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93
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THE EPIDEMIOLOGICAL INVESTIGATION OF PIG DISEASES

**A thesis presented in partial fulfilment of the requirement for the
Degree of Doctor of Philosophy at Massey University**

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Abstract

A series of epidemiological studies was carried out to identify methods of improving productivity of New Zealand and Thai pig herds. Disease surveillance at slaughter of 2,807 finisher pigs from 3 piggeries in the North Island of New Zealand was conducted over a 13 month period. This was used to establish and apply procedures suited to New Zealand conditions, for monitoring the subclinical status of 8 production-limiting diseases and 1 zoonotic disease. Enzootic pneumonia, sarcoptic mange and oesophagogastric ulcer were the most commonly observed lesions. Seasonal patterns were found for enzootic pneumonia, pleurisy and ascariasis lesions. Seasonal effects were found to be associated in part with temperature variation.

The effectiveness of simultaneous administration of commercial *Mycoplasma hyopneumoniae* and *Actinobacillus pleuropneumoniae* vaccines was assessed in 380 pigs from an indoor commercial piggery. These vaccines produced significant improvement of growth rate during the high risk period for clinical pneumonia, and increased slaughter weight. Enzootic pneumonia lesions were significantly reduced by more than 50%, but pleurisy and pleuropneumonia lesions were not significantly reduced. No evidence of synergy between the vaccines in influencing lesion severity for pleuropneumonia was detected.

A longitudinal study of thirty cohort pigs was conducted within the vaccination trial, to describe the epidemiological pattern of subclinical *A. pleuropneumoniae* infection of healthy pigs. *A. pleuropneumoniae* was first isolated at 4 weeks of age from one vaccinated pig. The incidence of *A. pleuropneumoniae* infection reached a maximum of 54% and 40% at 11 weeks of age in vaccinated and control pigs. No evidence was found to support the hypothesis that infection with *M. hyopneumoniae* increases susceptibility to *A. pleuropneumoniae* infection.

Pig production data from 16 Thai and 18 New Zealand pig herds for 1991, and from 14 Thai and 16 New Zealand herds for 1992 were analysed to define opportunities for improving productivity in temperate and tropical environments. In Thailand, potential areas for improving productivity are particularly through increasing total litter size and improved management of breeding procedures. In New Zealand, potential areas for improvement are particularly reduction of stillbirths and pre-weaning mortality, and reduction of sow mortality. A new method of graphical presentation of important productivity parameters was used to clearly demonstrate differences in performance between the two countries.

PigFIX, a fertility investigation expert system linked to a computer-based herd recording system, was developed to provide diagnostic guidance on likely causes of fertility problems and offer guidance on possible corrective action. A novel approach was used in developing the method by which PigFIX assessed reproductive performance. Graphical and text-based reports were developed to show the user what conclusions had been drawn in the analysis. PigFIX was shown in verification studies on six herds to produce conclusions which agreed with a human expert on identification of major reproductive problems.

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TABLE OF CONTENTS

	Page
ABSTRACT	i
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	v
LIST OF TABLES	xi
LIST OF FIGURES	xiv
 CHAPTER 1 INTRODUCTION	 1
 CHAPTER 2 LITERATURE REVIEW	 9
Introduction	11
Observational investigations	11
Descriptive study	11
Cross-sectional study	12
Case-control study	12
Cohort study	13
Experimental investigations	13
Intervention study	13
Theoretical investigations	15
Outbreak investigations	17
Factors which influence epidemiological investigation methods	17
Randomization	17
Statistical power	19
Bias	19
Pig production recording systems	19
Expert systems	20
Components of expert systems	21
Expert system shells	23
Type of expert systems	23
Towards expert system development in agriculture	25
 CHAPTER 3 DISEASE SURVEILLANCE AT SLAUGHTER UNDER NEW ZEALAND CONDITIONS	 27

Introduction	29
Materials and methods	29
Data collection	30
Statistical analysis	33
Results	34
Sarcoptic mange	34
Enzootic pneumonia	37
Pleurisy	43
Pleuropneumonia	45
Liver white spot	48
Nephritis	50
Proliferative enteropathy	53
Oesophagogastric ulcer	55
Discussion	59
Sample size	60
Sarcoptic mange	60
Enzootic pneumonia	60
Pleuropneumonia and pleurisy	61
Liver white spot	61
Nephritis	61
Proliferative enteropathy	61
Oesophagogastric ulcer	62
Atrophic rhinitis	62
Environmental temperature	63
Conclusion	63
CHAPTER 4 FIELD EFFICACY OF <i>MYCOPLASMA HYOPNEUMONIAE</i> AND <i>ACTINOBACILLUS PLEUROPNEUMONIAE</i> VACCINES IN PIGS	67
Abstract	68
Introduction	69
Materials and methods	70
Clinical trial design	70
Vaccination programme	70
Data collection	70
Lung scoring procedure	71
Statistical analysis	71
Results	71
Weights, ADG, FCR at different stages and days to market	72
Degree of severity of enzootic pneumonia, pleurisy and pleuropneumonia lesions	73
Discussion	76
Acknowledgements	77

CHAPTER 5	EPIDEMIOLOGY OF <i>ACTINOBACILLUS PLEUROPNEUMONIAE</i>	
	INFECTION IN PIGS	81
	Abstract	82
	Introduction	83
	Materials and methods	84
	Clinical trial design	84
	Vaccination programme	84
	Collection of samples	84
	Culture media	85
	Microbiological techniques	85
	Lung scoring procedure	86
	Statistical analysis	86
	Results	87
	Culture of nasal swabs	87
	Lung lesions at slaughter	89
	Incidence of <i>A. pleuropneumoniae</i> infection	89
	Infection status of other pigs in litter	91
	Discussion	94
	Acknowledgements	97
CHAPTER 6	COMPARISON OF PIG PRODUCTION BETWEEN TWO	
	COUNTRIES WITH TROPICAL AND TEMPERATE CLIMATES	99
	Introduction	101
	Materials and methods	101
	Data	101
	<i>Production parameters</i>	102
	Data analysis	103
	<i>Graphical presentation</i>	103
	Results	104
	Yearly reproductive performance	104
	<i>Yearly population profile</i>	104
	<i>Yearly breeding performance</i>	108
	<i>Yearly farrowing performance</i>	113
	<i>Yearly weaning performance</i>	117
	Monthly reproductive performance	120
	<i>Monthly population profile</i>	120
	<i>Monthly breeding performance</i>	126

<i>Monthly farrowing performance</i>	136
<i>Monthly weaning performance</i>	148
Discussion	156
Violin plots	156
Areas for improving productivity in each management system	156
<i>Population profile</i>	156
<i>Breeding performance</i>	157
<i>Farrowing performance</i>	157
<i>Weaning performance</i>	158
Monthly figures	159
Summary	159
CHAPTER 7 PIGFIX - A PIG FERTILITY INVESTIGATION EXPERT SYSTEM	161
Abstract	162
Introduction	163
Program design	264
Components of the PigFIX system	165
<i>Knowledge base</i>	165
<i>Inference engine</i>	169
<i>User interface</i>	172
Development of suitable boundaries between ranges	173
Representation of results to the user	174
Discussion	183
Expert system VS Decision support system	183
Expert system design methods	183
Development to date	183
Further development of PigFIX	184
Conclusion	184
CHAPTER 8 VERIFICATION OF PIGFIX	185
Abstract	186
Introduction	187
Materials and methods	188
Results	188
Case 1	188
Case 2	192
Case 3	195
Case 4	198

Case 5	201
Case 6	204
Discussion	207
CHAPTER 9 GENERAL DISCUSSION	209
Introduction	211
Disease surveillance at slaughter	211
Control of respiratory diseases using vaccines	212
Investigation of <i>A. pleuropneumoniae</i> in healthy carrier pigs using a cohort study	214
Investigation of non-infectious diseases in the breeding area	214
Investigation of pig fertility using an expert system (PigFIX)	215
Verification against the real scenario	216
Future development of PigFIX	216
Conclusion	217
REFERENCES	219

LIST OF TABLES

	<i>Page</i>
Table 3.1 Averages of environmental temperature (mean $\pm$ SD) by severity categories of sarcoptic mange	37
Table 3.2 Averages of environmental temperature (mean $\pm$ SD) by severity categories of enzootic pneumonia	43
Table 3.3 Averages of environmental temperature (mean $\pm$ SD) by severity categories of pleurisy	45
Table 3.4 Averages of environmental temperature (mean $\pm$ SD) by pleuropneumonia lesion status	48
Table 3.5 Averages of environmental temperature (mean $\pm$ SD) by severity categories of liver white spot	50
Table 3.6 Averages of environmental temperature (mean $\pm$ SD) by nephritis lesion status	53
Table 3.7 Averages of environmental temperature (mean $\pm$ SD) by proliferative enteropathy lesion status	55
Table 3.8 Averages of environmental temperature (mean $\pm$ SD) by severity categories of oesophagogastric ulcer	58
Table 3.9 Average percent prevalence of disease conditions per slaughter check	58
Table 3.10 Prevalences of disease conditions (%) by season	59
Table 4.1 Average weights, ADG, FCR at different development stages and days to market (mean $\pm$ SD) by treatment status	73
Table 4.2 Results of two-way repeated measures ANOVA for effects of treatment, time and interaction between treatment and time on weight	73
Table 4.3 Degree of severity categories of enzootic pneumonia, pleurisy and pleuropneumonia lesions [number of affected pigs (percentage of affected pigs)] by treatment status	74
Table 4.4 Average total scores and average lung scores of enzootic pneumonia lesions for each lung lobe (mean $\pm$ SD) by treatment status	75
Table 4.5 Percentage prevalence of EP lesions on a lobar basis by treatment status ...	75
Table 5.1 Lung lesions between the 2 groups [percent prevalence (no. of findings / total samples)]	90

Table 5.2	Relationship between <i>A. pleuropneumoniae</i> infection and infection status of other pigs from same litter	92
Table 5.3	Relationship between age of first isolation of <i>A. pleuropneumoniae</i> and infection status of other pigs from same litter (Early = 4 - 11 wks; Late = greater than 11 wks)	92
Table 6.1	Comparison of yearly population profile between the two countries	106
Table 6.2	Comparison of yearly breeding performance between the two countries	109
Table 6.3A	Comparison of yearly farrowing performance between the two countries .	113A
Table 6.3B	Comparison of yearly farrowing performance between the two countries .	113B
Table 6.4	Comparison of yearly weaning performance between the two countries . . .	118
Table 6.5	Comparison of monthly population profile between the two countries	122
Table 6.6	Summary of results of 2-way ANOVA of 3 key parameters in the population profile area parameter group	122
Table 6.7	Comparison of monthly breeding performance between the two countries	128
Table 6.8	Summary of results of 2-way ANOVA of 6 key parameters in the breeding parameter group	129
Table 6.9	Comparison of monthly farrowing performance between the two countries	138
Table 6.10	Summary of results of 2-way ANOVA of 7 key parameters in the farrowing parameter group	139
Table 6.11	Summary of results of a multiple comparison analysis between months ($P < 0.05$) for adjusted farrowing rate and litters /mated female /year	140
Table 6.12	Comparison of monthly weaning performance between the two countries	150
Table 6.13	Summary of results of 2-way ANOVA of 4 key parameters in the weaning parameter group	151
Table 7.1	Relationship between ranges and points on performance line	167
Table 7.2	Values of ranges for pre-weaning mortality parameter	168
Table 7.3	Subset of parameters read from the Performance Monitor Report and stored in a flat table in Microsoft Access	170
Table 7.4	Actual values classified into ranges	171

Table 7.5	Possible parameter classification patterns associated with the diagnosis “High Pre-weaning Mortality”	171
Table 7.6	Numerical values of ranges associated with the diagnosis of “High Pre-weaning Mortality”	175
Table 8.1	Comparison of reports produced by an expert and PigFLX	207

LIST OF FIGURES

	<i>Page</i>
Figure 3.1 Bar chart of total pigs examined by month from May 1992 to July 1993 . . .	34
Figure 3.2 Bar chart of severity categories of sarcoptic mange for each farm (percent prevalence on top of bar)	35
Figure 3.3 Bar chart of percent prevalence of sarcoptic mange by month	36
Figure 3.4 Bar charts of severity categories of sarcoptic mange for each season (percent prevalence on top of bar)	36
Figure 3.5 Histogram distribution of total lesion scores of enzootic pneumonia (percentage on top of bar)	38
Figure 3.6 Histogram distribution of total lesion scores of enzootic pneumonia on farm A	39
Figure 3.7 Histogram distribution of total lesion scores of enzootic pneumonia on farm B	39
Figure 3.8 Histogram distribution of total lesion scores of enzootic pneumonia on farm C	39
Figure 3.9 Histogram distributions of total lesion scores of severity categories of enzootic pneumonia (percentage on top of bar)	40
Figure 3.10 Histogram distributions of total lesion scores of enzootic pneumonia by season (percentage on top of bar)	40
Figure 3.11 Histogram distributions of total lesion scores of enzootic pneumonia (acute category) by season (percentage on top of bar)	41
Figure 3.12 Bar charts of severity categories of enzootic pneumonia for each farm (percent prevalence on top of bar)	41
Figure 3.13 Bar chart of percent prevalence of enzootic pneumonia by month	42
Figure 3.14 Bar charts of severity categories of enzootic pneumonia for each season (percent prevalence on top of bar)	42
Figure 3.15 Bar charts of severity categories of pleurisy for each farm (percent prevalence on top of bar)	44
Figure 3.16 Bar chart of percent prevalence of pleurisy by month	44
Figure 3.17 Bar chart of severity categories of pleurisy for each season (percent prevalence on top of bar)	45

Figure 3.18	Bar charts of pleuropneumonia lesion status for each farm (percent prevalence on top of bar)	46
Figure 3.19	Bar chart of percent pleuropneumonia prevalence by month	47
Figure 3.20	Bar charts of pleuropneumonia lesion status for each season (percent prevalence on top of bar)	47
Figure 3.21	Bar chart of severity categories of liver white spot for each farm (percent prevalence on top of bar)	49
Figure 3.22	Bar chart of percent prevalence of liver white spot by month	49
Figure 3.23	Bar chart of severity categories of liver white spot for each season (percent prevalence on top of bar)	50
Figure 3.24	Bar charts of severity categories of nephritis for each farm (percent prevalence on top of bar)	51
Figure 3.25	Bar chart of percent prevalence of nephritis by month	52
Figure 3.26	Bar charts of severity categories of nephritis for each season (percent prevalence on top of bar)	52
Figure 3.27	Bar charts of severity categories of proliferative enteropathy for each farm (percent prevalence on top of bar)	54
Figure 3.28	Bar chart of percent prevalence of proliferative enteropathy by month	54
Figure 3.29	Bar chart of severity categories of proliferative enteropathy for each season (percent prevalence on top of bar)	55
Figure 3.30	Bar charts of severity categories of oesophagogastric ulcer for each farm (percent prevalence on top of bar)	56
Figure 3.31	Bar chart of percent prevalence of oesophagogastric ulcer by month	57
Figure 3.32	Bar charts of severity categories of oesophagogastric ulcer for each season (percent prevalence on top of bar)	57
Figure 3.33	Percent prevalence of proliferative enteropathy before and after fire on study farm	62
Figure 5.1	Positive predictive values for a differential combination of diagnostic attributes of <i>Actinobacillus pleuropneumoniae</i> infection (in percent)	88
Figure 5.2	Percent point prevalence of <i>A. pleuropneumoniae</i> infection in cohort pigs	88
Figure 5.3	Percent incidence of <i>A. pleuropneumoniae</i> infection in cohort pigs	91
Figure 5.4	Survivorship functions for vaccinated and control groups	93

Figure 6.1	Violin plots of average yearly replacement rate for the 2 countries	105
Figure 6.2	Violin plots of average yearly cull rate for the 2 countries	107
Figure 6.3	Violin plots of average yearly death rate for the 2 countries	107
Figure 6.4	Violin plots of average yearly entry to service interval for the 2 countries . .	110
Figure 6.5	Violin plots of average yearly wean to service interval for the 2 countries . .	110
Figure 6.6	Violin plots of average yearly percentage of sows bred by seven days for the 2 countries	111
Figure 6.7	Violin plots of average yearly percentage of repeat services for the 2 countries	111
Figure 6.8	Violin plots of average yearly non productive sow days for the 2 countries	112
Figure 6.9	Violin plots of average yearly non productive sow days per parity record for the 2 countries	112
Figure 6.10	Violin plots of average yearly total pigs per litter for the 2 countries	113
Figure 6.11	Violin plots of average yearly pigs born alive per litter for the 2 countries .	114
Figure 6.12	Violin plots of average yearly percentage of stillborn pigs for the 2 countries	114
Figure 6.13	Violin plots of average yearly percentage of mummies for the 2 countries . .	115
Figure 6.14	Violin plots of average yearly adjusted farrowing rate for the 2 countries . .	115
Figure 6.15	Violin plots of average yearly farrowing interval for the 2 countries	116
Figure 6.16	Violin plots of average yearly litters per mated female per year for the 2 countries	116
Figure 6.17	Violin plots of average yearly pigs weaned per litter for the 2 countries . . .	117
Figure 6.18	Violin plots of average yearly pre-weaning mortality rate for the 2 countries	119
Figure 6.19	Violin plots of average yearly age at weaning for the 2 countries	119
Figure 6.20	Violin plots of average yearly pigs weaned per mated female per year for the 2 countries	120
Figure 6.21	Violin plots of average monthly replacement rate for the 2 countries	123
Figure 6.22	Line plots of average replacement rate for the 2 countries by month (1991-92)	123

Figure 6.23	Violin plots of average monthly cull rate for the 2 countries	124
Figure 6.24	Line plots of average cull rate for the 2 countries by month (1991-92)	124
Figure 6.25	Violin plots of average monthly death rate for the 2 countries	125
Figure 6.26	Line plots of average death rate for the 2 countries by month (1991-92) . . .	125
Figure 6.27	Violin plots of average monthly entry to service interval for the 2 countries	130
Figure 6.28	Line plots of average entry to service interval for the 2 countries by month (1991-92)	130
Figure 6.29	Violin plots of average monthly wean to service interval for the 2 countries	131
Figure 6.30	Line plots of average wean to service interval for the 2 countries by month (1991-92)	131
Figure 6.31	Violin plots of average monthly percentage of sows bred by seven days for the 2 countries	132
Figure 6.32	Line plots of average percentage of sows bred by seven days for the 2 countries by month (1991-92)	132
Figure 6.33	Violin plots of average monthly percentage of repeat services for the 2 countries	133
Figure 6.34	Line plots of average percentage of repeat services for the 2 countries by month (1991-92)	133
Figure 6.35	Violin plots of average monthly non productive sow days for the 2 countries	134
Figure 6.36	Line plots of average non productive sow days for the 2 countries by month (1991-92)	134
Figure 6.37	Violin plots of average monthly non productive sow days per parity record for the 2 countries	135
Figure 6.38	Line plots of average non productive sow days per parity record for the 2 countries by month (1991-92)	135
Figure 6.39	Violin plots of average monthly total pigs per litter for the 2 countries	141
Figure 6.40	Line plots of average total pigs per litter for the 2 countries by month (1991-92)	141
Figure 6.41	Violin plots of average monthly pigs born alive per litter for the 2 countries	142

Figure 6.42	Line plots of average pigs born alive per litter for the 2 countries by month (1991-92)	142
Figure 6.43	Violin plots of average monthly percentage of stillborn pigs for the 2 countries	143
Figure 6.44	Line plots of average percentage of stillborn pigs for the 2 countries by month (1991-92)	143
Figure 6.45	Violin plots of average monthly percentage of mummies for the 2 countries	144
Figure 6.46	Line plots of average percentage of mummies for the 2 countries by month (1991-92)	144
Figure 6.47	Violin plots of average monthly adjusted farrowing rate for the 2 countries	145
Figure 6.48	Line plots of average adjusted farrowing rate for the 2 countries by month (1991-92)	145
Figure 6.49	Violin plots of average monthly farrowing interval for the 2 countries	146
Figure 6.50	Line plots of average farrowing interval for the 2 countries by month (1991-92)	146
Figure 6.51	Violin plots of average monthly litters per mated female per year for the 2 countries	147
Figure 6.52	Line plots of average litters per mated female per year for the 2 countries by month (1991-92)	147
Figure 6.53	Violin plots of average monthly pigs weaned per litter for the 2 countries ..	152
Figure 6.54	Line plots of average pigs weaned per litter for the 2 countries by month (1991-92)	152
Figure 6.55	Violin plots of average monthly pre-weaning mortality for the 2 countries	153
Figure 6.56	Line plots of average pre-weaning mortality for the 2 countries by month (1991-92)	153
Figure 6.57	Violin plots of average monthly age at weaning for the 2 countries	154
Figure 6.58	Line plots of average age at weaning for the 2 countries by month (1991-92)	154
Figure 6.59	Violin plots of average monthly pigs weaned per mated female per year for the 2 countries	155

Figure 6.60	Line plots of average pigs weaned per mated female per year for the 2 countries by month (1991-92)	155
Figure 7.1	Diagram of the components of PigFIX	164
Figure 7.2	Rapid prototyping (Roberts, 1990)	165
Figure 7.3	Points and ranges of actual parameter values on performance line	167
Figure 7.4	Pattern diagnosis of pre-weaning mortality in PigFIX	172
Figure 7.5	Performance monitor report generated by PigCHAMP	176
Figure 7.6	Final report generated by PigFIX	177
Figure 7.7	Diagnostic Tree Output - Basic Structure	178
Figure 7.8	PigFIX Diagnostic Tree - Example Problem Definition for High Sow Return Rate	180
Figure 7.9	PigFIX Diagnostic Tree - Example Problem Definition for High Pre-weaning Mortality	181
Figure 7.10	PigFIX Diagnostic Tree - Example Problem Definition for High Pre-weaning Mortality	182
Figure 8.1	Performance monitor report for AA1031 farm	190
Figure 8.2	Final report for AA1031 farm generated by PigFIX	191
Figure 8.3	Performance monitor report for AA1037 farm	193
Figure 8.4	Final report for AA1037 farm generated by PigFIX	194
Figure 8.5	Performance monitor report for AA1034 farm	196
Figure 8.6	Final report for AA1034 farm generated by PigFIX	197
Figure 8.7	Performance monitor report for AA1032 farm	199
Figure 8.8	Final report for AA1032 farm generated by PigFIX	200
Figure 8.9	Performance monitor report for AA1036 farm	202
Figure 8.10	Final report for AA1036 farm generated by PigFIX	203
Figure 8.11	Performance monitor report for AA1028 farm	205
Figure 8.12	Final report for AA1028 farm generated by PigFIX	206

CHAPTER 1

Introduction

Introduction

Worldwide, pig diseases represent one of the major limiting factors in intensive pig production. Epidemiological investigation methods have contributed increasingly over recent years to the control and eradication of pig diseases and improvement of productivity in pig herds. Examples of such investigational approaches are discussed in a literature review. However there is a need for exploring the value and limitations of various epidemiological methods in studying pig health and production, and in developing methods for delivering improved veterinary services to pig herds.

This thesis consists of a series of studies, in which diverse epidemiological techniques are applied to different categories of pig diseases. Two main themes are pursued - in the growing pig, diseases affecting performance; and in the breeding herd, non-infectious influences on annual piglet production per sow.

In the grower-finisher area of the intensive piggery, a range of infectious and non-infectious diseases affect growth rate, feed conversion efficiency, and survival. One way of exploring this is through the use of slaughter checks, which provide valuable data on the prevalence of a range of pathological conditions in slaughter weight pigs. This technique has become more widely used in recent years, especially in Australia. However only limited information has been published on results from slaughter checks in New Zealand, and epidemiological methods have not been used to examine patterns in such findings.

Monthly lesion prevalence data was therefore obtained over a 14 month period from three herds for which the clinical situation on the farm of origin was known, in order to examine in some detail seasonal variation and between-farm variability in the prevalence of those diseases which are susceptible to accurate detection in examinations conducted on the slaughter floor. This provided an evaluation of the value of such cross-sectional data in repeated sampling, and offers guidance for field veterinarians on how they can make best use of slaughter checks.

However, such methods are limited to examining diseases which are visually detectable at slaughter, and provide no insights into the dynamics of the diseases during the growth period of the pig. This requires a different approach, and the longitudinal study method can provide valuable understanding of this temporal aspect of disease processes. In order to provide such a dynamic viewpoint on one of

the main groups of diseases studied in the slaughter pigs, an intervention trial was conducted for respiratory disease using simultaneous vaccination against *Actinobacillus pleuropneumoniae* and *Mycoplasma hyopneumoniae*.

At the same time a longitudinal study of the epidemiology of *A. pleuropneumoniae* infection from weaning to slaughter was also conducted in cohorts of vaccinated and unvaccinated animals within the same herd, to determine the epidemiological pattern of *A. pleuropneumoniae* infection in a typical commercial piggery and to study the incidence and prevalence of *A. pleuropneumoniae* infection in pigs at various stages of growth. This aspect of the disease cannot be accurately assessed only on pigs of slaughter weight.

In combination, these three different epidemiological approaches provide understanding of the diseases beyond what could be obtained from any one of the approaches alone, and they complement each other in clarifying the importance of the diseases and the benefits of control measures. The value and limitations of each of the techniques is considered in the final discussion chapter.

In the breeding herd, computer software has become the standard method in recent years for conducting analyses of reproductive records to identify scope for improving performance. This requires skill in carrying out epidemiologically valid interpretation of variation between categories of animals, and variation over time within a herd. If this is to be extended to comparison between farms, it requires that the records are kept in a standard format in all of the herds under observation.

It is likely that the underlying factors affecting inter-herd variation in reproductive performance will differ between countries, especially where these differ as substantially in their climates as a tropical and a temperate country. In order to examine all these issues, reproductive records from selected Thai and New Zealand piggeries which had been recorded in the same computer program were used to study epidemiological patterns of reproductive performance for the two years 1991 and 1992.

This provides an understanding of the natural variability in various reproductive indices, which then helps in improving methods of diagnosis of reproductive disorders. Because diagnosis of such disorders through epidemiological methods requires quite subtle interpretation of changes in a range of indices, the technique of pattern diagnosis has been used to simultaneously evaluate a number of different indices. However many veterinarians have difficulty in applying such techniques, which rely on quantitative assessments of a number of variables being undertaken jointly, with interpretation

CHAPTER 2

Literature review

Introduction

Epidemiology involves the measurement of diseases on a population basis, and the use of these measurements to determine causal associations. In the second stage of the epidemiological approach to disease, control measures based on this understanding of causal associations are designed and implemented. "Study" is a general term which refers to any type of investigation (Thrusfield, 1986). Knowledge about causal factors may be obtained from various sources - personal experiences, information obtained from others, study of literature or formal studies of problems. To gain the knowledge about causal associations, epidemiological investigations are frequently used. Epidemiological field investigation methods can be divided into four major categories:

Observational investigations

Experimental investigations

Theoretical investigations

Outbreak investigations

Observational investigations

Observational investigations are non-experimental analytic studies in which the investigator monitors, but does not influence, the exposure status of individual subjects and their subsequent disease status (Greenberg, 1993). They include descriptive, cross-sectional, case-control and cohort studies. Advantages and limitations of observational studies have been described elsewhere (Schlesselman, 1982; Dohoo and Waltner-Toews, 1985a; Dawson-Saunders and Trapp, 1990; Morris, 1990a).

Descriptive Study

Descriptive studies are designed primarily to record events and observations, leading to generation of hypotheses. The essential feature of their design is that they do not include control animals or patients to compare with the study subjects. Descriptive studies include case report, case series and case study (Dohoo and Waltner-Toews, 1985b; Morris, 1990a).

Case report

The major feature of this type of descriptive study is that a rare condition or uncommon manifestation of a more common condition is described in some detail such as a case report of porcine pleuropneumonia (Cameron and Kelly, 1979).

Case series

A case-series report is a simple descriptive study covering multiple occurrences of the condition in different groups of animals, describing the usual clinical manifestations of a condition, and perhaps interesting or unusual characteristics of some incidents. Advantages and limitations of case series studies have been described by Dawson-Saunders and Trapp (1990).

Case study

A case study is a detailed study of one or more livestock units which are known to be affected by a disease of interest, or perhaps by multiple disease conditions. This study is used to provide detailed data for a large scale disease investigation, or to provide a description of a disease condition which is inadequately defined.

Cross-sectional study

A cross-sectional study (often called a survey in published papers) is defined as an observational study carried out on a representative sample of a population. It examines the relationship between a disease or other health-related characteristics and independent variables of interest (some of which may be the hypothesised causal factors), as they exist in a defined population at one particular time (Neumann, 1990a). Repeated cross-sectional studies or a longitudinal study can be used to measure epidemiological indicators such as prevalence and mortality rate, and to relate these to factors such as location, management system and farm income (Morris, 1990). Examples of cross-sectional studies or surveys include an investigation of pre-weaning mortality in a herd of Large White pigs (Sharpe, 1966), a survey of neutralizing antibodies against some porcine viruses in swine pig herds (Zindel *et al.*, 1980), a study of the epidemiology of *Haemophilus* (now *Actinobacillus*) *pleuropneumonia* infection in Ontario pork enterprises in 1981 (Rosendal and Mitchell, 1983) and a cross-sectional study of the seroprevalence of *Actinobacillus pleuropneumoniae* serotype 2 in Danish pig herds (Vraa-Andersen and Barfod, 1994). Advantages and limitations of cross-sectional studies have been described elsewhere (Dohoo and Waltner-Toews, 1985a; Perry, 1988; Dawson-Saunders and Trapp, 1990; Morris, 1990a).

Case-control study (Retrospective study)

A case-control study is defined as an observational study which starts with the identification of animals (or herds) which have the disease of interest and a suitable control (comparison, reference) group of animals (or herds) without the disease. It involves collection and analysis of data on disease determinants in the two groups (Neumann, 1990a). Design, conduct and analysis of case-control studies have been described elsewhere (Schwabe *et al.*, 1977; Schlesselman, 1982; Thrusfield, 1986;

Martin *et al.*, 1987). Modifications of case-control studies can improve their value such as nested case-control studies (Ernster, 1994). Examples of case-control studies include analyses of lung lesions at slaughter and the identification of associations with factors in the pig herd (Aalund *et al.*, 1976) and the prevalence of leptospirosis and its association with multi focal interstitial nephritis in swine at slaughter (Baker *et al.*, 1988). Advantages and limitations of case-control studies have been described elsewhere (Schlesselman, 1982; Dohoo and Waltner-Toews, 1985a; Perry, 1988; Dawson-Saunders and Trapp, 1990; Morris, 1990).

Cohort study (Prospective study)

The definition of cohort study is a study in which subsets (cohorts) of a defined population are identified which are exposed at different degrees to a factor which is hypothesised to influence the probability of occurrence of the disease or some other outcome of interest. The occurrence of the outcome in the cohorts is compared between groups over time. Examples of cohort studies include an investigation of the causes of mortality and morbidity in sows in a commercial herd (Jones, 1967), a prospective radiographic study of swine pneumonia (Noyes *et al.*, 1988), a prospective study of sow mortality in commercial breeding herds (Chagnon *et al.*, 1990), and an analysis of risk factors related to infection with *Actinobacillus pleuropneumonia* and *Mycoplasma hyopneumonia* in swine (Vraa-Andersen, 1991). Advantages and limitations of cohort studies have been described elsewhere (Schlesselman, 1982; Dohoo and Waltner-Toews, 1985a; Perry, 1988; Dawson-Saunders and Trapp, 1990; Morris, 1990).

Experimental investigation

An experimental investigation is defined as a study in which the conditions and the degree of exposure of animals to the factor of interest are under the direct control of the investigator. The basic difference between observational and experimental methods is that investigators have no control over the allocation or treatment of animals in observational studies (MacMahon and Pugh, 1970; Lilienfield, 1976)

Intervention study (clinical trial, experiment, field trial)

The term intervention study (and its various synonyms) is used for any controlled comparative study involving new treatments, procedures or (health) management systems. The essential feature of an intervention study is a planned comparison of two or more treatment (or prophylactic) regimens. The

intervention study provides the strongest available evidence that modification of a factor can influence occurrence of a disease, and is used extensively in both human and veterinary medicine. General concepts related to the design of field trial were described (Martin, 1978; Dohoo and Thomas, 1989).

Clinical trials can be divided into 2 categories: Controlled clinical trials and uncontrolled clinical trials. Controlled clinical trials are viewed as having far greater validity than uncontrolled clinical trials. Some studies use patients or animals as their own controls (self- controlled study) and the self controlled study design can be modified to provide a combination of concurrent and self controls, called a cross-over study. The cross-over study provides within-subject comparisons, which is more sensitive and precise for testing of treatment effects (Everitt, 1989). Examples of clinical trials include the evaluation of the effectiveness of a monoclonal antibody against K88ac for control of colibacillosis (Hall *et al.*, 1986), and a controlled clinical field trial against atrophic rhinitis in a problem herd (Agger *et al.*, 1988).

The major items to be considered in the design of field trials include:

- 1) Stating the hypothesis
- 2) Defining the reference population and selecting the experimental population
- 3) Calculating the sample size
- 4) Assigning members of the experimental population to treatment and control groups
- 5) Specifying the treatment regime
- 6) Measuring compliance and minimizing bias
- 7) Selecting and measuring response variables
- 8) Comparison of the level or frequency of the outcome of interest in the treatment and control groups

In human medicine, 67 papers describing clinical trials which had been published in the *New England Journal of Medicine*, the *Lancet* and the *British Medical Journal* from July to December 1979 and in the *Journal of the American Medical Association* from July 1979 to June 1980 were reviewed (DerSimonian *et al.*, 1982). Eleven important aspects of design and analysis were identified. They were: (1) eligibility criteria (information explaining the criteria for admission of patients to the trial); (2) admission before allocation; (3) random allocation; (4) method of randomization; (5) patients' blindness to treatment; (6) blind assessment of outcome; (7) treatment complications; (8) loss to follow-up; (9) statistical analyses; (10) statistical methods and (11) power. Of all 11 items in the 67 trials published in all 4 journals, 56% were clearly reported, 10% were ambiguously mentioned, and

34% were not reported at all. At least 80% of the trials reported information about statistical analyses, statistical methods used, and random allocation of subjects. However, only 19% reported the method of randomization. Patients' blindness to treatment were reported in 55% of the articles, treatment complications in 64%, eligibility criteria in 37% and power in only 12%.

In 1990, Altman and Doré reported that 30% of 80 reports of randomised clinical trials provided no clear evidence that the groups had been randomised. Among the clinical trials that used simple randomization the sample sizes in the two groups were similar, and there was an unexpected small bias in favour of there being fewer patients in the experimental group.

In veterinary medicine, 147 papers and short communications describing clinical field trials involving veterinary medical products (antibiotics and chemotherapeutics, anthelmintic and ectoparasite treatment, anaesthetics, hormones, minerals and vaccines) published in *The Veterinary Record* from 1988 to 1992 were reviewed (Elbers and Schukken, 1995). They found that half of the publications did not use random allocation to treatment or the allocation was unknown, and 94% did not state whether they used single or double blind techniques. Twenty-five per cent of the studies did not conduct a formal statistical analysis of the results and none of them calculated the statistical power of the analysis. Elbers and Schukken's study suggested that the use of good clinical trial designs was more common than an earlier report had indicated (Bording, 1990).

Statistical analysis used in epidemiological investigations is beyond the scope of this review. However, the statistical methods and analyses in clinical trials have been reviewed by a number of studies (Gore *et al.*, 1976; Shott, 1985; Bland and Altman, 1986; Altman, 1991; Simon, 1991; Hammer and Buffington, 1994).

Theoretical investigations

Modelling is the representation of events in quantitative mathematical terms, and prediction of events over a period of time by operation of a model (Thrusfield, 1986). The largest group of animal health models has dealt with infectious and parasitic disease processes, such as foot and mouth disease modelling (Klaering, 1980), mathematical modelling of the prevalence of *Ascaris suum* (Goodall *et al.*, 1991). Subsequently management strategies in livestock herds have been investigated by this approach (Marsh and Morris, 1985). The purposes of modelling are to make predictions of disease

incidence or prevalence, to better understand the underlying biomedical mechanism involved in the disease, and to test hypotheses about these mechanisms (Schwabe, 1977).

Morris and Marsh (1992) defined the purpose of modelling more broadly, as being to build a simplified representation of a complex system within the real world, in order to test procedures which would be too costly or impractical for various reasons to test on the real world system. Such models can include physical replicas, mental or conceptual models, mathematical representations which are solved by analytical methods and representations. Types of models and applications of the various modelling approaches have been described (Schwabe *et al.*, 1977; Thrusfield, 1986; Martin *et al.*, 1987; Morris and Marsh, 1992).

Computers have been used extensively to simulate diseases, and in some models economic factors have been incorporated (Morris, 1972). The graphical representation of concepts or processes, the statistical manipulation of data to determine associations between factors and the mathematical expression of dynamic processes of infectious diseases were presented in a series of papers on the modelling of vector-borne and other parasitic diseases (Perry and Hansen, 1992).

There are 2 fundamental ways of representing disease processes. The first is deterministic, in which the processes built into the model are fixed by the coefficients set for each variable, and no biological variability is allowed for. Such models always produce the same outcome for any given set of parameters and initial conditions. An example of the deterministic approach is the Reed-Frost model which describes major factors involved in herd immunity for human epidemics (Frost, 1976) and the economic return from a particular treatment in swine production (Borne, 1994). The second is stochastic or probabilistic, in which outcomes of at least some of the processes are obtained by drawing samples randomly from standard statistical distributions or empirical distributions based on field data. Such models produce different outcomes for each run, and it is necessary to run the model a number of times (commonly five, and in some cases as many as ten) in order to represent the range of likely outcomes and provide a reasonable estimate of the mean outcome (Meek and Morris, 1981). Deterministic models are faster to run, but it is more difficult to make them realistically represent the disease control issues of interest at a practical rather than a theoretical level. Both of the approaches have their uses, and the one chosen depend on the nature of the problem and the kinds of answers required; deterministic models are valuable for deriving general principles, while stochastic models are applicable to analysing specific practical problems.

Outbreak investigations

An outbreak is defined as an identified occurrence of disease involving one or more animals. The term generally implies that several animals are affected and that the incidence or prevalence of disease is above the expected range for the circumstances. The *Office International des Epizooties* has suggested that the occurrence of disease within a 50 km² area constitutes an outbreak, even though the disease may be found in several places in that area. Gardner (1988) outlined that the objectives of outbreak investigation are:

- to diagnose a disease condition
- to identify factors associated with disease prevalence, incidence and severity
- to identify factors associated with impaired productivity
- to estimate the financial impact of a disease condition or suboptimal performance
- to recommend treatment, control and preventive measures
- to change client's attitudes or methods.

Steps in the epidemiological approach to an outbreak investigation were described by Morris (1990b) and Neumann (1990b). Examples of outbreak investigations are an outbreak of pleuropneumonia among a group of baconers (Nielsen, 1973), an outbreak of *Haemophilus parahaemolyticus* pneumonia in growing pigs (Davidson and King, 1980), a stillbirth investigation (Gardner, 1988), and outbreaks of *Actinobacillus suis* septicemia in mature swine, which resembled erysipelas (Miniats *et al.*, 1989).

Factors which influence epidemiological investigation methods

A range of factors influence how well epidemiological investigations succeed in achieving their objectives. The following are factors over which the investigator has a substantial degree of control, and which can therefore be used to ensure that investigational objectives are achieved as well as possible.

Randomization

Randomization is defined as a procedure for assigning subjects to different treatment groups on a random basis (Dawson-Saunders and Trapp, 1990). The purpose of randomization is to achieve "equivalence" of baseline characteristics of treatment groups, so that the comparison of treatments is

considered fair, and to meet the requirement of statistical analysis that observations be based on randomly allocated animals, so that variances of groups are independent estimates of the population variance. Randomness can be achieved by selecting random numbers from a random number table available in standard statistics textbooks (Dawson-Saunders and Trapp, 1990) or using a computerized random number generator.

Random sampling from populations for choosing animals to be examined for estimating disease prevalence (or other epidemiological purposes) can be achieved using probability sampling to ensure that a sample will lead to reliable and valid inference. The four commonly used methods are simple random sampling, systematic sampling, stratified sampling and cluster sampling. However, non-probability sampling, such as convenience sampling and quota sampling, may be seen in some research articles. Non-probability samples are likely to reflect selection biases of the investigator conducting the study and do not fulfill the requirements of randomness needed to estimate sampling errors.

Simple random sampling

A simple random sample is one in which every subject has an equal probability of being selected for the study.

Systematic sampling

A systematic sample is one in which every k th item is selected; k is determined by dividing the number of items in the sampling frame by the desired sample size. Systematic allocation using a random starting point is an acceptable method of randomization for some study designs under field conditions, but should not be used when feasible alternatives are available, because it can produce bias in the sample.

Stratified sampling

A stratified random sample is one in which the population is first divided into relevant strata (subgroups), and a random sample is then selected from each stratum.

Cluster sampling

A cluster random sample results from a two-stage process in which the population is divided into clusters and a subset of the clusters is selected randomly, then all members of the selected clusters are examined.

Statistical power

Statistical power or power is defined as the probability of rejecting the null hypothesis when it is false or of accepting the alternative hypothesis when it is true. In general terms, the statistical power is the ability of a study to detect a difference with a given sample size if the difference really exists (Dawson-Saunders and Trapp, 1990). The statistical power is calculated as $1 - \beta$ (type II error) and the statistical power for a study with a beta level of 0.20 would be 0.80 or 80%. Such a study would have an 80% chance of detecting a specified difference in the outcome variable between treatment groups. Calculation of statistical power should be performed prior to implementation of the studies. The calculation can be performed using computer software (Goldstein, 1989). The statistical power of various study and statistical methods has been discussed in some studies (Martin, 1978; Ribble, 1989; Sedlmeier and Gigerenzer, 1989; Altman and Doré, 1990; Cohen, 1992; Elbers and Schukken, 1995).

Bias

Bias is defined as any effect at any stage of an investigation or inference tending to produce results that depart systematically from the true values. A comprehensive list of sources of bias has been published (Sackett, 1979). One of the most common types of bias is a confounding factor, which is a factor related to both the cause and outcome under investigation, and which alters the apparent relationship between the two (Stellman, 1987). Confounding factors can be controlled by study design or in the analysis if an appropriate form of analysis is used, such as multivariate statistical analysis and analysis of covariance. Examples of confounding factors in the analysis of pig production records have been described (Deen, 1991). Bias was discussed in some studies (Dohoo and Waltner-Toews, 1985c; Feinleib, 1987; Ribble, 1989; Kass and Greenland, 1991).

Pig production recording systems

Production data is an essential part in pig production, as this information keeps track of pigs from birth until slaughter. Examples of data which are recorded include farrowing date, total pigs born, pigs born alive, gestation length, birth weight, feed conversion ratio and weaning to service interval. A list of terms and definitions recommended for use in manual and computer-based recording systems has been described by Davies *et al.* (1983).

Initially, production data was recorded only for use by the producers themselves. The information was used to enhance and maintain the efficiency and profitability of the pig herds. Later on, pig production

information has become useful for a number of groups involved in the pig industry. Different users require different detail of information. Examples of potential users of the information include producers, veterinarians, artificial insemination stations, research scientists, slaughter houses and the feed mill industry. More recently recording systems have been modified from manual to computer-based systems. More advanced systems covering health and animal management are now available.

The following software packages represent a selection of pig herd health management software which is currently available. PigCHAMP® (University of Minnesota, College of Veterinary Medicine, St. Paul, Minnesota) is an MS-DOS based self-contained on-farm system running on a microcomputer platform. It is devised as a management support tool providing a range of reports and production statistics for producers. SWINE GRAPHICS (Swine Graphics Inc, Des Moines, Iowa) is a centralized system requiring mailing in of production records and is maintained for example by a consultancy bureau. It does not provide management support but facilitates horizontal comparison between production units. PIG TALES (Pig Improvement Company, Franklin, Kentucky) is used by the Pig Improvement Company to support the affiliated multipliers in terms of production control. In the same way, production records are mailed in and results returned by postage services. STAGES (Purdue University, Lafayette, Indiana) is a record collection system explicitly and exclusively geared towards genetic evaluation of pigs. Performance records are mailed to the center which computes predicted breeding values and returns them via mail.

An open information system for the pig production and marketing industry has been proposed by Groeneveld and Lacher (1992), on the basis of data originating from producers and users in the pig production industry that should cover the information needs of all participants in the process.

Expert systems

In recent years expert systems have become recognised as a new type of software technology for use in many research areas. Expert systems are a technology which resulted from attempts by artificial intelligence researchers to model human reasoning. Artificial intelligence consists of 4 main areas: robotics, natural-language interpretation, computer vision and expert systems. Overviews of expert systems have been described (Feigenbaum and McCorduck, 1983; Harmon and King, 1985; Hayes-Roth and Jacobstein, 1994; Zaheeruddin, 1995). Some advantages of expert systems compared with human expertise include that they are likely to be more consistent, can be cost-efficiently produced, and

different knowledge sources or domains can be combined as well as created (Doluschitz and Schmisser, 1988; Hochman *et al.*, 1991).

An expert or knowledge-based system is a program that achieves a high level of accuracy in analysing problems that are usually considered difficult enough to require significant human expertise for their solution (Feigenbaum, 1984). Expert systems can be thought of as a model of the expertise of the best practitioners in the field. The first expert systems were built by interviewing a recognized human expert and attempting to capture that expert's knowledge, hence the term "expert systems". Recently many systems have been built that contain knowledge of a decision-making situation that is quite useful, but not necessarily the equivalent of a human expert. The term "expert systems" and "knowledge-based systems" are interchangeable.

One of the earliest expert systems DENDRAL was developed at Stanford University in the mid 1960s to analyse mass spectral patterns to suggest the chemical structure of unknown compounds (Buchanan and Feigenbaum, 1978). Subsequently, the expert system MYCIN which was used for diagnosis of meningitis and bacteraemia demonstrated that expert systems can work and perform as well as an expert (Yu *et al.*, 1979). Later, the knowledge base and the inference procedure became separate components in the expert system EMYCIN (Feigenbaum, 1984). Since the work on EMYCIN ("empty" MYCIN or "essential" MYCIN), a large number of commercial expert systems have been developed.

Components of expert systems

An expert system generally consists of 3 main components: a Knowledge base, an Inference engine, and a User interface. Other expert system components may include knowledge acquisition (Spangler *et al.*, 1989), explanation system, blackboard or dynamic database.

The knowledge base

The knowledge base contains rules, heuristics and problem-solving know-how representing the knowledge of an or a number of experts in a particular domain. It is the most important part of the system. Knowledge can be encoded using a variety of methods including rules, frames, predicate calculus, object-attribute-value triplets, semantic networks, scripts, decision tables and neural networks. The implementation of production rules as a framework for knowledge representation has been described (Hayes-Roth, 1985).

The inference engine

The inference engine contains mechanisms, strategies, and controls used to manipulate and apply knowledge to the problem. It directs the process of establishing new facts (or verification of hypotheses) which are derived from the knowledge base. The most common inference principle used in knowledge systems is the application of a logical rule called *modus ponens* (Harmon and King, 1985). This rule says that when A is known to be true and if a rule states, "If A, then B," it is valid to conclude that B is true.

Two main strategies employed in the inference engine are forward chaining (data-driven reasoning) and backward chaining (goal-directed reasoning).

Forward chaining

Forward chaining is one of several inferential control strategies that uses existing or newly deduced data to trigger future deductions and conclusions about the data (Barr and Feigenbaum, 1981). Forward chaining in rule-based system begins by triggering all of the rules whose "If clauses" are true. It then uses the facts it has established to determine what additional rules might be executable, because their "If clause" is satisfied. The process is repeated until the program reaches its goal or runs out of new possibilities. This technique is typically used for state-space search or data-directed reasoning.

Backward chaining

Backward chaining is another inferential control strategy that works from goals to what is already known or needs to become known to satisfy those goals (Harmon and King, 1985). Backward chaining is initiated when (1) a user establishes some goal to be sought and (2) the system identifies one or more rules whose consequents would satisfy the goal. The matching goal is triggered, and if none of the conjuncts in its antecedent clause is already known to be false, the system establishes subgoals for not-yet-believed conjuncts. The system then attempts to satisfy the goal rule by satisfying the subgoals. This leads the system to evaluate other rules that would confirm the "If clause" conjuncts. Thus the system works back through its rule until a question is asked or a previously stored fact or belief is found. Backward chaining is typically employed in problem reduction or goal-directed approaches to problem solving.

The user interface

The user interface mediates information exchanges between the expert system and the human user (Zaheeruddin, 1995). It contains screen displays, a questioning strategy, and an explanation component allowing the user to question conclusions of the system. It is desirable to have a user-friendly natural

language interface to facilitate the use of the system. However, the more natural the interface, the greater the demands on permanent storage and memory.

Expert System Shells

An Expert system shell is software containing a collection of capabilities that enable users to develop expert systems. Shells contain knowledge-representation structures necessary to capture and structure expertise; an inference engine facilitating use of that expertise; development tools which the knowledge engineer can use to capture, understand, and manipulate knowledge; an interface used by the end user to provide input and examine the system's conclusions; and mechanisms interfacing the expert systems with other software systems. The expert system shell with the capabilities best suited for a particular problem can facilitate system development, and can lead to a more efficient system. The advantage of expert system shells is that they reduce the time for development of expert systems. The evaluation and selection of expert system shells available in the artificial intelligence community have been described (Stylianou *et al.*, 1992).

Types of expert systems

Up until now, there are thousands of expert systems working in different relevant fields. Existing expert system programs range from the very complex to those which are very task-specific and narrowly defined. Hayes-Roth *et al* (1983) classified expert systems into 10 types on the basis of functional categories.

Interpretation systems

These systems infer situation descriptions from observations. This category includes surveillance, speech understanding, image analysis, chemical structure elucidation, signal interpretation, and many kinds of intelligent analysis.

Prediction systems

These systems infer likely consequences from given situations. This category includes weather forecasting, demographic predictions, traffic predictions, crop estimations, and military forecasting.

Diagnosis systems

These systems infer system malfunctions from observations. This category includes medical, electronic, mechanical, and software diagnosis.

Design systems

These systems develop configurations of objects that satisfy the constraints of the design problems. Such problems include circuit layout, building design, and budgeting.

Planning systems

These systems specialise in problems of design and design actions concerned with objects that perform functions. They include automatic programming as well as robot, project, route, communication, experiment, and military planning problems.

Monitoring systems

These systems compare observations of system behaviour to features that seem crucial to successfully plan outcomes. These crucial features correspond to potential flaws in the plan. Many computer aided monitoring systems exist for nuclear power plant, air traffic, disease, regulatory, and fiscal management tasks.

Debugging systems

These systems prescribe remedies for malfunctions. The systems rely on planning, design, and prediction capabilities to create specifications or recommendations for correcting a diagnosed problem. Computer aided debugging systems exist for computer programming in the form of intelligent knowledge base and text editors, but none qualifies as an expert system.

Repair systems

These systems develop and execute plans to administer a remedy for some diagnosed problem. Such systems incorporate debugging, planning, and execution capabilities. Computer aided systems occur in the domains of automotive, network, avionic, and computer maintenance, as well as others, but expert systems are just entering this field.

Instruction systems

These systems diagnose and debug student behaviours. They incorporate diagnosis and debugging subsystems that specifically address the student as well as the system of interest.

Control systems

These systems adaptively govern the overall behaviour of a system. Problems addressed by control systems include air traffic control, business management, battle management, and mission control.

Toward expert system development in agriculture

In agriculture and animal production, a number of promising expert systems applications for problems in the scientific and technical area have been published (Lindsay *et al.*, 1980; Duda and Shortliffe, 1983; Feigenbaum and McCorduck, 1983). Applications in agriculture are discussed by McKinion and Lemmon (1985), Doluschitz and Schmisser (1988). Examples of expert systems in agriculture include a system for diagnosis of soya bean diseases (Michalski *et al.*, 1983), for diagnosis of reproductive problems in dairy cattle (Levins and Varner, 1987), for animal production management (Wain *et al.*, 1988), for management in dairy operations (Doluschitz, 1990), for culling management of beef cows (Oltjen *et al.*, 1990), for pig herd health (Vos *et al.*, 1990), for management strategies for beef cattle farmers (Hochman *et al.*, 1991) and for analysis of individual sow-herd performance (Huirne *et al.*, 1991).

CHAPTER 3

Disease surveillance at slaughter under New Zealand conditions

Introduction

Disease recording systems at slaughter have been developed in several parts of the world (Biering-Sørensen, 1965; Blamire *et al.*, 1970; Parkinson, 1972; Bäckström and Bremer, 1978; Christiansen and Hellstrom, 1979; Straw *et al.*, 1986a). Such systems provide information about subclinical and less well defined disease conditions. It is also possible to trace back to affected herds as part of a disease control program. Scandinavian countries have significantly contributed to the development of disease surveillance systems at slaughter (Willeberg, 1979; Willeberg *et al.*, 1984-85). Disease surveillance has been used to define interactions between animals, agents, environmental conditions and management practices (Lindqvist, 1974; Aalund *et al.*, 1976; Flesjå and Ulvesæter, 1980; Pointon *et al.*, 1987). The objectives of surveillance are to improve the diagnosis of subclinical diseases, to provide producers with cost-effective strategies for reducing losses during the growing-finishing period, and enabling veterinarians to link production-limiting diseases with certain environmental conditions and animal husbandry practices.

The objective of the current study was to monitor 8 production-limiting diseases and a zoonotic disease from pig farms of known health status using a disease surveillance system which was adapted to New Zealand conditions.

Materials and methods

The data for this study was collected between May 1992 and July 1993 and involved three 200-400 sow farrow-to-finish piggeries in the North Island, New Zealand. A total of 2,807 finisher pigs were examined at Longburn slaughterhouse, Palmerston North, New Zealand. Slaughter checks were conducted according to the procedures and recording system described by Pointon *et al.*, 1992, for sarcoptic mange, enzootic pneumonia, pleurisy, pleuropneumonia, liver milk spot, nephritis, proliferative enteropathy and oesophagogastric ulcer. Skin inspections were carried out while carcasses were hung on the rail in front of the viscera trays. Examinations through visual inspection and palpation were undertaken of lungs, livers, kidneys and terminal ileums on the viscera trays immediately after the meat inspectors had completed their tasks. Stomachs and those terminal ileums, in which lesions indicative of proliferative enteropathy were found, were collected and taken to the

post-mortem room at the Veterinary Faculty, Massey University, Palmerston North, New Zealand. Stomachs and terminal ileums were then opened, washed and scored.

Data collection

Disease surveillance at slaughter was carried out on a weekly basis, based on a sample of 30 pigs from each herd each time. Samples were selected using systematic random sampling. The interval between samples was calculated based on the total size of the preslaughter population divided by 30. To ensure that data was collected from the correct animals, two steps were required for each carcass. Firstly, the tattoo number on the carcass was read to identify the herd and secondly, the carcass was matched with a set of visceral organs. Visceral organs which had some parts trimmed or condemned were treated as missing data. The details of the scoring methodology for each disease condition are described below. Monthly weather data from 3 weather stations in proximity to each piggery was collated for the time period between November 1991 and July 1993 (New Zealand Climate Digest, National Institute of Water & Atmospheric Research Ltd, Wellington, New Zealand).

Sarcoptic mange

The carcasses were examined for the presence of hypersensitivity lesions. A scoring system with the numerical grades 0, 1, 2 and 3 was used :

Grade 0	=	no lesions visible
Grade 1	=	mild lesions localized predominantly on head, belly and buttocks
Grade 2	=	generalised distribution with mild lesions over the back and moderately dense lesions at other common sites
Grade 3	=	generalised distribution with severe lesions wide spread over body.

Enzootic pneumonia

Lungs were placed ventral side up on the viscera trays. Cranio-ventral pneumonia was classified as acute (grade 1) or chronic (grade 2). The following list of criteria was used to differentiate acute from chronic disease stages through pathological examination of lung tissues:

Acute	Chronic
confluent with normal lung or swollen	shrunk
rounded edges to lobes	sharp edges to lobes
soft, meaty texture	firm texture
pale colour	dark colour
moist exudate in airways	dry
swollen lobules	catarrhal exudate
oedematous	scarring

Lungs which contained both types of lesions were classified as acute. The volume of lung with cranio-ventral pneumonia was scored separately for each lung lobe including left apical, left cardiac, left diaphragmatic, intermediate, right diaphragmatic, right cardiac and right apical lobes. The apical and cardiac lobes had a maximum score of 10 each and the diaphragmatic and intermediate lobes 5 each, allowing for a total maximum score of 55.

Pleurisy

Pleurisy is defined as adhesions between lobes or between lobes and thoracic wall. When present, a scoring system of pleurisy with numerical grades 0, 1 and 2 was used:

Grade 0	=	no adhesions between lung lobes or ribs
Grade 1	=	adhesions between lung lobes
Grade 2	=	adhesions between lung lobes and chest wall.

Pleuropneumonia

Lesions of pleuropneumonia are chronic and characterised by discrete haemorrhagic lesions with necrotic centres with overlying pleuritis. Lungs were assessed particularly on the dorsal aspect of the diaphragmatic lobes for presence or absence of pleuropneumonia.

Liver white spot

Livers were examined for the presence of liver white spot caused by migration of *Ascaris suum* larvae.

A scoring system of liver white spot with numerical grades 0, 1 and 2 was used:

Grade 0	=	no milk spots
Grade 1	=	1-9 milk spots
Grade 2	=	10 or more milk spots.

Nephritis

Both kidneys of each carcass were examined for the presence of scars through visual examination of the capsule. A scoring system with numerical grades 0, 1 and 2 was used:

Grade 0	=	no lesions
Grade 1	=	lesions were characterized by multiple greyish white areas, 2-5 mm in diameter on the cortical surface
Grade 2	=	lesions were characterised by generalised mottling of the cortical surface, with hypertrophy and possible adhesion of the capsule to the cortex.

Proliferative enteropathy

Terminal ileums were inspected and palpated to detect mucosal thickening. A scoring system of proliferative enteropathy with numerical grades 0, 1 and 2 was used:

Grade 0	=	no lesions
Grade 1	=	lesions were characterised by thickening of the terminal ileum without signs of inflammation, epithelial folds visible through serosa or smooth muscle hypertrophy
Grade 2	=	lesions were characterised by oedema and congestion of the mesentery and serosa of the terminal ileum.

Oesophagogastric ulcer

Stomachs were opened along the greater curvature and washed. The pars oesophagea was examined and a scoring system with numerical grades 0, 1, 2 and 3 was used:

Grade 0	=	no lesions
Grade 1	=	lesions showed hyperkeratinization of the squamous epithelium which usually were stained yellow and corrugated
Grade 2	=	lesions showed erosion of the epithelium particularly at the squamous-glandular mucosal junction
Grade 3	=	lesions showed active ulcers or cicatrised lesions of the pars oesophagea.

Statistical analysis

Surveillance data and weather data were stored using the database management software PARADOX® for Windows version 4.5 (Borland International Inc, Scotts Valley, California) and analysed using the statistical software packages STATISTICA™ for Windows version 4.5 (StatSoft Inc, Tulsa, Oklahoma) and Statistix version 4.1 (Analytical Software, Tallahassee, Florida). In this study, season was classified into 4 periods : Autumn (March to May), Winter (June to August), Spring (September to November) and Summer (December to February). Data was checked for degree of fit to the normal distribution, and standard descriptive statistics are presented for each variable. The chi-squared test was used to compare prevalence of disease conditions between farms, months and seasons. Kruskal-Wallis multiple comparison z-values were used to compare average environmental temperature for each severity score of disease conditions. Kruskal-Wallis Anova by Ranks was used to evaluate total lung score of enzootic pneumonia of each farm. A *P* value of less than 0.05 was considered to be statistically significant. Percent prevalence of a disease condition was calculated using the following formula: $(\text{Number of animals with disease at a point in time}) / (\text{Number of animals at risk at that point in time}) \times 100$ (Martin *et al.*, 1987). Stepwise logistic regression was used to investigate the relationship between the monthly farm prevalence of specific types of pathological lesions found during slaughter check and a set of potential risk factors including monthly temperature estimates (minimum, mean and maximum) and dummy variables representing the farms pigs originated from. Variables were included into the model if their coefficients were significant at a *P* value of 0.05. The goodness-of-fit of the final models was assessed using the Hosmer-Lemeshow Statistic based on deciles of risk (Hosmer and Lemeshow, 1989). Due to the relatively low number of observations when summarizing the data for each farm by month no attempt was made to investigate potential interaction effects between risk factors.

Results

Data was available for 13 months (except October and December 1992) as shown in Figure 3.1. Monthly sample series averaged 187 and ranged between 0 and 447 samples, and there were 28 and 30 samples available in May 1992 and April 1993. A total of 2,713 stomachs was examined for the presence of oesophagogastric ulcers.

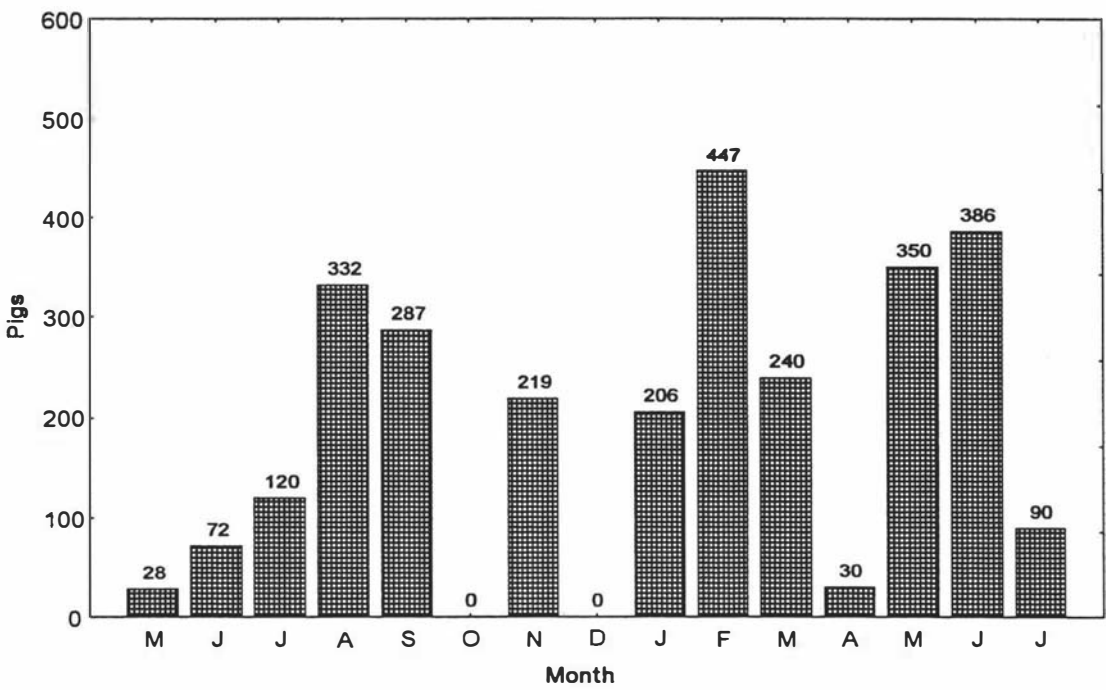


Figure 3.1 Bar chart of total pigs examined by month from May 1992 to July 1993

Sarcoptic mange

Lesions of sarcoptic mange were detected in 1,659 (59.1%) of 2,807 carcasses. Grade 1, grade 2 and grade 3 lesions were presented in 698 (24.9%), 545 (19.4%) and 416 (14.8%) pigs respectively. Prevalence of the four sarcoptic mange categories by farm is shown in Figure 3.2. The statistical analysis was restricted to prevalence of at least grade 2 sarcoptic mange lesions as diagnosis of grade 1 sarcoptic mange was considered to have a low specificity. The prevalence of pigs with at least grade 2 lesions for farms B, C and A was 9.4%, 39.5% and 47.4% respectively. In April, the percent prevalence of sarcoptic mange lesions was at a peak, which could be related to the small sample size

of 30 pigs. The peak of percent prevalence of sarcoptic mange lesions grade 2 occurred in June (40.0%) as shown in Figure 3.3 ($\chi^2 = 46$, $df = 18$, $P = 0.0004$). Results of chi-squared test indicate that 2 variables: farm and month were statistically significant associated with sarcoptic mange prevalence ($\chi^2 = 462$, $df = 4$, $P = 0.0000$ and $\chi^2 = 46$, $df = 18$, $P = 0.0000$). Seasonal analysis indicates that prevalence of sarcoptic mange lesions was 36.0% in autumn, 34.9% in summer, 33.3% in winter and 32.8% in spring as shown in Figure 3.4 ($\chi^2 = 4$, $df = 6$, $P = 0.6346$).

Table 3.1 shows the results of stepwise logistic regression analysis for identification of important environmental risk factors associated with monthly farm prevalence of sarcoptic mange. The final model includes the risk factors 'average monthly minimum temperature' and two dummy variables representing Farms A and B. The regression coefficients suggest that an increase in 'average monthly minimum temperature' or if the pigs originated from Farm A resulted in an increase of the risk of sarcoptic mange lesions. If the pigs were sourced from Farm B the risk of sarcoptic mange lesions was reduced. The Hosmer-Lemeshow statistic indicates that the final regression model does not represent a good fit to the data.

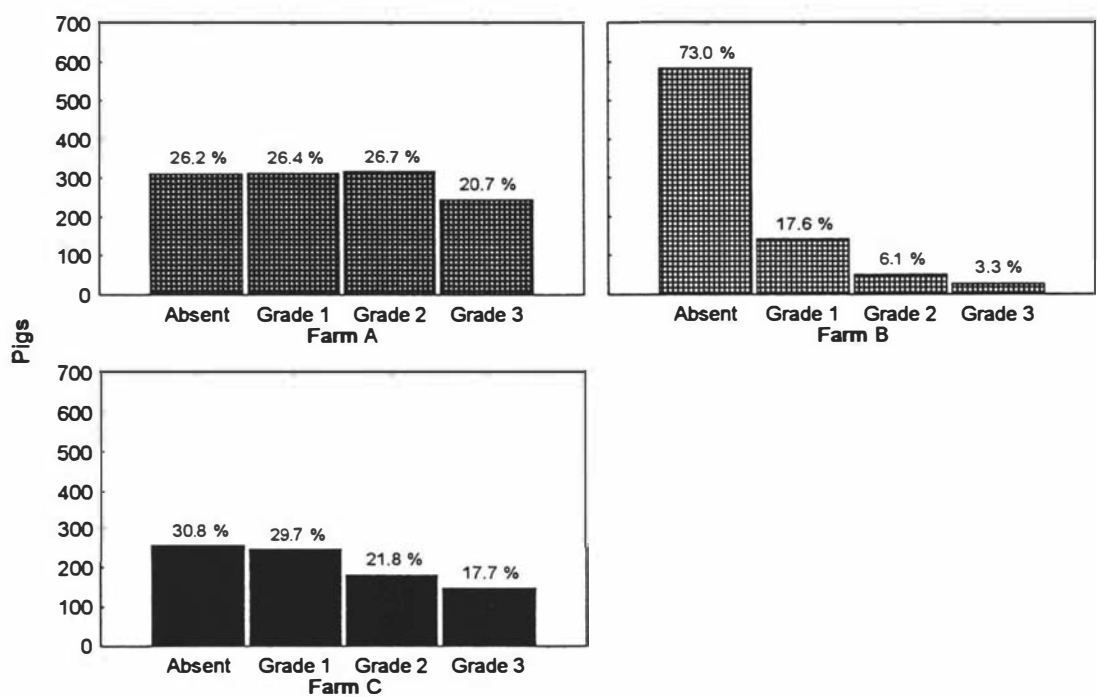


Figure 3.2. Bar charts of severity categories of sarcoptic mange for each farm (percent prevalence on top of bar)

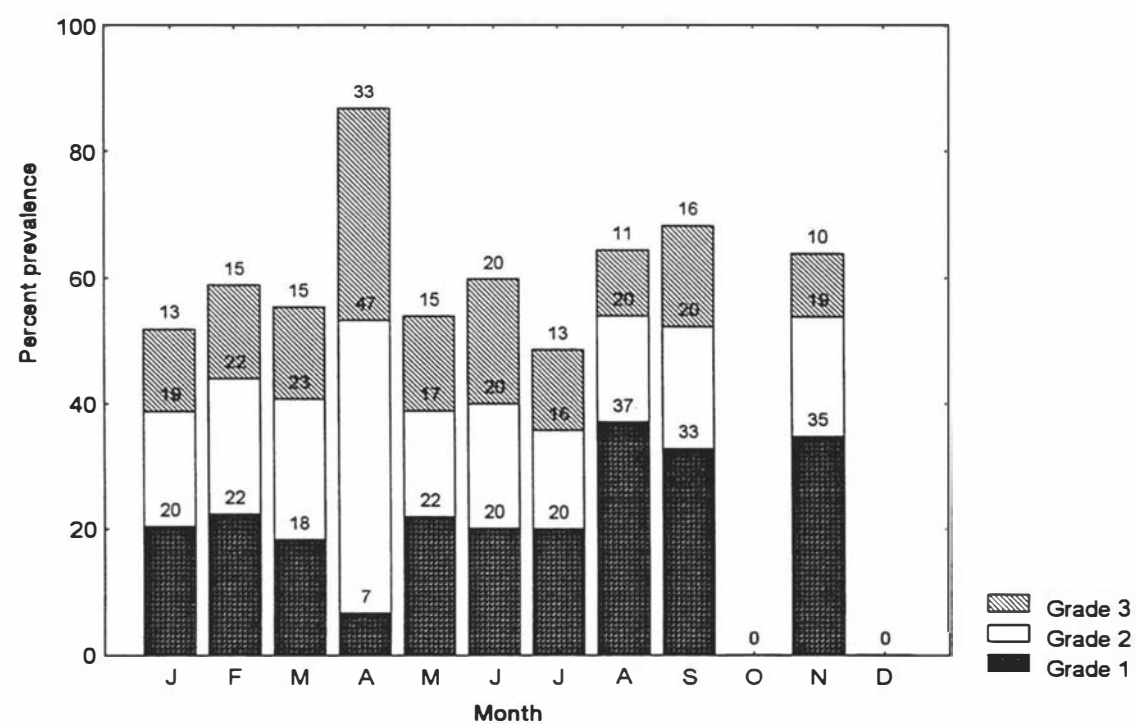


Figure 3.3. Bar chart of percent prevalence of sarcoptic mange by month

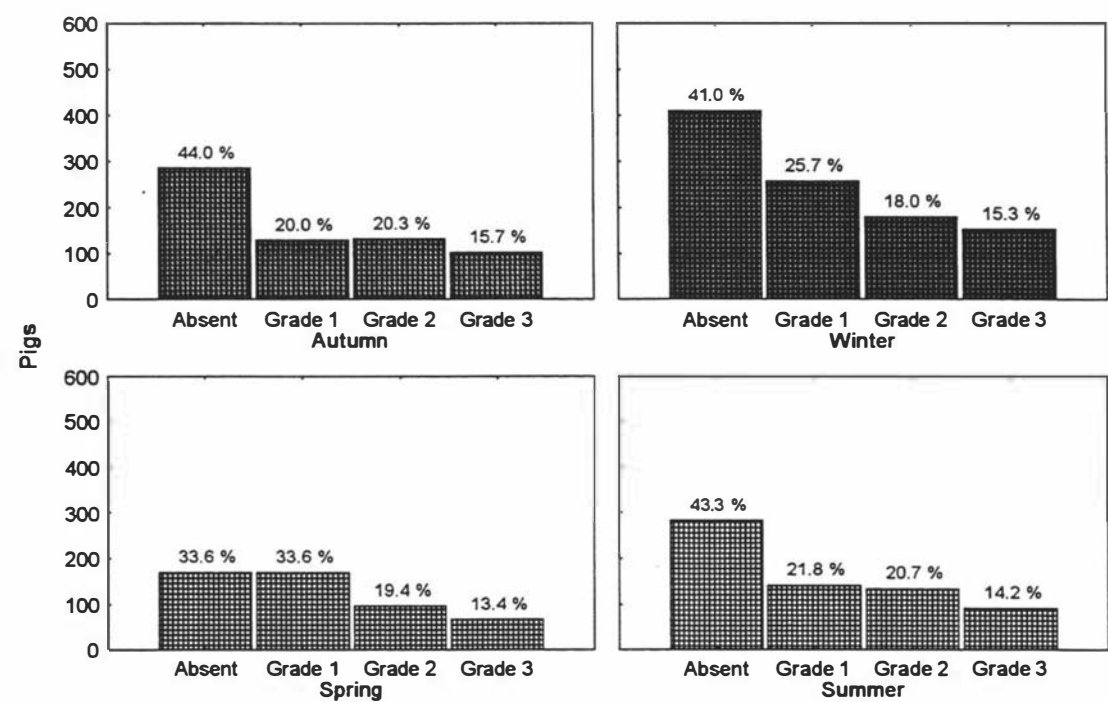


Figure 3.4. Bar charts of severity categories of sarcoptic mange for each season (percent prevalence on top of bar)

Table 3.1. Final logistic regression model for monthly farm prevalence of sarcoptic mange

Risk Factors	Coefficient	Standard error	P-value
Minimum Temperature	0.0367	0.0174	0.0353
Farm A	0.3391	0.0925	0.0002
Farm B	-2.0046	0.1581	0.0000

Hosmer-Lemeshow Statistic (C) = 53.96, df = 8, $P = 0.0000$; n = 34

Enzootic pneumonia

The distribution of total lung score of enzootic pneumonia is shown in Figure 3.5. In total, 775 (27.6%) pigs were found to be without lesions. The majority of lesioned pigs (26%) had scores of less than or equal to 5. The maximum score of 55 was found in 7 pigs (0.3%). The total lung scores of enzootic pneumonia were significantly different between farms ($P = 0.0000$) as shown in Figures 3.6, 3.7 and 3.8. Enzootic pneumonia lesions were classified as acute and chronic. The total lung scores of acute and chronic lesions were significantly different ($\chi^2 = 3039$, df = 108, $P = 0.0000$) as shown in Figure 3.9. The total lung scores of enzootic pneumonia were significantly different between seasons ($\chi^2 = 211$, df= 162, $P = 0.0058$) (Figure 3.10) . As the acute category of enzootic pneumonia may be linked to sudden losses in pig production, the total lung score of acute category by season was analysed, and found not to be statistically different, as shown in Figure 3.11 ($\chi^2 = 155$, df = 153, $P = 0.4409$).

The prevalence of enzootic pneumonia on farms A, C and B was 76.4%, 74.4% and 64.0%, respectively, (Figure 3.12). The peak of percent prevalence of the acute category was recorded in July (33%) as shown in Figure 3.13. Prevalence of acute category in winter, spring, summer and autumn was 24.6%, 20.2%, 19.8% and 17.4%, respectively, as shown in Figure 3.14. Results of chi-squared test indicate that 3 variables: farm, month and season were statistically significantly associated with enzootic pneumonia prevalence ($\chi^2 = 79$, df = 4, $P = 0.0000$, $\chi^2 = 69$, df = 18, $P = 0.0000$, $\chi^2 = 41$, df = 6, $P = 0.0000$).

Table 3.2 shows the results of stepwise logistic regression analysis for identification of important environmental risk factors associated with monthly farm prevalence of enzootic pneumonia. The final model includes the risk factors 'average monthly maximum temperature' and a dummy variable representing Farm A. The regression coefficients suggest that an increase in 'average monthly maximum temperature' or if the pigs originated from Farms B or C rather than Farm A resulted in a

decrease of the risk of enzootic pneumonia lesions. The Hosmer-Lemeshow statistic indicates that the final regression model does not represent a good fit to the data.

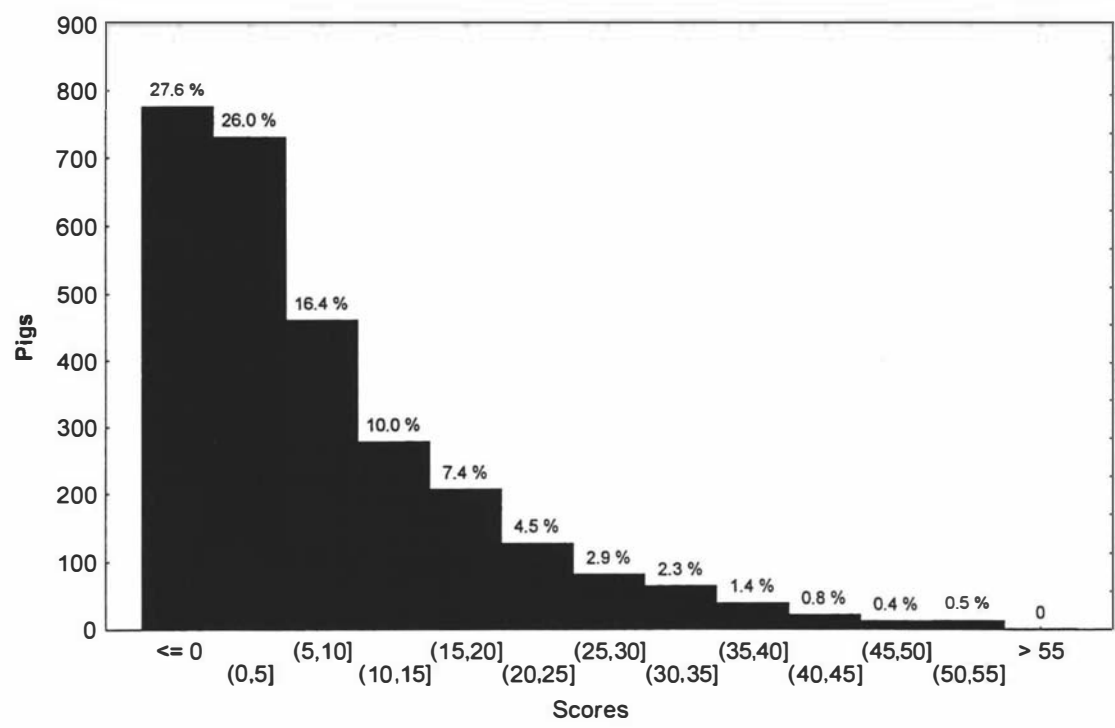


Figure 3.5. Histogram distribution of total lesion scores of enzootic pneumonia (percentage on top of bar)

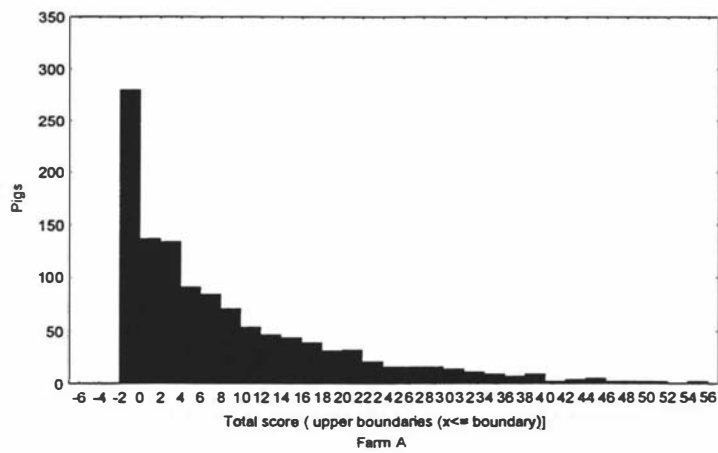


Figure 3.6. Histogram distribution of total lesion scores of enzootic pneumonia on Farm A

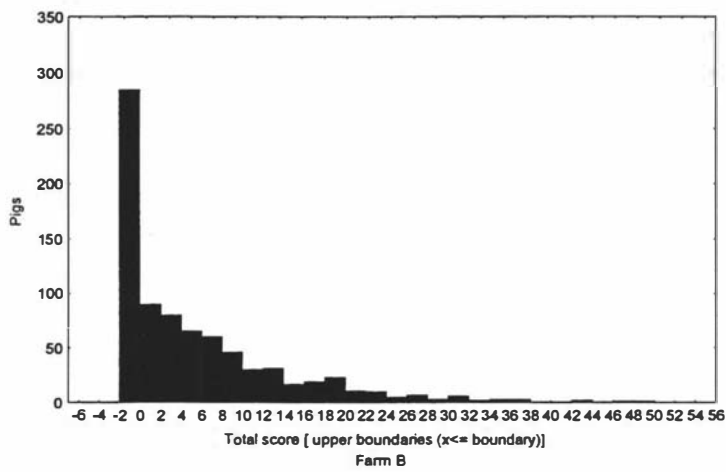


Figure 3.7. Histogram distribution of total lesion scores of enzootic pneumonia on Farm B

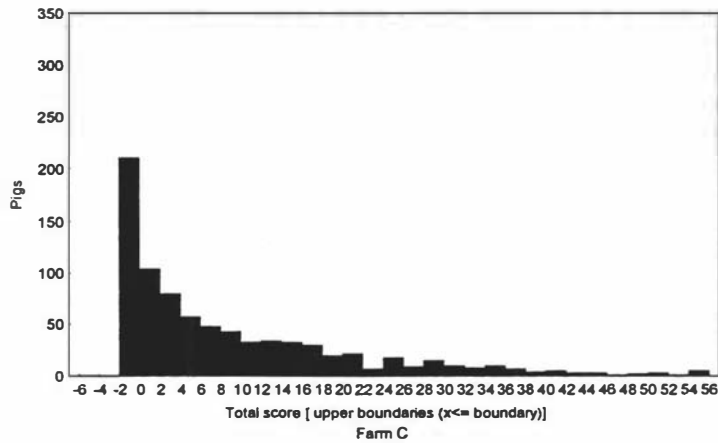


Figure 3.8. Histogram distribution of total lesion scores of enzootic pneumonia on Farm C

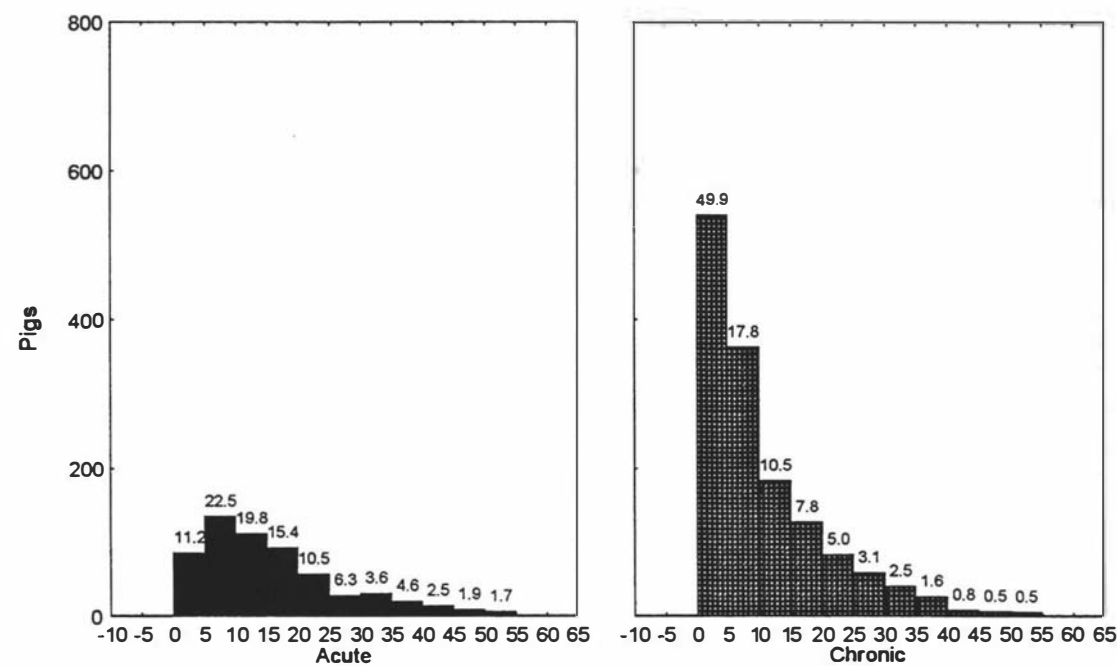


Figure 3.9. Histogram distributions of total lesion scores of severity categories of enzootic pneumonia (percentage on top of bar)

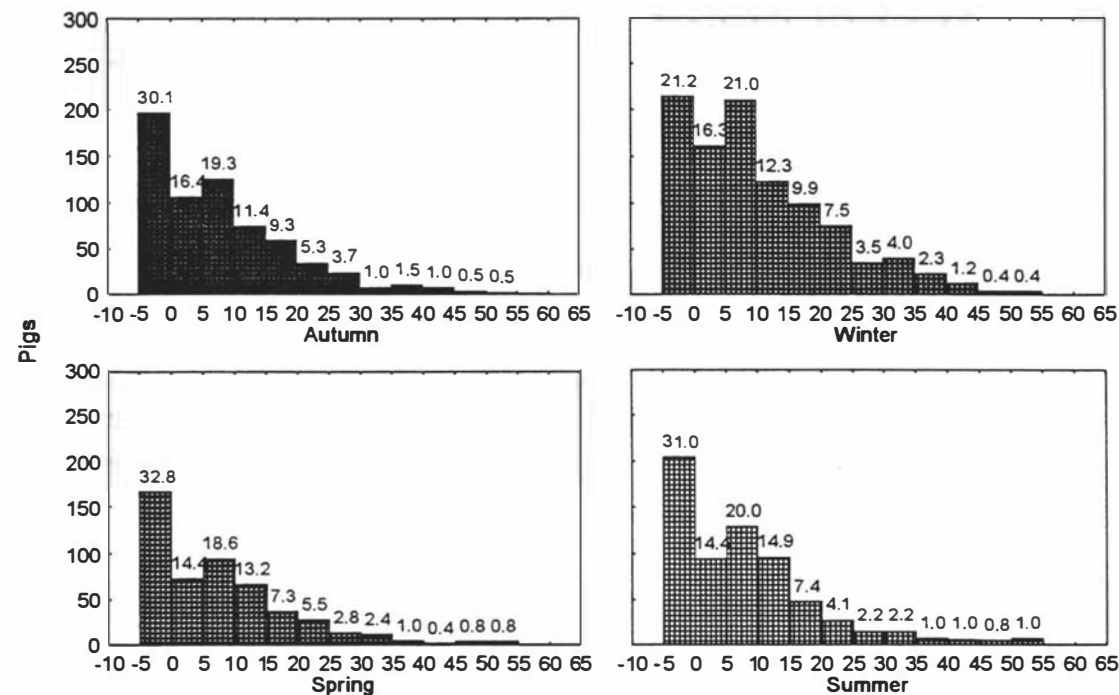


Figure 3.10. Histogram distributions of total lesion scores of enzootic pneumonia by season (percentage on top of bar)

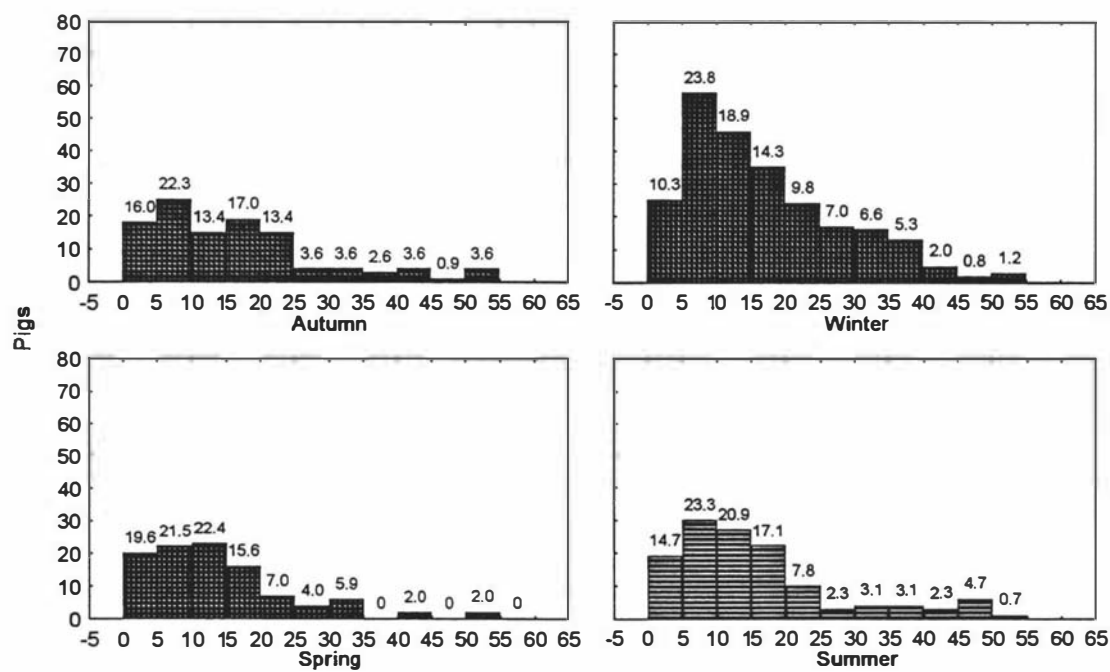


Figure 3.11. Histogram distributions of total lesion scores of enzootic pneumonia (acute category) by season (percentage on top of bar)

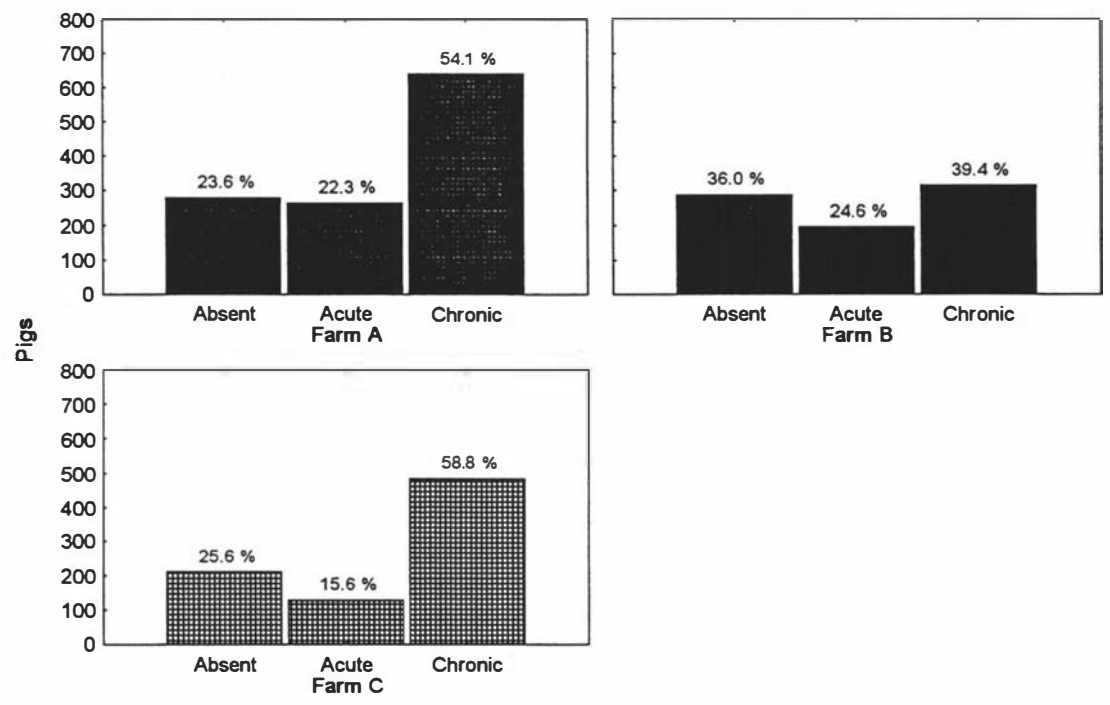


Figure 3.12. Bar charts of severity categories of enzootic pneumonia for each farm (percent prevalence on top of bar)

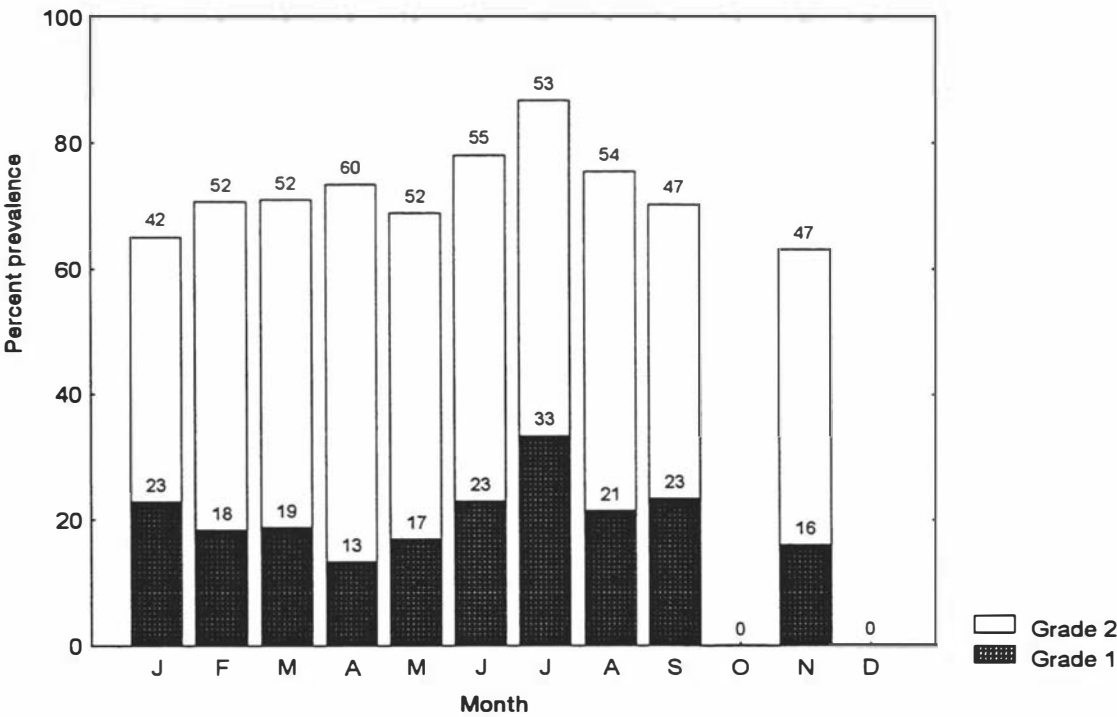


Figure 3.13. Bar chart of percent prevalence of enzootic pneumonia by month

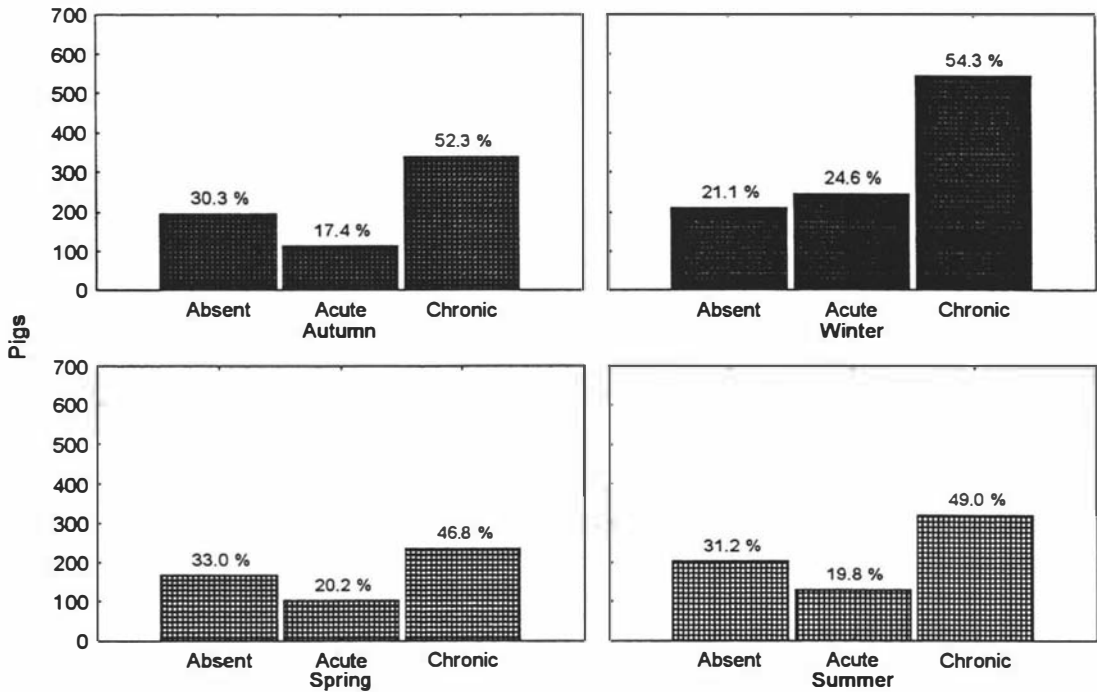


Figure 3.14. Bar charts of severity categories of enzootic pneumonia for each season (percent prevalence on top of bar)

Table 3.2. Final logistic regression model for monthly farm prevalence of enzootic pneumonia

Risk Factors	Coefficient	Standard error	P-value
Maximum Temperature	-0.0798	0.0160	0.0000
Farm A	0.2931	0.1149	0.0108

Hosmer-Lemeshow Statistic (C) = 26.79, df = 8, P= 0.0008; n = 34

Pleurisy

From a total of 2,807 pigs, 2520 pigs(89.8%) were in the pleurisy category "absent", 159 (5.7%) in category grade 1 and 128 (4.6%) in category grade 2. The prevalence of pleurisy lesions on farms C, A and B was 14.2%, 11.7% and 4.0% respectively as shown in Figure 3.15. The peak of prevalence of grade 1 pleurisy occurred in May (9%) and grade 2 in July (11%), respectively, as shown in Figure 3.16. The prevalence of pleurisy lesions was 13% in winter, 10% in autumn, 8.5% in spring and 7.5% in summer (Figure 3.17). Results of chi-squared test indicate that 3 variables: farm, month and season were statistically significant associated with pleurisy prevalence ($\chi^2 = 56$, df = 4, $P = 0.0000$, $\chi^2 = 61$, df = 18, $P = 0.0000$, $\chi^2 = 26$, df = 6, $P = 0.0003$).

Table 3.3 shows the results of stepwise logistic regression analysis for identification of important environmental risk factors associated with monthly farm prevalence of pleurisy. The final model includes the risk factors 'average monthly maximum temperature' and a dummy variable representing Farm B. The regression coefficients suggest that an increase in 'average monthly maximum temperature' or if the pigs originated from Farm B rather than Farms A and C resulted in a decrease of the risk of pleurisy lesions. The Hosmer-Lemeshow statistic indicates that the final regression model fits the data fairly well.

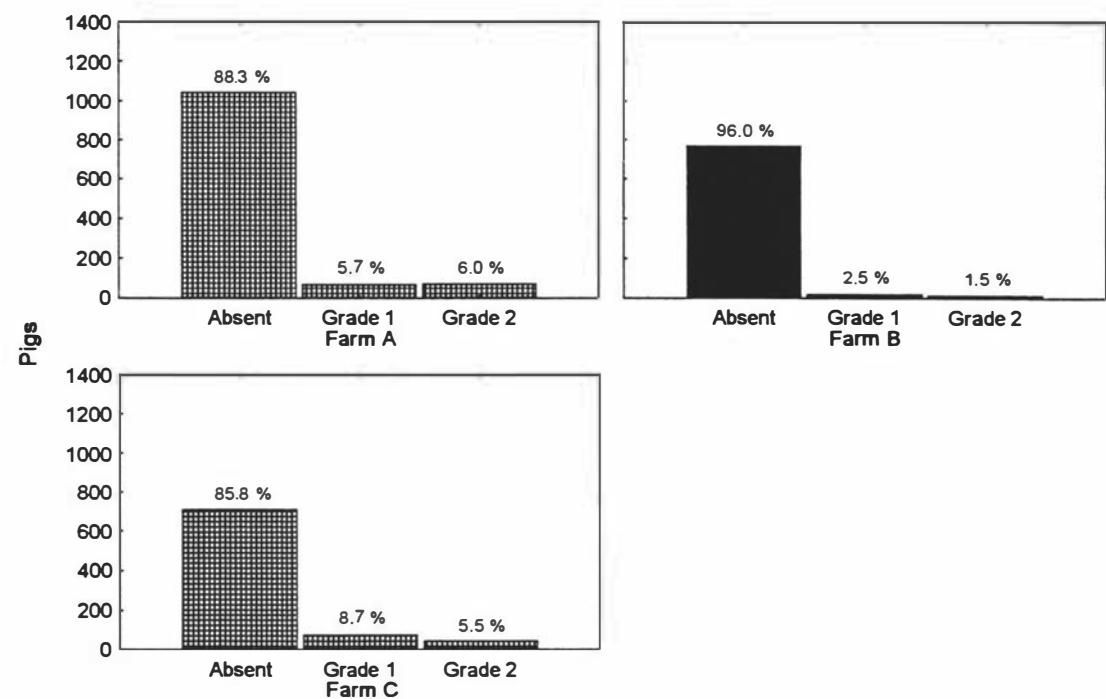


Figure 3.15. Bar charts of severity categories of pleurisy for each farm (percent prevalence on top of bar)

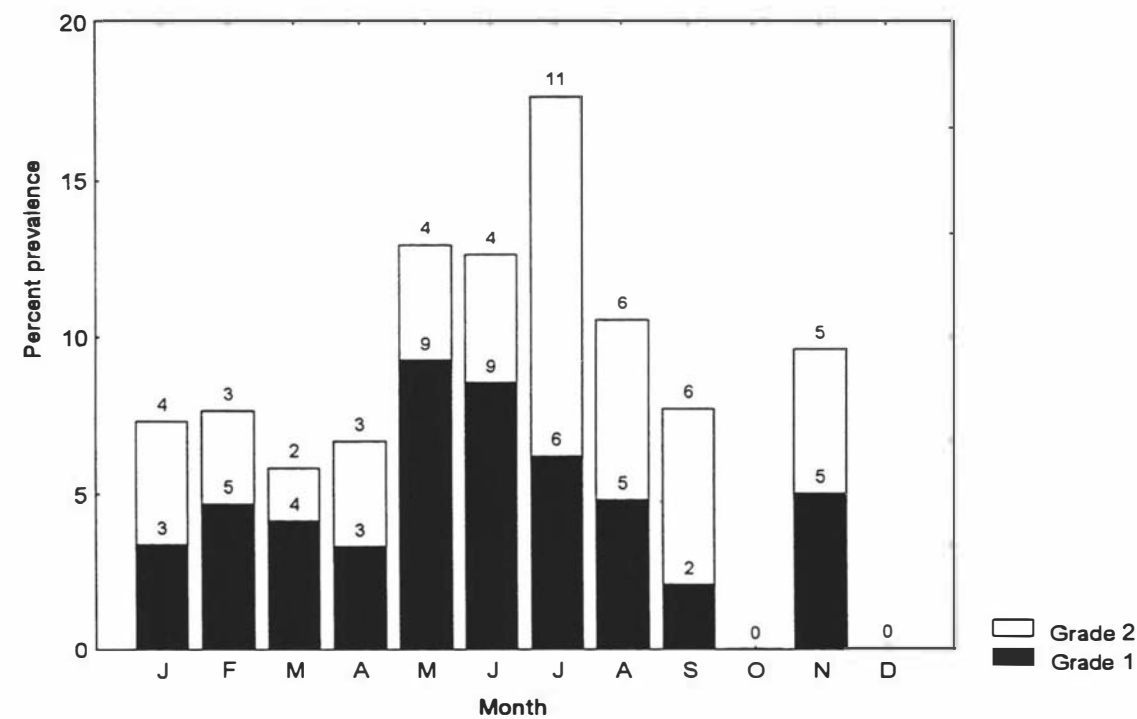


Figure 3.16. Bar chart of percent prevalence of pleurisy by month

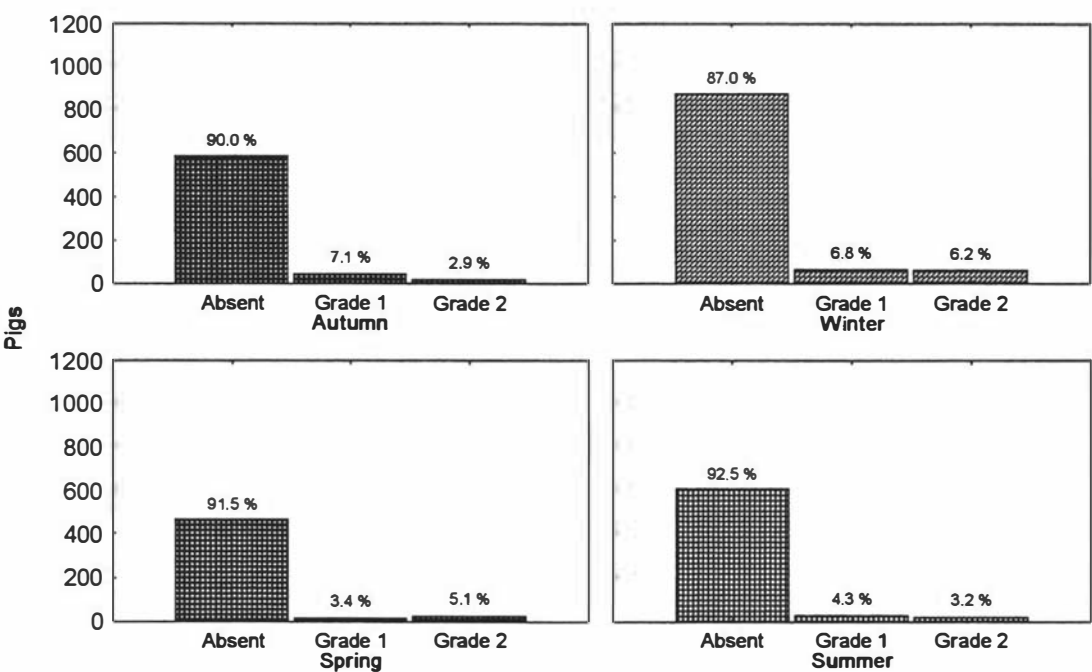


Figure 3.17. Bar charts of severity categories of pleurisy for each season (percent prevalence on top of bar)

Table 3.3. Final logistic regression model for monthly farm prevalence of pleurisy

Risk Factors	Coefficient	Standard error	P-value
Maximum Temperature	-0.0768	0.0192	0.0001
Farm B	-1.1657	0.2051	0.0000

Hosmer-Lemeshow Statistic (C) = 13.05, df = 8, P= 0.1100; n = 34

Pleuropneumonia

Of 2,807 pigs, 64 pigs (2.3 %) were found pleuropneumonia lesions. Prevalence on farms A, C and B was 4.5%, 1.0% and 0.4% showed pleuropneumonia lesions (Figure 3.18). Pleuropneumonia prevalence reached a peak of present score was in July (6 %) as shown in Figure 3.19. Prevalence of pleuropneumonia lesions was 3.0% in winter, 2.5% in autumn, 1.8% in summer and 1.4% in spring as shown in Figure 3.20. Results of chi-squared test indicate that 2 variables: farm and month were significantly associated with pleuropneumonia prevalence ($\chi^2 = 45$, df = 2, $P = 0.0000$, $\chi^2 = 28$, df = 18, $P = 0.0010$). However, season did not show an association with pleuropneumonia prevalence ($\chi^2 = 4$, df = 3, $P = 0.2379$).

Table 3.4 shows the results of stepwise logistic regression analysis for identification of important environmental risk factors associated with monthly farm prevalence of pleuropneumonia. The final model includes the risk factors 'average monthly maximum temperature' and a dummy variable representing Farm A. The regression coefficients suggest that an increase in 'average monthly maximum temperature' or if the pigs originated from Farms B or C rather than Farm A resulted in a decrease of the risk of pleuropneumonia lesions. The Hosmer-Lemeshow statistic indicates that the final regression model does represent a good fit to the data.

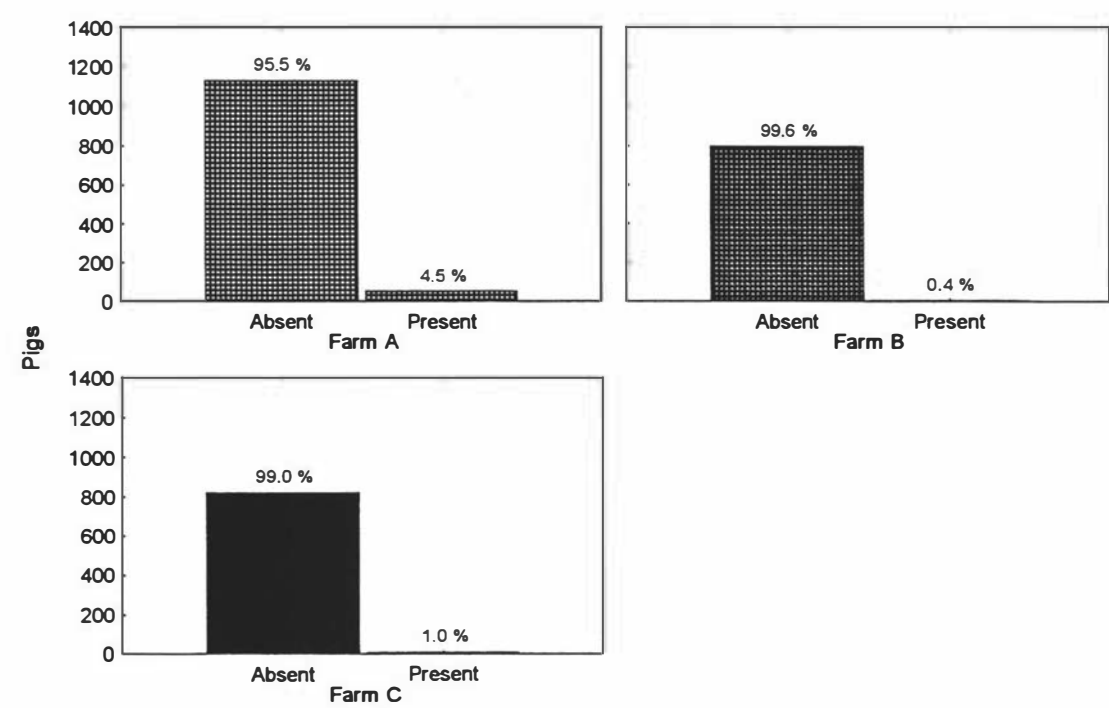


Figure 3.18. Bar charts of pleuropneumonia lesion status for each farm (percent prevalence on top of bar)

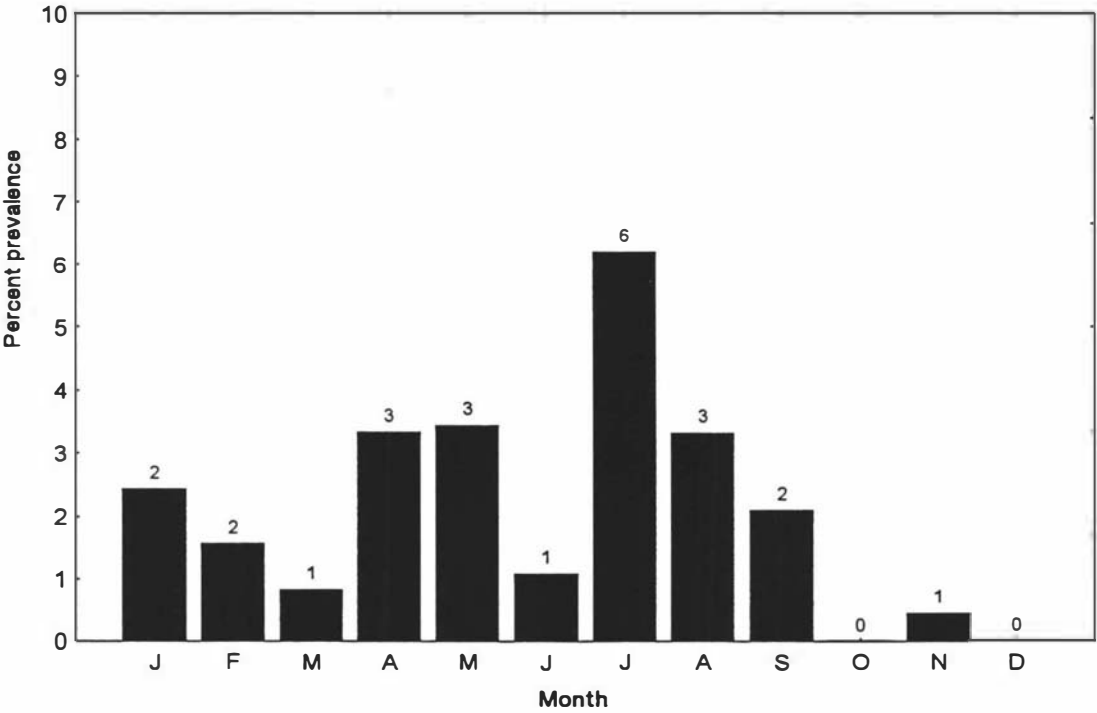


Figure 3.19. Bar chart of percent pleuropneumonia prevalence by month

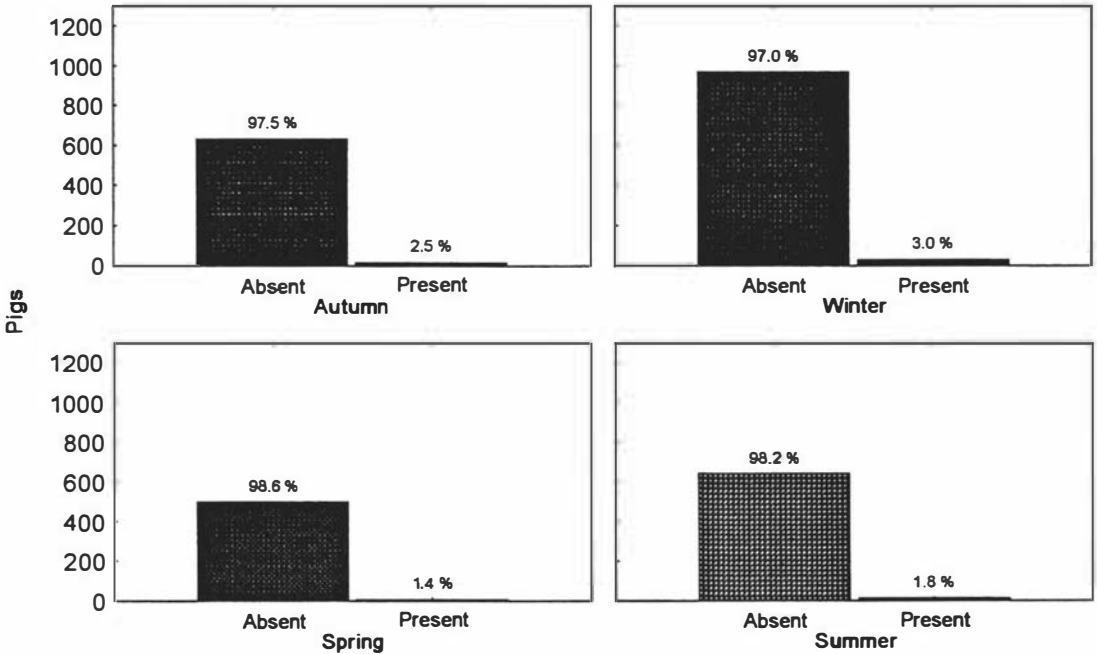


Figure 3.20. Bar charts of pleuropneumonia lesion status for each season (percent prevalence on top of bar)

Table 3.4. Final logistic regression model for monthly farm prevalence of pleuropneumonia

Risk Factors	Coefficient	Standard error	P-value
Maximum Temperature	-0.1017	0.0396	0.0102
Farm A	1.8090	0.3326	0.0000

Hosmer-Lemeshow Statistic (C) = 7.81, df = 8, P= 0.4522; n = 34

Liver white spot

Of 2,807 pigs, the categories absent, grade 1 and grade 2 for liver white spot were found in 2,508 pigs (89.4%), 201 pigs (7.2%) and 98 pigs (3.5%) respectively. Prevalence of at least grade 1 lesions on farms A, C and B was 14.8%, 8.2% and 7.0%, respectively, as shown in Figure 3.21. The high percent prevalence of liver white spot in April could have been the result of a small sample size. Prevalence of grade 1 category reached a maximum in June (17%) and the two highest prevalences of grade 2 were recorded in June (7%) and September (7%) as shown in Figure 3.22. Prevalence of at least grade 1 liver white spot was 16.3% in winter, 11.7% in autumn, 7.7% in spring and 3.2% in summer as shown in Figure 3.23. Results of chi-squared test indicate that 3 variables: farm, month and season were statistically associated with liver white spot prevalence ($\chi^2 = 42$, df = 4, $P = 0.0000$, $\chi^2 = 181$, df = 18, $P = 0.0000$, $\chi^2 = 98$, df = 6, $P = 0.0000$).

Table 3.5 shows the results of stepwise logistic regression analysis for identification of important environmental risk factors associated with monthly farm prevalence of liver white spot. The final model includes the risk factors 'average monthly maximum temperature' and a dummy variable representing Farm A. The regression coefficients suggest that an increase in 'average monthly maximum temperature' or if the pigs originated from Farms B or C rather than Farm A resulted in a decrease of the risk of liver white spot lesions. The Hosmer-Lemeshow statistic indicates that the final regression model does not represent a good fit to the data.

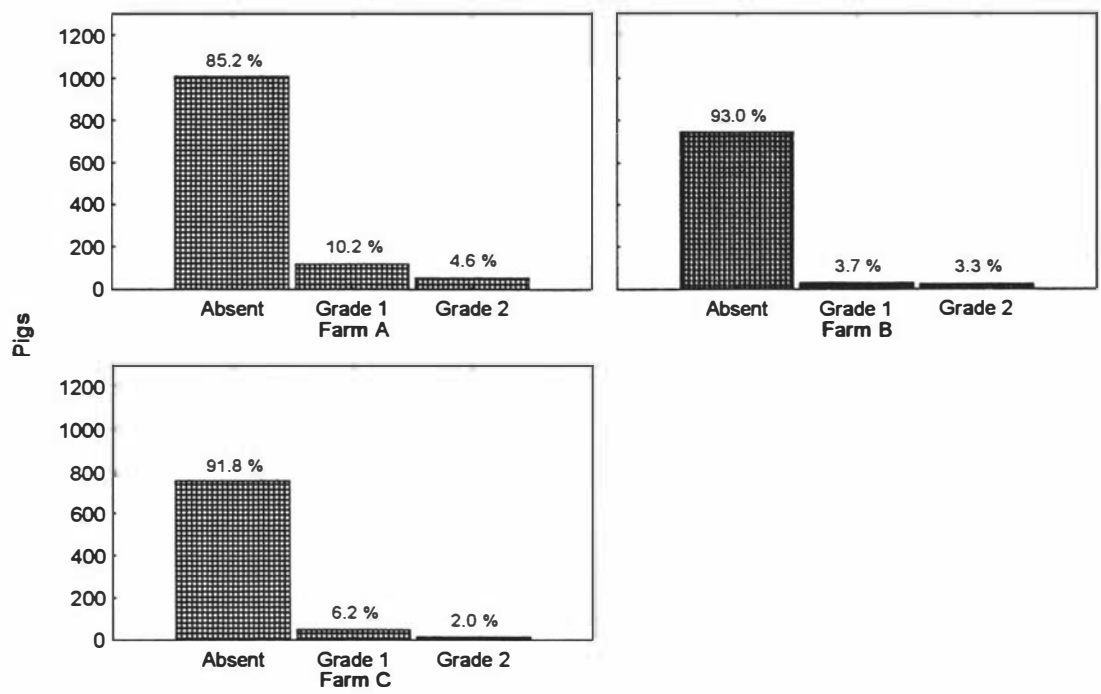


Figure 3.21. Bar charts of severity categories of liver white spot for each farm (percent prevalence on top of bar)

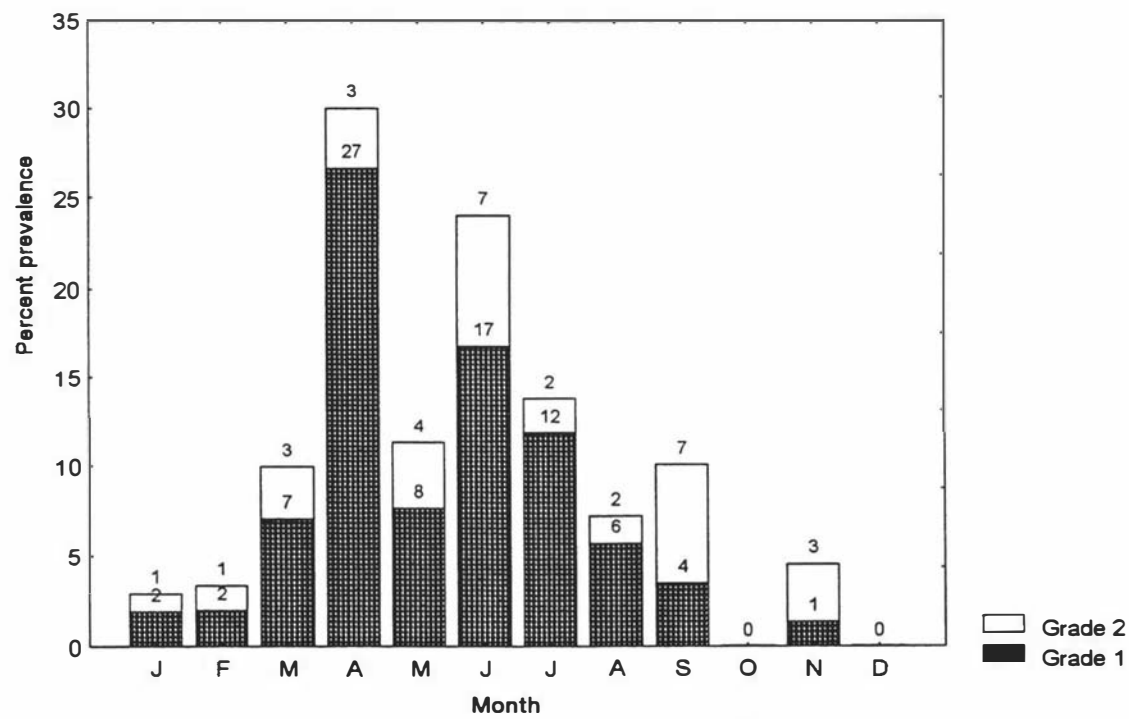


Figure 3.22. Bar chart of percent prevalence of liver white spot by month

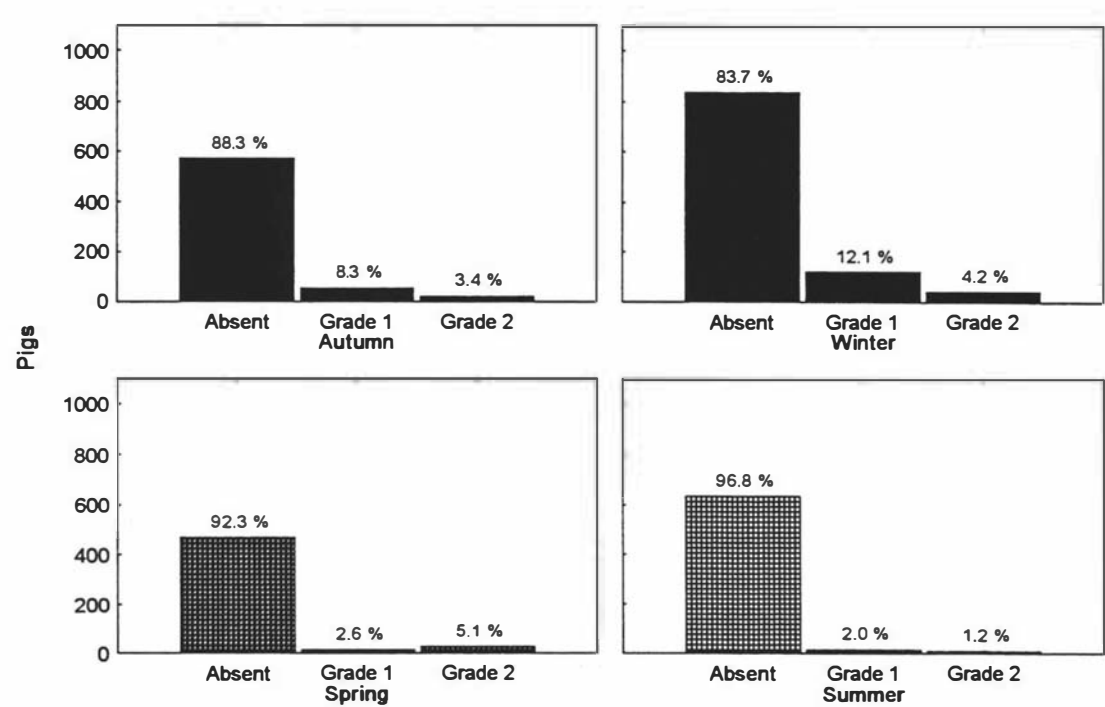


Figure 3.23. Bar charts of severity categories of liver white spot for each season (percent prevalence on top of bar)

Table 3.5. Final logistic regression model for monthly farm prevalence of liver white spot

Risk Factors	Coefficient	Standard error	P-value
Maximum Temperature	-0.1207	0.0195	0.0000
Farm A	0.6953	0.1281	0.0000

Hosmer-Lemeshow Statistic (C) = 117.34, df = 8, P = 0.0000; n = 34

Nephritis

Of 2,807 pigs, the categories absent, grade 1 and grade 2 of nephritis lesions were found respectively in 2,748 pigs (97.9%), 57 pigs (2.0%) and 2 pigs (0.1%). Prevalence of at least grade 1 nephritis lesions on farms A, B and C was 2.7%, 1.7% and 1.6%, respectively, as shown in Figure 3.24. Maximum nephritis prevalence of grade 1 score was recorded in July (6%) and the only occurrence of grade 2 nephritis was in July (1%) as shown in Figure 3.25. The prevalence of at least grade 1 nephritis

was 3.9% in winter, 3.4% in spring, 0.5% in autumn and 0% in summer as shown in Figure 3.26. As a result of the small number of grade 1 and grade 2 lesion categories, the data was aggregated into absent and present categories for statistical analysis. Results of chi-squared test indicate that farm was not associated with prevalence of nephritis lesions ($\chi^2 = 4$, $df = 2$, $P = 0.1575$), while month and season were both statistically significant associated with nephritis prevalence ($\chi^2 = 66$, $df = 9$, $P = 0.0000$) and ($\chi^2 = 42$, $df = 3$, $P = 0.0000$).

Table 3.6 shows the results of stepwise logistic regression analysis for identification of important environmental risk factors associated with monthly farm prevalence of nephritis. The final model only includes the risk factor 'average monthly maximum temperature'. The regression coefficient suggests that an increase in 'average monthly maximum temperature' resulted in a decrease of the risk of nephritis lesions. The Hosmer-Lemeshow statistic indicates that the final regression model does not represent a good fit to the data.

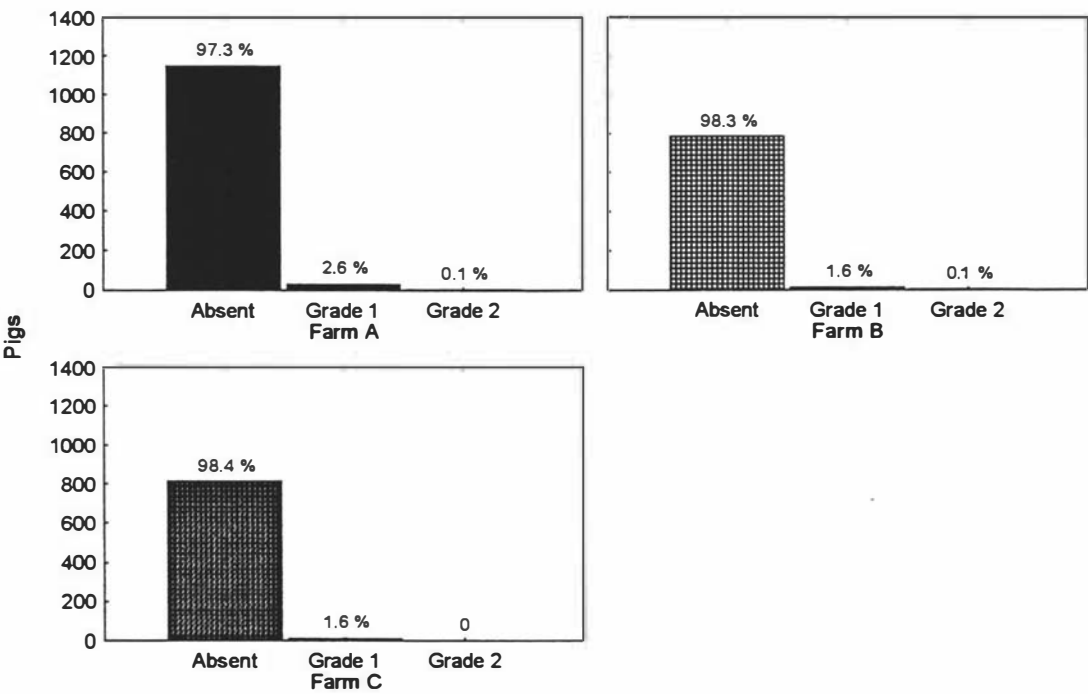


Figure 3.24. Bar charts of severity categories of nephritis for each farm (percent prevalence on top of bar)

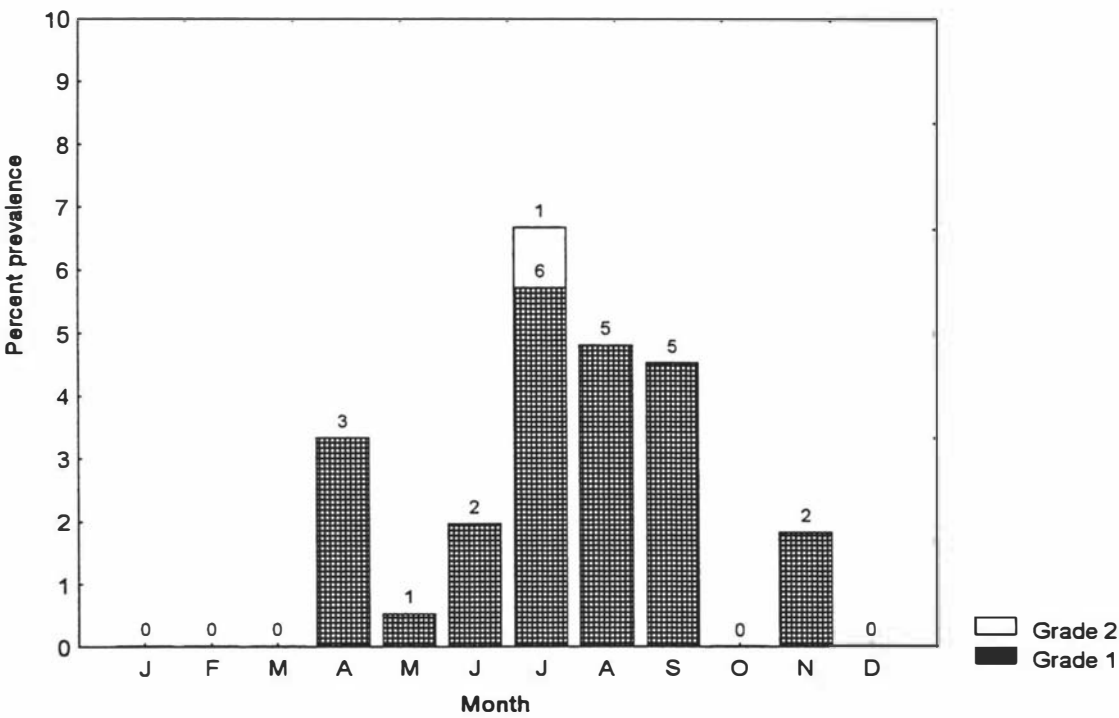


Figure 3.25. Bar chart of percent prevalence of nephritis by month

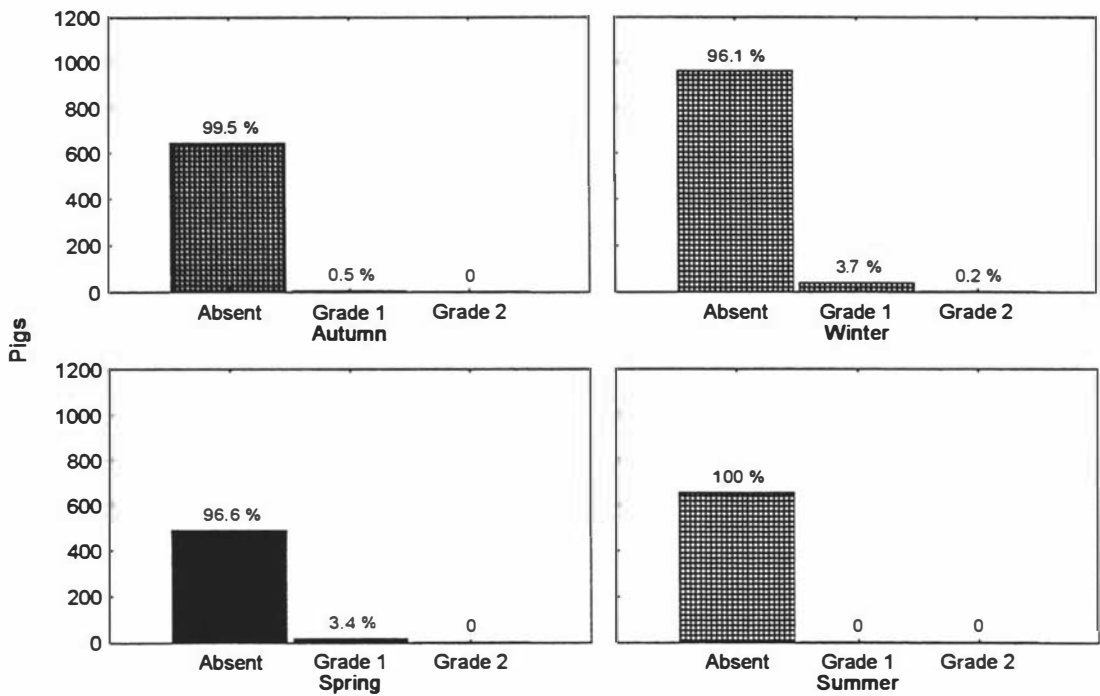


Figure 3.26. Bar charts of severity categories of nephritis for each season (percent prevalence on top of bar)

Table 3.6. Final logistic regression model for monthly farm prevalence of nephritis

Risk Factors	Coefficient	Standard error	P-value
Maximum Temperature	-0.4616	0.0859	0.0000

Hosmer-Lemeshow Statistic (C) = 24.42, df = 8, P= 0.0019; n = 34

Proliferative enteropathy

Of 2,807 pigs, grade 1 and 2 of proliferative enteropathy were found in 53 pigs (1.9 %) and 67 pigs (2.4%) respectively. Prevalence of proliferative enteropathy lesion on farms A, C and B was 5.9%, 4.2% and 1.9%, respectively, as shown in Figure 3.27. Maximum prevalences of grade 1 category were recorded in February (4%), March (4%), April (3%) and July (4%) as shown in Figure 3.28. The prevalence of at least grade 1 proliferative enteropathy was 7.0% in summer, 6.0% in autumn, 2.5% in winter and 2.2% in spring as shown in Figure 3.29. Due to the small numbers of cases with proliferative enteropathy lesions grade 1 and 2 were aggregated into one category for statistical analysis. Results of chi-squared test indicate that 3 variables: farm, month and season were statistically significant associated with proliferative enteropathy prevalence ($\chi^2 = 19$, df=2, $P = 0.0001$, $\chi^2 = 59$, df=9, $P = 0.0000$, $\chi^2 = 29$, df=3, $P = 0.0000$).

Table 3.7. shows the results of stepwise logistic regression analysis for identification of important environmental risk factors associated with monthly farm prevalence of proliferative enteropathy. The final model includes the risk factors 'average monthly maximum temperature', 'average monthly mean temperature', 'average monthly minimum temperature' and a dummy variable representing Farm B. The regression coefficients suggest that an increase in 'average monthly maximum temperature', a decrease in 'average monthly mean temperature' or an increase in 'average monthly minimum temperature' or if the pigs originated from Farms A or C rather than Farm B resulted in an increase of the risk of proliferative enteropathy lesions. The Hosmer-Lemeshow statistic indicates that the final regression model does not represent a good fit to the data.

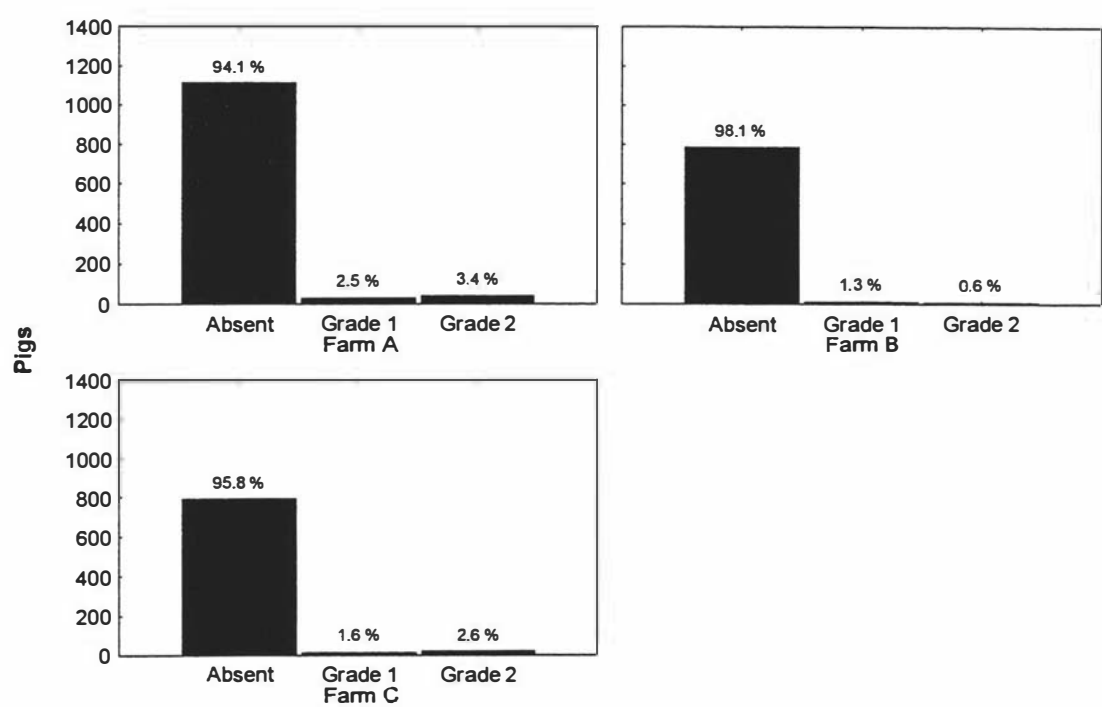


Figure 3.27. Bar charts of severity categories of proliferative enteropathy for each farm (percent prevalence on top of bar)

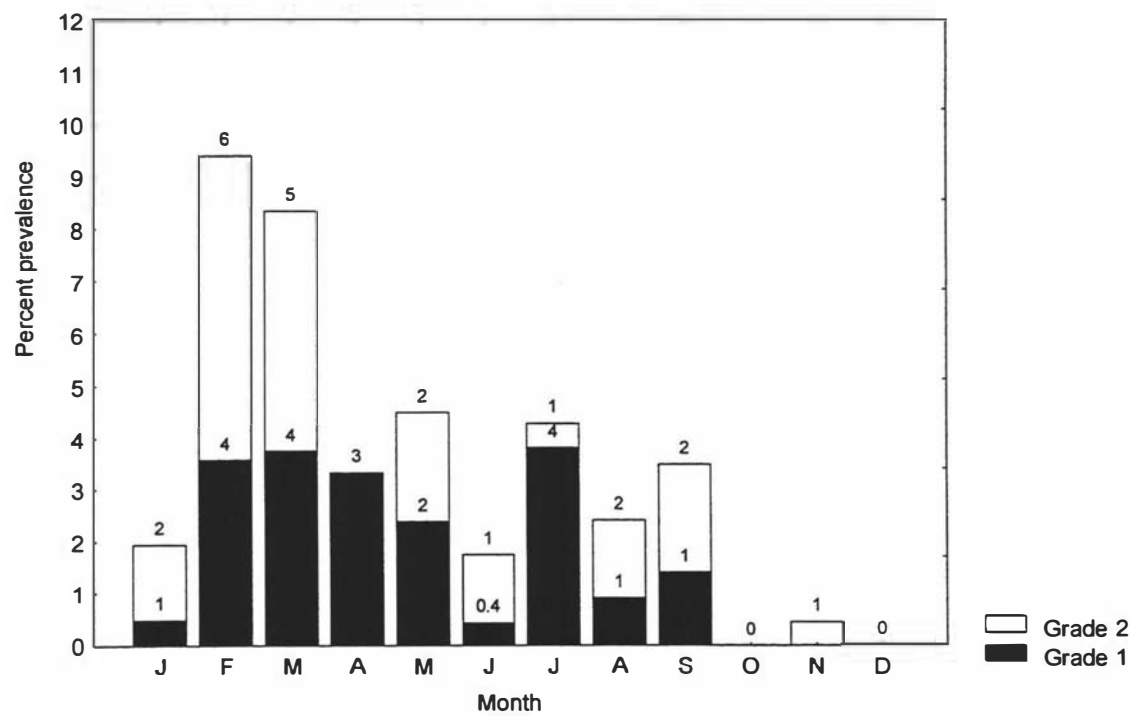


Figure 3.28. Bar chart of percent prevalence of proliferative enteropathy by month

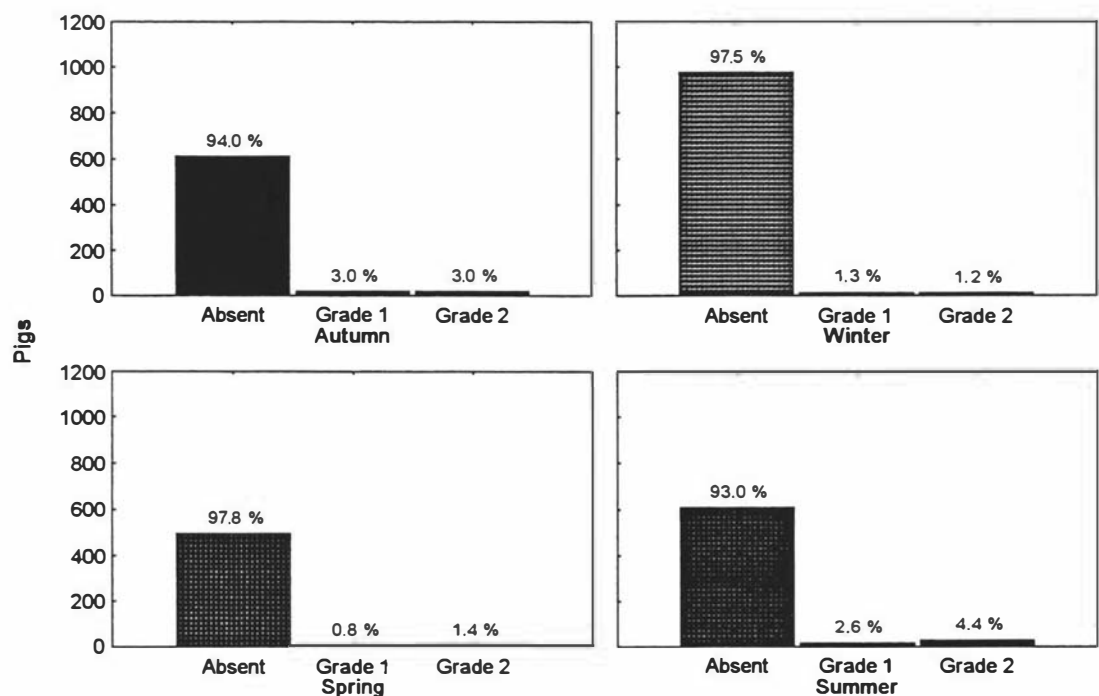


Figure 3.29. Bar chart of severity categories of proliferative enteropathy for each season (percent prevalence on top of bar)

Table 3.7. Final logistic regression model for monthly farm prevalence of proliferative enteropathy

Risk Factors	Coefficient	Standard error	P-value
Maximum Temperature	4.9081	2.0323	0.0157
Mean Temperature	-8.7953	4.0649	0.0305
Minimum Temperature	3.8319	2.0387	0.0602
Farm B	-2.6093	0.4216	0.0000

Hosmer-Lemeshow Statistic (C) = 30.03, df = 8, P= 0.0002; n = 34

Oesophagogastric ulcer

Of 2,713 pigs, grade 1, 2 and 3 of oesophagogastric ulcers were found in 203 pigs (7.5%), 732 pigs (27.0%) and 355 pigs (13.0%) respectively. Prevalence of grade 3 lesion on farms C, B and A was 40.8%, 2.3% and 2.1%, respectively, as shown in Figure 3.30. The two highest prevalences of grade 3 oesophagogastric ulcer were recorded in January (17%) and August (17%) as shown in Figure 3.31.

The prevalence of grade 3 lesion category was 14.7% in winter, 13.8% in autumn, 13.2% in summer and 8.9% in spring as shown in Figure 3.32. Results of chi-squared test indicate that 3 variables: farm, month and season were statistically significant associated with grade 3 oesophagogastric ulcer prevalence ($\chi^2 = 1409$, $df = 6$, $P = 0.0000$, $\chi^2 = 124$, $df = 27$, $P = 0.0000$, $\chi^2 = 69$, $df = 9$, $P = 0.0000$).

Table 3.8 shows the results of stepwise logistic regression analysis for identification of important environmental risk factors associated with monthly farm prevalence of oesophagogastric ulcer. The final model includes the risk factors 'average monthly maximum temperature' and the dummy variables representing Farms B and C. The regression coefficients suggest that a decrease in 'average monthly maximum temperature' or if the pigs originated from Farm C resulted in an increase of the risk of oesophagogastric ulcer lesions. If the pigs came from Farm B rather than Farms A and C, the risk of oesophagogastric ulcer lesions was increased. The Hosmer-Lemeshow statistic indicates that the final regression model does not represent a good fit to the data.

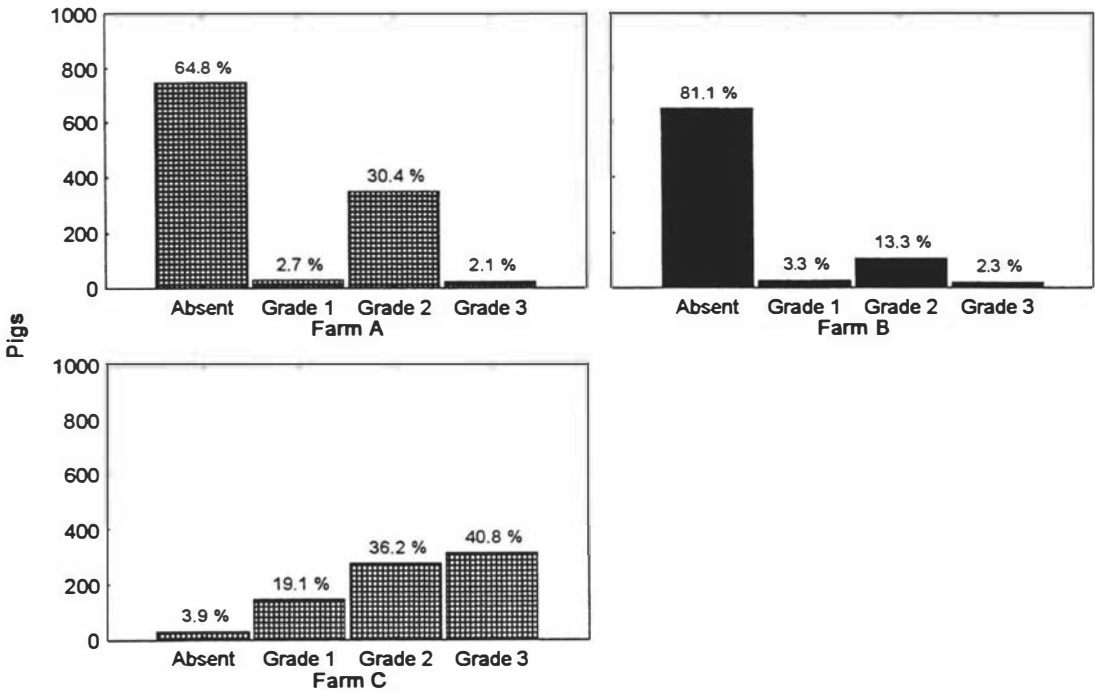


Figure 3.30. Bar charts of severity categories of oesophagogastric ulcer for each farm (percent prevalence on top of bar)

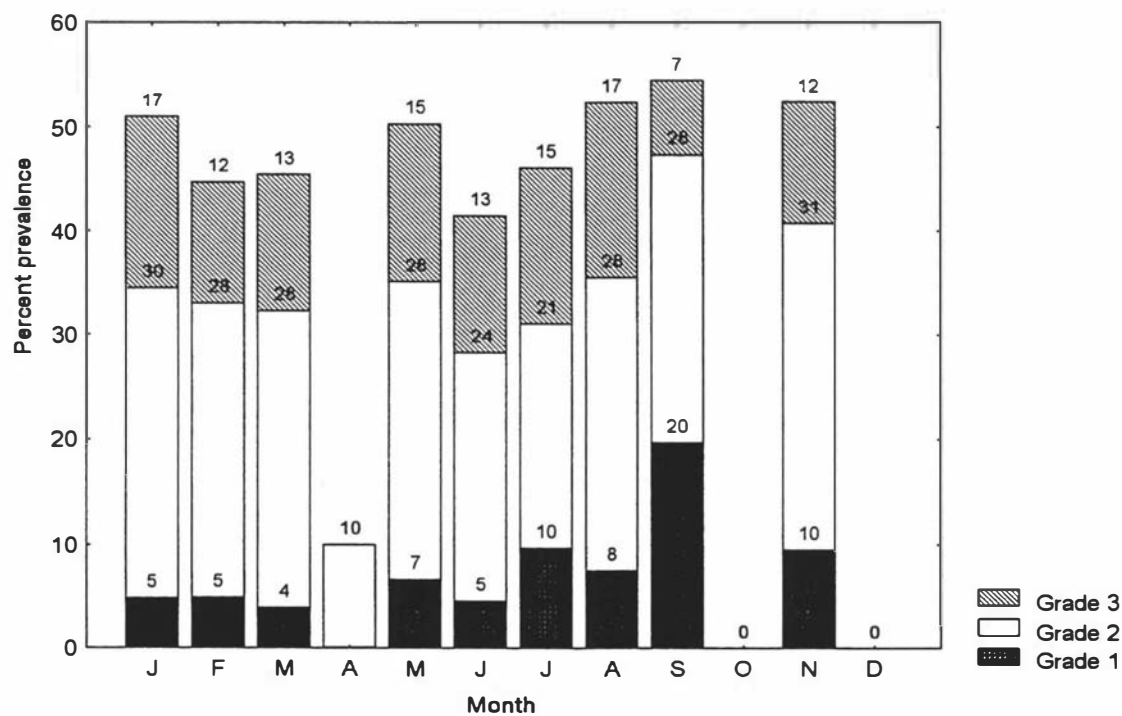


Figure 3.31. Bar chart of percent prevalence of oesophagogastric ulcer by month

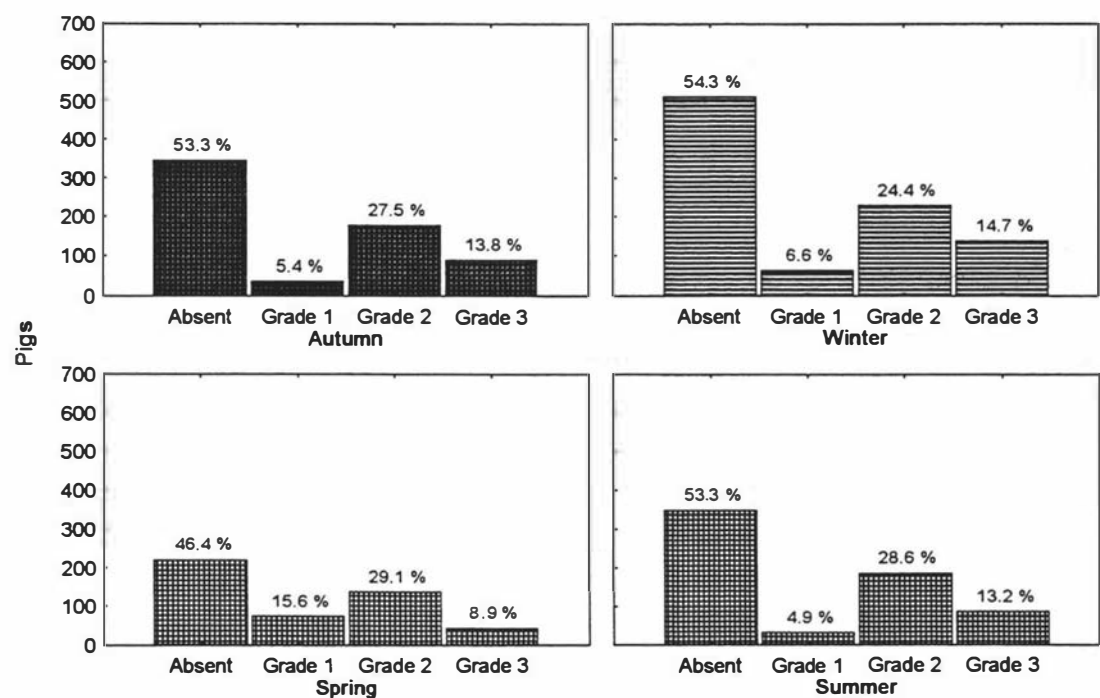


Figure 3.32. Bar charts of severity categories of oesophagogastric ulcer for each season (percent prevalence on top of bar)

Table 3.8. Final logistic regression model for monthly farm prevalence of oesophagogastric ulcer

Risk Factors	Coefficient	Standard error	P-value
Maximum Temperature	-0.0264	0.0151	0.0808
Farm B	-0.9968	0.1278	0.0000
Farm C	3.9475	0.2132	0.0000

Hosmer-Lemeshow Statistic (C) = 42.26, df = 8, P= 0.0000; n = 35

Table 3.9. Average percent prevalence of disease conditions per slaughter check

Disease conditions [†]	Mean	95 % CI
Mange	34	31 - 38
Enzootic pneumonia	73	71 - 76
Pleurisy	11	9 - 13
Pleuropneumonia	3	2 - 4
Liver white spot	9	7 - 12
Nephritis	3	1 - 5
Proliferative enteropathy	4	3 - 5
Oesophagogastric ulcer	13	9 - 16

† based on presence or absence of lesions except for grade 2 and grade 3 of mange and grade 3 of oesophagogastric ulcer

Table 3.10. Prevalences of disease conditions (%) by season

Diseases [†]	Autumn	Winter	Spring	Summer	<i>P</i> - value
Mange	36	33.3	32.8	34.9	0.5736
Enzootic pneumonia	17.4	24.6	20.2	19.8	0.0000
Pleurisy	10	13	8.5	7.5	0.0016
Pleuropneumonia	2.5	3	1.4	1.8	0.2379
Liver white spot	11.7	16.3	7.7	3.2	0.0000
Nephritis	0.5	3.9	3.4	0	0.0000
Proliferative enteropathy	6	2.5	2.2	7	0.0000
Oesophagogastric ulcer	13.8	14.7	8.9	13.2	0.0207

[†] based on presence or absence of lesions except for grade 2 and grade 3 of mange and grade 3 of oesophagogastric ulcer, chi-squared test

Discussion

The results of this slaughter surveillance study suggest that subclinical levels of severity are common for a number of important diseases in the lower part of the North Island. Disease surveillance at slaughter is useful in several areas of animal health management (Martin *et al.*, 1987):

- (i) to estimate prevalence of subclinical disease;
- (ii) to detect exotic or emerging diseases and;
- (iii) to monitor efficacy of disease control programmes.

For instance, information on repeated negative results of liver white spot from slaughter surveillance can be used to recommend reduction of anthelmintic programs used within a herd. Consequently effective control of ascarid infection, in combination with slaughter surveillance can save producers costs and reduce the exacerbation of respiratory diseases.

However, the use of slaughter checks as an indicator of infection status in individual pigs is unreliable, due to the low prevalence of some disease conditions such as pleuropneumonia, nephritis and

proliferative enteropathy. Slaughter checks would need to be performed at quarterly or shorter intervals over several years to study seasonal variation of disease conditions, and separate normal seasonal variation from long term trends resulting from control measures.

Sample size

Amongst other factors the reliability of the results obtained from slaughter surveillance depends on the sample size of animals examined. The appropriate sample size is determined by the expected prevalence of a disease and the required level of confidence. In order to be confident about the absence of a disease condition, the sample size has to be adequate to detect at least one positive sample. In this study, sample size was 30 pigs for each herd for each slaughter check. Average percent prevalence of disease conditions of 3 herds based on results from individual slaughter checks is shown in Table 3.9.

There are a number of factors which influence the prevalence of diseases found at slaughter. The factors include herd size (Aalund *et al.*, 1976), season and environmental temperature. Herd of origin influences prevalence due to differences in management systems, health status and geographical location.

Sarcoptic mange

Davies *et al.*, (1991) reported that the false positive rate for grade 1 lesions was estimated as 0.22 and for grade 2 and grade 3 lesions less than 0.02. Therefore, grade 2 and 3 of mange lesions were used in Tables 3.9, 3.10 for comparison. However, these authors also found that the predictive value of grade 1 lesion is poor, so slaughter surveillance result cannot be used to prove the absence of sarcoptic mange in a herd.

Enzootic pneumonia

In the study of Christensen and Cullinane (1990) which is the only comparable study reported in New Zealand, overall prevalence of enzootic pneumonia based on herds from 46 herds in New Zealand during the period 1986-90 was 45%. Enzootic pneumonia prevalence in the herds included in the current study were 64.0%, 74.4% and 76.4%. This could indicate that more recently enzootic pneumonia had become more common, or more possibly it may reflect the different composition of the two groups of herds, since enzootic pneumonia varies widely between herds.

Pleuropneumonia and pleurisy

The sensitivity of monitoring pleuropneumonia lesions at slaughter as an indication of herd infection status is low. However, a high prevalence of pleurisy lesions in slaughtered pigs can indicate pleuropneumonia lesions (Nielsen, 1973; Christensen, 1981; Straw *et al.*, 1986b).

Liver white spot

Floor temperature, humidity and oxygen tension are environmental factors controlling the process of egg embryonation. Floor temperature exceeding 15 °C and the presence of excess water in fattening pens are important factors in the acceleration of the development of *A. suum* eggs (Nilsson, 1982). In this study, the peak prevalence of liver white spot grade 1 was recorded in June (Figure 3.22). It is likely that pigs had been exposed early in their lives to eggs of *A. suum* during warmer temperatures in summer, and reached slaughter weights in the following winter.

Nephritis

White spot lesions are regarded in meat inspection as a sign of leptospirosis occurring in the herd of origin. However, Jones *et al.* (1987) found that some infected pigs failed to develop macroscopic lesions (white spot). Moreover, the lesions which were found indicated past infection not current infection at the time of slaughter. Therefore, careful interpretation of kidney lesions is recommended. Leptospirosis is still a major zoonotic threat to meat workers, meat inspectors and piggery staff. Kidney lesions provide a reasonable provisional indication of previous leptospiral infection, but are of very limited value in detecting individual pigs which are actually shedding or carrying leptospores.

Cystic kidney lesions were also commonly found in this study.

Proliferative enteropathy

Up until now little information has been available on the prevalence of proliferative enteropathy in New Zealand. Christensen and Cullinane (1990) reported that the prevalence of porcine intestinal adenomatosis and associated ileal lesions in New Zealand was 7%. Holyoake *et al.* (1994), in a series of 3 surveys of proliferative enteritis on pig farms in Australia, reported that the prevalence of this disease on Australian farms was low and variable. This finding came from 3 different sources: producers, diagnostic laboratories and swine-specialist veterinarians. During the recording period of May 1992 to July 1993 in this study, a building in one farm suffered a major fire on 5 February 1993. Proliferative enteropathy lesions were detected subsequently at 7 consecutive slaughter checks as shown in Figure 3.33. This may indicate that proliferative enteropathy is a stress related disease, exacerbated by such a stressful experience so as to produce visible lesions. The two highest prevalences

of proliferative enteropathy in February and March (10 % and 9%) is likely to be related to the fire in the piggery (Figure 3.28).

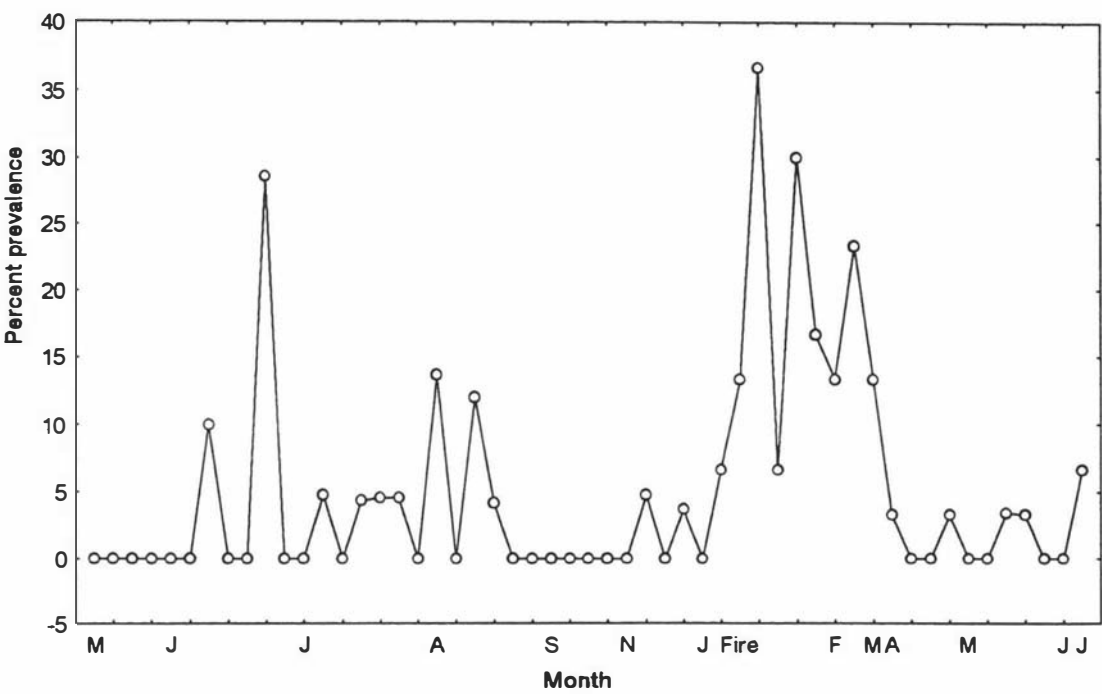


Figure 3.33. Percent prevalence of proliferative enteropathy before and after fire in study farm

Oesophagogastric ulcer

Oesophagogastric ulceration is a problem in one of the 3 herds in this study. This lesion is a disease condition of multiple aetiology (Kavanagh, 1994). Predisposing factors are pelleted feed, whey feeding, particle size, diet density, vitamin E and selenium levels, genetics, management and concurrent disease (Reiman *et al.*, 1967; Baustad and Nafsta, 1969; O’Brien, 1992). Figure 3.32 and Table 3.10 suggest that oesophagogastric ulcers follow a seasonal pattern. Further studies are needed to elucidate causal factors of oesophagogastric ulcers. The herd which suffered severely from ulceration in this study was the only one which used pelleted feed, and had some of the other listed predisposing factors as well.

Atrophic rhinitis

Recently Christensen and Cullinane (1990) reported that in New Zealand atrophic rhinitis occurs as a mild disease. They found that only one of 534 pig snouts examined showed grade 4 lesions. Therefore, it is unnecessary to monitor atrophic rhinitis for evaluation of health status within herds.

The toxigenic strains of *Pasteurella multocida* which are believed to be essential for the pathogenesis of atrophic rhinitis, have never been isolated from New Zealand pigs and New Zealand is considered free of atrophic rhinitis.

Environmental temperature

Results of multivariate analysis suggest that an increase in prevalence of a number of disease conditions is associated with lower environmental temperature. The disease conditions include enzootic pneumonia, pleurisy, pleuropneumonia, liver white spot, nephritis and oesophagogastric ulcers. This supports the findings of the authors reviewing the epidemiology of these diseases (Gordon, 1963; Nilsson, 1982; Done, 1991; Goodall *et al.*, 1993).

The analyses suggests that mange prevalence increases with an increase in average minimum environmental temperature. This agrees with the findings by other authors (Davies *et al.*, 1991). Further investigation are required to assess the validity of this relationship under New Zealand conditions.

The final model for prevalence of proliferative enteropathy did not allow a clear interpretation of the results. This could have been caused by the combination of a relatively study sample and a very low disease prevalence.

Most of the logistic regression models produced in this analysis for each of the nine diseases did not provides a good fit to the data. This suggests that a number of factors with significant effects on disease prevalence had not been included in the analyses.

Conclusion

Slaughter surveillance is a cost-effective measure, which can provide the following information under appropriate circumstances: estimates of subclinical disease prevalence, detection of exotic or emerging diseases and monitoring efficacy of control programs.

The following recommendations can be made for New Zealand conditions: Slaughter checks should be performed regularly every three months in the middle of each season for monitoring disease conditions within a herd. Samples of thirty pigs should be examined at each slaughter check to provide sufficient

confidence in the information gathered. Systematic random sampling can be used to select individual samples.

For monitoring of the effectiveness of a disease control program, slaughter checks should be conducted on a monthly basis. A single slaughter check in winter per year can only provide very limited information about the animal health status of a herd. Eight production-limiting diseases and a zoonotic disease include sarcoptic mange, enzootic pneumonia, pleurisy, pleuropneumonia, liver white spot, nephritis, proliferative enteropathy and oesophagogastric ulcer, were investigated using slaughter checks. Seasonal patterns were found for enzootic pneumonia, pleurisy and liver white spot.

Slaughter surveillance is a practicable and inexpensive method for veterinarians and pig producers to monitor subclinical or production-limiting diseases. Further work will be needed to monitor changes in occurrence of other subclinical diseases, for example, arthritis, tail biting and pericarditis. It will be necessary to link slaughter check data with productivity data to provide better direction for research and control programs at a herd or national level.

This study has shown that disease surveillance at slaughter can be used to monitor specific disease conditions and zoonotic disease, such as sarcoptic mange, enzootic pneumonia, pleurisy, pleuropneumonia, liver white spot, nephritis, proliferative enteropathy and oesophagogastric ulcer under New Zealand conditions. Slaughter surveillance data may be linked with pig productivity and production-cost data to reduce financial loss from subclinical diseases within a herd, and to improve management practices and animal welfare.

CHAPTER 4

**Field efficacy of *Mycoplasma hyopneumoniae*
and *Actinobacillus pleuropneumoniae* vaccines in
pigs**

Abstract

The effectiveness of simultaneous administration of commercial *Mycoplasma hyopneumoniae* and *Actinobacillus pleuropneumoniae* vaccines was tested in an indoor commercial piggery which had experienced continuing respiratory disease problems confirmed as due to both of these pathogens. Piglets were randomly assigned in equal numbers to vaccination and control groups, and each vaccine was administered at a separate site to assigned piglets at 2 and 4 weeks of age.

Liveweight of vaccinates immediately prior to slaughter was 2.49 kg higher ($P = 0.029$) than controls at equal mean slaughter age of 132 days. Average daily gain (ADG) from 15 weeks to slaughter of vaccinates was also significantly higher (40 g/day) than controls ($P = 0.026$). Daily gain was not significantly different in younger age groups. The average lung scores for enzootic pneumonia in vaccinated animals (3.46) were significantly lower than in control pigs (7.32, $P = 0.034$). There were no significant differences between groups with regard to severity of either pleurisy or pleuropneumonia lesions at slaughter.

Log-linear modelling was to test the statistical association between treatment, enzootic pneumonia lesions, pleurisy lesions and pleuropneumonia lesions. This showed an association between severity of enzootic pneumonia lesions and treatment, and an association between the presence of pleuropneumonia lesions and of pleurisy lesions ($\chi^2 = 13.31$; $df = 25$; $P = 0.972$). No other association was significant.

Simultaneous administration of both vaccines produced significant improvement of growth rate during the high-risk period for clinical pneumonia, and increased slaughter weight. It was associated with reduced enzootic pneumonia lesions, but was not associated with reduced severity of pleurisy or pleuropneumonia in the same pigs. No evidence of synergy between the vaccines in influencing lesion severity for pleuropneumonia was detected, within the limitations set by the trial design.

Introduction

Enzootic pneumonia (EP) of pigs caused by *Mycoplasma hyopneumoniae* (MH), is a chronic nonfatal respiratory tract disease that principally affects growing pigs in intensive pig production. EP is characterized by cranio-ventral consolidation and discolouration in the lung. EP causes substantial economic losses, attributable to reduced growth efficiency (Pointon *et al.*, 1985) and increased susceptibility to *Actinobacillus pleuropneumoniae* infection (Yagihashi *et al.*, 1984).

Actinobacillus pleuropneumoniae (AP), the aetiological agent of porcine pleuropneumonia, causes great economic loss in many countries. In New Zealand, the agent was first diagnosed in 1989 (Lake, 1990), and since then five serotypes (1, 5, 6, 7 and 12) have been reported. Serotype 7 was diagnosed from 12 of 17 isolates examined from various sources (Hilbink *et al.*, 1992). The disease is characterized by either peracute to acute fibrino-haemorrhagic pneumonia, or chronic and necrotizing pneumonia with pleurisy. Lesions are most commonly found in the diaphragmatic lobes of the lung, followed by the cardiac and the apical lobes (Mylrea *et al.*, 1974). Typically, the lesions are in the dorsal portions of the diaphragmatic lobes and fibrinous pleuritis occurs over the area of the lesion (Straw *et al.*, 1986b).

Eradication programmes for *M. hyopneumoniae* have been used extensively in pig herds, but the risk of reinfection is high. Methods to control endemic infection with these agents are limited to the use of antibiotics, environmental improvement and vaccination. The use of antibiotics has been associated with increased prevalence of antimicrobial resistant strains of AP (Kim and Jung, 1994; Raemdonck *et al.*, 1994). Improving ventilation, reducing overcrowding and reducing the level of dust and toxic gases are important for control of respiratory diseases.

Vaccination may also represent a practicable control measure from an economic point of view. Vaccination against AP reduces the incidence of pleuritis and the time required for pigs to reach market weight (Riising, 1980). However, commercial vaccines which are available on the world market provide only partial protection (Fenwick and Henry, 1994; MacInnes and Rosendal, 1988). Herds which are free of *M. hyopneumoniae* generally show very limited evidence of pneumonia, even though other respiratory pathogens such as *Pasteurella multocida* may be present and would cause severe disease in the presence of *M. hyopneumoniae*. Therefore, the use of simultaneous vaccination against MH and AP may be useful to control two economically important diseases and perhaps provide synergistic benefits in jointly controlling the two diseases.

The purpose of the current study was to assess efficacy of commercial MH and AP vaccines under field conditions in a typical piggery.

Materials and methods

A 340 sow farrow-to-finish piggery operating a continuous flow system of intensive production was selected in the north of the North Island, New Zealand. Pigs on the farm were known to be naturally infected with MH, AP and *Pasteurella multocida*. In part due to unfavourable conditions in grower buildings, the herd suffered quite severely from clinical pneumonia with substantial mortality in growing pigs, and there had been microbiologically confirmed clinical cases of pleuropneumonia. The health status of this herd was evaluated 3 months prior to the experimental period through clinical observation and inspection of lungs at slaughter. At that time base line data was collected and AP lesions of serotype 7 were confirmed by a reference microbiological laboratory.

Clinical trial design

The trial commenced in August 1993 and data collection was completed by March 1994. Landrace/LargeWhite crossbred piglets were identified individually by ear notching shortly after birth. Identification numbers of the piglets were recorded to create a sampling frame, from which piglets were randomly assigned to vaccinated and control groups. Over three successive weekly weaning periods, 190 pigs were randomly allocated to vaccinated and control groups at 2 weeks of age. Individual ear tagging was used as a secondary identification system. After weaning, vaccinated and control pigs were kept in separate pens by week groups, but each pair of groups was housed adjacent to each other in comparable pens during each phase of the growth period.

Vaccination programme

An inactivated and adjuvanted MH vaccine (Suvaxyn® Respifend MH serial 10027) and an adjuvanted AP bacterin containing AP serotype 1, 5 and 7 (Suvaxyn® Respifend APP serial 17021C) were used in the trial. Pigs were vaccinated intramuscularly with 2 ml of each vaccine at 2 and 4 weeks of age, at separate vaccination sites.

Data collection

Pigs were individually weighed at five different points in their growth period, as follows: 2 weeks, 4 weeks, 11 weeks, 15 weeks of age and one day before slaughter (SL). Deaths of pigs included in the

trial were recorded. Days to market were calculated, based on the time period from weaning to slaughter. Average daily weight gain (ADG) for each pig was calculated using total weight gain divided by total days. Feed consumption was recorded for each group. Feed conversion ratio (FCR) was calculated by group using the amount of feed delivered, divided by total weight gain of pigs in the group.

Lung scoring procedure

Lungs and tag numbers of all pigs in the trial were collected at a local abattoir. Slaughter checks were conducted at a local animal health laboratory. The left apical, left cardiac, left diaphragmatic, intermediate, right diaphragmatic, right cardiac and right apical lobes, pleurisy lesions and pleuropneumonia (PP) lesions were scored using the procedure described by Pointon *et al.* (1992). The apical and cardiac lobes had a maximum score of 10. The diaphragmatic and intermediate lobes were each scored up to 5, giving a total maximum score of 55.

Statistical analysis

The required sample size for the different outcome variables was estimated using the Power Analysis and Sample Size program (NCSS-PASS version 1.0, Kaysville, Utah). Data was analyzed using the statistical software STATISTICA™ for Windows (StatSoft Inc, Tulsa, Oklahoma). Data was checked for conformity with the normal distribution, and descriptive statistics were calculated. One-way ANOVA was used to compare weights, ADG and FCR among treatment groups. ANOVA for repeated measures was used to determine statistical significance of the effects of treatment on weights, ADG and FCR. Chi-squared analysis was used to compare treatment status and degree of severity categories of enzootic pneumonia, pleurisy and pleuropneumonia lesions. Average total lung score, detail of severity of lung scores, and days to market were analyzed using the Mann-Whitney U test. These results are expressed using mean $\pm$ SD.

Hierarchical log-linear modelling (Fienberg, 1980) was used to test the statistical association between treatment, presence of enzootic pneumonia, pleurisy and pleuropneumonia. A value of 0.5 was added to cells to prevent empty cells.

Results

Growth rate and feed efficiency data for 21 pigs were excluded from the analysis because these pigs were affected with health problems or injuries unrelated to pneumonia. Slaughter check data was

available for 348 pigs. Twenty pigs lost their ear tags during transportation to the abattoir or in the ante-mortem pens at the abattoir.

Weights, ADG, FCR at different stages and days to market

Average weights of pigs were very similar between the two groups during the early phase of growth. A difference developed in older pigs, and the average slaughter weight (SLwt) of vaccinated pigs was 2.49 kg per live pig higher than in controls (Table 4.1). The overall ADG from weaning to slaughter was not significantly different between the groups. During the period from 15 weeks of age to slaughter the ADG of the vaccinated group was significantly higher than in controls by 40 g/day ($P = 0.026$, Table 4.1).

FCR data was analysed by groups, providing results for the periods from 4 to 11 wks, 11 to 15 wks and 15 wks to slaughter. Feed efficiency showed a similar trend to ADG, but the difference in FCR was not statistically significant. Mean number of days to market in the two groups was almost identical (Table 4.1). Two-way repeated measures ANOVA showed that apart from the normal weight increase as pigs aged, treatment alone had no significant effect, but there was a significant time x treatment interaction, reflecting the specific effect of the vaccine on pigs late in the growth period referred to above (Table 4.2).

Table 4.1. Average weights, ADG, FCR at different stages and days to market (mean ± SD) by treatment status

Stages (kg)	Vaccinated (n=174)	Control (n=185)
Wt 2 wks	4.65 ± 1.13	4.69 ± 1.14
Wt 4 wks	7.69 ± 1.56	7.69 ± 1.72
Wt 11 wks	30.03 ± 4.80	29.68 ± 5.60
Wt 15 wks	52.76 ± 7.00	52.60 ± 8.04
SLwt	91.62 ± 10.04	89.13 ± 11.56 [*]
ADG 4-11 wks	0.459 ± 0.084	0.452 ± 0.099
ADG 11-15 wks	0.791 ± 0.154	0.791 ± 0.137
ADG 15 wks- SL	0.740 ± 0.158	0.700 ± 0.180 ^{**}
ADG 4 wks- SL	0.646 ± 0.089	0.628 ± 0.094
FCR 4-11 wks(n=6)	1.50 ± 0.06	1.44 ± 0.06
FCR 11-15 wks(n=12)	2.24 ± 0.26	2.29 ± 0.22
FCR 15 wks-SL(n=15)	2.70 ± 0.50	2.91 ± 0.35
Days to market(days)	132.4 ± 8.0	131.9 ± 8.3

^{*} $F_{1,361}=4.79$; $P=0.029$

^{**} $F_{1,357}=4.97$; $P=0.026$

Table 4.2. Results of two-way repeated measures ANOVA for effects of treatment, time and interaction between treatment and time on weight

Effect	df	F	P-level
Treatment	1,355	1.40	0.2382
Time	4,1420	17209.50	0.0000
Treatment × Time	4,1420	2.90	0.0209

Degree of severity of enzootic pneumonia, pleurisy and pleuropneumonia lesions

The association between treatment status and categorised degree of severity was analyzed for EP, pleurisy and pleuropneumonia lesions using the χ^2 (Table 4.3). Active pneumonia lesions were found in 40% of lungs from the vaccinated group and 54% in the control group. There were no significant

differences between the two groups with respect to the prevalence of pleurisy and pleuropneumonia lesions ($\chi^2 = 0.18$, $df = 2$, $P = 0.91$; $\chi^2 = 0.48$, $df = 2$, $P = 0.49$).

Table 4.3. Degree of severity categories of enzootic pneumonia, pleurisy and pleuropneumonia lesions [number of affected pigs (percentage of affected pigs)] by treatment status

Lesions	Vaccinated (n=171)	Control (n=177)
Enzootic pneumonia*		
absent	87 (51%)	70 (40%)
active	69 (40%)	96 (54%)
chronic	15 (9%)	11 (6%)
Pleurisy		
absent	105 (61%)	111 (63%)
grade 1	35 (20%)	33 (19%)
grade 2	31 (18%)	33 (19%)
Pleuropneumonia		
absent	159 (93%)	161 (91%)
present	12 (7%)	16 (9%)

* $\chi^2=6.77$; $df=2$; $P=0.0338$

Enzootic pneumonia lesions were mainly confined to the cranio-ventral part of the lungs. Average total lung score of enzootic pneumonia lesions and average lung scores for different lobes of vaccinated pigs were significantly lower than in control pigs (Table 4.4). Percentage prevalence of EP lesions on a lobar basis, comparing between vaccinated and control groups, is shown in Table 4.5.

Table 4.4. Average total score and average lung scores of enzootic pneumonia lesions for each lung lobe (mean $\pm$ SD) by treatment status

Lung scores	Vaccinated (n=171)	Control (n=177)	<i>P</i> -value
average total score	3.46 $\pm$ 5.31	7.32 $\pm$ 9.02	0.00038*
left apical lobes	0.82 $\pm$ 1.60	1.44 $\pm$ 2.40	0.01690*
left cardiac lobes	0.86 $\pm$ 1.81	1.92 $\pm$ 2.79	0.00015*
left diaphragmatic lobes	0.24 $\pm$ 0.77	0.64 $\pm$ 1.20	0.00006*
intermediate lobes	0.34 $\pm$ 0.95	0.64 $\pm$ 1.29	0.01389*
right diaphragmatic lobes	0.17 $\pm$ 0.70	0.27 $\pm$ 0.68	0.00743*
right cardiac lobes	0.84 $\pm$ 1.59	1.81 $\pm$ 2.77	0.00357*
right apical lobes	0.19 $\pm$ 0.75	0.59 $\pm$ 1.33	0.00009*

*Values are significantly different when tested by Mann-Whitney U test.

Table 4.5. Percentage prevalence of EP lesions on a lobar basis by treatment status

Lung lobes	Vaccinated	Control
right cardiac	29.8	41.2
left cardiac	28.7	45.8
left apical	25.7	36.7
intermediate	15.2	25.4
left diaphragmatic	11.1	28.3
right apical	8.2	23.7
right diaphragmatic	7.6	17.5

The association between the variables treatment status, presence of EP, pleurisy and pleuropneumonia lesions was analyzed using log-linear modelling. Only main effects and first order interaction terms were considered during the modelling process to allow biologically sensible interpretation of the results. The final log-linear model included the interaction terms between EP lesions and treatment and between PP lesions and pleurisy lesions. The maximum likelihood χ^2 and Pearson χ^2 for assessment of model

fit were 13.31 ($df = 25$, $P = 0.9724$) and 12.89 ($df = 25$, $P = 0.9778$) respectively. No statistically significant interaction was found between pleurisy and treatment, pleurisy and EP lesions, PP lesions and treatment and between PP lesions and EP lesions.

Discussion

Vaccination against both MH and AP produced a substantial and significant improvement (2.49 kg) in slaughter weight of pigs, with significantly higher daily gain during the period from 15 weeks to slaughter weight, at an average for both groups of 132 days. The groups remained similar in mean weight up to the weighing at 105 days, but then diverged significantly by 40 g/day in rate of gain and hence in body weight over the period when clinical pneumonia and pleurisy typically occurred in this herd. Although FCR was 0.21 kg better per kg of gain in the vaccinated pigs over the same period, the limited number of replicate measurements possible for this index under group feeding conditions meant that there was insufficient statistical power in the trial design to discriminate whether this was a true or a chance difference. The trial was limited to three grower groups in a single herd because of the extensive measurements required, and reliable assessment of whether or not vaccination was associated with a difference in FCR would have required replication across a substantial number of herds, or at least a much larger number of grower groups within a single herd. However the results of this trial are consistent with those obtained by other workers using MH vaccine (Weiss and Peterson, 1992; Christensen and Deitemeyer, 1993; Lium *et al.*, 1994; Vraa-Andersen *et al.*, 1994) and AP vaccines (Heard and Tuck, 1986; Thacker and Mulks, 1988; Beskow *et al.*, 1992; Tarasiuk *et al.*, 1994).

Pigs were immunized with both vaccines, so it is not possible to directly differentiate each of their effects on production. However, some insights into their relative contributions were obtained. The use of both vaccines reduced the proportion of pigs with lungs with active (acute) EP (Bahnson *et al.*, 1992) to 40% compared with 54% in control pigs, and increased the proportion with no lesions of EP to 51% in vaccinated pigs compared with 40%. The average total lung score for EP lesions was halved compared with unvaccinated pigs. Lesions identified at slaughter do not of course reflect the full history of the pigs, since earlier lesions could have already resolved (Morrison *et al.*, 1986). Other techniques such as volumetric measurement of pneumonia (Hill *et al.*, 1992) and radiographically measured lifetime pneumonia (Noyes *et al.*, 1990) provide more comprehensive data, but the association between lung lesions and production data produced by these methods were consistent with our results. These more extensive techniques are impractical as an alternative to routine slaughter checks, and the

evidence from this study shows that MH vaccination is associated with both improved productivity and less EP lesions, each of which is measurable in slaughter animals.

The results of the log-linear analysis show that the use of vaccine is associated with lower prevalence of enzootic pneumonia lesions, but no association was detected for pleurisy or pleuropneumonia. It is likely that the killed whole cell AP bacterin as used here protects mainly against mortality (which the trial had insufficient power to evaluate) and only against infection with the homologous serotype (Tarasiuk *et al.*, 1994). A fully effective AP vaccine should ideally contain both bacterial whole cell antigens and secreted toxins (capsular polysaccharide, lipopolysaccharide, outer membrane proteins, cytotoxin and haemolysin) as has been demonstrated in mice by Bhatia *et al.* (1990). However, no vaccines of this type are yet available.

Because the prevalence of pleuropneumonia lesions in pigs is much lower than EP lesions, the trial had only poor power to reliably detect whether there was a valid difference in the prevalence of pleuropneumonia lesions between the vaccinated and the control group. A sample size of 2,800 pigs per group would have been required to reach a power of 0.8 ($\alpha = 0.05$). Thus it is not possible to decide whether the use of AP vaccine in combination with MH vaccine provides any additional benefit under field conditions (Elbers and Schukken, 1995).

Log-linear analysis showed that the presence of pleuropneumonia lesions was positively associated with the presence of pleurisy lesions, supporting findings from other studies on the link between these conditions (Christensen, 1981; Nielsen, 1973; Straw *et al.*, 1986b). However, there was no association between these two types of lesions and the presence of EP at slaughter, although because of the temporal sequencing involved this does not argue strongly against a possible predisposing influence of EP on initiation of pleuropneumonia (Yagihashi *et al.*, 1984).

Acknowledgements

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CHAPTER 5

**Epidemiology of *Actinobacillus*
pleuropneumoniae infection in pigs**

Abstract

Thirty cohort pigs within a larger 380 animal study of vaccination against *Mycoplasma hyopneumoniae* and *Actinobacillus pleuropneumoniae* were followed from birth to slaughter to study epidemiological patterns of porcine pleuropneumonia caused by *Actinobacillus pleuropneumoniae* in a 340 sow farrow-to-finish piggery, operating a continuous system of intensive production in the North Island of New Zealand. The cohort pigs were allocated into two equal groups: vaccinated and control. Pigs in the first group were vaccinated at 2 and 4 weeks of age with both *Mycoplasma hyopneumoniae* vaccine and *A. pleuropneumoniae* vaccine at separate vaccination sites. Series of nasal swabs were taken at 4, 8, 10, 11, 12, 14, 16 and 18 weeks of age. The swab was streaked onto the surface of a selective medium on the farm and the plates were immediately transported to a laboratory and incubated at 37°C for 5 days. After the trial pigs were slaughtered at an average of 132 days of age, Lungs were examined and taken for bacteriological culture and isolation.

Thirty-five out of 256 samples produced haemolytic colonies which were, Gram-negative, V factor-dependent and positive to the CAMP test. *A. pleuropneumoniae* was first isolated at 4 weeks of age from one vaccinated pig. This finding suggests that piglets became infected in the farrowing pen and source of transmission may come from a healthy carrier sow. The incidence of *A. pleuropneumoniae* infection reached a maximum of 54% and 40% at 11 weeks of age in vaccinated and control groups respectively.

Infection status of the litter is considered to be a factor influencing morbidity in infected herds during weaner and grower periods. The results suggest that simultaneous vaccination with *M. hyopneumoniae* and *A. pleuropneumoniae* vaccines at 2 and 4 weeks of age cannot prevent *A. pleuropneumoniae* infection during the weaner or grower-finisher periods. No evidence was found to support the hypothesis that *M. hyopneumoniae* increases susceptibility to *A. pleuropneumoniae* infection.

Introduction

Porcine pleuropneumonia caused by *Actinobacillus pleuropneumoniae* biovar 1 affects pigs of all ages and causes great economic losses throughout the world. *A. pleuropneumoniae* causes peracute to acute fibrinohaemorrhagic pneumonia or chronic and necrotizing pneumonia with pleurisy or inapparent infection. In New Zealand, the agent was first diagnosed in 1989 (Lake, 1990), and since then five serotypes (1, 5, 6, 7, and 12) have been reported. Twelve of 17 isolates examined from early diagnostic samples were serotype 7 (Hilbink *et al.*, 1992).

Relatively little has been published on the epidemiology of *A. pleuropneumoniae* although movement of subclinical carrier pigs is considered a major contributing factor in the spread of *A. pleuropneumoniae* between herds (Alexander, 1992). In addition, field observations found that new outbreaks occurred in closed or semi-closed herds in which no pigs were introduced from any known infected source. Therefore, healthy carrier pigs play an important role in the spread of the disease in herds. Direct transmission from an infected pig to susceptible pigs by aerosol appears to be the most frequent means for spreading the disease, since these bacteria are highly susceptible to drying and commonly used disinfectants (Nielsen and Mandrup, 1977).

Prevention and control programmes for porcine pleuropneumonia often remain ineffective due to the complicated nature of the disease. To study *A. pleuropneumoniae* infection in the upper respiratory tract is laborious, as isolation of the organism from the nasopharyngeal cavity is impeded by overgrowth of the less fastidious and rapidly growing normal bacterial flora. A selective medium has been used to provide a practical method to detect the presence of *A. pleuropneumoniae* in the nasal cavities of pigs (Gilbride and Rosendal, 1983; Wilson *et al.*, 1987; Sidibé *et al.*, 1993).

Mixed infections of *Mycoplasma hyopneumoniae* and *A. pleuropneumoniae* are common in pigs. Yagihashi *et al.* (1984) found that previous infection with *M. hyopneumoniae* increased susceptibility to *A. pleuropneumoniae*.

The objective of the current study was to describe the epidemiological pattern within a typical commercial herd of *A. pleuropneumoniae* infection in pigs, half of which were vaccinated with *M. hyopneumoniae* and *A. pleuropneumoniae* vaccines. The herd was endemically infected with *M. hyopneumoniae* and *A. pleuropneumoniae*.

Materials and methods

A 340 sow farrow-to-finish piggery operating a continuous flow system of intensive production was selected in the north of the North Island, New Zealand. Pigs on the farm were known to be naturally infected with *M. hyopneumoniae*, *A. pleuropneumoniae* and *Pasteurella multocida*. In part due to unfavourable environmental conditions in the grower buildings, the herd suffered quite severely from clinical pneumonia, with substantial mortality in growing pigs, and there had been confirmed clinical cases of pleuropneumonia. The health status of this herd was evaluated 3 months prior to the experimental period by clinical observation and inspection at slaughter. At that time base line data was collected and *A. pleuropneumoniae* serotype 7 was isolated from lesions in pneumonic lungs by a reference microbiological laboratory.

Clinical trial design

The trial commenced in August 1993 and data collection was completed by March 1994. Landrace/LargeWhite crossbred piglets were identified individually by ear notching shortly after birth. The identification numbers of the piglets were recorded to create a sampling frame, from which piglets were randomly assigned to vaccinated and control groups. Over three weekly weaning periods, a total of 380 pigs were randomly allocated in equal numbers to each of the vaccinated and control groups at 2 weeks of age. Within each group, 15 pigs were randomly selected using a random number table from each of the vaccinated and control groups for investigation of *A. pleuropneumoniae*. Individual ear tagging was used as a secondary identification system. After weaning, vaccinated and control pigs were kept in separate pens by weight. Both groups were housed adjacent to each other in comparable pens during each phase of the growth period.

Vaccination programme

An inactivated and adjuvanted *M. hyopneumoniae* vaccine (Suvaxyn® Respifend MH serial no. 10027) and an adjuvanted *A. pleuropneumoniae* vaccine containing *A. pleuropneumoniae* serotypes 1, 5 and 7 (Suvaxyn® Respifend APP serial no. 17021C) were used in the trial. Pigs were vaccinated intramuscularly with 2 ml of each vaccine at 2 and 4 weeks of age, at separate vaccination sites.

Collection of samples

Nasal swabs were collected by inserting a Cultureswab™ (Difco Laboratories, West Molesey, Surrey) 3 to 5 cm into each nostril of each pig and rotating gently. Samples were taken at 4, 8, 10, 11, 12, 14, 16 and 18 weeks of age. As soon as a swab had been collected on the farm it was spread across the

surface of a plate containing selective medium, and a sterile inoculating loop was used to further streak the plate, allowing isolation of individual colonies. The selective plates were then transported as rapidly as possible in a chilled container to the laboratory about 300 km away, and incubated there. At the end of the trial, pigs were slaughtered at a local abattoir, and all lungs were taken to a local animal health laboratory. Samples of lesions were taken aseptically, and if no lesion was present sample were taken from the left and right dorsal areas of the diaphragmatic lobes.

Culture Media

A selective medium for *Actinobacillus pleuropneumoniae* was prepared using the formula described by Wilson et al. (1987). This contained 20 µg/mL tryptic soy agar (Difco Laboratories, Michigan, USA), 50 µg/mL whole calf blood, 0.1% Nicotinamide Adenine Dinucleotide (NAD), 1 µg/mL crystal violet, 16 µg/mL spectinomycin and 60 µg/mL bacitracin. Crystal violet, spectinomycin, bacitracin and NAD were supplied as a lyophilised antimicrobial mixture in vials (Lot no. 3I03S, SCIANZ Corporation Ltd., Auckland, New Zealand)

Microbiological techniques

At the microbiology laboratory, the selective media were incubated at 37°C in the presence of 10% CO₂ and were examined for haemolytic colonies after 12, 24, 36 and 48 hrs of incubation. They were examined for up to 5 days if no haemolytic colony was present at earlier stages. All haemolytic colonies were picked off and stained using Gram's method. Haemolytic colonies which contained Gram-negative coccobacilli or pleomorphic rods were inoculated over the entire surface of a nutrient agar (tryptic soy agar) plate. X factor, V factor (NAD) and X + V factor discs (Lot no. 41055, 40964 and 41058, Oxoid Unipath Ltd., Hampshire, England) were then placed onto the agar surface. After 24, 48, 72 and 96 hrs of incubation at 37°C, the nutrient agar plates were examined for growth of colonies around each disc. V factor-dependent colonies were picked off and the Christie-Atkins-Munch-Petersen reaction (CAMP) was tested by streaking isolates on to 5% calf blood agar (base medium) perpendicular to a non-haemolytic strain of *Staphylococcus aureus*. An enhanced haemolytic zone around the suspected *A. pleuropneumoniae* streak was considered as a positive reaction (Gilbride and Rosendal, 1983). Colonies showing a positive CAMP test were stored at -70° C in trypticase soy broth (BBL, Becton Dickinson, USA) containing 15 % glycerol (Park, 1976). After all samples had been examined, isolates were thawed and tested for urease reactions. The urease test was performed by streaking a loopful of bacteria onto urea slopes in a bijoux bottle containing urea agar base (Difco Laboratories, Michigan, USA) and bacto agar (Difco Laboratories, Michigan, USA). After 4 hrs of incubation at 37°C, bijoux bottles were examined. A pink colouration around the streak was interpreted as a positive reaction. Four attributes were considered as distinguishing characteristics of *A. pleuropneumoniae*

biovar 1: haemolysis on calf blood agar, V-factor growth requirement only, positive CAMP test and positive urease test (Lombin *et al.*, 1985; Møller and Kilian, 1990) (Table 5.1).

Lung scoring procedure

All lung lobes from the studied pigs were examined for the presence of lung lesions such as enzootic pneumonia, pleurisy and pleuropneumonia at a local animal health laboratory. Enzootic pneumonia lesions, pleurisy lesions and pleuropneumonia lesions were scored using the procedure described by Pointon *et al.* (1992).

Statistical analysis

Data was analysed using the statistical software STATISTICA™ for Windows (StatSoft Inc, Tulsa, Oklahoma), NCSS 6.0 Statistical system for Windows (Number Cruncher Statistical Systems, Kaysville, Utah) and Epi Info, version 6 (Centers for Disease Control and Prevention, Atlanta, Georgia, USA). Isolates which were haemolytic (H), Gram-negative (G), V factor-dependent (V), CAMP test (C) and urease test (U) positive were treated as positive (b) for *A. pleuropneumoniae*. Isolates which were haemolytic, Gram-positive and V-factor test negative or haemolytic, Gram-negative and V-factor test negative were treated as false positive (d). The positive predictive value of *A. pleuropneumoniae* using the presence of haemolysis and Gram's staining as a diagnostic method was calculated using the formula of $(b/b+d) \times 100$ (Martin *et al.*, 1987). Variable 'days to market' was analysed using ANOVA. Days to market was calculated from birth to slaughter date. All results are expressed as mean $\pm$ SD. Chi-squared analysis was used to compare enzootic pneumonia, pleurisy and pleuropneumonia lesions between vaccinated and control groups. The relative risk (RR) was calculated using the formula of $[a/(a+b)]/[c/(c+d)]$ (Martin *et al.*, 1987). Survival analysis was used for comparing the time between birth and the first recovery of *A. pleuropneumoniae* from nasal cavities between vaccinated and control groups.

Results

A total of 15 pigs per group was selected for the trial. Two pigs died in October and November 1993 respectively. One died of a broken leg, and the cause of death of the other pig was undetermined but was not due to respiratory disease. Two hundred and fifty-six samples were collected for bacteriological culture. Average days to market (mean $\pm$ SD) in vaccinated and control pigs, was 160 ± 11 and 167 ± 8 days respectively ($P=0.0768$). Three pigs lost their ear tags during transportation to the abattoir or in the ante-mortem pens at the abattoir. Therefore, slaughter check data was available for 25 pigs.

Culture of nasal swabs

Thirty-five out of 256 samples produced haemolytic colonies which were Gram-negative, V factor-dependent and positive in the CAMP test. Seventy-nine strains were recovered from 35 samples and were stored at -70°C . During the storage time, the freezer broke down over a weekend before the urease test could be performed, resulting in the thawing of all strains. It was possible to recover only 35 isolates from 23 samples. All 35 isolates showed positive urease tests. Based on these samples, a percent positive predictive value of 100% for *A. pleuropneumoniae* diagnosis using a series of 3 diagnostic attributes (haemolysis, Gram-negative and V factor-dependent) was achieved. This suggests that the 12 samples which could not be subjected to the urease test, but which had shown haemolysis, were Gram-negative and V factor positive can be assumed for the purposes of this epidemiological analysis to be positive for *A. pleuropneumoniae* (Figure 5.1).

This microorganism was isolated from swabs taken from pigs at all stages from 4 weeks to slaughter age. Infection was prevalent in nasal swab samples at each sampling except in pigs at 8, 10 and 12 weeks of age. Percent point prevalence reached a maximum of 50% and 40% at an age of 11 weeks in treatment and control groups respectively (Figure 5.2).

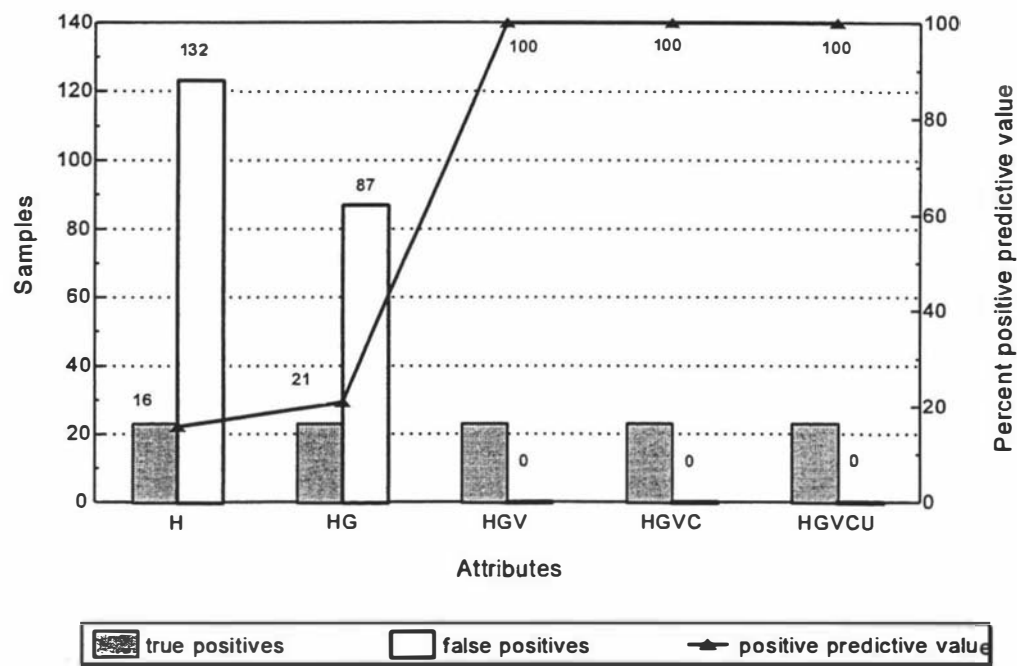


Figure 5.1. Positive predictive values for progressive combinations of diagnostic attributes of *Actinobacillus pleuropneumoniae* infection (in percent)

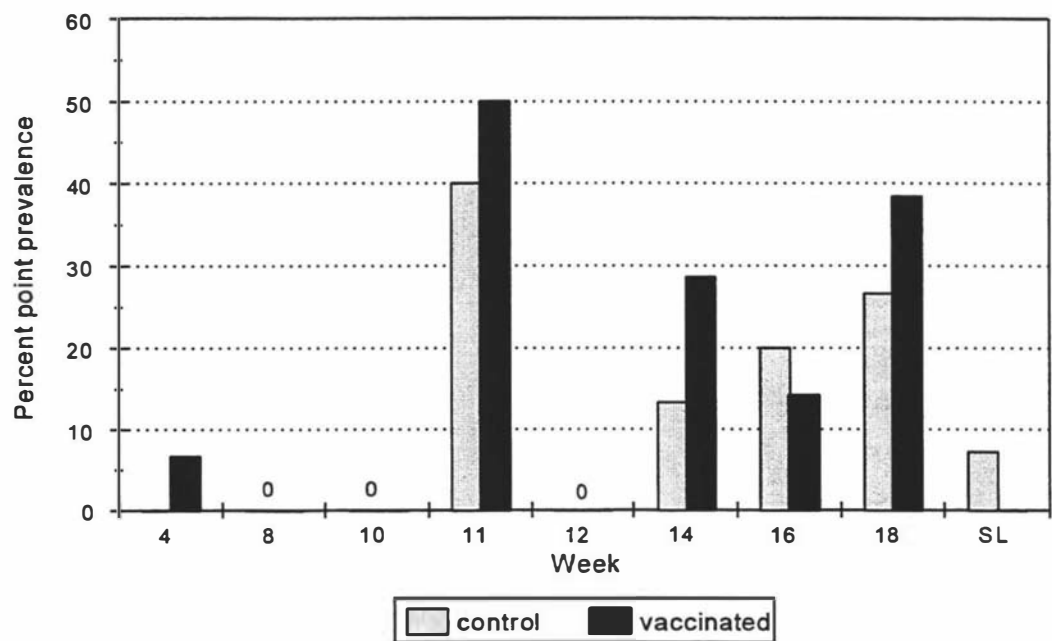


Figure 5.2 Percent point prevalence of *A. pleuropneumoniae* infection in cohort pigs

Lung lesions at slaughter

Prevalence of pleuropneumonia and pleurisy does not appear to be associated with treatment status. Prevalence of enzootic pneumonia lesions was significantly different between vaccinated and control groups as shown in Table 5.1.

Incidence of *A. pleuropneumoniae* infection

A. pleuropneumoniae was first recovered from one vaccinated pig at 4 weeks of age and in control pigs at 11 weeks of age. Peak percent incidence of *A. pleuropneumoniae* infection of vaccinated and control pigs was 54% and 40% at 11 weeks of age. The microorganism was last recovered from one vaccinated pig at 18 weeks of age and at slaughter in one control pig (Figure 5.3).

Table 5.1 Lung lesions in the 2 trial groups [percent prevalence (no. of findings / total samples)]

Lesions	Vaccinated	Control	RR*	χ^2	P-value	Power
Pleuropneumonia	9%(1/11)	14%(2/14)	0.64	0.05	1.0000	0.0773
Pleurisy	36%(4/11)	46%(6/13)	0.79	0.00	0.6968	0.0801
Enzootic pneumonia	18%(2/11)	85%(11/13)	0.21	8.09	0.0044	0.5379

* That vaccinated animals will have the particular lesion, compared with controls

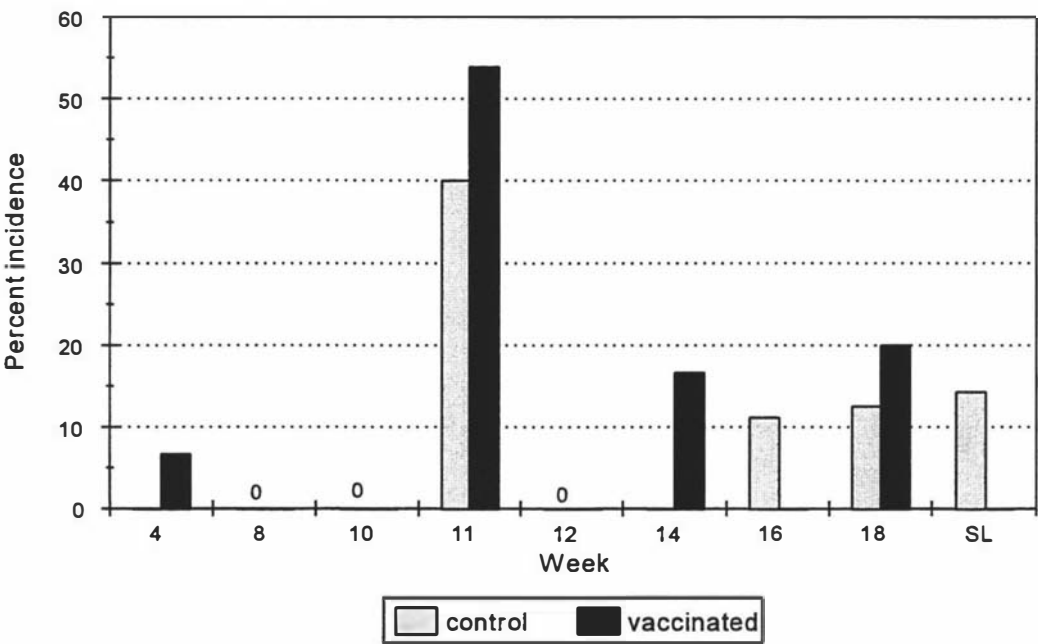


Figure 5.3. Percent incidence of *A. pleuropneumoniae* infection in cohort pigs

Infection status of other pigs in litter

The association between the infection status of other pigs from the same litter and the risk of infection for individual pigs was investigated. Only litters with at least one pig in the vaccinated group and another in the control group were included in this analysis. The results suggest that pigs which came from litters which produced other infected pigs were 1.5 times as likely to be themselves infected as pigs which came from litters which did not have other infected pigs. This difference was not statistically significant with the small sample size (Table 5.2) (RR =1.50, $P = 0.3714$). All of the pigs which became infected and came from litters with no other infected pigs were diagnosed as infected early (between the ages of 4 and 11 weeks), compared with 66% of pigs with infected litter mates as shown in Table 5.3 ($\chi^2 = 3.11$, $P = 0.2110$).

Table 5.2. Relationship between *A. pleuropneumoniae* infection and infection status of other pigs from same litter

Infection status of other pigs in litter	Infected (D+)	Noninfected (D-)
Yes	15	5
No	4	4
RR	1.50 (0.72 < RR < 3.14)	$P = 0.3714$

Table 5.3 Relationship between age of first isolation of *A. pleuropneumoniae* and infection status of other pigs from same litter (Early = 4 - 11 wks; Late = greater than 11 wks)

Infection status of others pigs in litter	Early	Late	Total
Yes	66% (10/15)	34% (5/15)	15
No	100% (4/4)	0	4
RR	0.67 (0.47 < RR < 0.95)	$P = 0.5304$	

Survival analysis was used to compare age of first recovery of *A. pleuropneumoniae* between treatment and control groups. The survival curves were not significant different by Log Rank Test ($\chi^2 = 0.23$, $df=1$, $P = 0.6338$). Both curves dropped sharply at the age of 76-82 days (Figure 5.4).

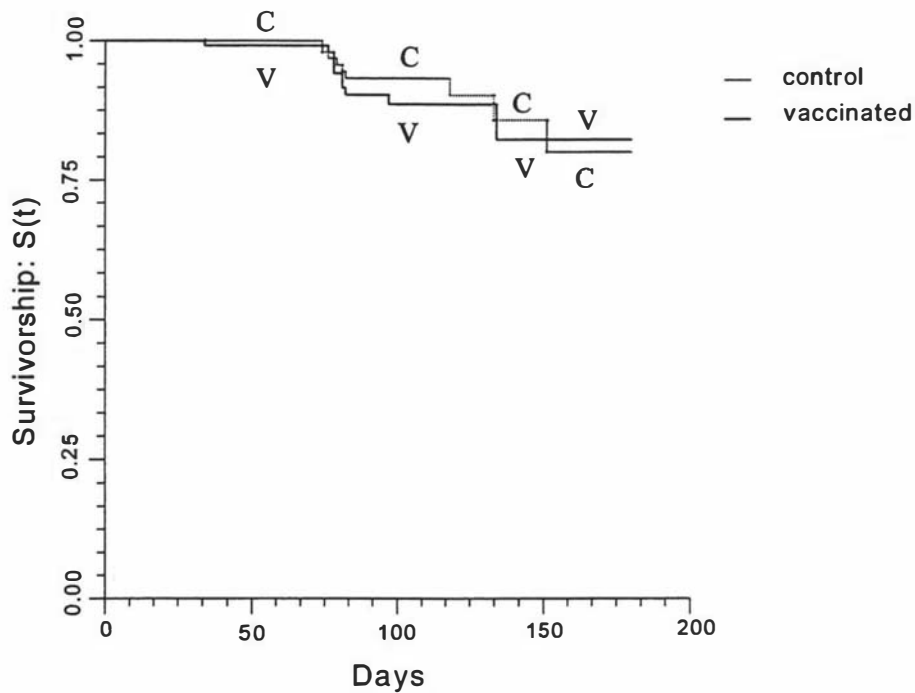


Figure 5.4. Survivorship functions for vaccinated and control groups

Discussion

This study was based on data from a single indoor piggery in the North Island of New Zealand, which was confirmed as infected with *M. hyopneumoniae* and *A. pleuropneumoniae* serotype 7.

A number of microorganisms can be isolated from the pig's respiratory tract, including staphylococci, α - haemolytic streptococci sp, non-haemolytic streptococci, *Escherichia coli*, *Pasteurella multocida*, other *Pasteurella* spp, *Actinomyces pyogenes*, and *Proteus* spp (Gilbride and Rosendal, 1983; Hensel *et al.*, 1994). During this study the following diagnostic criteria were used in steps to differentiate *A. pleuropneumoniae* from other bacteria:

- (i) The selective medium used in this study contained crystal violet and bacitracin (which are effective mainly against Gram-positive bacteria) and spectinomycin (which is effective against Gram-negative bacteria). These additives suppressed the growth of some of the normal flora from porcine upper respiratory tracts. However, some bacteria are able to grow on the selective agar, such as *Pasteurella* spp. and *Proteus* spp. (Gilbride and Rosendal, 1983).
- (ii) Therefore, only colonies which showed haemolysis on the selective plates were picked off and Gram stained. Colonies which contained Gram-negative coccobacilli or pleomorphic rods were tested for V factor-dependency.
- (iii) Colonies which showed V factor-dependent growth were subcultured and tested for CAMP reactions.
- (iv) Only these cultures which showed positive CAMP tests were then tested for positive urease reactions.

The selective medium used made possible the study of the epidemiological patterns of *A. pleuropneumoniae* infection on this farm. However, it has to be taken into account that bacteriological culture and isolation of *A. pleuropneumoniae* is specific, but not sensitive enough for detecting the microorganism in individual pigs (Sidibé *et al.*, 1993). Thus, a number of steps were taken to increase the probability of isolation of *A. pleuropneumoniae*. Firstly, as carrier pigs may have had only a few organisms in the nasal cavity, two swabs were used for each pig to increase the possibility of detection of the microorganisms. These were streaked onto the surface of the selective plates shortly after collection, and the plates were sent to the laboratory as soon as possible, between 8 and 12 hrs after collection. Secondly, the plates were examined and colonies

were selected on the basis of haemolysis after 12 hr incubation to reduce overgrowth by other bacteria. Finally, three morphologically similar haemolytic colonies were picked from each plate to reduce the risk of false-negative results.

The traditional method used for the differential diagnosis of *A. pleuropneumoniae* (biovar 1) requires 4 attributes (positive CAMP reaction, positive urease reaction, V-factor requirement and haemolysis) to identify the microorganism (Biberstein *et al.*, 1977; Kilian *et al.*, 1978; Lombin *et al.*, 1985; Møller and Kilian, 1990 and Blanchard *et al.*, 1993). In this study, a series of diagnostic attributes (haemolysis, Gram-negative, V-factor requirement and positive CAMP reaction) was used (Figure 5.1) and the positive predictive value reached 100% using only haemolysis, Gram staining and V-factor dependency. This has implications for future studies as it reduces the time to confirmation and the cost of media.

A. pleuropneumoniae was first isolated from one vaccinated pig at 4 weeks of age. This finding suggests that this animal became infected in the farrowing pen, probably from a healthy carrier sow. Protective maternal antibodies decline to a low level by about 8 - 12 weeks (Gardner *et al.*, 1991). This could explain the peak incidence of *A. pleuropneumoniae* at 11 weeks of age in both vaccinated and control groups. This finding supports the retrospective epidemiological study of Sebunya *et al.* (1982) which showed that *Haemophilus pleuropneumoniae* was more common in 3-month-old pigs. It also confirms the findings of Kume *et al.* (1984), who described a peak isolation rate of *H. pleuropneumoniae* at 11-15 weeks of age and Wilson *et al.* (1987) who reported a peak isolation rate at 12 weeks of age.

This study suggests that pigs from an infected litter are 1.5 times as likely to carry *A. pleuropneumoniae* as pigs from non-infected litters (Table 5.2) although numbers were too small for this to be statistically significant. In addition, *A. pleuropneumoniae* is more likely to be first isolated from pigs at 4 - 11 weeks of age than from pigs which are older than 11 weeks of age (Table 5.3) if pigs come from non-infected litters (which presumably have lower maternal immunity than from infected litters. These results suggest that transmission of infection is more likely to occur in the farrowing pen than after weaning. Nevertheless, it is surprising that transmission is not more common in the post weaning period. The highest incidence of animals likely to shed the microorganisms is at about 11 weeks of age.

Enzootic pneumonia lesions were significantly reduced in vaccinated pigs when compared with control pigs (Table 5.1), whereas pleuropneumonia and pleurisy lesions were not statistically different between the two groups. Furthermore, *A. pleuropneumoniae* was isolated from vaccinated pigs at several stages of growth, so the vaccine did not prevent carrier age of *A. pleuropneumoniae*. In support of the findings of Gardner *et al.* (1991), the field data in this study does not appear to support the hypothesis that *M. hyopneumoniae* infection increases the susceptibility to *A. pleuropneumoniae* infection, as found by Yagihashi *et al.* (1984).

In summary, this study supports the hypothesis that the risk of transmission of *A. pleuropneumoniae* is highest in the farrowing pen. Incidence of *A. pleuropneumoniae* infection reached a peak at 11 weeks of age. Between 14 and 18 weeks of age, the risk of infection appeared to be lower. Simultaneous vaccination with *M. hyopneumoniae* vaccine and *A. pleuropneumoniae* vaccine at 2 and 4 weeks does not appear to prevent *A. pleuropneumoniae* infection during the weaner or grower-finisher periods and data does not support the hypothesis that *M. hyopneumoniae* infection increases the susceptibility to *A. pleuropneumoniae* infection.

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CHAPTER 6

**Comparison of pig production between two
countries with tropical and temperate
climates**

Introduction

With increasing size and economic value of commercial pig herds, the traditional role of veterinary services has to be reconsidered. Treatment and control of clinical disease are no longer the single most important objective of veterinary services. Non-infectious causes as well as subclinical diseases have become increasingly important as a result of intensification of production systems (Wrathall, 1977; Morris, 1982; Van Der Leek and Becker, 1993). Losses in productivity are associated with a range of health and management factors.

The considerable effect of climate and type of management systems is widely recognized. Different production systems and geographical locations have their advantages and disadvantages. Comparing production data between piggeries in tropical and temperate climates may allow identification of the parameters most likely to be affected by such differences.

The presence of production-limiting disease is recognized by comparing actual production with target values. In farrow-to-finish operations, reproductive problems or diseases are rarely caused by a single factor. Diagnosis of these diseases is based on examination of production data and assessment of reproductive performance of the breeding herd (Muirhead, 1978; Stein, 1990).

Only little information has been published on herd performance of commercial herds in tropical locations. The objective of this study was to analyse reproductive performance based on two groups of pig herds representing tropical and temperate locations, to define opportunities for improving productivity in each management system. Production data from intensive piggeries in Thailand (TH) and New Zealand (NZ) was used to represent tropical and temperate locations respectively.

Materials and methods

Data

Pig production data from 21 Thai herds and 22 New Zealand herds for the year 1991, and from 20 Thai herds and 20 New Zealand herds for the year 1992, were stored and summarised using the computerised animal health management program, PigCHAMP® (University of Minnesota College

of Veterinary Medicine, St. Paul, Minnesota). Data integrity for each herd for the periods 1991 and 1992 were checked using PigCHAMP® version 3.0. Records from pig herds which contained incomplete data were excluded from the analysis. Data files were renamed with unique letter codes to assure full confidentiality of herd data. For 26 herds data was available for both years, whereas for 8 herds data was only available for 1991 and for 5 herds only for 1992.

Overall and monthly reports of reproductive performance were produced for each year using PigCHAMP®'s performance monitor report procedure. The output was imported into the database management software, PARADOX® for Windows version 4.5 (Borland International Inc, Scotts Valley, California). The statistical software packages STATISTICA/W® (StatSoft Inc, Tulsa, Oklahoma) and NCSS 6.0 (Statistical System for Windows, Kaysville, Utah) were used for statistical analysis and graphical analyses. Violin plots and line plots were produced using NCSS and STATISTICA software respectively.

Production parameters

Thirty two production parameters from the performance monitor report can be classified into 4 main groups: population profile, breeding, farrowing and weaning performance. The parameters were calculated on a monthly and a yearly basis.

Population profile comprises 7 production parameters: average female inventory, average gilt pool inventory, sow-boar ratio, average parity of female pigs, replacement rate, cull rate and death rate. Three key parameters in this group are replacement rate, cull rate and death rate.

Breeding performance is described based on 7 production parameters: percentage of multiple matings, entry to service interval, wean to service interval, percentage of sows bred by 7 days, percentage of repeat services, average nonproductive sows days (NPD) and average NPD /parity record. Six key parameters in this group are entry to service interval, wean to service interval, percentage of sows bred by 7 days, percentage of repeat services, NPD and average NPD /parity record.

Farrowing performance comprises 11 production parameters: average parity of farrowed sows, average gestation length, average total pigs /litter, average pigs born alive /litter, percentage of stillborn pigs, percentage of mummies, average litter birth weight, farrowing rate, adjusted farrowing rate, farrowing interval and litters /mated female /year. Seven key parameters in this group are

average total pigs /litter, average pigs born alive /litter, percentage of stillborn pigs, percentage of mummies, adjusted farrowing rate, farrowing interval and litters /mated female /year.

Weaning performance is described based on 7 production parameters: pigs weaned /litter, pigs weaned/lifetime female, pre-weaning mortality, average weaning weight, adjusted 21 day litter weight, average age at weaning and pigs weaned /mated female /year. Four key parameters in this group includes pigs weaned /litter, pre-weaning mortality, average age at weaning and pigs weaned /mated female /year.

Analyses were restricted to the key parameters in each parameter group.

Data analysis

Graphical presentation

Violin plots

Violin plots were used to present distributions of production parameters. This new method of graphical presentation is based on a combination of box plots and two vertical density traces (Hintze, J. L., 1995). The density trace is an effective display technique for showing the distribution of data. In the violin plot, the lower and upper quartiles are indicated through thick black vertical lines. The median value is shown as a circle. One density trace extends to the left and the other extends to the right. The shape of the density trace is influenced by the percentage of data in a particular part of the ranges, as used in the density calculation and determines the smoothness of the plot. This value was determined automatically by the software. The number of density points used for the plot determines the resolution of the density trace. A value of 100 points was used in this analysis. Percentiles were calculated using the empirical distribution function.

Line plots

Line plots were used to present averages of some production parameters by month and country.

Descriptive statistics

Data was analysed using monthly and yearly summaries of production data from individual herds. Data was examined for conformity with the normal distribution. Descriptive statistics and 10th, 15th,

20th, 80th, 85th and 90th percentiles were calculated. Reproductive performance was analysed based on four parameter groups: population profile, breeding, farrowing and weaning performance. Student's t- test was used for comparison of yearly productivity parameters. The results are presented as means together with their 95% confidence intervals (95%CI). Production parameters which were not normally distributed were analysed using the Mann-Whitney U test.

Two way ANOVA was used to analyse the statistical association between the 2 main effects 'country' and 'month of year' and production parameters. If the main effect 'month of year' was statistically significant, a multiple comparison between months was conducted using Tukey's HSD procedure. Individual months were not compared between countries as it was not considered biologically meaningful given the climatic difference between the two countries. A *P* value of less than 0.05 was considered to be statistically significant.

Results

This analysis is focused on production data from 16 Thai and 18 New Zealand pig herds for 1991, 14 Thai and 16 New Zealand herds for 1992. In the analysis of yearly and monthly data; data from herds with information available yearly for both years were treated as independent observations.

Yearly reproductive performance

Overall reproductive performance can be described based on the parameter groups defined as a population profile, breeding, farrowing and weaning performance as shown in Tables 6.1, 6.2, 6.3A, 6.3B and 6.4.

Yearly population profile

The averages of 'average female inventory' and 'average gilt pool inventory' were significantly higher in TH compared with NZ whereas average 'sow-boar ratio' was significantly higher in NZ ($t = 5$, $df = 59$, $P = 0.0000$; $t = 6$, $df = 52$, $P = 0.0000$ and $U = 300$, $P = 0.0420$). No difference

was found between the two countries with regard to the averages of parity of female pigs, replacement rate, cull rate and death rate as shown in Table 6.1 ($t = 0.5$, $df = 59$, $P = 0.6531$; $t = 0.8$, $df = 56$, $P = 0.4090$; $t = 0.9$, $df = 57$, $P = 0.3630$ and $t = -2$, $df = 55$, $P = 0.0817$). Violin plots are used to present the distributions of replacement rate, cull rate and death rate of the two countries. (Figures 6.1, 6.2 and 6.3)

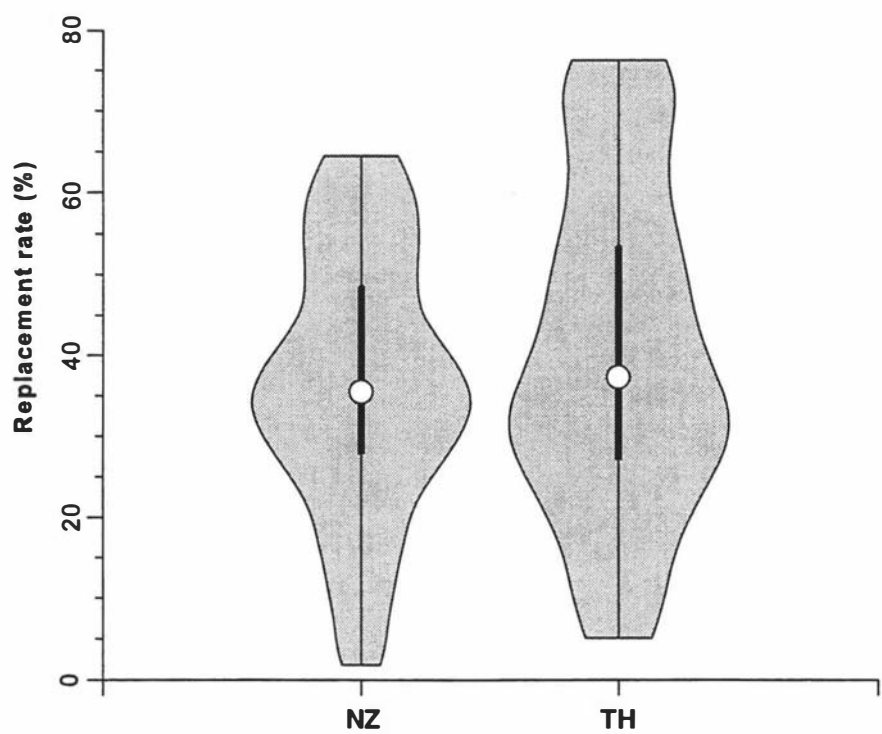


Figure 6.1. Violin plots of average yearly replacement rate for the 2 countries

Table 6.1 Comparison of yearly population profile between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
Av. female inventory ($P=0.0000$)	TH	30	144.1 - 979.7	400.5	335.9	339.9 - 461.1	246.2	279.4	293.5	542.9	563.8	594.5
	NZ	31	57.8 - 620.2	216.7	180.8	166.6 - 266.7	77.5	97.8	126.9	293.6	357.0	399.3
Av. gill pool inventory ($P=0.0000$)	TH	27	3.3 - 51.6	23.1	20.0	18.0 - 28.2	6.8	10.6	11.7	33.2	34.3	44.9
	NZ	27	0 - 22.0	7.4	5.6	4.7 - 10.0	0.2	0.5	0.9	13.6	16.5	18.1
Sow-boar ratio ($P=0.0420$)	TH	28	3.6 - 43.3	12.4	10.7	9.1 - 15.6	4.0	4.4	4.9	15.3	20.2	24.5
	NZ	31	4.6 - 24.2	14.8	15.5	12.7 - 16.9	5.2	5.4	5.7	7.4	8.2	22.5
Av. parity ($P=0.6531$)	TH	30	1.8 - 7.1	3.4	3.3	3.0 - 3.8	2.3	2.5	2.7	4.2	4.5	4.7
	NZ	31	2.0 - 5.3	3.3	3.3	3.0 - 3.6	2.3	2.4	2.5	4.0	4.2	4.8
Replacement rate(%) ($P=0.4090$)	TH	30	5.1 - 76.3	40.3	37.3	32.4 - 48.2	10.5	18.0	21.1	64.2	69.0	74.0
	NZ	29	1.8 - 64.5	36.2	35.5	29.9 - 42.5	3.0	4.5	5.8	12.8	13.3	58.8
Cull rate(%) ($P=0.3630$)	TH	28	10.3 - 69.5	32.6	31.3	27.1 - 38.1	15.0	16.5	21.6	41.5	45.5	57.2
	NZ	31	3.7 - 57.2	29.6	28.2	25.6 - 33.5	12.6	21.0	23.8	36.0	40.2	44.9
Death rate (%) ($P=0.0817$)	TH	27	0.9 - 6.4	3.7	3.4	3.1 - 4.3	1.3	1.9	2.6	5.0	5.5	5.8
	NZ	30	1.2 - 11.3	4.7	4.1	3.7 - 5.7	1.8	2.5	2.7	7.2	7.8	9.4

* the Mann-Whitney U test

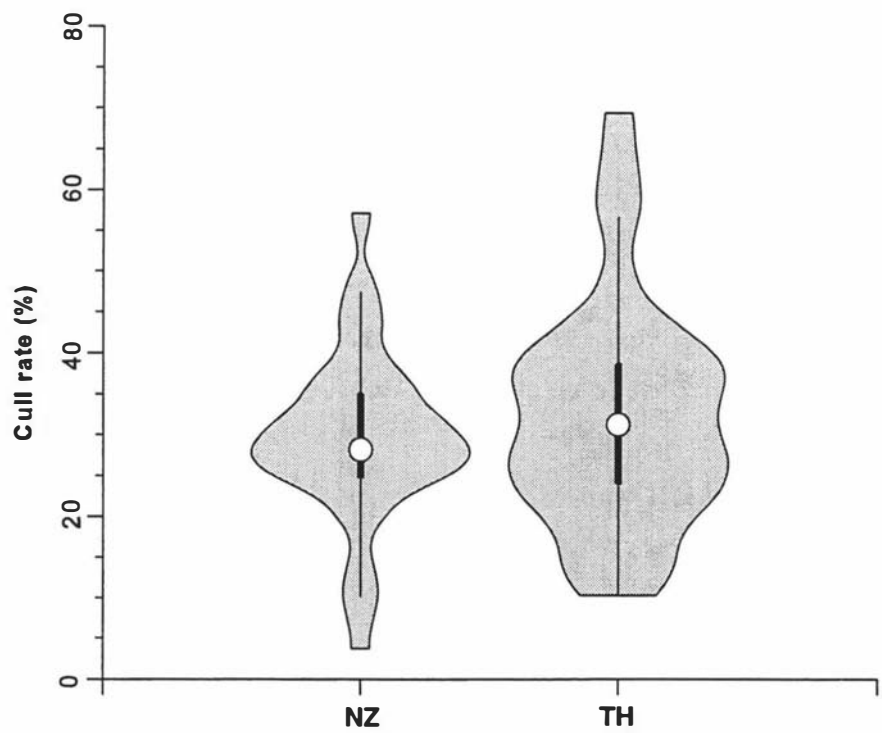


Figure 6.2. Violin plots of average yearly cull rate for the 2 countries

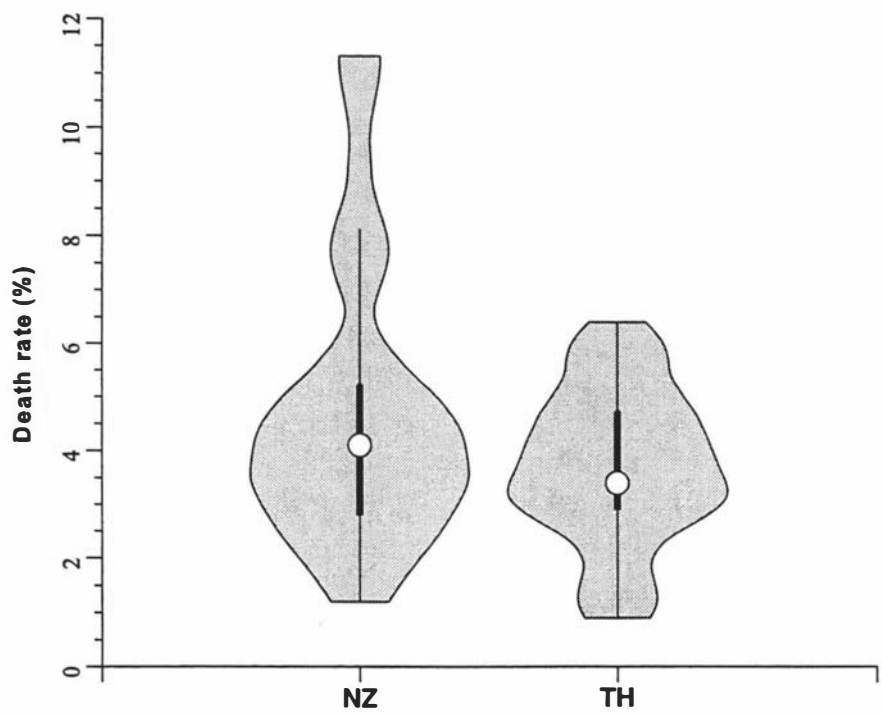


Figure 6.3. Violin plots of average yearly death rate for the 2 countries

Yearly breeding performance

Averages of 'percentage of multiple mating', 'entry to service interval', 'percentage of repeat services', 'average NPD' and 'average NPD /parity record' were significantly higher in TH compared with NZ, whereas the average of 'percentage of sow bred by 7 days' was significantly higher in NZ ($U = 178$, $P = 0.0002$; $U = 269$, $P = 0.0076$; $U = 220$, $P = 0.0004$; $U = 254$, $P = 0.0023$; $U = 289$, $P = 0.0109$, $U = 301$, and $U = 301$, $P = 0.0180$) (Table 6.2). No difference between the 2 countries was found in the average of 'wean to service interval' ($U = 357$, $P = 0.1175$). Violin plots are presented for 'entry to service interval', 'wean to service interval', 'percentage of sows bred by 7 days', 'percentage of repeat services', 'average NPD' and 'average NPD /parity record' in Figures 6.4, 6.5, 6.6, 6.7, 6.8 and 6.9.

Table 6.2. Comparison of yearly breeding performance between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
%Multiple mating (<i>P</i> =0.0002)	TH	29	11.6 - 99.7	88.4	97.5	79.4 - 97.5	26.3	86.0	90.2	99.2	99.5	99.7
	NZ	29	0 - 99.1	75.0	83.5	63.7 - 86.3	10.0	30.6	73.5	95.0	95.4	95.8
Entry-service interval(days) (<i>P</i> =0.0076)	TH	29	4.3 - 97.8	45.4	51.8	36.4 - 54.4	13.6	14.9	21.9	66.9	70.5	75.0
	NZ	31	0 - 92.7	28.4	32.1	18.5 - 38.2	0.1	0.1	0.2	51.4	55.3	66.4
Wean-service interval(days) (<i>P</i> =0.1175)	TH	30	5.3 - 9.4	7.1	7.1	6.6 - 7.6	5.6	5.7	5.8	8.1	9.0	9.3
	NZ	31	4.8 - 12.2	6.7	6.4	6.1 - 7.3	5.2	5.4	5.7	7.4	8.2	9.1
%Sow bred by 7 days (<i>P</i> =0.0180)	TH	30	63.2 - 93.0	84.4	86.3	81.8 - 87.0	76.0	76.5	77.8	90.4	90.9	92.0
	NZ	31	70.0 - 98.1	88.7	89.0	86.5 - 90.9	81.2	82.9	84.9	94.1	95.5	96.3
%Repeat services (<i>P</i> =0.0004)	TH	30	5.2 - 24.4	13.0	11.9	11.3 - 14.8	7.5	8.6	8.8	16.2	16.7	21.5
	NZ	31	0.9 - 16.6	8.9	8.3	7.4 - 10.3	3.0	4.5	5.8	12.8	13.3	14.7
Av.NPD (days) (<i>P</i> =0.0023)	TH	30	37.3 - 128.5	64.2	59.7	56.8 - 71.6	38.9	46.9	49.5	82.2	86.6	88.0
	NZ	31	31.5 - 102.3	50.9	47.7	45.6 - 56.2	33.2	37.0	40.8	62.0	67.4	68.2
Av.NPD/parity record (days) (<i>P</i> =0.0108)	TH	30	15.1 - 43.8	26.0	24.7	22.8 - 29.1	15.7	17.5	18.6	36.5	38.4	41.1
	NZ	31	12.2 - 44.1	20.8	19.8	18.5 - 23.2	12.6	14.1	15.5	25.3	26.1	29.1

* the Mann-Whitney U test

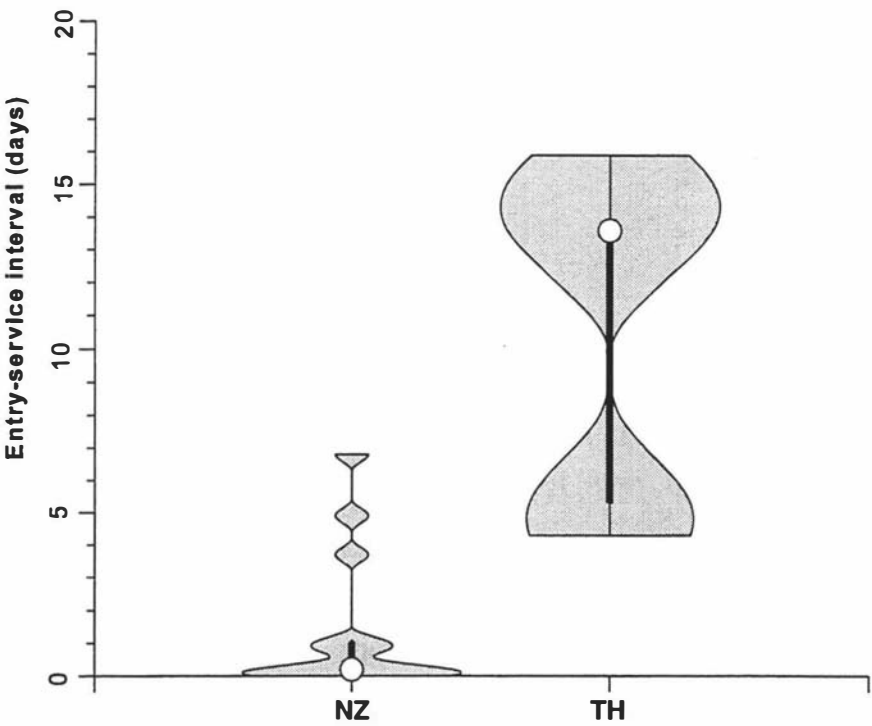


Figure 6.4. Violin plots of average yearly entry to service interval for the 2 countries

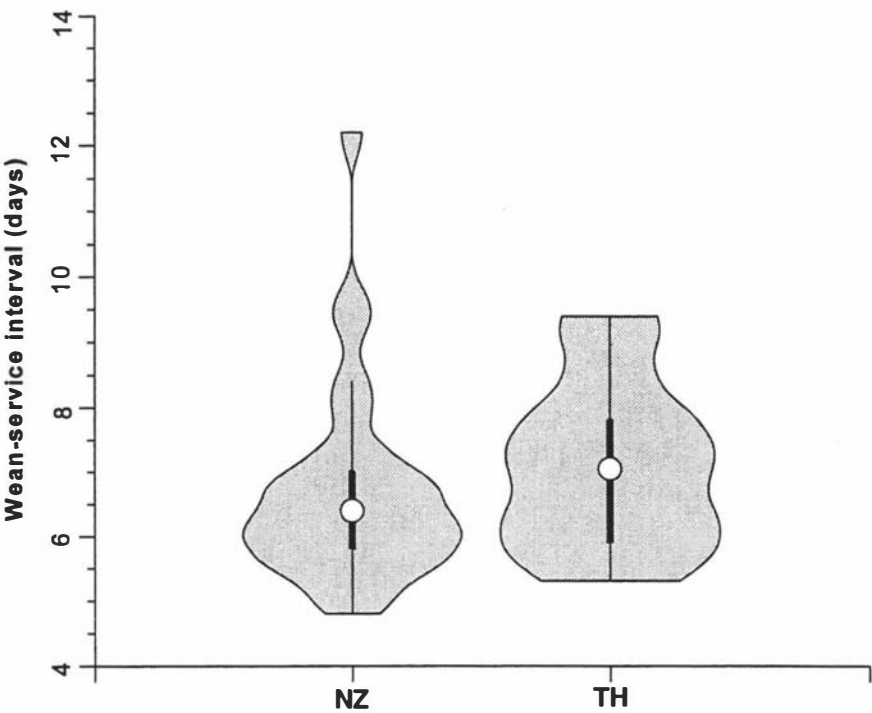


Figure 6.5. Violin plots of average yearly wean to service interval for the 2 countries

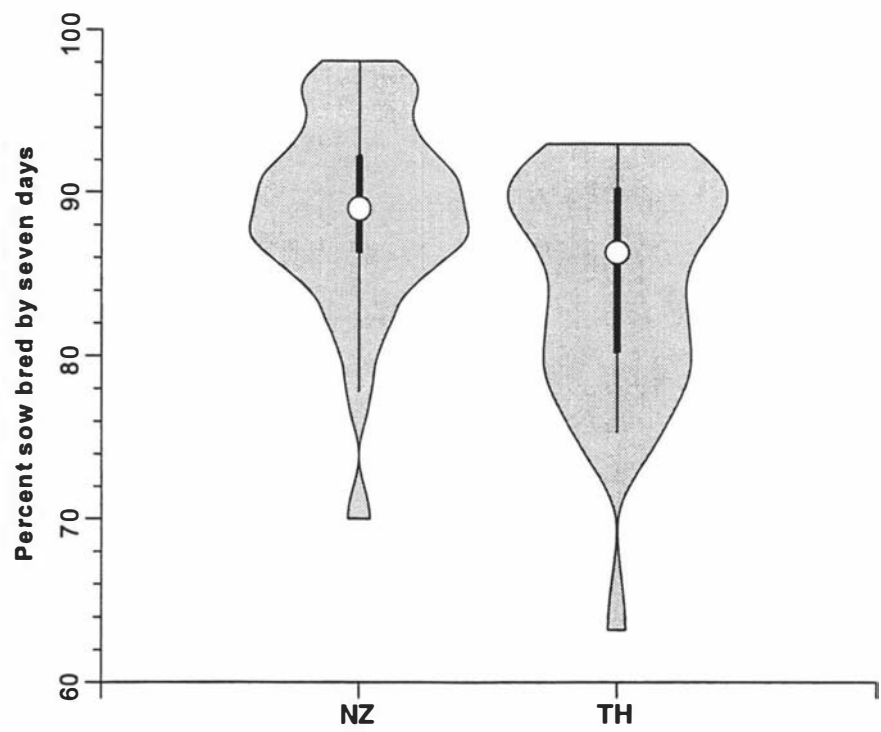


Figure 6.6. Violin plots of average yearly percentage of sows bred by seven days for the 2 countries

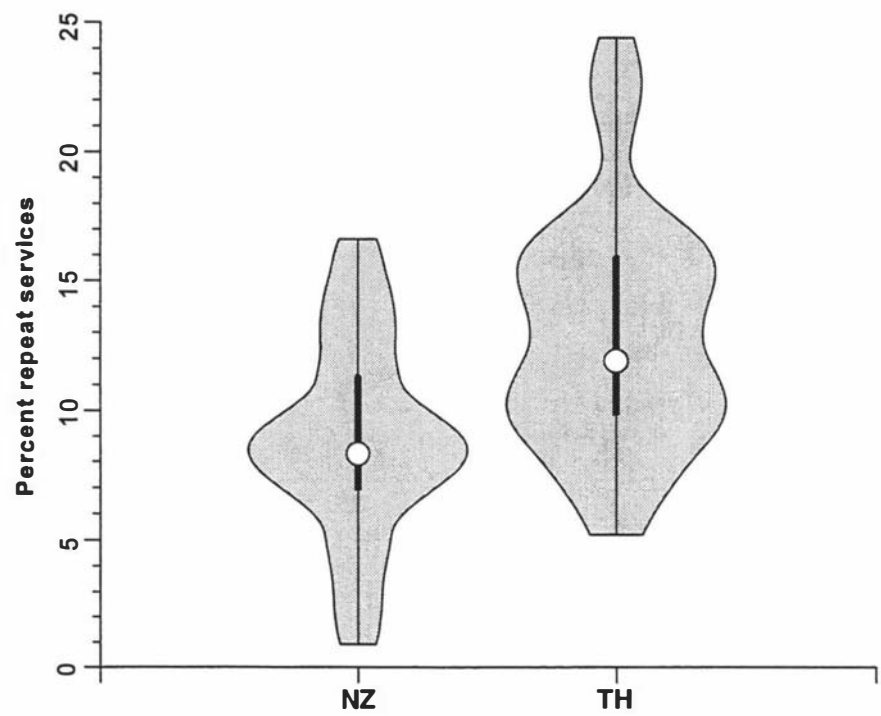


Figure 6.7. Violin plots of average yearly percentage of repeat services for the 2 countries

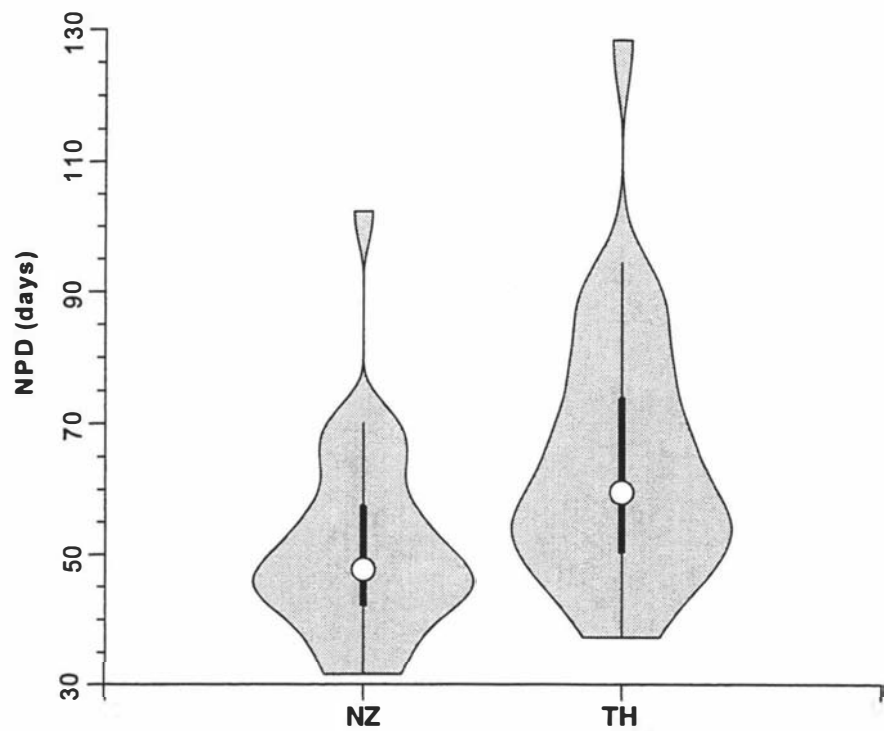


Figure 6.8. Violin plots of average yearly non productive sow days for the 2 countries

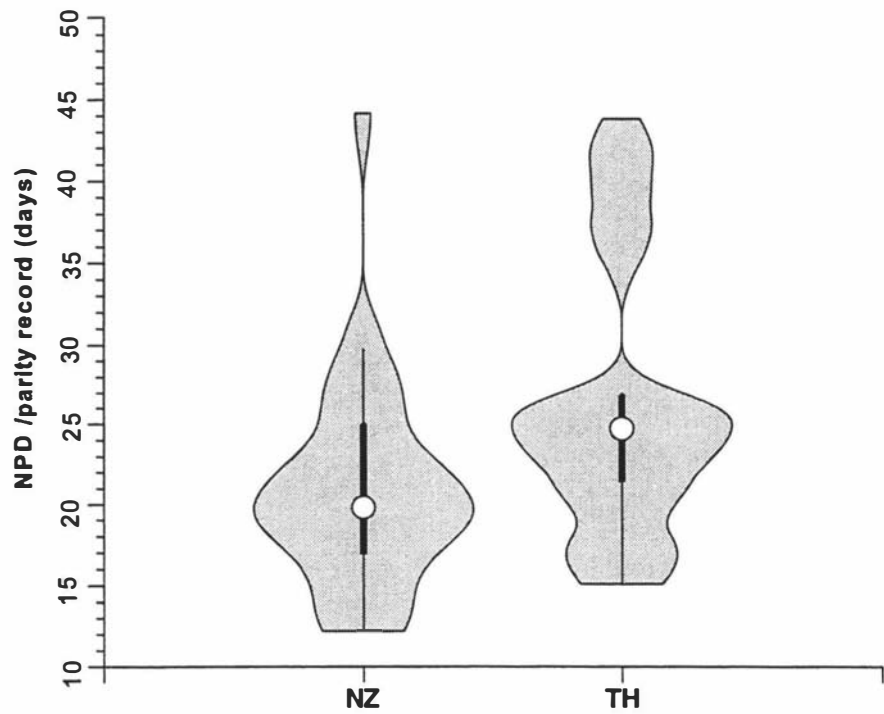


Figure 6.9. Violin plots of average yearly non productive sow day per parity record for the 2 countries

Yearly farrowing performance

Averages of the parameters 'average gestation length', 'average total pigs /litter', 'average pigs born alive /litter' and 'percentage of stillborn' were significantly higher in NZ compared with TH whereas average of 'percentage of mummies' was higher in TH as shown in Table 6.3A ($t = -2$, $df = 59$, $P = 0.0424$; $t = -7$, $df = 59$, $P = 0.0000$; $t = -8$, $df = 59$, $P = 0.0000$; $U = 221$, $P = 0.0011$ and $U = 194$, $P = 0.0007$). However, 'average parity of farrowed sows' was very similar ($t = 0.08$, $P = 0.9398$).

Averages of the parameters 'average litter birth weight', 'farrowing rate', 'adjusted farrowing rate', 'farrowing interval' were significantly higher in NZ compared with TH whereas averages of 'litters/mated female /year' was higher in TH as shown in Table 6.3B ($U = 34$, $P = 0.0001$; $U = 291$, $P = 0.0121$; $U = 318$, $P = 0.0334$; $t = -2$, $df = 59$, $P = 0.0230$ and $U = 318$, $P = 0.0333$). Violin plots are presented for 'average total pigs /litter', 'average pigs born alive /litter', 'percentage of stillborn pigs', 'percentage of mummies', 'adjusted farrowing rate', 'farrowing interval' and 'litters /mated female /year' in Figures 6.10, 6.11, 6.12, 6.13, 6.14, 6.15 and 6.16.

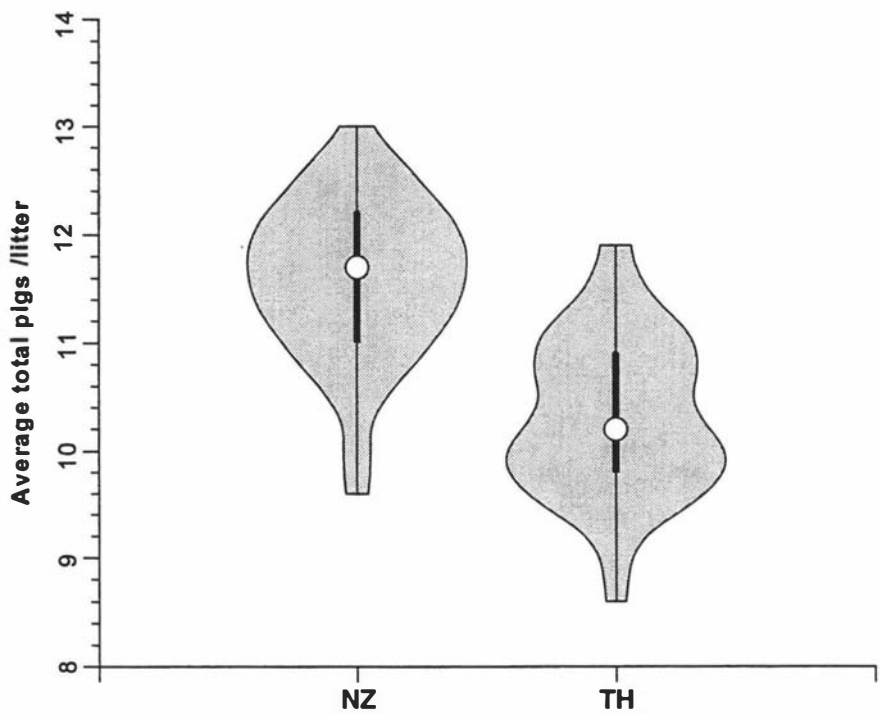


Figure 6.10. Violin plots of average yearly total pigs per litter for the 2 countries

Table 6.3A. Comparison of yearly farrowing performance between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
Av. parity of farrowed sow (P=0.9398)	TH	30	1.9 - 7.2	4.2	3.9	3.7 - 4.6	2.9	3.1	3.2	4.9	5.4	6.0
	NZ	31	2.5 - 6.6	4.1	4.0	3.8 - 4.5	3.0	3.1	3.3	4.9	5.5	5.7
Av. gestation length(day) (P=0.0314)	TH	30	113.0 - 116.0	114.7	115.0	114.3 - 115.1	113.0	113.0	114.0	116.0	116.0	116.0
	NZ	31	114.0 - 116.0	115.2	115.0	115.0 - 115.4	114.0	115.0	115.0	116.0	116.0	116.0
Av. total pigs/litter (P=0.0000)	TH	30	8.6 - 11.9	10.3	10.2	10.0 - 10.6	9.4	9.6	9.7	11.1	11.1	11.2
	NZ	31	9.6 - 13.0	11.6	11.7	11.3 - 11.9	10.7	10.9	11.0	12.2	12.4	12.5
Av. pigs born alive/litter (P=0.0000)	TH	30	8.1 - 11.1	9.5	9.4	9.3 - 9.8	8.7	8.8	8.9	10.1	10.4	10.5
	NZ	31	9.4 - 11.8	10.7	10.7	10.5 - 10.9	10.1	10.1	10.2	11.3	11.3	11.5
%Stillborn pigs* (P=0.0011)	TH	30	3.6 - 9.3	5.3	4.8	4.8 - 5.9	3.8	4.0	4.1	6.7	6.9	7.6
	NZ	29	1.4 - 10.8	6.7	6.6	5.9 - 7.5	4.4	5.2	5.6	8.1	9.4	9.9
%Mummies* (P=0.0007)	TH	30	0.7 - 4.4	2.1	2.0	1.7 - 2.4	0.8	1.0	1.2	2.8	3.1	3.4
	NZ	27	0.1 - 2.8	1.2	1.2	0.9 - 1.4	0.3	0.3	0.5	1.7	1.9	2.0

* the Mann-Whitney U test

Table 6.3B. Comparison of yearly farrowing performance between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
Av. litter birth weight [*] (kg) (<i>P</i> =0.0001)	TH	29	9.6 - 15.6	13.4	13.6	12.9 - 14.0	11.6	11.8	11.8	15.0	15.2	15.3
	NZ	11	13.6 - 18.0	15.7	15.3	14.9 - 16.5	13.9	14.6	15.0	17.0	17.7	18.0
Farrowing rate [*] (%) (<i>P</i> =0.0121)	TH	30	57.8 - 89.2	77.8	79.7	74.5 - 81.2	61.3	66.8	70.5	86.1	87.0	87.4
	NZ	31	68.9 - 94.9	83.6	84.4	81.7 - 85.6	77.5	78.1	79.1	88.0	89.6	90.4
Adj. farrowing rate [*] (%) (<i>P</i> =0.0334)	TH	30	60.9 - 92.3	80.8	83.3	77.4 - 84.2	63.7	70.3	74.0	89.6	90.3	91.0
	NZ	31	75.1 - 96.3	86.1	87.1	84.4 - 87.8	80.0	81.4	81.6	90.0	91.3	91.8
Farrowing interval(days) (<i>P</i> =0.0230)	TH	30	147.0 - 167.0	155.3	154.0	153.4 - 157.1	149.1	150.0	151.2	158.8	160.8	164.0
	NZ	31	151.0 - 173.0	158.4	158.0	156.4 - 160.5	151.2	152.8	153.4	161.6	163.2	169.6
Litters/mated female/yr [*] (<i>P</i> =0.0334)	TH	30	2.1 - 2.5	2.3	2.3	2.2 - 2.3	2.15	2.16	2.17	2.34	2.34	2.35
	NZ	31	1.8 - 2.5	2.2	2.2	2.1 - 2.2	2.0	2.13	2.14	2.27	2.30	2.37

* the Mann-Whitney U test

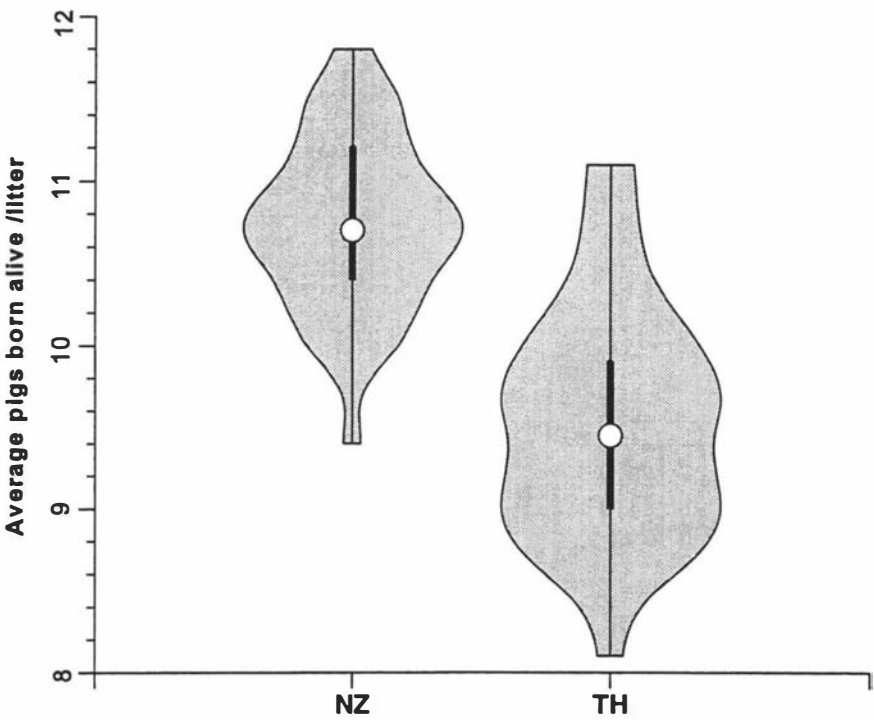


Figure 6.11. Violin plots of average yearly pigs born alive per litter for the 2 countries

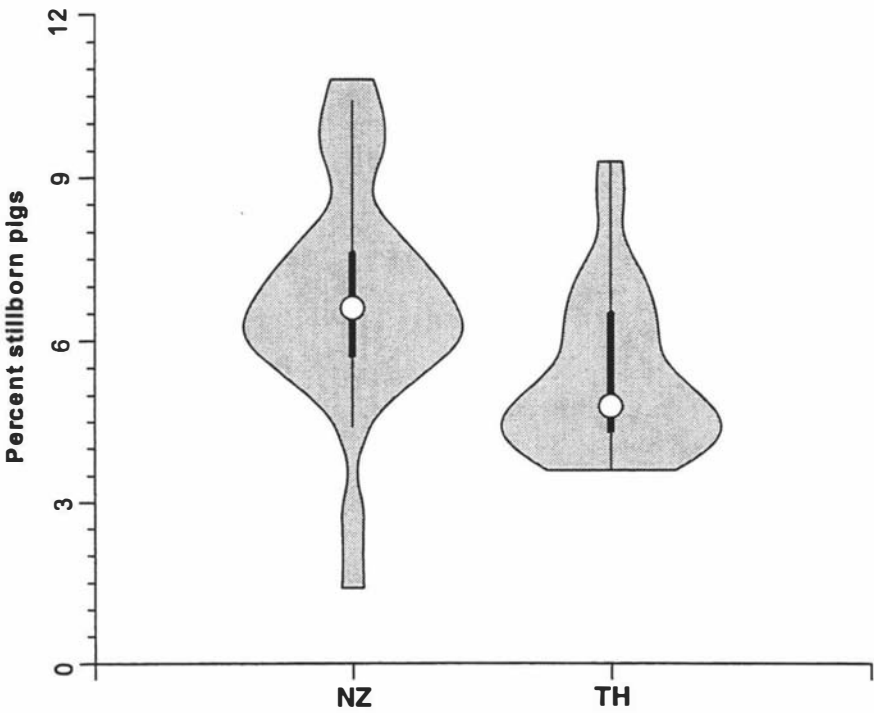


Figure 6.12. Violin plots of average yearly percentage of stillborn pigs for the 2 countries

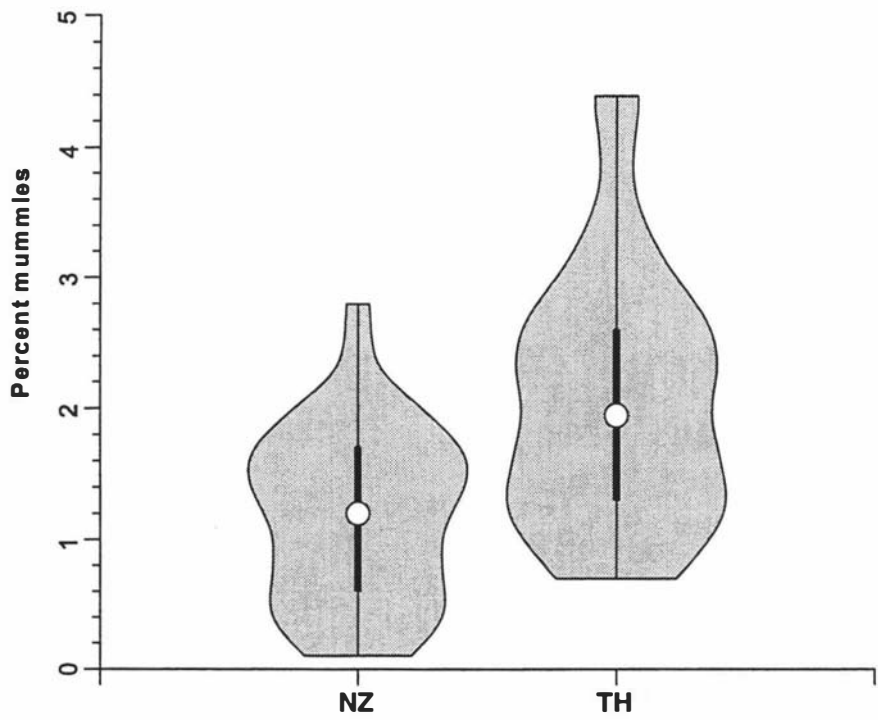


Figure 6.13. Violin plots of average yearly percentage of mummies for the 2 countries

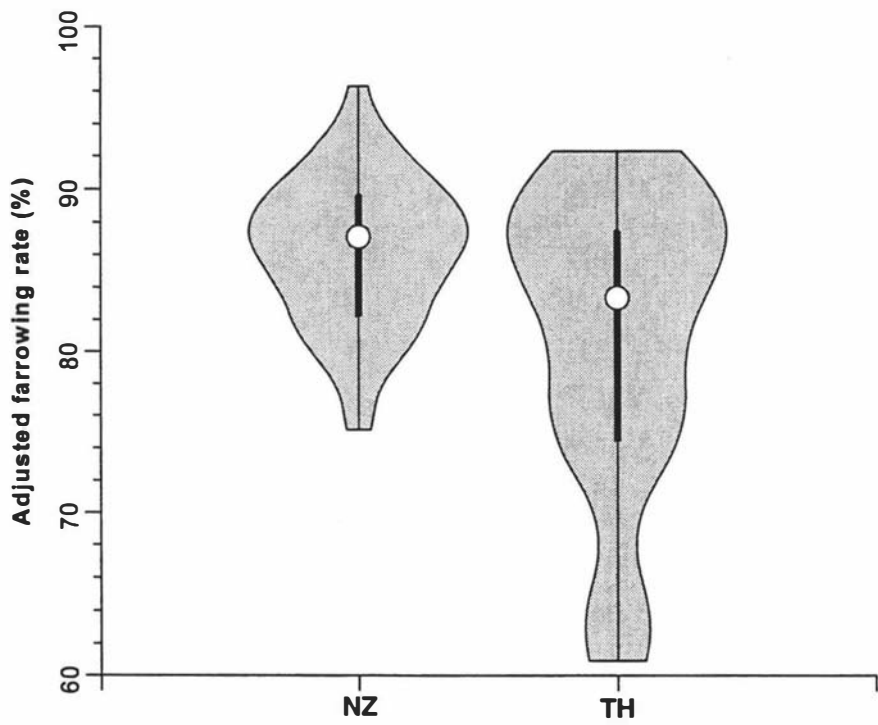


Figure 6.14. Violin plots of average yearly adjusted farrowing rate for the 2 countries

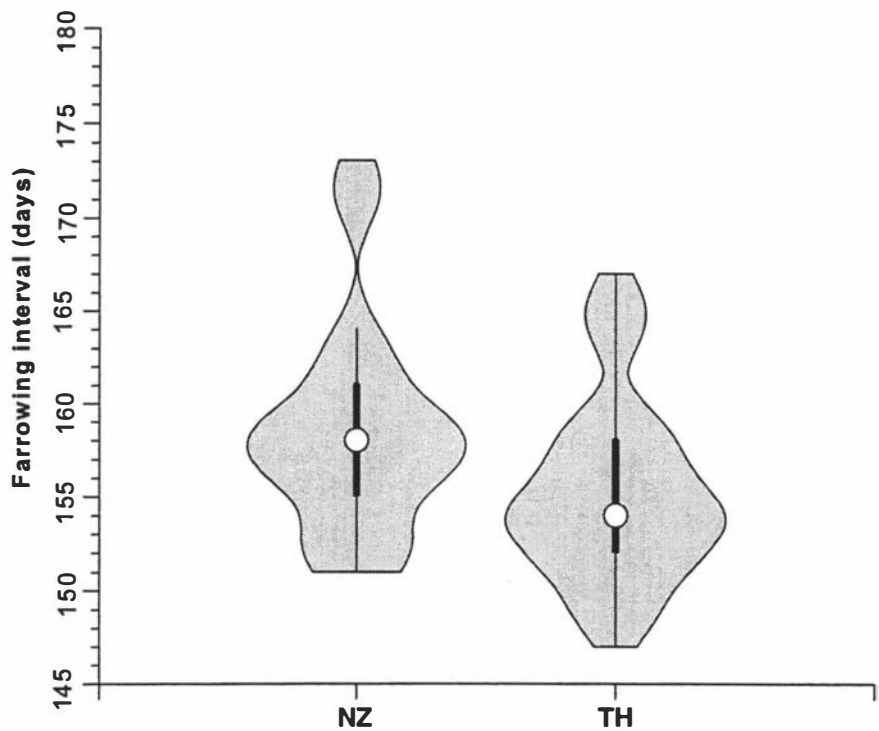


Figure 6.15. Violin plots of average yearly farrowing interval for the 2 countries

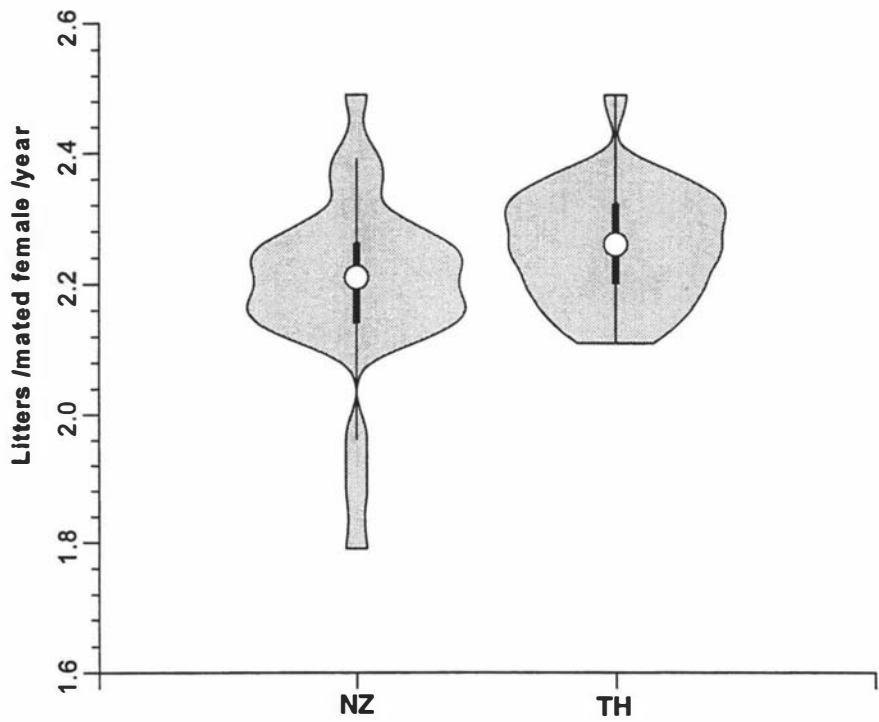


Figure 6.16. Violin plots of average yearly litters per mated female per year for the 2 countries

Yearly weaning performance

Averages of the parameters 'pigs weaned /litter', 'pigs weaned /lifetime female', 'pre-weaning mortality rate', 'average weaning weight', 'adjusted 21 day litter weight', 'average age at weaning' and 'pigs weaned /mated female year' were significantly higher in NZ compared with TH as shown in Table 6.4 ($t = -5$, $df = 59$, $P = 0.0000$; $t = -2$, $df = 57$, $P = 0.0400$; $t = -4$, $df = 59$, $P = 0.0004$; $t = -3$, $df = 35$, $P = 0.0030$; $U = 83$, $P = 0.0050$; $t = -4$, $df = 59$, $P = 0.0000$ and $t = -3$, $df = 59$, $P = 0.0161$). Violin plots are presented for 'pigs weaned /litter', 'pre-weaning mortality', 'average age at weaning' and 'pigs weaned /mated female /year' in Figures 6.17, 6.18, 6.19 and 6.20.

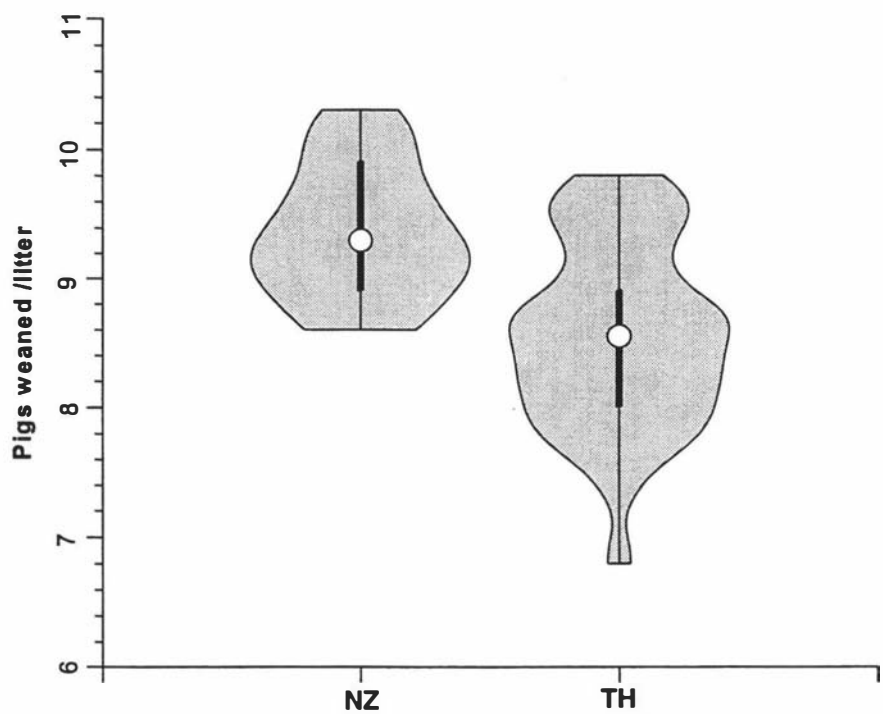


Figure 6.17. Violin plots of average yearly pigs weaned per litter for the 2 countries

Table 6.4. Comparison of yearly weaning performance between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
Pigs weaned/litter ($P=0.0000$)	TH	30	6.8 - 9.8	8.5	8.6	8.3 - 8.8	7.6	7.8	8.0	9.4	9.5	9.5
	NZ	31	8.6 - 10.3	9.3	9.3	9.2 - 9.5	8.7	8.8	8.9	10.0	10.0	10.0
Pigs weaned /lifetime female ($P=0.0400$)	TH	28	6.0 - 74.0	34.0	29.5	26.3 - 41.6	10.9	12.4	17.0	53.8	57.7	69.2
	NZ	31	5.0 - 80.0	44.7	45.0	37.5 - 52.0	14.2	17.4	27.0	63.0	66.4	72.0
Pre-weaning mortality(%) ($P=0.0004$)	TH	30	3.0 - 14.5	10.2	10.4	9.2 - 11.2	6.4	7.0	7.5	12.5	13.0	14.3
	NZ	31	8.2 - 19.6	12.8	12.5	11.8 - 13.8	8.9	9.7	10.7	14.9	15.3	16.8
Av. weaning weight(kg) ($P=0.0030$)	TH	25	4.5 - 8.6	6.2	6.1	5.8 - 6.5	4.6	5.3	5.7	6.8	6.8	6.9
	NZ	12	5.0 - 8.5	7.2	7.6	6.5 - 7.9	5.0	5.0	6.0	8.0	8.0	8.4
Adj. 21 day litter weight(kg) ($P=0.0050$)	TH	26	41.0 - 66.0	50.6	51.0	48.3 - 53.0	43.4	45.0	45.0	55.6	56.0	57.3
	NZ	14	43.0 - 64.0	56.5	57.0	52.7 - 60.3	43.5	46.0	52.0	63.0	63.8	64.0
Av. age at weaning(days) ($P=0.0000$)	TH	30	25.3 - 31.9	27.4	27.4	26.9 - 28.0	25.8	26.1	26.2	28.4	28.6	29.4
	NZ	31	25.8 - 40.8	30.6	29.5	29.3 - 32.0	26.5	26.7	27.2	33.9	34.3	35.0
Pigs weaned /mated female/yr ($P=0.0161$)	TH	30	14.9 - 22.7	19.3	18.9	18.6 - 20.0	17.0	17.5	17.8	21.6	22.1	22.3
	NZ	31	15.7 - 24.6	20.5	20.6	19.8 - 21.2	17.5	18.6	19.3	21.9	22.4	23.3

* the Mann-Whitney U test

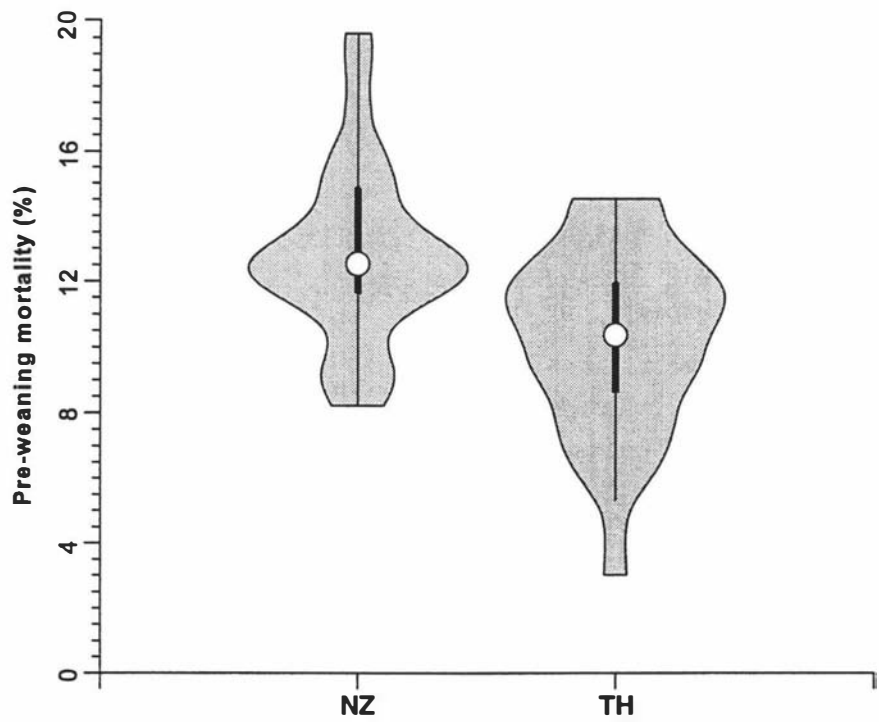


Figure 6.18. Violin plots of average yearly pre-weaning mortality rate for the 2 countries

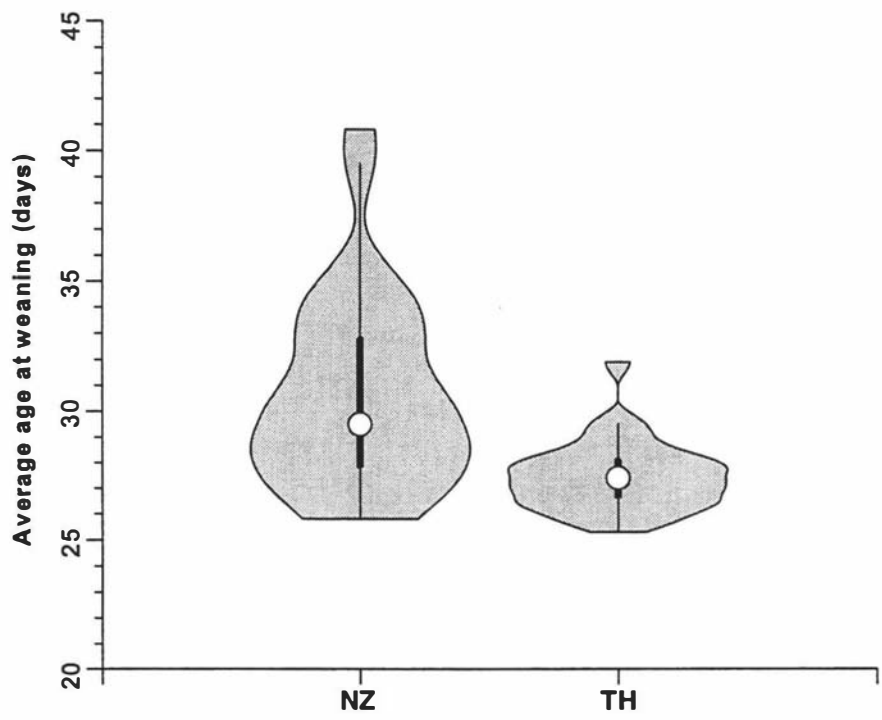


Figure 6.19. Violin plots of average yearly age at weaning for the 2 countries

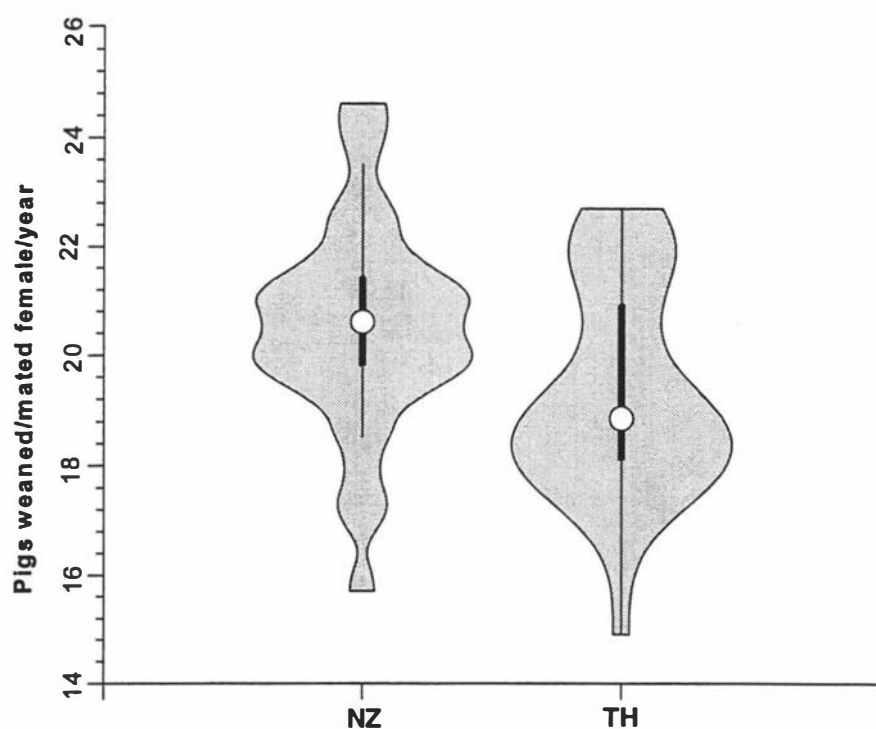


Figure 6.20. Violin plots of average yearly pigs weaned per mated female per year for the 2 countries

Monthly reproductive performance

Monthly production figures for 1991 and for 1992 from each herd were analysed. Monthly production data comprising 347 observations from Thai and New Zealand herds were included in this analysis. Key parameters from the following four parameter groups were analysed: population profile, breeding, farrowing and weaning performance.

Monthly population profile

Results of descriptive statistics for the following 3 key parameters: replacement rate, cull rate and death rate are shown in Table 6.5. Results of 2-way ANOVA, with 'country' and 'month of year' as main effects are summarised in Table 6.6.

Replacement rate

Results of two way ANOVA indicate that the main effect 'country' was significantly associated with 'replacement rate' ($F_{1,516} = 5.38$, $P = 0.0208$) whereas the 'month of year', and the interaction between 'country' and 'month of year' were not significant ($F_{11,516} = 0.80$, $P = 0.6375$; $F_{11,516} = 0.50$, $P =$

0.9012). Violin plots and line plots of replacement rates for the 2 countries are presented in Figures 6.21 and 6.22 respectively.

Cull rate

Results of two way ANOVA indicate that the main effect 'country', and the interaction between 'country' and 'month of year' were not significant ($F_{1,630} = 0.34$, $P = 0.5628$, $F_{1,630} = 0.63$, $P = 0.8031$) whereas the main effect 'month of year' was significantly associated with 'cull rate' ($F_{11,630} = 2.59$, $P = 0.0032$). Violin plots and line plots of cull rates for the 2 countries are presented in Figures 6.23 and 6.24.

A multiple comparison of average cull rates for the main effect 'month of year' was conducted using Tukey's Honest Significant Difference (HSD) procedure. Results of the comparison ($P < 0.05$) showed that both March and May were different from cull rates in September and December.

Death rate

Results of two way ANOVA indicate that the main effect 'country' was significantly associated with 'death rate' ($F_{1,346} = 49.85$, $P = 0.0000$) whereas the main effect 'month of year' and the interaction between the two main effects were not significant ($F_{11,346} = 0.93$, $P = 0.5152$ and $F_{11,346} = 1.66$, $P = 0.0800$). Violin plots and line plots of death rates for the two countries are presented in Figures 6.25 and 6.26.

Table 6.5. Comparison of monthly population profile between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
Replacement rate(%) ($P=0.0208$)	TH	259	2.1 - 235.5	55.7	51.7	50.5 - 60.9	8.0	12.5	19.0	80.4	91.9	106.5
	NZ	281	3.2 - 179.7	48.0	42.1	44.3 - 51.7	12.7	18.9	23.5	66.1	74.2	85.5
Cull rate(%) ($P=0.5628$)	TH	306	2.6 - 176.6	35.4	29.0	32.5 - 38.3	10.8	12.4	15.2	54.2	59.0	67.5
	NZ	348	3.3 - 153.7	34.1	29.1	31.8 - 36.4	10.0	13.4	15.2	50.0	56.1	61.8
Death rate (%) ($P=0.0000$)	TH	195	1.1 - 22.9	6.1	4.8	5.6 - 6.6	2.7	3.4	3.5	8.3	9.8	11.2
	NZ	175	0 - 38.1	10.1	8.1	9.1 - 11.1	3.8	4.7	5.0	13.9	16.0	20.0

Table 6.6. Summary of results of 2-way ANOVA of 3 key parameters in the population profile area parameter group

Parameters	Country	Month	Interaction between Country and Month
Replacement rate	$F_{1,516} = 5.38,$ $P = 0.0208$	$F_{11,516} = 0.80,$ $P = 0.6375$	$F_{11,516} = 0.50,$ $P = 0.9012$
Cull rate	$F_{1,630} = 0.34,$ $P = 0.5628$	$F_{11,630} = 2.59,$ $P = 0.0032$	$F_{11,630} = 0.63,$ $P = 0.8031$
Death rate	$F_{1,346} = 49.86,$ $P = 0.0000$	$F_{11,346} = 0.93,$ $P = 0.5152$	$F_{11,346} = 1.66,$ $P = 0.0800$

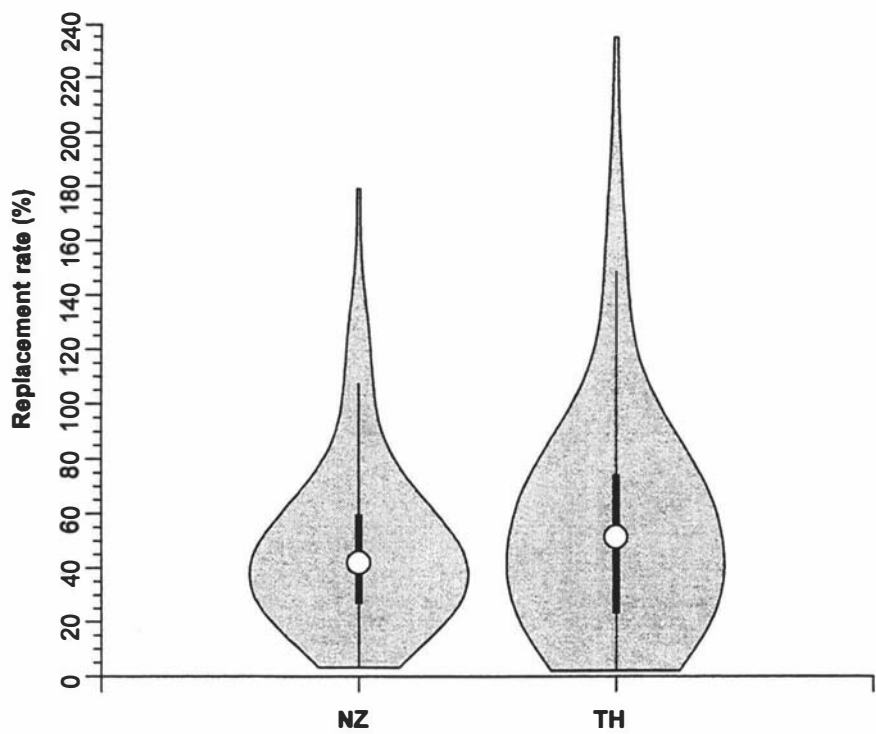


Figure 6.21. Violin plots of annualized average monthly replacement rate for the 2 countries

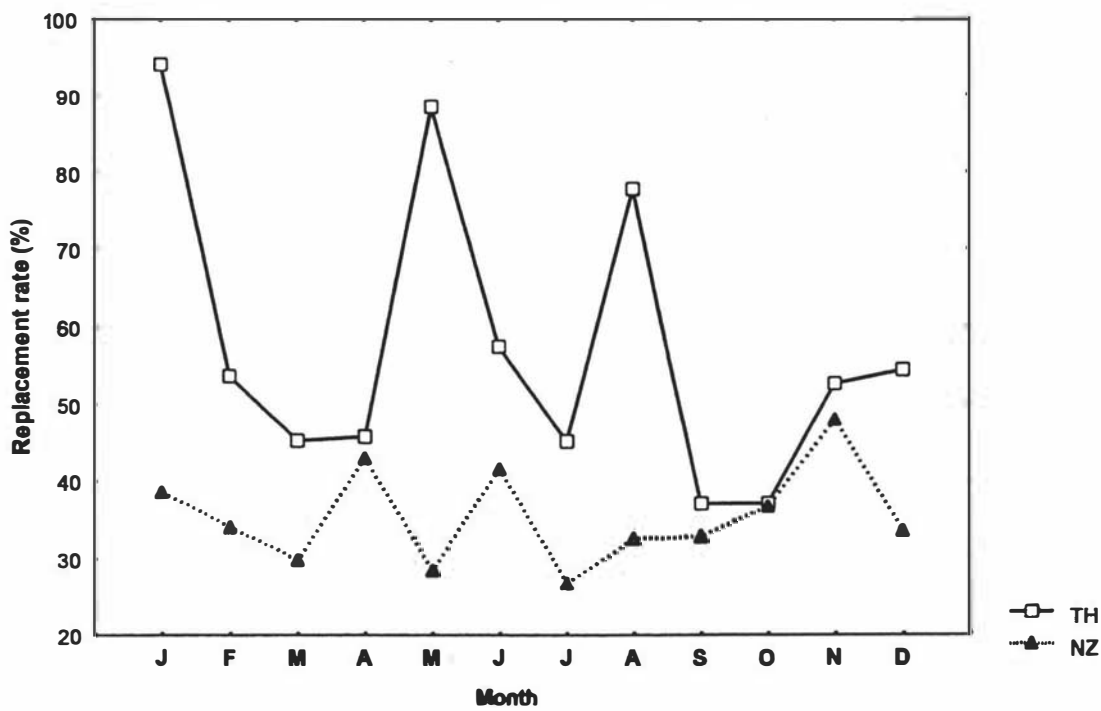


Figure 6.22. Line plot of annualized average replacement rate for the 2 countries by month (1991-92)

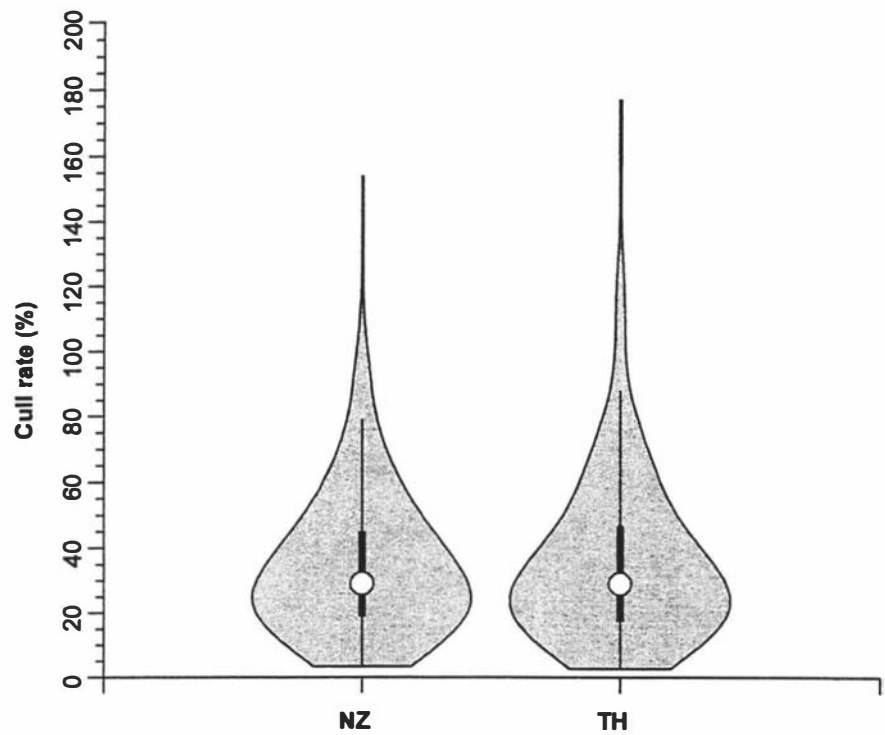


Figure 6.23. Violin plots of annualized average monthly cull rate for the 2 countries

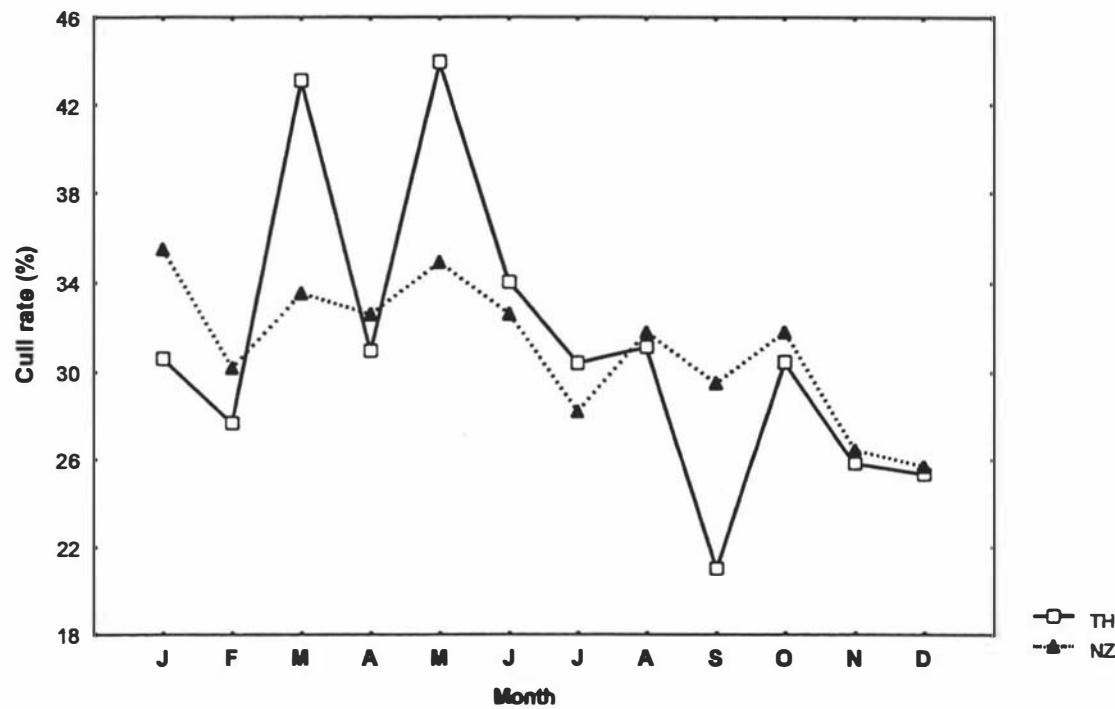


Figure 6.24. Line plot of annualized average cull rate for the 2 countries by month (1991-92)

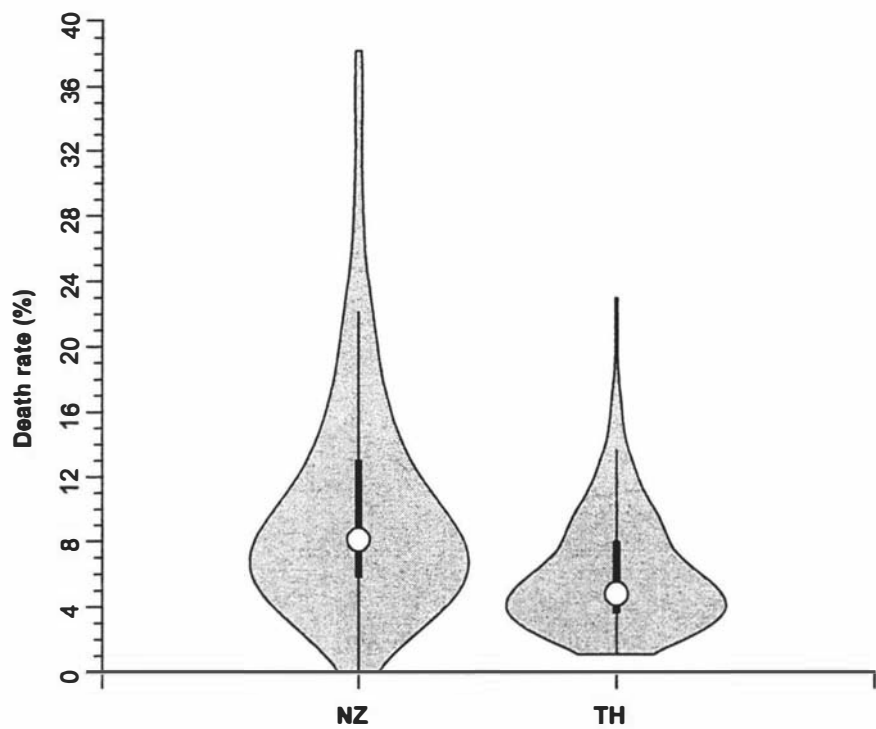


Figure 6.25. Violin plots of annualized average monthly death rate for the 2 countries

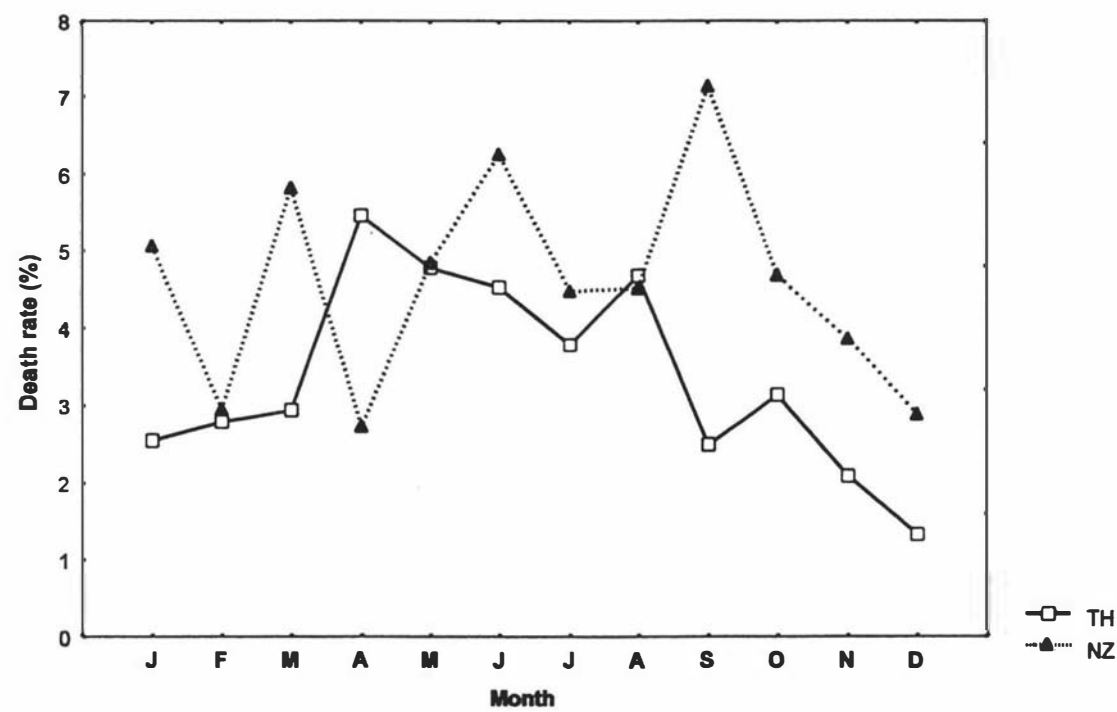


Figure 6.26. Line plot of annualized average death rate for the 2 countries by month (1991-92)

Monthly breeding performance

Descriptive statistics for 6 key parameters (entry-service interval, wean-service interval, percentage of sows bred by 7 days, percentage of repeat services, average NPD and average NPD /parity record) are presented in Table 6.7. Results of 2-way ANOVA, with 'country' and 'month of year' as main effects are summarised in Table 6.8.

Entry-service interval

Results of two way ANOVA indicate that the main effect 'country' was significantly associated with average 'entry to service interval' ($F_{1,626}=38.12$, $P = 0.0000$) whereas 'month of year', and the interaction between 'country' and 'month of year' were not significant ($F_{11,626}= 0.36$, $P = 0.9715$; $F_{11,626}= 0.31$, $P = 0.9835$). Violin plots and line plots of average entry-service interval for the 2 countries are presented in Figures 6.27 and 6.28 respectively.

Wean-service interval

Results of two way ANOVA indicate that the 2 main effects 'country' and 'month of year', and the interaction between the 2 main effects were not significantly associated with average 'wean to service interval' ($F_{1,701} = 2.75$, $P = 0.0977$; $F_{11,701} = 0.63$, $P = 0.6150$ and $F_{11,701} = 0.85$, $P = 0.5940$). Violin plots and line plots of average wean-service interval for the 2 countries are presented in Figures 6.29 and 6.30.

Percentage of sows bred by 7 days

Results of two way ANOVA indicate that the main effect 'country' was significantly associated with average 'percentage of sows bred by 7 days' ($F_{1,706}=42.62$, $P = 0.0000$) whereas the main effect 'month of year', and the interaction between 'country' and 'month of year' were not significant ($F_{11,706}= 1.16$, $P = 0.3080$; $F_{11,706}= 1.34$, $P = 0.1952$). Violin plots and line plots of average percentage of sows bred by 7 days for the 2 countries are presented in Figures 6.31 and 6.32 respectively.

Percentage of repeat services

Results of two way ANOVA indicate that the 2 main effects 'country' and 'month of year', and the interaction between the 2 main effects were significantly associated with average percentage of

repeat services ($F_{1,716} = 60.04$, $P = 0.0000$; $F_{11,716} = 2.21$, $P = 0.0126$ and $F_{11,716} = 1.91$, $P = 0.0349$). Violin plots and line plots of average percentage of repeat services for the 2 countries are presented in Figures 6.33 and 6.34.

A multiple comparison of average percentage of repeat services for the main effect 'month of year' was conducted using Tukey's HSD procedure. Results of the comparison ($P < 0.05$) showed that no difference between months could be detected.

Average NPD

Results of two way ANOVA indicate that the main effect 'country' and the interaction between the 2 main effects were significantly associated with 'average NPD' ($F_{1,712} = 15.11$, $P = 0.0001$ and $F_{11,712} = 2.11$, $P = 0.0178$) whereas the main effect 'month of year' was not significant ($F_{11,712} = 1.39$, $P = 0.1735$). Violin plots and line plots of average NPD for the 2 countries are presented in Figures 6.35 and 6.36 respectively.

Average NPD /parity record

Results of two way ANOVA indicate that the main effect 'country' and the interaction between the 2 main effects were significantly associated with 'average NPD /parity record' ($F_{1,709} = 4.29$, $P = 0.0386$ and $F_{11,709} = 2.58$, $P = 0.0032$) whereas the main effect 'month of year' was not significant ($F_{11,709} = 1.13$, $P = 0.3380$). Violin plots and line plots of average NPD /parity record for the 2 countries are presented in Figures 6.37 and 6.38 respectively.

Table 6.7. Comparison of monthly breeding performance between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
Entry-service interval(day) (<i>P</i> =0.0000)	TH	315	0 - 167.0	45.5	47.6	42.1 - 48.8	7.4	11.5	17.8	67.4	71.0	79.9
	NZ	335	0 - 131.0	30.4	30.6	27.2 - 33.6	0	0	0.2	54.4	62.0	71.0
Wean-service interval(day) (<i>P</i> =0.0976)	TH	343	3.3 - 62.6	2.3	6.7	6.9 - 7.6	5.0	5.2	5.4	8.4	8.8	9.7
	NZ	382	2.4 - 55.3	6.8	6.1	6.4 - 7.2	4.6	4.9	5.0	7.8	8.4	9.5
%Sow bred by 7 days (<i>P</i> =0.0000)	TH	342	39.3 - 100.0	84.3	86.8	83.2 - 85.4	71.4	75.0	77.3	92.9	93.7	94.7
	NZ	388	39.1 - 100.0	89.1	90.9	88.2 - 90.1	76.9	80.0	82.6	96.8	100.0	100.0
%Repeat services (<i>P</i> =0.0000)	TH	347	0 - 47.2	12.8	11.4	12.1 - 13.5	5.8	6.8	7.1	17.7	19.7	21.4
	NZ	393	0 - 38.1	9.0	8.2	8.3 - 9.6	0	1.8	3.3	14.7	16.7	17.9
Av.NPD(day) (<i>P</i> =0.0001)	TH	344	17.0 - 204.0	60.1	56.0	57.5 - 62.7	36.0	39.0	42.0	73.0	79.0	88.0
	NZ	392	13.0 - 158.0	53.3	50.0	51.2 - 55.5	30.0	34.0	38.0	64.0	71.0	78.0
Av.NPD/parity record (day) (<i>P</i> =0.0385)	TH	344	6.9 - 100.4	25.2	22.4	23.8 - 26.7	13.3	15.0	16.3	30.4	34.2	38.7
	NZ	389	7.4 - 127.0	23.1	20.3	21.8 - 24.5	12.1	13.4	15.4	28.2	30.1	33.4

Table 6.8. Summary of results of 2-way ANOVA of 6 key parameters in the breeding parameter group

Parameters	Country	Month	Interaction between Country and Month
Entry-service interval (day)	$F_{1,626} = 38.12,$ $P = 0.0000$	$F_{11,626} = 0.36,$ $P = 0.9715$	$F_{11,626} = 0.31,$ $P = 0.9835$
Wean-service interval (day)	$F_{1,701} = 2.75,$ $P = 0.0977$	$F_{11,701} = 0.83,$ $P = 0.6150$	$F_{11,701} = 0.85,$ $P = 0.5940$
%Sow bred by 7 days	$F_{1,706} = 42.62,$ $P = 0.0000$	$F_{11,706} = 1.16,$ $P = 0.3080$	$F_{11,706} = 1.34,$ $P = 0.1952$
%Repeat services	$F_{1,716} = 60.04 ,$ $P = 0.0000$	$F_{11,716} = 2.21,$ $P = 0.0126$	$F_{11,716} = 1.91,$ $P = 0.0349$
Av.NPD (day)	$F_{1,712} = 15.11 ,$ $P = 0.0001$	$F_{11,712} = 1.39,$ $P = 0.1735$	$F_{11,712} = 2.11,$ $P = 0.0178$
Av.NPD/parity record (day)	$F_{1,709} = 4.29 ,$ $P = 0.0386$	$F_{11,709} = 1.13,$ $P = 0.3380$	$F_{11,709} = 2.58,$ $P = 0.0032$

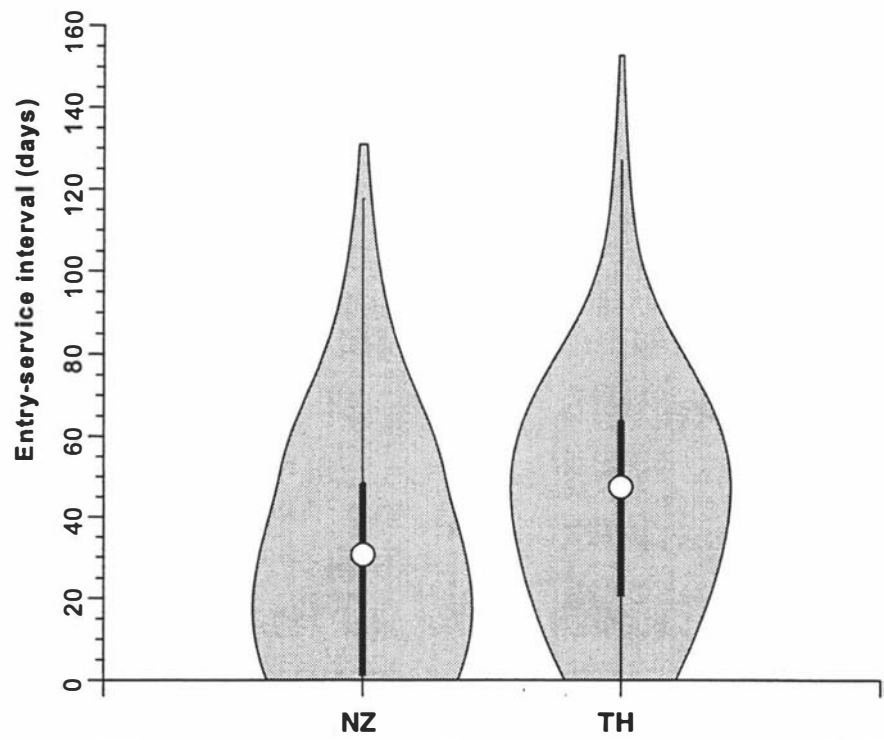


Figure 6.27. Violin plots of average monthly entry to service interval for the 2 countries

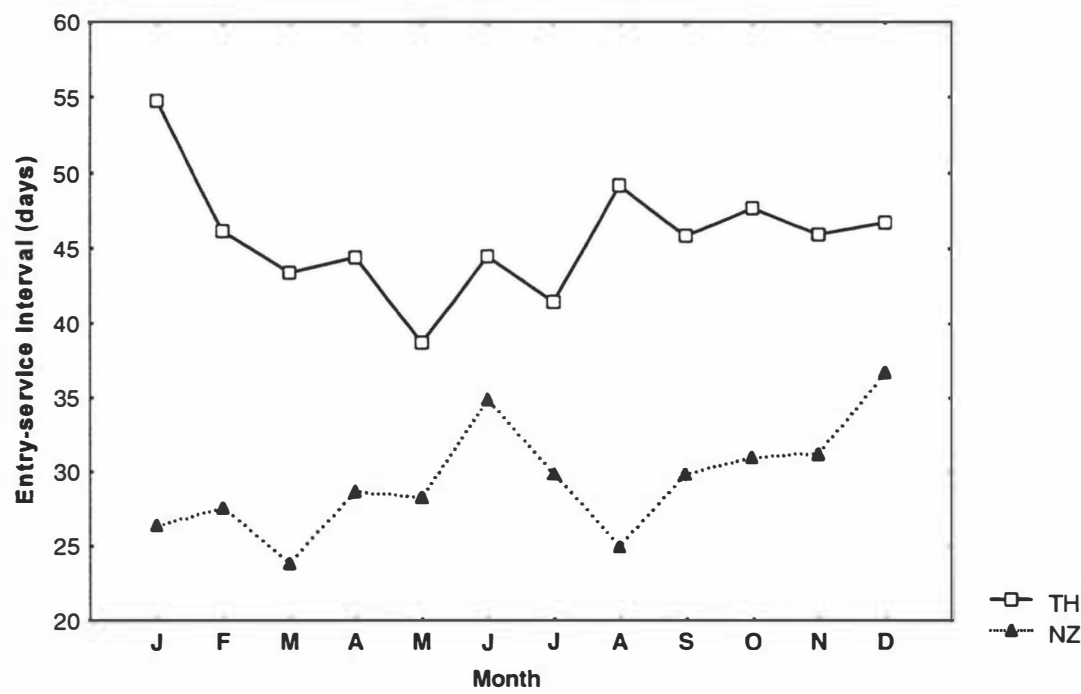


Figure 6.28. Line plot of average entry to service interval for the 2 countries by month (1991-92)

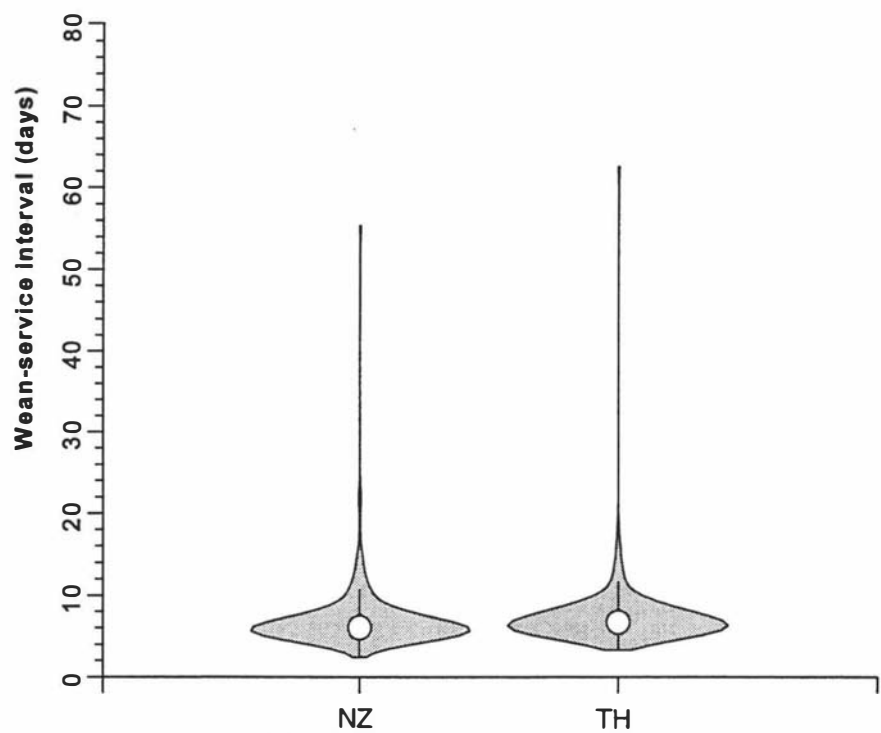


Figure 6.29. Violin plots of average monthly wean to service interval for the 2 countries

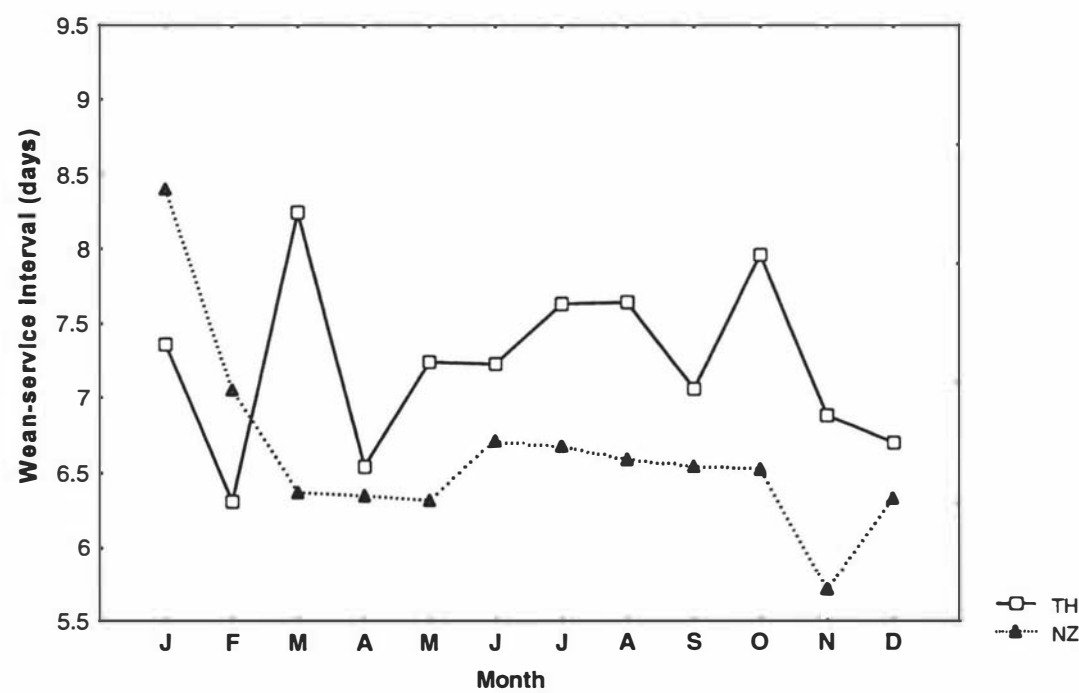


Figure 6.30. Line plot of average wean to service interval for the 2 countries by month (1991-92)

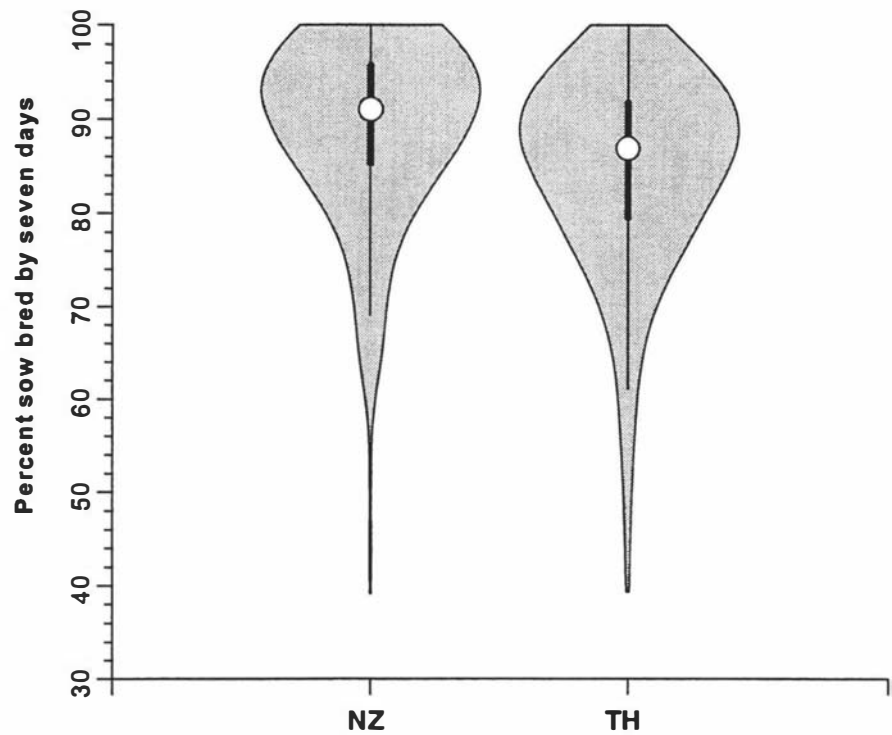


Figure 6.31. Violin plots of average monthly percentage of sow bred by seven days for the 2 countries

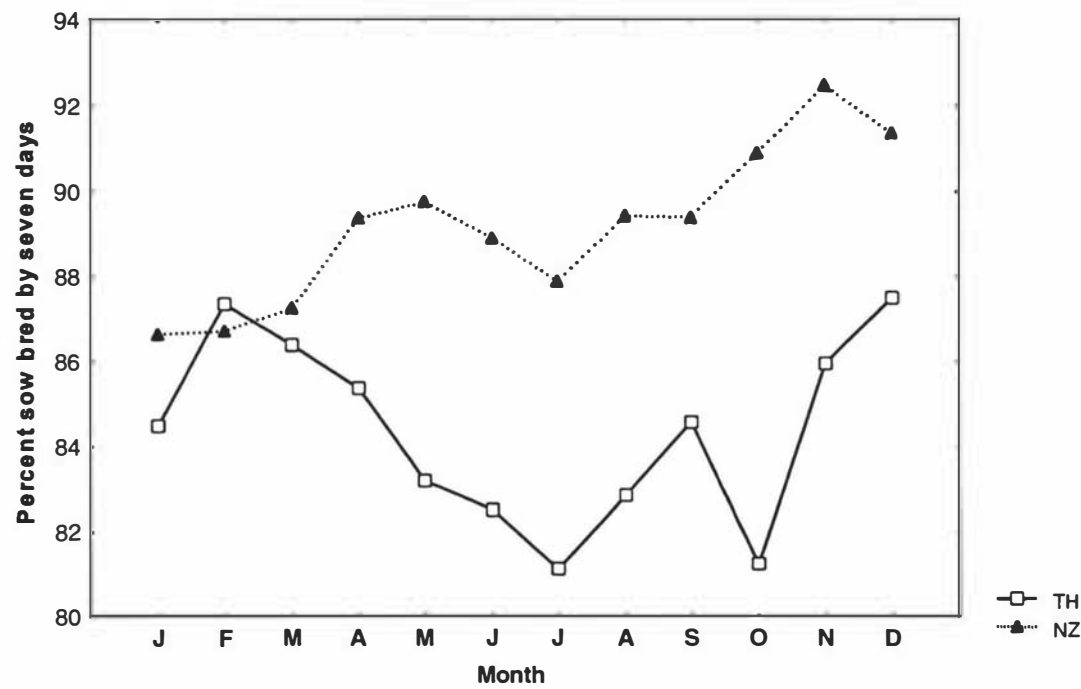


Figure 6.32. Line plot of percentage of sow bred by seven days for the 2 countries by month (1991-92)

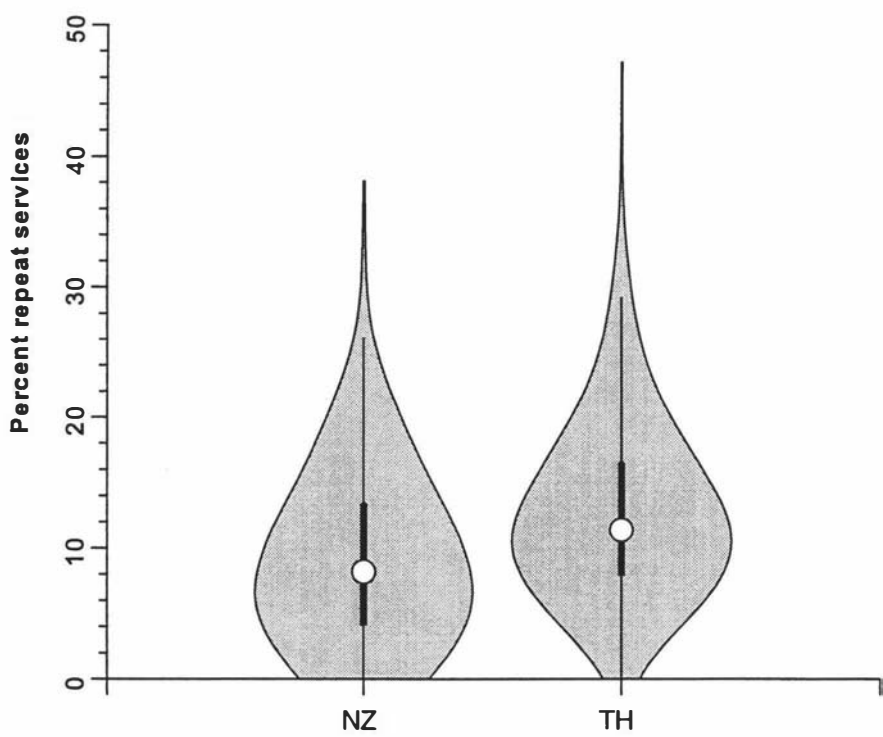


Figure 6.33. Violin plots of average monthly percent repeat services for the 2 countries

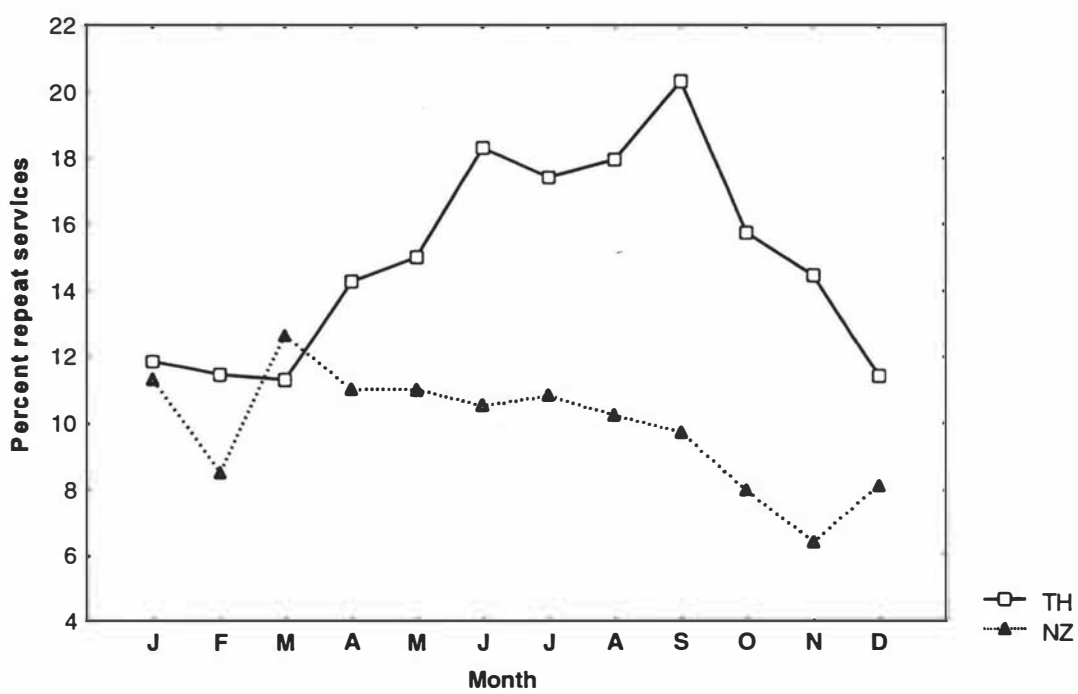


Figure 6.34. Line plot of percentage of repeat services for the 2 countries by month (1991-92)

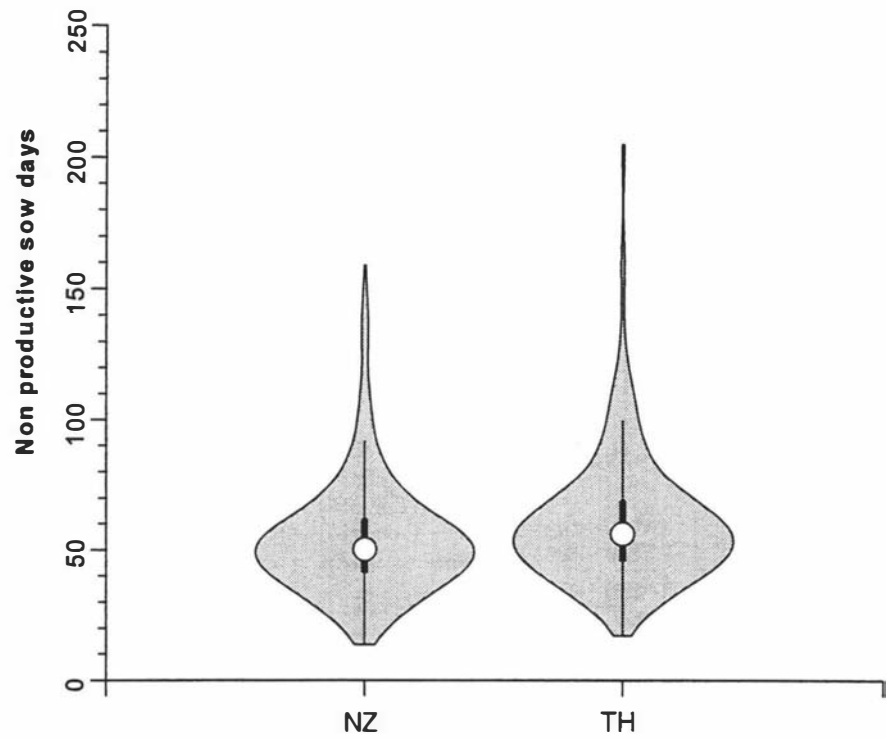


Figure 6.35. Violin plots of average monthly non productive sow days for the 2 countries

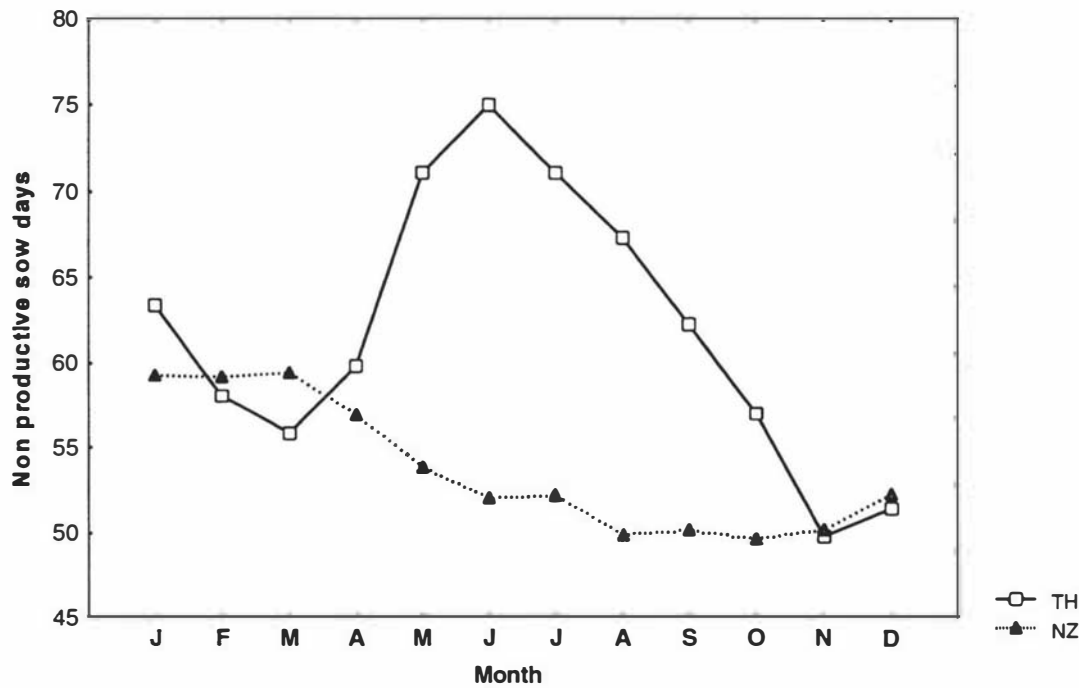


Figure 6.36. Line plot of non productive sow days for the 2 countries by month (1991-92)

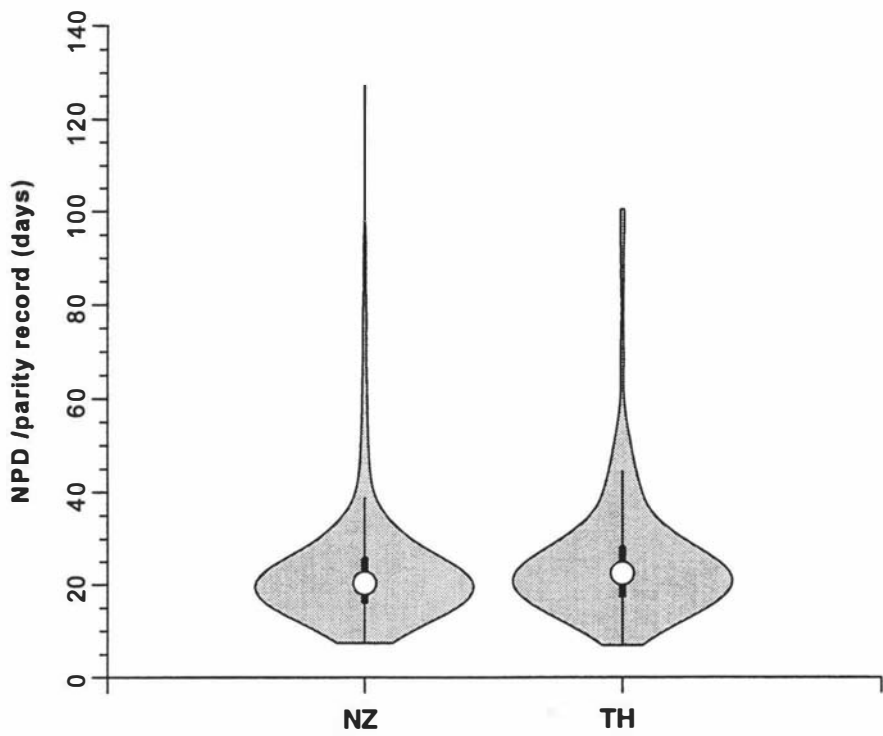


Figure 6.37. Violin plots of average monthly non productive sow days per parity record for the 2 countries

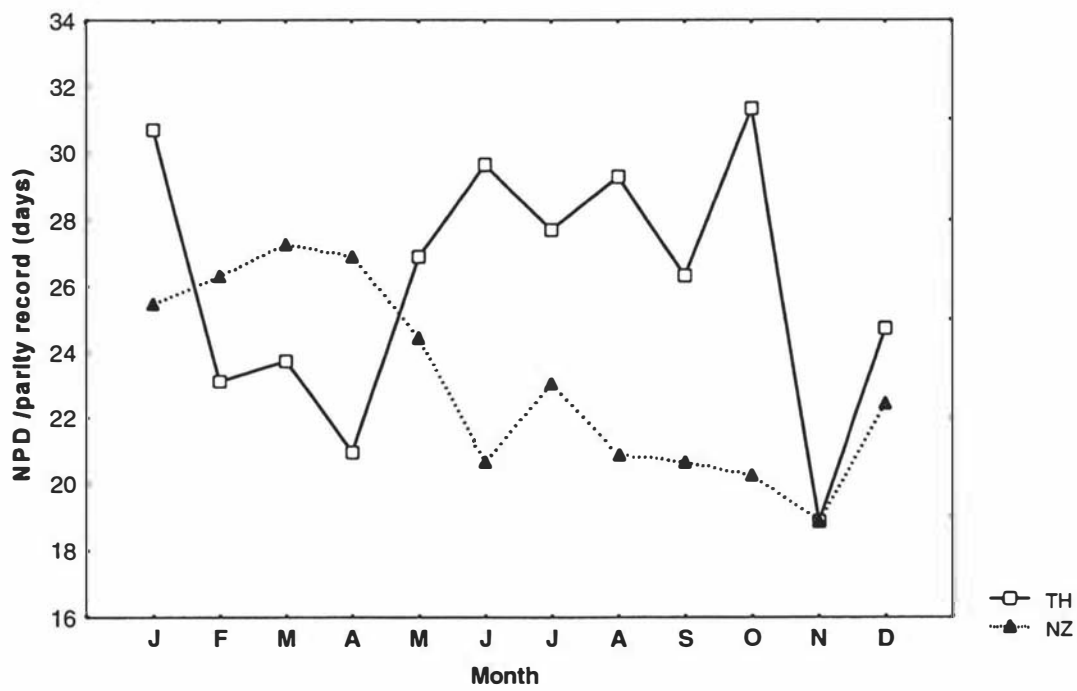


Figure 6.38. Line plot of non productive sow days per parity record for the 2 countries by month (1991-92)

Monthly farrowing performance

Descriptive statistics for 7 key parameters (average total pigs /litter, average pigs born alive /litter, percentage of stillborn pigs, percentage of mummies, adjusted farrowing rate, farrowing interval and litters /mated female /year) are presented in Table 6.9. Results of 2-way ANOVA, with 'country' and 'month of year' as main effects are summarised in Table 6.10.

Average total pigs /litter

Results of two way ANOVA indicate that the main effect 'country' was significantly associated with 'average total pigs /litter' ($F_{1,713} = 321.56$, $P = 0.0000$) whereas the main effect 'month of year', and the interaction between 'country' and 'month of year' were not significant ($F_{11,713} = 0.49$, $P = 0.9121$; $F_{11,713} = 1.27$, $P = 0.2369$). Violin plots and line plots of average total pigs/litter for the 2 countries are presented in Figures 6.39 and 6.40 respectively.

Average pigs born alive /litter

Results of two way ANOVA indicate that the main effect 'country' was significantly associated with 'average pigs born alive /litter' ($F_{1,713} = 361.06$, $P = 0.0000$) whereas the main effect 'month of year', and the interaction between 'country' and 'month of year' were not significant ($F_{11,713} = 0.54$, $P = 0.8760$; $F_{11,713} = 1.63$, $P = 0.0859$). Violin plots and line plots of average pigs born alive /litter for the 2 countries are presented in Figures 6.41 and 6.42 respectively.

Percentage of stillborn pigs

Results of two way ANOVA indicate that the main effect 'country' was significantly associated with average 'percentage of stillborn pigs' ($F_{1,713} = 21.11$, $P = 0.0000$) whereas the main effect 'month of year', and the interaction between 'country' and 'month of year' were not significant ($F_{11,713} = 1.31$, $P = 0.2118$; $F_{11,713} = 0.33$, $P = 0.9790$). Violin plots and line plots of average percentage of stillborn pigs for the 2 countries are presented in Figures 6.43 and 6.44 respectively.

Percentage of mummies

Results of two way ANOVA indicate that the main effect 'country' was significantly associated

with average 'percentage of mummies' ($F_{1,713} = 129.64$, $P = 0.0000$) whereas the main effect 'month of year', and the interaction between 'country' and 'month of year' were not significant ($F_{11,713} = 0.74$, $P = 0.7015$; $F_{1,713} = 1.68$, $P = 0.0733$). Violin plots and line plots of average percentage of mummies for the 2 countries are presented in Figures 6.45 and 6.46 respectively.

Adjusted farrowing rate

Results of two way ANOVA indicate that the 2 main effects 'country' and 'month of year', and the interaction between 'country' and 'month of year' were significantly associated with average 'adjusted farrowing rate' ($F_{1,713} = 11.70$, $P = 0.0007$; $F_{11,713} = 2.92$, $P = 0.0009$; $F_{11,713} = 6.15$, $P = 0.0000$). Violin plots and line plots of average adjusted farrowing rate for the 2 countries are presented in Figures 6.47 and 6.48 respectively.

A multiple comparison of average adjusted farrowing rate for the main effect 'month of year' was conducted using Tukey's HSD procedure. Results of the comparison ($P < 0.05$) are summarised and presented in Table 6.11.

Farrowing interval

Results of two way ANOVA indicate that the main effect 'country' and the interaction between the 2 main effects were significantly associated with average 'farrowing interval' ($F_{1,713} = 29.81$, $P = 0.0000$ and $F_{11,713} = 3.06$, $P = 0.0005$) whereas the main effect month of year was not significant ($F_{11,713} = 0.68$, $P = 0.7543$). Violin plots and line plots of average farrowing interval for the 2 countries are presented in Figures 6.49 and 6.50 respectively.

Litters /mated female /year

Results of two way ANOVA indicate that the 2 main effects and the interaction between the 2 main effects were significantly associated with average 'litters /mated female /year' ($F_{1,699} = 26.02$, $P = 0.0000$; $F_{11,699} = 3.64$, $P = 0.0000$ and $F_{11,699} = 3.75$, $P = 0.0000$). Violin plots and line plots of average litters /mated female /year are presented for the 2 countries in Figures 6.51 and 6.52.

A multiple comparison of average litters /mated female /year for the main effect 'month of year' was conducted using Tukey's HSD procedure. Results of the comparison ($P < 0.05$) are summarised and presented in Table 6.11.

Table 6.9. Comparison of monthly farrowing performance between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
Av. total pigs/litter (<i>P</i> =0.0000)	TH	347	6.0 - 13.0	10.3	10.3	10.2 - 10.4	9.2	9.4	9.6	11.2	11.4	11.7
	NZ	390	8.9 - 14.2	11.6	11.7	11.5 - 11.7	10.3	10.6	10.9	12.4	12.5	12.7
Av. pigs born alive/litter (<i>P</i> =0.0000)	TH	347	5.7 - 12.0	9.5	9.5	9.4 - 9.6	8.4	8.6	8.8	10.3	10.6	10.9
	NZ	390	8.9 - 13.0	10.7	10.8	10.7 - 10.8	9.7	9.9	10.1	11.4	11.5	11.7
%Stillborn pigs (<i>P</i> =0.0000)	TH	347	0 - 11.7	5.3	5.0	5.1 - 5.5	3.0	3.3	3.6	7.0	7.6	8.0
	NZ	390	0 - 16.8	6.3	6.3	5.9 - 6.6	0.5	3.4	3.9	8.9	9.5	10.4
%Mummies (<i>P</i> =0.0000)	TH	347	0 - 13.7	2.1	1.8	1.9 - 2.3	0.5	0.7	0.9	3.0	3.5	4.2
	NZ	390	0 - 6.8	1.0	0.8	0.9 - 1.1	0	0	0	1.8	2.1	2.5
Adj. farrowing rate(%) (<i>P</i> =0.0000)	TH	347	11.9 - 100	84.1	86.3	82.8 - 85.3	72.7	77.3	78.5	91.8	92.9	94.3
	NZ	390	55.0 - 100	86.3	87.2	85.4 - 87.1	75.0	78.1	80.0	92.9	94.3	96.2
Farrowing interval(day) (<i>P</i> =0.0000)	TH	340	142.0 - 188.0	155.3	154.0	154.5 - 156.0	148.0	149.0	149.0	160.0	162.0	164.0
	NZ	379	141.0 - 202.0	158.5	157.0	157.7 - 159.4	150.0	151.0	152.0	164.0	166.0	168.0
Litters/mated female/yr (<i>P</i> =0.0000)	TH	339	1.7 - 2.6	2.3	2.3	2.2 - 2.3	2.10	2.13	2.16	2.37	2.39	2.41
	NZ	384	1.2 - 2.5	2.2	2.2	2.19 - 2.22	2.03	2.09	2.12	2.34	2.36	2.37

Table 6.10. Summary of results of 2-way ANOVA of 7 key parameters in the farrowing parameter group

Parameters	Country	Month	Interaction between Country and Month
Av. total pigs/litter	$F_{1,713} = 321.56,$ $P = 0.0000$	$F_{11,713} = 0.49,$ $P = 0.9121$	$F_{11,713} = 1.27,$ $P = 0.2369$
Av. pigs born alive/litter	$F_{1,713} = 361.06,$ $P = 0.0000$	$F_{11,713} = 0.54,$ $P = 0.8760$	$F_{11,713} = 1.63,$ $P = 0.0859$
%Stillborn pigs	$F_{1,713} = 21.11,$ $P = 0.0000$	$F_{11,713} = 1.31,$ $P = 0.2118$	$F_{11,713} = 0.33,$ $P = 0.9790$
%Mummies	$F_{1,713} = 129.64 ,$ $P = 0.0000$	$F_{11,713} = 0.74,$ $P = 0.7015$	$F_{11,713} = 1.68,$ $P = 0.0733$
Adj.farrowing rate (%)	$F_{1,713} = 11.70 ,$ $P = 0.0007$	$F_{11,713} = 2.92,$ $P = 0.0009$	$F_{11,713} = 6.15,$ $P = 0.0000$
Farrowing interval (day)	$F_{1,695} = 29.81 ,$ $P = 0.0000$	$F_{11,695} = 0.68,$ $P = 0.7543$	$F_{11,695} = 3.06,$ $P = 0.0005$
Litters/mated female/yr	$F_{1,699} = 26.02 ,$ $P = 0.0000$	$F_{11,699} = 3.64,$ $P = 0.0000$	$F_{11,699} = 3.75,$ $P = 0.0000$

Table 6.11. Summary of results of a multiple comparison analysis between months ($P < 0.05$) for adjusted farrowing rate and litters /mated female /year

Parameters	JAN (1)	FEB (2)	MAR (3)	APR (4)	MAY (5)	JUN (6)	JUL (7)	AUG (8)	SEP (9)	OCT (10)	NOV (11)	DEC (12)
Adj. farrowing rate		10	10,12	10						2,3,4		3
Litters/mated female/yr				10,11		10,11	10,11			4,6,7	4,6,7	

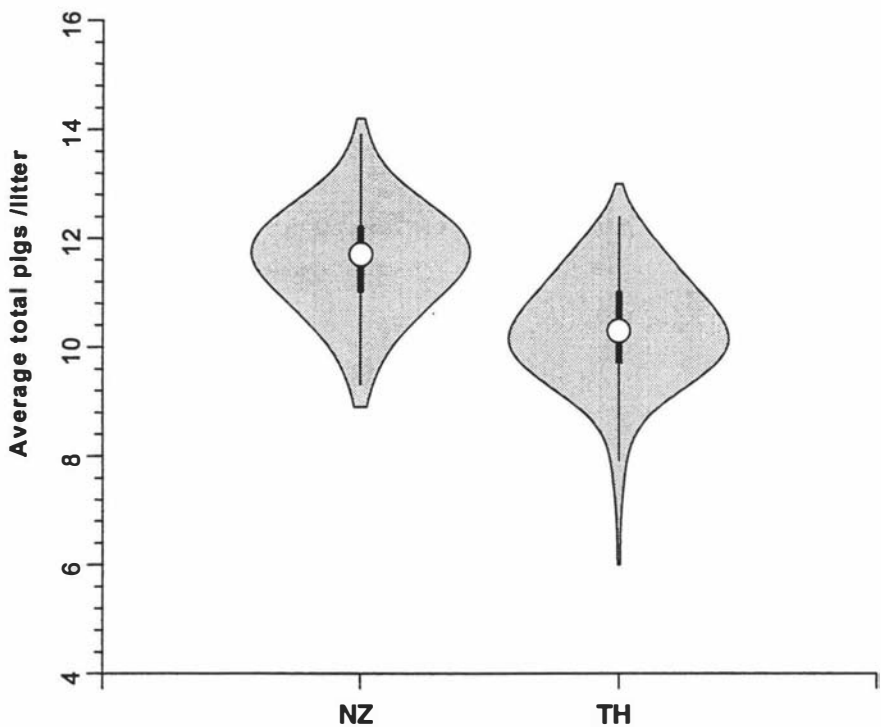


Figure 6.39. Violin plots of average monthly total pigs per litter for the 2 countries

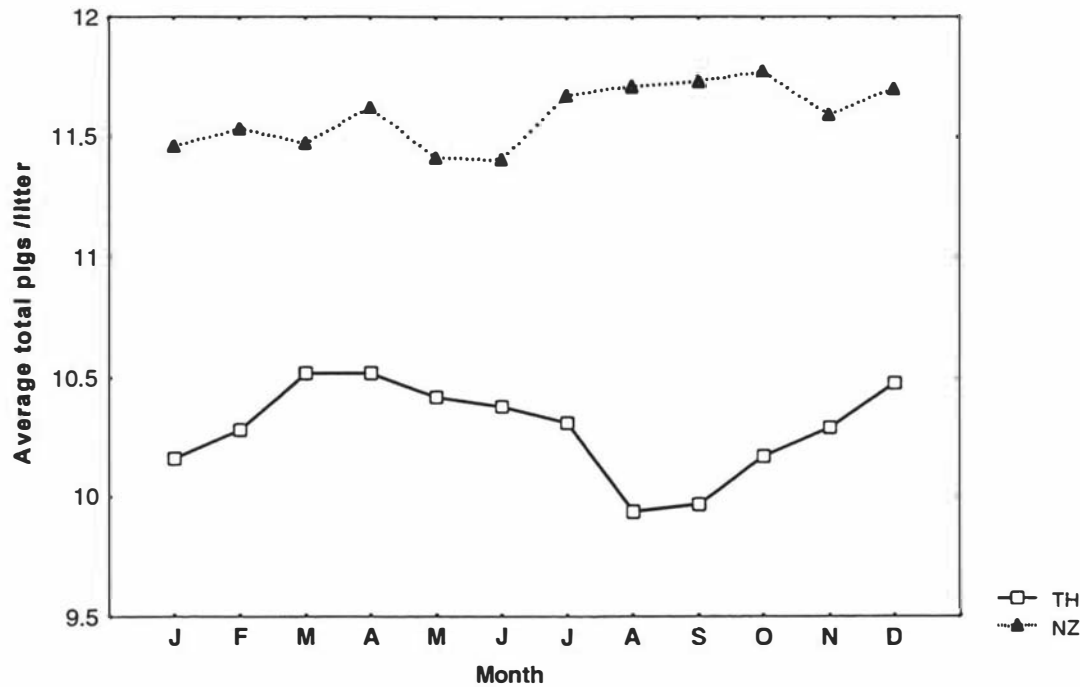


Figure 6.40. Line plot of average total pigs per litter for the 2 countries by month (1991-92)

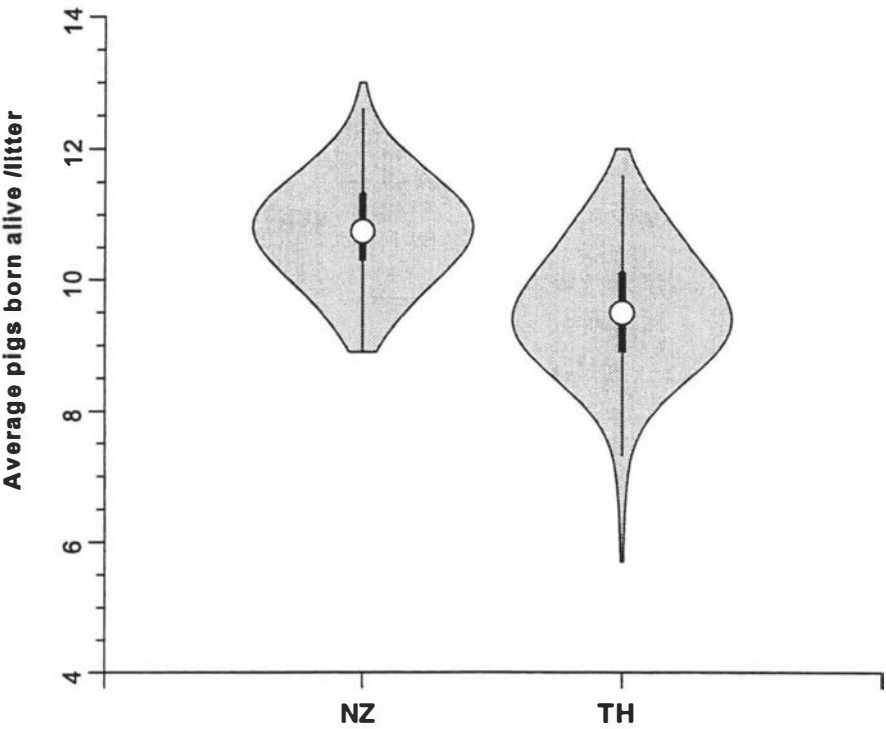


Figure 6.41. Violin plots of average monthly pigs born alive per litter for the 2 countries

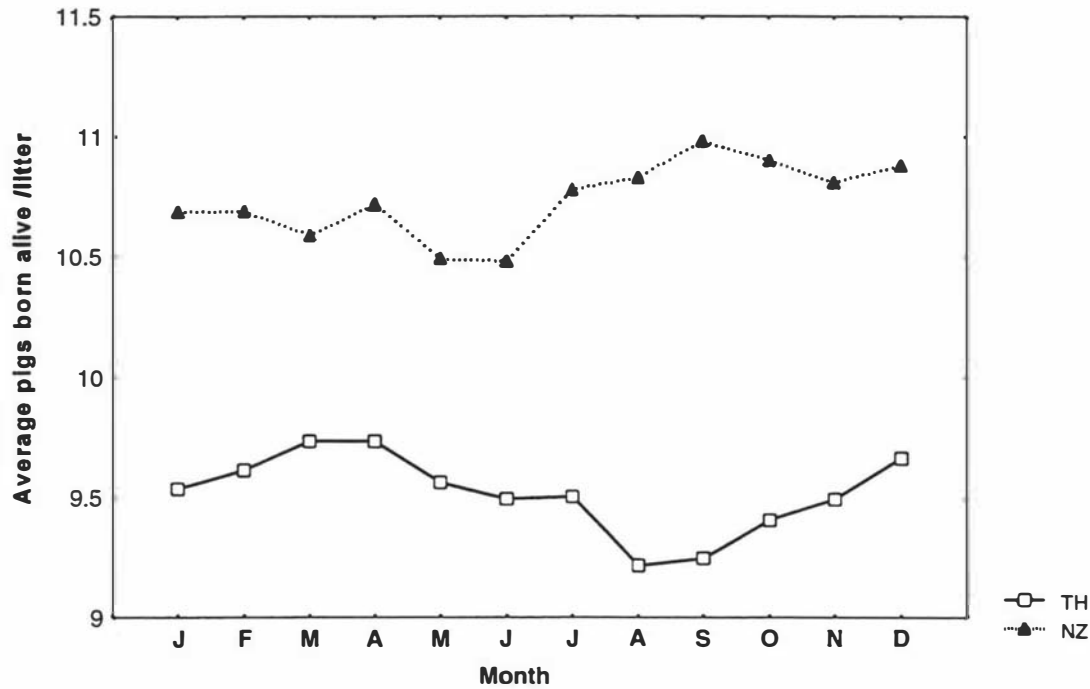


Figure 6.42. Line plot of average pigs born alive per litter for the 2 countries by month (1991-92)

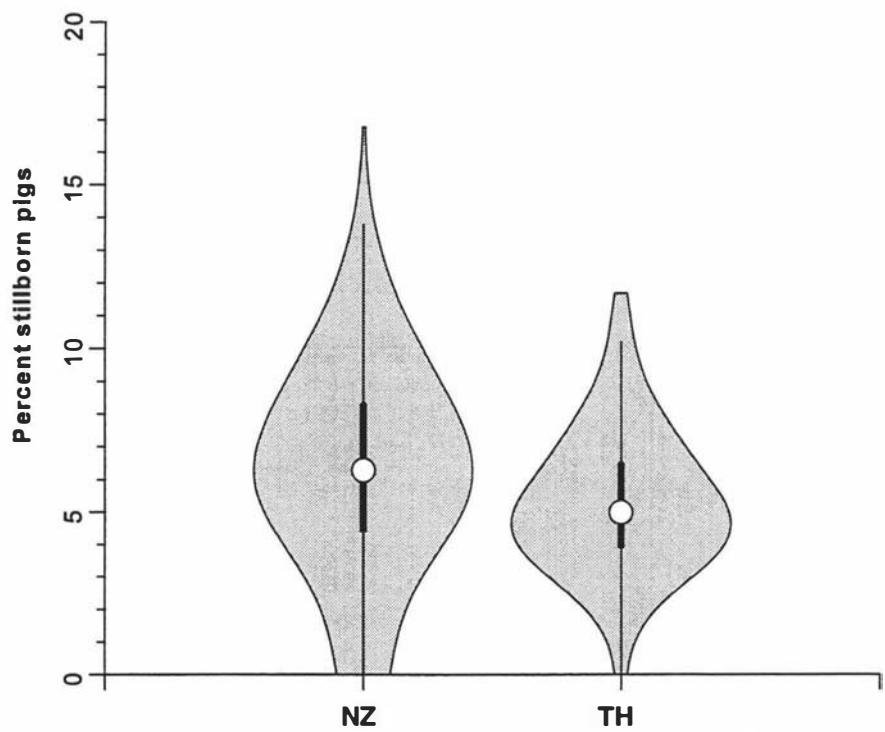


Figure 6.43. Violin plots of average monthly percentage of stillborn pigs for the 2 countries

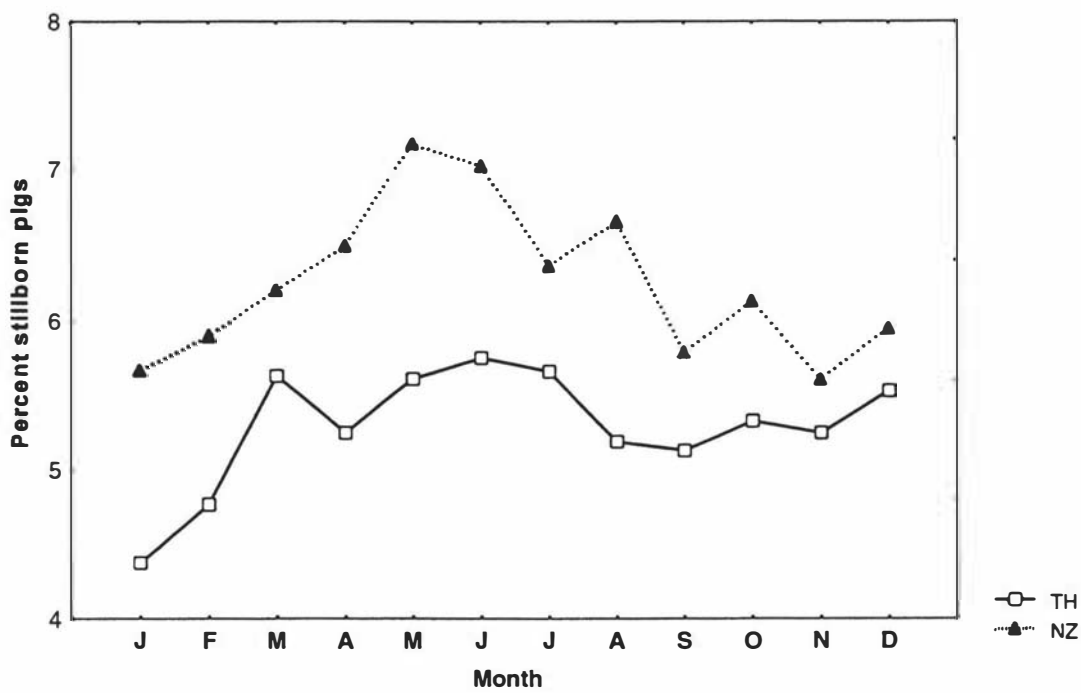


Figure 6.44 Line plot of average percentage of stillborn pigs for the 2 countries by month (1991-92)

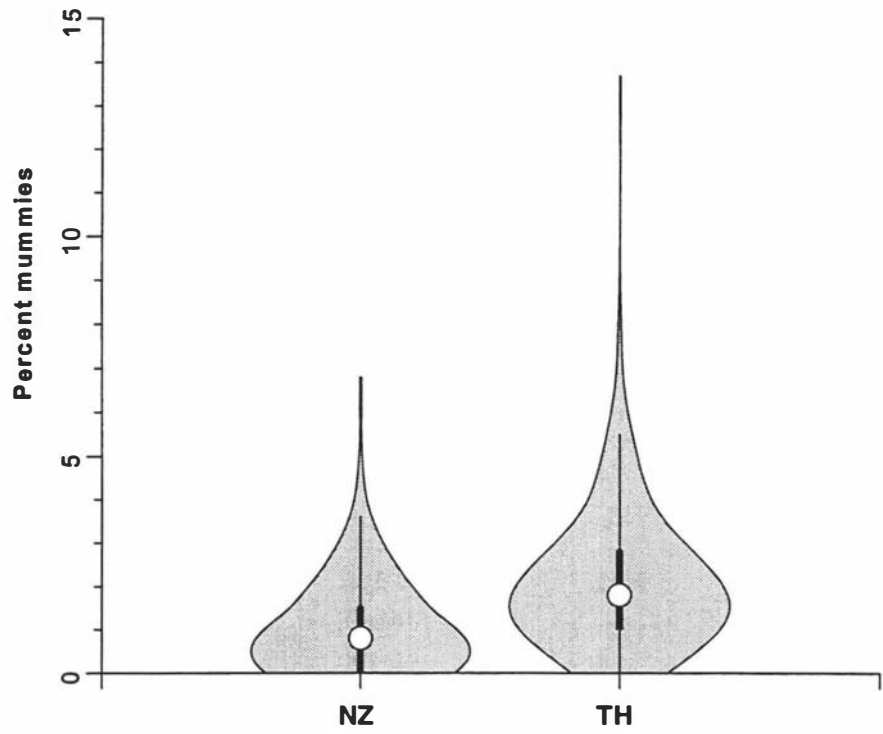


Figure 6.45. Violin plots of average monthly percentage of mummies for the 2 countries

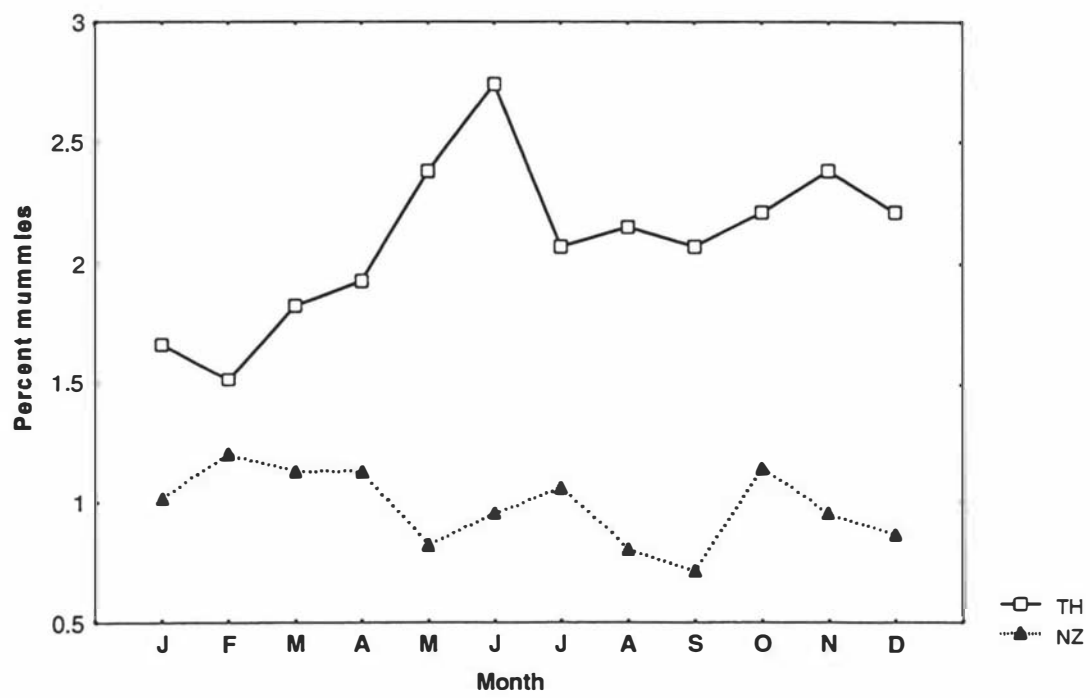


Figure 6.46. Line plot of average percentage of mummies for the 2 countries by month (1991-92)

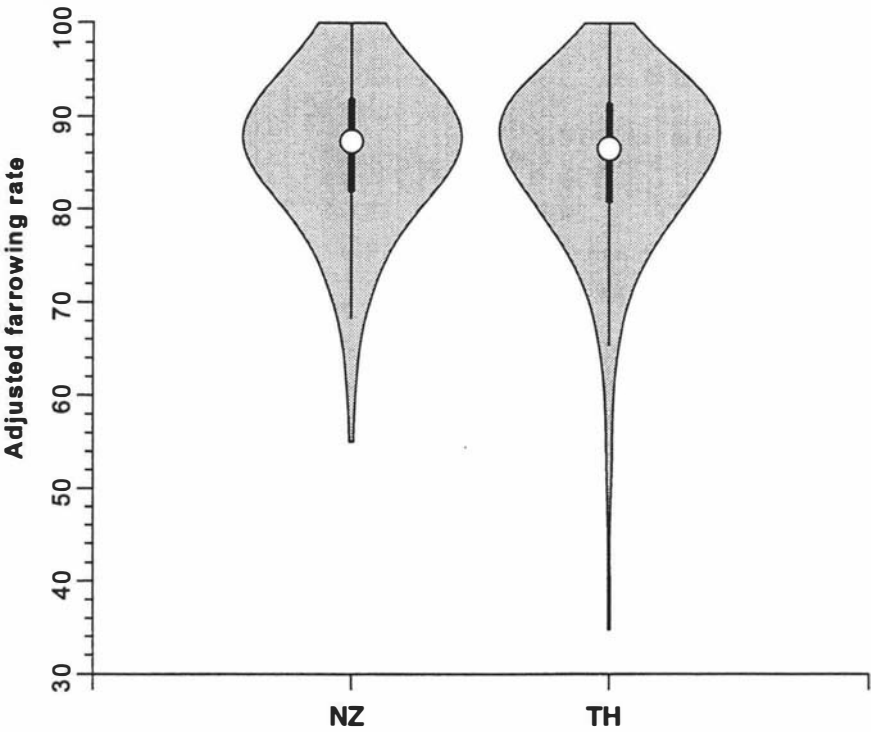


Figure 6.47. Violin plots of average monthly adjusted farrowing rate for the 2 countries

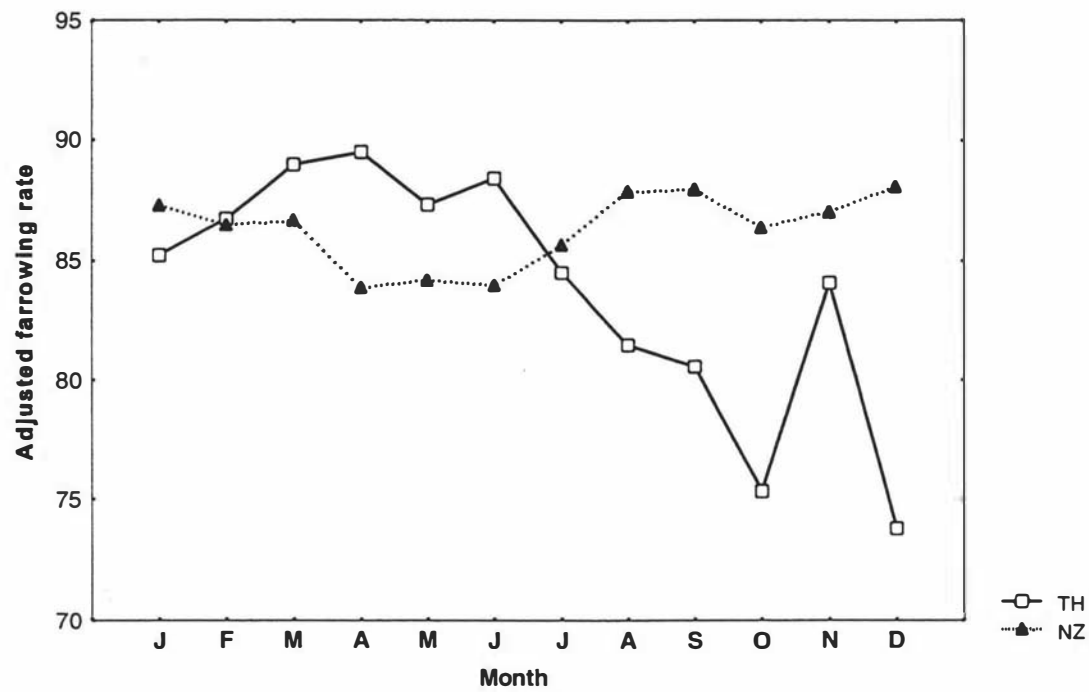


Figure 6.48. Line plot of average adjusted farrowing rate for the 2 countries by month (1991-92)

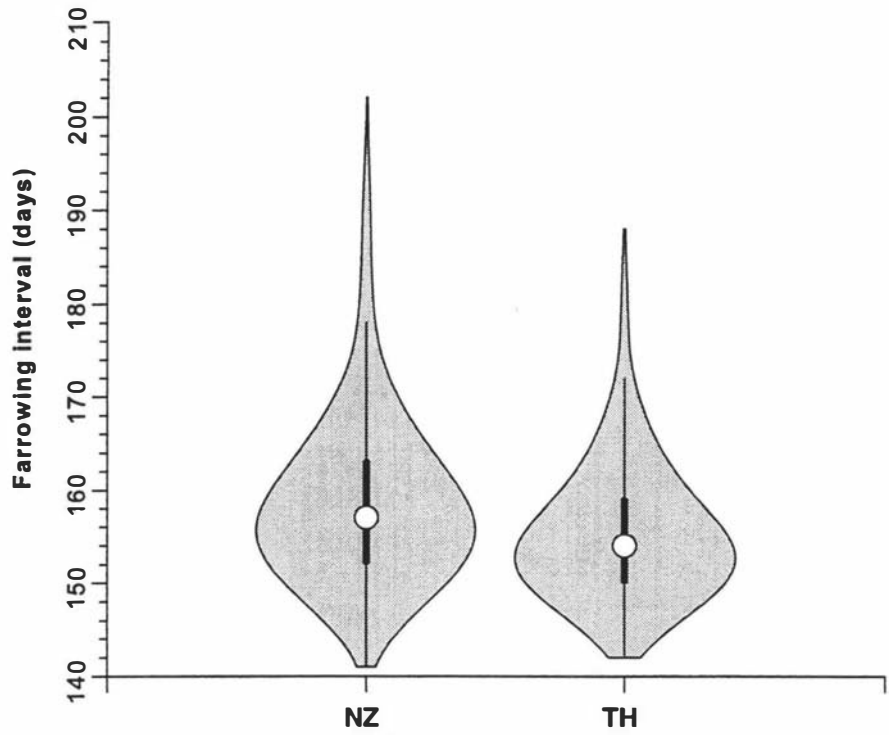


Figure 6.49. Violin plots of average monthly farrowing interval for the 2 countries

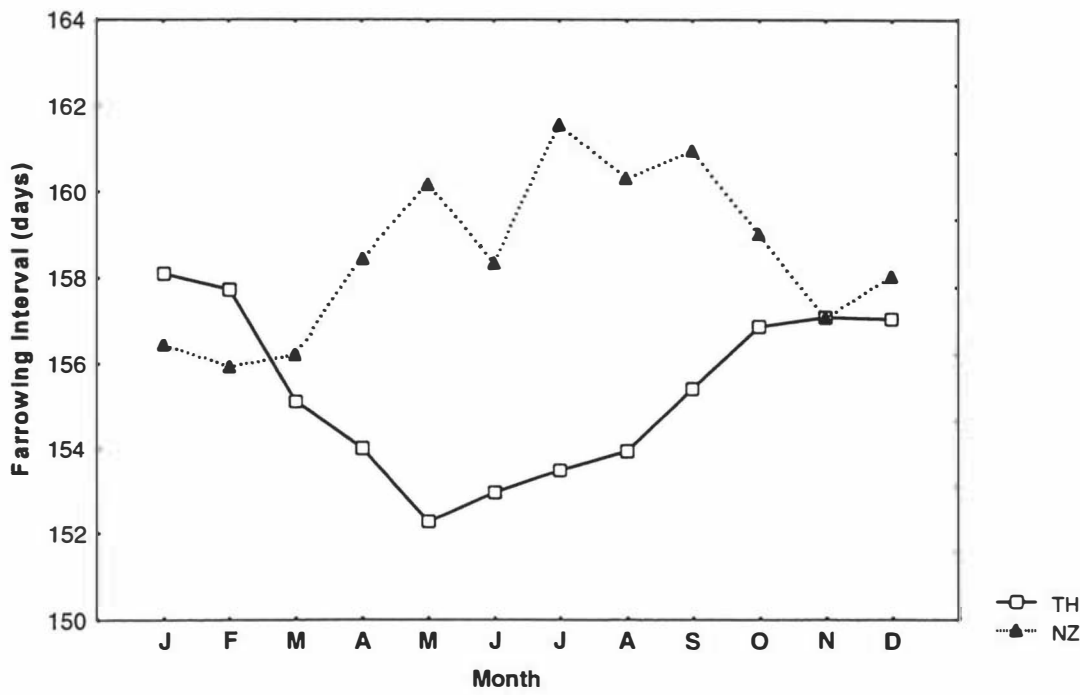


Figure 6.50. Line plot of average farrowing interval for the 2 countries by month (1991-92)

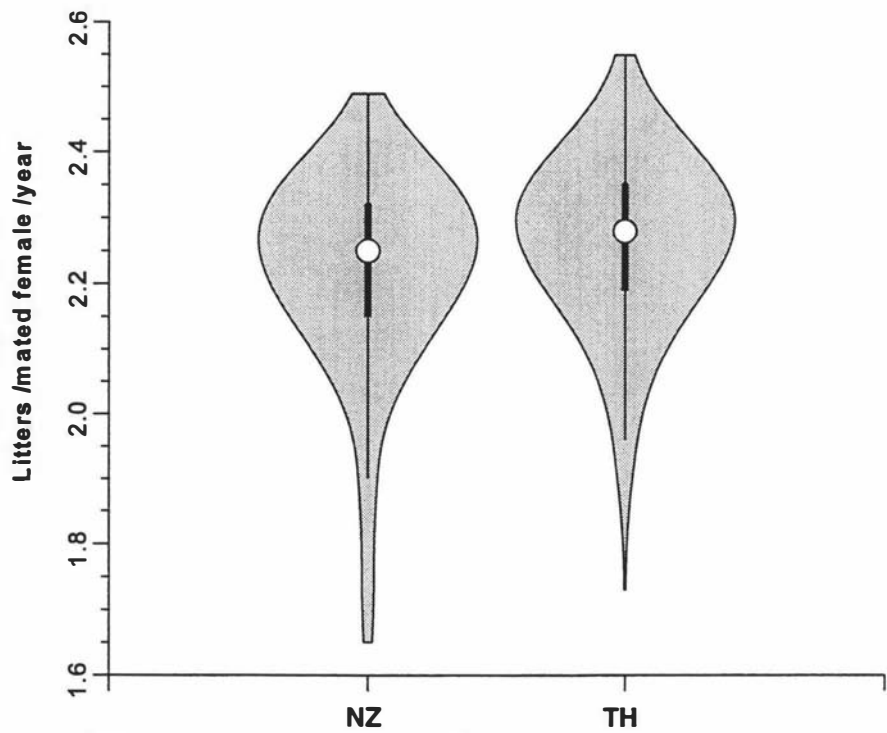


Figure 6.51. Violin plots of average monthly litters per mated female per year for the 2 countries

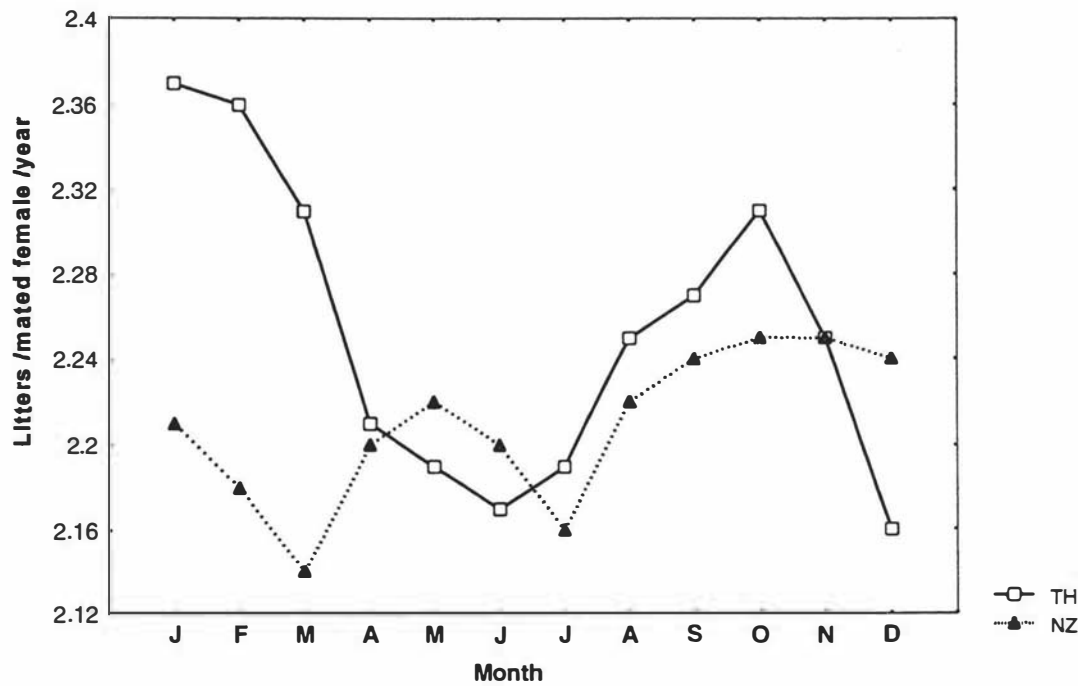


Figure 6.52. Line plot of average litters per mated female per year for the 2 countries by month (1991-92)

Monthly weaning performance

Descriptive statistics for 4 key parameters (pigs weaned /litter, pre-weaning mortality rate, average age at weaning and pigs weaned /mated female /year) are presented in Table 6.12. Results of 2-way ANOVA, with 'country' and 'month of year' as main effects are summarised in Table 6.13

Pigs weaned /litter

Results of two way ANOVA indicate that the main effect 'country' and the interaction between 'country' and 'month of year' were significantly associated with average 'pigs weaned /litter' ($F_{1,709} = 166.97, P = 0.0000$ and $F_{11,709} = 1.91, P = 0.0346$) whereas the main effect 'month of year' was not different ($F_{11,709} = 1.20, P = 0.2847$). Violin plots and line plots of average pigs weaned /litter for the 2 countries are presented in Figures 6.53 and 6.54 respectively.

Pre-weaning mortality rate

Results of two way ANOVA indicate that the 2 main effects 'country' and 'month of year' were significantly associated with average 'pre-weaning mortality rate' ($F_{1,709} = 69.37, P = 0.0000$ and $F_{11,709} = 2.13, P = 0.0165$) whereas the interaction between the 2 main effects was not different ($F_{11,709} = 0.64, P = 0.7974$). Violin plots and line plots of average pre-weaning mortality rate for the 2 countries are presented in Figures 6.55 and 6.56 respectively.

A multiple comparison of average pre-weaning mortality rate for the main effect 'month of year' was conducted using Tukey's HSD procedure. Results of the comparison ($P < 0.05$) showed that no months were different.

Average age at weaning

Results of two way ANOVA indicate that the main effect 'country' was significantly associated with 'average age at weaning' ($F_{1,709} = 141.37, P = 0.0000$) whereas the main effect 'month of year' and the interaction between the 2 main effects were not different ($F_{11,709} = 0.66, P = 0.7807$ and $F_{11,709} = 0.48, P = 0.9176$). Violin plots and line plots of average age at weaning for the 2 countries are presented in Figures 6.57 and 6.58 respectively.

Pigs weaned /mated female /year

Results of two way ANOVA indicate that the main effect 'country' and the interaction between the 2 main effects were significantly associated with average 'pigs weaned /mated female /year' ($F_{1,709} = 35.39, P = 0.0000$ and $F_{11,709} = 2.68, P = 0.0022$) whereas the main effect 'month of year' was not different ($F_{11,709} = 1.76, P = 0.0574$). Violin plots and line plots of average pigs weaned /mated female /year for the 2 countries are presented in Figures 6.59 and 6.60 respectively.

Table 6.12. Comparison of monthly weaning performance between the two countries

Parameters	Country	N	Min - Max	Mean	Median	95%CI of Mean	10 th P	15 th P	20 th P	80 th P	85 th P	90 th P
Pigs weaned/litter (<i>P</i> =0.0000)	TH	346	5.2 - 11.0	8.7	8.7	8.6 - 8.8	7.8	7.9	8.0	9.4	9.5	9.7
	NZ	387	6.5 - 11.0	9.3	9.4	9.3 - 9.4	8.6	8.8	8.9	9.9	10.0	10.0
Pre-weaning mortality(%) (<i>P</i> =0.0000)	TH	346	0 - 39.2	10.3	9.9	9.8 - 10.8	5.1	5.9	6.8	13.6	14.5	15.9
	NZ	387	4.0 - 37.5	13.0	12.5	12.6 - 13.5	8.0	8.6	9.4	16.2	17.1	18.9
Av. age at weaning(day) (<i>P</i> =0.0000)	TH	346	19.3 - 34.6	27.5	27.3	27.2 - 27.7	25.2	25.5	25.9	29.0	29.8	30.8
	NZ	387	15.3 - 46.8	30.6	29.6	30.2 - 31.1	26.1	26.7	27.2	34.2	34.9	36.4
Pigs weaned /mated female/yr (<i>P</i> =0.0000)	TH	345	11.2 - 27.5	19.5	19.7	19.2 - 19.7	16.2	16.8	17.2	21.7	22.0	22.7
	NZ	387	9.0 - 26.6	20.6	20.9	20.3 - 20.9	17.4	18.3	19.0	22.6	22.9	23.6

Table 6.13. Summary of results of 2-way ANOVA of 4 key parameters in the weaning parameter group

Parameters	Country	Month	Interaction between Country and Month
Pigs weaned/litter	$F_{1,709} = 166.97,$ $P = 0.0000$	$F_{11,709} = 1.20,$ $P = 0.2847$	$F_{11,709} = 1.91,$ $P = 0.0346$
Pre-weaning mortality (%)	$F_{1,709} = 69.37,$ $P = 0.0000$	$F_{11,709} = 2.13,$ $P = 0.0165$	$F_{11,709} = 0.64,$ $P = 0.7974$
Av. age at weaning (day)	$F_{1,709} = 141.37,$ $P = 0.0000$	$F_{11,709} = 0.66,$ $P = 0.7807$	$F_{11,709} = 0.48,$ $P = 0.9176$
Pigs weaned /mated female/yr	$F_{1,709} = 35.39 ,$ $P = 0.0000$	$F_{11,709} = 1.76,$ $P = 0.0574$	$F_{11,709} = 2.68,$ $P = 0.0022$

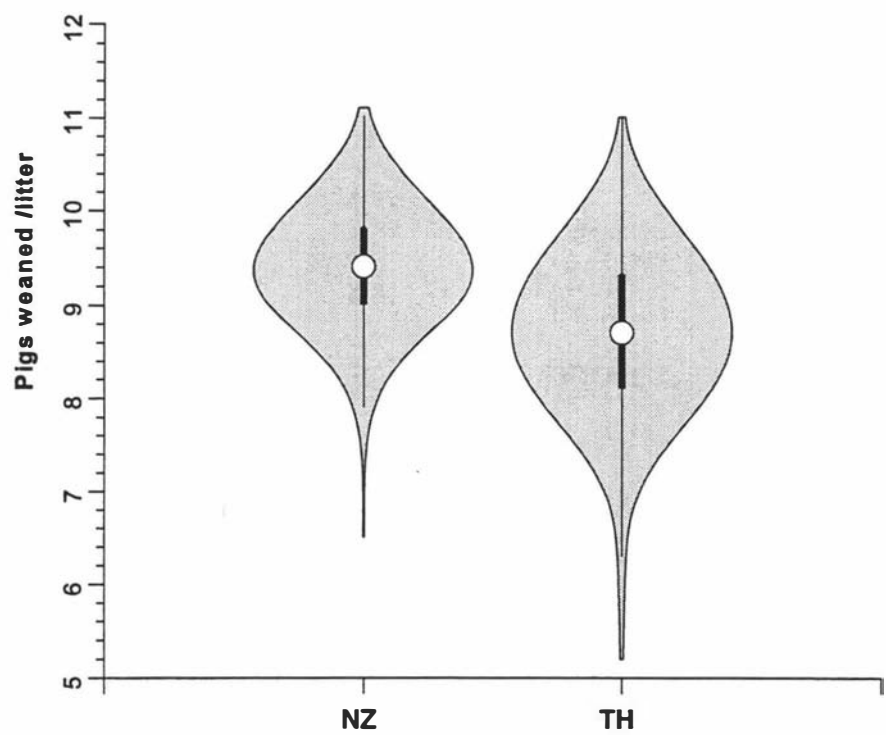


Figure 6.53. Violin plots of average monthly pigs weaned per litter for the 2 countries

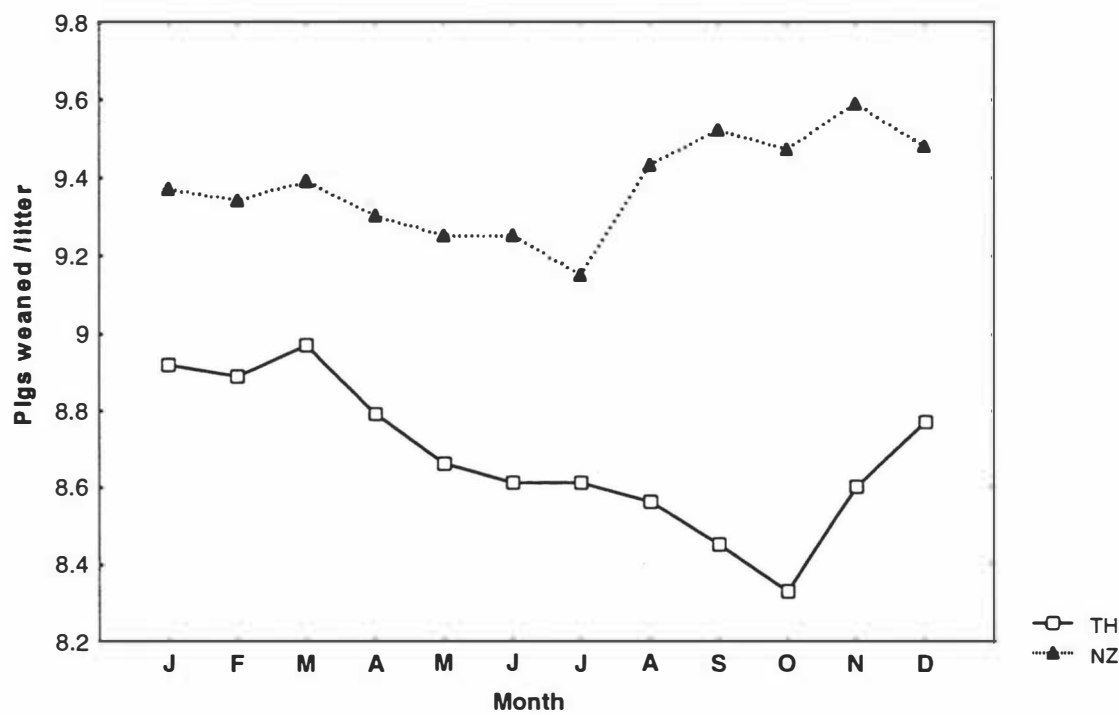


Figure 6.54. Line plot of average pigs weaned per litter for the 2 countries by month (1991-92)

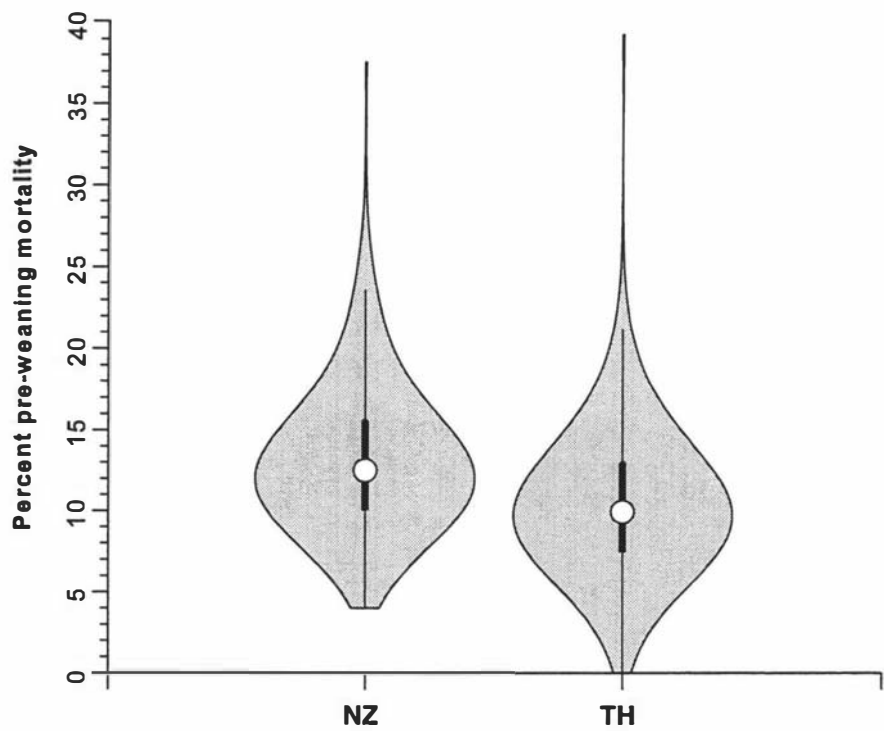


Figure 6.55. Violin plots of average monthly pre-weaning mortality for the 2 countries

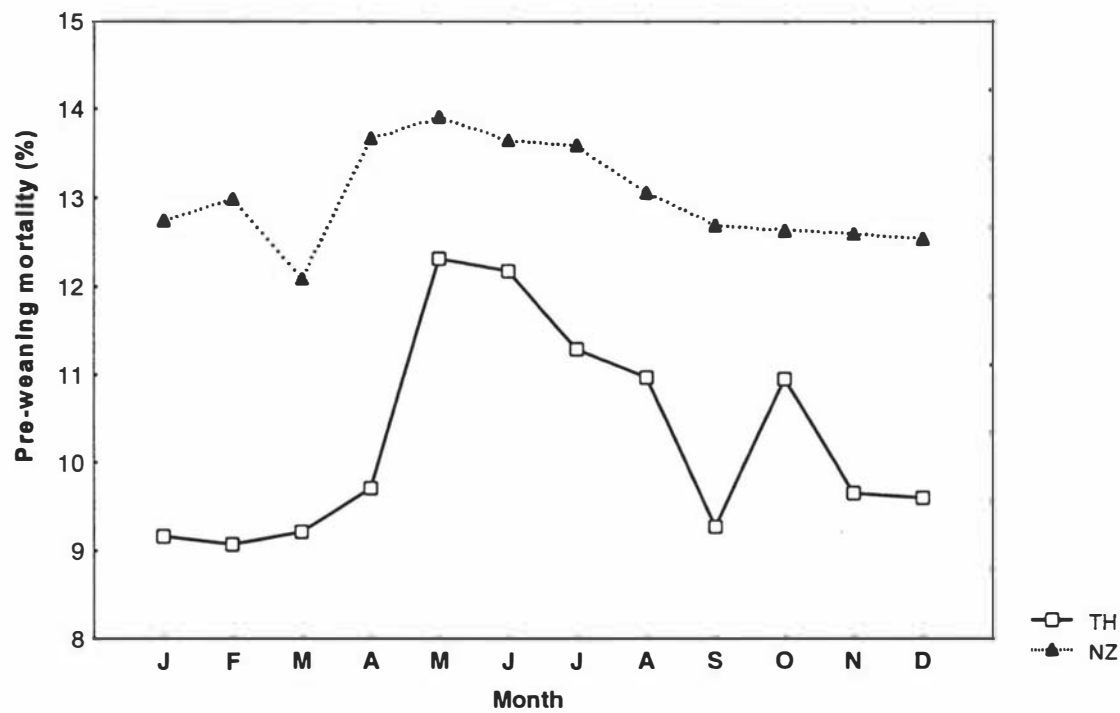


Figure 6.56. Line plot of average pre-weaning mortality for the 2 countries by month (1991-92)

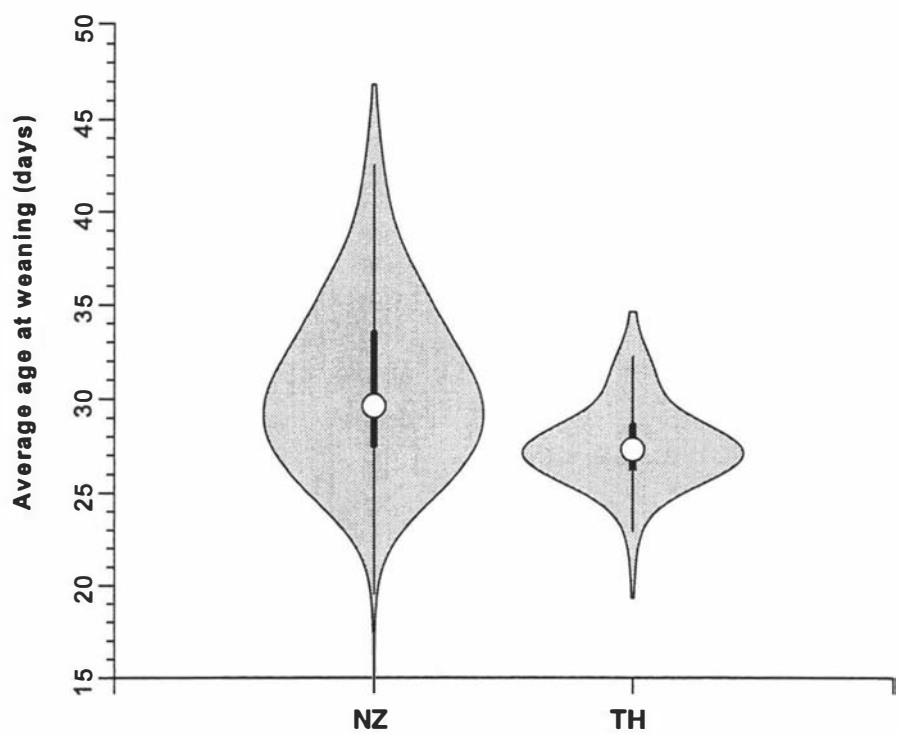


Figure 6.57. Violin plots of average monthly age at weaning for the 2 countries

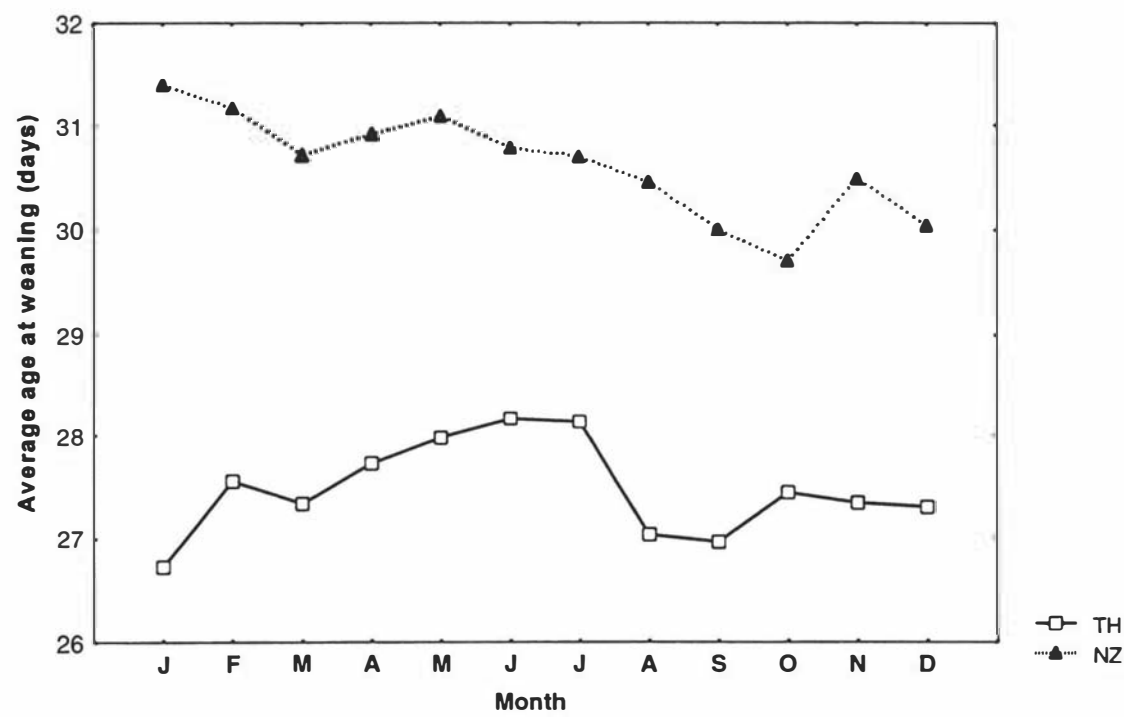


Figure 6.58. Line plot of average age at weaning for the 2 countries by month (1991-92)

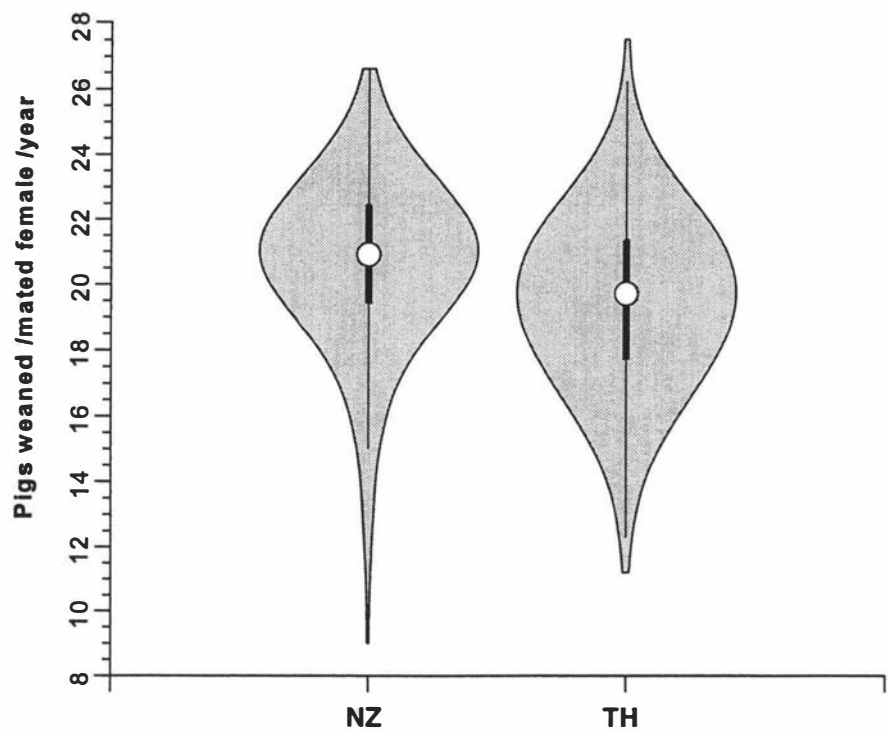


Figure 6.59. Violin plots of average monthly pigs weaned per mated female per year for the 2 countries

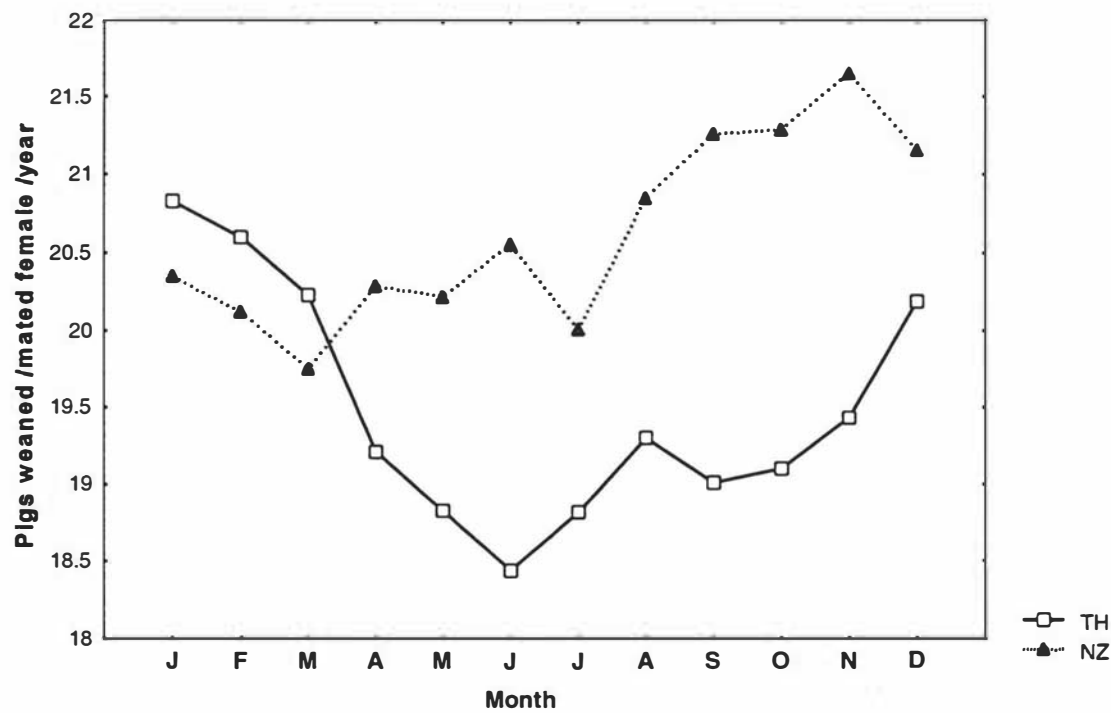


Figure 6.60. Line plot of average pigs weaned per mated female per year for the 2 countries by month (1991-92)

Discussion

Violin plots

When comparing distributions of continuous variables, means and standard deviations cannot express all the characteristics of a set of data for non-normal distributions - particularly with regard to the shape of the distribution. Violin plots were selected to display the spread of individual production parameters in this study instead of histograms. Histograms can show the spread of data but not median values and percentiles, and they do not give the same overview of a data set as do violin plots.

Violin plots are a hybrid between density traces and box plots. A density trace describes the relative frequency (concentration) of data points along the data range and the interval width is specified as a percentage of all data points, as seen in Figure 6.4. When the percentage is increased, the chart becomes smoother. The box plot component contributes a display of median and the 25th and 75th percentiles to the plot.

Areas of improving productivity in each management system

In practice, both a complete data set of herd records and on-site inspection of farm practices and management are necessary to diagnose herd problems and improve herd productivity. However the violin plots of various herd indicators provide an overview of the performance of herds in the two countries, and offer useful guidelines to show possible areas of increasing productivity on the farms in the two different environments. Results for Thailand are discussed as TH, and those for New Zealand as NZ.

Population profile

The population profile is a demographic description of the herd plus the dynamics of population change. Some indicators in this group, such as average female inventory, are more a reflection of investment opportunities and limits set by facilities. Such aspects are not discussed in this study.

Replacement rates are surprisingly similar in the two countries, with medians both close to 40%.

Maximum replacement rates are somewhat higher for Thailand. In a stable herd situation, replacement rate should equal cull rate plus death rate. For NZ, the mean death rate was 4.7 % compared with 3.7% for Thailand (Table 6.1), and the median was also higher. There were also more herds with high death rates, some over 10%. The cull rate was slightly lower for NZ. Monthly rates showed broadly similar patterns, but caution is required in interpreting monthly figures for herd turnover, since the figures are annualised from monthly data, and are not stable estimates of true annual figures (Table 6.5). It is unclear why death rates should be higher in NZ, but the difference is due mainly to the small number of herds in NZ with very high death rates, something not found in the TH herds. The high mortality herds in NZ presumably have specific risk factors affecting sow mortality, such as oesophagogastric ulceration or torsion of abdominal organs, but this could not be explored further in this study.

Breeding performance

From this study, some PigCHAMP® users did not consistently use ENTER events to record the actual date of entry gilts into the breeding herd but used ENTER and MATING events with identical dates. This practice resulted in underestimates of entry to first service intervals and average NPD. This finding is similar to that reported by Marsh *et al.* (1992), as seen in Tables 6.2 and 6.6, and Figures 6.4 and 6.27. For NZ, results would be more comparable between herds if actual date of entry of gilts was recorded.

For TH, improved breeding management practices (such as better oestrus detection, timing of mating, type of service, boar usage and quality of mating) should be pursued to achieve a higher percentage of sows bred by 7 days and to reduce the percentage of repeat services, average NPD and average NPD /parity record. NZ herds in general showed satisfactory breeding indices.

Farrowing performance

Inconsistencies were found to have occurred in data entry for litter weights. Therefore, average litter birth weight, average weaning weight and adjusted 21 day litter weights were incomplete, as seen in Tables 6.3B and 6.4.

For NZ, total litter sizes and pigs born alive were higher than for TH herds (Tables 6.3A and 6.7), but the percentage of piglets stillborn was higher. However, this increased number of pigs born dead is to some extent an inevitable consequence of increased total litter size (Stein, 1985). Litters

/mated female /year is an area in which there may be scope for NZ herds to improve, as shown in Tables 6.3B and 6.7.

For TH conditions, small litter size is one of the most important areas of emphasis for improvement, as both average total pigs /litter and average pigs born alive /litter are limiting factors for Thai farmers wishing to increase pigs weaned /mated female /year. Percentage of mummies and adjusted farrowing rate are other areas which can be improved. To correct the problem of small litter size may not be easy under Thai conditions because of environmental considerations. Some factors related to this issue include parity distribution, lactation length, status of infectious diseases, ambient temperature, plane of nutrition and genetics (Dial *et al.*, 1992). Further investigation would be required to determine whether manipulation of the other factors could overcome the limitations imposed by high ambient temperatures.

Weaning performance

This was better for NZ than TH herds, but the margin was narrower than for total pigs per litter or pigs born alive per litter, because NZ herds had higher pre-weaning mortality. For NZ herds, pre-weaning mortality is the component of herd performance which offers the single greatest potential for pig herds to increase pigs weaned /mated female /year. Clearly some herds can perform much better than the average, and herds could aim to reduce pre-weaning mortality rate from the 12.8% mean found for NZ herds to 8.6 % (NZ 15th Percentile), while TH herds could aim to get from the mean of 10.2% to 6 % (TH 15th Percentile) (Table 6.8). Various factors could explain the superior performance of the TH herds in this aspect of performance, such as closer supervision, fewer disease problems in baby piglets, or absence of cold stress.

Pigs weaned /mated female /year is a consequence of pigs weaned /litter and litters /mated female /year (Stein, 1985). For TH, pigs weaned /mated female /year in June was the lowest point (Figure 6.60) and its contributing factor was lower litters /mated female /year in June (Figure 6.52). However, to improve pigs weaned /mated female /year, both contributing factors need to be improved - particularly total pigs /litter.

Monthly Figures

The monthly figures are presented in the results, because they were needed for the development of the PigFIX expert system. However caution is required in interpreting the indices calculated on a monthly basis, because although some are quite valid in this time frame, others which depend on longer term patterns may be quite unstable when calculated for a single month. Examples of extreme values can be seen in some of the monthly indices, and the expert system needs to deal with such problems in drawing its conclusions.

Summary

Different climates and management systems cause differences in pig productivity. There are advantages and disadvantages in operating in each production system and geographical location. Comparing overall reproductive performance between the two countries in tropical and temperate climates may elucidate the complexity of production data of intensive pig production. Production data of 16 Thai herds and 18 New Zealand herds for 1991, and of 14 Thai herds and 17 New Zealand herds for 1992 were analysed.

Potential priority areas for improving productivity in Thai herds are through increased total litter sizes and pigs born alive per litter, and reduced non-productive sow days. Priority areas for New Zealand herds are lowering pre-weaning mortality and sow death rates.

CHAPTER 7

PigFIX

A pig fertility investigation expert system

Abstract

The expert system PigFIX can be used by pig farmers and veterinarians to evaluate herd reproductive performance as assessed through the performance monitor of the program PigCHAMP[®], provide advice on likely problems, and offer guidance on possible corrective action in the diagnosis of fertility problems. This expert system was written using the software development tool Microsoft Visual Basic version 3.0 for Windows. The database management software Microsoft Access version 2.0 for Windows was used to store the knowledge base.

The inference engine of PigFIX follows a diagnostic tree approach. Thirty one production indices contained in the performance monitor report produced by PigCHAMP[®] are evaluated. Firstly, a series of overall performance indicators which relate to various particular potential problem areas of performance is assessed, then these indicators are compared with Target, Warning and Action limits. Next, if one of these parameters falls outside the Target range, appropriate diagnostics indicators are examined to determine which elements in the diagnostic tree are linked to the performance problem. Finally, these results are assessed using pattern diagnosis to trigger a particular output.

At the end of each session PigFIX generates a complete report describing which performance parameters were outside warning or action limits, then for those requiring further investigation it suggests processing additional PigCHAMP[®] reports as necessary, and lists the various putative diagnoses which would be consistent with the information assessed.

Introduction

Pig fertility is one of the main factors influencing pig production, particularly in intensive management systems. Factors such as management, nutrition, season, temperature, light, breed and infectious agents affect fertility in gilts and sows (Wrathall, 1977; Love, 1978; Hurtgen, 1982; Hill, 1985; Egbunike, 1986; Thacker and Gonzalez, 1988; Tubbs, 1988; Tubbs, 1990; Enne and Greppi, 1993; Love *et al.*, 1993). Investigations of reproductive efficiency can be based on analysis of breeding herd records, allowing identification of the problem area.

The computerised health and management program PigCHAMP® (University of Minnesota, College of Veterinary Medicine, St. Paul, Minnesota) produces a performance monitor report and a wide range of diagnostic reports for solving herd problems. However, not all PigCHAMP® users have adequate time or skills to make maximum use of the full power of the program. In order to provide advice on likely problems and guidance on possible corrective action in the diagnosis of fertility problems, the expert system PigFIX was developed. PigFIX is an acronym for *Pig Fertility Investigation eXpert* system.

Artificial intelligence consists of four main areas: robotics, natural-language interpretation, computer vision and expert systems (ES). An expert or knowledge-based system is a program that achieves a high level of accuracy in analysing problems that are usually considered difficult enough to require significant human expertise for their solution (Feigenbaum, 1984). The expert system MYCIN which was used for medical diagnosis demonstrated that ES can work and perform as well as an expert (Yu *et al.*, 1979). Afterwards, it was realised that the knowledge base and the inference procedure were separate components in an ES (Feigenbaum, 1984). The terms "expert system" and "knowledge-based system" are interchangeable.

In agriculture and animal production, ES have been developed, for example, to diagnose soya bean diseases (Michalski *et al.*, 1983), for the diagnosis of reproductive problems in dairy cattle (Levins and Varner, 1987), for animal production management (Wain *et al.*, 1988), for culling management of beef cows (Oltjen *et al.*, 1990), for pig herd health (Vos *et al.*, 1990), management strategies for beef cattle farmers (Hochman *et al.*, 1991) and for analysis of individual sow-herd performance (Huirne *et al.*, 1991).

Program design

The PigFIX program was developed using the software development tool Visual Basic version 3.0 for Windows (Microsoft Corporation, Inc). The database management software Microsoft Access version 2.0 for Windows (Microsoft Corporation, Inc) was used to design and store the knowledge base. The system has been developed to run under Microsoft Windows on a microcomputer platform. PigFIX has three main components: a knowledge base, an inference engine and a user interface. The structure of PigFIX is presented in more detail in Figure 7.1.

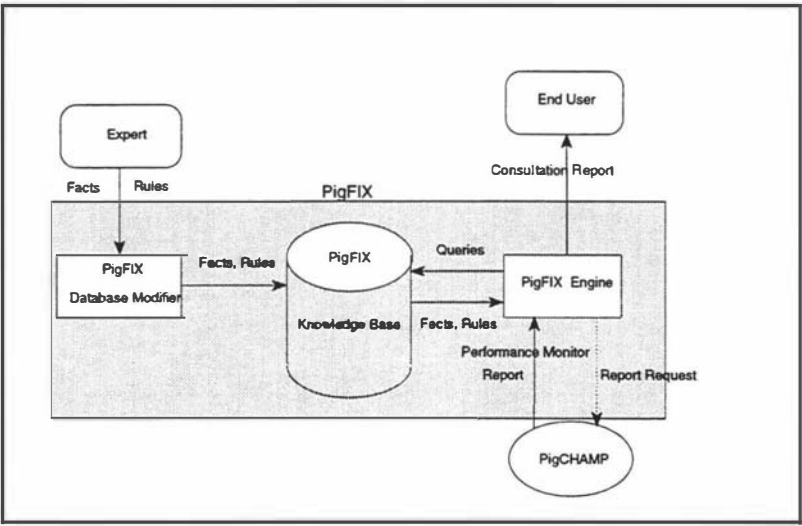


Figure 7.1. Diagram of the components of PigFIX

For the development of PigFIX an approach called rapid prototyping, as described by Roberts (1990) was used. During the development phase PigFIX went through a number of stages. Each stage consisted of a knowledge acquisition phase, an implementation (representation) phase, a testing phase and a review phase (Figure 7.2).

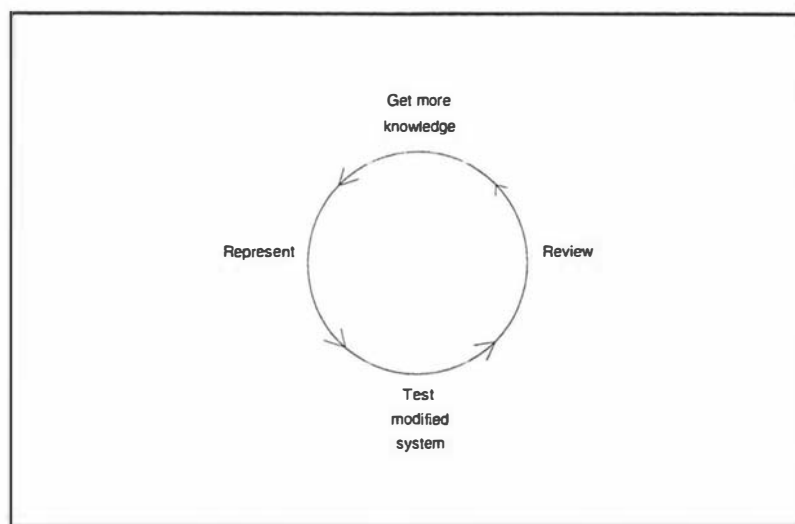


Figure 7.2. Rapid prototyping development cycle (Roberts, 1990)

Components of the PigFIX System

The knowledge base

The knowledge base represents the understanding of human experts about the factors and interactions in the system for which the expert system has been designed. In PigFIX, knowledge about the underlying pig production system is represented on the basis of categorizing production and performance parameters together with sets of rules defining the investigative decision process. The PigFIX database modifier (knowledge acquisition system) was developed to allow experts to transfer their knowledge into the knowledge base without the direct involvement of a computer programmer. The information stored in the PigFIX knowledge base includes:

- the actual parameters of interest for determining a fertility problem;
- possible levels for each parameter, categorized into performance levels considered satisfactory, marginal and unsatisfactory;
- recommended corrective action associated with specific patterns of categorized performance parameters.

Thirty one parameters, in a standard format of the performance monitor report from PigCHAMP®, are used by PigFIX. The parameters can be classified into 2 groups: performance parameters and diagnostic parameters. Examples of performance parameters are "average total pigs per litter", "pigs weaned per sow per year", "litters per mated female per year". Example of a diagnostic parameter is "wean to first service interval". The distribution of possible values for each parameter is divided into a set of ranges representing specific performance categories for the parameter. Each parameter is associated with three performance categories:

- 1) Target the ideal level to reach or exceed. Being below target but exceeding warning indicates that performance could be improved.
- 2) Warning the level at which things are starting to go wrong and some preemptive action is required.
- 3) Action the level at which things are going seriously wrong and immediate action is required.

For some parameters higher values are more desirable (Target > Warning) such as for "average pigs born alive per litter", whereas for others lower values are desirable (Target < Warning) such as for "pre-weaning mortality".

Classification categories of production indicators

For every production indicator, each value obtained from PigCHAMP® has to be classified into one of the performance categories. The performance line represents the range of all possible values. The 6 possible parameters ranges are defined by seven points on the performance line (Figure 7.3). The points and ranges are derived from Target, Warning and Action levels defined by experts. A maximum of 7 points can be defined on the performance line: (+) infinity, Upper Action Point(UAP), Upper Warning Point (UWP), Target Point, Lower Warning Point (LWP), Lower Action Point (LAP) and (-) infinity. Ranges are defined by consecutive points on the performance line. The relationship between the different points and ranges is presented in Table 7.1 and Figure 7.3.

Table 7.1 Relationship between ranges and points on performance line

Ranges	Points	
	From	To
Upper Action Range (UAR)	+ Infinity	Upper Action Point (UAP)
Upper Warning Range (UWR)	Upper Action Point (UAP)	Upper Warning Point (UWP)
Upper Target Range (UTR)	Upper Warning Point (UWP)	Target
Lower Target Range (LTR)	Target	Lower Warning Point (LWP)
Lower Warning Range (LWR)	Lower Warning Point (LWP)	Lower Action Point (LAP)
Lower Action Range (LAR)	Lower Action Point (LAP)	- Infinity

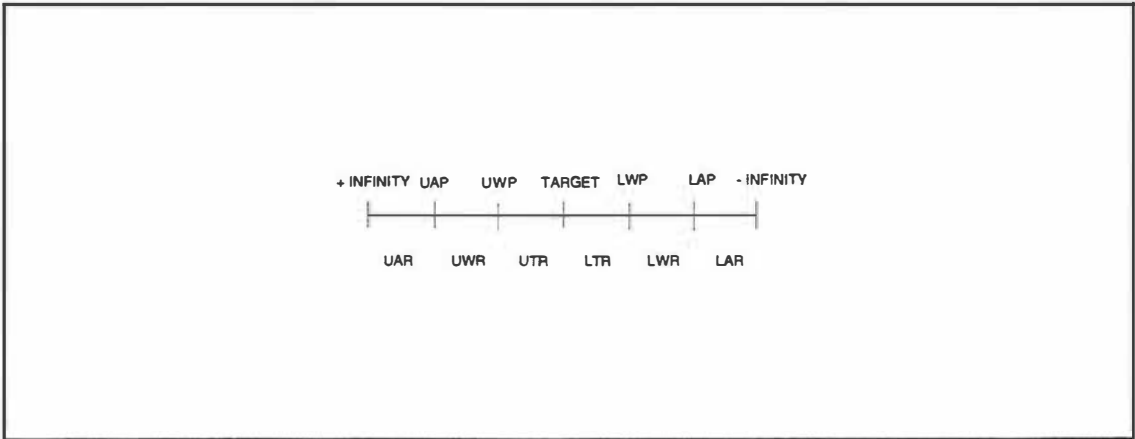


Figure 7.3. Points and ranges of possible parameter values on performance line

Thus each production indicator value read from the performance monitor report is translated for the PigFIX data file into a range code (such as UAR). Therefore the operation of PigFIX is independent of decisions on where range boundaries should be set for a particular country or type of herd.

Based on an interpretation of the categorized parameter values, individual production range codes can be grouped and examined jointly, with the assessment process depending on the potential for production problems for particular indicies to occur at values on just one side or on both sides of the target value ("one-sided problem" (OSP) or "two-sided problems" (TSP)).

With an OSP type parameter only one of the possible parameter ranges represents poor performance, such as in the case of a high percentage "pre-weaning mortality". Therefore, the potential range of "pre-weaning mortality" values can be divided into 3 ranges: Upper Action Range (UAR), Upper Warning Range (UWR) and Upper Target Range (UTR) (Table 7.2). Whereas possible values for parameters such as "pigs weaned per sow per year" can fall within one of the following 3 ranges: Lower Action Range (LAR), Lower Warning Range (LWR) or Lower Target Range (LTR).

Table 7.2 Values of ranges for pre-weaning mortality parameter

Parameter	UTR	UWR	UAR
Pre-weaning mortality	0 - <16.2	>16.2 - <17.1	>17.1 - infinity

TSP type parameters include parameters with undesirable values below and above target values such as excessively high or low percentage "replacement rate". Therefore, actual values of percentage of "replacement rate" can fall within one of potentially 6 ranges: Upper Action Range (UAR), Upper Warning Range (UWR), Upper Target Range (UTR), Lower Target Range (LTR), Lower Warning Range (LWR) and Lower Action Range (LAR). All that is required in PigFIX to achieve OSP and TSP definitions is to set ranges appropriately. Therefore if a particular user has a personal view that a production index should be treated as a TSP when others consider it an OSP, a suitable definition of range boundaries will achieve this easily.

Production rules

This type of knowledge is either procedural in nature (that is "to determine the performance level, do this") or conditional in nature ("if there is a problem with this parameter, do this"). In PigFIX,

production rules analyse performance levels for particular parameters which influence productivity.

Examples of rules for diagnosing high pre-weaning mortality.

```

If      Pre-weaning mortality = Upper Action Range,
        AND Pigs weaned per litter = Lower Target Range,
        AND Pigs weaned per sow per year = Lower Target Range,
then   Pre-weaning mortality is a problem.

If      Pre-weaning mortality = Upper Action Range,
        AND Pigs weaned per litter = Lower Target Range,
        AND Pigs weaned per sow per year = Lower Warning Range,
then   Pre-weaning mortality is a problem.

If      Pre-weaning mortality = Upper Action Range,
        AND Pigs weaned per litter = Lower Target Range,
        AND Pigs weaned per sow per year = Lower Action Range,
then   Pre-weaning mortality is a problem.

If      Pre-weaning mortality = Upper Action Range,
        AND Pigs weaned per litter = Lower Action Range,
        AND Pigs weaned per sow per year = Lower Target Range,
then   Pre-weaning mortality is a problem.

```

The inference engine

The inference engine of PigFIX interprets information about performance of a pig herd using expert knowledge stored in the knowledge base. It uses a pattern matching approach combined with forward chaining for problem diagnosis.

Production problems which can be identified by PigFIX are classified into problems representing a long term (strategic) effect such as low pigs weaned per sow per year and problems representing a short term (tactical) effect such as slow return to oestrus after weaning. The diagnostic process implemented in PigFIX follows a diagnostic tree approach as described by Van Der Leek and Becker (1993).

In the current implementation of PigFIX, 31 productivity parameters included in the standard format of the performance monitor report produced by PigCHAMP® are read by the PigFIX system. The performance monitor report format chosen for use in PigFIX includes monthly data for a 3 month period as well as a summary column with cumulative information for the 3 month period. Table 7.3 presents an example for a subset of parameters from the performance monitor report, which have been imported into Microsoft Access.

Table 7.3 Subset of parameters read from the Performance Monitor Report and stored in a flat table in Microsoft Access

Parameters	Sep 91	Oct 91	Nov 91	Sep-Nov 91
Pre-weaning mortality	22.3	21.1	24.1	22.4
Pigs weaned/ Litter	9.6	9.1	8.3	9.0
Pigs weaned/ Sow/ Year	17.4	15.1	14.1	15.5

The diagnostic process begins with the classification of a series of "performance indicators" such as "pigs weaned per mated female per year" into the appropriate performance range which can be Lower Target Range, Lower Warning Range or Lower Action range. This is done by comparing the actual values (as shown in Table 7.3) with bounday values for the performance ranges, to categorise each value (as shown in Table 7.4). The system begins with the most recent month in the three month period and then proceeds onto analyse the previous months. If the most recent month is satisfactory. The diagnosis under consideration is triggered if any or all of the following three conditions are met:

- (i) Most recent month's data match diagnostic criteria.
- (ii) Both of the prior month's data match diagnostic criteria.
- (iii) Cumulative data for the 3 month period match the diagnostic criteria.

The range boundaries set for the cumulative 3-month assessment can differ from these used for individual monthly data. Before putting a range code on a particular variable, it is assessed to determine whether the number of animals on which the value was based was marginal or inadequate to represent a valid assessment of perfomance. If so, the output is flagged accordingly.

Table 7.4 Actual values classified into ranges

Parameters	Sep 91	Oct 91	Nov 91	Sep-Nov 91
Pre-weaning mortality	UAR	UAR	UAR	UAR
Pigs weaned/ Litter	LTR	LTR	LTR	LTR
Pigs weaned/ Sow/ Year	LTR	LWR	LAR	LAR

If one of the production parameters (or a group of related parameters) falls outside the Target range, appropriate "diagnostic parameters" are examined to determine which elements in the diagnostic tree are associated with the performance problem, for example, "average total pigs per litter", "percentage of stillborn pigs" and "pre-weaning mortality".

The result of this data interpretation is a classification pattern of performance and diagnostic parameters which is then compared with the diagnostic patterns stored in the knowledge base (Table 7.5). Every diagnostic classification pattern stored in the knowledge base is associated with a particular diagnostic output (Figure 7.4). If the problem is severe the diagnosis can be printed in bold face type, whereas if it is mild the diagnosis can be shown in standard typeface.

For example the diagnosis "High pre-weaning mortality" can be associated with a range of patterns representing different combinations of performance and diagnostic parameters. As the result of a particular diagnosis, PigFIX recommends the action required following this diagnosis. This can include recommending that the user generate additional PigCHAMP® diagnostic reports to clarify the situation, or recommending direct corrective actions without further analysis..

Table 7.5 Possible parameter classification patterns associated with the diagnosis "High Pre-weaning Mortality"

Parameters	Parameter classification for individual or cumulative month
Pre-weaning mortality	UAR
Pigs weaned/ Litter	LTR or LWR or LAR
Pigs weaned/ Sow/ Year	LTR or LWR or LAR

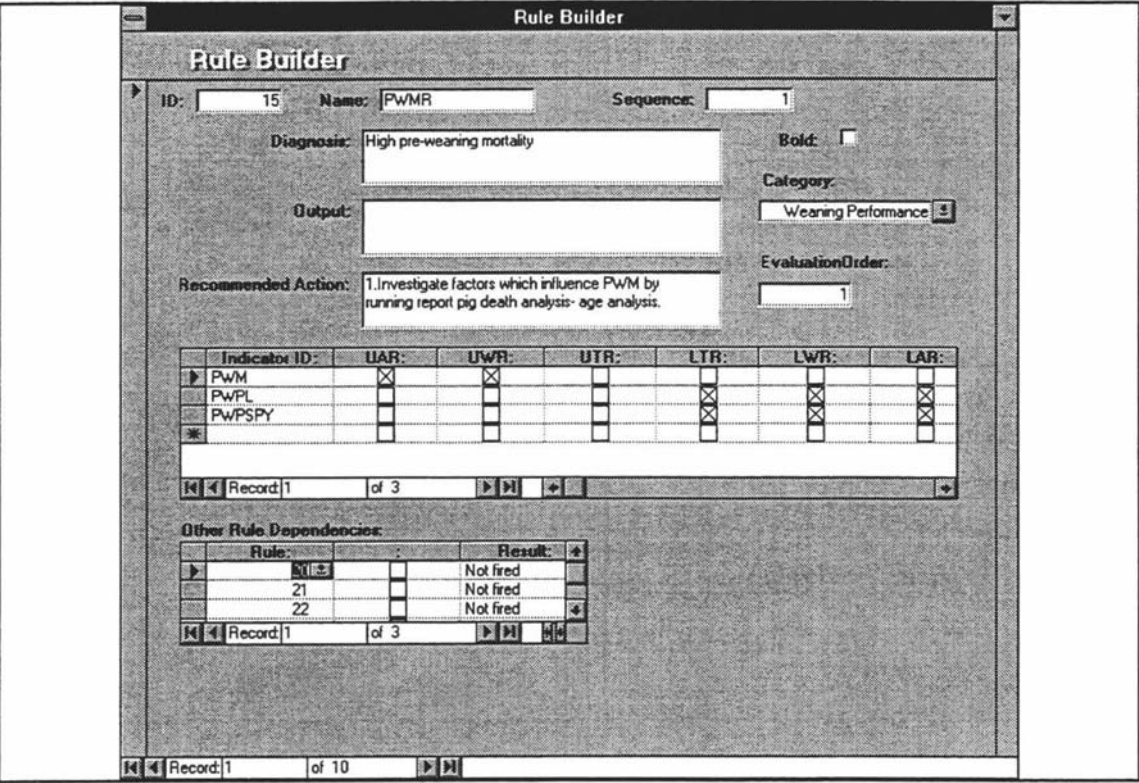


Figure 7.4. User interface of database modifier in PigFIX for rules related to the diagnosis "High Pre-weaning Mortality"

The user interface

In this version of PigFIX, users employ the PigFIX database modifier to select an ASCII text file as input to the system, to view and to print out a final report after completion of the analysis. The user can create a personal set of ranges which are suited to particular circumstances, in addition to the default values which remain available. The final version of PigFIX system will be an embedded expert system requiring little or no end-user input. Input to the expert system will come directly from data structures used and reports generated by records software such as PigCHAMP®.

The rule builder

The rule builder/database modifier component of PigFix allows the designer (and potentially an experienced and knowledgeable user) to adjust each of the components of the evaluation process to suit their particular requirements. Figure 7.4 shows the main screen through which the adjustment process is undertaken. Using the 31 performance and diagnostic indicators in the performance monitor report, the user formulates a series of classification patterns which will all produce a

diagnosis of "High Pre-weaning Mortality", this diagnosis being given the variable name PWMR for processing purposes. The user enters into data entry boxes what is to be printed out as output information and as recommended action, in cases where this diagnosis is triggered (in expert systems terminology, the rule is fired).

The designer is free to decide the sequence in which particular assessments take place (evaluation order) and the ways in which processing of this particular assessment is made contingent on other parts of the evaluation process (shown as "Other Rule Dependencies"). Output statements can be bolded for serious problems, at the discretion of the designer.

The designer is free to add, delete and modify evaluation procedures as PigFIX evolves, and direct programming of procedures is not necessary, as this is handled by the rule builder. Thus the system can evolve as experience with its use grows. The designer can control the modifications which users can make to the evaluation process.

Development of Suitable Boundaries Between Ranges

Apart from the problem of designing the evaluation process for diagnosing different patterns of reproductive failure, the second major problem lies in deciding what numerical values should be used to set dividing lines between the various ranges. These are crucial, since they determine the extent to which the system diagnoses problems, and the sensitivity and specificity of these diagnoses.

PigFIX can be adjusted to suit individual judgment on where these dividing lines should lie, but values need to be worked out to use as default. Table 7.6 shows an example default set of boundary values for indices which would be used in evaluating pre-weaning mortality. Equivalent values are set in PigFIX for each other aspect of herd performance. These defaults may in some cases need to be adjusted to different environments, since the desirable and feasible range for some indices will depend on environmental factors.

The analysis of performance for sets of Thai and New Zealand herds described in Chapter 6 provides a basis for setting these cut-off points. This information was therefore used to set the action, warning and target ranges for the various parameters, against which performance of a particular herd could be evaluated. While such figures represent herds at the upper end of the performance range rather

than all herds, they are typical of herds which use a computerised recording system. It is therefore appropriate to use such data for evaluating performance in herds likely to adopt PigFIX.

There is inevitably some subjective element in the evaluation of where these cut-off points should lie, but violin plots as used in Chapter 6 offer a particularly helpful way of visualising the range of the various indices, and therefore deciding on the appropriate cut-off points. Whether the judgments made will prove appropriate can really only be determined through a program verification and validation process.

Representation of Results to the User

One of the major purposes of incorporating an expert system into a decision support system such as PigCHAMP® is to make evaluation of herd data easier for the user to carry out, and to focus attention on areas in need of improvement. Thus the design of the output format is crucial to achieving this goal.

PigFIX has two types of output in its current form. The first is a text report which summarises the findings from the analysis, and the recommendations for action. Figures 7.5 and 7.6 show an example performance monitor for a herd from PigCHAMP®, and the report produced from PigFIX to interpret this performance monitor. This is designed for the user to read without difficulty, and then to follow up its recommendations through production of recommended reports and field investigation of the herd. The second output is a graphical representation of a diagnostic tree for reproductive problems, as shown in Figure 7.7. The diagnostic tree uses data available in the PigCHAMP® performance monitor to show which parts of the tree deserve further investigation. In the on-screen version which is currently being implemented, boxes within the diagnostic tree are coloured red if the particular component of performance has been determined by PigFIX to be in the action range, and yellow if it is in the warning range. Boxes are green if the component is within the target range. When this is converted into printed output, the colours are converted into degrees of box shading, to emphasise those of most concern.

Table 7.6 Numerical values of ranges associated with the diagnosis of "High Pre-weaning Mortality"

Indicator	Rangeset	LAP	LWP	Target	UWP	UAP	LAPC	LWPC	Target	UWPC	UAPC
PWM	Default			0	16.2	17.1			12.5	14.9	15.3
PWPL	Default	7.8	8	8.7			7.6	8	8.6		
PWSPY	Default	15	17.4	22.9			15.7	19.8	22.4		

Figure 7.5 Performance monitor report generated by PigCHAMP®

PERFORMANCE MONITOR	PigCHAMP 3.0			
1 SEP 91 - 30 NOV 91	(C) 1985,87,88,91 Univ of Minn			
FARM: AA1034	Licensed to R S Morris			
	Printed: 15 JAN 95			
	SEP 91			
	SEP 91	OCT 91	NOV 91	NOV 91
BREEDING PERFORMANCE				
Total number of services	26	21	24	71
Percent repeat services	0.0	0.0	8.3	2.8
Percent multiple matings	3.8	0.0	0.0	1.4
Weaning - 1st service interval	6.1	5.4	6.2	5.9
Percent sows bred by 7 days	95.5	93.8	88.9	92.9
Entry - 1st service interval	66.7	.	9.0	52.3
FARROWING PERFORMANCE				
Number of sows farrowed	33	25	35	93
Ave parity of farrowed sows	3.1	4.2	3.8	3.7
Average total pigs per litter	12.0	13.3	10.8	11.9
Average pigs born alive/litter	11.3	12.2	10.1	11.1
Ave birth wt / liveborn pig	0.0	0.0	0.0	0.0
Percent stillborn pigs	5.1	5.7	6.1	5.6
Percent mummies	0.8	3.0	0.5	1.4
Farrowing rate	80.5	69.4	94.6	81.6
Adj. farrowing rate	84.6	73.5	94.6	84.5
Farrowing interval	167	163	158	162
Litters / mated female / year	1.81	1.66	1.70	1.72
Litters / crate / year	0.0	0.0	0.0	0.0
WEANING PERFORMANCE				
Number of litters weaned	22	29	24	75
Total pigs weaned	212	265	208	685
Pigs weaned per sow	9.6	9.1	8.3	9.0
Pre-weaning mortality	22.3	21.1	24.1	22.4
Average weaning weight	.	.	.	.
Average age at weaning	27.2	26.3	27.9	27.1
Adjusted 21 day litter weight	.	.	.	.
Pigs wnd / mated female / yr	17.4	15.1	14.1	15.5
Pigs weaned / crate / year	0.0	0.0	0.0	0.0
Pigs weaned / lifetime female	30	25	54	33
POPULATION				
Ending female inventory	172	168	198	198
Average parity	2.8	2.9	2.5	2.5
Average female inventory	169.6	170.8	196.4	179.2
AFI / Crate	0.0	0.0	0.0	0.0
Average gilt pool inventory	12.6	11.3	31.7	18.5
Gilts entered	4	0	29	33
Sows and gilts culled	2	3	2	7
Sow and gilt deaths	5	0	0	5
Ending boar inventory	33	34	35	35
Sow - Boar Ratio	5.2	4.9	5.7	5.7
Replacement rate	28.7	0.0	179.7	73.9
Culling rate	14.3	20.7	12.4	15.7
Death rate	35.9	0.0	0.0	11.2
Ave non-productive sow days	95.9	113.0	140.1	118.0
Ave NPD / parity record	36.1	65.6	35.3	41.8

Figure 7.6 Final report generated by PigFIX

PigFIX Analysis of Herd Performance		
FARM: AA1034	1 SEP 91 - 30 NOV 91	Printed: 17- Feb- 95
Page 1		

Diagnoses	Recommended Action
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Overall Herd Performance

High death rate of female pigs	1.Investigate factors which influence death rate by running Removal Analysis-report type (all reasons), report format (results).
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Breeding Performance

No problems found

Weaning Performance

High pre-weaning mortality	1.Investigate factors which influence PWM by running Report Pig Death Analysis- age analysis.
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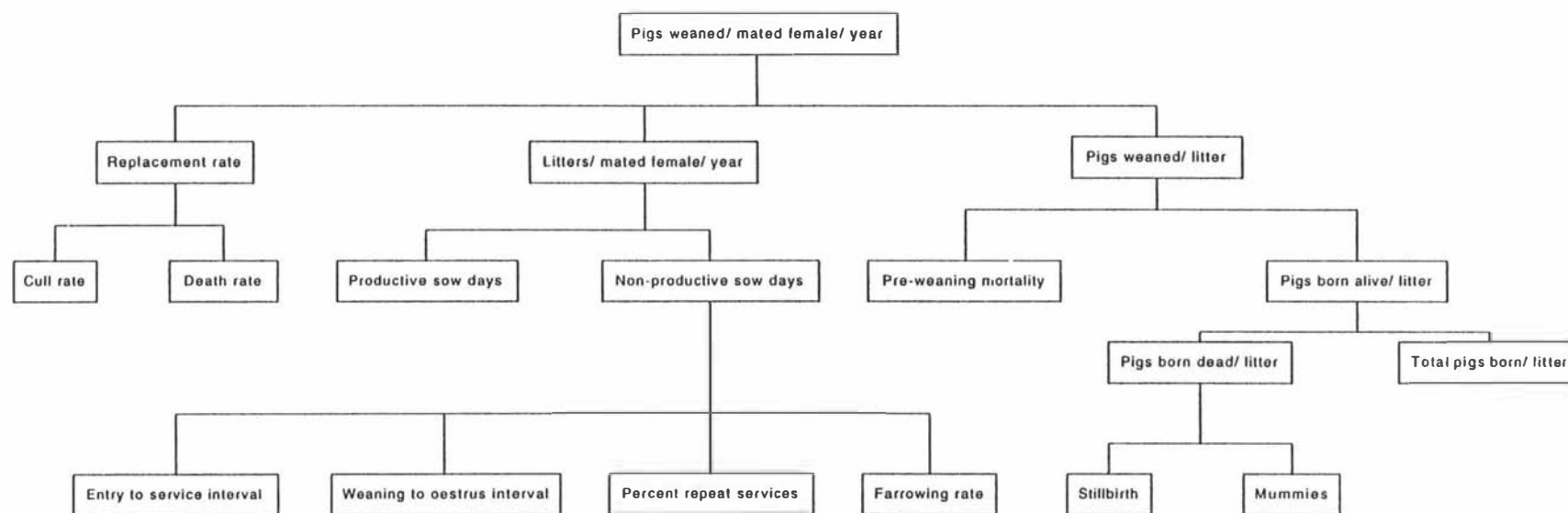


Figure 7.7. Diagnostic Tree Output - Basic Structure

In the next version of PigFIX, it is intended that clicking the right mouse button over a box in the diagnostic tree will produce a menu of more detailed diagnostic reports which can be selected to amplify the information available on that aspect of reproduction. Figure 7.8 shows one such example in printed form, where the problem identified is low pigs weaned per mated female per year, due to reduced litters per sow per year. This in turn is due to increased non-productive sow days, which PigFIX in turn traces to a high return rate for sows. It is intended that the boxes in the diagnostic tree can be linked back to the menu system of a program such as PigCHAMP®, so that a right mouse button click on a box produces a menu of reports which would clarify the nature of the problem identified by PigFIX. This is shown at the point of the arrow in Figure 7.8.

Figure 7.9 shows a similar example, in which increased pre-weaning mortality is identified as the underlying cause of a performance problem, and a menu of reports which would clarify the problem is available through a right mouse button click. Figure 7.10 shows how the system will operate on the computer screen, using colour coding.

Thus PigFIX will guide the user through the diagnostic process, making it easy to use the power of modern pig records software to understand where problems are arising. Ultimately, a hierarchy of diagnostic trees is envisaged, where each time the user explores deeper into an aspect of herd performance, a sub-tree is produced which identifies areas of concern, using the same principles as described for the main performance monitor. This will take time to produce, but the design problems have all been solved for this first phase of development, and remaining sub-systems can follow the same model.

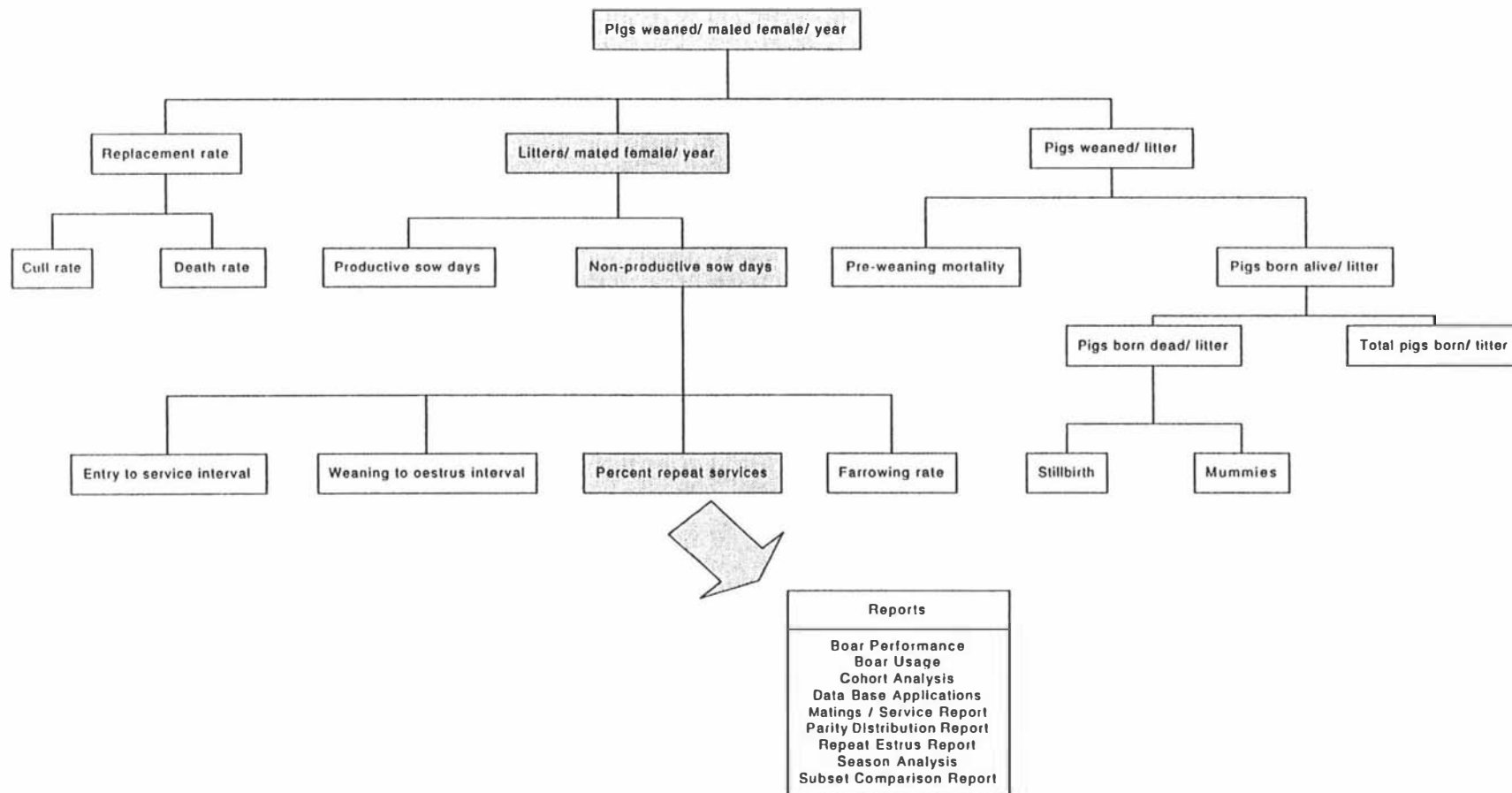


Figure 7.8 PigFIX Diagnostic Tree - Example Problem Definition for High Sow Return Rate

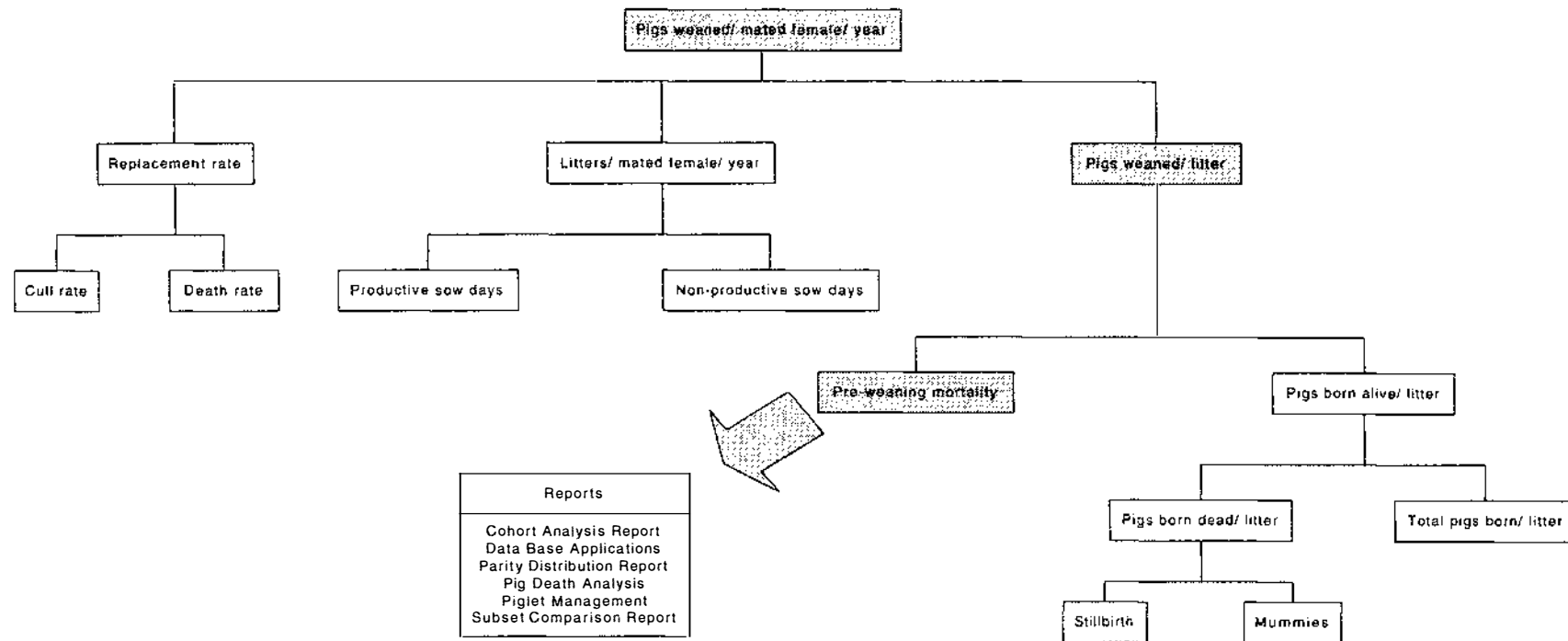


Figure 7.9 PigFIX Diagnostic Tree - Example Problem Definition for High Pre-weaning Mortality

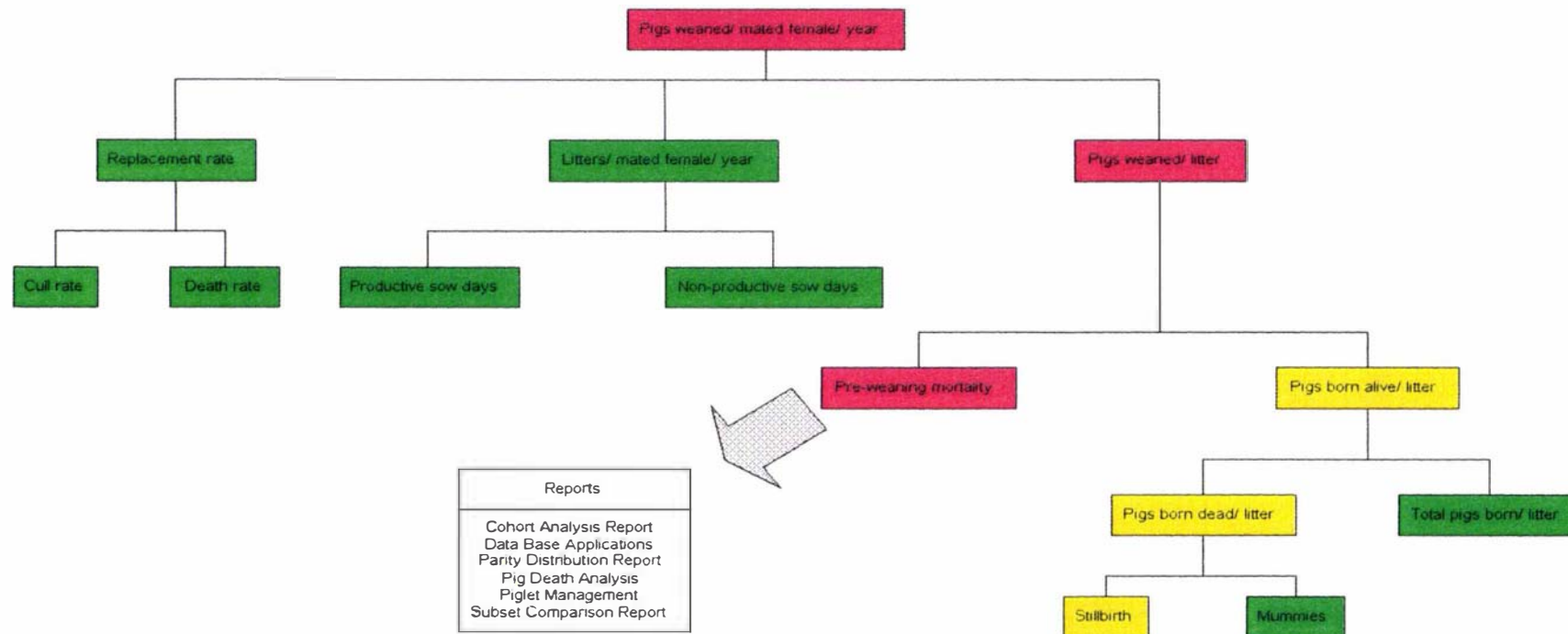


Figure 7.10 PigFIX Diagnostic Tree - Example Problem Definition for High Pre-weaning Mortality

Discussion

Expert system vs Decision support system

A decision support system (DSS) integrates computer hardware and software specifically designed to complement the human thought process in problem-solving, decision-making and information processing. The differences between DSS and ES have been described by Turban (1988). ES operates as independent expert consultation systems whereas DSS operates as support devices to decision makers. However, there is now a general trend where both types of systems are developed and implemented as DSS/ES integrated systems such as an integrated decision support and expert systems for analysis of individual sow-herd performance (Huirne, 1991) and a decision support system for an animal disease emergency (EpiMAN) (Sanson, 1993).

Expert system design methods

Prototyping has been crucial to the development of this expert system. Using the approach of rapid prototyping the knowledge engineer elicits knowledge from the expert and builds it directly into the system. Then, the expert tests the system allowing to identify any faults or omissions, which can then be corrected. The process is repeated until the prototype reaches the desired stage. This method reduces the time required for expert system development compared with the conventional approach which is based on 4 steps: request analysis, system design, coding and testing (Roberts, 1990).

Development to date

This expert system adopts a novel approach to evaluating information, in that it works by recognition of patterns of abnormal indicators which together identify a likely problem area of herd reproductive performance, rather than implementing a rule-based form of logic as most expert systems do. The approach is considered to be intuitively reasonable for veterinarians to adopt, since it follows more closely the logic of report analysis which experienced pig veterinarians use.

It has developed a visual method of representing problems through a colour-coded diagnostic tree, with extensions into sub-trees in future, and the use of guided diagnostic exploration of the records of a herd. The diagnostic tree results can easily be explained to farmers, and are supported by the

text output which explains the findings of PigFIX in more detail. Therefore it is considered that PigFIX makes a valuable contribution to making herd records systems more accessible to users who do not have expertise in this area.

Further development of PigFIX

This version of PigFIX imports PigCHAMP® reports as ASCII text files and produces final reports which may require the user to produce further reports in PigCHAMP®. It does not interact directly with the program menus or data files. The current version is able to diagnose some fertility problems such as high pre-weaning mortality, long weaning to first service interval and high stillbirth levels. To diagnose all aspects of fertility problems and to complete all analyses, PigFIX requires more extensive implementation of expert knowledge and more details from other PigCHAMP® reports. In a later version of PigFIX, it is envisaged that PigFIX could send a request directly to PigCHAMP® for further analyses to diagnose additional problems such as seasonal infertility and parvovirus infection. The outcomes of such additional analyses would be represented through diagnostic sub-trees and additional text reports. Eventually most aspects of performance in both breeding and growing herds could be covered by this approach.

Conclusion

PigFIX is based on a diagnostic tree (Van Der Leek and Becker, 1993) approach, in that identification of an abnormality in a performance parameter either over a single time period or on average over three successive time periods, leads to investigation of other "upstream" contributing parameters. These may have to be investigated through the same or other PigCHAMP® reports, to isolate as accurately as possible the alternative diagnoses which have to be considered in follow-up investigations on the farm. At the end of each session PigFIX generates a final report describing which performance parameters were within warning or action ranges. Then for those requiring further investigation it suggests producing additional PigCHAMP® reports, and lists the various putative diagnoses which are consistent with the information assessed.

PigFIX reduces the extent to which reports must be individually produced and evaluated, and can reduce time spent on such evaluations by the PigCHAMP® user. Expert systems must be used with awareness that they do not produce "the answer", but rather support and focus the evaluation process by drawing attention to critical items and explaining why particular items have been flagged as important (Morris and Dijkhuizen, 1992).

CHAPTER 8

Verification of PigFIX

Abstract

PigFIX was developed in order to help managers of pig herds in interpreting output produced by computerised health and management software. Before a system can be used it has to be verified and validated. Verification is white-box testing, designed to determine if the system completely and accurately implements user specifications. Validation is black-box testing, designed to determine if the system meets user needs.

Data from 6 known health status pig herds in New Zealand was used for the verification process of PigFIX development. The standard performance monitor report generated by PigCHAMP® was used as input for PigFIX. Each performance monitor report was evaluated by an expert and by PigFIX. The comparison of both evaluations indicates that conclusions produced by PigFIX were close to an expert's opinions with regard to overall herd, breeding and weaning performance. However, this verification stage has to be followed by a validation stage where a number of independent human experts will be used to validate PigFIX output.

Introduction

In intensive pig production, a range of animal health and management software is used by pig producers. One of the most common products is the software PigCHAMP® (University of Minnesota, College of Veterinary Medicine, St. Paul, Minnesota). It produces a large number of different reports including a performance monitor report and a wide range of diagnostic reports for solving particular herd problems. However, only few PigCHAMP® users will have adequate time or skills to make maximum use of the full power of the software. The expert system PigFIX (A *Pig Fertility Investigation EXpert* System) was developed to introduce a structured approach towards interpretation of PigCHAMP reports. PigFIX has been developed for a personal computer platform. It analyses the standard format of the performance monitor report produced by PigCHAMP® and provides a final report for the end user.

The structure of the system was explained in the previous chapter. The next stage of the expert system consists of the verification stage. The results of the verification process are used by the software developers to make sure that the knowledge-based system works correctly. The terms "validation" and "verification" are often used interchangeably. However, each term has distinct implications in software engineering. Validation is black-box testing, designed to determine if the system meets user needs. Validation means "building the right system" (O'Keefe *et al.*, 1987). Verification is white-box testing, designed to determine if the system completely and accurately implements user specifications. Verification means "building the system right".

The objective of this study was to verify PigFIX against known results to ensure that the system produces correct conclusions and recommendation given real data as input.

Materials and methods

Six known health status pig herds in New Zealand were selected for this study. Performance monitor reports using a standard format were produced using the computerised health and management program, PigCHAMP® (University of Minnesota's College of Veterinary Medicine, St. Paul, Minnesota). The reports included monthly data over a 3 month period as well as cumulative data over the 3-month period. The reports were generated as ASCII text files which were then used as input for PigFIX. Each performance monitor report was analysed by an expert and PigFIX. The conclusions from both the expert and the final report of PigFIX for each herd were compared.

Results

Performance monitor reports in a standard format were produced for six different pig herds. In the following paragraphs each report is interpreted individually by a human expert (the author of this thesis) and PigFIX.

Case 1 (Farm AA1031)

The report for this pig herd was produced for the period from September to October 1985 (Figure 8.1). During this period, the herd had the following general population characteristics: the female inventory averaged about 187 sows with an average number over the 3 month period of a replacement rate of 74.1% and of a culling rate of 54.5%. The averages of number of non-productive sow days and non-productive sow days/ parity record were 57 and 20.6 days respectively.

In the weaning area: an average of 23.1 pigs were weaned per mated female per year. On average 10 pigs were weaned per sow. The average pre-weaning mortality was 9.4% ranging between 8.3% and 10.2%.

In the farrowing area: an average of 2.31 litters were produced per mated female per year monthly values ranging between 2.25 and 2.37. Pigs born alive/ litter averaged 10.8 monthly values ranging between of 10.3 and 11.1. On average 7.6% pigs born were stillbirths and mummies.

In the breeding area: average 96.4% of sows were bred by 7 days with the an average period from weaning to first service of 5 days and average percentage of repeat services of 5%.

The human expert

Inspection of the performance monitor report by the human expert reveals that productivity of this herd was satisfactory, but pre-weaning mortality in September was marginal. Replacement rate in November and September was high corresponding with a high culling rate in November.

PigFIX

The report generated by PigFIX is presented in Figure 8.2. The expert system could not identify any problems with regard to overall herd, breeding or weaning performance.

Figure 8.1 Performance monitor report for AA1031 farm

PERFORMANCE MONITOR		PigCHAMP 3.0			
1 SEP 85 - 30 NOV 85		(C) 1985,87,88,91 Univ of Minn			
FARM: AA1031		Licensed to R S Morris			
		Printed: 15 JAN 95			
		SEP 85			
	SEP 85	OCT 85	NOV 85	NOV 85	
BREEDING PERFORMANCE					
Total number of services	40	42	37	119	
Percent repeat services	2.5	9.5	2.7	5.0	
Percent multiple matings	0.0	0.0	0.0	0.0	
Weaning - 1st service interval	5.0	5.0	5.2	5.0	
Percent sows bred by 7 days	97.0	100.0	90.5	96.4	
Entry - 1st service interval	48.5	47.9	39.2	43.7	
FARROWING PERFORMANCE					
Number of sows farrowed	31	35	27	93	
Ave parity of farrowed sows	2.9	2.9	3.2	3.0	
Average total pigs per litter	11.2	11.9	11.9	11.7	
Average pigs born alive/litter	10.3	11.1	10.9	10.8	
Ave birth wt / liveborn pig	0.0	0.0	0.0	0.0	
Percent stillborn pigs	7.8	7.2	7.8	7.6	
Percent mummies	0.0	0.0	0.0	0.0	
Farrowing rate	88.6	85.4	75.0	83.0	
Adj. farrowing rate	88.6	87.5	75.0	83.8	
Farrowing interval	155	159	157	157	
Litters / mated female / year	2.32	2.25	2.37	2.31	
Litters / crate / year	0.0	0.0	0.0	0.0	
WEANING PERFORMANCE					
Number of litters weaned	32	39	31	102	
Total pigs weaned	300	367	281	948	
Pigs weaned per sow	9.7	10.2	10.0	10.0	
Pre-weaning mortality	10.2	8.3	9.9	9.4	
Average weaning weight	.	.	.	.	
Average age at weaning	31.9	28.0	32.7	30.7	
Adjusted 21 day litter weight	.	.	.	.	
Pigs wnd / mated female / yr	22.5	22.9	23.7	23.1	
Pigs weaned / crate / year	0.0	0.0	0.0	0.0	
Pigs weaned / lifetime female	26	19	30	27	
POPULATION					
Ending female inventory	183	187	187	187	
Average parity	1.8	2.0	1.9	1.9	
Average female inventory	177.9	186.4	187.4	183.9	
AFI / Crate	0.0	0.0	0.0	0.0	
Average gilt pool inventory	11.1	16.7	14.6	14.2	
Gilts entered	13	7	14	34	
Sows and gilts culled	8	3	14	25	
Sow and gilt deaths	0	0	0	0	
Ending boar inventory	26	21	24	24	
Sow - Boar Ratio	7.0	8.9	7.8	7.8	
Replacement rate	88.9	44.2	90.9	74.1	
Culling rate	54.7	19.0	90.9	54.5	
Death rate	0.0	0.0	0.0	0.0	
Ave non-productive sow days	54.6	59.9	56.3	57.0	
Ave NPD / parity record	18.1	22.6	21.1	20.6	

Figure 8.2 Final report for AA1031 farm from PigFIX

PigFIX Analysis of Herd Performance		
FARM: AA1031	1 SEP 85 - 30 NOV 85	Printed: 17-Feb-95
Page 1		

Diagnoses	Recommended Action
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Overall Herd Performance

No problems found

Breeding Performance

No problems found

Weaning Performance

No problems found

Case 2 (Farm AA1037)

The report for this pig herd was produced for the period from May to July 1990 (Figure 8.3). During this period, the herd had the following general population characteristics: the female inventory averaged about 591 sows with an average number over the 3 month period of a replacement rate of 22.3% and of a culling rate of 48.5%. The averages of number of non-productive sow days and non-productive sow days/ parity record were 42.1 and 17.3 days respectively.

In the weaning area: an average of 22.8 pigs were weaned per mated female per year. On average 9.6 pigs were weaned per sow. The average pre-weaning mortality was 8.2% ranging between 6.6% and 10.8%.

In the farrowing area: an average of 2.38 litters were produced per mated female per year monthly values ranging between 2.36 and 2.40. Pigs born alive/ litter averaged 10.7 monthly values ranging between of 10.2 and 10.9. On average 9.2% pigs born were stillbirths and mummies.

In the breeding area: average 95.6% of sows were bred by 7 days with the an average period from weaning to first service of 4.8 days and average percentage of repeat services of 6.6%.

The human expert

Inspection of the performance monitor report by the human expert reveals that productivity of this herd was satisfactory but pre-weaning mortality in May was marginal. Percentage of stillborn pigs and mummies in May was high but these parameters were lower using cumulative figures for the 3 month period.

PigFIX

The report generated by PigFIX is presented in Figure 8.4. The expert system could not identify any problems with regard to overall herd, breeding or weaning performance.

Figure 8.3 Performance monitor report for AA1037 farm

PERFORMANCE MONITOR		PigCHAMP 3.0			
1 MAY 90 - 31 JUL 90		(C) 1985,87,88,91 Univ of Minn			
FARM: AA1037		Licensed to R S Morris			
		Printed: 9 JAN 95			
		MAY 90			
	MAY 90	JUN 90	JUL 90	JUL 90	
BREEDING PERFORMANCE					
Total number of services	124	112	140	376	
Percent repeat services	6.5	7.1	6.4	6.6	
Percent multiple matings	91.9	92.0	91.4	91.8	
Weaning - 1st service interval	6.3	3.4	4.8	4.8	
Percent sows bred by 7 days	94.8	95.7	96.1	95.6	
Entry - 1st service interval	46.6	50.5	19.5	33.7	
FARROWING PERFORMANCE					
Number of sows farrowed	114	109	114	337	
Ave parity of farrowed sows	4.3	4.2	4.4	4.3	
Average total pigs per litter	11.4	12.0	11.9	11.8	
Average pigs born alive/litter	10.2	10.9	10.9	10.7	
Ave birth wt / liveborn pig	0.0	0.0	0.0	0.0	
Percent stillborn pigs	9.2	8.9	7.5	8.5	
Percent mummies	1.3	0.3	0.5	0.7	
Farrowing rate	84.4	88.6	82.6	85.1	
Adj. farrowing rate	87.7	90.8	85.7	88.0	
Farrowing interval	153	157	154	154	
Litters / mated female / year	2.36	2.38	2.40	2.38	
Litters / crate / year	0.0	0.0	0.0	0.0	
WEANING PERFORMANCE					
Number of litters weaned	119	106	102	327	
Total pigs weaned	1118	988	1040	3146	
Pigs weaned per sow	9.4	9.3	10.1	9.6	
Pre-weaning mortality	10.8	6.6	6.8	8.2	
Average weaning weight	.	.	0.5	0.5	
Average age at weaning	29.5	26.6	27.0	27.8	
Adjusted 21 day litter weight	.	.	5	5	
Pigs wnd / mated female / yr	22.2	22.2	24.2	22.8	
Pigs weaned / crate / year	0.0	0.0	0.0	0.0	
Pigs weaned / lifetime female	51	65	62	59	
POPULATION					
Ending female inventory	616	589	591	591	
Average parity	3.4	3.4	3.4	3.4	
Average female inventory	625.4	603.0	589.2	605.9	
AFI / Crate	0.0	0.0	0.0	0.0	
Average gilt pool inventory	34.6	23.7	13.5	24.0	
Gilts entered	17	0	17	34	
Sows and gilts culled	28	27	19	74	
Sow and gilt deaths	0	1	1	2	
Ending boar inventory	34	34	34	34	
Sow - Boar Ratio	18.1	17.3	17.4	17.4	
Replacement rate	32.0	0.0	34.0	22.3	
Culling rate	52.7	54.5	38.0	48.5	
Death rate	0.0	2.0	2.0	1.3	
Ave non-productive sow days	50.9	41.7	33.3	42.1	
Ave NPd / parity record	20.6	19.0	12.7	17.3	

Figure 8.4 Final report for AA1037 farm from PigFIX

PigFIX Analysis of Herd Performance		
FARM: AA1037	1 MAY 90 - 31 JUL 90	Printed: 17-Feb-95
Page 1		

Diagnoses	Recommended Action
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Overall Herd Performance

No problems found

Breeding Performance

No problems found

Weaning Performance

No problems found

Case 3 (Farm AA1034)

The report for this pig herd was produced for the period from September to November 1991 (Figure 8.5). During this period, the herd had the following general population characteristics: the female inventory averaged about 198 sows with an average number over the 3 month period of a replacement rate of 73.9% and of a culling rate of 15.7%. The averages of number of non-productive sow days and non-productive sow days/ parity record were 118.0 and 41.8 days respectively.

In the weaning area: an average of 15.5 pigs were weaned per mated female per year. On average 9.0 pigs were weaned per sow. The average pre-weaning mortality was 22.4% ranging between 21.1% and 24.1%.

In the farrowing area: an average of 1.72 litters were produced per mated female per year monthly values ranging between 1.66 and 1.81. Pigs born alive/ litter averaged 11.1 monthly values ranging between of 10.1 and 12.2. On average 7.0% pigs born were stillbirths and mummies.

In the breeding area: average 92.9% of sows were bred by 7 days with the an average period from weaning to first service of 5.9 days and average percentage of repeat services of 2.8%.

The human expert

Inspection of the performance monitor report by the human expert reveals that this herd had some problems with low overall herd performance and an immediate problem of high pre-weaning mortality. Further investigation is required to examine data integrity as indicated by a high death rate in September but none in the other 2 months and a high replacement rate in November. Average NPD and NPD/ parity record together with farrowing interval influence litters/ mated female/ year, then pigs weaned/ mated female/ year were dropped. Other details such as data about parity, location, animal handler and post mortem results have to be kept in order to allow corrective actions for high pre-weaning mortality.

PigFIX

The report generated by PigFIX is presented in Figure 8.6. The expert system identified problems of high death rate of female pigs and high pre-weaning mortality. It made some suggestions for further investigation of these problems. However, PigFIX could not recognise longer period of NPD.

Figure 8.5 Performance monitor report for AA1034 farm

PERFORMANCE MONITOR	PigCHAMP 3.0			
1 SEP 91 - 30 NOV 91	(C) 1985,87,88,91 Univ of Minn			
FARM: AA1034	Licensed to R S Morris			
	Printed: 15 JAN 95			
	SEP 91			
	SEP 91	OCT 91	NOV 91	NOV 91
BREEDING PERFORMANCE				
Total number of services	26	21	24	71
Percent repeat services	0.0	0.0	8.3	2.8
Percent multiple matings	3.8	0.0	0.0	1.4
Weaning - 1st service interval	6.1	5.4	6.2	5.9
Percent sows bred by 7 days	95.5	93.8	88.9	92.9
Entry - 1st service interval	66.7	.	9.0	52.3
FARROWING PERFORMANCE				
Number of sows farrowed	33	25	35	93
Ave parity of farrowed sows	3.1	4.2	3.8	3.7
Average total pigs per litter	12.0	13.3	10.8	11.9
Average pigs born alive/litter	11.3	12.2	10.1	11.1
Ave birth wt / liveborn pig	0.0	0.0	0.0	0.0
Percent stillborn pigs	5.1	5.7	6.1	5.6
Percent mummies	0.8	3.0	0.5	1.4
Farrowing rate	80.5	69.4	94.6	81.6
Adj. farrowing rate	84.6	73.5	94.6	84.5
Farrowing interval	167	163	158	162
Litters / mated female / year	1.81	1.66	1.70	1.72
Litters / crate / year	0.0	0.0	0.0	0.0
WEANING PERFORMANCE				
Number of litters weaned	22	29	24	75
Total pigs weaned	212	265	208	685
Pigs weaned per sow	9.6	9.1	8.3	9.0
Pre-weaning mortality	22.3	21.1	24.1	22.4
Average weaning weight	.	.	.	.
Average age at weaning	27.2	26.3	27.9	27.1
Adjusted 21 day litter weight	.	.	.	.
Pigs wnd / mated female / yr	17.4	15.1	14.1	15.5
Pigs weaned / crate / year	0.0	0.0	0.0	0.0
Pigs weaned / lifetime female	30	25	54	33
POPULATION				
Ending female inventory	172	168	198	198
Average parity	2.8	2.9	2.5	2.5
Average female inventory	169.6	170.8	196.4	179.2
AFI / Crate	0.0	0.0	0.0	0.0
Average gilt pool inventory	12.6	11.3	31.7	18.5
Gilts entered	4	0	29	33
Sows and gilts culled	2	3	2	7
Sow and gilt deaths	5	0	0	5
Ending boar inventory	33	34	35	35
Sow - Boar Ratio	5.2	4.9	5.7	5.7
Replacement rate	28.7	0.0	179.7	73.9
Culling rate	14.3	20.7	12.4	15.7
Death rate	35.9	0.0	0.0	11.2
Ave non-productive sow days	95.9	113.0	140.1	118.0
Ave NPD / parity record	36.1	65.6	35.3	41.8

Figure 8.6 Final report for AA1034 farm from PigFIX

PigFIX Analysis of Herd Performance		
FARM: AA1034	1 SEP 91 - 30 NOV 91	Printed: 17- Feb- 95
Page 1		

Diagnoses	Recommended Action
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Overall Herd Performance

High death rate of female pigs	1. Investigate factors which influence death rate by running Removal Analysis-report type (all reasons), report format (results).
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Breeding Performance

No problems found

Weaning Performance

High pre-weaning mortality	1. Investigate factors which influence PWM by running Report Pig Death Analysis- age analysis.
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Case 4 (Farm AA1032)

The report for this pig herd was produced for the period from November 1992 to January 1993 (Figure 8.7). During this period, the herd had the following general population characteristics: the female inventory averaged about 58 sows with an average number over the 3 month period of a replacement rate of 34.5% and of a culling rate of 34.5%. The averages of number of non-productive sow days and non-productive sow days/ parity record were 25.5 and 9.7 days respectively.

In the weaning area: an average of 24.6 pigs were weaned per mated female per year. On average 10.2 pigs were weaned per sow. The average pre-weaning mortality was 11.0% ranging between 8.9% and 14.0%.

In the farrowing area: an average of 2.42 litters were produced per mated female per year monthly values ranging between 2.36 and 2.45. Pigs born alive/ litter averaged 10.6 monthly values ranging between of 9.4 and 12.0. On average 8.3% pigs born were stillbirths and mummies.

In the breeding area: average 96.4% of sows were bred by 7 days with the an average period from weaning to first service of 5.3 days and average percentage of repeat services of 0%.

The human expert

Inspection of the performance monitor report by the human expert reveals that productivity of this herd was satisfactory given the overall herd performance of 24.6 pigs weaned/ mated female/ year. However, an immediate problem of a high percentage of mummies (5.4%) in January 1993 has to be investigated and the 14% of pre-weaning mortality in November 1992 should be brought to the attention of the manager.

PigFIX

The report generated by PigFIX is presented in Figure 8.8. The expert system identified a problem with a high percentage of mummies and made some suggestions for further investigation of this problem. However, PigFIX did not recognise the marginal problem with pre-weaning mortality in November 1992.

Figure 8.7 Performance monitor report for AA1032 farm

PERFORMANCE MONITOR		PigCHAMP 3.0			
1 NOV 92 - 31 JAN 93		(C) 1985,87,88,91 Univ of Minn			
FARM: AA1032		Licensed to R S Morris			
		Printed: 15 JAN 95			
		NOV 92			
		NOV 92	DEC 92	JAN 93	JAN 93
BREEDING PERFORMANCE					
Total number of services		10	12	11	33
Percent repeat services		0.0	0.0	0.0	0.0
Percent multiple matings		0.0	0.0	0.0	0.0
Weaning - 1st service interval		5.5	5.2	5.4	5.3
Percent sows bred by 7 days		87.5	100.0	100.0	96.4
Entry - 1st service interval		71.5	.	43.3	54.6
FARROWING PERFORMANCE					
Number of sows farrowed		9	10	14	33
Ave parity of farrowed sows		4.8	5.3	3.8	4.5
Average total pigs per litter		12.8	12.0	10.6	11.6
Average pigs born alive/litter		12.0	11.2	9.4	10.6
Ave birth wt / liveborn pig		1.4	1.4	1.4	1.4
Percent stillborn pigs		3.5	5.8	6.1	5.2
Percent mummies		2.6	0.8	5.4	3.1
Farrowing rate		100.0	100.0	93.3	97.1
Adj. farrowing rate		100.0	100.0	100.0	100.0
Farrowing interval		157	162	157	158
Litters / mated female / year		2.36	2.45	2.45	2.42
Litters / crate / year		0.0	0.0	0.0	0.0
WEANING PERFORMANCE					
Number of litters weaned		10	13	9	32
Total pigs weaned		98	133	94	325
Pigs weaned per sow		9.8	10.2	10.4	10.2
Pre-weaning mortality		14.0	8.9	10.5	11.0
Average weaning weight		7.9	7.6	7.2	7.6
Average age at weaning		34.5	32.4	28.1	31.8
Adjusted 21 day litter weight		58	63	63	62
Pigs wnd / mated female / yr		23.1	25.1	25.6	24.6
Pigs weaned / crate / year		0.0	0.0	0.0	0.0
Pigs weaned / lifetime female		49	99	70	67
POPULATION					
Ending female inventory		58	57	58	58
Average parity		3.3	3.4	3.3	3.3
Average female inventory		57.5	57.3	57.7	57.5
AFI / Crate		0.0	0.0	0.0	0.0
Average gilt pool inventory		0.8	2.0	3.0	1.9
Gilts entered		2	0	3	5
Sows and gilts culled		2	1	2	5
Sow and gilt deaths		0	0	0	0
Ending boar inventory		5	4	5	5
Sow - Boar Ratio		11.6	14.3	11.6	11.6
Replacement rate		42.3	0.0	61.2	34.5
Culling rate		42.3	20.5	40.8	34.5
Death rate		0.0	0.0	0.0	0.0
Ave non-productive sow days		18.4	24.4	33.3	25.5
Ave NPd / parity record		7.9	11.9	9.6	9.7

Figure 8.8 Final report for AA1032 farm from PigFIX

PigFIX Analysis of Herd Performance		
FARM: AA1032	1 NOV 92 - 31 JAN 93	Printed: 17- Feb- 95
Page 1		

Diagnoses

Recommended Action

Overall Herd Performance

No problems found

Breeding Performance

High mummies

1.Investigate factors which influence PWM by running Report Pig Death Analysis- age analysis.

Weaning Performance

No problems found

Case 5 (Farm AA1036)

The report for this pig herd was produced for the period from December 1992 to February 1993 (Figure 8.9). During this period, the herd had the following general population characteristics: the female inventory averaged about 154 sows with an average number over the 3 month period of a replacement rate of 32.7% and of a culling rate of 5.5%. The averages of number of non-productive sow days and non-productive sow days/ parity record were 86.5 and 33.4 days respectively.

In the weaning area: an average of 20.0 pigs were weaned per mated female per year. On average 9.5 pigs were weaned per sow. The average pre-weaning mortality was 9.4% ranging between 6.7% and 13.2%.

In the farrowing area: an average of 2.10 litters were produced per mated female per year monthly values ranging between 2.00 and 2.30. Pigs born alive/ litter averaged 10.5 monthly values ranging between of 10.2 and 11.0. On average 0% pigs born were stillbirths and mummies.

In the breeding area: average 75.4% of sows were bred by 7 days with the an average period from weaning to first service of 17.7 days and average percentage of repeat services of 0%.

The human expert

Inspection of the performance monitor report by the human expert reveals that this herd had a problem of long weaning to first service interval which influenced some parameters such as average NPD, average NPD/ parity record, litters/ mated female/ year and pigs weaned/mated female/ year. However, other information such as breeding management, parity and infectious disease status has to be investigated before corrective action can be taken. The pre-weaning mortality of 13.2% in December 1992 was considered a marginal problem.

PigFIX

The report generated by PigFIX is presented in Figure 8.10. The expert system identified a problem with the long weaning to first service interval and made some suggestions for further investigation of this problem. However, PigFIX did not recognise marginal problem of pre-weaning mortality in December 1992.

Figure 8.9 Performance monitor report for AA1036 farm

PERFORMANCE MONITOR		PigCHAMP 3.0			
1 DEC 92 - 28 FEB 93		(C) 1985,87,88,91 Univ of Minn			
FARM: AA1036		Licensed to R S Morris			
		Printed: 15 JAN 95			
		DEC 92			
	DEC 92	JAN 93	FEB 93	FEB 93	
BREEDING PERFORMANCE					
Total number of services	20	27	41	88	
Percent repeat services	0.0	0.0	0.0	0.0	
Percent multiple matings	0.0	7.4	2.4	3.4	
Weaning - 1st service interval	5.9	15.5	22.9	17.7	
Percent sows bred by 7 days	90.9	76.2	69.7	75.4	
Entry - 1st service interval	53.7	53.3	59.1	55.5	
FARROWING PERFORMANCE					
Number of sows farrowed	25	33	25	83	
Ave parity of farrowed sows	2.1	2.1	2.2	2.1	
Average total pigs per litter	10.5	10.2	11.0	10.5	
Average pigs born alive/litter	10.5	10.2	11.0	10.5	
Ave birth wt / liveborn pig	0.0	0.0	0.0	0.0	
Percent stillborn pigs	0.0	0.0	0.0	0.0	
Percent mummies	0.0	0.0	0.0	0.0	
Farrowing rate	96.2	100.0	100.0	98.8	
Adj. farrowing rate	96.2	100.0	100.0	98.8	
Farrowing interval	157	159	161	159	
Litters / mated female / year	2.30	2.01	2.00	2.10	
Litters / crate / year	0.0	0.0	0.0	0.0	
WEANING PERFORMANCE					
Number of litters weaned	10	29	25	64	
Total pigs weaned	99	280	228	607	
Pigs weaned per sow	9.9	9.7	9.1	9.5	
Pre-weaning mortality	13.2	6.7	10.9	9.4	
Average weaning weight	.	.	.	.	
Average age at weaning	38.3	32.4	32.9	33.5	
Adjusted 21 day litter weight	.	.	.	.	
Pigs wmd / mated female / yr	22.8	19.4	18.3	20.0	
Pigs weaned / crate / year	0.0	0.0	0.0	0.0	
Pigs weaned / lifetime female	.	0	0	0	
POPULATION					
Ending female inventory	144	155	154	154	
Average parity	1.2	1.4	1.5	1.5	
Average female inventory	143.1	149.7	154.1	148.8	
AFI / Crate	.	0.0	0.0	0.0	
Average gilt pool inventory	22.6	17.9	16.5	19.1	
Gilts entered	0	12	0	12	
Sows and gilts culled	0	1	1	2	
Sow and gilt deaths	0	0	0	0	
Ending boar inventory	10	10	11	11	
Sow - Boar Ratio	.	15.5	14.0	14.0	
Replacement rate	0.0	94.4	0.0	32.7	
Culling rate	0.0	7.9	8.5	5.5	
Death rate	0.0	0.0	0.0	0.0	
Ave non-productive sow days	92.6	86.1	80.5	86.5	
Ave NPD / parity record	45.0	24.3	38.1	33.4	

Figure 8.10 Final report for AA1036 farm from PigFIX

PigFIX Analysis of Herd Performance

FARM: AA1036 1 DEC 92 - 28 FEB 93 Printed: 17-Feb-95

Page 1

Diagnoses	Recommended Action
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Overall Herd Performance

No problems found

Breeding Performance

Long weaning to first service interval	1.Investigate factors which influence Wean to service interval by running Returns Post Weaning Report. 2.Revision of breeding managements: oestrus detection, feed intake of female pigs and boar contact.
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Weaning Performance

No problems found

Case 6 (Farm AA1028)

The report for this pig herd was produced for the period from December 1991 to February 1992 (Figure 8.11). During this period, the herd had the following general population characteristics: the female inventory averaged about 152 sows with an average number over the 3 month period of a replacement rate of 31.8% and of a culling rate of 45.1%. The averages of number of non-productive sow days and non-productive sow days/ parity record were 113.6 and 58.6 days respectively.

In the weaning area: an average of 12.9 pigs were weaned per mated female per year. On average 8.8 pigs were weaned per sow. The average pre-weaning mortality was 15.8% ranging between 13.2% and 17.7%.

In the farrowing area: an average of 1.46 litters were produced per mated female per year monthly values ranging between 1.44 and 1.49. Pigs born alive/ litter averaged 10.6 monthly values ranging between of 9.7 and 11.5. On average 8.5% pigs born were stillbirths and mummies.

In the breeding area: average 78.9% of sows were bred by 7 days with the an average period from weaning to first service of 10.3 days and average percentage of repeat services of 9.1%.

The human expert

Inspection of the performance monitor report by the human expert reveals that this herd had a severe problem of long weaning to first service interval which influenced some parameters such as average NPD, average NPD/ parity record, percentage of sow bred by 7 days, litters/ mated female/ year and pigs weaned/ mated female/ year. However, other information about breeding management, parity and infectious disease status has to be obtained before corrective action can be taken. Further problems were identified as indicated by an average pre-weaning mortality of 15.8%, a high percentage of stillborn pigs and mummies, and a high death rate in December 1991.

PigFIX

The report generated by PigFIX is presented in Figure 8.12. The expert system identified problems of long weaning to first service interval, high death rate of female pigs and high pre-weaning mortality. It made some suggestions for further investigation of these problems. However, PigFIX could not recognise marginal problem of stillborn pigs and mummies in January 1992.

Figure 8.11 Performance monitor report for AA1028 farm

PERFORMANCE MONITOR		PigCHAMP 3.0			
1 DEC 91 - 29 FEB 92		(C) 1985,87,88,91 Univ of Minn			
FARM: AA1028		Licensed to R S Morris			
		Printed: 15 JAN 95			
		DEC 91			
	DEC 91	JAN 92	FEB 92	FEB 92	
BREEDING PERFORMANCE					
Total number of services	34	36	29	99	
Percent repeat services	11.8	8.3	6.9	9.1	
Percent multiple matings	70.6	83.3	82.8	78.8	
Weaning - 1st service interval	0.9	9.3	22.0	10.3	
Percent sows bred by 7 days	91.3	77.8	66.7	78.9	
Entry - 1st service interval	0.2	2.5	0.0	1.1	
FARROWING PERFORMANCE					
Number of sows farrowed	20	22	19	61	
Ave parity of farrowed sows	6.5	4.5	3.1	4.7	
Average total pigs per litter	11.6	11.1	12.1	11.6	
Average pigs born alive/litter	10.8	9.7	11.5	10.6	
Ave birth wt / liveborn pig	0.0	0.0	0.0	0.0	
Percent stillborn pigs	7.7	10.6	3.5	7.4	
Percent mummies	0.0	2.4	0.9	1.1	
Farrowing rate	83.3	73.3	59.4	70.9	
Adj. farrowing rate	90.9	84.6	73.1	82.4	
Farrowing interval	163	163	160	162	
Litters / mated female / year	1.44	1.49	1.46	1.46	
Litters / crate / year	0.0	0.0	0.0	0.0	
WEANING PERFORMANCE					
Number of litters weaned	28	32	14	74	
Total pigs weaned	256	297	128	681	
Pigs weaned per sow	8.5	9.3	8.5	8.8	
Pre-weaning mortality	17.7	13.2	17.9	15.8	
Average weaning weight	.	.	.	.	
Average age at weaning	37.8	35.1	34.8	36.0	
Adjusted 21 day litter weight	.	.	.	.	
Pigs wnd / mated female / yr	12.3	13.8	12.5	12.9	
Pigs weaned / crate / year	0.0	0.0	0.0	0.0	
Pigs weaned / lifetime female	6	10	5	6	
POPULATION					
Ending female inventory	149	152	152	152	
Average parity	3.3	3.3	3.3	3.3	
Average female inventory	150.6	151.3	151.5	151.1	
AFI / Crate	0.0	0.0	0.0	0.0	
Average gilt pool inventory	1.1	1.5	0.9	1.1	
Gilts entered	4	3	4	11	
Sows and gilts culled	9	2	6	17	
Sow and gilt deaths	2	1	0	3	
Ending boar inventory	8	8	9	9	
Sow - Boar Ratio	18.6	19.0	16.9	16.9	
Replacement rate	31.3	23.3	41.5	31.8	
Culling rate	70.4	15.6	49.8	45.1	
Death rate	15.6	7.8	0.0	8.0	
Ave non-productive sow days	93.1	112.9	136.0	113.6	
Ave NPd / parity record	49.6	58.0	68.2	58.6	

Figure 8.12 Final report for AA1028 farm from PigFIX

PigFIX Analysis of Herd Performance		
FARM: AA1028	1 DEC 91 - 29FEB 92	Printed: 17-Feb-95
Page 1		

Diagnoses	Recommended Action
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Overall Herd Performance

High death rate of female pigs	1.Investigate factors which influence death rate by running Removal Analysis-report type (all reasons), report format (results).
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Breeding Performance

Long weaning to first service interval	1.Investigate factors which influence wean to service interval by running Returns Post Weaning Report. 2.Revision of breeding managements: oestrus detection, feed intake of female pigs and boar contact.
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Weaning Performance

High pre-weaning mortality	1.Investigate factors which influence PWM by running Report Pig Death Analysis- age analysis.
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Table 8.1 Comparison results between an expert and PigFIX

Test cases	Conclusions	
	Expert	PigFIX
AA1031	no major problem but pre-weaning mortality was marginal	no problem found
AA1037	no major problem but pre-weaning mortality, stillborn and mummies were marginal	no problem found
AA1034	death rate and pre-weaning mortality and longer NPD	death rate and pre-weaning mortality
AA1032	percent mummies and pre-weaning mortality was marginal	percent mummies
AA1036	long weaning to first service interval and pre-weaning mortality was marginal	long weaning to first service interval
AA1028	death rate, long weaning to first service interval; stillborn and mummies were marginal	death rate and long weaning to first service interval

Discussion

In this study, PigFIX has been verified against 6 real scenarios. The program could draw conclusions and make suggestions which were close to an expert's opinions with regard to overall herd, breeding and weaning performance. However, while PigFIX was able to identify problems which were clearly defined, it had difficulty with current range boundary settings detecting marginal problems. This had to be expected as the system had been designed to achieve a good specificity, which meant having to accept a reduced sensitivity. It may however be desirable to set the warning range so that it includes a higher proportion of marginal problems than in this first attempt at setting the boundaries, since the system failed to pick up virtually all of the marginal problems identified by the expert, but detected almost all of the serious problems he detected. The system showed very high specificity,

in that it did not report problems where the expert considered performance normal. Thus it would appear that the parameter settings used in this first trial of the system erred towards favouring very high specificity, at the expense of achieving adequate sensitivity, thereby failing to identify marginal problems. Correcting this problem simply requires broadening the limits for the warning range, while leaving the action range limits unchanged. This would seem likely to meet both requirements, and could be adjusted to suit the views of individual advisers.

The development of computer software is not a perfect process. In a real scenario, there are logic or process errors which represent departures from expected or intended behaviour. When these errors are detected during the early phase of software development, this saves time and money. Considerable work has been done to develop a verification and validation methodology for conventional software. However, methods for verification and validation of expert systems are still an important research topic particularly with regard to the verification and validation of the knowledge-base (Naser, 1988; Huirne, 1991). PigFIX has so far been verified by the developer to the point where it appears to conduct a rational evaluation of reproductive performance in a pig herd. The primary concern at this stage of the development process was to ensure adequate specificity, so that PigFIX did not exaggerate problems beyond the assessment of an expert. This has been achieved, but it will next be necessary to extend the limits for the warning range, to include cases where less clear-cut problems were considered by the expert to exist, but PigFIX did not report any problem. This will be an iterative process, with progressive refinement of the boundary points on the various parameters until they appear to the designer of the system to accurately reflect the appropriate balance in the diagnostic process.

It will then be necessary to make the system available to other people experienced in the diagnosis of reproductive problems, to determine the sensitivity and specificity of the system when judged by such independent evaluators. While it should be possible to provide adequate overall agreement, the opinions of such specialists will never agree entirely, so the system will never be perfect. However one of the virtues of PigFIX is that each user can without difficulty adjust the system to represent their personal judgment as closely as possible. Thus PigFIX is ultimately a personal decision aid which can help with records interpretation and further analysis, but is not intended to replace the informed judgment of the specialist.

CHAPTER 9

General discussion

Introduction

This thesis has applied epidemiological methods to further improve understanding of diseases of pigs, and of methods for applying health management principles in pig herds. A series of studies explored two main areas of intensive pig production: grower-finisher and breeding areas.

In the grower-finisher area, epidemiological techniques were used to investigate subclinical disease prevalence, assess the efficacy of two vaccines in independently or synergistically reducing disease levels, and investigate the epidemiological pattern of an infectious disease. In the breeding area, various techniques were used to investigate non-infectious diseases. Furthermore, veterinary expertise and advanced computer technologies were combined to develop a system which can help investigate causes of reproductive inefficiency, and hence overcome important limitations in productivity of the sow breeding herd.

Disease surveillance at slaughter

Production-limiting diseases, often in subclinical form, substantially reduce productivity in the grower and finisher periods. Disease surveillance at slaughter has been used to diagnose subclinical disease and to define interactions between animals, agents, environmental conditions and management practices (Bäckström, 1973; Lindqvist, 1974; Aalund *et al.*, 1976; Flesja and Ulvesæter, 1980; Straw *et al.*, 1986a; Pointon *et al.*, 1987; Elbers *et al.*, 1992). Furthermore, slaughter surveillance data may be linked with data on pig productivity and costs of production to reduce financial loss from subclinical diseases within a herd, and to improve management practices and animal welfare (Straw *et al.*, 1985; Morrison *et al.*, 1986; Bernardo *et al.*, 1990; Mercy and Buddle, 1990; Elbers *et al.*, 1994).

Under New Zealand conditions, slaughter surveillance of 30 pigs per test occasion provided an adequate level of confidence for monitoring 8 production-limiting diseases and a zoonotic disease. The thirty samples could be satisfactorily selected using systematic random sampling. Seasonal patterns were found for some disease conditions (such as enzootic pneumonia, pleurisy and liver white spot), so the evaluation of preventive or control measures needs to take account of such variation during the course of a year. The slaughter surveillance should be performed regularly every 3 months, as far as possible in the middle of each season, instead of only one slaughter check in

winter which provides very limited information (Straw *et al.*, 1986a). The nature of the seasonal effects could not be examined in great detail in this study because although a large number of pigs was examined, the number of replicate observations for particular seasons available to assess effects of seasonality was small. Much longer sequences of observations for each participating farm would be required in order to properly evaluate seasonal variation. Of the various factors which could influence seasonality, the only one which could be investigated in this study was temperature effect, and this had to be done through recordings made at the nearest meteorological station, not through data recorded on the farms. However the analysis of the influence of temperature shows that for a number of diseases which showed seasonal variation, there also appears to be an association between temperature data and occurrence of the disease. It appeared that enzootic pneumonia, pleurisy, pleuropneumonia are more prevalent at low environmental temperatures. Other factors which influence the microclimate and the prevalence of pneumonic lesions are stocking density, group size, ventilation, quality of housing and management (Done, 1991). There was also evidence from the logistic regression analysis that variation between farms (other than temperature variation) was substantial, no doubt reflecting management differences between the participating farms. The farms which participated in the study were all under veterinary supervision by University staff, and the slaughter check data obtained was consistent with clinical experience on the same farms, and assessments of management performance.

However, while slaughter checks are a valuable guide to the disease status of farms, they are unreliable as an indicator of infection status in small groups or individual pigs, due to the low prevalence of some disease conditions such as pleuropneumonia and proliferative enteropathy (Pointon *et al.*, 1992), the imperfect sensitivity and specificity of some of the examination procedures, and the fact that some animals may have been affected by some of the diseases earlier in life, but have recovered partially or totally by the time they reach slaughter weight. Nevertheless, slaughter surveillance has become established as a routine part of health management for many commercial piggeries in New Zealand.

Control of respiratory diseases by vaccination

To control enzootic pneumonia and porcine pleuropneumonia, vaccination is a practicable control measure from an economic point of view. Use of antibiotics is also effective, but has been associated with increased prevalence of antimicrobial resistant strains of *Actinobacillus pleuropneumoniae* (Kim and Jung, 1994; Raemdonck *et al.*, 1994). Therefore in a herd where control cannot be achieved by environmental management alone, it is preferable in principle to use vaccination to

achieve control, supplemented if necessary by antibiotic therapy. Although various workers have shown a benefit from vaccination against *Mycoplasma hyopneumoniae*, results have generally been disappointing for vaccination against *Actinobacillus pleuropneumoniae* with current commercial vaccines.

Field trials face considerable problems in reconciling practical limitations on the scale of any particular study against the need for large numbers to show significance for all variables of interest. Before the trial commenced, power analysis was conducted to assess the likely sample size required to reach statistical significance for each of the variables of interest in the study. This showed that feed conversion ratio and mortality rate would require a far larger trial to achieve adequate power (for some variables in excess of 2,000 animals), and practical limitations on the amount of time and resource which could be put into the trial meant that the sample size used was set by the numbers required for evaluation of weight gain, not the variables for which much larger numbers of animals would be necessary. This type of difficulty faces all research workers conducting trials on commercial farms, and many clinical trials have difficulties on this point (Elbers and Schukken, 1995).

Simultaneous administration of both vaccines produced significant improvement of growth rate during the high risk period for clinical pneumonia and increased slaughter weight. However differences in feed conversion ratio and mortality rate were not significant. The results of this trial are consistent with those obtained by other workers using *Mycoplasma hyopneumoniae* vaccines (Weiss and Peterson, 1992; Christensen and Deitemeyer, 1993; Lium *et al.*, 1994; Vraa-Andersen *et al.*, 1994) and *Actinobacillus pleuropneumoniae* vaccine (Heard and Tuck, 1986; Thacker and Mulks, 1988; Beskow *et al.*, 1992; Tarasiuk *et al.*, 1994). In addition, log-linear analysis showed that the presence of pleuropneumonia lesions was positively associated with the presence of pleurisy lesions. This suggests that *A. pleuropneumoniae* could be a cause of pleuritis which confirms the findings from other studies (Nielsen, 1973; Christensen, 1981; Straw *et al.*, 1986b). However, the results of the log-linear analysis did not show an association between use of *A. pleuropneumoniae* vaccine and the prevalence of pleuropneumonia or pleurisy lesions at slaughter. No evidence of synergy between these vaccines in influencing lesion severity for pleuropneumonia was detected. This finding is consistent with other evidence (Gardner *et al.*, 1991). Ideally, the trial would have had four groups with each vaccine used in two groups so that effectiveness and synergy could have been definitively determined. However the numbers required would have been impossible to obtain in a commercial herd in New Zealand, and the use of log-linear modelling provides useful indirect evidence of the lack of substantial direct or synergistic effects.

Investigation of *A. pleuropneumoniae* in healthy carrier pigs using a cohort study

Prevention and control programs for porcine pleuropneumonia often remain ineffective due to the complicated nature of the disease. Healthy carrier pigs play an important role in the spread of the disease (Alexander, 1992). A cohort study was conducted to describe the epidemiological pattern of *A. pleuropneumoniae* infection at the same time as the vaccination trial was being carried out. Results of the study indicate that the risk of transmission of *A. pleuropneumoniae* is highest in the farrowing pen and incidence of *A. pleuropneumoniae* reach a peak at 11 weeks of age. This finding supports the studies of Sebunya *et al.* (1982), Kume *et al.* (1984) and Wilson *et al.* (1987). This study suggests that pigs from an infected litter are 1.5 times as likely to carry *A. pleuropneumoniae* as pigs from non-infected litters, although numbers were too small for this to be statistically confirmed. Furthermore, *A. pleuropneumoniae* is more likely to be isolated from pigs at 4 - 11 weeks of age than from pigs which are older than 11 weeks of age. Simultaneous vaccination of both vaccines at 2 and 4 weeks of age does not appear to prevent *A. pleuropneumoniae* infection during the weaner or grower-finisher periods. The field data from this study does not support the hypothesis put forward by Yagihashi *et al.* (1984) that *M. hyopneumoniae* infection increases the susceptibility to *A. pleuropneumoniae* infection, and this result agrees with the findings of Gardner *et al.* (1991).

Investigation of non-infectious diseases in the breeding area

In modern pig production, computerised health and management evaluation software plays an important role in keeping track of productivity on farms. As a result of intensification of commercial pig herds, treatment and control of clinical diseases are no longer the dominant form of veterinary service provided, and consultancy supported by such software has become the norm. Non-infectious causes have become increasingly important.

In order to provide a comparison of factors determining herd productivity between a tropical environment (Thailand) and a temperate environment (New Zealand), data files for herds in the two countries which used PigCHAMP® for herd recording purposes and were willing to provide data for analysis were compared with respect to major breeding herd indices. The capacity to make such comparisons is one of the advantages offered by worldwide availability of suitable software, which helps ensure comparability of data between countries.

As might be expected, the herds in the temperate environment generally performed better, although differences due to environmental factors are indistinguishable from those due to management

differences in this analysis. Pigs weaned per mated female per year is an overall indicator of breeding herd productivity, and the New Zealand herds averaged 20.5, against 19.3 for the Thai herds. The difference between medians was even more marked, reflecting the fact that a few superior herds in Thailand kept the mean higher than the figure achieved by the majority of herds, whereas in New Zealand herds the median was slightly above the mean - a rather unusual situation.

This poor litter productivity provides a severe constraint to pig production in Thailand. Small total litter size and low pigs born alive jointly limit the number of pigs weaned per litter, despite the superior survival of pigs to weaning. The overall mean productivity of 19.3 pigs weaned /mated female /year reflects this constraint. To correct the problem of small litter size, some factors are involved: parity distribution, lactation length, status of infectious diseases on the farm, ambient temperature, plane of nutrition, genetics and breeding management (Dial. *et al.*, 1992). It is noteworthy that some Thai herds achieved as much as 22.7 pigs per year, so improvement is possible.

In temperate herds, reduction of pre-weaning mortality and sow death rate offer the greatest potential for improvement, especially for herds with high values in one or both of these areas.

Investigation of pig fertility using an expert system (PigFIX)

Factors which influence fertility in gilts and sows are breeding management, plane of nutrition, season, ambient temperature, genetics and infectious disease status (Wrathall, 1977; Love, 1978; Hurtgen, 1982; Hill, 1985; Egbunike, 1986; Thacker and Gonzalez, 1988; Tubbs, 1988; Tubbs, 1990; Enne and Greppi, 1993; and Love *et al.*, 1993). To develop an expert system, an expert system shell has been used for this purpose in some cases - such as ACQUAINT in The Electronic Pig (Vos *et al.*, 1990).

In contrast, PigFIX was written using a standard software development tool and a database management program, thus reducing development costs and making the software more generic. The PigFIX knowledge base was represented in form of a combination of objects and production rules. A performance indicator (such as total pigs /litter) is an object and contains 3 performance levels: Target, Warning and Action. The PigFIX engine reads a standard format of performance monitor report and uses data-driven (forward chaining) logic to reach its conclusion. To identify an abnormality in a performance parameter, the engine follows a diagnostic tree approach (Van Der Leek and Becker, 1993) which was modified from Stein's productivity algorithm (1988). At the present, the input to PigFIX comes directly in a form of an ASCII text file generated by

PigCHAMP®. At the end of each analysis PigFIX generates a final report describing which performance variables were outside warning or action limits, and suggests other report which could be used for further investigation.

It is considered that the expert system operated quite satisfactorily in its test mode, and provided a flexible and effective tool for guiding the user in interpreting herd performance indicators to identify causes of suboptimal performance. However, expert systems must be used with awareness that they do not produce "the answer" (Morris and Dijkhuizen, 1992), but rather help the user undertake the process of making informed assessments.

Verification of PigFIX against assessment of herd performance by a single expert

PigFIX was designed and developed under temperate conditions. Verification and validation are important further steps in software development. The expert system has been verified against the judgment of its developer using data from six piggeries of known health status, using information from the standard format of performance monitor reports as described in chapter 8. PigFIX was able to detect clear cut problems, and the conclusions it offered were close to those drawn independently by the system designer from the same data. Thus it appears to successfully operate in accordance with the intentions of its designer. However it needs fine-tuning to detect marginal problems more reliably, even if this means some increase in false detections.

Future development of PigFIX

PigFIX has been developed and will ultimately become an add-on product to a commercial pig management program. It will interact tightly with this program to the extent where most input to PigFIX will come directly from data structures used and reports generated by this program. There will also be some advanced features not used in any earlier software - for example, PigFIX will be able to display a diagram of the diagnostic tree, identifying which performance indicators lie in warning and action ranges, and guiding the user to carry out further evaluation. This will help the user to identify where problems lie in a breeding herd.

Conclusion

In the real world of intensive pig production, treatment and control of clinical diseases as the sole or even the primary objective of veterinary service is no longer appropriate. Losses in productivity have become more closely associated with changes in subclinical disease or management practices. To reach maximum productivity, epidemiological methods offer considerable potential in dealing with both infectious and non-infectious diseases.

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