column, the lower the significance level.

133 pounds is probably meaningful. However, because the estimate is still highly positive, the model does not accurately estimate the loss of production potential caused by disease. Further adjustments, as suggested in Chapter 3, are necessary.

Another interesting difference between the two analyses is the change in the significance of the quadratic days in milk parameters. In Table 18 they are very insignificant, but in Table 19 they are very significant. This suggests that non-linear effects of the length of lactation may be more important in culled cows.

The drastic change in the parameter estimate for metritis from 127 to -221 should be ample warning not to depend on parameter estimates with low significance levels.

F. Regression Results Including Indices of Genetic Potential

Table 20 presents the results from a correlation analysis using the cows in the sample for which genetic indices were available retrospectively. As indicated by the degrees of freedom (36), the sub-sample is quite small. However, the parameter estimate for cow index is particularly significant, which means it contributes important information to the model. This emphasizes the importance of including genetic information among current FAHRMX data.

G. Summary and Conclusions

This protocol for the cost-benefit analysis of dairy cattle health management has discussed the opportunities presented by the data storage and analysis capabilities of microcomputers such as those utilized in the FAHRMX project. Microcomputers can be used to reorganize the health management information fed into them. In this application, they are an electronic library--essentially limited to serving as a herd health reporting system. However, this library of health-related data can also be used for comparative medical purposes--for the cost-benefit analysis of different disease control procedures. Cost-benefit analysis centers around the partial budget, which is in this case an itemization of disease

Table 20

Single Equation Run Including Indices of Genetic Potential

Dependent Variable = Pounds of Milk per Lactation
Degrees of Freedom = 36
F-Ratio = 6.19   Significance Level of F-Ratio = .0001
R-Square = .7451

Variable	Parameter Estimate	Standard Error	Significance Level[c]
Intercept	4226	13655	.7565
Age of Calving[a]	51	22	.0241
Spring Calving (0,1)[b]	-2015	1390	.1558
Summer Calving (0,1)	-4682	1467	.0029
Fall Calving (0,1)	-1231	1270	.3386
Herd 2 (0,1)	-3.70	2059	.9986
Herd 3 (0,1)	3235	1562	.0456
Herd 4 (0,1)	4558	2272	.0523
Herd 5 (0,1)	188	2161	.9312
Herd 6 (0,1)	4545	1699	.0112
Total Days in Milk	-141	158	.3800
$(\text{Total Days in Milk})^2$	.919	.577	.1201
$(\text{Total Days in Milk})^3$	-.00127	-1.96	.0575
Metritis (0,1)	-1046	1185	.3831
Cystic Ovaries (0,1)	1777	1319	.1863
Cow Index	3.82	1.78	.0387
Dam Index	1.33	1.59	.4092
Sire PD	.978	1.22	.4288

[a]Age in months.

[b](0,1) indicates a zero-one categorical variable. The model must explicitly include one less than the total number of categorical variables in each category.

[c]The larger the number is in this column, the lower the significance level.

control expenditures and changes in disease impact. Relevant categories have been identified easily enough. However, substantial problems remain in estimating some of these categories--especially lost production potential. Production potential is lost due to disease in single lactations, across several lactations, and by death and "forced" culling. Therefore, complicated interrelationships exist between disease, culling behavior, and milk production.

Using data available previous to FAHRMX, this study was able to utilize disease information on culled cows and thus provide a more realistic data set. However, modeling capabilities were limited by retrospective data. The apparent joint determination of milk production and disease requires the identification of a set of simultaneous equations. Successful identification of these equations depends on the discovery of exogenous variables correlated with each disease but not with milk production.

Estimation of the cost and benefit parameters for specific disease control procedures on specific farms will help determine the pay-off from different disease control methods. This is, in itself, a worthwhile objective. It would tell the farmer the optimum return from investment in animal health care, as well as from which control procedure this maximum return could come. Without such detailed information on other farm enterprises, however, the economic value of cost-benefit analysis of disease control is limited. Farmers need to know where their money can best be spent. Investment in animal health care should not preclude investment in a more profitable farm enterprise because of lack of information. This is an argument for whole-farm modeling, parts of which exist today in various forms. The emphasis of FAHRMX on animal health care is due to the presumed high returns from investment in it. The scope of animal health care is very broad, being affected by many aspects of dairy farm management. Therefore, the successful modeling of disease control would be a substantial step towards modeling the whole dairy farm.

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APPENDIX 1

THE APPEAL OF NEW TECHNOLOGY

There is a danger of farmers aquiring computers mainly because they are fashionable (especially when their purchase is subsidized). Until the value of a pilot project like FAHRMX is proven, our cost-benefit analysis could reach the same conclusion as Shoe's new toy.

APPENDIX 2

FOOD ANIMAL HEALTH RESOURCE MANAGEMENT SYSTEM (FAHRMX) GRANT PROPOSAL

MICHIGAN STATE UNIVERSITY

COLLEGE OF VETERINARY MEDICINE
LARGE ANIMAL SURGERY AND MEDICINE

EAST LANSING · MICHIGAN · 48824

January 15, 1980

Robert C. Kramer, Director
W. K. Kellogg Foundation
400 North Avenue
Battle Creek, MI 49016

Dear Director Kramer:

As a result of earlier discussions between ourselves and officials of the W. K. Kellogg Foundation concerning the role of veterinary medicine in human and animal nutrition and health, you requested that a proposal be developed that would address the cost-benefits of animal disease prevention. Subsequently, a preproposal was prepared by the faculty of the Department of Large Animal Surgery and Medicine at Michigan State University and submitted for consideration by the Foundation (cf. Dean Welser's letter of September 26, 1979).

Also at your request, we received a proposal submitted to the Foundation from the College of Veterinary Medicine at the University of Idaho. Although we would be glad to cooperate with the Idaho project should it be funded, we believe the two proposals take different but complementary approaches to similar problems and therefore should be considered on their own merits.

Therefore we are submitting the enclosed proposal, which includes a detailed project budget, for your consideration. As we continue to identify animal health problems and potential nutritional needs of future world populations, we are increasingly convinced that the evaluation of cost-benefits of animal health is a necessity for maximizing food production. Although much of the data necessary for such analyses is available, it has never been brought together in a usable system. We believe that the program we are proposing addresses this need and would make a significant contribution to increasing world food production.

If additional information is needed, please feel free to contact either of us.

Respectfully,

Edward C. Mather, D.V.M., Ph.D.
Professor and Chairman
Large Animal Surgery and Medicine

John R. Welser, Dean
College of Veterinary Medicine

dl

cc: Dean J. R. Welser
Director H. G. Grider
V. P. John Cantlon
Director S. Wittwer
Dean J. Anderson
Dr. H. D. Hafs
Dr. R. H. Nelson
Director G. E. Guyer

A Program to Maximize Animal Production by Evaluation of Cost-Benefits of Animal Health Care

Department of Large Animal Surgery and Medicine
Michigan State University

The Need for Improved Management of Animal Health

The annual loss in revenue attributable to livestock diseases has been estimated at 140 million dollars in Michigan (not including poultry). This loss results in an increased cost of production which is either absorbed by the producer as lost profit or passed on to the consumer of food and fiber as increased cost for agricultural products.

In the past, livestock disease problems concerned, for the most part, epizootics of infectious and contagious diseases such as brucellosis, hog cholera, and tuberculosis. Regulatory efforts, vaccination programs, and eradication programs have effectively combated most of the losses from these types of diseases. The majority of the disease problems prevalent in today's livestock industry are greatly influenced by management practices and the environment; for example, long calving intervals or high calf mortality. In contrast to strictly infectious and contagious diseases, these health problems are more amenable to greater control and preventative medicine practices at the local management level.

In addition, the nature of animal production has changed dramatically in recent decades, shifting from numerous small, family-owned farms, where farmers cared for individual animals, to fewer large, corporate-owned farms and agribusinesses, where the emphasis is on the productivity of entire herds. As a result, the focus of food animal veterinary medicine also has shifted from the care of individual animals to management of the overall health of large herds.

This situation provides an opportunity for livestock producers to increase production and lower production costs through improved herd health care. This, in turn, would result in increased profit for the individual production unit and lower consumer prices for animal food and fiber.

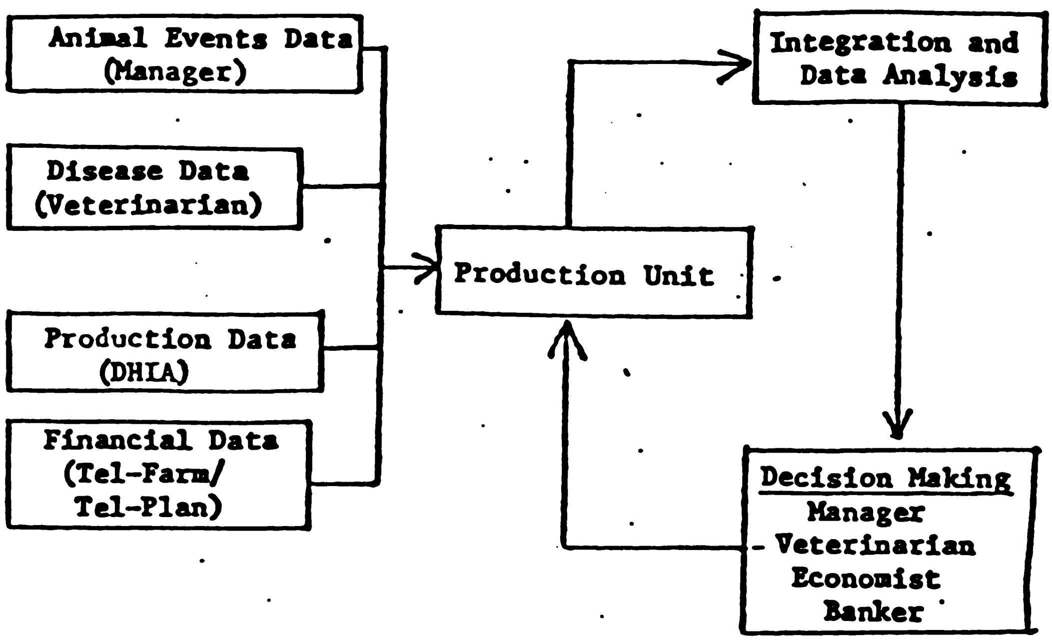
To make intelligent management decisions, including those related to health care, agricultural producers need to have accurate cost-benefit data concerning all controllable aspects of production. Such information is available in usable form for land-management decisions, such as fertilizer application and irrigation use. The same type of data is not presently utilized for decisjons concerning control of animal diseases and delivery and adoption of preventive health measures. Furthermore, most data on animal health that has been collected relates to animal mortality rather than morbidity despite the fact that morbidity has a greater effect on productivity and causes greater monetary losses than mortality.

Investigations by the Department of Large Animal Surgery and Medicine at Michigan State University indicate that information relevant to decisions concerning animal health can be obtained, but is not currently available in usable form. The department proposes to provide a delivery system enabling livestock producers to use available information as a tool to improve the control and management of animal diseases.

A Computer-based Information System for Improved Management of Animal Health

The goal of the proposed project is to establish, through the use of existing and available computer technology, a system whereby decisions regarding animal health management can be made on a cost-benefit basis. To achieve this objective, the following specific factors would be determined for each participating production unit: 1) the incidence and prevalence of disease; 2) the cost of disease in animal production; 3) the cost of making initial changes in management factors, such as space, building design, labor, etc., to prevent disease, and 4) the cost of controlling and minimizing disease in animal production on a continuing basis through such medical means as vaccination, antibiotics, etc.

To make these determinations, the computer system would analyze and integrate four types of data for each production unit: 1) animal events data; 2) disease data; 3) production data, and 4) financial data. Using this information, the production manager, in consultation with his/her veterinarian, banker, and an advisory economist, would be able to make more rational and reliable decisions concerning management of animal health problems. The chart below depicts the flow of information within the proposed system.



Michigan State University is uniquely qualified to develop and implement such a system, which initially would focus on dairy herds, but later would be expanded to include other agricultural species. Scientists currently on the faculty of the Department of Large Animal Surgery and Medicine would provide most of the expertise necessary to implement the project (see Appendix B for brief resumes of project participants). Existing University computer facilities and technology can be utilized for the proposed program. In addition, much of the necessary data already exists in computer-based form. Agricultural economists on the faculty at Michigan State University indicate that information from the University's Tel-Farm and Tel-Plan programs can be used for economic input with minimum supplementation in regard to health-related data. Moreover, certain health-related summaries as well as production data are available in computerized storage from the Michigan DHIA program, with which the University has a close working relationship. Finally, four large veterinary practices in Michigan have indicated a desire to cooperate in the proposed program using farms in their practice areas that participate in DHIA, Tel-Farm, and Tel-Plan programs.

The proposed program focuses on production units that already employ sophisticated management techniques, such as computerized production data and professional animal health programs, for several reasons. Most important, this type of unit comprises the greatest proportion of modern agribusinesses and produces most of the nation's agricultural products. Thus, even a small increase in the productivity of such units through the adoption of the proposed system would significantly improve the overall production of this important segment of the national economy and contribute to increasing world food supplies. Furthermore, these units could provide more reliable data for developing the system than could less intensively managed farms, and thus the results of the program could be assessed more accurately. Once the system is established, however, it could be adopted for use by traditionally operated farms, which would not only improve their productivity but would also demonstrate the advantages of adopting other modern management techniques.

The proposed program would be implemented in several stages over a period of five years. The first phase would be to determine: 1) what types of specific information are required from the various existing programs mentioned above; 2) optimal methods for data input and retrieval; 3) system differences required by various animal species; 4) the most appropriate type of data analysis, and 5) which type of computer systems are most efficient.

The second phase would be to select 20 dairy herds with DHI and Tel-Farm records and herd health programs as the pilot animal production units, and develop and test a model cost-benefit analysis system using these herds. Additional models for other species, particularly swine, beef, and sheep, and adaptations of these models for different types of production units, such as grassland or confinement units, would require minimal time and effort once a working model has been developed and tested.

The third phase of the program would be to convert to a financially self-sustaining operation through payments for services rendered. At this point, the program would be made available to all interested groups, both nationally and internationally. The final objective of the program is to develop a system that can be utilized in other states (as are the Tel-Farm and DHIA programs), and also can be a model for use in other countries through such programs as the Kellogg Foundation's small farm project.

To help guide the project, a statewide advisory group would be formed, including representatives from appropriate departments and the Cooperative

Extension Service at Michigan State University, the National DHIA Committee on Computers, dairymen, animal industries, and veterinarians. Once the system is ready to be offered nationwide, a national advisory committee composed of well-known experts in related fields would be formed to gain support of national agricultural groups and to provide national exposure for the program.

Benefits of the Proposed Program

The immediate objective of the proposed computer-based information system is increased profitability for the producing agricultural unit through increased animal productivity. The long-range objective is to increase consumer benefits and, ultimately, the national and international food supply.

The additional benefits to be derived from implementation of the proposed program are several. Diagnostic aids generated from the analysis of data from individual herds could aid the accurate determination of corrective action for short- and long-term disease prevention measures. Second, the detection of early changes in animal performance as influenced by animal health could be improved. Third, present Tel-Farm, DHIA, and veterinary herd health programs could be enhanced. Finally, improved herd disease incidence and cost information, especially in regard to morbidity, could be provided for the livestock industry.

Budget for the Proposed Program

Although Michigan State University would contribute the time of several faculty members to direct and participate in the project, implementation of the proposed program would require the addition of a veterinary epidemiologist and a computer programmer to the staff of the Department of Large Animal Surgery and Medicine. Moreover, computer terminals and other hardware would need to be purchased during the first year of the project to interface with existing equipment. A detailed budget is given in Appendix A.

APPENDIX 3

QUESTIONNAIRE ADMINISTERED TO TWELVE PILOT HERDS, 1981

Principally Developed By Dr. Paul Bartlett,
Department of Large Animal Surgery and Medicine, Michigan State University

YEARLY ANIMAL COST QUESTIONNAIRE (F-1)

I. General Health Care Costs

A. Do you have a facility where you "isolate" or give special care to sick animals? _____ Yes _____ No

C. What percent of the time is this facility used for other functions such as storage, maternity stalls, housing for calves, etc? ____________%

D. About how much money do you spend on medicine for your animals each year? (exclude medicines which are included in your veterinary bill?)

____

What is your approximate yearly veterinary bill? ______________________

E. What vaccinations do you usually give to your animals and at what age do they receive these vaccinations?

Vaccination	Age of Animal
Vicogen[R] (E. coli) __________	__________________
IBR __________	__________________
PI3 __________	__________________
BVD __________	__________________
Roto __________	__________________
Corona __________	__________________
Brucellosis __________	__________________
lepto __________	__________________

F. Describe your deworming program with regard to:

a. Brand of worming medicine used ____________________________

b. Frequency of deworming and age of animal at deworming _________
____

G. Describe your fly and grub control program in dollars per year with regard to:

Hrs. labor/wk (during the 4 month season)

a. Environmental sprays $________ per year. ____________________

b. Pest strips $____________ per year ____________________

c. Electric fly catchers $__________ per year ____________________

d. Materials feed or applied to animal $____________ per year _____

e. ______________________________ $______________ per year _____

f. ______________________________ $______________ per year _____

II. Milk Fever

A. What percentage of your milk fever cases do you treat yourself?

_____________% (If 0%, skip to III.)

B. What product do you yourself use to treat milk fever?

____

C. How many half liter (500cc) bottles do you usually need to treat a cow with milk fever? ____________________________

III. Prolapsed Uterus or Vagina

A. What percentage of the prolapses on your farm do you treat yourself? ______________________________

(Skip to section IV if you never treat this condition yourself.)

B. What medicines and materials do you use to treat this condition yourself.)____

____

C. What is the likelihood of your culling (within a year) a cow which had a prolapsed uterus? _______%

V. Pneumonia

A. What percent of calf pneumonia cases do you treat without the aid of your veterinarian? ________%

B. For those cases you treat yourself, what is your approximate daily cost of medicines (or type of medicine and dosage) for a calf with pneumonia? ______________________

For a cow with pneumonia? ______________________

C. How many extra minutes of labor are required for a calf which has pneumonia? ________

D. Fan Ratings:

Structure	cu/ft/min

VI. Mastitis

A. What percent of your cows receive dry cow therapy? ________%

If your answer was less than 100%, how do you select which cows will receive dry cow therapy? ______________________

____

____

B. What antibiotic do you use for dry cow therapy and what is the approximate cost per cow? ______________________

____

D. Do you have a program of regular maintenance for your milking machine equipment? _____ Yes _____ No

If yes, who checks the machine and how often is it checked?

____

What is your approximate yearly expenditure for milking machine maintenance? _______________________________________

E. What is your approximate yearly expenditure for the following items?

teat dip _________

paper towels _________

soap _________________________

____

____

F. What type (brand) of teat dip do you use? ____________________

G. How do you determine if a lactating cow has mastitis for which she needs to be treated? _____________________________________

____

H. Approximately how many days during 1981 have you been required to dump all of your milk because of antibiotic residue? _____ days

Because of high somatic cell count? _________

I. During 1981, how many days was your milk "down-graded"? ______

If your milk was ever down-graded, what was the reason given for it being down-graded? ________

K. How much time do you spend using the California Mastitis Test (CMT) or other (please specify) mastitis tests each week? _____

____

____

L. What is your yearly expenditure for mastitis testing equipment and/or testing program such as the DHIA somatic cell count program?

____

VII. Diarrhea (Scours)

A. What percentage of calf scour cases do you treat without the assistance of your veterinarian? _________

B. How and with what materials do you usually treat calf scours?

____

____

____

C. What is your approximate medicine cost per day for a calf with scours? ______________________________

D. What is the average duration of a treatment period? ___________

____

E. How many extra minutes of labor per day does a calf with scours require? ______________________________

VIII. Pink Eye

A. How many cases of pink eye did you have in the last 12 months?

____

B. What percentage of pink eye cases do you treat without the aid of a veterinarian? __________

C. What product(s) do you usually use, and what is the approximate cost per case of pink eye?

____

____

IX. Calving

A. What medicines or material do you usually use when you deliver a calf without the aid of your veterinarian? ________________

____

____

X. Retained Foetal Membrane (afterbirth).

A. Do you ever remove a retained placenta (foetal membrane) yourself?

_____ Yes _____ No (If yes, what percent do you remove yourself?)

____

Describe the medicines or materials you use for this procedure?

____

____

____

XI. Management

What is your labor expense (dollars per hour) for treating sick animals?

____

B. What breed are your cattle? ______________________________

C. Does your dairy use a

_________ Milking Parlor

_________ Stall Barn

_________ Other ____

____

D. What kind of record keeping systems are you currently using for

1. Feed ____

2. Financial ____

3. Animal Diseases ____

4. Management ____

E. What type of manure system do you use?

1. Gutter ____

2. Lagoon ____

3. Other ____

____

G. Is your barn heated during the winter? ____Yes ____No

H. At what age do you wean your calves? ___________________________

I. What is your estimated percentage calf loss by weaning? ____________%

J. Do you have a calf barn? ______Yes ______No

1. Size of stalls? ____________

2. Number of calves per stall? ___________

3. Type of bedding used? ______________

4. Ground is: ___dirt, ___ concrete, ___other __________________.

5. Are the stalls elevated? _____________________________________

K. Do you use calf hutches? ____Yes ____No

If not, go to next question.

1. Size of hutches? ____________

2. Type of bedding used? ________________

3. Ground is: _____dirt, ____concrete, ____other ________________.

L. With regard to your lactating cows, what type of housing do you use and what type of floor does it have?

_______ Free Stall____

_______ Tie Stall____

_______ Loose Stall____

_______ Pasture____

M. What groups are your lactating cattle in?

1. ____

2. ____

3. ____

4. ____

5. ____

N. With regard to your lactating cows, what percent of their exercise area is:

dirt? ___________

concrete? ___________

other? ____________

O. What is the size of the lactating cows' exercise area?

__________________ (_______ sq. ft./cow)

P. How many maternity stalls do you have? _________________________

Q. With regard to your weaned heifers (weaning to breeding):

1. Housing? ____free stall _____loose housing

other ____

2. Bedding type? ____

3. Exercise area _____% dirt floor, _____% concrete,

_____% other ___________________________________

________size (______sq. ft./cow)

R. With regard to your bred heifers:

1. Housing? ____free stall ___loose housing

____other ____

2. Bedding type? ____

3. Exercise area? _____% dirt floor, _____% concrete,

_____% other ___________________________________

___________________size (____sq. ft./cow)

S. With regard to your Dry cows:

1. Housing? ____free stall ____loose housing

____other ____

2. Bedding type? ____

3. Exercise area? _____% dirt floor, ____% concrete,

_____% other ___________________________________

___________________size (_____sq. ft./cow)

T. With regard to your animal disease records during 1979-1980:

1. What percent of the time did you record cows which required antibiotic treatment for <u>mastitis</u> during their lactation?

____yes ____no

2. What percent of the time did you record lactating cows which had a positive CMT (or other mastitis test), but were not treated until dry? ____yes ____no

Approximately how many times per year did this occur?

____

3. What percent of the time did you record as having mastitis lactating cows which had high SCC (500,000) but were not treated until dry?______________________________________

Approximately how many times per year did this occur?

____

4. For the following diseases, please estimate the percentage of cases which were recorded on your barn record during the past 2 years. Comment to your criteria for recording.

pneumonia __________ diarrhea __________

milk fever __________ pink eye __________

lameness __________ bloat __________

metritis __________ displaced abomasum__________

cystic ovaries __________ ketosis __________

hardware's disease __________

APPENDIX 4

STRUCTURE AND USE OF FAHRMX RETROSPECTIVE DATA FILE

APPENDIX 4

All jobs from the Cyber 750 must be submitted to SAS as editor-work files. I catalogued my file permanently as an editor-work file. When ready to submit a job to SAS, type:

ATTACH, SAS, SAS, PW = _____.

then

EXEC, SAS.

The computer will respond with a sequence number starting with MBS.

The structure of my file is as follows. Lines 1-5 allow SAS to recognize you and accept your job. The body of the file begins with the "DATA" statement on line 6. Lines 7-10 identify the variables that will be keypunched on cards. The column numbers in which the variables appear follow the variable names. A description of the variables is included in the "LABEL" statement beginning on line 159. The space from lines 11-158 defines additional variables not included on the cards.

Lines 112-158 are relatively straightforward. Lines 11-111 determine seasons (spring, summer, fall, winter) and compute differences between dates. As programmed, it will only accept dates from 1979 through 1983. Additional programming statements will have to be added for later years. Lines 11-14 change the four dates keypunched by month, day, and year into julian dates. Julian dates are five-digit numbers. The first two digits specify the year. The last three are the number of days into the year that the date represents, e.g., 01/01/79 = 79001 = January 1, 1979. Once all the dates are converted to julian dates, in lines 11-14, the computer is told to take the differences between dates. To compute the days in milk at treatment (DIMT), for example, the julian calving date (DATEC1) must be subtracted from the julian treatment date (DATET). When both dates are in the same year, the simple difference of the two is adequate. For an example, refer to line 15. If the date of treatment (DATET) and the first calving date (DATEC1) are in the same year, then the difference between them will be less than 367. If the two dates meet this criterion, then the days in milk at treatment (DIMT) is the simple difference of the two.

When the dates are in different years, the problem is more complicated. When the dates fall in adjacent years, the earlier date must be subtracted from the latest julian date for that year to yield the total number of days in that year taken up by the period we are trying to measure. The difference of the later date and the julian date for the beginning of the next year is then added to the previous figure to yield the total period. Take lines 16 and 17 as an example. Line 16 places the first calving date (DATEC1) in 1979 and the date of treatment (DATET) in 1980. Line 17 says that, if these are the relevant years, then the days in milk at treatment (DIMT) equals:

79365 - DATEC1 + DATET - 80000.

The third possibility for two dates is that they "include" a year in between. For example, lines 22 and 23 deal with a first calving date (DATEC1) in 1979 and a treatment date (DATET) in 1981. The net days in 1979 is computed as before (79365 - DATEC1). The net days in 1981 is also computed (DATET - 81000). These two differences are then added to the total number of days in 1980 (366) to yield the total days in milk at the date of treatment.

Lines 48-111 define the seasons of treatment and calving. These statements first define the year, and then the days in that year in which the season falls. Referring to lines 48 and 49, winter in 1979 includes any days less than 80 (until

March 21) or greater than 355 (later than December 22). These season statements only accommodate dates through 1983.

Another statement that will need adjustment is on line 115, the PRICE variable. PRICE represents the price of milk per hundredweight, which is currently at $13.42 for 3.5% milk (add $1.66 for each percent deviation from 3.5).

The remaining statements are relatively straightforward. The definition of culled cows on lines 146 and 147, however, needs some explanation. A culled cow (CULL) is defined as any animal that had a cull code (CULLCD) other than 30 during the period of study. Thirty signifies that a cow was sold for dairy purposes. Line 146 tells the computer to assume CULL=1. Line 147 says that if CULLCD is missing or 30, then change CULL from 1 to 0.

The data is entered after the "CARDS" statement on line 221. After the cards come "TITLE" and "PROC" statements. The procedure or "PROC" statements I used most often were "SORT," "PRINT," "MEANS," and "SYSREG."

A few general comments about SAS:

Note that variable names must be no more than eight characters.

I made the mistake several times of sorting by two variables, one of which had many values, e.g.:

```
PROC SORT;
BY AGE DISCODE;
```

then directing the computer to print by those same variables, e.g.:

```
PROC PRINT;
BY AGE DISCODE;
```

with the result that the procedure would print a separate page for each age-disease code category and exceed my print limit. When one of several subgroups has many values, sort by the variables in question, but don't use a "BY" statement with "PROC PRINT;". Using the above example, what I should have entered was:

```
PROC SORT;
BY AGE DISCODE;
PROC PRINT;
```

As an aid to catching coding or keypunching errors, note the "IF" statements before "CARDS" (lines 156 and 157):

```
IF DIMT LT     Ø  THEN LIST;
IF TOTDIM LT   Ø  THEN LIST;
```

which list the data lines for cows with negative days in milk at treatment (DIMT) or total days in milk (TOTDIM) figures. This saves having to check the observations visually, which is tedious and prone to error.

For analysis of residuals, see "PROC UNIVARIATE." Two-stage least squares will require "BLOCK" statements.

When I had more than one job to send to Wayne State, I had less problems when I logged out between jobs. That is, when I was done making modifications in the file for the first job, such as excluding culled cows, I would attach and execute SAS, then log out. After logging back on and including all cows, for example, I would attach and execute SAS again.

```
//*LOGONID
//*PASSWORD
// EXEC SAS
//SAS.SYSIN  DD  *
DATA FAHRMX;
INPUT HERD 1-2 CONTROLN 4-7 DISCODE 9-10 MT 12-13 DT 14-15 YT 16-17 MC1 19-20
     DC1 21-22 YC1 23-24 LACTN 25-26 AGEC1 27-29 MD 31-32 DD 33-34 YD 35-36
     MC2 38-39 DC2 40-41 YC2 42-43 FPROD 45-49 FBF 51-54 F305 56-60 CINDEX 62-66
     DINDEX 68-72 SIREPD 74-78 CULLCD 79-80;
DATET=JULDATE(MDY(MT,DT,YT));
DATEC1=JULDATE(MDY(MC1,DC1,YC1));
DATEC2=JULDATE(MDY(MC2,DC2,YC2));
DATED=JULDATE(MDY(MD,DD,YD));
IF DATET-DATEC1 LT 367 THEN DIMT=DATET-DATEC1;
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND DATET GT 80000 AND DATET LT 81000
     THEN DIMT=79365-DATEC1+DATET-80000;
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND DATET GT 81000 AND DATET LT 82000
     THEN DIMT=80366-DATEC1+DATET-81000;
IF DATEC1 GT 81000 AND DATEC1 LT 82000 AND DATET GT 82000 AND DATET LT 83000
     THEN DIMT=81365-DATEC1+DATET-82000;
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND DATET GT 81000 AND DATET LT 82000
     THEN DIMT=79365-DATEC1+DATET-81000+366;
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND DATET GT 82000 AND DATET LT 83000
     THEN DIMT=80366-DATEC1+DATET-82000+365;
IF DATED-DATEC1 LT 367 THEN TOTDIM=DATED-DATEC1;
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND DATED GT 80000 AND DATED LT 81000
     THEN TOTDIM=79365-DATEC1+DATED-80000;
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND DATED GT 81000 AND DATED LT 82000
     THEN TOTDIM=80366-DATEC1+DATED-81000;
IF DATEC1 GT 81000 AND DATEC1 LT 82000 AND DATED GT 82000 AND DATED LT 83000
     THEN TOTDIM=81365-DATEC1+DATED-82000;
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND DATED GT 81000 AND DATED LT 82000
     THEN TOTDIM=79365-DATEC1+DATED-81000+366;
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND DATED GT 82000 AND DATED LT 83000
     THEN TOTDIM=80366-DATEC1+DATED-82000+365;
IF DATEC2-DATEC1 LT 367 THEN CALVINT=DATEC2-DATEC1;
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND DATEC2 GT 80000 AND DATEC2 LT 81000
     THEN CALVINT=79365-DATEC1+DATEC2-80000;
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND DATEC2 GT 81000 AND DATEC2 LT 82000
     THEN CALVINT=80366-DATEC1+DATEC2-81000;
IF DATEC1 GT 81000 AND DATEC1 LT 82000 AND DATEC2 GT 82000 AND DATEC2 LT 83000
     THEN CALVINT=81365-DATEC1+DATEC2-82000;
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND DATEC2 GT 81000 AND DATEC2 LT 82000
     THEN CALVINT=79365-DATEC1+DATEC2-81000+366;
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND DATEC2 GT 82000 AND DATEC2 LT 83000
     THEN CALVINT=80366-DATEC1+DATEC2-82000+365;
IF DATET GT 79000 AND DATET LT 80000 AND (DATET-79000 LT 80 OR DATET-79000 GT
     355) THEN SEASONT= 'WINTER';
IF DATET GT 79000 AND DATET LT 80000 AND (DATET-79000 GT 79 AND DATET-79000 LT
     172) THEN SEASONT='SPRING';
IF DATET GT 79000 AND DATET LT 80000 AND (DATET-79000 GT 171 AND DATET-79000 LT
     266) THEN SEASONT='SUMMER';
IF DATET GT 79000 AND DATET LT 80000 AND (DATET-79000 GT 265 AND DATET-79000 LT
     356) THEN SEASONT='FALL';
IF DATET GT 80000 AND DATET LT 81000 AND(DATET-80000 LT 80 OR DATET-80000 GT
     355) THEN SEASONT='WINTER';
IF DATET GT 80000 AND DATET LT 81000 AND(DATET-80000 GT 79 AND DATET-80000 LT
     173) THEN SEASONT='SPRING';
IF DATET GT 80000 AND DATET LT 81000 AND (DATET-80000 GT 172 AND DATET-80000 LT
     266) THEN SEASONT='SUMMER';
IF DATET GT 80000 AND DATET LT 81000 AND (DATET-80000 GT 265 AND DATET-80000 LT
     356) THEN SEASONT='FALL';
```

```
IF DATET GT 81000 AND DATET LT 82000 AND(DATET-81000 LT 79 OR DATET-81000 GT
      354) THEN SEASONT='WINTER';
IF DATET GT 81000 AND DATET LT 82000 AND (DATET-81000 GT 78 AND DATET-81000 LT
      172) THEN SEASONT='SPRING';
IF DATET GT 81000 AND DATET LT 82000 AND (DATET-81000 GT 171 AND DATET-81000 LT
      265) THEN SEASONT='SUMMER';
IF DATET GT 81000 AND DATET LT 82000 AND (DATET-81000 GT 264 AND DATET-81000 LT
      355) THEN SEASONT='FALL';
IF DATET GT 82000 AND DATET LT 83000 AND (DATET-82000 LT 79 OR DATET-82000 GT
      354) THEN SEASONT='WINTER';
IF DATET GT 82000 AND DATET LT 83000 AND (DATET-82000 GT 78 AND DATET-82000 LT
      172) THEN SEASONT='SPRING';
IF DATET GT 82000 AND DATET LT 83000 AND (DATET-82000 GT 171 AND DATET-82000 LT
      266) THEN SEASONT='SUMMER';
IF DATET GT 82000 AND DATET LT 83000 AND (DATET-82000 GT 265 AND DATET-82000 LT
      355) THEN SEASONT='FALL';
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND (DATEC1-79000 LT 80 OR DATEC1-79000
      GT 355) THEN SEASONC1='WINTER';
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND (DATEC1-79000 GT 79 AND DATEC1-79000
      LT 172) THEN SEASONC1='SPRING';
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND (DATEC1-79000 GT 171 AND DATEC1-79000
      LT 266) THEN SEASONC1='SUMMER';
IF DATEC1 GT 79000 AND DATEC1 LT 80000 AND (DATEC1-79000 GT 265 AND DATEC1-79000
      LT 356) THEN SEASONC1='FALL';
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND (DATEC1-80000 LT 80 OR DATEC1-80000
      GT 355) THEN SEASONC1='WINTER';
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND (DATEC1-80000 GT 79 AND DATEC1-80000
     LT 173) THEN SEASONC1='SPRING';
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND (DATEC1-80000 GT 172 AND DATEC1-80000
      LT 266) THEN SEASONC1='SUMMER';
IF DATEC1 GT 80000 AND DATEC1 LT 81000 AND (DATEC1-80000 GT 265 AND DATEC1-80000
      LT 356) THEN SEASONC1='FALL';
IF DATEC1 GT 81000 AND DATEC1 LT 82000 AND (DATEC1-81000 LT 79 OR DATEC1-81000
      GT 354) THEN SEASONC1='WINTER';
IF DATEC1 GT 81000 AND DATEC1 LT 82000 AND (DATEC1-81000 GT 78 AND DATEC1-81000
      LT 172) THEN SEASONC1='SPRING';
IF DATEC1 GT 81000 AND DATEC1 LT 82000 AND (DATEC1-81000 GT 171 AND DATEC1-81000
      LT 265) THEN SEASONC1='SUMMER';
IF DATEC1 GT 81000 AND DATEC1 LT 82000 AND (DATEC1-81000 GT 264 AND DATEC1-81000
      LT 355) THEN SEASONC1='FALL';
IF DATEC1 GT 82000 AND DATEC1 LT 83000 AND (DATEC1-82000 LT 79 OR DATEC1-82000
      GT 354) THEN SEASONC1='WINTER';
IF DATEC1 GT 82000 AND DATEC1 LT 83000 AND (DATEC1-82000 GT 78 AND DATEC1-82000
      LT 172) THEN SEASONC1='SPRING';
IF DATEC1 GT 82000 AND DATEC1 LT 83000 AND (DATEC1-82000 GT 171 AND DATEC1-82000
      LT 266) THEN SEASONC1='SUMMER';
IF DATEC1 GT 82000 AND DATEC1 LT 83000 AND (DATEC1-82000 GT 265 AND DATEC1-82000
      LT 355) THEN SEASONC1='FALL';
TOTDIMSQ=TOTDIM**2;
TOTDIMCU=TOTDIM**3;
PCTBF=(FBF/FPROD)*100;
PRICE=(PCTBF-3.5)*1.66+13.42;
VALUE=PRICE*(FPROD/100);
VALRATIO=VALUE/CALVINT;
IF DISCODE=0 THEN CTRL=1;
IF DISCODE NE 0 THEN CTRL=0;
IF DISCODE=2 THEN MASTITIS=1;
IF DISCODE NE 2 THEN MASTITIS=0;
IF DISCODE=1 THEN METRITIS=1;
IF DISCODE NE 1 THEN METRITIS=0;
IF DISCODE=3 THEN CYSTIC=1;
```

```
IF DISCODE NE 3 THEN CYSTIC=0;
COMBDIS=0;
IF DISCODE=1 OR DISCODE=3 THEN COMBDIS=1;
IF HERD=1 THEN HERD1=1;
IF HERD NE 1 THEN HERD1=0;
IF HERD=2 THEN HERD2=1;
IF HERD NE 2 THEN HERD2=0;
IF HERD=9 THEN HERD9=1;
IF HERD NE 9 THEN HERD9=0;
IF HERD=10 THEN HERD10=1;
IF HERD NE 10 THEN HERD10=0;
IF HERD=6 THEN HERD6=1;
IF HERD NE 6 THEN HERD6=0;
IF HERD=7 THEN HERD7=1;
IF HERD NE 7 THEN HERD7=0;
IF HERD=11 THEN HERD11=1;
IF HERD NE 11 THEN HERD11=0;
IF HERD=12 THEN HERD12=1;
IF HERD NE 12 THEN HERD12=0;
IF HERD=13 THEN HERD13=1;
IF HERD NE 13 THEN HERD13=0;
CULL=1;
IF CULLCD= . OR CULLCD=30 THEN CULL=0:
IF SEASONC1='WINTER' THEN WINTER=1;
IF SEASONC1 NE 'WINTER' THEN WINTER=0;
IF SEASONC1='SPRING' THEN SPRING=1;
IF SEASONC1 NE 'SPRING' THEN SPRING=0;
IF SEASONC1='SUMMER' THEN SUMMER=1;
IF SEASONC1 NE 'SUMMER' THEN SUMMER=0;
IF SEASONC1='FALL' THEN FALL=1;
IF SEASONC1 NE 'FALL' THEN FALL=0;
IF DIMT LT 0 THEN LIST;
IF TOTDIM LT 0 THEN LIST;
DPERIOD= CALVINT - TOTDIM;
LABEL CONTROLN=DHIA CONTROL NUMBER
      DISCODE=DISEASE CODE
      LACTN=LACTATION NUMBER
      AGEC1=AGE AT ONSET OF RECORDED LACTATION
      FBF=FINAL BUTTER FAT
      F305=FINAL 305 DAY ADJUSTED PRODUCTION
      FPROD=FINAL MILK PRODUCTION
      DATET=DATE OF TREATMENT FOR DISEASE
      DATEC1=DATE OF ONSET OF RECORDED LACTATION
      DATEC2=DATE OF ONSET OF NEXT LACTATION
      DATED=DRY OFF DATE
      RATIO=FINAL PRODUCTION OVER CALVING INTERVAL
      CALVINT=CALVING INTERVAL IN DAYS
      CTRL=DUMMY VAR FOR CONTROLS
      MASTITIS=DUMMY VAR FOR MASTITIS
      METRITIS=DUMMY VAR FOR METRITIS
      CYSTIC=DUMMY VAR FOR CYSTIC OVARIES
      SEASONC1=SEASON OF ONSET OF RECORDED LACTATION
      WINTER=DUMMY VAR FOR SEASONC1
      SPRING=DUMMY VAR FOR SEASONC1
      SUMMER=DUMMY VAR FOR SEASONC1
      FALL=DUMMY VAR FOR SEASONC1
      MT=MONTH OF TREATMENT
      DT=DAY OF TREATMENT
      YT=YEAR OF TREATMENT
      MC1=MONTH OF ONSET OF RECORDED LACTATION
      DC1=DAY OF ONSET OF RECORDED LACTATION
```

```
      YC1=YEAR OF ONSET OF RECORDED LACTATION
      MD=MONTH DRIED OFF
      DD=DAY DRIED OFF
      YD=YEAR DRIED OFF
      MC2=MONTH OF ONSET OF NEXT LACTATION
      DC2=DAY OF ONSET OF NEXT LACTATION
      YC2=YEAR OF ONSET OF NEXT LACTATION
      CINDEX=COW INDEX OF GENETIC POTENTIAL
      DINDEX=DAM INDEX OF GENETIC POTENTIAL
      SIREPD=SIRE PREDICTED DIFFERENCE
      DIMT=DAYS IN MILK AT TREATMENT DATE
      TOTDIM= TOTAL DAYS IN MILK
      DPERIOD= LENGTH OF DRY PERIOD IN DAYS
      PCTBF=PERCENT BUTTER FAT
      PRICE=PRICE/CWT($13.42)$0.166/0.1 DEV FR 3.5
      VALUE=DOLLAR VALUE OF PRODUCTION
      VALRATIO=VALUE/CALVING INTERVAL
      HERD1=
      HERD2=
      HERD3=
      HERD4=
      HERD5=
      HERD6=
      HERD7=
      HERD8=
      HERD9=
      HERD10=
      HERD11=
      HERD12=
      HERD13=
      HERD14=
      CULL= DUMMY VAR FOR CULLING
      CULLCD=DHIA CULL CODE, REASON FOR CULLING
     TOTDIMSQ=TOTAL DAYS IN MILK SQUARED
     TOTDIMCU=TOTAL DAYS IN MILK CUBED;
CARDS;
01 0275 01 111479 102879 3 50 092880 103080 20624 0652 19768       00579
01 0189 01 102879 101179 6 85 092480 111780 23326 0829 21569
01 0435 01 080580 072580 2 40 060581 071581 13692 0593 13472
01 0448 01 062480 062080 1 28 052681 071281 13431 0582 12583
01 0437 02 050880 111379 3 56 092980 110580 17806 0690 17217
01 0218 02 040180 021780 4 63 122080 021681 18114 0640 18090
01 0287 02 112779 112679 2 48 101480 010381 16297 0705 16147        201
01 0444 02 052880 030580 2 41 012081 030181 14234 0486 14081
01 0286 02 060780 040980 2 45 031881 072081 17987 0706 17207   591   134   1047
01 0256 02 032380 031880 3 53 012681 031181 19704 0728 19538
01 0290 02 091480 110779 3 49 091980 102780 16810 0626 16467  1137   580   1694
01 0292 03 011680 011680 3 53 112580 011181 19448 0730 19147         -91
01 0271 03 041680 032680 6 92 012781 030581 17699 0602 17645   916   319   1513
01 0189 03 121479 101179 6 85 092480 111780 23326 0829 21569
01 0424 03 031380 021680 2 46 102880 011581 12323 0402 12323
01 0156 00 000000 011880 8115 120680 012081 16697 0588 16315
01 0280 00 000000 011380 4 59 111580 013081 15906 0663 15886  -199  -661    264
01 0441 00 000000 121579 3 48 092680 111480 15351 0538 15351
01 0240 00 000000 011880 6 85 011881 031581 19241 0792 18061
01 0167 00 000000 040580 7106 032381        23112 0874 21134                  37
01 0286 00 000000 031980 2 44 012781 022881 15218 0581 15048
01 0274 00 000000 101879 2 40 082580 101180 17279 0635 17065   738    72   1403
01 0277 00 000000 011680 3 53 112080 010181 19240 0605 19182
01 0272 00 000000 102779 4 66 111080 012681 21648 0768 19364
01 0449 00 000000 082080 1 28 042881 061681 16064 0656 15905
```

247=01	0216	00	000000	022980	4	69	031381	062081	20246	0743	18475				
248=01	0443	00	000000	120779	1	26	013181	051481	18717	0705	14903				
249=01	0447	00	000000	110879	1	24	110580	122280	16017	0568	15713			1431	
250=01	0436	00	000000	122579	1	29	022081	041781	21250	0810	16984				
251=01	0268	00	000000	112479	2	89	111780		19780	0768	18144				38
252=01	0440	00	000000	020680	1	25	121680	012981	15246	0504	14945				
253=01	0123	00	000000	101479	8	99	082580		20832	0684	21641				31
254=01	0444	00	000000	030580	2	41	012081	030181	14234	0486	14081				
255=01	0438	00	000000	021680	3	52	030681	051681	19631	0852	17233				
256=01	0273	00	000000	100179	3	50	082680	111480	22166	0759	21430		555		
257=01	0225	00	000000	053180	8	81	061181	080481	23959	0862	21831		851		
258=01	0227	00	000000	121879	3	65	122480	021681	21978	0781	19965		712		
259=02	0457	00	000000	022080	5	87	031881	051881	23039	0840	19846	582	135	911	
260=02	0500	00	000000	021680	3	61	030181	042181	16621	0664	14531				
261=02	0505	00	000000	011380	3	62	120380	011681	20153	0747	19595				
262=02	0517	00	000000	020580	4	64	010181	030981	17710	0727	17205				
263=02	0531	00	000000	041580	3	52	010181	040481	12478	0417	12478				
264=02	0556	00	000000	080480	2	40	060281	073181	17345	0636	17345	724		1108	
265=02	0558	00	000000	062480	2	39	041381	060881	14117	0537	14117	443	271	1754	
266=02	0575	00	000000	020480	1	26	020281	031581	15803	0591	13605				
267=02	0576	00	000000	020480	1	20	031081	042681	16598	0640	13118				
268=02	0577	00	000000	020880	1	20	041281	060181	18142	0659	13527				
269=02	0578	00	000000	032180	1	27	010181	031581	13739	0421	13739	537		425	
270=02	0583	00	000000	032280	1	28	021281	040181	15491	0574	14784	948	855	1108	
271=02	0580	00	000000	032380	1	29	031881	050881	15908	0592	13896				
272=02	0586	00	000000	040980	1	32	021281	040581	12791	0476	12664				
273=02	0572	03	011281	122180	2	48	121081	020382	20907	0698	19447	962	310	1754	
274=02	0573	03	020981	011881	2	41	111281	010482	18250	0638	18250				
275=02	0480	03	091580	041380	4	77	060881	062981	21016	0968	17605				
276=02	0530	03	071580	053180	3	51	051481		16778	0663	15552				
277=02	0539	03	081180	011780	2	37	031881	051881	19731	0772	16270	639	211	911	
278=02	0584	01	040780	032780	1	32	050181	053081	17705	0751	14401				
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369=06	0370	00		121680	1	32	110981		14112	0565	13535				30
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375=06	0327	00		090380	2	39	070781	080981			15227	650	1191	425	
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414=13	0223	00		033180	1	30	040181	070981	17094	0671	15530				
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423=13	0192	00		021280	3	54	120180	050781	16912	0638	16912	-535	163		
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435=12	0514	03	070381	022881	3101		081781		12256	0520	17476				54
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439=12	0505	00		021481	5	68	090781		10938	0473	13613				31
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444=06	0082	01	081880	053080	10156		081181		22309	0870	19993				37
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450=06	0163	01	030981	022181	7109		072881		09883	0332	15206				61
451=06	0377	01	030981	123180	1	40	121981		16980	0685	18738				30
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458=06	0369	00		121180	1	39	082481		19628	0733	25951				33
459=06	0177	00			6	81	031081				22718				32
460=06	0142	00		053180	8127		040281		15024	0552	15457				58
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474=09	0392	00		071580	6101		031081		11389	0483	13883				31
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490=10	0269	00		011480	1	24	102880		11837	0388	17234				31

491=10	0098	00		061880	7	100	052681		21330	0740	20530			37
492=10	0235	00		061980	2	46	010281		10142	0355	15412			31
493=10	0278	00		040880	1	30	100780		06639	0216	12563			31
494=10	0105	00		032380	10	148	010281		14629	0483	15821			38
495=10	0193	00		050680	3	56	123180		11721	0383	14164			31
496=10	0217	00		040680	2	41	082680		09221	0273	17557			31
497=10	0216	00		030980	2	43	102180		14614	0518	19478			31
498=10	0203	00		071480	3	54	010281		09976	0383	16463			50
499=10	0242	00		062680	2	41	123180		09075	0272	15659			31
500=10	0293	00		061180	1	35	022481		13802	0466	19477			31
501=10	0277	00		040680	1	33	122380		12060	0438	16734			31
502=10	0247	00		062280	2	43	010281		11558	0421	18139			31
503=10	0248	00		080780	2	45	031781		08506	0303	12248			31
504=10	0251	00		070980	2	46	051981		14733	0582	17591			31
505=10	0253	00		071480	2	44	031681		10292	0284	13812			37
506=11	0136	00		060280	2	52	122980		11645	0419	16157			31
507=11	0058	00		081780	6	118	061581		10465	0451	11093			37
508=11	0056	00		082180	6	102	060881		19037	0659	20583			31
509=11	0112	00		042680	3	57	030981		14870	0589	15386			31
510=11	0034	00		061680	7	159	022481		09714	0347	12715			38
511=11	0071	00		010381	6	87	020281		00736	0040	12842			31
512=13	0214	01	021481	021081	1	35	052781		03900	0099	08883	123	-65	54831
513=13	0162	03	020880	110779	7	142	062380		14408	0609	17851			38
514=13	0172	00		012780	8	149	022581		26008	1039	23348	283		-32661
515=02	0454	00		090680	6	91	060881		18424	0606	19925			31
516=02	0490	00		020880	4	71	071380		10371	0395	15894			31
517=02	0515	00		013180	3	65	121580		16739	0735	16379			31
518=02	0534	00		033180	3	62	020281		14251	0578	14370			30
519=02	0538	00		022780	2	50	111080		15041	0558	17543			31
520=02	0548	00		030180	2	52	120880		16105	0538	17754			31
521=02	0555	00		060180	1	34	060181		16031	0535	19350			31
522=02	0582	00		022480	1	28	012781		11602	0461	12549			31
523=02	0585	00		040980	1	38	090280		05078	0212	10602			31
524=02	0588	00		051080	1	31	081880		03811	0145	11763			31
525=02	0516	03	091580	011280	3	63	121580		22576	0736	21213			31
526=02	0540	03	051980	042480	2	53	060881		19404	0924	16752			31
527=02	0590	01	102780	101880	1	37	011281		03892	0160	13251			31
528=02	0516	01	012880	011280	3	60	121580		22576	0736	21213			31
529=01	0251	00		040380	4	67	071080		08394	0251	19529			39
530=01	0285	00		050880	2	81	111780		15502	0430	20618			37
531=01	0433	00		101279	1	25	041580		08254	0309	15064			30
532=01	0270	00		100279	2	57	021380		09035	0309	16496			30
533=01	0265	00		101479	5	104	081880	092480	18173	0764	18059			
534=01	0434	00		111279	1	25	041580		08852	0333	18770			30
535=01	0432	00		100979	1	29	010580		04593	0156	15649			53
536=01	0183	00		101179	5	87	062380		18082	0632	19709			31
537=01	0224	00		092979	5	77	041580		12928	0540	17310			30
538=01	0279	00		112979	3	51	092780	111180	16318	0562	16318			
539=01	0247	00		020680	4	67	121680	020481	23257	0718	22921			
540=01	0278	00		020780	3	55	012081	030581	20824	0865	19369			
541=01	0199	00		021780	5	82	022381	031381	23895	0886	21887			
542=01	0282	00		031080	3	58	012081	021681	18145	0727	17931			
543=01	0283	00		040980	2	55	031881	072081	17987	0706	17207			
544=01	0226	00		050680	6	92	041081	053081	19423	0726	18853			
545=01	0450	00		062780	1	28	052681	070881	13831	0615	13036			
546=01	0261	00		063080	5	88	050581	070881	20183	0693	20058			
547=01	0425	00		070480	2	48	102780		05873	0279	13536			53
548=01	0451	00		070780	1	27	011981		07324	0299	13125			39
549=01	0228	00		071480	4	67	070981	090481	22716	0877	20756			
550=01	0428	00		081380	2	63	011981		08042	0389	13338			37
551=01	0453	00		091080	1	26	102780		02376	0096	15537			53

552-01	0273	00	111480	4	63	042781		16519	0579	24695	32
553-01	0277	00	010181	4	65	050781		09834	0315	18028	53
554-01	0446	00	031580	2	39	021781	041481	20574	0636	19102	
555-02	0499	00	051080	4	67	050181	071281	20790	0686	19415	
556-02	0501	00	051180	4	65	010581	051381	13065	0453	13065	
557-02	0579	00	031780	1	28	031881	051081	15435	0649	13311	
558-02	0587	00	041180	1	34	052080		01310	0059		31
559-02	0519	00	052380	4	64	030181	042881	15519	0601	15519	
560-02	0557	00	061880	2	38	040681		15465	0550	18456	31
561-02	0589	00	051680	1	26	050181	062481	15246	0503	13875	
562-02	0487	00	060580	4	76	080681	101381	19901	0699	17776	33
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565-02	0560	00	071980	2	38	052181	070581	15078	0596	15046	
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567-02	0599	00	123180	1	24	030981		02218	0102	10064	35
568-02	0505	00	011681	4	74	060881		10341	0350	16777	31
569-06	0285	00	081080	3	60	102880		04918	0178	15137	30
570-06	0321	00	060680	2	45	102880		06331	0188	19803	30
571-06	0362	00	091180	1	28	102480		02013	0074		33
572-06	0361	00	070680	3	52	051981	070281	18090	0712	17816	
573-06	0367	00	102280	1	27	033081	101581	20569	0744	20236	
574-06	0093	00	100180	10	141	081081	091181	18115	0762	17980	
575-06	0205	00	060680	5	79	040781	050481	17752	0579	17752	
576-06	0179	00	090580	6	97	012781		09148	0323	15984	37
577-06	0345	00	053080	1	25	051981	060781	19552	0709	17458	
578-06	0328	00	122480	2	38	062781	091981	17576	0566	17554	
579-06	0357	00	072580	1	28	060181	062981	13665	0493	13471	
580-06	0050	00	071280	10	150	011281		06948	0328	14694	38
581-06	0225	00	062580	6	103	011281		10264	0388	13903	37
582-06	0356	00	072680	1	28	060381	063081	15099	0565	14816	
583-06	0146	00	101880	7	102	081081	091381	21402	0850	21402	
584-06	0300	00	090980	3	48	061081	082281	12334	0472	12334	
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586-06	0391	00	022481	1	28	121981		13208	0509	15875	30
587-06	0161	00	020980	6	92	061081	072081	30119	1010	25381	
588-06	0163	00	022180	7	104	072881		09883	0332	15206	61
589-06	0200	00	020281	6	87	111281		16752	0644	16752	
590-06	0378	00	010481	1	24	112581		17032	0658	16515	
591-06	0373	00	122480	2	40	111581		18590	0766	18041	
592-06	0383	00	012181	1	24	113081		15944	0537	15674	
593-06	0333	00	020481	4	64	121081		21550	0724	21472	
594-06	0379	00	091580	10	158	041181		14553	0566	21821	30
595-06	0316	00	052981	3	57	082481		06155	0219	16386	33
596-06	0347	00	052881	2	42	072381		04273	0186	18472	30
597-06	0343	00	040281	2	36	101081	110981	13036	0429	13036	52
598-06	0392	00	030981	1	32	011282	022382	13525	0535	13377	
599-06	0393	00	032281	1	31	011482	030382	12850	0534	12850	
600-06	0186	00	042081	6	92	112481		13743	0544	16431	37
601-06	0398	00	060481	1	28	072381		02390	0082	15085	30
602-06	0400	00	061781	1	23	072381		01785	0068		30
603-06	0351	00	071380	2	40	072381		01555	0069	17483	30
604-06	0347	00	053081	2	42	072381		04273	0186	18472	30
605-06	0082	00	053081	10	143	081181		22309	0870	19993	37
606-06	0300	00	082281	4	59	112481		02843	0120	07461	32
607-06	0413	00	110481	1	28	121981		02117	0085	13261	30
608-06	0412	00	110381	1	29	121981		02592	79	16348	30
609-06	0326	00	081181	3	47	122481		08873	0266	17747	54
610-06	0411	00	110181	1	29	121981		02342	0085	14186	30
611-06	0317	00	052480	2	41	102880		12555	0337	21879	30
612-06	0289	00	052980	3	50	110480		12928	0382	21040	33

613=06	0320	00	061380	2	36	062581	081881			13277	
614=06	0216	00	061280	5	75	042681	060381	18868	0318	18674	
615=06	0346	00	053080	1	26	040781	043081	11652	0434	11409	
616=06	0081	00	070380	10	143	100780		05683	0212	16163	32
617=06	0352	00	071580	1	31	102880		05127	0175	15385	30
618=06	0353	00	071680	1	28	102880		04334	0168	13430	30
619=09	0059	00	092380	4	70	120980		03750	0078	11240	33
620=10	0273	00	012580	1	24	102880	010281	10946	0374	10946	
621=10	0028	00	020280	4	56	061780		09978	0301	17385	32
622=10	0171	00	042380	3	49	040181	050581	22204	0677	20949	
623=10	0051	00	020680	6	82	120180	021081			19353	
624=10	0074	00	031880	5	66	042981	061681	20894	0734	19084	
625=10	0138	00	043080	4	65	040881	061481	20811	0629	20304	
626=10	0082	00	032280	4	50	020381	032681	21157	0604	20971	
627=10	0086	00	042980	4	62	020481	042581	15642	0469	15642	
628=10	0115	00	033180	4	56	022481		19429	0587	19261	31
629=10	0224	00	032380	2	35	122880	020881	15540	0484	15542	
630=10	0182	00	060680	3	50	041181	071181	17361	0497	17346	
631=10	0190	00	062280	3	50	032381	061581	18014	0532	18014	
632=10	0294	00	061480	2	39	041481	060181	16900	0588	16900	
633=10	0148	00	062180	4	56	042181	052681	21584	0713	21584	
634=10	0219	00	061180	2	39	041781	052381	19114	0603	18960	
635=10	0157	00	061880	7	89	041081	051781	16659	0559	16295	
636=10	0297	00	062480	1	27	042181	061281	13869	0447	13869	
637=10	0295	00	070680	1	25	042481	060181	14854	0469	14854	
638=10	0300	00	081780	1	24	061581	083081	12280	0464	12280	
639=10	0291	00	062080	1	27	041581	052281	12759	0406	12759	
640=10	0301	00	072380	1	24	091681		01848	0090	10938	31
641=10	0298	00	081880	1	24	041681	061381	10418	0364	10418	
642=10	0292	00	061280	1	28	051081	062081	16989	0507	16344	
643=10	0267	00	012781	2	35	021781				13111	58
644=10	0172	00				030381				21531	33
645=10	0118	00	012181	5	65	022881		02824	0139	23164	32
646=10	0260	00	090480	2	35	051981		09581	0381	12770	31
647=10	0302	00	091280	1	27	051981		10369	0345	14905	31
648=10	0304	00	082980	1	24	052281	070881	16415	0522	16415	
649=10	0016	00	091280	5	57	052281	072581	18850	0588	18850	
650=10	0306	00	090980	1	26	060681		07874	0248	10715	31
651=10	0234	00	090280	2	40	061581	062181	11038	0389	12804	
652=10	0151	00	082880	4	58	061581	071481	19923	0658	19933	
653=11	0105	00	050880	3	53	070380		02124	0139	08681	31
654=11	0114	00	062780	3	49	071280		00665	0021	23057	63
655=11	0031	00	040880	7	134	081880		07602	0282	14448	38
656=11	0110	00	042980	3	49	112280	041381	07059	0251	07059	
657=11	0087	00	061680	4	60	0320[illegible]	061181	11332	0412	11332	
658=11	0081	00	042180	4	63	0201[illegible]	051581	15338	0601	15338	
659=11	0089	00	081980	4	62	093080		01055	0061	19435	31
660=11	0194	00	121080	1	30	040681		06039	0256	15677	33
661=11	0175	00	122380	2	39	042781		05512	0223	11625	31
662=11	0213	00	122080	1	27	052681		07261	0246	14848	31
663=11	0167	00	011381	2	41	052681		06102	0230	11863	33
664=12	0540	00	111180	2	48	091681	110281	17604	0735	17463	
665=13	0160	00	110779	6	106	030380		06357	0255	12778	31
666=13	0181	00	031480	5	78	120180	031781	19956	0757	19956	
667=13	0217	00	102179	1	27	072280	080680	14868	0498	19568	32
668=13	0184	00	110879	4	68	100180	110480	27519	0962	27113	
669=13	0180	00	030580	5	80	021581	040781	19001	0655	18382	
670=13	0171	00	032480	8	132	062581	101481	22138	0891	17192	
671=13	0219	00	110179	1	27	091580	101180	17668	0608	17278	
672=13	0136	00	101079	3	55	080180	100681	15177	0587	15177	
673=13	0213	00	100479	1	38	110380	010581			15396	

```
13 0204 00        040880 2 50 111580                                          50
13 0132 00        03238010138 071480        07339 0229 15952                  47
13 0228 00        080180 1 22 091580        01907 0076 14264                  55
13 0216 00         102980 2 54 071581 092981 12725 0563 12725
13 0226 00        070780 1 28 051581 071181 16784 0598 16514
13 0235 00        013081 1 27 041681        04090 0121 16049                  30
13 0214 00        021081 2 45 052781        03900 0099 08883                  31
PROC SORT;
      BY DISCODE;
PROC MEANS;
      BY DISCODE;
```

APPENDIX 5

CULLING RATE IS DETERMINED PRIMARILY BY THE NUMBER OF REPLACEMENTS THAT CAN BE RAISED

To substantiate this assumption, let us work through a hypothetical example. Assume we have a 100-cow herd. How many calves will we have from which to choose replacements? If we assume that our herd's average calving interval is 13 months, our 100 cows will produce about 92 calves per year if they all calve before being culled (100 cows * 1 calf / 13 months * 12 months/year = 92.3 calves/year). Of those, 92, 46, or 50 percent will be female. If 5 percent of the females die, about 42 will remain. Of those 42, how many will be successfully bred? If about one-third have breeding problems, we only have 30 heifers that can serve as replacements. Therefore, within this hypothetical herd, we could sustain at most a 30 percent annual culling rate using only our own replacements.

Disease and health management problems obviously influence replacement options. For treatment of this subject, refer to the costs associated with extended calving intervals in the text.

APPENDIX 6

POSSIBLY PREVENTABLE CULLS DUE TO DISEASE AND ACCIDENTS, DATA FROM EIGHT FARHMX PILOT HERDS*

Reason for Culling	Cull Code	Number Culls
Physical Injury	32	12
Mastitis	33	13
Sterility	37	18
Hardware Disease	39	2
Milk Fever	40	1
Pneumonia	47	2
Unknown Reason	50	8
Illness	52	3
Udder Problems	53	5
Leg Problems	54	6
Slow Milker	55	1
Displaced Abomasum	58	4
Unknown Cause	61	4
TOTAL		79

Total cull for all reasons = 187.
79/187 = .42 of all culls possibly due to disease and accidents.
Weighted average culling rate for all reasons = 24%
.42 (24%) = 10% of all culls possibly due to disease and accidents.

*Derived from Table 17.

APPENDIX 7

IS THE PROBABILITY OF BEING CULLED DUE TO DISEASE RANDOM ACROSS PRODUCTION LEVELS?

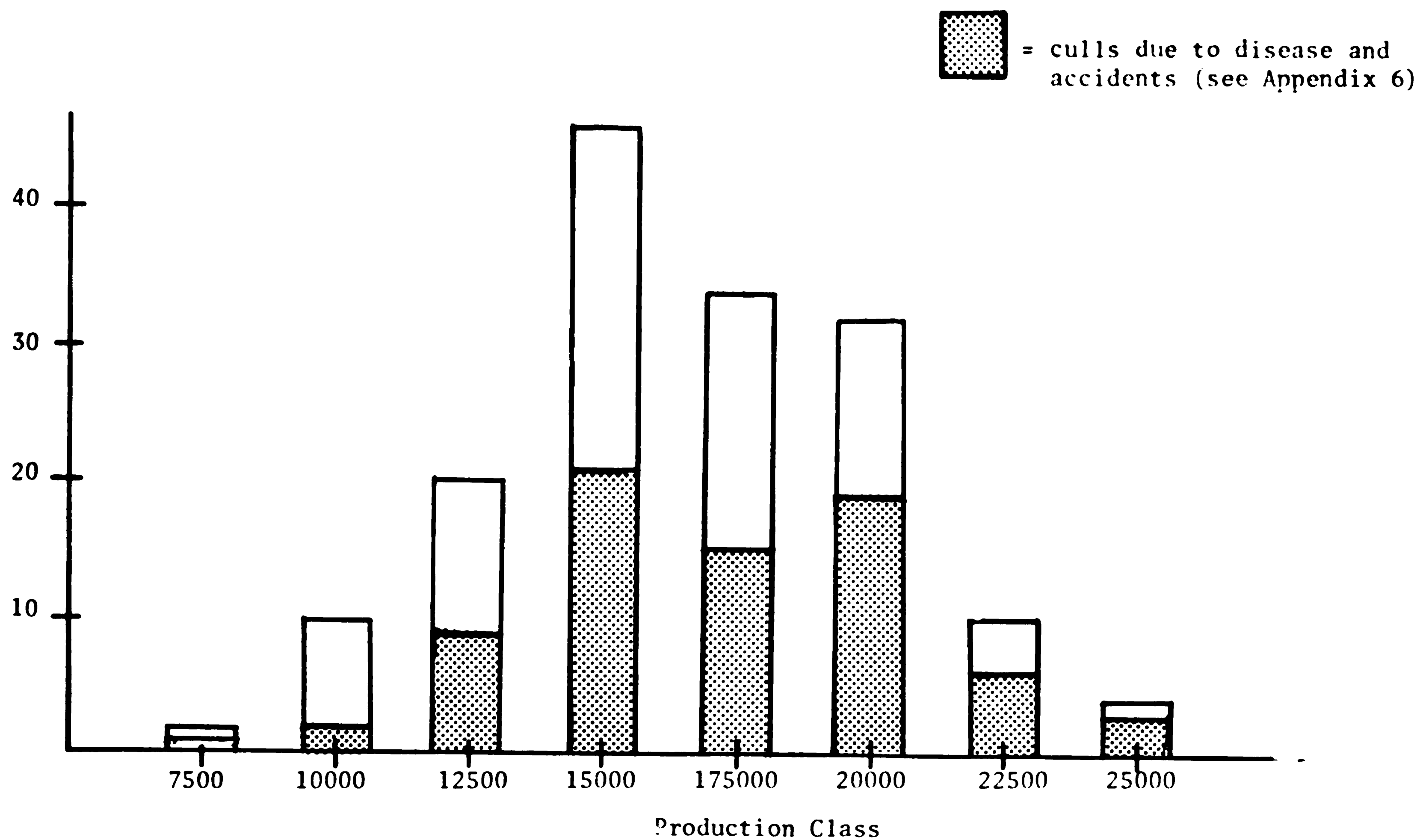
Evidence from Erb et al. (1981) suggests that high production makes cows more susceptible to disease, which would mean that the probability of disease is not random across production levels. However, this same evidence, along with results presented in this thesis, suggests that disease would probably have to be less severe in a low producer to warrant culling. This is because farmers are willing to pay less to maintain a low producing cow. Therefore, higher producers may be more likely to get diseased, but low producers are more likely to get culled if they get diseased. Because these two phenomena counteract each other, the assumption of random probability of culling <u>and</u> disease, across production levels, is probably acceptable.

The results presented in Figure 14 support this conclusion. The larger histogram shows the distribution of all culls in the eight-herd sample by production level (excluding culls for dairy purposes). Milk production has been mature equivalent adjusted to 305 days in both histograms. The mean milk production of all cows in the sample is about 17,000 pounds of milk per year. The larger histogram is skewed to the left demonstrating the higher culling rate for low producers.

The smaller histogram depicts only the culls from Appendix 6, which is a subset of the whole culling sample. The smaller histogram, therefore, represents

Figure 14

Distribution of Culls by Production Level, Eight Pilot Herds



only those animals which may have been culled for disease or accident reasons. Its distribution is less skewed than the larger histogram, which provides some evidence that a higher propensity for high producing cows to get diseased counteracts the increased likelihood of culling low producers because of disease problems.