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SWINE PRODUCTIVITY

AND

ECONOMIC EFFICIENCY

A Thesis

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ABSTRACT

This study involved a one year survey of performance indicators of the PEI swine industry. These indicators included disease levels (respiratory disease, leptospirosis), biological productivity parameters, feed conversion, and economic parameters. Analytical procedures were used to examine relationships between parameters.

Sow and feeder pig productivity was measured on a random sample of 32 PEI swine farms (each producing over 1,000 market hogs per year). Biological productivity was best described by 19.6 ± 2.2 (Mean$\pm$SD) pigs weaned per sow per year on farrow-finish farms, and $0.58 \pm .07$ kg average daily gain on feeder farms.

The remainder of the study was carried out using 18 randomly sampled farms (a subset of the previous random sample). Anteroventral lung lesions were present in 50.5% of hogs at slaughter, and pleuritis was present in 15.4% of the hogs. There were significant correlations between lung lesions and serologic titres to both *Mycoplasma hyopneumoniae* (MH) (r=.646, P=.004) and *Actinobacillus pleuropneumoniae* (AP) (r=.587, P=.010), although the association with MH appeared to be stronger. MH and AP were not associated. Control of the confounding effect of farm decreased the significance of both MH and AP. This suggested herd-level factors play an important role in the development of lung lesions. As well, some herds maintained very low levels of lung lesions despite moderate (up to 30%) prevalence of MH. Pleuritis did not appear to be associated with either of the agents studied (P=.478).

Leptospiral titres to any serovar were prevalent in 66.4% of slaughter hogs. The four most common serovars were *L. icterohaemorrhagiae(RGA)*, *L. bratislava*, *L. autumnalis*, and *L. pomona*. They were present, respectively, in 57.1%, 35.1%, 3.4%, and 1.5% of slaughter hogs. None of these serovars were associated with increased frequency of stillbirths. *L. pomona* and *L. bratislava* were associated with infertility, as measured by nonproductive sow days per parity.

Relative economic efficiency of the operations was measured using return to management and labour (RML). Regression analysis was used to determine the ability of a number of biological parameters to predict RML and its components (revenue, fixed costs, and variable costs). Of the routinely monitored biological parameters, RML on PEI farrow-finish operations is best predicted (R^2=64.8%) by: marketed per square meter per year (P=.008), and marketed per sow per year (P=.096). Regression of fixed costs revealed that biological parameters have limited ability to predict fixed costs on farrow-finish operations (R^2=30.7%). The only parameter contributing to the prediction of the fixed cost component of RML was feeder hog density (P=.077). The variable cost component of RML on farrow-finish operations was predicted (R^2=94.3%) by feed cost per kg gain (P=.000), and marketed per sow per year (P=.044). The biological parameters recorded on feeder farms in this study had only limited ability to predict RML (R^2=43.7%). The only parameter of any importance was marketed per square meter per year (P=.106). Prediction of the fixed cost component of RML on feeder farms (R^2=67.4%) was best realized by measuring feeder hog density (P=.045). The variable cost component of RML on feeder farms was reasonably well predicted (R^2=74.7%) by feed cost per kg gain (P=.012).

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TABLE OF CONTENTS

1. INTRODUCTION

Performance indicators are the cornerstones of service to the swine industry. For veterinarians, the more traditional indicators are disease levels, such as respiratory disease (Chapter 3), or the prevalence of Leptospirosis (Chapter 4). The limiting effect of disease on productivity has led to the examination of productivity parameters (Chapter 2) as preferable indicators at the herd level. Chapter 5 enters a new area for many involved with the swine industry: economic efficiency. Encouragement of management changes requires knowledge of the relationship between productivity and economic efficiency.

This study was undertaken as part of the development of a major computerized information network, APHIN (1). The survey of productivity (Chapter 1) and lung lesions (Chapter 2) can be used as a baseline for the assessment of APHIN's major swine services: the Swine Productivity Program, and the abattoir data collection system.

This study had five specific objectives.

The first objective was to conduct a baseline survey of PEI's swine productivity, as measured by biologic parameters (Chapter 2). The parameters include: sow reproductive performance, weaner performance, feeder performance, and carcass quality (2). A random sample of approximately 30 PEI swine herds was selected to participate in the Department of Agriculture's Swine Productivity Program (SPP) for one year. Carcass quality information was collected from the federally inspected abattoir. Any farm on PEI that markets more than 1000 hogs per year was eligible for inclusion in this study. This category contained approximately 60 feeder and farrow to finish operations, which account for 57% of PEI's production of market hogs.

The second objective was to compare productivity parameters from the random sample study herds to those obtained from herds that have chosen to participate in the SPP (Chapter 2).

The third objective was to determine the serological prevalence of specific infectious disease agents in PEI slaughter hogs. The subsample of farms (the same as the third objective) detected subclinical health problems at the federally inspected abattoir via records of routine post mortem examinations, and serum samples from slaughter hogs. Since respiratory disease has a demonstrable detrimental effect on the productivity of PEI hogs (3), the associations between lung lesions and serologic results for *Mycoplasma hyopneumoniae*, and *Actinobacillus pleuropneumoniae* were investigated (Chapter 3). The impact of respiratory disease on production parameters was evaluated from the literature. Serum samples were also tested for a variety of leptospiral serovars, and associations between leptospiral titres and herd measures of reproduction were investigated (Chapter 4).

The fourth objective was to conduct a baseline survey of the economic efficiency of PEI's swine industry, as measured by economic parameters and feed conversion (Chapter 5). The parameters evaluated include: profit, return to management and labour (4), feed conversion, feed cost per kg gain (5), marketed per square meter, and weaned per crate per year (2). A subsample of approximately 15 farms was randomly chosen from the 30 farms described above. Detailed financial data relating to the cost of production of market hogs were collected on these farms.

The fifth and most important objective was to analyze the relationship between biological production parameters and economic performance (Chapter 5). This was done to determine which measures of productivity are most important in predicting the economic efficiency of a swine farm.

2. BIOLOGICAL PRODUCTIVITY

2.1 Introduction

The role of the veterinarian on swine farms has become one of preventive herd health (6). This shift from emergency medicine requires a focus on the herd as a population, and a re-definition of disease as any deviation between actual production and a target (7). Disease defined in this manner has led to the concept of "performance-related diagnosis" (8). These diagnoses require records of productivity (9, 10), and production targets tailored to each operation's situation. Establishing targets for an operation requires detailed knowledge of the farm's current and past production levels, an understanding of the owner's aspirations, and reference values on levels of productivity achieved by other producers in the region.

This chapter reports the productivity of a group of randomly selected farrow-finish and feeder farms in PEI, using standard performance indicators (7). Correlations between biologically related parameters are presented, as well as correlations between major parameters and herd size. A comparison of results from randomly selected farms and a group of self-selected farms is also presented.

2.2 Materials and Methods

Swine farms located on Prince Edward Island producing more than 1000 market hogs per year, and planning to continue operations for the year of 1988 were eligible for this study. This definition encompassed farrow-to-finish operations as well as feeder operations, and excluded weaner operations. Feeder operations acquired pigs at approximately 14 kg. Hogs were marketed to attain a dressed carcass weight between 75 and 80 kg.

Two groups of farms were included in this study. The sampling frame for the first, randomly selected group was based on provincial records for the year ending June 30, 1987. A random sample (based on computer generated numbers) was taken from the 63 farms meeting the eligibility criteria. With the objective of obtaining complete data from 30 farms, 38 eligible farms were contacted by telephone in October 1987, and asked to keep production records until January 1, 1989. In addition, every second farm contacted was asked to keep detailed feed and economic records which will be further described in Chapter Four.

The second group (designated as self-selected) were herds already participating in the provincial Swine Productivity Program(SPP) before October 1987. Farms which were already enroled in SPP and which were selected as part of the random sample were considered to belong to both groups.

SPP is an inventory based recording system developed jointly by the Prince Edward Island Department of Agriculture, and the Animal Productivity and Health Information Network(APHIN)(1). Events are recorded in 28 day periods (see Appendix A). These events include all sales, purchases, deaths, breedings, farrowings, born alive, born dead, weaned, pigs moved to feeder barn, and gilts retained. Inventories of all animals are done at the end of each period. Definitions used are:

Open gilt: A female selected or purchased for breeding, but not yet bred.

Sow: A female bred at least once in her lifetime.

Number bred: Number of females serviced by a boar; multiple matings in a 5 day period count as a single breeding event.

This study used records (13 periods) for the year of 1988. Verification of the data was done on the farm on a monthly basis using actual inventory head counts. Summary information on the carcass weight and index (11) of all hogs shipped was obtained from the PEI Hog Commodity Marketing Board.

For analysis, all data was entered into a microcomputer based data management software package. The experimental unit was the farm. Descriptive statistics and correlations were calculated using "Minitab" (12) on the VAX 8550 at the University of Prince Edward Island. Sample means were calculated from simple unweighted averages of each farm's mean. Formulae used to calculate the relevant production indices are similar to that used by others (2, 13) and are found in Table I. Minimum and maximum values show the range for each index. Farrow-to-finish farms were ranked by Weaned per Sow per Year for calculation of quartiles. Feeder farms were ranked by Average Daily Gain for calculation of quartiles. The random and self-selected groups were compared by multivariate analysis of variance using the microcomputer version of SAS (14).

TABLE I. Calculations of Productivity Indices

Index	Acronym	Calculation
Weaned per Sow per Year	W/S/Y	$\frac{\text{total pigs weaned}}{\text{average sow inventory}}$
Litters per Sow per Year	L/S/Y	$\frac{\text{total farrowings}}{\text{average sow inventory}}$
Average Weaning Age (days)	AWA	$\frac{365(\text{average nursing inventory})}{\text{total pigs weaned}}$
NonProductive Sow Days per Parity	NPSD/P	$\frac{365-((AWA+114)L/S/Y)}{L/S/Y}$
Weaned per Litter	W/L	$\frac{\text{total pigs weaned}}{\text{total farrowings}}$
Average Born Alive	ABA	$\frac{\text{total born alive}}{\text{total farrowings}}$
% PreWeaning Mortality	PWM	$\frac{(\text{total born alive})-(\text{total weaned})}{\text{total born alive}} \times 100$
Percent Born Dead	%BD	$\frac{(\text{total born dead})}{\text{total born alive + born dead}} \times 100$
Annual Replacement Rate (%)	REPR	$\frac{(\text{total sows sold}) + (\text{sows died})}{\text{average sow inventory}} \times 100$
% PostWeaning Mortality	POSTWM	$\frac{(\text{total weaned}) - (\text{total shipped})}{\text{total weaned}} \times 100$
Marketed per Sow per Year	M/S/Y	$\frac{\text{total adjusted marketed}^{a}}{\text{average sow inventory}}$
Days on Feed	DOF	$\frac{365(\text{average feeder inventory})}{\text{total adjusted marketed}}$
Days to Market	DTM	$AWA + DOF + \frac{(365(\text{ave weaner inventory}))}{\text{total weaners moved to feeder barn}}$
Percent Open Gilts	%OPENG	$\frac{\text{average unbred gilt inventory}}{\text{average sow inventory}} \times 100$
FARROW-FINISH FARMS ONLY: Average Daily Gain	ADG	$\frac{\text{average carcass weight (conversion factor to liveweight}^{b})}{DTM}$
FEEDER FARMS ONLY: Average Daily Gain	ADG	$\frac{(\text{ave carcass wt X conversion to livewt})-\text{purchase wt}}{DTM}$

[a] total adj. marketed=(marketed+gilts retained)-(year start hog inventory/2)+(year end hog inventory/2)
[b] Dr. Gordon Bowman, University of Guelph, written communication

2.3 Results

Eighty-four percent (32 farms) of the randomly sampled farms agreed to participate. The most common reason for not participating was a lack of interest in keeping the records required for this study. One farm was lost to the study mid-way through the year. The 31 participating farms included 17 farrow-finish operations, and 14 feeder operations. These farms accounted for 58% of the hogs marketed by farms in the sampling frame, and 31% of PEI's hogs marketed during the study.

Levels of production on the 17 randomly selected farrow-finish operations are presented in Table II. Levels of production on the 14 randomly selected feeder farms are presented in Table III.

There were no significant correlations between herd size and production indices. On farrow-finish farms, correlations between Ave Sow Inventory and W/S/Y, L/S/Y, W/L, PWM, ADG were respectively: r=-.219, r=.198, r=.283, r=.049, r=.299. On feeder farms, correlations between number of pigs marketed per year and ADG, feeder mortality were respectively: r=.118, r=.212. All P-values were greater than 0.05.

TABLE II.
Descriptive Statistics of Productivity on 17 randomly selected Farrow-Finish Farms on PEI

INDEX	MEAN	STDEV	MIN	MAX	TOP QUARTILE[a]	BOTTOM QUARTILE[a]
Ave Sow Inventory	106[b]	54.5	53	229	73	111
Weaned/Sow/Year	19.6	2.4	16.2	24.9	20.6	17.6
Litters/Sow/Year	2.19	0.15	1.92	2.43	2.20	1.98
Ave Weaning Age, d	33.6	4.8	26.0	44.0	36.5	33.0
NonProductive Sow Days/Parity	19.9	11.0	3.2	41.9	15.5	37.6
Sow:Boar Ratio	21.1	5.3	13.5	32.0	18.9	17.5
Weaned/Litter	8.9	0.6	8.0	10.5	9.5	8.9
% PreWeaning Mortality	15.5	3.9	9.6	21.8	16.3	16.0
Ave Born Alive	10.6	0.5	9.9	11.6	11.3	10.6
% Born Dead	6.9	2.6	3.5	11.6	4.3	9.5
% Open Gilts	3.6	2.7	0.0	9.5	1.5	2.2
Annual Replacement Rate (%)	38.0	14.0	11.4	62.1	18.5	46.5
Marketed/Sow/Year	18.3	2.7	14.1	24.0	19.8	16.2
% PostWeaning Mortality	7.5	4.1	3.1	15.8	4.2	8.5
Days To Market	201	12.3	185	222	188	204
Ave Index	103.8	2.1	100.1	107.8	101.3	103.1
Ave Daily Gain, kg	0.49	0.04	0.44	0.55	0.48	0.48
Ave Carcass Weight,kg	78.1	2.1	72.7	82.1	80.4	77.5

[a] 25th or 75th percentile of farms as ranked by Weaned/Sow/Year
[b] Skewed distribution of ave sow inventory: more appropriately described by median=85.

TABLE III.
Descriptive Statistics of Productivity on 14 randomly selected Feeder Farms on PEI

INDEX	MEAN	STDEV	MIN	MAX	TOP QUARTILE[a]	BOTTOM QUARTILE[a]
Ave Daily Gain, kg	0.58	0.07	0.44	0.71	0.62	0.54
Days On Feed	146	18.4	127	186	129	149
% Mortality	3.32	1.3	1.7	5.9	1.7	4.6
Carcass Index	102.9	1.4	100.6	106.2	101.6	102.7
Carcass Weight	78.7	1.9	75.1	83.1	78.0	77.2

[a] 25th or 75th percentile of farms as ranked by Ave Daily Gain

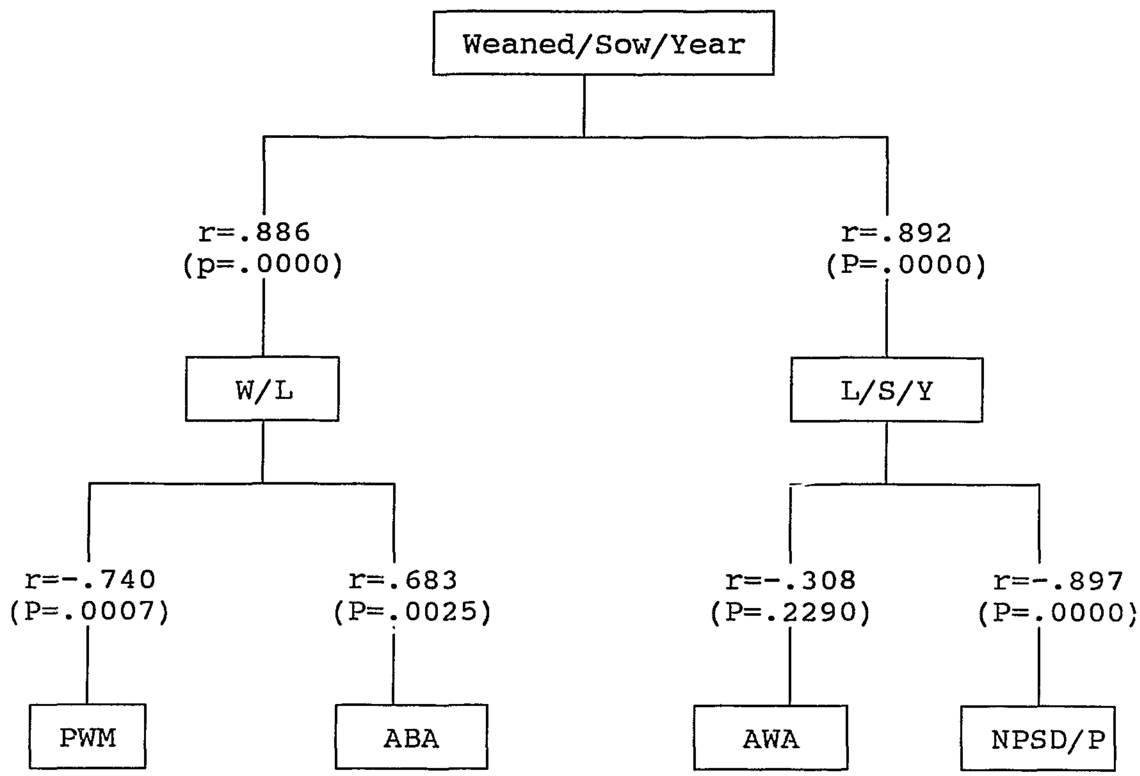
Sow productivity, as indicated by W/S/Y, and its relationships with contributing factors, is presented in Figure 1. The relationship between L/S/Y and AWA was further explored, controlling for NPSD/P. The regression equation: L/S/Y = 2.95 - 0.014 AWA - 0.018 NPSD/P + 0.0001(NPSD/P)^2 revealed AWA as a significant contributor (P=.000).

Regression analysis of ABA on parameters previously reported to influence ABA (using predictors: PWM, %BD, %OPENG, REPLR, and AWA) revealed no statistically significant contributions to ABA (respective P values: .285, .147, .944, .378, .811).

ADG on feeder farms was correlated with mortality (r=-.662, P=.010), but not with Index (r=-.375, P=.187).

One of the objectives was to compare productivity parameters from the random sample study herds to those obtained from herds that have chosen to participate in the SPP (self-selected herds). Fifteen self-selected farrow-finish farms met the eligibility criteria. This number included nine farms that were also in the random sample. These nine farms were defined as "neccessary" to the random group. The remaining six self-selected farms were regarded as equally representative of the self-selected group as the original fifteen. This created exclusive, independent groups for comparison. Multivariate analysis of variance was used to determine that there were no statistically significant differences between the randomly selected and self-selected groups of farrow-finish farms (Wilks' Lambda = 0.224, P= 0.2671) (see Appendix B). Only one feeder operation that was self-selected met the eligibility criteria for this study. This precluded comparison with the randomly selected group.

FIGURE 1.
Correlations between Sow Productivity and its Primary and Secondary Components



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r= Pearson's Product-Moment correlation coefficient

2.4 Discussion

The mean productivity values reported in this study are probably close to the average for herds of similar size on PEI. Although another study that attempted a random sample found farms that did not participate showed little interest in record-keeping, and had below average productivity (2), the participation rate of 82% in this study is much higher than that study's rate of 29%.

Comparisons of herd productivity must take into account criteria used to define numerators and denominators (7). Differences can be created, exaggerated, or masked by the use of different denominators. Specifically, a previous study has defined "sow" as all females, bred or not (13). This definition has the advantage of incorporating gilt performance (that is otherwise ignored) into the herd indices. However, the definition of herd entry for an unbred gilt is difficult to standardize across farms; hence this study has used the more traditional definition of "sow" as all females bred at least once. This approach appears to be warranted when comparing %OPENG in this study of 3.6% to the previous study in which the %OPENG was 20.0% (13).

The results obtained in this study are compared with three other studies using the definitions found in Table I. The first study was based on 30 randomly selected herds from major pork-producing counties in Ontario during 1983 (referred to as the Ontario study) (2). The second study was based on 68 North American herds using the computer software package PigCHAMP during 1985/1986 (referred to as the PigChamp study) (13). The third study was based on 72 farrow-finish herds participating in the Cambridge Pig Management Scheme in 1986 (referred to as the Cambridge study) (5). The productivity indices from all four studies are found in Table IV.

PEI's mean W/S/Y of 19.6 is higher than Ontario's, compares well with the Pigchamp study's mean, and falls just short of the Cambridge study's mean (using mated females as the denominator). Nonetheless, between-farm variation in W/S/Y was large. The highest producing herd weaned 8.7 more pigs per sow per year than the lowest producing herd. This variation could not be explained by herd size (r=-.219, P=.400). This finding is similar to the PigChamp study (13), although it contradicts others' suggestion that larger herds are more productive (2).

By definition, improvement in W/S/Y is dependent on achieving higher L/S/Y and W/L (see Figure 1). L/S/Y and W/L contributed equally to the variability in W/S/Y.

TABLE IV.
Comparison of average Productivity Indices from four different studies

INDEX	PEI	Ontario	PigChamp	Cambridge
Ave Sow Inventory	106	118	188	144
Weaned/Sow/Year	19.6	16.8	19.7	19.9
Litters/Sow/Year	2.19	2.1	2.23	2.21
Ave Weaning Age, d	33.6	37.6	25.9	28
NonProductive Sow Days/Parity	19.9	24.2	23.9	23.2
Weaned/Litter	8.9	8.2	8.7	9.0
% PreWeaning Mortality	15.5	18.7	15.1	13.5
Ave Born Alive	10.6	10.1	10.2	10.4
% Born Dead	6.9	7.0	8.9	?
% Open Gilts	3.6	?	19.2	?
Annual Replacement Rate (%)	38.0	?	41.2	?
Marketed/Sow/Year	18.3	?	?	?
% PostWeaning Mortality	7.5	5.0	?	?
Days To Market	201	197	?	?
Ave Index	103.8	103.6	?	?
Ave Daily Gain[a], kg	0.49	0.49	?	?

[a] ADG from 0 kg to approx. 98 kg liveweight

L/S/Y averaged 2.19, similar to the other studies. Its components, as defined by Stein (15) are AWA, and NPSD/P. These components are important to emphasize, since seemingly minor changes in L/S/Y have a large impact on productivity as measured by W/S/Y. Although AWA was not found correlated to L/S/Y (P=.2290) in this study, results of multiple regression show that after controlling for NPSD/P there is significant contribution of AWA to L/S/Y, as was found by others (2, 13). The discrepancy in this study is explained by the much larger contribution of NPSD/P to the variability in L/S/Y. AWA averaged 33.6 days, with all farms but one weaning later than 28 days. This is comparable to Ontario's 37.6 days (2). In contrast, the PigChamp study averaged 25.2 days with 76% weaning earlier than 28 days (13), and the Cambridge study averaged 28 days with 73% weaning at 28 days or earlier. Reducing AWA below 28 days has been associated with a reduction in litter size (16) but this threshold has not yet been reached by the majority of PEI swine herds.

Nonproductive Sow Days are an important subcomponent of L/S/Y. They are influenced by AWA, farrowing rate, and the wean-to-breed (or wean-to-cull) interval. Reducing nonproductive days represents the most significant route to increasing sow productivity. In spite of this, many producers do not understand the concept of "nonproductive days". Swine Productivity Program has made an effort to make NPSD easier to conceptualize by dividing it by L/S/Y. Now, for each producer, NPSD/P is easier to relate to his wean-to-breed interval, allowing for farrowing rate. Herd farrowing "rate" (actually a measure of risk) was estimated to average 93% for these farms (using the numerator: number of sows farrowing in the last 9 periods of 1988, and the denominator at risk of farrowing: number of sows bred in the first 9 periods of 1988). This suggests that for the majority of producers, NPSD/P can be used as a substitute for average wean-breed (or wean-to-cull) intervals, which cannot be calculated from inventory data.

NPSD/P averaged 19.9 days in this study; this is lower than all the other studies. Comparisons with the other studies, however, are misleading without taking into consideration AWA. It then becomes obvious that PEI's longer AWA, rather than an improvement in the farrowing rate or wean-to-breed interval, account for the incongruity, since PEI's W/S/Y does not reflect an improvement over the W/S/Y of the PigChamp or Cambridge studies.

W/L is the other major contributor to W/S/Y. W/L averaged 8.9, similar to other studies. Its components, as defined by Stein (15) are ABA, and PWM. ABA was positively correlated with W/L (P=.0025). PWM was negatively correlated with W/L (P=.0007). These results support the findings of others (2, 13).

PWM averaged 15.5%; some improvement will be necessary to match the lower rate found in the Cambridge study. One out of four herds had PWM of 18% or greater, although two herds managed less than 10%. This suggests that many herds could reduce this loss, using management techniques of attended farrowings (17), all-in, all-out farrowing (17), supplemental feeding (18), good hygiene in the farrowing area (19), and crossfostering to equalize birthweights within litters (19, 20). Other studies show primary disease accounting for only 5% of preweaning deaths (19).

ABA averaged 10.6, within a narrow range of 9.9 to 11.6. This is similar to the reports of other studies, suggesting the pig's fecundity has limited potential for increasing productivity. Nonetheless, factors affecting ABA have been well researched. They include genetics (the maximizing effect of heterosis) (21), nutrition (especially for parity one sows) (22), number of matings, season, lactation length (16), reproductive diseases (23), and the effect of parity (16, 24, 25, 26). A herd's parity distribution and culling rate are closely related (27). As an index of herd parity distribution, average herd parity (7), and %OPENG (13) have been used. Neither parameter was significantly correlated with ABA. Similarly, this study found no correlation between ABA and %OPENG, or REPR (respective P values: .944, .378). This supports the hypothesis that parity distribution on a herd basis is inadequately described by these oversimplified parameters.

POSTWM averaged 7.5% compared to Ontario's 5.0%. The average Index of 103.8 and ADG of .49 kg per day are identical to Ontario's. A study based on herds maintaining Swine Graphics records in Iowa achieved an ADG of .51 kg per day (28).

Production records available for the feeder farms were limited to % mortality, average index, and ADG. Comparisons with other studies are difficult to make since PEI feeders are acquired at a light weight; they are fed from about 14 kg to 98 kg. PEI's feeder mortality of 3.2% compares well with a study of one experimental Danish herd with 4.4% mortality during 1969-1973 on feeders from 20 kg to 90 kg (29). A 1986 Cambridge study of 22 herds feeding from approximately 27 kg to 90 kg reported 1.9% mortality, and .64 kg ADG (5). This suggests that PEI could learn from Britain's feeder management techniques. PEI's ADG of .58 kg is similar to the ADG of .55 kg per day found in a study of 6 Ontario herds feeding from 21 kg to 98 kg (2). The negative correlation of ADG with mortality (P=.010) supports the connection between productivity and management techniques described by others (2, 30). Previous studies have demonstrated that average index decreases with improved ADG (31, 32, 33). This trend was also demonstrated in this study, with herds in the top quartile showing a lower index than herds in the bottom quartile. However, the correlation between ADG and AVEINDEX (P=.187) was not statistically significant.

It is interesting to note the lack of significant difference between the randomly selected and self-selected farrow-finish operations. This is probably due to the level of participation in SPP that has been encouraged over the years by PEI's Department of Agriculture swine extension staff. However, the similarity between the two groups cannot be used to justify non-random sampling in future studies of swine productivity. There is no way of knowing, based on this one study, if the similarity was mere coincidence.

Feeder operations on PEI were considerably less inclined than farrow-finish operations to volunteer for data recording. This prevented any comparisons between random and self-selected groups, and justified the effort required for a random sample. The level of cooperation achieved in this study implies that feeder producers are willing to maintain records, but receive less encouragement to do so, even though they account for half the current hog production on PEI.

In summary, this study shows that sow production records have become an accepted part of farrow-finish operations. W/S/Y, L/S/Y, and W/L have been demonstrated to be accurate indices for herd monitoring. PEI's sow productivity is generally higher than reported by Ontario, similar to PigChamp, and falls short of that achieved by Cambridge. This should be tempered by the knowledge that gilt performance has not been addressed, and wide variation in sow productivity is also revealed. The major opportunities for improvement lie in three areas: (1) reducing AWA to 28 days, (2) reducing PWM to 11%, and (3) reducing NPSD/P to 10 days. The last point compels producers **not** to accept 2.2 as an adequate L/S/Y. Also, on-farm awareness and investigation of the components of nonproductive sow days is needed. Much encouragement is required for better production records and subsequent improved productivity for the grower-finisher area of both farrow-finish and feeder operations.

3. RESPIRATORY DISEASE

3.1 Introduction

Respiratory disease has been shown to have detrimental effects on the growth rates and feed efficiency of feeder hogs. The results of these investigations are summarized in Table V. While the evidence for these negative effects is equivocal, the weight of the evidence suggests that they do exist and may be of considerable magnitude. All but one of the experimental studies show decreased average daily gain (ADG) with enzootic pneumonia (34, 35, 36). The one exception (37) had insufficient power to detect anything but a very large difference. Many observational studies ignored important confounding variables (atrophic rhinitis: 38, 39, 40; herd effects: 41; time: 42, 43; and treatments: 44). Of the remaining observational studies, the majority (five) show reduced ADG associated with enzootic pneumonia (3, 32, 45, 46, 47). One study showing no effect had insufficient power to detect anything but a large effect (48). One study based on one herd found no effect (49). However, another study (50) showed that different herds may respond differently, accounting for the lack of association when using herd level parameters, and accounting for the occasional herd (49) that does not demonstrate the expected association between enzootic pneumonia and decreased ADG. Although the effect of enzootic pneumonia cannot be predicted for any one herd, it appears the majority of herds will respond with decreased growth rate.

Table V.
Effect of enzootic pneumonia on performance of feeder hogs

Author	Year Publ	Materials & Methods	Results
EXPERIMENTAL STUDIES:			
Betts (34)	1953	16 hogs	decr ADG[a], incr F/G[b]
Betts (35)	1955	43 hogs	decr ADG, incr F/G
Zimmerman (37)	1982	14 hogs	no effect
Pointon (36)	1985	32 hogs in endemic stage	decr ADG
OBSERVATIONAL STUDIES (Individual animals):			
Huhn (39)	1970	test station; 116 hogs disregarded AR[c]	decr ADG comparing mild to mod/sev lesions
Lindqvist (40)	1974	2 herds; 27 batches disregarded AR	decr ADG comparing none to severe lesions
Jericho (44)	1975	progeny test station; 97 pairs disregarded treatment	no effect
Straw (45)	1983	progeny test station; 505 hogs	decr ADG with incr extent of lesions
Burch (47)	1984	2 herds; 111 hogs	decr ADG with incr extent of lesions
Flesja (32)	1984	12 herds; 60 batches	decr ADG with incr extent of lesions
Straw (46)	1984	progeny test station; 616 hogs	decr ADG with incr extent of lesions
Love (49)	1985	1 herd; 220 hogs	no effect
Morrison (48)	1985	4 herds; 19-28 hogs per farm	no effect
Wilson (50)	1986	1 herd; 38 hogs	decr ADG with incr extent of lesions
		1 herd; 34 hogs	incr ADG with incr extent of lesions
Bernardo (5)	1988	15 herds; 30 hogs per farm	decr ADG with presence of lesions
OBSERVATIONAL STUDIES (Herd level):			
Schuman (38)	1956	1 herd, before and after; disregarded AR	no effect
Young (41)	1959	2 herds	herd with Enz&AR longer DTM than control
Goodwin (42)	1963	1 herd, before and after	decr ADG, incr F/G (farm basis)
Braude (43)	1975	1 herd, before and after	decr ADG, incr F/G
Wilson (50)	1986	27 herds	no effect using herd ADG and ave severity of lesions
Bernardo (5)	1988	15 herds	decr herd ADG with incr prevalence of lesions

[a] ADG = average daily gain
[b] F/G = feed to gain ratio
[c] AR = atrophic rhinitis

The regular examination of the lungs of slaughter hogs is an accepted method of monitoring levels of respiratory disease (51). The two main conditions detected at slaughter are enzootic pneumonia and pleuritis. The former is characterized by anteroventral consolidation and discolouration in the lung, while the latter usually manifests itself as fibrinous to fibrous tissue over the surface of the lungs and lining the thoracic cavity (52).

The two agents most commonly associated with these conditions are *Mycoplasma hyopneumoniae*, and *Actinobacillus pleuropneumoniae*, although the etiology of both conditions is considered multifactorial (53). Infection with both agents can be readily detected by serological techniques. This chapter looks at the potential role of those two agents as risk factors for the two conditions.

3.2 Materials and Methods

Twenty-one producers (a subset of the random sample described in Chapter Two) were asked to participate in regular slaughter checks and a serological survey, as well as maintain detailed production and feed records, for one year.

During 1988, a minimum of 3 slaughter checks were performed on 15 hogs from each farm. These checks were categorized as winter (October-March), spring (April-

June), or summer (July-Sept). Snouts were scored for atrophic rhinitis on a scale of 0 to 5 (52). Lungs were visually examined for anteroventral (AV) lesions (52) and categorized on the basis of percentage lung involvement (54) as normal (0%), mild (<10%), moderate (10-25%), or severe (>25%). AV lung lesion scores were subsequently dichotomized into present or absent. Lungs were also examined for the presence or absence of pleuritis.

During July and August of 1988, blood was collected from 25 slaughter hogs from each farm. The same animals were identified, and received a summer slaughter check of lungs only. The serum samples were tested for two common respiratory pathogens: *Mycoplasma hyopneumoniae*, and *Actinobacillus pleuropneumoniae* (formerly *Haemophilus pleuropneumoniae*). Mycoplasmal antibodies were detected using the complement fixation test (55). The test was considered positive if a titre of 1:5 or greater was observed. Actinobacillus antibodies were measured using a screening ELISA (56, 57) for serotypes 1 and 5. Suspicious and negative results were considered as a negative test. A farm was considered positive if one or more animals tested positive.

For analysis, all data were entered into a microcomputer based data management software package. Minitab (12) and BMDP (58) computer packages were used for all statistical analyses. Differences in the prevalence of AV lesions and pleuritis for the different categories of serology were tested using an overall chi-square. If this revealed significant differences, chi-square was subdivided, and the P values adjusted using the Bonferroni inequality (59). Finally, logistic regression was used to control the potential confounding effect of farm of origin.

Farm average snout scores in winter and spring were compared using a paired t-test. Farm average AV lung lesion prevalence in spring, summer, and winter were compared using repeated measures analysis of variance. Correlations and least squares regression were used to investigate the associations between farm prevalence of AV lung lesions and positive serology.

3.3 Results

Eighty-six percent (18 farms) of the randomly sampled farms agreed to participate; no farms were lost to follow-up. The 18 participating farms included 11 farrow-finish operations, and 7 feeder operations.

Individual Animal Analysis

Individual hog data was unavailable for one farm, due to a disruption on the kill line at the abattoir. On the remaining 17 farms, 9 hogs had incomplete data and were removed from the analysis. Therefore 416 hogs were used in the analysis.

TABLE VI.

Associations between lung lesions and serology results on 416 PEI slaughter hogs

	# hogs	% hogs with AV lung lesions[1]	% hogs with pleuritis[2]
Serology negative	252	38.5[a]	15.9
MH[3] titre only	116	64.7[b]	16.4
Positive AP[4] test only	24	70.8[b]	4.2
Both	24	87.5[b]	16.7
Total	416	50.5	15.4

1 percentages with the same letter were not significantly different from each other (P>.05)

2 nc statistically significant differences between ~ories (P>.05)

3 MH = *Mycoplasma hyopneumoniae*

4 AP = *Actinobacillus pleuropneumoniae*

Table VI presents associations between AV lung lesions and pleuritis, and serology results obtained from individual hogs.

Pleuritis was just as frequent in seronegative hogs, hogs positive to *M. hyopneumoniae* (MH), *A. pleuropneumoniae*(AP), or both (X^2=2.485, 3 df, P=0.478).

The frequency of AV lung lesions was significantly different among serology categories (X^2=40.94, 3df, P=0.000). Hogs positive to MH, AP, or both had more AV lung lesions than seronegative hogs (X^2=36.75, 1df, P=0.001). There were no differences between hogs positive to MH, AP, or both (X^2=4.892, 2df, P=0.261).

Presence of AV lung lesions was further analyzed using logistic regression, to control for the confounding effect of farms (P=.000). The interaction term between MH and AP was removed (P=.5120) as nonsignificant, and the final model including only main effects was as follows: a=-3.205, MH: b=0.527, P=.0620; AP: b=0.510, P=.2274.

Herd Level Analysis

The experimental unit for all other analyses was the farm. The average snout score per farm was higher in the winter than the spring (Paired t-test: T=3.71, P=0.0017).

Mean snout score for all farms in the winter was 0.86; in the summer it was 0.56.

The percentage of hogs showing any AV lung lesions did not differ (Repeated Measures Analysis of Variance: F=0.87, P=.427) from spring (46.8%) to summer (49.7%) to winter (43.6%). The mean herd average was 46.3% prevalence of AV lung lesions, with a range from 1.2% to 79.1%.

The simple correlation between the percentage of hogs showing AV lesions and the percentage of hogs positive for AP was significant (r=.587, P=.010). So too was the correlation between the percentage of hogs showing AV lesions and the percentage of hogs positive for MH (r=.646, P=.004). This relationship is presented in Figure 2.

The association between serologic results and prevalence AV lung lesions at the herd level was further investigated using least squares regression with MH, AP, and the MH/AP interaction. Prediction of the percentage hogs with AV lung lesions using the percentage of hogs positive for MH (b=.805, P=.035), the percentage of hogs positive for AP (b=1.60, P=.133), and the interaction between MH and AP (b=-0.020, P=.325) resulted in an R^2 of 52.9%.

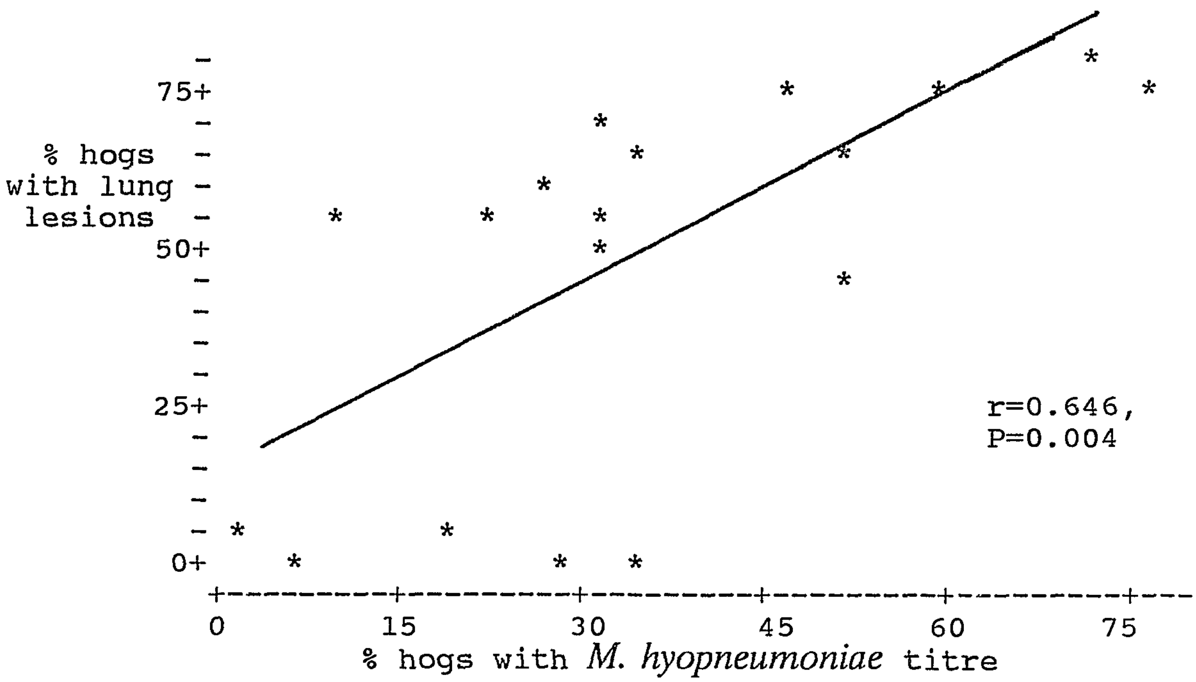


FIGURE 2.
Association between anteroventral lung lesions and herd prevalence of M. hyopneumoniae titres on 18 PEI swine farms

3.4 Discussion

Examination of lung lesions at slaughter can be used to monitor enzootic pneumonia, since AV lung lesions are indicative of this condition (52). Gross lung lesions are indicative of an inflammatory disease process in the lungs (60). This chapter looks at the role of MH and AP as risk factors for AV lung lesions.

Individual Animal Analysis

The univariable analysis of the role of infection with MH (53) or AP (57), as indicated by serologic titres, on the prevalence of AV lung lesions showed positive associations for both organisms (Table VI). A multivariable analysis (logistic regression) was subsequently used to remove the potential confounding effect of farm (a surrogate for management, environment, genetics, and nutrition), and to assess the significance of the interaction between MH and AP. Neither AP (P=.227) nor the interaction between MH and AP (P=.512) were significant once MP was included in the model. Although MP was the only risk factor remaining in the model, the P value of 0.0620 indicates that it cannot be considered the only risk factor. Although some studies suggest that *Pasteurella multocida* (61), diarrhea (62, 63), and TGE (64) may influence the prevalence of lung lesions, these diseases were beyond the scope of this study. Previous studies suggest that it is not necessary to control for ascariasis (5, 65), or atrophic rhinitis (45, 46, 48, 50, 66).

Despite the positive association between serologic status and prevalence of AV lesions, a high percentage, 38.5%, of seronegative hogs had lung lesions. There are several possible explanations. First, mycoplasmal titres last approximately 13 weeks (67), and may have disappeared before the hog was slaughtered. As well, lung lesions can also be caused by slaughter artifacts (52), the hog's environment (68), or infection with other pathogens such as *P. multocida*, *Mycoplasma hyorhinis*, *Haemophilus suis*, and others (69). Very few of these "false negatives" can be explained by imperfect serology. Sensitivity of the ELISA for AP has been estimated to be 97% (70), and sensitivity of the complement fixation for MH has been estimated to be 100% (67).

Thirty one percent of seropositive hogs had no lung lesions. The most likely explanation lies with the resolution of lesions (71). Again, very few of these "false positives" can be explained by imperfect serology. Specificity of the ELISA for AP has been estimated to be 96% (70), and specificity of the complement fixation for MH has been estimated to be 94% (72).

Herd Level Analysis

Figure 2 shows the relationship between prevalence of AV lesions and positive MH titres, with both parameters summarized on a herd basis. On a herd basis, prevalence of AV lesions is as useful a measure of the extent of enzootic pneumonia as the herd average of the percentage pneumonic lesions in each lung (73). There was an association between prevalence of AV lung lesions and prevalence of positive MH titres (r=.646, P=.004). Multiple linear regression was subsequently used with the result that neither AP nor the interaction between AP and MH were significant predictors of the prevalence of AV lesions (P=.133, P=.325 respectively).

These results suggest that interpretation of herd serology showing from 5 to 30% prevalence of MH is difficult, since some herds may exhibit up to 30% prevalence of MH, but have virtually no AV lung lesions at slaughter. These results also have an impact on the interpretation of AV lung lesions at slaughter. It has been suggested that the prevalence of lung lesions at slaughter be interpreted as follows: 5% suspicious, 10-30% subclinical enzootic pneumonia, 30-50% mild, 50-70% moderate, 70-100% severe enzootic pneumonia (74). However, these results suggested modification of the suspicious category to include from 1% to 10%, as it appeared possible to have very few hogs with lung lesions at regular slaughter checks, despite a high prevalence of MH.

In summary, there are significant associations between lung lesions and serologic titres to both MH and AP, although the association with MH appeared to be stronger. MH and AP are associated. Control of the confounding effect of farm decreases the significance of both MH and AP. This suggests herd-level factors, such as the environment, play an important role in the development of lung lesions. As well, some herds maintained very low levels of AV lesions despite moderate (up to 30%) prevalence of MH.

4. LEPTOSPIROSIS

4.1 Introduction

Leptospirosis is a zoonotic disease that causes a persistent infection in swine leading to reproductive problems such as abortions, infertility, stillbirths, and weak piglets. All pathogenic serovars are designated as *Leptospira interrogans* (75). Many pathogenic serovars have been recovered from swine (76, 77, 78, 79), although the clinical significance of these findings is difficult to interpret.

The objectives of this study were to determine the serological prevalence of leptospirosis in PEI slaughter hogs, and to investigate associations between leptospiral titres, and herd measures of reproduction.

4.2 Materials and Methods

Of the farms described in Chapter Two, the farrow-finish operations (11 farms) were asked to participate in a Leptospirosis serological survey, as well as maintain detailed production records for one year.

During July and August of 1988, blood was collected from 25 slaughter hogs from each farm. This sample size was calculated to allow detection of 5% prevalence (76) within each farm, 95% of the time. The serum samples were tested for *Leptospira interrogans* with the following antigens: *pomona* (swine reservoir), *hardjo* (cattle reservoir), *canicola* (dog reservoir), *icterohemorrhagiae(copenhageni)* (rat reservoir), *icterohaemorrhagiae(icterohaemorrhagiae-RGA)*, *grippotyphosa* (wildlife reservoir), *tarassovi*, *australis(ballico)*, *australis(bratislava)*, *autumnalis* (wildlife reservoir), *ballum*, *hebdomadis*, *javanica(poi)*, and *bataviae*. The test used was the microscopic agglutination test (80). A titre of 1:100 or greater was considered positive. A farm was classified positive if one or more animals tested positive.

For analysis, all data were entered into a microcomputer based data management software package. Descriptive statistics, correlations and t-tests were calculated using the mainframe computer package "Minitab" (12). To determine if the two most common serovars were reacting to the same antigen, Kappa (81), and McNemar's chisquare (59) were calculated.

4.3 Results

All producers agreed to participate; there was no loss to follow-up.

Prevalence results are found in Table VII.

TABLE VII.
Prevalence of leptospiral titres in porcine sera on PEI

Serovar	Sera (N=268) #	% seropositive	Herds (N=11) #	% seropositive
icterohaemorrhagiae (icterohaemorrhagiae-RGA)	153	57.1	11	100
australis(bratislava)	94	35.1	11	100
autumnalis	9	3.4	6	55
pomona	4	1.5	3	27
hardjo	3	1.1	1	9
icterohemorrhagiae(copenhageni)	2	0.7	2	18
canicola	1	0.4	1	9
javanica(poi)	1	0.4	1	9
australis(ballico)	0	0	0	0
ballum	0	0	0	0
bataviae	0	0	0	0
grippotyphosa	0	0	0	0
hebdomadis	0	0	0	0
tarassovi	0	0	0	0
any of the above serovars	178	66.4	11	100

A total of 8 serovars were detected with all herds having *L. bratislava* and *L. icterohaemorrhagiae-RGA*. With the exception of those two serovars, all others were low prevalence (<4%). Since 75% of the serum samples with a titre to *L. bratislava* also had a titre to *L. icterohaemorrhagiae-RGA*, the possibility of a cross reaction (79, 82) was investigated. Results were put in a 2X2 contigency table which had a McNemar's chi-square of 32.53 (P=.000). As well, Kappa was 0.23, with 60% agreement between the two serovars observed, and 48% expected by chance.

Associations between two herd measures of reproductive problems, piglets born dead and nonproductive sow days per parity (NPSD/P, see Chapter Two), and the four most prevalent serovars were evaluated. Two serovars, *L. autumnalis*, and *L. pomona*, were evaluated as either present or absent on the farm. The reproductive parameters from these two groups of farms were compared with a t-test. The other two serovars, *L. icterohaemorrhagiae-RGA* and *L. bratislava*, were found on all farms. Subsequently, least squares regression was used to assess the relationship between the herd prevalence and the level of each reproductive parameter.

There were no significant associations between the percent piglets born dead on a farm and the % hogs with *L. bratislava* titres (r=.372, P=.324), or the % hogs with *L. icterohaemorrhagiae-RGA* titres (r=.459, P=.214). Farms without *L. pomona* averaged 6.0% born dead; this was not significantly different (t=-0.94, P=.378) than the average 7.5% born dead on farms with *L. pomona*. Farms without *L. autumnalis* averaged 5.8% born dead; this was not significantly different (t=-1.02, P=.342) than the average 7.4% born dead on farms with *L. autumnalis*.

No association was found between the average NPSD/P on a farm and the % hogs with *L. icterohaemorrhagiae-RGA* titres (r=.431, P=.186). Farms without *L. autumnalis* averaged 23.1 NPSD/P: this was not significantly different (t=0.39, P=.708) than the average 19.9 NPSD/P on farms with *L. autumnalis*. Farms without *L. pomona* had an average of 14.7 NPSD/P, compared to 39.1 NPSD/P for farms with *L. pomona* (t=-5.83, P=.0002). Figure 3 shows the relationship between the % hogs with *L. bratislava* titres and NPSD/P (r=.738, P=.009).

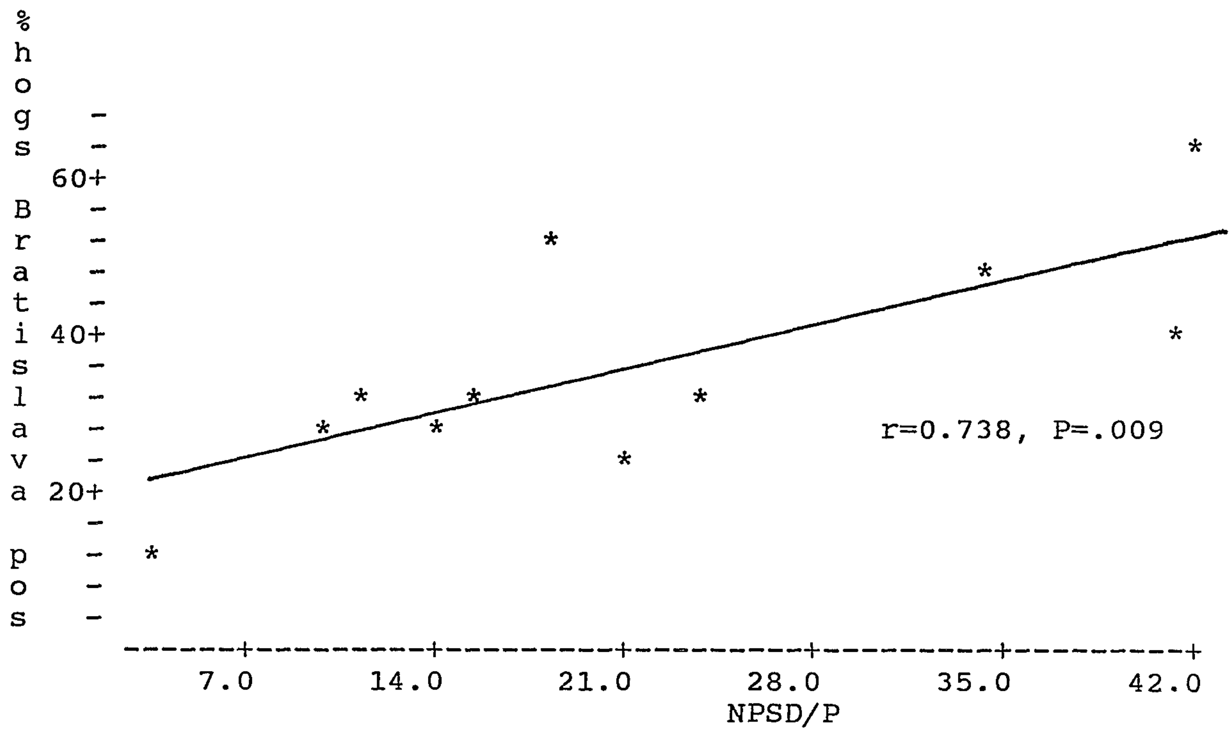


FIGURE 3.
Association between nonproductive sow days per parity (NPSD/P) and the percent slaughter hogs showing L. bratislava titres on 11 PEI farrow-finish herds

4.4 Discussion

The prevalence data in this study were taken from a random sample of herds, although the slaughter hogs were not randomly sampled. Post-exposure titres to leptospirosis persist for more than six months (75), justifying the use of slaughter hogs. Prevalence data can be influenced by vaccination rate, but only one herd had a sporadic history of vaccination, and that herd had vaccinated sows only. Vaccine titres are usually less than 1:100 (83, 84), and therefore would not be detected by the testing procedure. This cross-section of seroprevalence in slaughter hogs will underestimate the cumulative incidence of leptospirosis in the older sow population (85).

The possibility of cross reactions obscuring the results in Table VII was investigated. McNemar's chi-square (P=.000) indicated that there was a significant difference between the prevalence of the two most common serovars, *L. bratislava* and *L. icterohaemorrhagiae-RGA*, after controlling for any confounding association between them. This lack of evidence of a cross reaction was substantiated by the low Kappa (0.23), indicating that there was no substantial difference between the observed agreement between the two serovars, and the agreement expected by chance.

The herd measure of infertility was NPSD/P. Reproductive disease causes abortions, missed heats that lengthen the wean-to-breed interval, reduced farrowing rates and conception rates. All of these increase NPSD/P. Stillbirths, often associated with leptospirosis (75), were measured as % born dead.

For swine herds with clinical signs including abortions, infertility, stillbirths, and weak piglets, the most commonly incriminated serotype is *L. pomona* (77, 86). The prevalence of *L. pomona* was low in this survey (1.5%, see Table VII). Other prevalences have been reported: 4.6% in 197 Ontario slaughter hogs (76), 0% in 792 hogs in England (77), and 0.7% in 687 hogs from Illinois farms with a history of reproductive problems (78). The risk of stillbirth was no different (P=.378) on farms with *L. pomona* (7.5% born dead) than on farms without *L. pomona* (6.0% born dead). The lack of significance may be a result of lack of power due to the use of only 11 farms. However, a significant difference (P=.0008 using the conservative Bonferroni adjustment for four serovars) was found between 39.1 NPSD/P on farms with *L. pomona* and 14.7 NPSD/P on farms without *L. pomona*. This suggests that NPSD/P, a measure of infertility, should be considered along with parameters traditionally used to diagnose leptospirosis, such as % born dead and litter scatter.

The most common serovar in this survey was *L. icterohaemorrhagiae(icterohaemorrhagiae-RGA)* with a prevalence of 57.1%. This contrasts with the 0.7% found with the more traditional antigen of *L. icterohaemorrhagiae(copenhageni)*. However, the clinical significance of *L. icterohaemorrhagiae-RGA* is dubious. No relationship could be established between the prevalence of reactors on a farm, and the farm's measures of reproduction (% born dead: r=.372, P=.214; or NPSD/P: r=.431 P=.186).

L. bratislava was prevalent in 35.1% of slaughter hogs. This is similar to other prevalences reported: 32% in 197 hogs in Ontario (76), 42% in 762 hogs in Iowa (79), 19.2% in 792 hogs in England (77). The significance of titres to *L. bratislava* is debatable (78, 82). On the one hand, this serovar is considered host-adapted to swine, and therefore causes mild infection (87), not associated with a clinical syndrome (88). Titres have been interpreted as the result of cross-reactions with other serovars (82). However, *L. bratislava* has been isolated from aborted fetuses (89, 90), and reproductive disease has resulted from experimental infection (91).

Interpretation of individual titres is difficult; serum antibodies were an unreliable guide to carrier status in cattle (92). Therefore herd level data were used in this study, resulting in farms with higher prevalence of *L. bratislava* titres being associated with infertility, as measured by NPSD/P (see Figure 3; r=.738, P=.036 using the conservative Bonferroni adjustment for four serovars). These results are similar to an English study that found *L. australis* (including *bratislava*, *lora*, and *australis*) serotitres were associated with infertility in sows (77). There was no association between prevalence of *L. bratislava* titres and % born dead (r=.372, P=.324).

L. autumnalis was prevalent in 3.4% of slaughter hogs. Stillbirths were no different (P=.342) on farms with *L. autumnalis* (7.4% born dead) than on farms without *L. autumnalis* (5.8% born dead). As well, there was no significant difference (P=.708) between 19.9 NPSD/P on farms with *L. autumnalis* and 23.1 NPSD/P on farms without *L. autumnalis*. This lack of significance suggests limited clinical use of *L. autumnalis* titres, although lack of power due to the use of only 11 farms may be a factor.

In summary, both *L. pomona* and *L. bratislava* were associated with infertility, as measured by NPSD/P. None of the four serovars tested were associated with increased stillbirths. Clinical significance could be established for neither *L. icterohaemorrhagiae-RGA* nor *L. autumnalis*.

5. ECONOMIC EFFICIENCY

5.1 Introduction

Veterinarians and others giving advice to swine producers have assumed that productivity and profitability are synonymous (6), although this is not necessarily the case (10). Adverse times require producers to improve profit by concentrating on improving the efficiency of their operation, rather than expanding facilities (93). However, there have been few references to economic efficiency of swine operations in the literature. Most "economic" references refer to the benefits and costs of health interventions on a single farm (94, 95, 96, 97, 98, 99). One paper (100) deals with the larger social picture of economic analysis (101). The computer spreadsheet PIGMONEY addresses the effect of changes of production parameters on production cost and income (102), but gives no consideration to the feasibility of change, and the cost of achieving and sustaining the change.

This chapter examines the cost of production as a preliminary step in evaluating profit and economic efficiency. Next the components of profit are examined; one of these, return to management and labour, is used as the measure of economic efficiency. Since economic efficiency is difficult to monitor on a regular basis, the ultimate objective of this chapter is to determine the ability of measures of biological productivity to predict economic efficiency. Productivity will be measured using standard parameters that are easily calculated, including pigs weaned per sow per year, marketed per sow per year, days to market or days on feed, and average daily gain. These were previously discussed in Chapter Two. Three additional parameters suitable for routine monitoring (weaned per crate per year, marketed per m^2 per year, and feeder barn animal density) were also evaluated. The relationships between these parameters and the overall measure of economic efficiency, RML, are examined as well as the relationships of the parameters with the components of RML (revenue, fixed costs, and variable costs). Since currently used biological parameters were at times inadequate to predict economic efficiency, a final parameter "feed cost per kg liveweight gain" was also included although it requires records not routinely kept.

5.2 Materials and Methods

A subset (21 producers) of the random sample described in Chapter Two was asked to keep detailed feed and financial records, in addition to production records, for one year.

The basic method of determining 1988 feed consumption was from year start feed inventory, plus feed purchased, plus feed harvested, less year end inventory. This was straightforward for herds feeding purchased feeds. On other farms, feed entered into storage tanks was recorded by volume, then converted to tonnes.

For farms mixing a protein concentrate with their own grain, a comparison was made between two methods of estimating feed consumption: (1) based on grain inventories and (2) based on the amount of concentrate fed and its proportion of the total ration. This comparison revealed an average 5% discrepancy between the two methods (see Appendix C). For these farms, the estimate based on concentrate consumption was used.

A few farms used only a vitamin/mineral premix with their own protein and grain ingredients. There were much larger discrepancies between the two methods of estimation on these farms, since very small errors in the amount of premix, or the mixing procedure were magnified in the amount of grain used. On these farms, therefore, the estimates based on grain inventory were chosen. Feed consumption on farrow-finish operations included all feed consumed by the breeding herd as well as the feeder pigs.

Production parameters for 1988 were also calculated for each farm. The indices previously described in Chapter Two were:

Marketed per sow per year (M/S/Y)
Weaned per sow per year (W/S/Y)
Days to Market (DTM)
Days on Feed (DOF)
Average Daily Gain (ADG)
Carcass Weight
Carcass Index

In addition the following parameters were calculated:

Weaned per farrowing crate per year (W/Cr/Y)
Feed conversion (F:G)
Marketed per square meter feeder pen space per year ($M/m^2/Y$)
Square meters pen space per feeder pig (m^2/pig)

Feed Conversion was calculated from farm feed consumption divided by total liveweight gain. Floor space allowance in the feeder barn (not including walkways or gutters) was measured in square meters. The m^2/pig referred to average density, since feeder barns were continuous flow, not all in - all out.

This study also utilized financial records for the calendar year 1988. Expenses were accounted for on an accrual basis, rather than the cash basis that all farms were using. Financial data (3) collected on the farm are shown in Table VIII. Costs of production have been classified into fixed or variable costs using the approach of cost-volume-profit analysis. Total fixed costs remain unchanged over a wide range of production levels; total variable costs rise with the level of production (103). Land value was ignored because it cannot be depreciated. Also, many problems are encountered in evaluation of farm real estate. Capital asset pricing of farm real estate requires knowledge of the percentage change in the index of farm real estate values, the percent return to land from farm production, and risk-free and risk premium rates of diversified investments (104). Capital costs were discounted at 12%. Operating capital was discounted at the same long-term rate, since an average inventory in animals and feed must be maintained over the long-term in order to ..main in business.

TABLE VIII. Cost of Production[a] for a Swine Operation

FIXED COSTS:	
Cost of Capital	-cost of average capital investment[b] at 12%
Equipment	-actual cost of swine equipment (not for crops) at time of purchase, depreciated over 10 years
Buildings	-actual cost of housing, grain storage, and manure storage at time of building or purchase, depreciated over 25 years (using straight line depreciation)
Repair and Maintenance	-1988 repair and maintenance costs of buildings and machinery
Property Taxes & Insurance	-1988 property tax and insurance costs
Miscellaneous	-1988 accounting and legal fees, office supplies
Total Fixed Expenses	-total of above fixed costs
VARIABLE COSTS:	
Feed Cost	-1988 costs (accounting for inventories) of purchased ingredients; homegrown grains were assigned year ave prices of: $120/T Barley $140/T Wheat $170/T Soybeans
Weaner Purchases	-adj. marketed[c] X farm's ave weaner price
Cost of Operating Capital	-Cost of average investment in feed and animals[d] at 12%
Utilities	-1988 telephone, electric, and heating costs
Total Drugs	-Sum of following drug costs:
Feed Medication	1988 costs of feed medication (extracted from feed bills)
Veterinary Bills	1988 veterinary service and drug costs
Other Veterinary Supplies	1988 drug and syringe costs (extracted from feed bills)
HCMB deduction	-$2.40 deduction per hog marketed
Fuel/Trucking	-1988 trucking and fuel costs (associated with manure handling, not crops)
Mortality Cost[e]	-FARROW-FINISH: PostWean Mortality X $25.00 FEEDER: Mortality X ave weaner price
Sow Depreciation	-Assumed difference between purchase and salvage of $100; used actual replacement rate
Boar Depreciation	-Assumed difference between purchase and salvage of $100; used actual replacement rate
Total Variable Expenses	-Total of above variable expenses
COSTS OF PRODUCTION	-Sum of Fixed and Variable Costs
Revenue	-ave carcass wt X $\frac{\text{aveindex}}{100}$ X $1.78[f] X adj marketed[c]
RETURN TO MANAGEMENT & LABOUR	-Revenue less costs of production
Labour	-First person-year assigned $25,000 Remaining assigned $6.00 per hour
PROFIT	-Revenue less (costs of production + labour)

[a] associated with operation of swine enterprise only

[b] cost of capital = $\frac{\text{cost of buildings+equipment}}{2}$ X .12

[c] adjusted marketed = hogs marketed + gilts retained + 1/2(change in inventory)

[d] operating capital = $\frac{\text{Feed Cost + Sow Depreciation+Boar Depreciation+Weaner Purchases}}{2}$*.12

[e] underestimated: accounts for replacement value, with remainder buried in other variable costs

[f] revenue includes market price and provincial stabilization

Economic efficiency was measured by return to management and labour (RML; see Table VIII). It is the conventional measure for evaluating relative economic efficiency, and making judgements about the allocation of resources to their highest and best use (105). It addresses important features such as facility availability (fixed costs were based on actual costs, not adjusted to avoid excess capacity), constant (1988) dollars, opportunity costs, and the use of actual farm productivity values instead of industry standards (106). It should be noted that this approach is not suitable for evaluation of short-term economic viability (105), since no attempt has been made to evaluate cash flow, asset liquidity, financial leverage (106), or income taxes (105). In the long-term, however, RML measures economic viability as well as economic efficiency.

For analysis, all data was entered into a microcomputer based data management software package. The experimental unit was the farm. Correlations, t-tests, and regression analyses were calculated using the mainframe computer package MINITAB (12). Statistical significance was assumed for p values less than 0.05 unless otherwise stated.

5.3 Results

Eighty-six percent (18 farms) of the randomly sampled producers agreed to participate; no farms were lost to follow-up. The 18 participating farms included 11 farrow-finish operations, and 7 feeder operations.

Productivity parameters are presented in Table IX. Financial parameters are presented in Tables X and XI. Since both farrow-finish and feeder operations market the same product, comparisons made between farrow-finish and feeder operations revealed that the two farm types were similar in marketed per m^2 space (T= 0.83, P=0.42), weight (T= -0.71, P=0.49), index (T=1.95, P=0.069), and density, as measured by m^2 space per feeder pig (T= 2.02, P=0.060). Farrow-finish operations, on average, demonstrated a higher return to management and labour per hog (RML) than feeder operations (T=3.23, P=.0028), although there was no difference in profit per hog (T=-.49, P=.634).

TABLE IX.
Descriptive Statistics of Biological Productivity

INDEX	MEAN	STDEV	MIN	MAX
11 RANDOMLY SELECTED FARROW-FINISH FARMS:				
Marketed/Sow/Yr	18.2	3.3	12.1	24.0
Wean/Sow/Yr	19.6	2.6	16.2	24.9
Weaned/Crate/Yr	82.8	23.7	64.2	146.6
Days to Market	200.1	12.7	185.0	217.0
Days on Feed	117.6	23.7	82.0	172.0
Average Daily Gain[a], kg	0.49	0.04	0.45	0.55
Kg Feed per Hog per Day	1.99	0.29	1.46	2.49
Feed:Gain Ratio	4.1	0.7	2.9	5.4
Feed cost/kg gain, $	0.86	0.09	0.71	1.01
m^2 space/feeder pig	0.75	0.12	0.61	0.94
Marketed per m^2 space	4.3	0.7	3.1	5.3
Carcass Weight, kg	78.6	1.6	76.4	82.1
Carcass Index	104.3	2.0	101.4	107.8
Sows kept per man equivalent	54	18	28	92
7 RANDOMLY SELECTED FEEDER FARMS:				
Days On Feed	145.9	20.5	127.0	186.0
Ave Daily Gain[b], kg/d	0.58	0.08	0.44	0.71
Kg Feed per Hog per Day	2.05	0.24	1.61	2.34
Feed/Gain	3.6	0.6	2.6	4.6
Feed cost/ kg gain, $	0.74	0.10	0.52	0.81
m^2 space / feeder pig	0.64	0.10	0.51	0.80
Marketed per m^2 space	4.0	0.9	2.8	5.5
Carcass Weight, kg	79.2	2.1	76.6	83.1
Carcass Index	102.8	0.9	101.6	104.1
Marketed per man equivalent	1938	699	1355	3368

[a] from birth to slaughter

[b] from purchase (at approximately 14 kg) to slaughter

Costs of production (excluding labour) are broken down for the average farrow-finish operation in Figure 4. The category "other variable costs" included fuel, marketing, sow and boar depreciation, and mortality, each of which contributed less than two percent to the costs of production. Costs of production (excluding labour) are broken down for the average feeder operation in Figure 5. The category "other variable costs" included fuel, marketing, utilities, and mortality, each of which contributed approximately one percent to the costs of production. It is interesting to note that feed companies, rather than veterinarians, accounted for 71% of drug costs on farrow-finish farms, and 86% of drug costs on feeder farms.

TABLE X.
Descriptive Statistics of Financial Parameters on 11 randomly selected farrow-finish farms

INDEX	MEAN	STDEV
Profit(Loss)/hog	($9.65)	$20.57
Labour/hog	$22.69	$7.95
Return to management&labour/hog	$13.05	$15.39
Revenue/hog	$146.01	$3.96
Fixed cost/hog	$25.27	$8.95
Variable costs/hog	$107.69	$10.99
Fixed cost/crate/year	$1893	$712
Feed cost per Tonne	$217.00	$35.2

FIGURE 4. Costs of Production for Farrow-Finish Operations

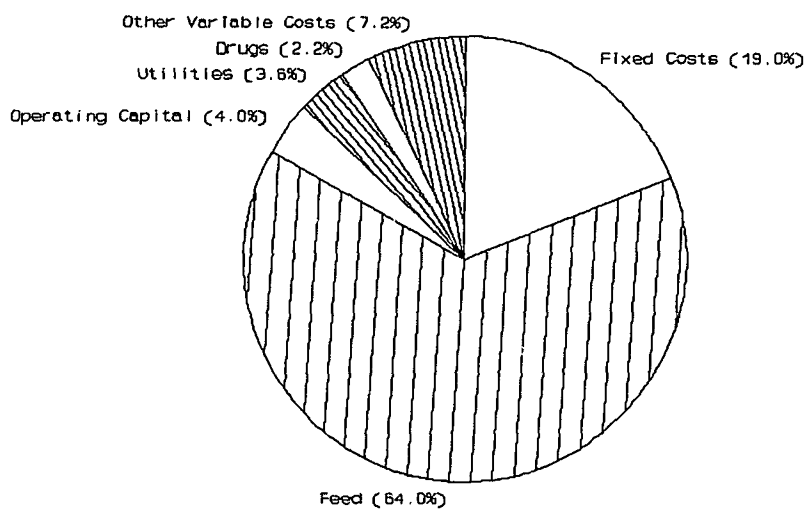
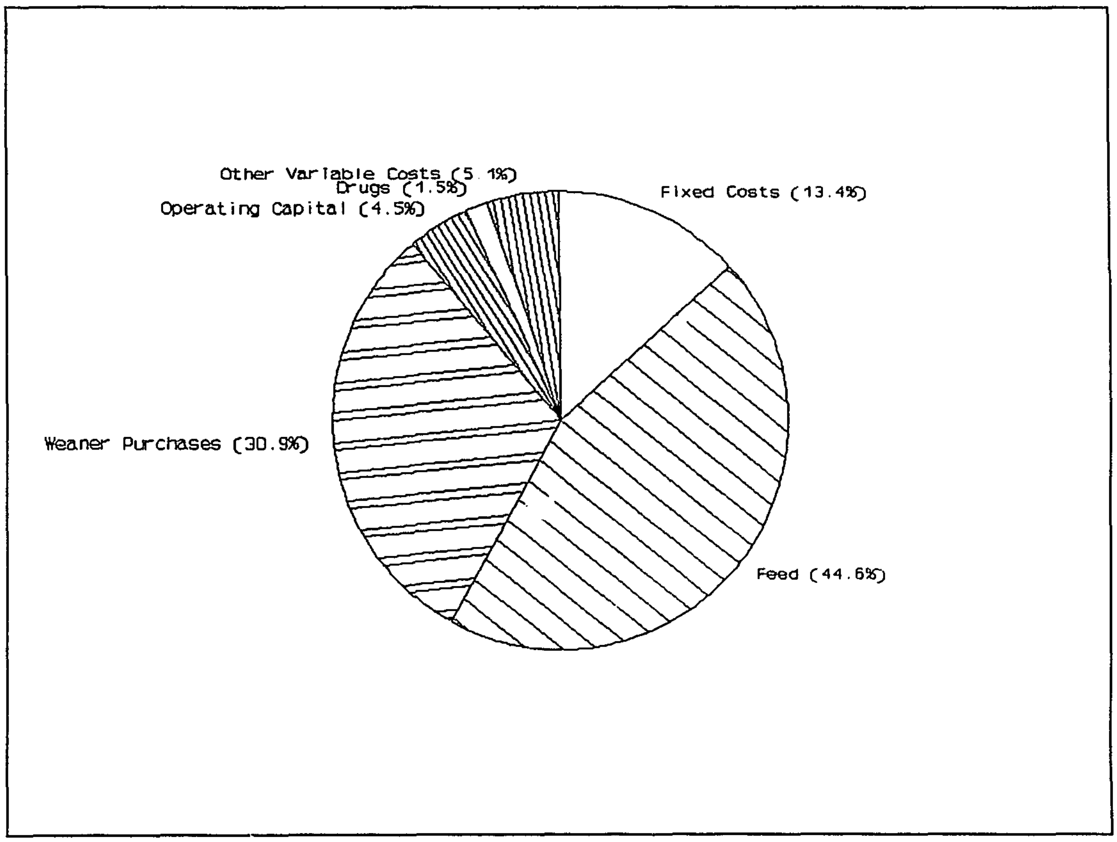


TABLE XI.
Descriptive Statistics of Financial Parameters
on 7 randomly selected feeder farms

INDEX	MEAN	STDEV
Profit(Loss)/hog	($5.54)	$10.48
Labour/hog	$12.72	$2.70
Return to management&labour/hog	$7.18	$9.21
Revenue/hog	$144.98	$3.78
Fixed cost/hog	$18.48	$5.67
Variable costs/hog	$119.32	$10.81
Feed cost per Tonne	$207.20	$27.8

FIGURE 5. Costs of Production for Feeder Operations

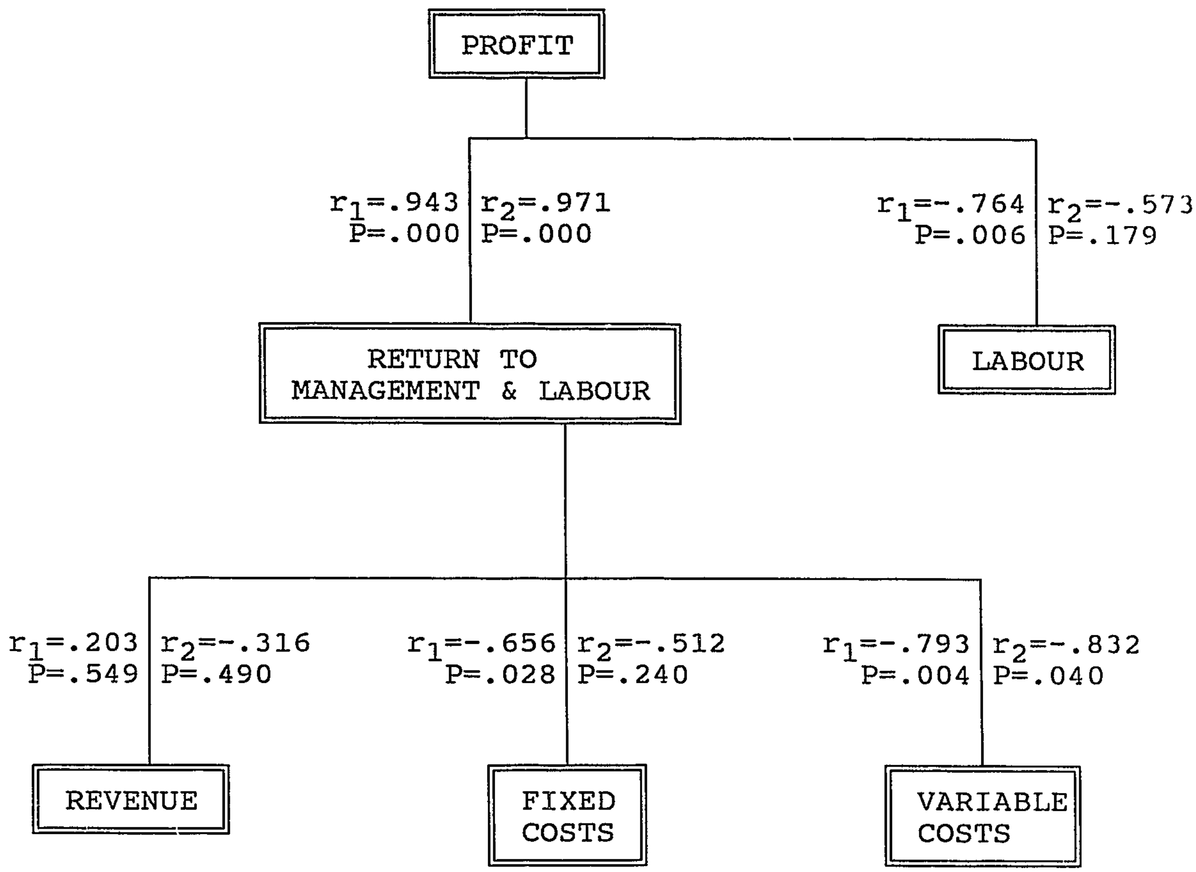


The components of profit and their correlations are displayed in Figure 6. There was no significant correlation between labour and RML on either farrow-finish farms (r=-.093, P=.798) or feeder farms (r=-.359, P=.429). Lack of correlation between these components means the variance of profit is approximated by the following sum (107): (SD return to management and labour)^2 + (SD labour)^2 Using the standard deviations in Table XI, 92% of the variation in profit between feeder farms was due to RML. On farrow-finish farms, RML accounted for 79% of variation in profit.

On farrow-finish farms, the components of RML also failed to show any significant correlations. (Revenue and fixed costs: r=.091, P=.790; revenue and variable costs: r=.001, P=.997; fixed and variable costs: r=.136, P=.689). This allows a breakdown of the variance of RML with variable costs accounting for 56%, fixed costs accounting for 37%, and revenue accounting for 7% of the variation in RML between farrow-finish farms.

On the other hand, feeder operations demonstrated a significant correlation between revenue and variable costs (r=.826, P=.022). This was due to significant correlations between market weight and revenue (r=.946, P=.001) and between market weight and variable costs (r=.786, P=.036). The other components of RML were not significantly correlated. (Revenue and fixed costs: r=-.394, P=.381; fixed and variable costs: r=-.227, P=.625).

FIGURE 6.
Components of Profit and their correlations for randomly selected Farrow-Finish farms (n=11) and Feeder Farms (n=7) in PEI



[box] contents on a per hog basis

r_1 = Pearson's P-M correlation coefficient using farrow-finish farms
r_2 = Pearson's P-M correlation coefficient using feeder farms

Regression analysis was used to determine the ability of a number of biological parameters to predict RML and its components. To avoid problems of collinearity, independence of all potential predictors that can be easily monitored were evaluated using a correlation matrix (Appendix D). Correlation coefficients greater than 0.40 were considered unacceptable. Strong correlations (>0.4) were found between W/S/Y, M/S/Y, and W/Cr/Y. Of these, M/S/Y was most highly correlated with RML; therefore it was chosen for inclusion in the analysis. Final regression models were determined using backward elimination (108) with alpha set at the .10 level, since statistical power was decreased by the small sample sizes. The results for farrow-finish farms are presented in Table XII.

The results for feeder farms are presented in Table XIII. Strong correlations (>0.4) were also found between $M/m^2/Y$, ADG, and DOF. $M/m^2/Y$, the most highly correlated with RML, was selected for inclusion in the regression analysis. Although $M/m^2/Y$ was not significantly correlated with RML, it was very close, and included in the analysis as the only parameter of any importance.

TABLE XII.

Prediction of Economic Efficiency and its components using Regression Analysis for 11 randomly selected Farrow-Finish Farms

Parameter	Coefficient	P-value
Return to Management and Labour:		
R^2=64.8%		
Marketed/sow/yr	1.84	0.096
Marketed/m^2/yr	16.5	0.008
Average Daily Gain		not significant
Weight		not significant
Constant	-91.6	0.012
Fixed Costs:		
R^2=30.7%		
Density	42.87	0.077
Days to Market		not significant
Weaned/crate/yr		not significant
Constant	-6.92	0.681
Variable Costs:		
R^2=94.3%		
Marketed/sow/yr	-0.66	0.044
Feed cost/kg gain	118.7	0.000
Days to Market		not significant
Constant	17.24	0.129

TABLE XIII.

Prediction of Economic Efficiency and its components using Regression Analysis for 7 randomly selected Feeder Farms

Parameter	Coefficient	P-value
Return to Management and Labour:		
R^2=43.7%		
Marketed/m2/yr	6.51	0.106
Index		not significant
Weight		not significant
Constant	-18.8	0.222
Fixed Costs:		
R^2=67.4%		
Density	32.68	0.045
Days on Feed		not significant
Constant	-0.79	0.919
Variable Costs:		
R^2=94.3%		
Feed cost/kg gain	91.98	0.012
Days on Feed		not significant
Constant	51.61	0.033

5.4 Discussion

Components of Profit and RML

The objective of commercial swine operations is to produce a single product, meat, for profit. Profit is determined by revenues less costs of production. Table III shows the average farm operated at a loss, although profit can be demonstrated using cash-based accounting, which ignores depreciation, inventory, and the owner's equity and labour. This situation is not limited to 1988; the standard measure of relationship between costs and revenues, the feed:pig ratio (4) was 23.3, very close to the ten year average of 23.5 bushels barley equalling 100 pounds of index 100 live hog (109). This means that in order to withdraw a living allowance from the operation, the average producer is not paid opportunity costs for his investment. This amounts to living off the depreciation, a situation that does not encourage new producers.

In order to deal with this situation, producers are interested in efficient production costs. This study first looked at the cost of labour. Labour was negatively correlated with profit (see Figure 3). However, labour accounted for only 8% of the variation in profit between feeder farms, and 21% of profit's variation between farrow-finish farms. For farms on this study, decreasing labour costs had limited potential for improving profit. Labour was difficult to quantify, since an arbitrary value was placed on the owner's time spent doing manual labour and managing the business. Also, decisions on labour costs are often based on availability, rather than financial consideration.

The difficulties with labour costs can be avoided by the removal of the labour component from profit. The remainder is called return to management and labour (RML). RML was highly correlated with profit (see Figure 6).

RML showed marked variance, with a difference of $47.95 per hog between the top and bottom producers. The source of this variation can be found by examining the components of RML (see Figure 6). Revenue was poorly correlated to RML, in contrast to fixed and variable costs. Revenue accounted for only 7% of the variation in RML between farrow-finish farms. The current marketing system allows little potential for improving profit through increasing revenue. This is not unique to swine farming; the entire agriculture sector has no control over market prices. Therefore, to maximize profit, the emphasis is placed on minimizing the costs of production. This is consistent with the findings on 109 herds near Cambridge, U.K., and on 324 Iowa herds, where researchers found 97% and 80% of variance in profit due to the cost of production including labour (4, 110).

RML is the accepted measure for evaluating relative economic efficiency (105). However, very few producers calculate this, since they record costs on a cash-flow basis. Veterinarians and other consultants have even less access to this information. Their recommendations on productivity attempt to help with farm decisions, in spite of the financial void they work in. There is a need to know how well current measures of productivity predict economic efficiency.

Predicting RML

Prediction of RML on farrow-finish farms revealed $M/m^2/Y$ and M/S/Y account for 64.8% of variation in RML (see Table XII). M/S/Y was a better determinant of economic efficiency than W/S/Y. W/S/Y, in research done on 15 sows in India, determined 84.5% of the variance in the sow's economic efficiency (111). However, marketed pigs are more closely associated with the farm's economic efficiency than are weaners.

The importance of $M/m^2/Y$ supports a previous reference to it as a measure of physical resource utilization (2). Improvement of $M/m^2/Y$ requires a balance between its components. The idea is to minimize DOF, and minimize space per pig, in spite of the negative correlation between the two ($r=-.519$, $P=.027$). Using average density recommendations of .54 m^2/pig (112), and 140 DOF, the optimum calculates to 4.8 $M/m^2/Y$. PEI's average of 4.3 $M/m^2/Y$ demonstrates competence at balancing these factors, especially compared to 26 Ontario farms that averaged 2.86 $M/m^2/Y$ (2).

Prediction of RML on feeder farms revealed $M/m^2/Y$ accounts for only 43.7% of variation in RML (see Table XIII). Presently recorded parameters on feeder farms are not adequate to effectively predict RML. This is most likely due to their failure to incorporate feed costs, the largest single cost of production.

It should be emphasised that there is no substitute for recording costs of production. The previous predictions were based on "average" costs detailed in Figures 4 and 5. The proportions will vary from farm to farm and year to year. On any one farm, fixed costs will be stable from year to year with the use of straight line depreciation. However, on a farm with recent capital investments, fixed costs represent a larger portion of the cost of production than demonstrated by the graphs in Figures 4 and 5.

Predicting Fixed Costs

Capital investments (fixed costs) are often justified as a substitute for labour. While this relationship was present on farrow-finish farms it was small and non-significant ($r=-.244$, $P=.470$). This is in agreement with an Iowa study of 324 farms (28). Fixed costs also failed to be warranted on the basis of reducing variable costs ($P=.689$, P=.625). The Iowa study also found that capital investment or age of facility has no effect on cash expenses to produce pork (28). In spite of this, fixed costs accounted for 40% of the variability in costs of production on farrow to finish farms. (The same formulae were used previously when breaking down the variance of profit).

Prediction of fixed costs revealed that biological parameters fail to adequately predict fixed costs on farrow-finish operations (see Table XII). W/Cr/Y is an index that describes the connection between facilities and sow productivity better than W/S/Y, since the number of crates fluctuates less than sow inventories, and the number of crates are more closely associated with the fixed costs of weaner production. However, W/Cr/Y, previously suggested as "an indicator of economic efficiency" (113), was not significant. This does not mean that this is a useless index; rather that both capital and production management are required to successfully operate a swine business. This is demonstrated by breaking down fixed costs:

$$\text{FIXED COSTS/WEANER} = \frac{\text{FIXED COSTS/CRATE}}{\text{WEANED/CRATE}}$$

This illustrates that low fixed costs per hog can be attained either by minimizing fixed costs per crate, or by maximizing W/Cr/Y. Each farm must find its own balance between these two extremes. However, fixed costs are inherited with the purchase of a facility, or put into place by longterm decisions; therefore, all farms, regardless of their fixed cost investment, can benefit from increasing W/Cr/Y. The optimum is 100 W/Cr/Y, assuming 4 week weaning of 9.5 pigs per litter, and 1 week optimum is 100 W/Cr/Y, assuming 4 week weaning of 9.5 pigs per litter, and 1 week crate turn around time. This exceeds this study's average of 83 W/Cr/Y, and the results of 60 W/Cr/Y in Iowa (114), and 57 W/Cr/Y in Ontario (2).

On feeder farms only 22% of the cost of production's variability was due to fixed costs; feeder operations are less variable in capital investment. This could be used to justify the use of gross margin analysis for feeder operations, the method used by Charette and Martineau (30). However, this method would underestimate the value of density, which predicts 67.4% of the fixed costs per hog (see Table XIII).

Predicting Variable Costs

Variable costs are the most important contributor to RML. As well, feed costs, the major component of variable costs, change from year to year. For example, barley prices paid at the PEI elevators have ranged over the last ten years from $75 per tonne in 1978 to $170 per tonne in 1985. Since feed costs are the number one cost of production, a related parameter (feed cost/kg gain) was included in the analysis, even though it is much more difficult to monitor than other biological parameters. Feed cost per kg gain accounted for 74.7% of variation in variable costs on feeder farms (see Table XIII). Feed cost per kg gain and M/S/Y account for 94.3% of variation on farrow to finish farms (see Table XII). The (not surprising) importance of feed cost per kg gain warrants a look at its definition:

FEED COST/KG GAIN = (FEED COST/KG) X (FEED:GAIN RATIO)

This index quantifies the need to consider not only feed conversion, but also feed cost (5).

Feed cost per tonne ranged $105.99 from the most to least expensive. Although the spread may be overestimated, since the cost of mixing ingredients is buried in other costs of production, it does demonstrate that considerable variation exists. A Cambridge study using 200 farms found this due mostly to the method of mixing ingredients; home-mix with mineral premix was less expensive than home-mix with protein concentrate, or purchased rations (5).

Feed conversion on farrow to finish farms averaged 4.1:1. Feeder operations averaged 3.6:1 from 14 kg to 98 kg liveweight. Feed conversion is dependent on genetics, feed quality or energy density, the physical and social environment, and disease prevalence (115). These factors make it almost impossible to compare feed conversion ratios reported elsewhere: farrow to finish farms in Iowa at 3.8:1 (114), feeder farms at 3.8:1 in Ontario (21 kg to 98 kg) (2), and the 3.0:1 of Cambridge herds feeding "baconers" from 27 kg to 90 kg (5). These difficulties underscore the advantages of using feed cost/kg gain for between farm comparisons. However, feed conversion, the measure of the relationship between feed consumption and weight gain, remains an important index to monitor on the farm. Feed intake above maintenance is utilized for gain, and consequently there is a positive relationship between average daily food intake and daily live-weight gain (33, 116). This study, however, did not find a correlation between feed consumption and daily gain (r=.018, P=.943). Assuming that operations on PEI have similar environments, it follows that the farm measurement of feed consumption accounts not only for the pig's intake, but also significant feed wastage.

An evaluation of feed cost vs. market weight was not possible with this farm-based data, since most farms marketed at about the same weight, and no two farms were feeding the same ration. One paper which looked at this using weight, index, dressing percentage, and the relationship between feed intake and daily gain on individual pigs found the ideal market weight between 100 to 110 kg (117). The relationship between feed intake and daily gain has been shown to diminish at high levels of feed intake (33, 116). The diminishing return response of daily gain to increasing feed intake corresponds to curvilinear feed conversion; this supports the proponents of restricted feeding (33, 118, 119). On the other hand, Kanis admits that maximum feed efficiency on a corn and soy bean meal diet is at 87% *ad lib* for barrows, and 100% *ad lib* for gilts (33), which is very close to the *ab lib* feeding recommended by others (116, 120).

Interrelations between components obscure any one "ideal" route to maximize return. Days on feed are a function of feed efficiency and market weight; increased DOF increases all variable costs (121). Maximum density, on the other hand, will minimize fixed costs. However, decreasing space allowances below the recommended .55 m^2 (for a pig between 24 and 100 kg) reduces feed conversion (112, 122, 123), while more space than recommended has not been shown to improve feed conversion (112, 122). The powerful influence of density on profitability was also demonstrated by Backstrom, who showed that although crowding pigs at twice the recommended density did translate into a smaller operating profit per hog, the larger quantity of pigs moving through the facilities created more profit per farm (124).

In summary, there are many pathways to improving performance. The currently measured production indices most closely associated with economic efficiency were $M/m^2/Y$ and M/S/Y. Feeder operators with concern about fixed costs should concentrate on improving the hog density. All farms should be encouraged to record feed consumption, to be able to monitor feed conversion, and the index best associated with economic efficiency, feed cost per kg gain.

6. SUMMARY OF RESULTS AND CONCLUSIONS

6.1 Biological Productivity

Sow and feeder pig productivity was measured on a random sample of 32 PEI swine farms (each producing over 1,000 market hogs per year). Productivity parameters can be arranged in a hierarchy, with the highest level on farrow-finish operations represented by weaned per sow per year. The 17 farrow-finish farms in this study averaged 19.6±2.2 pigs weaned per sow per year. This average compares well with other regions: 16.8 in Ontario, 19.9 in Cambridge, England, and 19.7 on North American PigChamp herds. However, large variation between farms was also revealed with a range from 16.2 to 24.9 weaned per sow per year. The major opportunities for improvement, as compared to reviewed targets, lie in reducing the average weaning age from 33.6±4.8 days, reducing preweaning mortality from 15.5±3.9 percent, and reducing nonproductive sow days per parity from 19.9±11.0 days.

Feeder operations were characterized by 0.58±.07 kg average daily gain (ADG). Days on feed averaged 146±18.4 days, and mortality averaged 3.3±1.3 percent. ADG was negatively correlated with mortality ($r=-.662$, $P=.010$), suggesting that herds that manage a high rate of gain also manage lower mortality.

6.2 Respiratory Disease

Slaughter checks and serology for *Mycoplasma hyopneumoniae* (MH) and *Actinobacillus pleuropneumoniae* (AP) were carried out on twenty-five slaughter hogs from each of eighteen randomly sampled farms (a subset of the previous random sample).

<u>Individual Hog Data</u>

Anteroventral lung lesions were present in 50.5% of hogs. Hogs with serologic titres greater than 1:100 for MH and/or positive ELISA for AP were more likely to have lung lesions than hogs with negative serology (P=.000). Multivariable analysis (logistic regression) was subsequently used to assess the potential confounding effect of farm, and to assess the significance of the interaction between MH and AP. Neither AP (P=.227) nor the interaction between MH and AP (P=.512) were significant once MH and a farm of origin were included in the model. These analyses suggest that of the two agents studied, MH was more closely associated with the presence of anteroventral lung lesions.

Pleuritis was present in 15.4% of the hogs. Pleuritis did not appear to be associated with either of the agents studied. There were no differences in the prevalence of pleuritis among seronegative hogs, hogs exposed to MH, AP, or both (P=.478).

Herd Level Data

Lung lesions were present, on average, in 46.3% of hogs per farm with a range of 1.2% to 79.1%. Interestingly, herds could easily be categorized into two groups according to prevalence of lung lesions: 5 farms had 0-5% prevalence of lung lesions, and the other 13 farms had 44-80% prevalence of lung lesions. No seasonal trends in the prevalence of lung lesions were found (P=.427) with average prevalences of 43.6% in the winter, 46.8% in the spring, and 49.7% in the summer.

Snout scores were more severe in the winter, when the mean herd average snout score was 0.86, than in the summer, when the mean herd average snout score was 0.56 (P=.0017).

Farms with a high percentage of hogs showing lung lesions also had a high percentage of hogs test positive to MH (r=.646, P=.004). Although AP was also associated with lung lesions (r=.587, P=.010), the correlation was not as strong. Linear regression was subsequently used to simultaneously assess the relationship between prevalence of lung lesions, and the prevalence of MH, AP, and the interaction between MH and AP. Neither AP (P=.133) nor the interaction between MH and AP (P=.325) were significant once MH was included in the model. This parallels the individual hog results, suggesting that of the two agents studied, MH was more closely associated with the presence of anteroventral lung lesions.

6.3 Leptospirosis

Production records and leptospirosis serology were analyzed for twenty-five slaughter hogs from each of eleven randomly sampled farrow-finish operations (a subset of the previous random sample of 18 producers). Nonproductive sow days per parity (NPSD/P) was chosen as the overall measure of infertility. Reproductive disease causes abortions, missed heats that lengthen the wean-to-breed interval, reduced farrowing rates and conception rates. All of these increase NPSD/P. The effect of selected leptospiral serovars on the proportion of pigs born dead was also evaluated.

The possibility of cross reactions confusing the prevalence results was investigated using contingency table analysis. The two most common serovars, *L. bratislava* and *L. icterohaemorrhagiae-RGA*, did not appear to be reacting to the same antigen (McNemar's chi-square=32.53, P=.000; Kappa=0.23).

Leptospiral titres to any serovar were prevalent in 66.4% of slaughter hogs. *L. pomona*, the serotype most commonly incriminated in reproductive problems, was present in only 1.5% of slaughter hogs.The frequency of stillbirths was no different (P=.378) on the 3 farms with *L. pomona* (7.5% born dead) than on the 8 farms without *L. pomona* (6.0% born dead). However, a significant difference (P=.0008 using the conservative Bonferroni adjustment for four serovars) was found between the mean of 39.1 NPSD/P on farms with *L. pomona* compared to 14.7 NPSD/P on farms without *L. pomona*. This suggests that NPSD/P should be considered along with parameters traditionally used to monitor the effects of leptospirosis (% born dead and litter scatter).

The most common serovar was *L. icterohaemorrhagiae(icterohaemorrhagiae-RGA)* with a prevalence of 57.1%. However, this serovar was not associated with either herd measure of reproduction (% born dead: r=.372, P=.214; or NPSD/P: r=.431 P=.186).

Titres to *L. bratislava* were prevalent in 35.1% of slaughter hogs. Farms with a higher prevalence of *L. bratislava* titres tended to have more infertility, as measured by NPSD/P (r=.738, P=.036 using the conservative Bonferroni adjustment for four serovars). There was no association between prevalence of *L. bratislava* titres and % born dead (r=.372, P=.324).

L. autumnalis was prevalent in 3.4% of slaughter hogs. The frequency of stillbirths were no different (P=.342) on the 6 farms with *L. autumnalis* (7.4% born dead) than on the 5 farms without *L. autumnalis* (5.8% born dead). There was also no significant difference (P=.708) between 19.9 NPSD/P on farms with *L. autumnalis* and 23.1 NPSD/P on farms without *L. autumnalis*. This suggests that *L. autumnalis* has little impact on fertility on swine farms.

In summary, the seroprevalences evaluated by this study in slaughter hogs have likely underestimated the cumulative incidence of leptospirosis in the older sow population, since the limited lifespan of a slaughter hog has fewer opportunities for exposure compared to the longer lifetime of a sow. Both *L. pomona* and *L. bratislava* were associated with infertility, as measured by NPSD/P. None of the four serovars tested were associated with increased stillbirths.

6.4 Economic Efficiency

Detailed feed, financial, and production records were maintained by a random sample of twenty-one producers (a subset of the original random sample of 32 producers). Relative economic efficiency of the operations was measured using return to management and labour (RML). It is the conventional measure for evaluating relative economic efficiency, and making judgements about the allocation of resources to their highest and best use. In the long-term RML measures economic viability as well as economic efficiency.

RML can be broken into three components: revenue, fixed costs, and variable costs. Revenue was poorly correlated to RML, in contrast to fixed and variable costs. Revenue accounted for only 7% of the variation in RML. The limited potential for improving RML through increasing revenue placed the emphasis on minimizing the costs of production.

Regression analysis was used to determine the ability of a number of biological parameters to predict RML and it's components.

<u>Farrow-finish Operations</u>

Of the routinely monitored biological parameters, RML on PEI farrow-finish operations is best predicted (R^2=64.8%) by: marketed per square meter per year (P=.008), and marketed per sow per year (P=.096). Marketed per sow per year was a better determinant of economic efficiency than weaned per sow per year, since marketed pigs are more closely associated with the farm's economic efficiency than are weaners.

Fixed costs accounted for 40% of the variability in costs of production on farrow to finish farms. Regression of fixed costs revealed that biological parameters have limited ability to predict fixed costs on farrow-finish operations (R^2=30.7%). The only parameter contributing to the prediction of the fixed cost component of RML was feeder hog density (P=.077).

The variable cost component of RML was predicted (R^2=94.3%) by feed cost per kg gain (P=.000), and marketed per sow per year (P=.044). Although feed cost per kg gain is difficult to calculate from records currently maintained on most farms, it was included in this analysis to reflect feed cost, the number one cost of production.

Feeder Operations

The biological parameters recorded on feeder farms in this study had only limited ability to predict RML (R^2=43.7%). The only parameter of any importance was marketed per square meter per year (P=.106).

On feeder farms, 22% of the variability in the cost of production was due to fixed costs; feeder operations were less variable in capital investment than farrow-finish operations. Prediction of the fixed cost component of RML (R^2=67.4%) was best realized by measuring feeder hog density (P=.077).

The variable cost component of RML was reasonably well predicted (R^2=74.7%) by feed cost per kg gain (P=.012). Although difficult to monitor from records currently maintained on most farms, it points out the need to record feed consumption on swine farms.

7. APPENDIX A

P.E.I. DEPARTMENT OF AGRICULTURE

SWINE PRODUCTIVITY PROGRAM

IDENT. #: ______________________

NAME: ______________________

ADDRESS: ______________________

TELEPHONE: ______________________

REPORT FOR PERIOD ENDING: ______________________

INVENTORY AT END OF 28 DAY PERIOD				**END OF PERIOD**
# Open Gilts				______
# Sows & Bred Gilts				______
# Boars				______
# Nursing Pigs				______
# Weaners				______
# Feeders				______
SALES	**WEEK 1**	**WEEK 2**	**WEEK 3**	**WEEK 4**
# Gilts	______	______	______	______
# Sows	______	______	______	______
# Boars	______	______	______	______
# Weaners	______	______	______	______
# Hogs	______	______	______	______
PURCHASES				
# Gilts/Sows	______	______	______	______
# Boars	______	______	______	______
# Weaners	______	______	______	______
PRODUCTION				
# Gilts Retained	______	______	______	______
# Boars Retained	______	______	______	______
# Sows/Gilts Bred	______	______	______	______
# Return to Heat	______	______	______	______
# Abortions	______	______	______	______
# Sows Farrowed	______	______	______	______
# Pigs Born Alive	______	______	______	______
# Pigs Born Dead	______	______	______	______
# Sows Weaned	______	______	______	______
# Pigs Weaned	______	______	______	______
# Pigs to Feeder Barn	______	______	______	______
DEATH LOSSES				
# Gilts/Sows	______	______	______	______
# Boars	______	______	______	______
# Preweaning	______	______	______	______
# Weaners	______	______	______	______
# Feeders	______	______	______	______

Notes: Complete report for every 4 weeks (28 day period). Suggest weeks begin Monday a.m. and finish Sunday p.m.

Return to: LIVESTOCK SERVICES, PEI DEPARTMENT OF AGRICULTURE
P.O. BOX 1600, CHARLOTTETOWN, PEI C1A 7N3

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8. APPENDIX B

Comparison between Self-Selected and Random groups of Farrow-Finish Farms

Index	Self-Selected	Random	Pvalue
Number of Herds	6	17	
Weaned/Sow/Year	18.8	19.6	.4418
Litters/Sow/Year	2.11	2.19	.2187
NonProductive Sow Days/Parity	19.2	19.9	.8883
Sow:Boar Ratio	17.8	21.1	.2506
Ave Weaning Age, d	37.5	33.6	.1034
Weaned/Litter	8.9	9.0	.7454
PreWeaning Mortality	16.7	15.5	.5824
Ave Born Alive	10.7	10.6	.7286
% Born Dead	4.3	5.0	.0458
Replacement Rate	44.6	38.0	.3421
Marketed/Sow/Year	17.3	18.3	.4356
PostWeaning Mortality	7.9	7.5	.8179
Days To Market	196	201	.5630
Ave Sow Inventory	81	106	.3070
% Open Gilts	12.8	3.6	.0769

Wilks' Lambda = 0.224 (P= 0.2671)

9. APPENDIX C

Rations fell into three categories: (1) Purchased complete ration, (2) Purchased protein concentrate separately from grain, or (3) Purchased mineral premix separately from grain and protein source.

Operations that purchased complete rations had accurate weights to calculate farm feed consumption. Operations in the other two categories had some error in estimating farm grain consumption. The different estimates using the grain inventory method and the proportional to purchased concentrate or premix method are detailed below.

TABLE OF GRAIN CONSUMPTION

Farm ID	T Grain (inventory)	T Grain (proportional)	% discrepancy
PURCHASED CONCENTRATE:			
1	777.3	856	+9.1%
4	569	626.6	+9.2%
6	463	430	-7.1%
7	549.32	587.66	+6.5%
10	475.77	494.06	+3.7%
11	581	556	-4.3%
12	757	739.7	-2.3%
13	466.3	421.3	-9.6%
14	640	635	-0.8%
16	322.88	328	+1.6%
Average of Absolute Values:			5.4%
PURCHASED PREMIX:			
2	527	459	-13%
5	499	364	-27%
18	860	1050	·18%
17	360	295	·18%

10. APPENDIX D

Correlation matrices used to determine inclusion of variable in regression analyses to predict RML and its components are detailed below.

Correlation matrix for predictors of RML on Farrow-Finish operations:

	W/S/Y	M/S/Y	W/Cr/Y	M/m2/Y	ADG	index
M/S/Y	0.928					
W/Cr/Y	0.668	0.533				
M/m2/Y	-0.162	-0.106	-0.055			
ADG	-0.151	-0.073	-0.368	0.3125		
index	0.867	0.814	0.469	0.083	-0.369	
weight	-0.009	0.098	-0.155	-0.139	0.374	-0.151

Correlation matrix for predictors of RML on Feeder operations:

	M/m2/Y	ADG	index
ADG	0.544		
index	-0.244	-0.594	
weight	-0.439	0.315	-0.204

Correlation matrix for predictors of Fixed Costs on Farrow-Finish operations:

	M/m2/Y	m2/pig	DTM
m2/pig	-0.242		
DTM	-0.631	-0.095	
W/Cr/Y	-0.055	-0.370	0.387

Correlation between predictors of Fixed Costs on Feeder operations:
Correlation of DOF and m2/pig = 0.143

Correlation matrix for predictors of Variable Costs on Farrow-Finish operations:

	W/S/Y	M/S/Y	feed cost/kg gain
M/S/Y	0.928		
feed cost/kg gain	0.134	0.044	
DTM	0.178	0.129	0.267

Correlation matrix for predictors of Variable Costs on Feeder operations:

	DOF	feed cost/kg gain
feed cost/kg gain	0.348	
ADG	-0.942	-0.247

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