Investigation into the influence of yearling sale production parameters on the future career longevity and success of New Zealand thoroughbred race horses

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Kristi Louise Waldron

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Abstract

Few studies have investigated the influence of yearling sale production parameters on racing performance of Thoroughbred horses. The aim of this study was to quantify the impact of yearling sales parameters, in particular dam (mare) age at the time of conception, on future career success and longevity in a population of Thoroughbred racehorses in New Zealand. A retrospective cohort study was used to investigate racing success and longevity in a population of Thoroughbred horses in New Zealand, over eight and a half racing seasons. Retrospective records of the 2002 born Thoroughbred foals in New Zealand were obtained from the New Zealand Bloodstock (NZB) online database and the New Zealand Thoroughbred Racing (NZTR) database. Logistic regression models using the binary outcomes trial, race and prize money earned were analysed with exposure variables. Cox regression survival analysis was used to investigate the association between the number of race starts and the time to cessation of racing. Linear regression was preformed to assess the effect of exposure variables with the outcome measure prize money earned (*ln,* $NZ).

A total of 513 horses ran in 8,261 flat races, in New Zealand, during the study period. Of all the horses that had at least one race start (n=513), the median number of race starts per horse was twelve (IQR 5-22). The age of a horse's dam (mare) at the time of conception was not significantly associated with; 1) her progeny obtaining a trial or race start, 2) her progeny racing and earning >$1 prize money, 3) the amount of prize money earned by her progeny, and 4) longevity of her progeny's career. Female horses had less race starts during their career (P=0.019) compared to male horses. The median number of race starts for a female was eleven (95% C.I 9-14) whereas, the median number of race starts for a male was thirteen (95% C.I. 10-15). Horses catalogued in the select session were more likely to earn prize money (P=0.029) compared to horses catalogued in the premier session. Horses catalogued in the festival session were more likely to cease racing compared to horses catalogued in the premier session (P=0.018). The median number of race starts for a horse catalogued in the premier session was ten (95% C.I. 8-14) compared to fourteen (95% C.I. 12-16) for the select session and ten (95% C.I. 8-13) for the festival session. Horses that had started in a trial were more likely to start in a race (P<0.001) and earn prize money (P<0.001) compared to horses that had not started in a trial. As the number of years racing increased the likelihood of a horse ceasing racing decreased (p<0.001). Linear regression showed that total career starts was the greatest predictor in determining the amount of prize money a horse will earn. Horses that had more than twenty-five race starts were more likely to earn more prize money (*ln*) compared to horses that had less than twenty-five race starts (P<0.001).

The results of this study highlight associations, or lack thereof, between yearling sales parameters and outcome measures of performance and may influence the future buyer behaviour in the New Zealand Thoroughbred market.

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List of Abbreviations

>	Two year-old
2YO	Three year-old
3YO	Three year-old or above
3YO+	Average Earnings Index
AEI	Confidence interval
CI	Early Embryonic Death
EED	Gross Domestic Product
GPD	Hazard ratio
HR	International Federation of Horseracing Authorities
IFHA	Inter-quartile range
IQR	Natural logerithmic
ln	Natural logarithmic of prize money in $NZ
ln (prize money $NZ)	Likelihood ratio statistic
LRS	National Yearling Sales Series
NYSS	New Zealand Bloodstock
NZB	New Zealand Racing Board
NZRB	New Zealand Thoroughbred Racing
NZTR	Odds ratio
OR	Performance index
PI	Standard Starts Index
SSI	World Thoroughbred Rankings Conference
WTRC	

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Chapter one

Introduction

The New Zealand racing industry generates $1.635 million in revenue annually, which represents approximately 1% of the total Gross Domestic Product (GPD), and provides 16,930 people in New Zealand with full-time employment (Anonymous, 2010a; Fennessy, 2010). This revenue is derived from the production of racing stock, exportation of horses, overseas buyer investments, wagering, government wagering tax, and returns to owners (Anonymous, 2004; Anonymous, 2010a). As well as these direct earnings, the industry also has multiplicative effects on related industries such as the indirect income generated from transportation, utilities, communications, wholesale and retail trade, manufacturing, real estate and insurance (Buzby & Jessup, 1994; Thiruvenkadan *et al.*, 2009). In New Zealand, the Thoroughbred industry is the most prominent equine industry, providing 72.2% ($791 million) of the total industry share (Anonymous, 2010a; Rogers & Cogger, 2010). The Thoroughbred industry relies heavily on international buyers to sustain market values, with approximately 65% of the total yearling sales revenue originating from overseas buyers (Rogers *et al.*, 2009; Anonymous, 2010a).

Racing in New Zealand is controlled, in majority, by one governing body, the New Zealand Racing Board (NZRB). The NZRB is appointed by the Minister of Racing and is comprised of representatives from the three race codes (Thoroughbred, Harness and Greyhound), and includes some non-racing professionals (Anonymous, 2010c). The NZRB controls the racing calendar and the distribution of betting licenses. They develop polices within the industry and the rules associated with betting. They are also the drivers for research done in order to expand and enhance the future of the industry and its associated profits. Ultimately, the NZRB are the link between the racing industry and the Minister of Racing. All profits from gambling are received and distributed to the three racing codes by the NZRB in an attempt to secure a strong future in New Zealand's racing industry. New Zealand Thoroughbred Racing (NZTR) is the authority responsible for the management and production of the Thoroughbred industry and reports to the NZRB.

In the 2003-2004 season there were fifty-two Thoroughbred racecourses distributed throughout New Zealand, thirty of which are located in the North Island. During this season these racecourses held a total of 283 tote meetings where 5,564 horses ran in 2,791 races all trying to claim a piece of the $36.2 million in prize money that was on offer (Anonymous, 2004; Anonymous, 2010b). In the 2009-2010 season two racecourses ceased to operate commercially. However, during this season there was an observed increase in the number of tote meetings (328), horses racing (5,794), races run (3,068) and the total prize money on offer ($49.6 million) (Anonymous, 2010a; Anonymous, 2010b).

A large number of Thoroughbred horses are offered for sale prior to commencing their career as a racehorse. The New Zealand Bloodstock (NZB) National Yearling Sales Series (NYSS) presents around 1,500 yearlings annually, which represents approximately 24% of the annual foal crop. These yearlings are allocated into one of three sales categories; premier, select or festival. The sales company selection committee meets in August to establish the number of entries and tentatively place nominated yearlings into sales categories based on pedigree. Bloodstock agents from the auction house then go into the field and assess all nominated yearlings based on growth/size and conformation. At the end of the selection process the committee is reconvened to make the final allocation of yearlings into each sales category.

The 2004 NZB NYSS saw 1,113 lots sell, for an aggregate price of $60.6 million and a clearance rate of 82%. The average price fetched for a yearling was $54,476, with the top price being $1.1 million (Anonymous, 2010b). Moreover, during the 2003-2004 season, 1,797 horses were exported for a total value of $115 million (Anonymous, 2010b). The sustainability of the local breeding industry can be attributed, in part, to the income generated from exports; therefore, international recognition is a crucial feature of the New Zealand Thoroughbred industry. Currently, New Zealand has an unsurpassed reputation for breeding high class, internationally competitive Thoroughbred racehorses. This is represented in the recent success of New Zealand bred horses in international group one events; including races in Hong Kong, Singapore, Dubai and Australia (Anonymous, 2010a; Anonymous, 2010b; Fennessy, 2010).

Previous studies have examined how yearling sale production parameters influence sales price in Britain (Robbins & Kennedy, 2001; Parsons & Smith, 2008), America (Commer, 1991; Buzby & Jessup, 1994; Chezum & Wimmer, 1997; Vickner & Koch, 2001), Australia (Hastings, 1987) and New Zealand (Waldron *et al*., 2010). Yearling specific variables such as gender, birth month, size and conformation have found to be associated with sales price (Robbins and Kennedy 2001; Parsons and Smith 2008; Waldron *et al.* 2011). Factors such as the sire and dam pedigree and the performance of the sire, dam and progeny have also been found to be associated with sales price (Hastings 1987; Parsons and Smith 2008). Furthermore, extensive research has been done to investigate the influence of a range of factors that influence racing performance in Thoroughbreds, including early exercise (Perkins *et al.*, 2004a,b; Rogers *et al.*, 2008) exercise during training (Perkins *et al.*, 2004a,b; Verheyen *et al.*, 2009; Bolwell *et al.*, 2010a,b), respiratory conditions (Stick *et al.*, 2001; Strand *et al.*, 2000), skeletal development in response to training (Firth & Rogers, 2005; Rogers *et al.*, 2008; van Weeren *et al.*, 2008; Verheyen *et al.*, 2009), wastage in the racing industry (Jeffcott *et al.*, 1982; Bailey *et al.*, 1999; McCarthy, 2009) and career longevity (Ricard & Fournet-Hanocq, 1997; Bailey *et al*., 1999; Burns *et al.*, 2006; Sobczynska, 2007; Cheetham *et al*., 2010; Tanner *et al.*, 2010). However, despite the extensive research that has been undertaken with regards to yearling sales and racehorse performance, it is somewhat surprising that there is a paucity of data examining how yearling sale production parameters influence the future racing performance of racehorses.

The aim of this study was to quantify the impact of yearling sale production parameters, specifically, birth month of yearling, gender of yearling, sales category and dam (mare) age at the time of conception (dam (mare) age is the *a priori* variable of interest), on future career success and longevity in a population of Thoroughbred racehorses in New Zealand. The objectives were to a) investigate the association between yearling sale production parameters and the length of a horse's career, in terms of years raced and number of race starts, and b) to investigate the association between yearling sale production parameters and the career success of horses (*ln* prize money earned). This study elaborates on a pilot study undertaken by Waldron *et al.* (2010). These authors investigated yearling sale production parameters that influenced the auction sales price of New Zealand Thoroughbred yearlings.

Chapter two

Literature Review

2.1 SIZE AND SCOPE OF THE NEW ZEALAND THOROUGHBRED INDUSTRY

2.1.1 International

On an international scale, the New Zealand Thoroughbred industry ranks around eleventh with respect to the number of horses starting in flat races per season, and around eighth with respect to the number of foals bred per season. *Table 2-1* provides an international comparison of the top thirteen Thoroughbred racing and breeding industries (Fennessy, 2010).

Table 2-1: International Thoroughbred industry rankings for 2007 according to prize money for 2008 (Fennessy, 2010).

Country	No. of foals	Starters in flat races	Flat races run	Total prize money ($US million, 2008)
USA	36,071	67,930	51,132	$1,165
Japan	7,516	24,143	17,476	$1,220
Australia	18,255	31,419	19,382	$421
France	5,384	8,726	4,156	$335
Great Britain	5,839	11,323	5,659	$158
Canada	2,632	7,482	5,057	$127
Hong Kong	Nil	1,154	726	$98
Ireland	12,633	3,458	958	$84
Argentina	7,538	11,123	6,101	$64
Singapore	Nil	1,099	704	$41
New Zealand	4,338	5,489	2,734	$40
South Africa	3,246	6,567	3,883	$31
Macau	Nil	768	737	$23

2.1.2 Breeding in New Zealand

Over the 2008-2009 season there were 8,326 registered broodmares in the country (see *Figure 2-1*). Interestingly, this number has been in steady decline (a total decline of 8%) since the 1999-2000 season, where 9,015 broodmares were registered. The number of stallions standing in New Zealand during the 2008-2009 season reached 166, an approximate decline of 31% since the 1999-2000 season. The decline in the number of both broodmares and stallions has resulted in an unavoidable decline in foal crop. Throughout the 2008-2009 season, 4,288 foals were registered. In comparison, 4,868 foals were registered in the 1999-2000 season. This equates to a 12% decline over the years, and reflects the economics of breeding horses for sale (Anonymous, 2009; Anonymous, 2010b; Fennessy, 2010). It is imperative to keep the breeding numbers high in order to improve industry sustainability. There has been an observed shift in the Thoroughbred market, as the market for low to mid quality foals and broodmares is exhibiting a greater decline. On the other hand the number of mares being mated with commercially appealing stallions is increasing. These commercially appealing stallions are now aggressively marketed and as a result attract the most genetically desirable broodmares. The remaining stallions get a selection of second tier mares with less genetic potential thus, in the wake of the economic recession, making it difficult to sell the resultant foals. As a result, many low profile owners (owners of low service fee stallions and second tier broodmares) have parted with the Thoroughbred industry (Castle *et al.*, 2008).

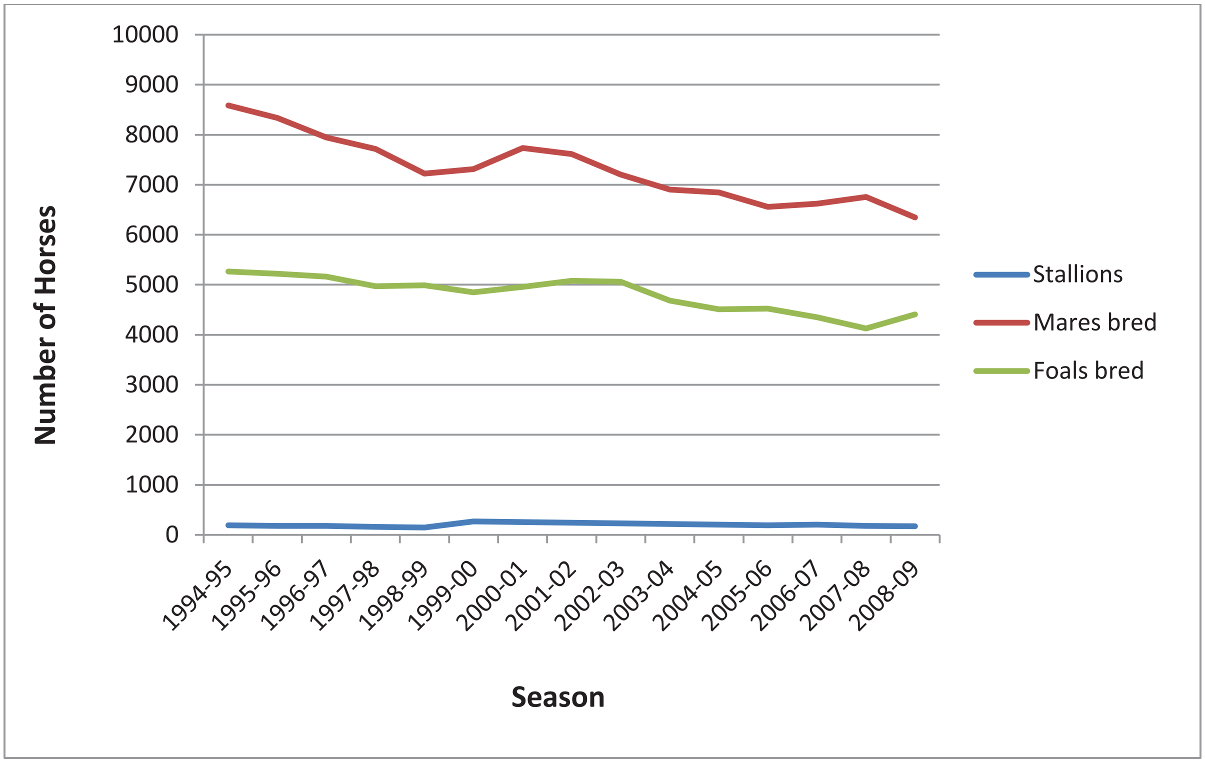

Figure 2-1: New Zealand Thoroughbred breeding trend from 1994-2009 (Anonymous, 2010b).

2.1.3 Yearling sales in New Zealand

Each year, approximately 1,500 yearlings (24% of the annual foal crop) are offered for sale at the NZB NYSS, with an average clearance rate of 78% over the past ten years. The aggregate value and average price fetched for a yearling has been increasing relatively steadily since 2001, with 2008 an exception (2008 was a peak year where 1,171 lots were sold accumulating an aggregate value of $NZ111 million). Meanwhile, the number of lots sold, the percentage of annual foal crop and clearance rate has remained relatively uniform.

Table 2-2: NZB NYSS statistics from 2001 to 2010 (Anonymous, 2010b).

Year	Number of Lots sold	% of foal crop	Clearance rate	Aggregate ($NZ)	Average ($NZ)	Top Price ($NZ)
2001	1,165	23%	76%	68.3 million	58,220	1.45 million
2002	1,170	23%	76%	54.6 million	46,670	1.05 million
2003	970	19%	72.5%	47.2 million	48,690	0.66 million
2004	1,113	24%	82%	60.6 million	54,476	1.10 million
2005	1,029	23%	78%	69.6 million	67,666	1.30 million
2006	1,043	23%	79%	65.7 million	63,012	2.20 million
2007	1,023	24%	83%	81.3 million	79,546	2.00 million
2008	1,171	28%	83%	111.2 million	94,918	1.45 million
2009	1,199	27%	76%	74.6 million	62,239	0.80 million
2010	1,129	27%	76%	93.6 million	82,876	2.00 million

2.1.4 Exports from New Zealand

Since 1999, New Zealand has exported approximately 39% of the annual foal crop, for an estimated $NZ120 million, annually (see *Table 2-3*). Hence, exports are a predominant feature of the New Zealand Thoroughbred industry. Once a New Zealand bred horse has won a race or a trial, they can potentially become a target of export for other countries trying to strengthen their own racing industries. This strong reputation held by New Zealand bred horses helps to drive the export market. International recognition is therefore crucial to ensure there is an ongoing demand for New Zealand racing stock thus, sustaining the domestic industry (Anonymous, 2010a; Fennessy, 2010). Australia is the biggest export market and in turn buyer of New Zealand bred horses, however the Asian market is becoming increasingly predominant (see *Figure 2-2*).

Table 2-3: New Zealand Thoroughbred export statistics from 1999 to 2010 (Anonymous, 2010b).

Season	Number of Exports	% of foal crop	Value of Exports ($NZ)
1999-00	1,937	40%	110 million
2000-01	2,000	40%	115 million
2001-02	1,914	38%	115 million
2002-03	1,763	35%	115 million
2003-04	1,797	38%	115 million
2004-05	1,803	40%	120 million
2005-06	1,831	40%	125 million
2006-07	1,888	43%	130 million
2007-08	1,670	40%	145 million
2008-09	1,578	36%	130 million
2009-10	1,465	35%	140 million

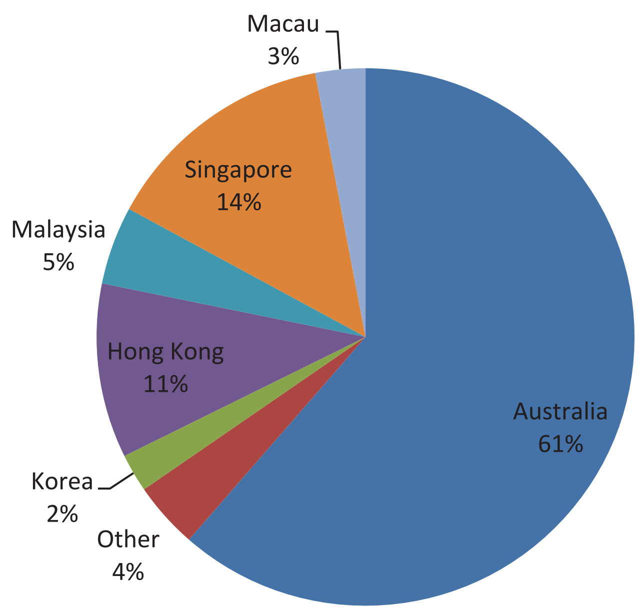

Figure 2-2: The New Zealand Thoroughbred international export market share (Anonymous, 2010a).

2.1.5 Racing in New Zealand

The number of Thoroughbred race meetings held at racecourses all over New Zealand has remained relatively constant over the last sixteen years (see *Table 2-4*). The number of horses in the racing population declined by 15% until the 2000-2001 season where the number of horses racing have since been climbing relatively steadily, reaching levels 10% below the 1994-1995 peak season. The number of races being run has also declined by 15%, until the 2001-2002 season where the amount of races run were in line with the number of the individual horses racing. The number of races run has since increased to 3,068, only 5% below the sixteen year high (3,254) in 1994-1995. Despite these facts, very few fluctuations have been observed in the number of trainers in New Zealand over the past sixteen years. However, the 2008-2009 season bucked this trend and saw a 25% increase from the previous season although these numbers have since declined to be in line with the previous sixteen years. In addition, there has been a 31% decline in the number of jockeys registered in New Zealand since the 1995-1996 season. This decline could be due, in part, to the more attractive prize money and therefore, higher earning potential that is on offer abroad. The total prize money on offer has been steadily increasing since 1995, until the 2005-2006 season where a significant rise of 33% was observed from $NZ39.7 million in 2005-2006 to $NZ58.4 million in 2008-2009. Based on the number of starters and wagering turnover in the 2008-2009 season, Thoroughbred racing in New Zealand would generate an additional income of over $NZ0.6 million if starter numbers increased by 2.5% (145 additional horses having a start). Furthermore, if starters were increased by 5%, equating to 291 additional horses starting, the additional income would increase to over $NZ1.25 million. If these starter numbers were increased by 8.5% (495 additional horses starting) the additional income to New Zealand Thoroughbred racing would be over $NZ2 million. Finally, if starter numbers again reached the levels of the 1994-1995 season, there would be an additional income of over $NZ2 million available to the Thoroughbred industry. This increase in revenue could then be distributed accordingly, thereby increasing stakes, improving club facilities and providing an overall improved service to the community (Anonymous, 2009).

Table 2-4: New Zealand Thoroughbred racing statistics from 1995-2009 (Anonymous, 2010b).

Season	Meetings	Horses raced	Races Run	Trainers	Jockeys	Prize money ($NZ)
1994-5	331	6,426	3,254	410	146	28.2million
1995-6	328	6,171	3,242	423	194	30.3million
1996-7	326	6,124	3,206	417	188	30.5million
1997-8	320	5,973	3,142	397	181	31.4million
1998-9	314	5,837	3,074	387	177	31.8million
1999-0	301	5,599	2,945	383	180	31.8million
2000-1	286	5,462	2,793	369	166	32.2million
2001-2	289	5,493	2,771	348	112	32.0million
2002-3	286	5,469	2,810	361	154	35.0million
2003-4	283	5,564	2,791	354	159	36.2million
2004-5	295	5,706	2,807	366	129	37.2million
2005-6	296	5,642	2,855	351	116	39.7million
2006-7	299	5,566	2,863	333	124	49.4million
2007-8	326	5,576	2,970	353	112	56.2million
2008-9	333	5,826	3,088	474	131	58.4million
2009-10	328	5,794	3,068	370	133	49.6million

Regardless of the fall in starting numbers, the average earnings per runner have dramaticly increased 45% in just four years (from $NZ6,524 to $NZ10,026) (see *Table 2-5*). The average stakes per race has also significantly increased approximately 30%, from $NZ13,262 in 2004-2005 to $NZ18,932 in 2008-2009. The average number of starts per runner per season has returned to levels as seen ten years ago after facing an all time low from 2003-2006 (Anonymous, 2009). It has been predicted that increasing the amount of starts by half a start per horse (to 6.4) will increase the domestic wagering turnover by approximately $NZ20 million (Anonymous, 2009).

Table 2-5: New Zealand Thoroughbred race statistics per horse in from 2005-2009 (Anonymous, 2010b).

Season	Ave. Starts per runner	Ave. Stakes Per race ($NZ)	Ave. Earnings per runner ($NZ)
2004-5	5.5	13,262	6,524
2005-6	5.5	13,915	7,041
2006-7	5.7	17,265	8,881
2007-8	5.8	18,932	10,084
2008-9	5.9	18,932	10,026

2.1.6 Wagering in New Zealand

On-course, off-course and total betting turnover has decreased dramatically since the 1997-1998 season, with numbers falling 20%, 17% and 9%, respectively. As a result of the introduction of fixed odds betting, its subsequent popularity, and also the increase in on- and off-course betting, total betting started to improve, increasing from $NZ423 million in 2003-2004 to $NZ482 million in 2007-2008 (13% increase). However, during the 2008-2009 season, there was a significant drop in on- and off-course betting which resulted in an unavoidable decrease in total betting. This could be attributed to the introduction of casinos, poker machines, and lotto facilities, which provided greater gambling opportunities to the public.

Table 2-6: New Zealand totalisator turnover on New Zealand Thoroughbred racing from 1998-2009 (Anonymous, 2010b).

Season	On-course Betting ($NZ)	Off-course Betting ($NZ)	Fixed Odds Betting ($NZ)	Total Betting ($NZ)
1997-8	58.5million	452.9million		511.4million
1998-9	54.8million	452.9million		479.2million
1999-0	50.4million	411.1million		461.5million
2000-1	48.2million	388.0million		436.3million
2001-2	46.7million	373.6million		420.3million
2002-3	48.2million	369.4million	1.6million	423.7million
2003-4	46.5million	377.3million	3.7million	423.3million
2004-5	45.5million	380.5million	8.8million	443.6million
2005-6	44.2million	382.3million	30.0million	456.7million
2006-7	47.8million	385.1million	32.8million	465.6million
2007-8	48.6million	392.5million	41.2million	482.3million
2008-9	46.6million	377.2million	42.1million	465.9million

2.2 GROWING FOALS AND YEARLING PREPARATION

2.2.1 Demand for producing a yearling

The demand for producing a Thoroughbred yearling is initially derived by bettors investing in wagering pools that in turn supply the prize money that race horse owners compete for (Neibergs & Thelheimer, 1997). Betting in New Zealand is a major contributor to the local economy, the Thoroughbred industry alone provides approximately $NZ466 million in turnover, annually (Anonymous, 2009). The majority of Thoroughbred breeders rely on selling their foals to sustain their breeding operation (Nagy, 2005). The cost of breeding a Thoroughbred foal in New Zealand compares favorably with the rest of the world. This is due to reduced stabling, feeding and veterinary costs which are provided by New Zealand's temperate climate and horse friendly environment. However, the reproductive efficiency of a Thoroughbred mare is relatively low and she will often not fall pregnant in a given season, thus incurring a huge economic loss to her owner (Carnevale & Ginther, 1982; Bruck *et al.*, 1993; Morris & Allen, 2002; Hemburg *et al.*, 2004; Bosh *et al.*, 2009a,b; Nath *et al.*, 2010; Van Rijssen *et al.*, 2010). As a result, breeding Thoroughbred foals can be an extremely risky and expensive process, thus increasing the demand for top tier foals.

2.2.2 Yearling production costs

The breeding process begins with an owner or breeder selecting and valuing the mares with which they want to breed. An appropriate stallion will then be chosen for the mare, usually by evaluating a combination of pedigree, size, conformation and service fee. The expected value imposed on the foal will determine the level of investment into the breeding and rearing process (Nagy, 2005). A summary of the average investment that is required to produce a Thoroughbred yearling fit for yearling sales is provided for a commercial stud farm and a private agistment farm in *Table 2-7*. In addition to these aforementioned costs, and the cost breakdown outlined in *Table 2-7*, the vendor will generally incur a 2-3% commission fee (being 2-3% of the sales price) upon sale of the yearling.

Table 2-7 Cost ($NZ) of producing a Thoroughbred yearling in New Zealand (Anonymous, 2010d).

	Commercial Stud	**Private Agistment Farm**
Agistment	5,000	4000
Feet trim every six weeks	286	286
Drench every six weeks	308	308
Vet costs (ovulation, scanning, drugs)	550	550
Transport to stud	150	150
Sub-Total	**6,294**	**5,294**
Foaling fee	450	400
Agistment & Hard feed	2,525	1683
Foal feet trim every six weeks	132	132
Mare feet trim every six weeks	132	132
Foal & mare drench every six weeks	264	264
NZTR Return (mare)	77	77
Branding & Blood-typing (foal)	176	176
Sub-Total	**3,756**	**2,864**
Weaning Charge	450	350
Agistment	4,500	4080
Feet trim every four weeks	350	350
Drench every six weeks	200	200
Sub-Total	**5,500**	**4,980**
Preparation	4,050	3750
Farrier every four weeks	132	132
Drench every four/six weeks	110	110
Gear hire or purchase	385	330
Shoeing	100	100
Transport	150	150
Sub-Total	**4,927**	**4,572**
Sale Entry	1,500	1500
Promotion & Hospitality	1,650	1100
Sub-Total	**3,150**	**2,600**
X-Rays	900	900
TOTAL COSTS	**$24,527**	**$21,210**

2.3 PRODUCTION PARAMETERS THAT INFLUENCE YEARLING SALES PRICE

Estimating the amount a yearling will sell for at Thoroughbred yearling sales (auctions) has been proven to be very difficult due to the subjective nature of the many phenotypic variables involved (Hastings, 1987; Buzby & Jessup, 1994; Neibergs & Thelheimer, 1997; Neibergs, 2001; Robbins & Kennedy, 2001; Vickner & Koch, 2001; Nagy, 2005; Parsons & Smith, 2008). Conformation, for example, cannot be measured objectively, yet it is a major deterministic variable when estimating the amount a yearling will sell for at auction. As a result, conformation is rarely included in research investigating the cost of a yearling at auction. Existing research has focused on pedigree, gender, birth month, dam (mare) age, vendor, and buyer of a yearling (see: MacCarthy & Mitchell, 1974; Hastings, 1987; Commer, 1991; Buzby & Jessup, 1994; Chezum & Wimmer, 1997; Neibergs & Thalheimer, 1997; Neibergs, 2001; Robbins & Kennedy, 2001; Smith, 2001; Vickner & Koch, 2001; Brown-Douglas *et al.*, 2005; Morel *et al.*, 2007; Parsons & Smith, 2008; Van Rijissen *et al.*, 2010; Waldron *et al.*, 2010)

2.3.1 Pedigree

The sales catalogue provides potential buyers with a detailed summary of the racing performance of the relatives of each yearling. The racing performance of a yearling's sire, his birth date, and the date he retired to stud, sire statistics and his most successful progeny are listed in the catalogue. The maternal relations of each yearling are also listed and include; racing performance, the number of foals, and number of wins by progeny, with black type races highlighted (that is races that have Listed, Group 3, Group 2 or Group 1 status). Hastings (1987) collated data for 617 yearlings that attended one of five sales around Australia in 1984 to determine the yearling specific variables that influence the price fetched for a Thoroughbred yearling at auction. The author found that the price fetched for a yearling at auction was significantly affected by the racing performance of both the sire and the dam (i.e. amount of 'black type' in the pedigree) which was more recently supported by Buzby & Jessup (1994) and Commer (1991). This indicates that buyers are willing to invest in yearlings from successful racing stock. In addition, Parsons & Smith (2008) found that dam performance is more valuable when there is no record of progeny performance and vice versa, but when sufficient information is available on both, it is progeny performance that has the greatest influence on the price fetched for a yearling at auction. This is consistent with the findings of Robbins & Kennedy (2001) and Vickner & Koch (2001). Robbins & Kennedy (2001) reported that buyers focus on the number of progeny that are black type (a black type win raised the price paid for a yearling, at auction, by 16%) and the number of grand-dam progeny that are black type (a black type win raised the price paid for a yearling, at auction, by 5%). Interestingly, yearlings whose dam has had no progeny to race are considered to be on par with yearlings from dams whose progeny have raced and won nothing. Vickner & Koch (2001) stated that various Thoroughbred families, when interbred, have histories of producing successful runners. Reproducing these breeding lines that have previously produced stakes winners should therefore add market value to a similarly bred yearling.

2.3.2 Gender

It is generally perceived that the Thoroughbred yearling market desires colts as opposed to fillies. This is due to the increased earning capacity of colts, as they win a larger proportion of open-class races. Moreover, there is a greater interest for exporting colts to markets such as Hong Kong and colts have a higher residual breeding value (Commer, 1991; Chezum & Wimmer, 1997; Robbins & Kennedy, 2001; Vickner & Koch, 2001; Parsons, & Smith, 2008).

Previous studies by Commer (1991), Robbins & Kennedy (2001) and Parsons & Smith (2008) have proved this perception to be true. Commer (1991) examined data from the Fasig-Tipton mid-Atlantic region sales between 1987 and 1989 and found that Thoroughbred colts command a significantly higher price at auction than fillies. In addition, Parsons & Smith (2008) collected data on every Thoroughbred yearling auction in Britain in 2004 from the British sales catalogue and reported that colts commanded an estimated 46% higher selling price than a filly. In agreement, Waldron *et al.* (2010) examined yearlings catalogued in the 2004 NZB NYSS and reported that colts sold for significantly more than fillies. Robbins & Kennedy (2001) studied all yearlings sold in the British Columbia Thoroughbred yearling auction market from 1985 to 1997 and estimated that the market value of colts is 10% higher than that of fillies. However, Vickner & Koch (2001), Buzby & Jessup (1994) and Hastings (1987) contrastingly found the overall price paid for a yearling at auction to be not significantly different between colts and fillies. The inconsistency reported in the literature regarding the gender effect on sales price may be attributed to the actual quality of the sale being examined. For example in a poor quality sale, colts may command a significantly higher price at auction whereas in a high quality sale the differences in price of a yearling between colts and fillies may be less pronounced.

2.3.3 Sire

Stallion quality is an important determinant of the overall quality of its offspring. A few successful stallions may be all that is needed to sustain the breeding industry in a country, as a stallion can produce many offspring in a given season as opposed to a mare (Smith, 2001). Buzby & Jessup (1994) examined 3,027 yearlings that were sold at the Keeneland yearling sales between 1980 and 1990 and found that the stud fee of a yearling’s sire at the time of the auction was the most influential yearling-specific variable. A sire’s stud fee reflects current market estimation of that stallion's ability to produce future successful racehorses (Vickner & Koch, 2001). This is supported by Robbins & Kennedy (2001) who stated that doubling the amount spent on a stud fee will result in an approximate 45% increase in the price fetched for a yearling. In agreement, Waldron *et al.* (2010) reported a significant effect of sire on yearling sales price which was driven in majority by the significantly lower sales price of yearlings by sires with a service fee of less than $NZ5,000. Furthermore, Parsons & Smith (2008) reported that the stud fee of a yearling's sire at the time of conception had the most influential effect on yearling price. Interestingly, these authors also reported that the price fetched for a Thoroughbred yearling at auction increased by 17% when it was by a first season sire. This is consistent with the findings of Vickner & Koch (2001) who stated that first season sires possess a unique quality, as a comparison cannot be drawn from previous progeny because none exists. In addition, these authors also reported that the price attained for a Thoroughbred yearling at auction decreases as the number of yearlings by the same sire increases. In other words yearlings by the same sire, being sold at the same auction take sales away from each other.

2.3.4 Birth month

Thoroughbred foals are often bred with the intention of attending a yearling sale (Neibergs & Thalheimer, 1997). Strong economic pressure exists for a mare to fall pregnant as early in the season as possible, as older foals usually present size, strength and maturity, compared to their younger counterparts, when offered at a yearling sale (MacCarthy & Mitchell, 1974; Buzby & Jessup, 1994; Vickner & Koch, 2001; Brown-Douglas *et al.,* 2005; Morel *et al.,* 2007; Van Rijssen *et al*., 2010). Older yearlings are more developed physically, and therefore have a greater probability of early success (Parsons & Smith, 2008; Brown-Douglas *et al.*, 2005; Morel *et al.*, 2007). Analogous studies completed by Buzby & Jessup (1994), Vickner & Koch (2001) and

Commer (1991) reported that a later birth month of a Thoroughbred yearling is negatively correlated with the price fetched for that yearling at auction. This supports the theory that yearlings born nearest to the start of the season will command a higher auction price, as they have more time to develop prior to the sale. In addition, Robbins & Kennedy (2001) reported that yearlings born in January or February have an estimated 50% higher market value than yearlings born after February. Also, yearlings born in March or April have a market value that is approximately 18% higher than yearlings born after April (this would correspond to Southern hemisphere yearlings born in August or September and October or November respectively). Waldron *et al.* (2010) documented similar results. These authors reported that yearlings born early in the New Zealand season (July-September) sold for significantly more than those born later in the season (November or December) at yearling sales.

2.3.5 Dam (mare) age and parity

Increasing mare age has been linked to significant decreases in the pregnancy rate, live foal rate, and the survival rate among live foals (Mcdowell *et al.*,1992; Bruck *et al.*,1993; Morley & Townsend, 1997; Morris & Allen, 2002; Hemburg *et al.*, 2004; Bosh *et al.*, 2009a,b; Nath *et al.*, 2010). Older mares have also been found to be more susceptible to degenerative changes in the endometrium and infection in the uterus thus compromising the *in utero* environment of the growing foal (Carnevale & Ginther, 1982; Bruck *et al.*, 1993; Morris & Allen, 2002; Hemburg *et al.*, 2004; Nath *et al.*, 2010; Van Rijssen *et al*,. 2010). Studies have also indicated that foals born from aged, multiparous mares are lighter than those born from younger mares that have had few foals (Hintz *et al.*, 1979; Bhuvanakumar & Satchidanandam, 1989; Wilsher & Allen, 2003). It has been reported that yearlings that are smaller than the generally accepted minimum size, do not maximise sales returns. This bias exists, in part, because of the desire of the purchaser to have a horse that is mature enough to race as a two year old (MacCarthy & Mitchell, 1974; Brown-Douglas *et al.*, 2005; Morel *et al.*, 2007). Evidence also points to an association between parity, dam age and performance of progeny, specifically, first foals tend to be less successful (Barron, 1995; Finocchio & Rosenzweig, 1995). It could therefore be expected that dam (mare) age and parity should play a significant role in determining yearling sales price. However, to the author's knowledge, only three studies (Neibergs, 2001; Vickner & Koch, 2001; Waldron *et al.* 2010) have included the age of the mare as a yearling specific variable. Neibergs (2001) found that the age of a mare negatively affects the sales price, reporting that each additional year a mare ages reduces the yearlings value by approximately $USD3,051. This is in agreement with the study undertaken by Waldron *et al.* (2010). These authors reported yearlings with dams aged between six and twelve years old, obtained greater sales prices than those from dams aged between thirteen and seventeen. Conversely, Vickner & Koch (2001) found mare age not to be a significant factor in determining yearling sales price. The contrasting results presented here indicate that although mare age and parity has not been extensively researched as a variable to determining sales price, an industry bias against older mares may exist.

2.4 REPRODUCTIVE EFFICIENCY OF THE BROODMARE

Thoroughbred foals are often bred with the intention of attending a yearling sale. Strong economic pressure exist for a mare to fall pregnant as early in the season as possible, as older foals usually present size, strength and maturity, compared to their younger counterparts, when offered at a yearling sale. Due to the long gestation period of a mare, around 335-342 days, it has been suggested that a mare must become pregnant within twenty-five days of the start of the breeding season or twenty-five days post-foaling in order to maintain reproductive efficiency (Van Rijssen *et al.*, 2010). Missing this window in consecutive years can have dire consequences, resulting in a successively later foaling period or the mare may eventually have to forfeit an entire season, imposing an economic loss to her owner (Bosh *et al.* 2009).

To an owner, a broodmare is thought of as a potential long term investment (due to the extended period before there is a return on the initial investment). Therefore, reproductive performance must remain consistently high throughout her career to ensure profitability. As a result of these pressures, the Thoroughbred breeding industry has been provided with a significant advantage (due to the high individual value imposed on each animal). The owners are willing to invest in extensive management techniques and methods to maximise the chances of both breeding success and in turn their investment return. However, it has been noted that the broodmare has a relatively low pregnancy rate when compared to other species such as sheep and beef cattle, which are selected for fertility with target/cycle pregnancy rates of over 79% and live birth rates of over 90% (Morris & Allen, 2002). In contrast, the broodmare is selected according to her pedigree and racing merits. Therefore, it can be concluded that extensive management techniques are crucial for these broodmares in order to achieve and maintain a high reproductive efficiency.

The developments in reproductive technology, in particular ultrasonography, have enabled detection of a conceptus in the uterus as early as day 12 after ovulation (Morris & Allen, 2002). This has provided stud masters and owners with an earlier opportunity to re-serve non-pregnant broodmares, which is important given the small window of opportunity for breeding (25 days). Additionally, the treatment with hormones such as prostaglandin (F2α) and human chorionic gonadotropin (hCG) has enabled stud managers to control ovarian cyclicity, allowing for an earlier onset of estrus. Therefore, the lower proportion of barren broodmares (14.2 - 14.9%) that have been reported recently (Morris and Allen, 2002; Bosh *et al.*, 2009; Nath *et al.*, 2010) in comparison with the figures from two decades ago (24- 29.1%) (Sanderson and Allen, 1987;

Bruck et al., 1993) could be attributed to the improved management techniques that are employed by studs, including the increased culling of barren broodmares (Morris & Allen, 2002). These developments together with improvements in knowledge of reproductive physiology have assisted stud masters, veterinarians, and broodmare owners in their ploy to increase the reproductive potential of the broodmare.

2.4.1 Pregnancy rate (per cycle & per season) & live foal rates

Studies undertaken in the UK, Ireland and Australia have documented an observed increase in the fertility of the Thoroughbred horse over the last two decades (Sanderson and Allen, 1987; Morris and Allen, 2002; Hemburg *et al.,* 2004; Bosh *et al.* 2009; Nath *et al.,* 2010). Recent studies of Thoroughbred broodmares revealed overall pregnancy rates of 82-94%, per cycle pregnancy rates of 55-62%, and live foal rates of 70-83% (see: Bruck *et al.*, 1993; Morley & Townsend, 1997; Morris & Allen, 2002; Hemberg *et al.,* 2004; Bosh *et al.*, 2009; Nath *et al.*, 2010). These findings are significantly higher than what was previously documented by Sanderson and Allen (1987) and Bruck *et al.* (1993) who reported end of season pregnancy rates of 70-80%, per cycle pregnancy rates of 43-56%, and live foal rates of 50-70%. The significant increase in pregnancy rates (per cycle and per season) and live foal rates that have been observed over the past two decades can be heavily attributed to the increased management practices that are now employed by studs and veterinarians. The increased culling of both aged broodmares and broodmares with low fertility rates have decreased the proportion of barren broodmares in the population. As a result, the breeding population consists of broodmares with relatively high fertility, thus importantly increasing the overall pregnancy rate. Furthermore, increased knowledge into the reproductive physiology has enabled the use of hormones to control ovarian cyclicity in the broodmare (Morris & Allen, 2002). This has permitted the stud manager to cope with the demands imposed by the short window of opportunity for breeding (twenty-five days), by allowing the broodmare to come into estrus earlier than what would occur naturally.

2.4.2 Pregnancy loss rates & early embryonic death (EED)

Recent studies have reported the per cycle pregnancy rates, of a broodmare at day fifteen post breeding, to be approximately 60% (Morris & Allen, 2002; Hemburg *et al.*, 2004; Bosh *et al.*, 2009). Of the pregnancies reported at fifteen days, approximately 20% will be lost throughout the duration of gestation (Bruck *et al.*, 1993; Morley & Townsend, 1997; Sanderson & Allen, 1987; Hemburg *et al.*, 2004; Bosh *et al.*, 2009). The pregnancies lost after fifteen days can be divided into four categories: reabsorbed fetuses, abortion (identified and unidentified), premature, and still-born. Together, reabsorbed fetuses and abortions accounted for 16% of the overall pregnancy loss (Morley & Townsend, 1997). However, these figures were not inclusive of early embryonic death (EED). EED is where pregnancy loss occurs in the period from fertilisation until day 40 of pregnancy (Madill, 2002). Older broodmares have been shown to have a higher rate of EED and a reduced ability to hold a conceptus to term. One study showed the percentage of broodmares failing to fertilise or suffering from EED to be 13.4% for two-four year olds compared with 51.1% in broodmares ages seventeen or older (Madrill, 2002). The period of the greatest chance embryonic death occurs before the pregnancy can be detected through an ultrasound, which is usually around day eleven. Maternal factors such as hormonal deficiency and the condition of the uterine environment could be responsible for these losses. Another reason for EED could be due to embryonic factors. For example, aged sub-fertile broodmares have been shown to have smaller embryo's with more morphological defects which was discovered upon embryo recovery (Anonymous, 2001).

2.4.3 Twin ovulation

A 7.8% incidence of twinning was reported in a study undertaken by Bruck *et al.* (1993). This was similar to what was more recently documented by Morris & Allen (2002) and Hemburg *et al.* (2004) who reported a 10 and 10.5% incidence of twinning respectively. More often than not, one conceptus will spontaneously reduce during the first thirty days of pregnancy (Hemberg *et al*. 2004). If left alone, approximately 65% of twin pregnancies are aborted during the final eight months of gestation. Moreover, if a twin pregnancy is carried to term and delivered only 14% of these foals will see through the first three weeks of life (Bruck *et al.*, 1993). This demonstrates that twin pregnancies must be extensively managed (manually eliminating one conceptus) to ensure live foal rates and pregnancy rates do not suffer.

2.5 REPRODUCTIVE EFFICIENCY IN AGED BROODMARES

It has been well documented that the pregnancy loss rate increases with increasing broodmare age (see: Sanderson & Allen, 1987; Mcdowell *et al.*,1992; Bruck *et al.*,1993; Morley & Townsend, 1997; Morris & Allen, 2002; Hemburg *et al.*, 2004; Bosh *et al.*, 2009; Nath *et al.*, 2010). Increasing broodmare age has also been linked to significant decreases in the pregnancy rate, live foal rate, and the survival rate among live foals (Mcdowell *et al.*,1992; Bruck *et al.*,1993; Morley & Townsend, 1997; Morris & Allen, 2002; Hemburg *et al.*, 2004; Bosh *et al.*, 2009; Nath *et al.*, 2010). Morris and Allen (2002) concluded that older broodmares (age forteen-eighteen) had a lower per cycle pregnancy rate after day fifteen and they required more services per conception (2.2) than did younger (≤ thirteen years old) broodmares (1.8). This presents a problem not only for owners trying to get their broodmares in foal but also to studs standing stallions. The cost of a broodmare not falling pregnant during her first estrous cycle could potentially be more detrimental to the stallion. Stallions that have attained a full book are associated with a tight breeding schedule. If a broodmare does not fall pregnant during her first visit she must be rescheduled for a second and if required, maybe a third time. This has the potential to negatively influence the stallions other breeding commitments, thus producing a lower fertility rate which plays a significant role in determining a stallion's future. Therefore, to maximise productivity, when considering older broodmares for a stallion's book only those with the highest genetic potential should be selected. This could explain the current pattern in the New Zealand broodmare herd were older broodmares are getting bottlenecked out of the population.

2.5.1 The uterus

Older broodmares have been found to be more susceptible to degenerative changes in the endometrium and infection in the uterus compared to younger broodmares (Carnevale & Ginther, 1982; Bruck *et al.*, 1993; Morris & Allen, 2002; Hemburg *et al.*, 2004; Nath *et al.*, 2010; Van Rijssen *et al.*, 2010). A study undertaken by Morris and Allen (2002) who documented the use of uterine therapy was lowest in maiden broodmares (4%) and young (≤ 14 years old) broodmares (9-10%) compared with older broodmares (>14 years), where the incidence of uterine treatment increased to 20%. Additionally, Hemburg *et al.* (2004) also reported 72.7% of the barren broodmares were age thirteen years or above, indicating older broodmares are more susceptible to pregnancy loss through abortion/reabsorbed fetuses. It has been determined that embryos of older broodmares may already be compromised before entering the uterus or may be subject to nutritional or hormonal deficiencies and/or infections leading to embryonic death (Carnevale & Ginther, 1982; Hemburg *et al.*, 2004; Van Rijssen *et al.*, 2010).

2.5.2 Pregnancy loss

Pregnancy loss rates were found to be lowest in broodmares aged three-eight and pregnancy loss rates almost doubled in broodmares aged nine-thirteen (Morris & Allen, 2002). These findings are similar to those of Sanderson and Allen (1987). These authors documented that 82.5% of broodmares aged three-eight produced a live foal whereas only 47.1% of the broodmares aged eighteen and above produced a live foal. This could be due to the statement that degenerative changes in the endometrium that occur with increasing age can reduce its nutritive capacity for the developing conceptus (Bruck *et al.,* 1993; Morris & Allen, 2002; Van Rijssen *et al.,* 2010; Mcdowell *et al.*,1992).

Similar results have been documented for other species. A study undertaken by Bell (1918) concluded in humans, children born to older mothers have decreased longevity compared to children born to younger mothers. Moreover, the incidence of congenital abnormalities and still births (especially with mothers over forty) increased with maternal age in humans (Gavrilov & Gavrilova, 2000; Parsons, 1964). These studies are in accordance with Philippe (1980) who concluded that increased maternal age (> thirty-five years) at the time of childbirth is a main factor in the early (zero-five years) death of their offspring. Older mothers have been shown to have offspring with decreased longevity in Rotifers (Lansing, 1947), Fruit-flies (Priest *et al.*, 2002) and Nematodes (Klass, 1977). Therefore, it can be concluded that the age of a mare should be considered a significant factor when investigating the development and performance of her progeny.

2.6 THOROUGHBRED HORSE RACING AND INTERNATIONAL RANKINGS

2.6.1 Definition of Thoroughbred horse racing

Thoroughbred horse racing is a competition between horses, run over a pre-determined distance which is usually held for the purpose of betting. There are two types of Thoroughbred horse racing; flat racing and jumps racing. Flat racing is generally run over 1000-2500 meters, with no hurdles or steeples (Young *et al.,* 2005). Jumps racing can be divided into hurdle and steeple chase races and are run over longer distances than flat races, generally 3200-7200m. Hurdles are run over low obstacles compared to the more difficult fences that are seen in steeple chase racing (Thiruvenkadan *et al.,* 2009). Within these two types of racing there are classes of racing; such as - graded stakes or condition races, handicap, maiden, allowance and claiming races (Young *et al.,* 2005; Thiruvenkadan *et al.,* 2009).

The Thoroughbred industry benefits from horses that can race often, thus consistently earning money over a number of years. Revenue for the Thoroughbred racing industry is generated through gambling turnover where each starter is considered as a single betting unit. The industry must therefore structure its carnivals and race-days with the intension of maximising betting turnover which in turn, is influenced by the number of horses in training and racing (Tanner *et al.,* 2010). The recent, steady decline that has been observed in the Thoroughbred foal crop (see *Figure 2-1*) has resulted in fewer horses in training therefore these horses must race more often in order to maintain the same quantity of betting units.

2.6.2 International Thoroughbred ratings

The International Federation of Horseracing Authorities (IFHA) annually publishes an end of season assessment of the top Thoroughbred race horses. The assessment includes horses that have run during the previous calendar year that been rated at 115 or above by the World Thoroughbred Rankings Conference (WTRC). The IFHA also publishes a list of the world's leading horses at various times throughout the year. This consists of the fifty highest rated Thoroughbred horses to have raced in the six months prior to publication (Anonymous, 2010e).

2.7 MEASURING RACING PERFORMANCE

It is imperative that a reliable and accurate measure of racing performance is available to the gambling population, as this encourages wagering on the Thoroughbred product (Anonymous, 2009). There is no shortage of data available for determining racing performance of Thoroughbreds. The Thoroughbred industry records data such as earnings, number of starts, race time and number of placings annually, which can then be analysed to generate a racing performance measure for an individual horse within the population (Burns *et al.,* 2006). However, comparing racing performance of individuals has been proven to be a somewhat tedious task, due to the largenumber of variables that are involved (Hintz, 1980; Burns *et al.,* 2006; Thiruvenkadam *et al.,* 2009).

2.7.1 Variables influencing racing performance

There are a number of variables that can ultimately influence the racing performance of a horse and must be considered in order to achieve an accurate measure. These variables include; age, sex, handicap weight (weight carried by horse), track conditions, track variation, year, season, class of race, post-position, jockey effect, trainer effect, and race effect (Hintz 1980; Thiruvenkadam *et al.,* 2009). Commonly, these factors need to be accounted for when developing an optimal outcome measure. In addition to the sheer amount of variables that could influence a horse, another problem with the available measures of racing performance is that they do not always reflect the underlying biological variation of the trait in question. A normal distribution favors average horses with a few horses at each extreme, yet it is generally accepted that the racing industry favors the ‘exception’ rather than normal population distribution. This is in direct contrast to most other production industries, for example, in the dairy industry a shed full of average cattle is favoured over one, genetically exceptional, cow.

Although there is no shortage of data available to be quantified as a measure for racing performance, a universal method that produces a reliable outcome measure does not exist.

2.7.2 Problems measuring performance

It has been well documented that a significant proportion of foals fail to make an appearance on the racetrack and in addition, a large percentage of horses that do make the racetrack fail to perform to expectations (Jeffcott *et al.*, 1982; Bailey *et al.*, 1999; Perkins *et al.*, 2004a,b). This presents an initial binomial pattern of distribution (for example, a horse will have race performance or it will not) and results in some of the measures currently used to quantify race performance becoming heavily skewed.

Furthermore, the way the rating of races is distributed within in country is not representative of the underlying biological variation of the population. In New Zealand, races are divided into four categories:

1. **Group**- The top echelon of races, including; Group 1, Group 2, and Group 3.
2. **Listed**- Just below group races. These races identify quality racehorses that are unable to perform at group level.

3. **Handicap-** Each horse is individually allocated a weight be the NZTH handicapper, according to their previous performance. These races are designed to give each horse a theoretically equal chance of winning.
4. **Madien-** These races are solely for horses that have not yet won a race.

The majority of horses in the New Zealand racing population compete in maidens. A select group will break maiden status and run in handicapped races. From this select group the quality horses will run in listed races and only the top echelon of horses will run in group races (see *Figure 2-3).* It would be expected that the distribution of the number of rated races available to horses will mimic that of the rating distribution of horses. For example, given that most horses in the population are below average, it would be expected that majority of races would be of maiden status or low handicap to ensure every horse had an equal opportunity of winning a race. However this is not the case. The number of races available per rating follows a normal distribution, with most of the races available being those of an average rating (see *Figure 2-4*). This presents a problem as there are not enough races available to ensure each horse has an equal opportunity to win a race and thus owners may be losing interest. In addition, the field sizes in the average rated races are not large enough to produce optimal betting turnover (because most horses are still trying to break maiden status).

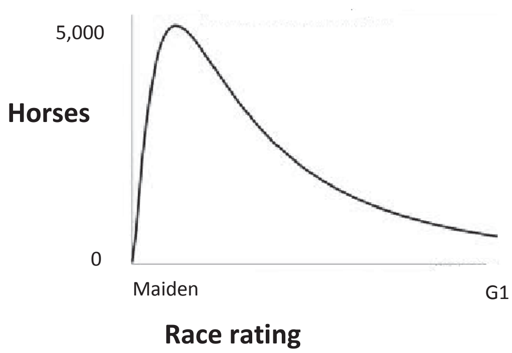

Fig 2-3: The underlying distribution how individuals are rated within the population

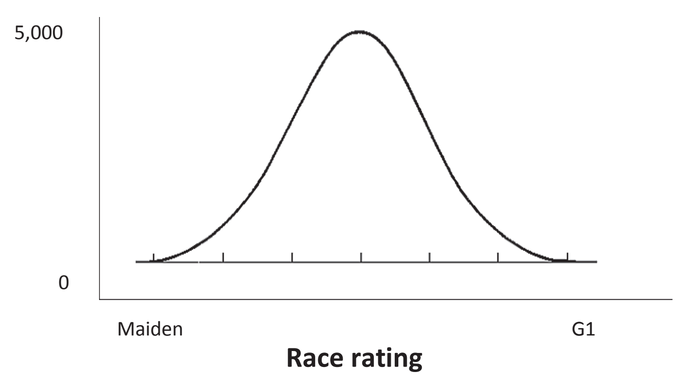

Fig 2-4: The actual distribution of rated races available for horses.

2.8 METHODS OF QUANTIFYING RACING PERFORMANCE

There are a number of parameters available to be used as measures of racing performance; however, not all of these measures can be classed as reliable outcome measures. For an outcome measure to be considered reliable it must be sensitive enough to compare within-horse variation and strong enough to cope with a rigorous statistical analysis. The performance measures listed below provide a comprehensive description of the methodologies used by the racing industry to quantify the racing performance of an individual.

2.8.1 Handicap or performance ratings

Weight handicap is the handicap that is applied to a horse due to its racing merits in the form of weight, with the elite horses being assigned the greatest weights. These weight allocations are put in place with the intention of evening out the field so all horses have an equal chance of winning (Williamson & Beilharz, 1996).

Timeform rating is a measure of the form a horse is capable of showing, under its optimum conditions, at a given point of time. It is based on race distance, race time, weight carried, age and winning margins. Together, these factors effectively establish how much better, or worse, a horse's performance was, compared to the others in the race.

Performance rates determine a horse's ability with respect to number of lengths it is expected to finish, in front or behind, the average horse in the population in a particular year. This method does not reflect the speed of horse and the beaten margin can differ significantly with distances and track conditions. Although, there are some advantages to this method, the first being that it is an objective measurement based on actual performance. Also, it is a more accurate measure for racing performance compared to using earnings, as it credits horses racing against top quality fields whereas earnings does not (Porter, 1971; Langlois, 1980).

Position or ranking rates are a measure of a horse's ability by ranking it against other horses in the race, but again does not reflect the speed of the horse. It is not influenced to a great extent by distances and track conditions (Langlois, 1980; Thiruvenkadam *et al.*, 2009).

Weight performance is a measure of performance that is analogous to position or ranking rates in that it depends upon finishing position. A horse is allocated an individual weight by a handicapper, according to their previous performance, with the intention of giving each horse in a race a theoretically equal chance of winning. This has proven to be a relatively reliable measure of racing performance, as it accounts for a large amount of variables such as prize money of the race, finishing position, and number of starters (Hintz, 1980; Williamson & Beilharz, 1996).

2.8.2 Performance Index (PI)

The performance index is a measure for racing success where horses are assigned points according to their finishing position. There are various modifications for generating a PI, but the general principles are that the point value that is obtained from a race is scaled based on the rating of the race and adjusted for race class (Thiruvenkadam *et al.,* 2009).

2.8.3 Time

Final time is the number of seconds it takes a horse to finish a race, therefore it is a direct measure of the horses speed (Hintz, 1980; Thiruvenkadam *et al.,* 2009).

Best time is the fastest time, over a given distance, of several races won by a horse. This reflects the maximum velocity of a horse (Hintz, 1980; Thiruvenkadam *et al.,* 2009).

Average time is the average of all of a horse's times over a given distance, therefore representing only the relative speed of the horse (Hintz, 1980; Thiruvenkadam *et al.,* 2009).

Time is not a reliable measure of performance due to the extreme variability that is seen between tracks and within tracks on different days. For example, it has been well documented that faster times are run on turf, compared to those run on a dirt surface (Hintz, 1980; Thiruvenkadam *et al.,* 2009). There is also considerable variation in size of the race track at different locations. This results in a variation in the length of the straight and the angle of the turn, which can ultimately have a major influence on the final time run by a horse. In addition, races run on the same track can have a significant variation in times when run on different days, as track conditions may differ. The condition of the track is given a rating (good, slow, dead, or heavy) before the first race, and this condition is monitored throughout the duration of the meeting. Races run on a good track generally boast faster times than races run on a heavy track over the same distance and with the same field of horses (Langolis, 1980; Thiruvenkadam *et al.*, 2009). The class of the field can have a significant effect on the time run for a race, for example, a quality horse in an average field may not produce the fastest time it is capable of due to the lack of competition from other horses (Hintz, 1980). Hence, time is not a particularly reliable measure when comparing horses that have run on different surfaces, on different tracks, or on the same track but a different day, or in different company.

2.8.4 Prize money/earnings

The earnings of a horse can be calculated; annually - as the total earnings received by a horse in a year, by cumulative earnings - where the quality of a race is measured on a horse's entire career, or by average earnings per start. Of these three measures the average earnings per start is probably the most valid, as it is indicative of how many starts a horse has had to achieve its earnings. Rating a horse according to its earnings is simple, as it does not require supplementary data and the earnings are directly comparable to the current handicapping systems. However, recording earnings results in a skewed distribution, as a few horses accumulate the majority of the prize money. In an attempt to account for this, with the intention of making the distribution more normal, logarithmic or square-root transformation of earnings or earnings per start can be made. However, the distribution of prize money does not reflect the underlying distribution of the population of racing stock (Hintz, 1980; Langolis, 1980; Tolley *et al.*, 1985; Ricard *et al.*, 2000; Thiruvenkadam *et al.*, 2009).

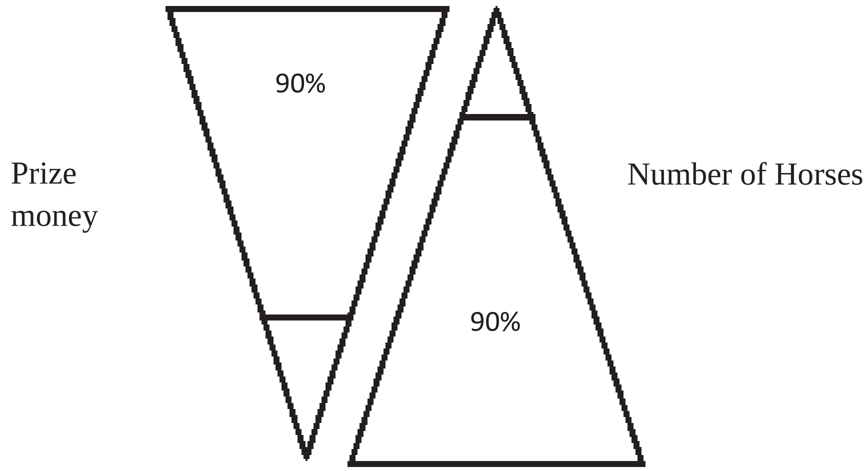

Figure 2-5: The distribution of prize money available to race horses

Figure 2-5 represents the amount of prize money that is available to horses. It shows that 10% of the horses contend for 90% of the prize money. Meanwhile, 90% of horses compete for the remaining 10% of the total prize money that available to all horses. With the underlying and actual distributions in mind, it is difficult to use earnings as a measure of racing performance because a large amount of horses will be clumped together in the low earnings bracket due to the limited availability of prize money on offer. Essentially, the elite horses have the potential to earn significantly more than the rest of the population.

Earnings can also be used to rank the success of a sire using the Average Earning Index (AEI) or the Standard Starts Index (SSI). The AEI ranks sires based on progeny performance in terms of amount earned per starter per year by the following calculation (Wright, 1989):

=Actual amount won by sire's progeny/ (number of starters x average entitlement of each starter)

This method of calculating sire performance creates bias when a sire has few starters, with one runner accumulating high earnings. To account for this the (SSI) was developed which separates the earnings of fillies from colts and geldings and two-year-olds from older horses.

2.8.5 Longevity

Longevity can be defined as the duration of productive racing life of an individual and can be quantified as the number of starts in a lifetime or the number of years racing (Burns *et al.*, 2006; Thiruvenkadan *et al.* 2009). The measurement of career longevity is important economically, as horses racing for a longer period require a greater investment of time and money, and also, from an industry perspective, in terms of maximising available betting product (Riccard *et al.*, 2000). Variables such as starting a horse at an earlier age, gender, and the first years performance on the race track have all been shown to influence the career length of the Thoroughbred horse (More, 1999). This is in accordance with the Standardbred industry, where it has been reported that horses that begin their careers at an early age often have longer careers and a greater level of success when compared with their later starting counterparts (Physick-Sheard, 1986; Saastamoinen & Osala, 1994). Previous research has shown that early exercise adapts the musculoskeletal system when it is most receptive, thus having a positive effect on growth and development of the young horse (Firth & Rogers, 2005; Rietbroek *et al*., 2007; Rogers *et al.*, 2008; Van Weeren *et al*., 2008). Therefore, those horses entering training at a young age could be more physiologically advantaged, allowing a longer career, when compared to horses that enter training later in life.

2.9 VARIABLES INFLUENCING RACING PERFORMANCE

Previous studies have investigated the influence of a range of factors that affect racing performance in Thoroughbreds, including; early exercise (Rogers *et al.,* 2008), exercise during training (Verheyen *et al.,* 2009; Bolwell *et al.,* 2011a,b), respiratory conditions (Strand *et al.,* 2000; Stick *et al.,* 2001), skeletal development (Firth & Rogers, 2005; Rogers *et al.,* 2008; van Weeren *et al.,* 2008; Verheyen *et al.,* 2009), gender (Bourke, 1995; More, 1999; Perkins *et al.,* 2004a,b; Wilsher *et al.,* 2006; Boden *et al.,* 2007; Bolwell *et al.,* 2011a,b), birth month (Wilsher *et al.,* 2006), dam age (Wilsher e*t al.,* 2006), and performance as a two year-old (More, 1999). To the Authors' knowledge no studies have investigated the influence of sales category on racing performance to date. The current study focuses on yearling sale production parameters only (gender, birth month, dam (mare) age, sales category), as outlined by Waldron *et al.,* (2010).

2.9.1 Gender

A longitudinal, cohort study of Thoroughbred horses in North Queensland using two outcome measures of performance, 1) race earnings during first year of racing and 2) proportion of horses still racing two years after first start, found that male horses were better performing than female horses (More, 1999). In agreement, an earlier study reported males are more likely to start in a race as a two year-old compared to females (Bourke, 1995). A recent study of Thoroughbred horses in New Zealand reported more males had a race start compared to females (Perkins *et al.,* 2004a,b). Interestingly, these authors also reported that as the age of the horse increases, a higher proportion of starts involved males, indicating females are leaving the racing population. This could be due, in part, to the greater breeding potential of females compared to males thus, females will be more likely to exit the racing population to begin a breeding career. In contrast, Wilsher *et al.* (2006) examined the racing performance of Thoroughbred horses born in Britain in 1999 and found that the gender of a two year-old made no difference to the likelihood of it running in or winning a race. Furthermore, Bolwell *et al.* (2011a), identified risk factors associated with interruptions to training, in a population of Thoroughbred horses in New Zealand. These authors found that females had a lower risk of involuntary and muscultoskeletal interruptions compared to males and horses that experienced interruptions took significantly longer to start in a trial and a race compared to horses that did not experience an interruption during training. This finding is in accordance with analogous studies on Thoroughbred racehorses undertaken by Wilsher *et al.* (2006) and Boden e*t al.* (2007) who reported males are at greater risk of fatality and more injury prone compared to females. Therefore, based on the results of the studies mentioned above (Wilsher *et al.*, 2006; Boden *et al.*, 2007; Bolwell *et al.*, 2011a), it could be inferred that males are more likely to experience an interruption to training that may prevent them from racing, compared to females. As a result, gender was included in the current study as a yearling sale production parameter.

2.9.2 Birth month

A study on Thoroughbred racehorses born in Britain in 1999 reported that two year-olds born between January and March were more likely to run at least once compared to those born from April to June. However, the birth date of a two year-old made no difference to the likelihood of it winning a race if it actually ran (Wilsher *et al.*, 2006). This could be due, in part, to the hypothesis that older yearlings are more developed physically, and therefore have a greater probability of early success (Brown-Douglas *et al.*, 2005; Morel *et al.*, 2007; Parsons & Smith, 2008). Limited data exists examining how birth month influences the race performance of Thoroughbred horses. However, previous research has proved birth month to be an important variable in determining yearling sales price (Commer, 1991; Buzby & Jessup, 1994; Robbins & Kennedy, 2001; Vickner & Koch, 2001; Waldron *et al.*, 2010). Therefore, birth month was included as a yearling sale production parameter, when investigating the influence on racing performance, in the current study.

2.9.3 Dam (mare) age

A study undertaken by Wilsher *et al.* (2006) on the racing performance of Thoroughbred horses born in Britain in 1999 reported that no significant relationship exists between dam (mare) age or parity and 1) the likelihood of a horse running as a two or three year-old, 2) the likelihood of a horse winning a race, and 3) the overall performance of a horse in regards to timeform rating. Limited data exists examining how dam (mare) age influences the race performance of Thoroughbred horses. However previous research has shown dam (mare) age to be an important variable in determining yearling sales price (Neibergs, 2001; Waldron *et al.*, 2010). Therefore, dam (mare) age was included as a yearling sale production parameter, when investigating the influence on, in the current study and was the *a priori* variable of interest.

2.10 AIMS AND OBJECTIVES OF THESIS

The aim of this thesis was to quantify the impact of yearling sale production parameters, in particular dam (mare) age at the time of conception, on future career success and longevity in a population of Thoroughbred racehorses in New Zealand. The objectives were to a) investigate the association between yearling sale production parameters and the length of a horse's career, in both years raced and number of race starts, and b) to investigate the association between yearling sale production parameters and the career success of horses (*ln* earnings).

Chapter 3

Materials and Methods

3.1 STUDY DESIGN

The current study is a cross sectional retrospective cohort study that examines the yearling sale production parameters that influence the racing performance of all yearlings catalogued in the 2004 NZB NYSS. The aim of this project was to quantify the impact of yearling sale production parameters, in particular gender, sales category, birth month and dam (mare) age at the time of conception (the *a priori* variable of interest), on future career success and longevity in a population of Thoroughbred racehorses in New Zealand.

3.2 DATA SET

Birth month and pedigree data on the yearlings offered for sale during the 2004 NZB NYSS were obtained from the online results published by New Zealand Bloodstock Ltd (www.nzb.co.nz). Annual racing data of the horses offered for sale as a yearling during the 2004 NZB NYSS were provided as an electronic extract by New Zealand Thoroughbred Racing (NZTR). The annual racing data were provided as annual totals of number of trials and annual totals of number of races. Data were also provided giving total career earnings and number of years spent racing for each individual horse. Data from all sources were combined, using lot numbers, to create a custom dataset. Included in the custom data set for each individual horse were; lot number, name of horse, gender, birth month, sales category, sire, dam, dam birth year, trainer, the year first registered with a trainer, total career earnings, number of years spent racing, number of race starts (including number of wins and placings), and number of trials (including number of wins and placings). All data were valid up to 3/03/2011 which was part way through the horses' eight-year-old racing season. Gender was recorded at birth therefore horse was recorded as either colt or a filly. For the purpose of this study colts were classed as males and fillies were classed as females. No attempt was made to differentiate between colts, geldings and entires or fillies and mares. The trainer was the trainer of the horse at the time of the electronic extract, and may not have been the trainer for that horse's entire career, and thus was not included in the statistical analysis. Horses were excluded from the dataset if they were exported at any stage during their career (n=767). From the remaining horses, only those horses that were registered with a trainer were included in the analysis (n=631). Racing data was not provided for international races thus, the dataset covers the domestic racing population only.

3.3 CLASSIFICATION OF GROUPINGS

Dam (mare) age and birth month were each divided into four categories based on viewing histograms and subsequent calculation of the median, inter-quartile range, upper percentile and lower percentile of each variable in the total population. The age categories of dam (mare) age are; 1) two-six (n=151), 2) seven-nine (n=166), 3) ten-twelve (n=152) and 4) thirteen + (n=162). The birth month categories are; 1) July-August (n=50), 2) September (n=184), 3) October (n=227) and 4) November-December (n=170). The total number of career starts was divided into four categories based on viewing the histogram and subsequent calculation of the median, inter-quartile range, upper percentile and lower percentile in the population that earned. These categories are; 1) one-seven starts (n=87), 2) eight-fourteen starts (n=109), 3) fifteen-twenty-four starts (n=102) and 4) twenty-five + starts (n=115).

3.4 DATA MANIPULATION

Raw data were collated within a customised Microsoft Access database (Microsoft Access, Microsoft Corporation, Redmond, Washington, USA) and imported into STATA 11 (Statacorp LP, College Station, Texas, USA) for analysis. Data were examined for outliers and validity using descriptive statistics, histograms, scatterplots and cross tabulations. When appropriate, missing or suspect values were compared with data from other sources including the online database of New Zealand Thoroughbred Racing Inc (www.nzracing.co.nz) and online yearling sales results published by New Zealand Bloodstock Ltd (www.nzb.co.nz).

3.5 STATISTICAL ANALYSIS

3.5.1 Exposure variables (yearling sale production parameters)

The age of a horse's dam (mare) at the time of conception was the *a priori* variable of interest, and was grouped into four categories. Additional exposure variables investigated were gender, birth month, sales category, sire (Logistic and linear regression only), if the horse started in a trial (logistic regression- outcome measures two and three only [refer below]), number of years racing (survival analysis only), raced as a two year-old and total career starts (linear regression only).

3.5.2 Logistic regression analysis

Logistic regression analysis was used to investigate associations between the exposure variables and three outcome measures of performance 1) obtaining a trial start, 2) obtaining a race start and 3) earning >$1 prize money. Exposure variables were selected for inclusion in the backward stepwise multivariable model building process if the p-value <0.25 at the univariable level.

Variables were retained for the final multivariable model if they significantly improved the model fit (likelihood ratio statistic [LRS] p-value <0.05). Dam (mare) age was forced into the final models, when a non-significant result was obtained, as it was *a priori* variable of interest. Sire was modeled as frailty terms to allow for potential clustering at the sire level and was only adjusted for in the final model if the result was significant (p<0.05). The results of this analysis show the clustering at sire level was not significant (p>0.05) and therefore sire was not reported in the results. The odds ratios (OR) and 95% confidence intervals (CI) were calculated and the critical probability for assigning statistical significance was set at p<0.05. All analyses were preformed in STATA 11 (Statacorp LP, College Station, Texas, USA).

3.5.3 Survival analysis

Kaplan-Meir survival analysis (Kaplan-Meir, 1958) was used to plot the total number of career starts obtained before the horse ceased racing for the whole cohort. Median time and 95% confidence interval (CI) until cessation of racing career for the whole cohort, and by each exposure variable (dam (mare) age, gender, sales category, and birth month), were also plotted. The mean (95% C.I), median, minimum and maximum number of race starts, were calculated for the exposure variables that were significant. The association between the exposure variables and the total number of career starts before a horse ceased racing were assessed by calculating the log-rank (Mantel-Cox) statistic. Variables that were associated at P<0.25 at the univariable level were investigated further using a multivariable proportional hazards model. The final multivariable model was built using a backward stepwise selection process, and exposure variables were retained in the model if they significantly improved the model fit (likelihood ratio statistic [LRS] P-value <0.05). The age of a horse's dam (mare) at the time of breeding was forced into the final multivariable model as it was *a priori* variable of interest. The number of years an individual horse raced was modeled as a frailty term to adjust for potential clustering of horses within this variable. Hazard ratios (HR) and 95% confidence intervals (CI) were calculated and the critical probability for testing significance was set at P<0.05. All analysis we completed in STATA 11 (Statacorp LP, College Station, Texas, USA).

3.5.4 Linear regression analysis

The natural logarithmic (*ln*) transformation of prize money earned (in $NZ) was used in the analysis to normalise the distribution of this outcome measure, which increased the likelihood of normally distributed residuals. Observations where earnings were recorded as zero were excluded from analysis. Linear regression was used to model the association between exposure variables and the continuous outcome measure *ln* (prize money $NZ). Exposure variables were selected for inclusion in the backward stepwise multivariable model building process if p-value <0.25 at the univariable level. Variables were retained for the final multivariable model if they significantly improved the model fit (likelihood ratio statistic [LRS] p-value <0.05). Sire was modeled as a frailty term to allow for potential clustering at the sire level and was only adjusted for in the final model if the result was significant (p<0.05). The co-efficient, standard errors (SE) and 95% confidence intervals (CI) were calculated and the critical probability for assigning statistical significance was set at p<0.05. All analyses were preformed in STATA 11 (Statacorp LP, College Station, Texas, USA).

Chapter 4

Results

4.1 DESCRPITIVE RESULTS

Of the 1,535 horses offered at the 2004 NZB NYSS, 767 were subsequently identified as exported and so not eligible for analysis. Of the 768 horses that were not exported, 631 (82%) were registered with a trainer and thus eligible for the study population. Eighty-one percent (513/631) of registered horses raced and had a total of 8,261 flat race starts, in New Zealand, during the study period. Of all the horses that had at least one race start (n=513), the median number of race starts per horse was twelve (IQR 5-22). The majority of race starts (96%) were by horses aged three years and older (4% of these race starts were by 2-year-olds). Males (colts, geldings and entires) had 5,003 (61%) race starts whereas females (fillies and mares) had a total of 3,258 race starts (39%). Altogether, 249 horses won a total of 749 races. Prize money was won by 413 of 631 horses (66%). The median amount of prize money won per race start was $NZ2,650 (IQR $NZ0-$NZ15,550). Excluding observations where no money was won, the median amount prize money won was $NZ8,685 (IQR $NZ3,106 - $NZ25,160).

Descriptive data of the horses examined is presented in *Table 4-1*. Of the 631 horses that were registered with a trainer, 118 (19%) never obtained a race start. Most horses were registered with a trainer as a two year old (80% or 499/631). Over half (57.2% or 361/631) of the horses started in their first trial as a two year old, yet only 22% (137/631) of these horses had a race start during their two year old career. Almost half (48% or 301/631) of the registered horses had under seven total career starts and most (92% or 579/631) of the horses were born between September and December

Table 4-1: Distribution of Thoroughbreds in the study population across independent variables.

Variable	Males		Females		Total	
	n	**%**	**n**	**%**	**n**	**%**
Gender	334	52.9	297	47.1	631	100
Dam (Mare) age						
2-6	80	53.0	71	47.0	151	23.9
7-9	70	42.2	96	57.8	166	26.3
10-12	77	50.7	75	49.3	152	24.1
13+	107	66.0	55	44.0	162	25.7
Sales category						
Premier	72	49.3	74	50.7	146	23.1
Select	110	45.8	130	54.2	240	38.1
Festival	152	62.0	93	38.0	245	38.8
Birth month						
July-August	19	38.8	31	61.2	50	7.9
September	91	49.5	93	50.5	184	29.2
October	114	50.2	113	49.8	227	36.0
November-December	109	64.1	61	35.9	170	26.9
Age first registered with trainer						
2YO	247	49.5	252	50.5	499	79.1
3YO+	87	65.9	45	34.1	132	20.9
Age first trial						
Never	30	62.5	18	37.5	48	7.6
2YO	165	45.7	196	54.3	361	57.2
3YO+	139	62.6	83	37.4	222	35.2
Age first race start						
Never	55	46.6	63	53.4	118	18.7
2YO	62	45.3	75	54.7	137	21.7
3YO+	217	57.7	159	42.3	376	59.6
Career Starts						
0-7	150	49.8	151	50.2	301	47.7
8-14	49	54.4	41	45.6	90	14.3
15-24	60	49.2	62	50.8	122	19.3
25+	75	63.6	43	36.4	118	18.7

2YO includes all two-year-old horses; 3YO+ includes all horses that are aged three or above.

4.2 TRIAL START (LOGISTIC REGRESSION ANALYSIS)

The results of the univariable logistic regression analysis for horses that started in a trial are presented in *Table 4-2.* The analysis shows that only gender (0.16) and sales category (0.013) are significantly associated with a horse having a start in a trial. Further analysis showed the p-value for the likelihood-ratio statistic was not significant (p=0.16). Therefore, there is no association between the variables (gender and sales category) and starting in a trial and a multivariable model could not be formed.

Table 4-2: Univariable logistic regression model for horses catalogued in the 2004 NZB NYSS that obtained a trial start in New Zealand.

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	P value
Dam (mare) age			
2-6	1.10	0.46-2.62	0.832
7-9	ref		
10-12	0.91	0.40-2.09	0.822
13+	0.82	0.37-1.84	1.84
Gender			
Males	ref		
Females	1.53	0.83-2.80	0.170
Birth Month			
July-August	4.64	0.607-35.41	0.139
September	1.27	0.61-2.63	0.518
October	ref		
November-December	1.07	0.53-2.20	0.839
Sales category			
Premier	ref		
Select	0.49	0.19-1.26	0.033
Festival	0.41	0.17-1.04	0.061

4.3 RACE START (LOGISTIC REGRESSION ANALYSIS)

The results of the univariable logistic regression analysis for horses that obtained a race start are presented in *Table 4-3*. Of the five variables that were screened at the univariable level, gender (p=0.13), sales category (P=0.12) and trialed (P<0.001) were significantly associated with a horse having a race start. Horses that had started in a trial prior to racing were more likely to start in a race compared to those that had not started in a trial prior to racing. Dam (mare) age was not significantly associated (P=0.63) with a horse obtaining a race start however, it was forced into the final model as it was *a priori* variable of interest. Further analysis showed that it is the trial variable that confounds the relationship between the variables; gender and sales category, and starting in a race. Thus, the variable trialed is the only significant variable and a multivariable model could not be formed.

Table 4-3: Univariable logistic regression model for horses catalogued in the 2004 NZB NYSS that obtained a race start in New Zealand.

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	P value
Dam (Mare) age			
2-6	0.68	0.39-1.21	0.190
7-9	ref		
10-12	0.84	0.46-1.52	0.560
13+	0.83	0.46-1.50	0.540
Gender			
Males	ref		
Females	0.73	0.49-1.09	0.128
Birth Month			
July-August	0.95	0.43-2.11	0.901
September	1.10	0.65-1.85	0.185
October	ref		
November-December	0.72	0.44-1.18	0.190
Sales category			
Premier	ref		
Select	1.72	1.02-2.90	0.042
Festival	1.25	1.02-2.90	0.042
Trialed			
No	ref		
Yes	8.47	4.55-15.76	P<0.001

4.4 EARNED >$1 IN PRIZE MONEY (LOGISTIC REGRESSION ANALYSIS)

The results of the univariable logistic regression analysis for horses that earned prize money during their career are presented in *Table 4-4*. Of the five Variables that were screened at the univariable level, birth month (P=0.05), sales category (P=0.005), and trialed (P<0.001) were significantly associated with a horse earning prize money. Horses that had a trial start were more likely to earn prize money compared to horses that had not obtained a trial start. There was no significant association between gender and earning prize money (P=0.26). Dam (mare) age was not significantly associated (P=0.49) with a horse earning prize money however, it was forced into the model as it was *a priori* variable of interest.

Table 4-4: Univariable logistic regression model for horses catalogued in the 2004 NZB NYSS that earned prize money in New Zealand.

Variable	Odds ratio (OR)	95% confidence interval (CI)	P value
Dam (mare) age			
2-6	0.85	0.57-1.28	0.443
7-9	ref		
10-12	0.78	0.52-1.17	0.228
13+	1.03	0.68-1.56	0.891
Gender			
Males	ref		
Females	0.85	0.64-1.13	0.260
Birth Month			
July-August	1.37	0.76-2.49	0.299
September	1.34	0.93-1.92	0.113
October	ref		
November-December	0.81	0.57-1.16	0.246
Sales category			
Premier	ref		
Select	1.19	0.81-1.76	0.378
Festival	0.71	0.48-1.03	0.073
Trialed			
No	ref		
Yes	21.21	12.33-36.50	P<0.001

The final multivariable logistic regression model (*Table 4-5*) shows earning prize money is associated with, sales category (P<0.001) and if the horse had started in a trial prior to racing (P<0.001). Horses catalogued in the select session were more likely to earn prize money compared to horses catalogued in the premier session. Horses that had a trial start were more likely to earn prize money compared to horses that had not had a trial start.

Table 4-5: Multivariable logistic regression model for horses catalogued in the 2004 NZB NYSS that earned prize money in New Zealand.

	Odds ratio (OR)	95% confidence interval (CI)	P value
Sales category			
Premier	ref		
Select	1.64	1.05-2.55	0.029
Festival	0.97	0.63-1.48	0.882
Trialed			
No	ref		
Yes	21.80	12.60-37.70	P<0.001

4.5 SURVIVAL ANALYSIS

The Kaplan-Meier survival graphs are shown for the whole population and stratified by, gender and sales category (*Figures 4-1*, *4-2*, and *4-3*). The log-rank test of equality across strata for the predictors gender and sales category were p< 0.001 and p=0.14, respectively. *Figure 4-1* shows the survival curve of the whole population. The median number of race starts for the entire racing population was twelve (95% C.I. 5-22).

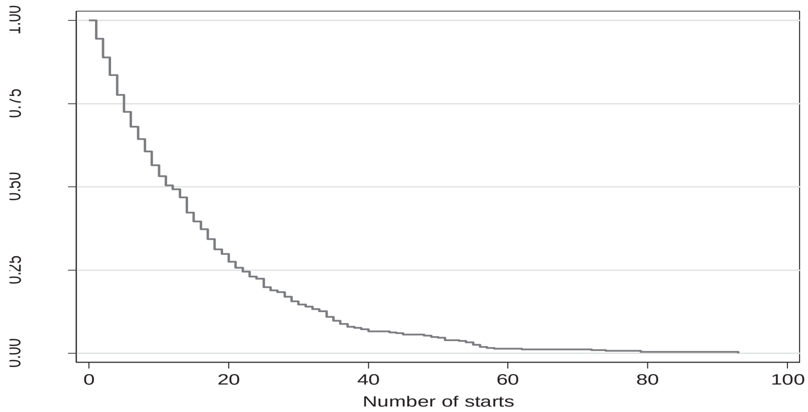

Figure 4-1: Kaplan-Meir survival graph for 2004 NZB NYSS graduates that raced in New Zealand only.

Figure 4-2 shows the survival cures for females and males. The median number of race starts for a female was eleven (95% C.I 9-14) and the median for a male was thirteen (95% C.I. 10-15).

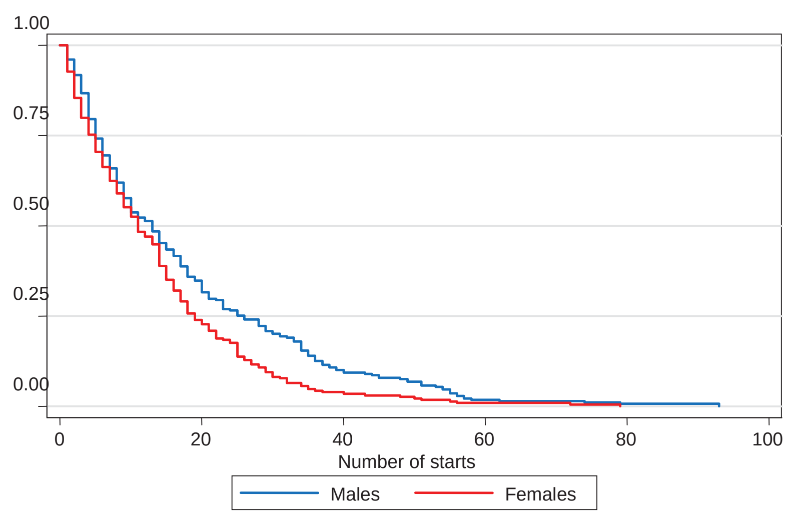

Figure 4-2: Kaplan-Meir survival graph of male versus female graduates from the 2004 NZB NYSS that raced in New Zealand only.

Figure 4-3 shows the survival curves for the three sales categories: premier, select and festival. There was no significant difference in number of race starts between the three sales categories. The median number of race starts for a horse catalogued in the premier session was ten (95% C.I. 8-14) versus fourteen (95% C.I. 12-16) for the select session and ten (95% C.I. 8-13) for the festival session.

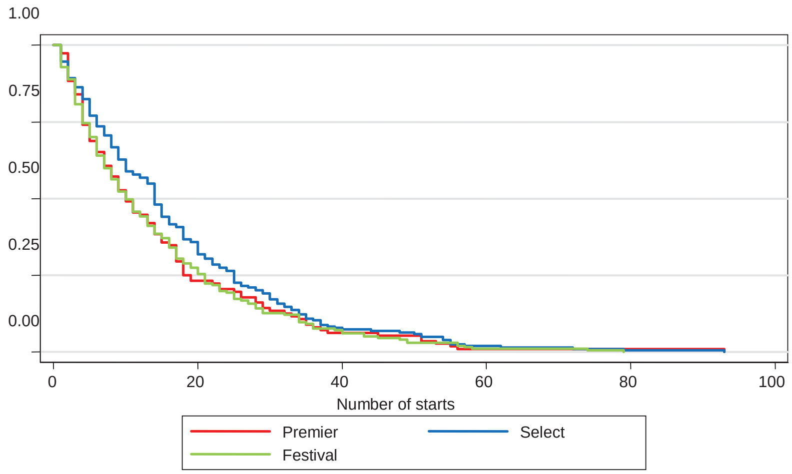

Figure 4-3: Kaplan-Meir survival graph for sales category (premier, select and festival sessions) for graduates from the 2004 NZB NYSS that raced in New Zealand only.

The results of the univariable survival analysis are presented in *Table 4-6*. Dam (mare) age was not significantly associated with the number of career starts obtained by a horse before cessation of racing (P=0.55). However, dam (mare) age was forced into the final model as it was *a priori* variable of interest. Gender (P=0.002), sales category (P=0.15), birth month (P=0.24) and number of years spent racing (P<0.001) were significantly associated with the number of career starts obtained by a horse before cessation of racing.

Table 4-6: Univariable survival analysis model for horses catalogued in the 2004 NZB NYSS that form the domestic racing population.

Variable	Hazard Ratio (HR)	95% Confidence Interval (CI)	P value
Dam (mare) age			
2-6	1.06	0.83-1.35	0.649
7-9	ref		
10-12	0.90	0.70-1.15	0.391
13+	1.04	0.83-1.35	0.649
Gender			
Males	ref		
Females	1.32	1.11-1.58	0.002
Birth Month			
July-August	1.07	0.76-1.50	0.709
September	0.87	0.70-1.01	0.203
October	ref		
November-December	1.10	0.88-1.37	0.418
Sales category			
Premier	ref		
Select	0.85	0.68-1.07	0.169
Festival	1.02	0.81-1.29	0.876
Number of years raced	0.28	0.25-0.31	P<0.001

The final multivariable survival analysis (*Table 4-7*) showed that gender, sales category and number of years spent racing were associated with total number of career starts (P<0.001). Females were more likely to cease racing compared to males. Horses catalogued in the festival session were more likely to cease racing compared to horses catalogued in the premier session. As the number of years spent racing increased the likelihood of a horse ceasing racing decreased.

Table 4-7: Multivariable survival analysis model for horses catalogued in the 2004 NZB NYSS that were not exported from New Zealand.

	Hazard Ratio (HR)	95% Confidence Interval (CI)	P value
Gender			
Males	ref		
Females	1.24	1.04-1.49	0.019
Sales Category			
Premier	ref		
Select	1.16	0.92-1.47	0.203
Festival	1.33	1.05-1.68	0.018
Number of years racing	0.28	0.25-0.31	P<0.001

4.6 LINEAR REGRESSION ANALYSIS

Descriptive data of horses in the population that earned prize money is presented in *table 4-9*. Eighty-one percent (513/631) of the horses in the study population earned prize money in New Zealand. Just over half of the horses that earned prize money were male (56%). The distribution of horses that earned prize money was relatively uniform, with respect to the age of a horse's dam (mare) at conception. Horses that were catalogued in the select session had the highest proportion of earners (42%) compared to the premier (22%) and festival (36%) sessions. Horses born early in the season (July or August) had the lowest proportion of earners (8%), compared to horses born in September (32%), October (35%), and November-December (25%). Most of the horses that earned (71%), did not have a race start in their two year-old season. The distribution of horses that earned prize money was relatively uniform, with respect to total career starts.

Table 4-8: Distribution of Thoroughbreds in the population that earned money across independent variables.

Variable	Males		Females		Total	
	n	**%**	**n**	**%**	**n**	**%**
Gender	230	55.7	183	44.3	413	54.5
Dam (mare) age						
2-6	59	55.1	48	44.9	107	25.9
7-9	45	45.5	54	54.5	99	24.0
10-12	53	52.0	49	48.0	102	24.7
13+	73	69.5	32	30.5	105	25.4
Sales category						
Premier	47	51.1	45	48.9	92	22.3
Select	85	49.1	88	50.9	173	41.9
Festival	98	66.2	50	33.8	148	35.8
Birth month						
July-August	12	35.3	22	64.7	34	8.2
September	70	54.7	58	45.3	128	31.0
October	78	52.3	71	47.7	149	36.1
November-December	70	68.6	32	31.4	102	24.7
Flat race start 2YO						
No	174	59.4	119	40.6	293	70.9
Yes	56	46.7	64	53.3	120	29.1
Career Starts						
1-7	47	54.0	40	46.0	87	21.1
8-13	57	52.3	52	47.7	109	26.4
14-23	52	51.0	50	49.0	102	24.7
24+	74	64.3	41	35.7	115	27.8

The results of the univariable linear regression analysis for the amount of prize money (*ln)* earned by horses are presented in *Table 4-9*. Birth month was not associated with prize money (*ln)* when unadjusted for other exposure variables (P=0.61). Dam (mare) age (P=0.10), gender (P=0.06), sales category (P=0.07), raced as a two-year-old (P=0.03) and total career starts (P<0.001) were significantly associated with the amount of prize money (*ln)* earned during a horses career.

Table 4-9: Univariable linear regression model for horses in the study population that raced and earned prize money.

Variable	Co efficient (Co-eff)	Standard error (SE)	95% confidence interval (CI)	P value
Dam (mare) age				
2-6	-0.01	0.25	-0.59--0.39	0.686
7-9	ref			
10-12	0.49	0.25	-0.005-0.98	0.052
13+	0.12	0.25	-0.37-0.61	0.637
Gender				
Males	ref			
Females	-0.33	0.18	-0.68-0.18	0.063
Birth Month				
July-August	-0.32	0.35	-1.01-0.36	0.353
September	-0.058	0.22	-0.48-0.37	0.792
October	ref			
November-December	-0.26	0.23	-0.72-0.20	0.265
Sales category				
Premier	ref			
Select	0.36	0.23	-0.10-0.82	0.122
Festival	-0.08	0.24	-0.55-0.39	0.734
Raced as a 2YO				
No	ref			
Yes	0.43	0.19	0.04-0.81	0.030
Career starts				
1-7	-3.93	0.16	-4.24--3.62	<0.001
8-14	-2.44	0.15	-2.73--2.15	<0.001
15-24	-1.31	0.15	-1.61--1.02	<0.001
25+	ref			

The final multivariable linear regression analysis (*Table 4-10*) showed that sales category and total number of career starts are associated with amount of prize money earned (P<0.001). Horses that had 1-7, 8-14, and 15-24 race starts earned 3.94±0.16, 2.46±0.15, and 1.31±0.15 times respectively, less prize money (*ln)* compared to horses that had more than twenty-five race starts (p<0.001). Total career starts were the most significant predictor in determining amount of prize money earned.

Table 4-10: Multivariable linear regression model for horses in the study population that raced and earned prize money.

Variable	Co efficient	Standard error	95% confidence interval (CI)	P value
Sales category				
Premier	Ref			
Select	0.003	0.15	-0.28-0.29	0.984
Festival	-0.25	0.15	-0.55-0.06	0.109
Career starts				
1-7	-3.94	0.16	-4.25--3.63	<0.001
8-14	-2.46	0.15	-2.75--2.17	<0.001
15-24	-1.31	0.15	-1.60--1.01	<0.001
25+	Ref			

Chapter 5

Discussion

To the author's knowledge, this is the first study to examine the association of yearling sale production parameters and the performance of the domestic racing product in New Zealand.

The aim of this study was to investigate the association of yearling sale production parameters, in particular dam (mare) age at the time of conception, with career success and longevity in a population of Thoroughbred horses. The results identified that the age of a dam (mare) at conception was not significantly associated with her progeny 1) obtaining a trial or race start, 2) racing and earning >$1 prize money, 3) the amount of prize money earned, and 4) longevity of career. This result is interesting, considering there appeared to be a buyer preference for yearlings from dams (mares) aged six-twelve at the 2004 NZB NYSS (Waldron *et al.*, 2010). The lack of association between dam (mare) age and the outcome measures of performance in the current study may be explained, in part, by the heavy pre-selection of yearlings by the auction company for entry into the sale, based on yearling pedigree and conformation. It would be expected that the yearlings selected by the auction company, were those yearlings from the population that appear to have the greatest chance of success, prior to reaching the racetrack. The biological effect of lower birth weights of foals from older, multiparous dams may result in these yearlings being less physically developed compared to their counterparts born to younger dams (mares) (Wilsher & Allen, 2003; Morel *et al.*, 2007). It is possible the yearlings born to older dams (mares) that were selected into the sale had above average pedigree, good conformation and/or advanced physical development thus, greater chance of success as a racehorse. The yearlings born to older dams (mares) catalogued in the sale may therefore not be representative of the underlying biological variation in the entire population, as they are subject to a stringent selection process by the auction sales company. The buyer preference reported by Waldron *et al.* (2010) indicates that yearlings born from dams (mares) aged six-twelve command the highest sales price at the NZB NYSS. This finding appears to not be justified on the racetrack.

The present study examined only a single offspring from each dam (mare). Therefore, inherent biological variation in broodmare quality may be influencing the lack of association between dam (mare) age and performance in our results. It may be of interest to examine all of the offspring born to a population of broodmares, with the intention of reducing the biological variation in broodmare quality.

Previous studies have reported that gender was associated with level of racing performance in Thoroughbred horses (Perkins *et al.*, 2004a,b; Wilsher *et al.*, 2006; Verheyen *et al.*, 2009). Two studies undertaken by Perkins *et al.* (2004a.b) found that gender was associated with measures of racing performance in the univariable analysis. However, these associations became not significant when adjusting for other exposure variables, particularly those relating to exercise. In agreement, the current study showed gender was associated with a horse obtaining a race start and the amount of prize money won at the univariable level but these associations became not significant when adjusting for other exposure variables. This suggests that gender may be an indicator of a horse having the opportunity to have a race start and earn prize money but the magnitude of the effect was not strong enough to carry through to the multivariable analysis. Therefore, other exposure variables must be greater drivers of a horse having a race start and the amount of prize money earned. This result could also be explained by exposure variables that were not measured in this study, such as the difference in training methods and racing patterns of males and females. Contrary to the results found by Perkins *et al.* (2004a,b), Wilsher *et al.*

(2006), and Verheyen *et al.* (2009) the current study showed that gender was not associated with a horse having a trial start. This result is not surprising as trial races are not split between genders, thus males and females have equal opportunity to obtain a trial start. In contrast, races can be restricted entry. For example; some races are open to only females (fillies and mares). This is an attempt to give the females an equal opportunity to perform, before taking on the males in open company.

The results of the current study show that female horses are less likely to start in a race and are more likely to cease racing compared to male horses. A market preference for colts was reported in a study on Thoroughbred yearlings cataloged in the 2004 NZB NYSS, where colts sold for significantly more than fillies (Waldron *et al.*, 2010). Owners may be more willing to persist with a horse until a race start has been achieved, when the initial investment is high, in an attempt to avoid failure. Male horses may generally have a greater opportunity for success, due to the high initial investment compared to females. Moreover, the differences in gender may be due, in part, to females exiting the training and racing population to begin a breeding career. Females have greater breeding potential compared to males. Therefore, there is likely to be increased interest in training and racing a gelding (male horse with no breeding value) for longer periods of time compared to females (with breeding potential) (Perkins *et al.*, 2004a,b). In New Zealand, the majority of male horses on the race track are geldings, who have little value post racing. In 2009, there were only 166 stallions registered compared to 8,326 broodmares that were registered, which indicates (based on a 50/50 ratio of males to females) the higher selection intensity for males compared to females in the breeding population. Wilsher *et al.* (2006) documented that of the 27% of horses that retired to stud 99% were fillies and one colt took up stallion duties. This suggests across racing jurastictions, females may be more likely to leave the racing population to begin a breeding career.

Although there appears to be a buyer preference for yearlings born early in the season (July-September) (Waldron *et al.,* 2010), the results of the current study indicate that there was no association between birth month and a horse 1) obtaining a trial or race start, 2) racing and earning >$1 prize money, 3) the amount of prize money earned, and 4) longevity of career. Foals born early in the season usually present size, strength and maturity at a yearling sale and are more developed physically thus, providing them with a greater probability of early success (MacCarthy & Mitchell, 1974; Buzby & Jessup, 1994; Vickner & Koch, 2001; Brown-Douglas *et al.,* 2005; Morel *et al.,* 2007; Parsons & Smith, 2008; Van Rijssen *et al*., 2010). It may be concluded that horses that are born earlier in the season may have a greater chance of success as a two-year-old due to a greater physical development compared to horses that are born later in the season. However, the physical advantage held by early born horses reduces as the later born horses are given time to develop and mature, meaning both late born horses and early born horses may have an equal chance of success later in their career. It could be expected that birth month will have a significant association with racing performance of horses when investigating their two-year-old career. As the current study does not distinguish between age groups (age milestones) of horses, it is not surprising that no association was found between birth month and the racing performance of horses. Interestingly, a retrospective cohort study on Standardbred foals born in New Zealand in 2001/2002 reported that horses that enter training, trial or race as a two year-old have longer more successful careers than those who do not reach these milestones until after their two year-old season (Tanner *et al.,* 2010). This indicates that horses that are able to be put into training early may have more successful careers. Therefore, as yearlings born early in the season are generally more developed compared to their later born counterparts, it may be interesting to investigate the association of birth month and racing performance at each age group in future studies.

The sales category was found to explain the greatest proportion of variance in yearling sales price at the 2004 NZB NYSS (Waldron *et al.*, 2010). Accordingly, it was not surprising that sales category was significantly associated with 1) a horse racing and earning >$1 in prize money, and 2) the longevity of a horses career. However, no significant association was found between sales category and 1) a horse obtaining a trial start, and 2) a horse obtaining a race start. Surprisingly, horses catalogued in the select session are more likely to race and earn prize money compared to horses in the premier session. This may be explained by the elite horses from the premier session being exported thus, leaving only a second tier population. Furthermore, horses from this category usually have a pre-destined career, meaning they will more than likely be trained by the best trainers (due to the high premium paid at yearling sale), thus giving them the greatest opportunity to succeed (Bolwell *et al.*, 2011a,b). A trade-off to this is that a top trainer must keep their turnover high in order to keep their strike rate up and a horse not showing early ability will often be removed from the stable. The number of premier horses that do not race and earn prize money could be higher than expected due to the possibility that the top tier of horses from this session are being exported. On the other hand, horses from the select session more than likely account for the majority of the domestic racing product. Horses from the select session usually will have an average pedigree compared to horses catalogued in the premier session and as a result, there could be less demand for a horse from the select session compared to a horse from the premier session on an international scale. In conclusion, it could be expected that more horses from the select session have an opportunity to earn prize money in New Zealand compared to the remaining horses from the premier session (after export).

Horses catalogued in the festival session had less career starts before cessation of racing occurs compared to horses catalogued in the premier session. Horses in the festival session have a mean sales price of $9,462, which is approximately 13% of the mean sales price of a horse catalogued in the premier session (Waldron *et al.*, 2010). The low initial investment, compared to premier horses, may mean owners will readily give up on horses from the festival session if they are showing little or no ability, to avoid losing more money.

A prospective, cohort study that recorded the training activity of a population of Thoroughbreds in New Zealand, over two seasons, reported the number of trial starts obtained by a horse is an important driver to whether or not it will start in race (Bolwell *et al.*, 2011a.b). In agreement, the results of the current study indicated that horses that had started in a trial were more likely to start in a race and to earn prize money compared to horses that had not started in a trial. However, unlike Bolwell *et al.* (2011a.b) the current study did not determine the effect the number of trial starts has on a horse starting in a race therefore, a direct comparison cannot be made. A trial can be considered an important indicator in determining the future direction of a horse. Through watching a trial, a trainer can assess a horse's progress and ability, or lack thereof, and make informed decisions regarding whether a horse should remain in training, ultimately progressing towards a race start (Bolwell *et al.*, 2011a,b). Therefore, it is expected that a trainer will usually start a horse in a trial before starting it in a race in order to evaluate its ability, so suitable future races can be assigned to each individual horse. A horse showing little or no ability at a trial may not start in a race due to recommendations from the trainer. Consequently, it may be expected that horses that trial prior to starting in a race possess ability and may have a greater chance of earning prize money, compared to those that have not started in a trial.

The current study reported that increasing years spent racing was associated with a reduced chance of early retirement. This is not surprising as a horse that is kept in racing for a number of years must be showing some level of talent or ability or it would most likely have been removed from the racing population. The most common reasons for not competing or competing less than average number of times was horses showing little or no racing ability, joint problems, foot problems and shin soreness (Jeffcott *et al.,*1982; Bailey *et al.,* 1999; Perkins *et al.,* 2004a,b; Wilsher *et al.,* 2006; Verheyen *et al.,* 2009). The current study does not investigate the reasons for a horse ceasing racing. It may be important to include the reasons for ceasing racing in future analysis for a more precise conclusion.

Linear regression showed that total career starts were the biggest predictor in determining the amount of prize money (*ln)* a horse will earn. Horses that have more than twenty-five race starts are more likely to earn more prize money (*ln)* compared to horses that have less than twenty-five race starts. This is not surprising as horses that run in a greater number of races are exposed to more opportunities to earn prize money. Horses are generally kept in racing, for a long duration (>twenty-four starts), if they continue to show their ability. These horses should therefore have an increased chance of earning money as they are exposed to a greater opportunity to receive prize money. In contrast, horses that do not race for a long duration may have little or no ability, lameness or disease (Jeffcott *et al.,*1982; Bailey *et al.,* 1999; Perkins *et al.,* 2004a,b; Wilsher *et al.,* 2006; Verheyen *et al.,* 2009). These factors will, more often than not, prevent a horse from starting in a race. A race provides a horse with the opportunity to earn prize money hence, horses that are not starting in races have no opportunity to earn prize money.

The natural logarithmic (*ln*) transformation of earnings (prize money $) was used in the analysis and as a result, observations where earnings were recorded as zero were excluded from analysis. The results of these analyses can therefore only be applied to horses capable of winning prize money (54.5% of horses in the current study population) and should not be extrapolated to the general racehorse population.

5.1 Limitations

Although associations of our yearling sale production parameters and racing performance have been demonstrated, it is important to recognise the limitations of this study. This study was limited to the use of NZB yearling sale records and NZTR trial and race results, thus this study could only account for yearling sale production parameters in the data that were available. Confounding is likely to confuse the interpretation of associations between yearling sale production parameters that appear to be related. It is possible that the relationships in this study were confounded by factors that were unable to be measured such as the conformation of the horse, pedigree and the intensity and methods of training received by each horse. Any future studies should attempt to include an assessment of these confounding factors, and any others, to provide a valid explanation of the factors that influence a horse's ability to perform on the racetrack.

The effect of trainer was not considered in the current study for two reasons. Firstly, the dataset provided by NZTR included only the most recent trainer, if any, associated with each horse. Therefore, the trainer recorded in the dataset may have not been the trainer for a horse's entire racing career. Studies have concluded that species clustered into herds are often correlated when examining factors such as disease (McDermott & Schukken, 1994; More, 1999). This occurs as a result of inter-mixing and common management practices. In the same respect, horses may be clustered under the same trainer and correlated in terms of performance. For example, a trainer may attract horses to their stable based on their reputation or fee (a respected reputation or high fee may attract horses of a high quality and vice versa). A study completed by Bolwell *et al.* (2011a) reported that horses with the same trainer were clustered together with regards to having a trial or race start. Secondly, the current study was a retrospective cohort study. As a result, the authors could not assess the training methods of each trainer as they were not included in the electronic dataset provided by NZTR. Training methods may influence performance outcomes. Recent studies have suggested that exercise during training is associated with skeletal injury in Thoroughbred racehorses (Bailey *et al.,* 1999; Perkins *et al.,* 2004a,b; Rogers *et al.,* 2008; Verheyen *et al.,* 2009; Bolwell *et al.,* 2010; Bolwell *et al.,* 2011a,b). One study reported that decreasing canter exercise in favor of high speed exercise may reduce the risk of developing fractures (Verheyen *et al.,* 2009). As trainers generally utilise a personalised method for training horses, differences in these methods may impose an increased or decreased risk of a horse developing a fracture. Moreover, some trainers can achieve success with certain age groups (More, 1999; Verheyen *et al.,* 2009). Verheyen *et al.* (2009) found three year-olds were less likely to win races or prize money compared to two year-olds. However, when adding the trainer in as an exposure variable this result was reported to be not significant. Further investigation indicated that the significance of this result was due to one trainer who had a good success rate with two year-olds. Therefore it may be unsuitable to interpret the results of the current study to be significant without adjusting for a trainer effect. Any further studies should investigate trainer as an exposure variable of a frailty term to provide a valid assessment of how the trainer influences the race performance of a horse.

Additionally, the current study cohort may not be representative of the 2004 New Zealand foal crop as horses were selected for this study based on their inclusion in the 2004 NZB NYSS catalogue. Yearling sales price is ultimately driven by expected success on the race track. The yearling sale production parameters examined by Waldron *et al.* (2010) are considered to be predictors of yearling sales price which therefore can be considered as indicators of racing success. Moreover, breeders have the opportunity to retain foals with the best bloodlines to race themselves. This is particularly apparent amongst fillies, as achieving success on the racetrack will sustain and may improve a breeder's broodmare herd for future generations. In contrast, yearlings that do not meet the standard required by the auction company will be retained by breeders and are likely to be on-sold privately. It is likely that the quality of horses in the sample population will differ from the quality of the 2004 New Zealand foal crop due to individual breeder requirements and the stringent selection process employed by the auction company.

A potential form of bias may be present in the data due to the horses that were exported prior to the analyses. Waldron *et al.* (2010) concluded that in order to maximise yearling sales returns vendors require colts which are marketed through the premier sale, with a pedigree that appeals to Australian buyers. The majority of yearlings that commanded a high sales price may therefore be exported to Australia and not included in the current study. As yearling sales price is ultimately driven by expected success on the race track, it could expected that the horses being exported have a greater chance of success because of the high premium paid. As a result, the remaining population may be second tier to the total population.

In the survival analysis the outcome of interest was cessation of a horses racing career. In this analysis, the data was not available from 3/03/2011 which was part way through the horses' eight-year-old racing season. Therefore, it is possible that some misclassification may have occurred with respect to the date that some horses ceased their racing careers.

Chapter Six

Conclusion

Although dam (mare) age and birth month were found to be significant factors in determining yearling sales price, there appears to be no association between these variables and the race performance of Thoroughbred horses. The preference for colts at yearling sales appears to be justified on the race track as colts out performed fillies in most instances. Sales category appeared to be an important driver for racing performance, highlighting the importance of the role of the auction company in placing yearlings in different sessions. However, the effects of sales category may be more pronounced when factoring in horses that were exported.

The associations, or lack thereof, of the yearling sale production parameters measured in this study, with outcome measures of performance may influence the future buyer behaviour, at auction, in the New Zealand Thoroughbred market.

References

ANONYMOUS. 2001. *Arther's veterinary reproduction & obstetrics, 8th edition*. Elsevier Ltd. Infertility in the mare. **26**: 577-620

ANONYMOUS. (2004). IER. Size and scope of the New Zealand racing industry. Economic impacts and community social benefit. Report to the New Zealand racing board. Retrieved on 15 June, 2010 from http://static.tab.co.nz/control/data/nzrb-other-reports/NZRB-Industry-Size-Scope-Study-June-2004

ANONYMOUS. (2009). New Zealand Racing Board (NZRB). *Annual report 2008/2009.* Retrieved on June 24, 2010 from http://www.nzracing.co.nz/About/Publications.aspx

ANONYMOUS. (2010a). IER. Size and scope of the New Zealand racing industry. Economic impacts and community social benefit. Report to the New Zealand racing board. Retrieved on 15 September, 2011 from http://static.tab.co.nz/control/data/nzrb-other-reports/NZRB_Size_and_Scope_Final.pdf

ANNONYMOUS. (2010b). New Zealand Thoroughbred Breeders' Association (NZTBA). *Facts and Figures.* Retrieved on June 15, 2010 from http://www.nzThoroughbred.co.nz/Facts-Figures.aspx

ANONYMOUS. (2010c). New Zealand Racing Board (NZRB). *About the New Zealand Racing Board.* Retrieved on June 15, 2010 from http://www.nzracingboard.co.nz/index.html.

ANNONYMOUS. (2010d). New Zealand Thoroughbred Breeders Association (NZTBA). Production and selling costs. Retrieved on November 29, 2010 from http://www.nzThoroughbred.co.nz/UserFiles/File/ARCHIVE/Production%20&%20Selling%20Costs,%20Feb%202010(1).pdf

ANNONYMOUS. (2010e). International Federation of Horseracing Authorities (IFHA). *World Thoroughbred Rankings*. Retrieved on 31st October, 2010 from http://www.horseracingintfed.com/racingDisplay.asp?section=16

BAILEY, C. J., REID, S. J. W., HODGSON, D. R., & ROSE, R. J. 1999. Impact of injuries and disease on a cohort of two- and three- year old thoroughbreds in training. *Veterinary Record*. **145**: 487-493

BARRON, J. K. 1995. The effect of maternal age and parity on the racing performance of Thoroughbred horses. *Equine Veterinary Journal*. **27**: 73-75.

BELL, A. G. 1918. The duration and life conditions associated with longevity: Study of Hyde geneology. Genealogical record office, Washington D.C.

BHUVANAKUMAR, C. K., & SATCHIDANANDAM, V. 1989. Effect of parity on the birth weight of foals in Thoroughbreds. *Centaur*. **6**: 43-45.

BODEN, L. A., ANDERSON, G. A., CHARLES, J. A., MORGAN, K. L., MORTON, J. M., PARKING, T. D. H., CLARKE, A. F., & SLOCOMBE, R. F. 2007. Risk factors for Thoroughbred racehorse fatality in flat starts in Victoria, Australia (1989-2004). *Equine Veterinary Journal*. **39**(5): 430-437.

BOLWELL, C. F., ROGERS, C. W., FIRTH, E. C., & FRENCH, N. P. 2010. Management and exercise of Thoroughbred yearlings during preparation for yearling sales in the North Island of New Zealand. *Proceedings of the New Zealand Society of Animal Production*. **70**: 157-161.

BOLWELL, C. F., ROGERS, C. W., FIRTH, E. C., & FRENCH, N. P. 2011a. The effect of interruptions during training on the time to the first trial and race start in Thoroughbred racehorses. Unpublished data.

BOLWELL, C. F., ROGERS, C. W., FIRTH, E. C., & FRENCH, N. P. 2011b. Risk factors for interruptions occurring before the first trial start of 2-year-old Thoroughbred racehorses in training. Unpublished data.

BOSH, K. A., POWELL, D., NEIBERGS, J. S., SHELTON, B., ZENT, W. 2009a. Impact of reproductive efficiency over time and mare financial value on economic returns among Thoroughbred mares in central Kentucky. *Equine Veterinary Journal*. **41**: 889-894.

BOSH, K. A., POWELL, D., SHELTON, B., ZENT, W. 2009b. Reproductive performance measures among Thoroughbred mares in central Kentucky, during the 2004 mating season. *Equine Veterinary Journal*. **41**: 883-888.

BOURKE, J. M. 1995. Wastage in Thoroughbreds. In: *Proceedings of the Annual Seminar of the Equine Branch of the New Zealand Veterinary Association*, Veterinary Continuing Education Publication Number: **167**, Massey University.

BROWN-DOUGLAS, C. G., PARKINSON, T. J., FIRTH, E. C., & FENNESSY, P. F. 2005. Bodyweights and growth rates of spring- and autumn- born Thoroughbred horses raised on pasture. *New Zealand Veterinary Journal*. **53**(5): 326-331.

BRUCK, I., ANDERSON, G., AND HYLAND, J. 1993. Reproductive performance of thoroughbred mares on six commercial stud farms. *Australian Veterinary Journal*. **70**(8): 299-303.

BUCCOLA, S. T. 1982. Price trends at livestock auctions. *American Journal of Agricultural Economics*. **64**(1): 63-69.

BURNS, E.M., ENNS, R.M. AND GARRICK, D.J. 2006. The effect of simulated censored data on estimates of heritability of longevity in the Thoroughbred racing industry. *Genetics and Molecular Research.* **5**: 7-15.

BUZBY, J. C. & JESSUP, E. L. 1994. The relative impact of macroeconomic and yearling specific variables in determining Thoroughbred yearling price. *Applied Economics*. **26**: 1-8.

CARNEVALE, E. M., AND GINTHER, O. J. 1982. Relationships of uterine function and reproductive efficiency in mares. *Theriogenology*. **37**: 1101-1115.

CASTLE, K., NICHOLAS, F. W., AND JAMES, J. W. 2008. An update on inbreeding in Australian Thoroughbred horses. *Proceedings of the Australian Equine Science Symposium.* **2**: 16.

CHAVAS, J. P., & KLEMME, R. 1986. Aggregate milk supply response and investment behaviour on U.S dairy farms. *American Journal of Agriculture and Economics.* **68**: 55-66.

CHEZUM, B. & WIMMER, B. 1997. Roses or lemons: adverse selection in the market for Thoroughbred yearlings. *The Review of Economics and Statistics*. **79**(3): 521-526.

CHEETHAM, J., RIORDAN, A. S., MOHAMMED, H. O., MCILWRAITH, C. W., & FORTIER, L. A. 2010. Relationships between race earnings and horse age, sex, gait, track surface and number of race starts for Thoroughbred and Standardbred racehorses in North America. *Equine Veterinary Journal.* **42:** 346-50.

CHVOSTA, J., RUCKER, R. R., & WATTS, M. J. 2001. Transaction costs and cattle marketing: the information content of seller-provided presale data at bull auctions. *American Journal of Agricultural Economics*. **83**(2): 286-301.

COMMER, M. 1991. The effect of non-phenotypic data on Thoroughbred prices in the mid-atlantic market. *The Professional Animal Scienctists.* **7**: 18-24.

FENNESSY, P. F. 2010. An overview of the New Zealand Thoroughbred industry. *Proceedings of the New Zealand Society of Animal Production*. **70**: 137-139.

FINOCCHIO, E. J., & ROSENZWEIG, M. 1995. Significance of birthrank, maternal age and parity on race performance in Thoroughbreds. *Proceedings of the Annual Convention of the American Association of Equine Practitioners*. **41**: 64-67.

FIRTH, E. C., & ROGERS C. W. 2005. Musculoskeletal responses of 2-year-old Thoroughbred horses to early training. Conclusions. *New Zealand Veterinary Journal*. **53**: 377-83.

GAVRILOV, L. A. & GAVRILOVA, N. S. 2000. Human longevity and parental age at conception. In: J.-M. Robine *et al.* (eds) sex and longevity: sexuality, gender, reproduction, parenthood, Berlin, Heidelburg. Springer-Verlag. 7-31.

HASTINGS, T. 1987. Price variations of yearling Thoroughbreds at Australian auctions. *Irish Journal of Agricultural Economics and Rural Sociology*. **12**: 19-29.

HEMBURG, E., LUNDEHEIM, N., AND EINARSSON, S. 2004. Reproductive performance of Thoroughbred mares in Sweeden. *Reproduction of Domestic Animals*. **39**: 81-85.

HINTZ, H. F., HINTZ, R. L., & VAN VLECK, L. D. 1979. Growth rate of Thoroughbreds, effect of age of dam, year and month of birth, and sex of foal. *Journal of Animal Science*. **48**: 480-487.

HINTZ, R.L. 1980. Genetics of performance in the horse. *Journal of Animal Science.* **51**: 582-594.

JEFFCOTT, L. B., ROSSDALE, P. D., FREESTONE, J., FRANK, C. J., & TOWERS-CLARK, P. F. 1982. An assessment of wasteage in thoroughbred racing from conception to 4 years of age. *Equine Veterinary Journal*. **14**(3): 185-198.

KLASS, M. R. 1977. Aging in the nematode *Caenorhabditis elegans:* major biological and environmental factors influencing lifespan. *Mechanisms of Aging and Development*. **6**:413-429.

LANGLOIS, B. 1980. Heritability of racing ability in Thoroughbreds-A review. *Livestock Production Science.* **7**: 591-605.

LANSING, A. I. 1947. A transmissible, cumulative and reversible factor in aging. *Journal of Gerontology*. **2**:228-239.

MACCARTHY, D. & MITCHELL, J. 1974. A study of growth rate in Thoroughbred foals and yearlings. *Irish Journal of Agricultural Research*. **13**: 111-117.

MADILL, S. 2002. Reproductive considerations: mare and stallion. *Veterinary Clinics Equine Practice*. **18**:591-619.

MCCARTHY, G. 2009. Analysis of supply chain wastage in the thoroughbred and harness racing codes. In: The Foundation Bulletin. Pp 2-5. (New Zealand Equine Research Foundation, Palmerston North, NZ).

MCDERMOTT, J. J., & SCHUKKEN, Y. H. 1994. A review of methods used to adjust for cluster effects in explanatory epidemiological studies of animal populations. *Preventative veterinary medicine.* **18**: 155-173.

MCDOWELL, K., POWELL, D., & BAKER, C. 1992. Effect of book size and age of mare and stallion on foaling rates in thoroughbred horses. *Journal of Equine Veterinary Science*. **12**(6):364-367.

MOREL, P. C. H., BOKER, A., ROGERS, C. W., & FIRTH, E. C. 2007. Growth curves from Birth to weaning for Thoroughbred foals raised on pasture. *New Zealand Veterinary Journal*. **55**(6): 319-325.

MORE, S. J. 1999. A longitudinal study of racing Thoroughbreds: performance during first years of racing. *Australian Veterinary Journal*. **77**: 105-12.

MORLEY, P. S., AND TOWNSEND, H. G. G. 1997. A survey of reproductive performance in Thoroughbred mares and morbidity, mortality and athletic potential of their foals. *Equine Veterinary Journal*. **29**(4): 290-297

MORRIS, L. H. A., AND ALLEN, W. R. 2002. Reproductive efficiency of intensively managed thoroughbred mares in Newmarket. *Equine Veterinary Journal*. **34**(1): 51-60.

NAGY, R. 2005. Effects of management on reproductive efficiency in Thoroughbreds. Thesis completed in partial fulfillment of the requirements of a Master of Science in the college of agriculture at the University of Kentucky, Lexington, Kentucky.

NATH, L. C., ANDERSON, G. A., AND MCKINNON, A. O. 2010. Reproductive efficiency of Thoroughbred and Standardbred horses in north-east Victoria. *Australian Veterinary Journal*. **88**(5): 169-174.

NEIBERGS, J. S. 2001. A hedonic price analysis of Thoroughbred broodmare characteristics. *Journal of Agribusiness*. **17**(2): 299-314.

NEIBERGS, J. S., & THALHEIMER, R. 1997. Price expectations and supply response in the Thoroughbred yearling market. *Journal of Agricultural and Applied Economics*. **29**(2): 419-435.

O'SULLIVAN, D. M. 1980. An investigation into the relationship between age of dam and performance of her progeny in Thoroughbreds. *New Zealand Veterinary Association Newsletter*: 25-31.

PAGAN, J. D., NASH, D. M., KOCH, A., CADDEL, S., & BROWN-DOUGLAS, C. G. 2006. The influence of body weight, wither height, and body condition score on the sale price of Thoroughbred yearlings at public auction. *Proceedings Australian Equine Science Synopsium*. **1**: 27.

PARSONS, C. & SMITH, I. 2008. The price of Thoroughbred yearlings in Britain. *Journal of Sports Economics*. **9**(1): 43-66.

PARSONS, P. A. 1964. Parental age and the offspring. *The quarterly review of Biology*. **39**(3): 258- 275

PERKINS, N. R., REID, S. W. J., & MORRIS, R. S. 2004a. Profiling the New Zealand Thoroughbred racing industry. 1. Training, racing and general health patterns. *New Zealand Veterinary Journal.* **53**(1): 59-68.

PERKINS, N. R., REID, S. W. J., MORRIS, R. S. 2004b. Profiling the New Zealand thoroughbred racing industry. 2: Conditions interfering with training and racing. *New Zealand Veterinary Journal*. **53**(1): 69-76.

PHILIPPE, P. 1980. Longevity: some familial correlates. *Proceedings of the Biological Society Washington*. **27**: 211-219.

PORTER, R. A. 1971. A new way to evaluate race horses introduction. *Thoroughbred Record.* 193: 960.

PRIEST, N. K., MACKOWIAK, B. & PROMISLOW, D. E. L. 2002. The role of parental age effects on the evolution of aging. *Evolution*. **56**(5): 927-935

PHYSICK-SHEARD, P. W., & RUSSELL, M. 1986. Career profile of the Canadian Standardbred III. Influence of temporary absence from racing and season. *Canadian Journal of Veterinary Research.* **50:** 471-8.

RIETBROEK, N. J., DINGBOOM, E. G., JOOSTEN, B., EIZEMA, K., & EVERTS, M. E. 2007. Effect of show jumping training on the development of locomotory muscle in young horses. *American Journal of Veterinary Research.* **68**: 1232-8.

RICARD, A., BRUNS, E., & CUNNINGHAM, E.P. 2000. Genetics of performance traits. In: *The Genetics of the Horse*, Eds: A.T. Bowling and A. Ruvinsky, CABI Publishing, Wallingford, UK. pp 411-438.

RICARD, A., & FOURNET-HANOCQ, F. 1997. Analysis of factors affecting length of competitive life of jumping horses. *Genetics Selection Evolution.* **29**: 251-67.

ROBBINS, M. & KENNEDY, P. E. 2001. Buyer behaviour in a regional Thoroughbred yearling market. *Applied Economics.* **33**: 969-977.

ROGERS, C. W., FIRTH, E. C., MCILWRAITHT, C. W., BARNEVELD, A., GOODSHIP, A. E., KAWCAK, C. E., SMITH, R. K. W., & VAN WEEREN, P. R. 2008**.** Evaluation of a new strategy to modulate skeletal development in Thoroughbred performance horses by imposing track-based exercise during growth. *Equine Veterinary Journal.* **40**: 111-8.

ROGERS, C. W., AND COGGER. N. 2010. A cross-sectional survey of biosecurity practices on Thoroughbred Stud farms in New Zealand. *New Zealand Veterinary Journal*. **58**(2): 64-68.

ROGERS, C. W., GEE, E. K., AND VERMEIJ, E. 2009. Retrospective examination of the breeding efficiency of the New Zealand Thoroughbred and Standardbred. *Proceedings of the New Zealand Society of Animal Production*. **69:** 126-131.

SAASTAMOINEN, M., & OJALA, M. 1994. Influence of different combinations of racing years on early career performance in trotters. *Acta Agriculturae Scandinavica.* **44**: 208-13.

SANDERSON, M. W., AND ALLEN, W. R. 1987. Reproductive efficiency of thoroughbred mares in the United Kingdom. *Proceedings from the 9th Brain Fallon Memorial lectures*. pp 31-41.

SMITH, M. D. 2001. Breeding incentive programmes and demand for California Thoroughbred racing: is there a quality/quantity tradeoff? *Applied Economics*. **33**: 1755-1762.

SOBCZYNSKA, M. 2007. The effect of selected factors on length of racing career in Thoroughbred racehorses in Poland. *Animal Science Papers and Reports.* **25**: 131-41.

STICK, J. A., PELOSO, J. G., MOREHEAD, J. P., LLOYD, J., EBERHART, S., & PADUNGTOD, P. 2001. Endoscopic assessment of airway function as a predictor of racing performance in Thoroughbred yearlings: 427 cases (1997–2000). *Journal of the American Veterinary Medical Association*. **219**(7): 962-967.

STRAND, E., MARTIN, G. S., HAYNES, P. F., MCCLURE, R., & VICE, D. 2000. Career racing performance in Thoroughbreds treated with prosthetic laryngoplasty for laryngeal neuropathy: 52 cases (1981-1989). *Journal of the American Veterinary Medical Association*. **217**(11): 1689-1696.

TANNER, J. C., ROGERS, C. W., & BOLWELL, C. F. 2010. Brief communication: Preliminary examination of training and racing milestones in a subset of Standardbred horses. In: 'New Zealand Society of Animal Production 70th Conference'. Palmerston North, New Zealand. (ed) Sumner R) Pp 149-51. (New Zealand Society of Animal Production).

THIRUVENKADAN, A.K., KANDASAMY, N. AND PANNEERSELVAN, S. 2009. Inheritance of racing performance of Thoroughbred horses. *Livestock Science.* **121**: 308-326.

TOLLEY, E.A., NOTTER, D.R. AND MARLOWE, T.J. 1985. A review of the inheritance of racing performance in horses. *Animal Breeding Abstracts.* **53**: 163-185.

VAN RIJSSEN, J. D., GEE, E. K., ROGERS, C. W., AND O'BRIEN, J. R. 2010. Factors influencing gestation length and interval from foaling to conception in mares managed on a commercial Thoroughbred studfarm. *Proceedings of the New Zealand Society of Animal Production*. **70**: 146-148.

VAN WEEREN, P. R., FIRTH, E. C., BROMMER, H., HYTTINEN, M. M., HELMINEN, H. J., ROGERS, C. W., DEGROOT, J., & BRAMA, P. A. J. 2008. Early exercise advances the maturation of glycosaminoglycans and collagen in extracellular matrix of articular cartilage in the horse. *Equine Veterinary Journal.* **40**: 128-35.

VERHEYEN, K., PRICE, J., & WOOD, J. 2009. Exercise during training is associated with racing performance in Thoroughbreds. *Veterinary Journal.* **181**: 43-7.

VICKNER, S. S. & KOCH, S. I. 2001. Hedonic pricing, information, and the market for Thoroughbred yearlings. *Journal of Agribusiness*. **19**(2): 173-189.

WILLIAMSON, S. A., & BEIHARZ, R. G. 1996. Heritibilities of racing performance in Thoroughbreds: a study of Australian data. *Journal of Animal Breeding Genetics.* **113**: 505-524.

WISHER, S. & ALLEN, W. R. 2003. The effects of maternal age and parity on placental and fetal development in the mare. *Equine Veterinary Journal*. **35**: 476-483.

WILSHER, S., ALLEN, W., & WOOD, J. 2006. Factors associated with failure of Thoroughbred horses to train and race. *Equine Veterinary Journal*. **38**: 113-8.

YOUNG, L. E., ROGERS, K., WOOD, J. L. N. 2005. Left ventricular size and systolic function in Thoroughbred racehorses and their relationship to race performance. *Journal of Applied Physiology*. **99**: 1278-1285