CHAPTER 1

GENERAL INTRODUCTION

"*Animal breeding can be defined as a combination of science and art*" (Braun J.A. 2004, personal communication). The science component refers to the genetic principles that are used in order to enhance animal performance. The art component refers to the actual implementation of these principles, combining them with the knowledge and practices that have been acquired by breeders after years, and in some cases, generations of breeding animals.

The main goal of any pig production system in Australia and worldwide is to produce, in a sustainable and profitable way, as many healthy pigs per sow per year as possible. Litter size at birth has been the main tool used worldwide in order to achieve this goal (Rydhmer, 2000). "Hyperprolific" selection schemes have been an effective way to improve litter size (Bidanel et al., 1994). However, litter size is negatively correlated with piglet birth weight and pre-weaning survival (Knol et al., 2002). Therefore the increase in litter size should be carefully optimized in order to enhance the number of piglets weaned per sow per year.

In order to achieve this goal, breeders face several challenges. One of the most common challenges faced by breeders worldwide despite their cultural background, environment, and management practices, among others is "How to make genetic improvement?"

There are two main tools available to pig breeders for enhancing the genetic merit of their animals to increase productivity in future generations. The first one is the identification and selection of animals with higher genetic merit. The second one is the use of crossbreeding.

Identifying and selecting animals with higher genetic merit can be facilitated by the use of a statistical method called Best Linear Unbiased Prediction (BLUP). This method is used to generate estimated breeding values (EBVs) using all known relationships between animals, information on all correlated traits (in a multi-trait analysis) and accounting for selection and non-random matings as well as for fixed effects.

The focus of this thesis is to study the reproductive traits of the maternal lines from Myora Farm's nucleus and multiplier herds, as well as from the crossbred sows at the Top Pork Network farms. The traits analysed at Myora Farm are: number of piglets born in total, number of piglets born alive, number of piglets weaned, average piglet birth weight, average piglet weight at 21 days and gestation length. The traits analysed at the Top Pork Network are: number of piglets born alive, number of piglets weaned, average piglet birth weight and average piglet weight at weaning. A description of Myora Farm and the Top Pork Network piggeries, location, climate, data recording procedures, as well as production levels are presented in Chapter 2.

Estimation of reliable EBVs requires the knowledge of genetic parameters such as heritabilities and genetic correlations. These genetic parameters essential for estimating EBVs can be obtained from previous studies or can be estimated from historic data collected from the different lines within a piggery (or population). The latter is regarded as the best option (Walters, 1998). The aim of Chapter 3 is to estimate heritabilities and genetic correlations across parities and reproductive traits, in order to provide a set of reliable and updated genetic parameters to be used for estimating EBVs at Myora Farm.

Selection on BLUP EBVs maximizes response with the next generation. Long term selection response is not necessarily optimized with BLUP selection (Kinghorn and van der Werf, 2002). This occurs due to a negative aspect of BLUP selection, that is, inbreeding and the loss of genetic variation. The inbreeding levels of a population under BLUP selection should be regularly monitored and the impact of these levels of inbreeding needs to be quantified to minimize losses due to inbreeding depression. Chapter 4 will address this issue and present the estimates of inbreeding of the sow and litter for the different breeds and herds within Myora Farm and its impact on the reproductive performance.

The second main tool available for enhancing the genetic merit of animals is the use of crossbreeding. This tool enables pig breeders to take full advantage of heterosis and to combine desirable characteristics of different breeds. For example, the prolificacy of the Large White breed with the maternal ability of the Landrace breed are combined at Myora Farm in order to create an F1 sow that combines the attributes of both maternal lines. The estimates of direct piglet heterosis on reproductive traits at Myora Farm are presented in Chapter 4.

The high emphasis placed on litter size in the breeding objective has facilitated the creation of sow and boar lines with high prolificacy. These hyperprolific lines generally provide a management challenge due to the size of the litters they deliver and the higher mortalities of their piglets. Therefore it is expected that the expression of maternal heterosis by the hyperprolific F1 sow as well as the direct heterosis of the F2 piglets will enhance the survivability of the piglets, increasing the number of piglets weaned by F1 sows and reducing the losses that occur at the purebred level. Chapter 5 will address these issues and the performance at the commercial level of F1-sows from hyperprolific lines are compared with F1-sows from average and low prolificacy lines.

In the final chapter, the main findings of the previous Chapters are discussed and suggestions are made for developing strategies to enhance the breeding program of Myora Farm. These suggestions will consider new traits to be included in the selection criteria of Myora Farm's breeding program in order to have a more efficient management of hyperprolific sows and enhance the reproductive performance of their progeny at the commercial level.

CHAPTER 2

MYORA FARM AND THE TOP PORK NETWORK

2.1 Description of the Piggeries

2.1.1 Myora Farm

Myora Farm is a 1,200 sow operation located in Mount Gambier, South Australia. The piggery consists of two herds known as the nucleus and the multiplier herds. These are denominations of virtual divisions within Myora Farm since both herds share the same environment as well as management practices.

Myora Farm organisation (Figure 2-1) consists of a pyramidal structure with a nucleus, at the top, with two specialized maternal lines (Landrace and Large White) and a paternal line (Duroc) commonly known as terminal sire line (TSL). The next level is the multiplier, which consists of a crossbreeding operation of the two maternal lines, producing crossbred F1 gilts that will be taken to the commercial level at the base of the pyramid and then mated to TSL boars in order to produce a three-way cross animal as a final product.

The nucleus herd consists of approximately 160 purebred Large White sows, 160 purebred Landrace sows, as maternal lines and 110 purebred Duroc sows as terminal sire lines. At this level, all matings are made between sows and boars of the same breed (pure matings). There are some minor sporadic introductions of new genetic material, namely fresh semen from other Australian breeders which are also part of the National Pig Improvement Program (NPIP). No genetic groups were fitted since too few animals were introduced over time. All the sows that form this nucleus herd are denominated great-grand parents or "GGPs".

The second herd, known as the multiplier herd, consists of approximately 380 Large White and 380 Landrace sows. At this level, all the matings are made between sows and boars from different

breeds within the maternal lines namely Large White sows with Landrace boars and Large White boars with Landrace sows. There are some introductions of new genetic material, similar to what happens at the nucleus level. All the sows that are part of this multiplier herd are denominated great-parents or "GPs".

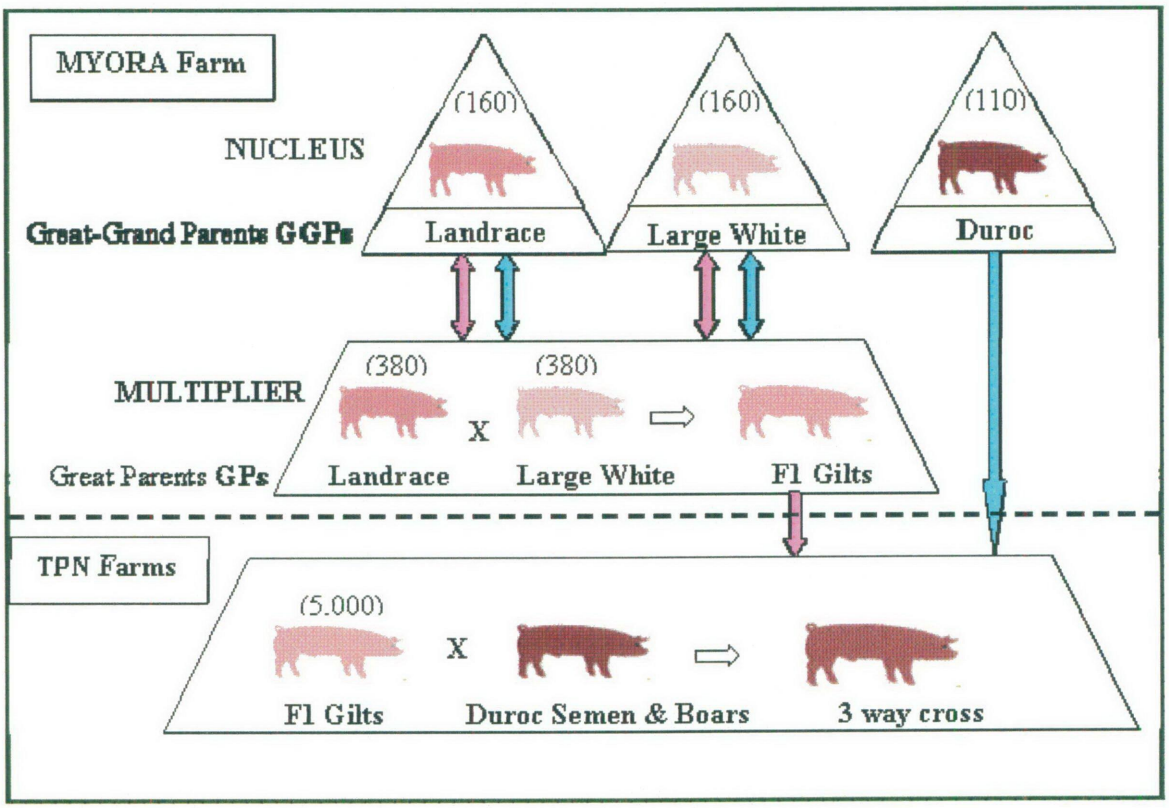

Figure 2-1 Structure of Myora Farm and the Top Pork Network (TPN) organisation. (In brackets the number of sows in each layer). The arrows indicate the flow of animals across layers.

2.1.2 Top Pork Network

The Top Pork Network includes 16 commercial piggeries that have approximately 5,000 F1 crossbred sows (Figure 2-1). The size of the piggeries ranges from 100 to 1,200 sows. These piggeries received F1 gilts on a monthly basis from Myora Farms' multiplier herd as well as young TSL boars from Myora Farms' nucleus and fresh semen from Myora Farm TSL boars' at SABOR artificial insemination centre.

2.2 Location

2.2.1 MYORA Farm

Myora Farm is located on the outskirts of Mount Gambier, South Australia, approximately 15 km North-East of town and 2 km West of the Victorian border. Mount Gambier has an average altitude of 40 to 75m above sea level and it is located at latitude 37° 49' 60 (deg S); longitude 140° 46' 0 (deg E). The location is shown in Figure 2-2.

2.2.2 Top Pork Network Farms

Two out of the 16 farms of the commercial level of the Top Pork Network were selected to be used in this study due to having sufficient data for data analysis.

The first piggery: "Piggery A" is located on the outskirts of Waikerie, SA. Waikerie is in South Australia at the centre of the Riverland area 172 km east of Adelaide (Figure 2-2), its exact location is at latitude 34° 10' 60 (deg S) and longitude 139° 58' 60 (deg E). The piggery is located at the sloping bank of the Murray River approximately 10 km out of town. The size of this piggery is around 250 breeding sows.

The second piggery: "Piggery B" is located in Lameroo, SA. Lameroo is 210 km east of Adelaide in the Mallee region of South Australia (Figure 2-2), its exact location is at latitude 35° 19' 60 (deg S) and longitude 140° 31' 0 (deg E). The piggery is located on a property approximately 20 km east of Lameroo. This piggery is a 1,200 breeding sows operation.

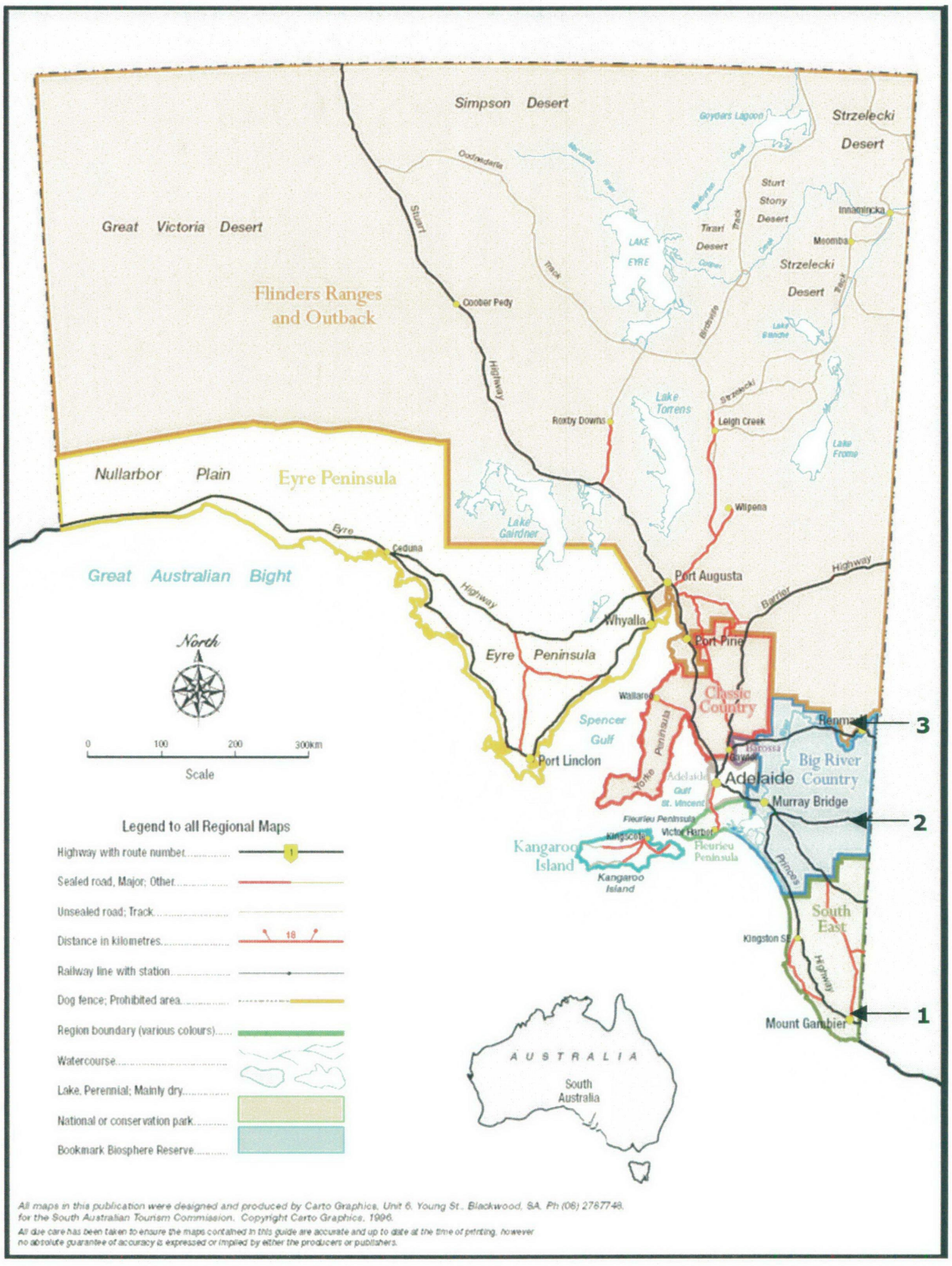

Figure 2-2 Map of South Australia, with references to: 1 Mount Gambier; 2 Lameroo and 3 Waikerie. Source: http://www.adhills.com.au/tourism/maps

2.3 Climate

2.3.1 Myora Farm

Mount Gambier had an average annual rainfall of 711.5 mm, considering the last 64 years, with higher volumes of water falling during winter as shown in Table 2-1. During eight months of the year sub-zero temperatures were recorded. Same number of months was recorded with temperatures over 30°C. Although having extreme temperatures most part of the year, the mean maximum and minimum temperatures recorded at Mount Gambier are more moderate than those recorded at Waikerie and Lameroo, particularly during the warmer months.

Table 2-1 Monthly mean maximum and minimum temperatures, highest maximum and lowest minimum temperature and mean rainfall for Lameroo and Waikerie SA (Bureau of Meteorology, 2004)

Element	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Maximum Temperature (°C)	Mt Gamb.	25.1	25.1	23	19.4	16.1	13.8	13.1	14	15.8	17.7	20.2	22.7
	Waikerie	33	31.4	29.2	24.1	19.5	16.9	16.5	18	20.8	24.1	27.4	29.9
	Lameroo	30.8	30.5	27.6	22.8	18.6	15.5	15	16.3	19.3	22.4	26	28.9
Highest Daily Max Temperature (°C)	Mt Gamb.	43.5	43.6	41.1	34.4	28.5	21.6	22.4	24.8	32.2	33.3	41.2	42
	Waikerie	46.5	45	41.6	35.7	30.3	26.1	28.7	31.6	35	40	44.2	44.2
	Lameroo	47.9	46.2	42.1	38.4	30.3	25.6	26.6	29.5	40	39.2	43.3	44
Mean min Temp (°C)	Mt Gamb.	11	11.6	10.4	8.6	7.2	5.7	5.1	5.4	6.2	7.1	8.2	9.9
	Waikerie	15.2	14.9	13.4	10.8	7.9	6.3	5.2	6	7.6	9.9	11.5	13.5
	Lameroo	13.2	13.5	11.4	8.9	6.9	5.1	4.3	4.7	5.9	7.7	9.9	12
Lowest daily Min Temp (°C)	Mt Gamb.	1.4	2.8	0	-1.8	-2.8	-3.9	-3.9	-2.6	-3.4	-1.6	-0.8	1.2
	Waikerie	3.9	8.3	6.4	2.8	0.2	-3.1	-1.7	-0.6	0	1.7	3.3	4
	Lameroo	3.9	4.6	3.4	0.1	-0.6	-3.9	-3.9	-2.2	-1.1	-0.6	1.7	3.9
Mean monthly rainfall (mm)	Mt Gamb.	26.5	25.6	35.8	54.7	71.8	84.7	99.6	93.5	72.8	62.6	46.5	37.4
	Waikerie	15.7	21.6	12.5	17.3	25	25.1	22	23.6	24.4	26.2	19.7	20
	Lameroo	19	22.6	18.3	27.3	40.6	41.5	41.9	44.6	42.7	38.4	26.6	24

2.3.2 Top Pork Network farms

The two piggeries are located in very dry areas of South Australia; Waikerie has an average yearly rainfall of 253.1 mm per year and Lameroo 387.5 mm per year (Table 2-1). Both regions have higher rainfall during the winter months; however at Waikerie this pattern is not so evident.

Both areas are very hot during summer months (November till March) reaching temperatures above 40 degrees during five and six months per year in Lameroo and Waikerie respectively. In addition, Lameroo has sub-zero temperatures over six months of the year, while Waikerie has them only during four months per year.

2.4 Data Recording of Reproductive Traits

2.4.1 Myora Farm

The following reproductive traits were available for Myora Farms' maternal lines:

- **Total Number of Piglets Born (TNB)**

After farrowing, the total number of piglets born is recorded. Fully formed piglets born dead are included in this trait. Mummified piglets are not included.

- **Number of Piglets Born Alive (NBA)**

Fully formed piglets that are born alive, include those that died minutes after farrowing. Dead piglets are examined individually to determine wether they are stillborn piglets. All piglets included in this trait are recorded within hours after farrowing ends.

- **Average Piglet Birth Weight (AvBW)**

The entire litter is weighed up to 12 hours after farrowing. All NBA piglets are weighed and the total litter weight is divided by the NBA in order to obtain an average piglet birth weight (AvBW).

- **Average Piglet Weight at 21 days (Av21dW)**

The entire litter is weighed at exactly 21 days post-farrowing. Piglets fostered on are included and piglets fostered off are excluded. The litter weight is divided by the number of piglets weighed in order to obtain an average piglet weight at 21 days (Av21dW).

- **Number of Piglets Weaned (NWea)**

The number of piglets weighed at 21 days post-farrowing is considered as the number of piglets weaned (NWea).

- **Gestation Length (GL)**

For each litter the mating date is recorded as well as the farrowing date. The trait gestation length (GL) is obtained by subtracting the mating date from the farrowing date.

2.4.2 Top Pork Network Farms

The same traits are also measured at Piggery 'A' and Piggery 'B'. The only difference is that for the trait Av21dW, the date of weighing the litter is not "exactly" 21 days post-farrowing like at Myora Farm. Therefore, this trait will be called average weaning weight (AvWW) for these two piggeries.

2.5 Management practices

2.5.1 Myora Farm

Approximately at four months of age the purebred gilts and boars with a good structure as well as pedigree are pre-selected and moved to pens into the breeders' shed. Purebred gilts are regularly assessed towards their maturity in regards to structural soundness and conformation. Their estimated breeding values (EBVs) and total merit index ($Index) are used to asses their genetic merit.

The EBVs used at Myora Farm are obtained from the on-farm genetic evaluation system PIGBLUP (Crump, 2003) that is run on a weekly basis. The $Index is used in order to select more efficiently for a number of traits, and to provide the selection team with a better tool at the moment of selection to assess the genetic merit of gilts and boars.

Pre-selected purebred gilts are used as replacements at the multiplier herd for their first mating. After the first litter, gilts face a new selection process that evaluates if they deserve to be part of the nucleus herd. This second selection process will evaluate their reproductive performance at their first parity at the multiplier level, as well as specific structural characteristics that distinguishes Myora Farm's sows. Nucleus replacements are usually second parity gilts or older.

Crossbred gilts at approximately four months of age will be assessed towards their structural soundness and conformation and will be moved to the breeders' shed. Different types of gilts are later selected in order to be sent to the Top Pork Network farms according to their specific requests and preferences.

Sixty sows farrow at Myora Farm every week. Cross-fostering of piglets is done from the moment they are born till a few days later. The aim of this management practice is to even the number of piglets in all the litters, helping those sows with high numbers of piglets born alive, as well as relieving those sows with udder problems or any other problem that could reduce their ability to raise healthy piglets.

Sows that are in their seventh or older parities are induced to farrow, with a lutelize injection, if they haven't farrowed by their due date (i.e. at 115 days post-mating). Sows younger than seventh parity are not induced.

2.6 Production Levels

2.6.1 Myora Farm

The reproductive performances from both maternal lines at Myora Farm recorded over the last ten years (1995 to 2004) are shown in Table 2-2. Litter size (NBA) average across the first ten parities was 11.83 for LW and 11.3 for LR. Comparing these figures with the average for the year 2003 published by Australian Pork Limited, where the average performance for NBA was shown to be 10.50 piglets with a range between 8.39 and 11.39 (APL, 2003). The highest figures from this overview are below Myora Farm's average performance over the last ten years for the LW breed. In addition, there was almost half a piglet difference between the Large White and Landrace breeds at Myora Farm for this trait due to the development of hyperprolific lines in the Large White breed over the last 10 years.

The trait NWea was defined as the number of piglets weaned by every sow that farrowed at least 2 piglets born alive. This definition does not include litters of foster sows that after weaning their own litter will stay in the farrowing shed rearing a new litter formed by fostering piglets from sows that will be culled for not being able to rear more than 5 piglets each. In this case, the culled sows will have a record of 0 piglets weaned and the foster sow will only have a record of her first litter. Including those litters from foster sows, the NWea performance exceeded 10 piglets weaned in both breeds averaged over the last ten years, however for the purpose of this study, those litters were excluded. Landrace sows at parities two and older had a higher performance for NWea than the Large White sows (Table 2-2). This difference reflects the superior maternal ability shown by this breed over the past ten years at Myora Farm.

Landrace sows farrowed heavier piglets on average than Large White sows across all parities (Table 2-2). In addition, these sows reared heavier piglets on average at 21 days after farrowing. Gestation length was longer on average for Landrace than for Large White sows by approximately half a day.

Table 2-2 Number of records (N), mean values, standard deviations (SD) and coefficient of variation (CV) for reproductive traits from Myora Farms' Large White and Landrace sows

	Landrace				Large White			
Parity	**N**	**Mean**	**SD**	**CV**	**N**	**Mean**	**SD**	**CV**
				Number Born Alive				
1	1,752	10.55	2.55	24.2	2,657	10.84	2.73	25.2
2	1,458	10.96	2.74	25.0	2,276	11.38	3.02	26.5
3	1,241	11.87	2.69	22.7	1,868	12.32	2.92	23.7
2-10	5,541	11.53	2.78	24.1	8,374	12.14	2.97	24.5
				Total Number Born				
1	1,752	11.21	2.67	23.8	2,657	11.59	2.88	24.8
2	1,458	11.65	2.89	24.8	2,276	12.06	3.23	26.8
3	1,241	12.94	2.91	22.4	1,868	13.30	3.25	24.4
2-10	5,541	12.78	3.05	23.9	8,374	13.28	3.33	25.1
				Number of Piglets Weaned*				
1	1,752	7.99	4.25	53.2	2,657	8.05	4.08	50.7
2	1,458	8.63	3.85	44.6	2,276	8.49	3.87	45.6
3	1,241	8.57	3.82	44.6	1,868	8.16	3.96	48.5
2-10	5,541	8.21	3.98	48.5	8,374	8.02	4.03	50.3
				Average Piglet Birth Weight				
1	913	1.52	0.23	15.1	1,109	1.43	0.24	16.8
2	811	1.67	0.27	16.2	979	1.61	0.27	16.8
3	706	1.62	0.25	15.4	870	1.56	0.25	16.0
2-10	3,241	1.60	0.26	16.3	4,221	1.53	0.26	17.0
				Average Piglet 21 day Weight				
1	1,378	6.25	0.80	12.8	2,152	6.10	0.84	13.8
2	1,205	6.75	0.76	11.3	1,916	6.60	0.87	13.2
3	1,023	6.88	0.71	10.3	1,536	6.65	0.87	13.1
2-10	4,447	6.81	0.74	10.9	6,810	6.60	0.87	13.2
				Gestation Length				
1	1,749	115.51	1.41	1.2	2,654	115.15	1.38	1.2
2	1,455	115.86	1.44	1.2	2,275	115.32	1.42	1.2
3	1,240	115.76	1.41	1.2	1,867	115.31	1.43	1.2
2-10	5,532	115.81	1.42	1.2	8,367	115.29	1.42	1.2

* The trait Number of piglets weaned at Myora Farm didn't include the records of foster sows. In addition the sows that were culled and their piglets fostered off will have a record of 0.

2.6.2 Top Pork Network farms

There was no difference in the litter size performance between both piggeries. Number of piglets born alive and total number born had no significant differences ($P<0.05$) across piggeries for parity 1 and parities 2 to 10 (Table 2-3).

Table 2-3 Number of records (N), mean values, standard deviations (SD) and coefficients of variation (CV) for reproductive traits, from Piggery 'A' and Piggery 'B'

	Piggery 'A'				Piggery 'B'			
Parity	**N**	**Mean**	**SD**	**CV**	**N**	**Mean**	**SD**	**CV**
				Number Born Alive				
1	574	10.90	2.78	25.5	3,158	10.89	2.81	25.8
2	488	10.85	2.90	26.7	2,878	10.95	2.85	26.0
3	402	11.45	2.71	23.7	2,608	11.66	2.88	24.7
2-10	2,064	11.29	2.85	25.2	15,135	11.32	2.93	25.9
				Total Number Born				
1	574	11.45	2.85	24.9	3,158	11.34	2.85	25.1
2	488	11.25	2.95	26.2	2,878	11.39	2.96	26.0
3	402	12.12	2.82	23.3	2,608	12.25	2.97	24.3
2-10	2,064	12.09	2.97	24.6	15,135	12.13	3.08	25.4
				Number of Piglets Weaned				
1	574	9.58	2.17	22.7	3,158	9.75	1.68	17.2
2	488	9.68	2.24	23.1	2,878	9.97	1.57	15.7
3	402	9.71	2.34	24.1	2,608	9.92	1.55	15.6
2-10	2,064	9.47	2.36	24.9	15,135	9.69	1.68	17.3
				Average Piglet Birth Weight				
1	574	1.46	0.25	17.1	609	1.47	0.25	17.0
2	485	1.60	0.27	16.9	553	1.61	0.24	14.9
3	401	1.57	0.28	17.8	531	1.60	0.26	16.3
2-10	2,052	1.55	0.26	16.8	3,077	1.57	0.26	16.6
				Average Piglet Weaning Weight				
1	508	6.24	1.07	17.2	333	6.69	0.94	14.1
2	430	6.20	1.07	17.3	308	7.02	0.93	13.3
3	353	6.25	0.99	15.9	310	7.25	0.86	11.9
2-10	1,835	6.20	1.03	16.6	1,832	7.18	0.89	12.4
				Gestation Length				
1	571	114.66	1.27	1.1	3,150	115.19	1.25	1.1
2	485	114.61	1.21	1.1	2,871	115.25	1.30	1.1
3	397	114.51	1.19	1.0	2,600	115.13	1.27	1.1
2-10	2,043	114.66	1.24	1.1	15,095	115.22	1.31	1.1

Number of piglets weaned was 0.22 of a piglet higher in Piggery 'B' than in Piggery 'A' for parities 2 to 10. The variability of this trait was higher at Piggery 'A' with a coefficient of variation (CV) of 24.9% against 17.3% of Piggery 'B'. When NWea by foster sows was considered this difference rose to 0.47 piglets. There was also a clearly higher AvWW of almost 1kg at Piggery 'B' based on parities 2 to 10. However these piglets were on average 1.5 days older than the ones at Piggery 'A'. There was a difference between the gestation lengths at Piggery 'B' and Piggery 'A'. On average sows from Piggery 'B' farrowed almost half a day later than sows from Piggery

'A'. The difference relies on the management of the sows due to farrow. At Piggery 'A' all sows, except those due on Wednesdays and Sundays, are induced to farrow, one day prior to their due date (i.e. 114 days after their mating date). In comparison Piggery 'B' sows due on Saturday or Sunday are induced on Monday and sows due on Friday are induced on Thursday to avoid having them farrowing on the weekend.