Quantification of equine reproductive loss

# A survey on the New Zealand Thoroughbred broodmare

Date: November 2010
By: Drs. L.A. van Leeuwen
 Faculty of Veterinary Medicine, Utrecht University, The Netherlands
Supervisors: Dr. C.W. Rogers, Massey University
 Dr. E.K. Gee, Massey University
 Prof. Dr. R. Van Weeren, Utrecht University

Institute of Veterinary, Animal and Biomedical Sciences, Massey University
Equine Department, Palmerston North, New Zealand

1. Abstract

To describe the biological risk factors for reproductive losses within the New Zealand commercial Thoroughbred horse breeding industry reproductive data of 1270 mares for the 2001/02 to 2008/09 breeding seasons were obtained from online databases and collated for analysis. Data were examined using Chi square tests, logistic regression and Kaplan Meier survival analysis.
The effects of mare age, parity and status on the rates of pregnancy losses were analysed.
The overall pregnancy rate and foaling rate was 83.9% and 80.5% respectively. Mare age and status significantly affected the incidence of misses and slips. Old mares (13-18) showed more slips and an increasing risk for missing. This risk does not increase in mares older than 12 years. Mares with a dead foal the previous year had a major decrease in pregnancy rate, while mares that were not served and maiden mares showed the highest pregnancy rates. No prospective value of having a miss or a slip one year is observed, so a missing or slipping mare is not likely to miss or slip more than foaling mares during the rest of their careers.
Embryonic loss in New Zealand Thoroughbred broodmares can be caused by a wide range of factors, directly or indirectly. More integrated research is needed to specify the risks. Stud masters must be aware of the risks and make sure that mares that gave birth to a dead foal are carefully examined. Older mares need to be inspected thoroughly to minimise embryonic loss.

# Contents

1. **Abstract**......................................................................................................................... **2**
2. **Table of Contents**.......................................................................................................... **3**
3. **Introduction**.................................................................................................................. **4**
	1. NZ Racing................................................................................................................ 4
	2. Stud farm management.......................................................................................... 4
	3. Equine pregnancy.................................................................................................... 6
		1. Early pregnancy (<40 days).................................................................................. 6
		2. Foetal stage (>40 days)........................................................................................ 7
	4. Pregnancy Loss........................................................................................................ 8
		1. ‘Missed’ mares................................................................................................... 9
		2. Slipping mares.................................................................................................... 9
4. **Materials and methods**.................................................................................................. **10**
	1. Dataset..................................................................................................................... 10
	2. Statistical analysis.................................................................................................... 11
5. **Results**............................................................................................................................ **12**
	1. Breeding records...................................................................................................... 12
	2. Pregnancy loss......................................................................................................... 14
	3. Risks for pregnancy loss........................................................................................... 16
		1. Age.................................................................................................................... 16
		2. Parity................................................................................................................. 17
		3. Breeding status................................................................................................... 18
			1. *Dead foal*............................................................................................18
			2. *Missed*................................................................................................19
			3. *Slipped*................................................................................................19
			4. *Not served*...........................................................................................19
			5. *Maiden*............................................................................................... 19
	4. Multivariate analysis................................................................................................ 21
	5. Prospective value..................................................................................................... 23
6. **Discussion**....................................................................................................................... **25**
7. **References**...................................................................................................................... **28**

# Introduction

Anecdotal evidence exists that within the New Zealand Thoroughbred and Standardbred breeding industry there is significant reproductive and early neonatal loss on commercial stud farms. Preliminary analysis of industry data has confirmed this. Associated with this high rate of reproductive and neonatal loss there has been a constant reduction in the number of mares bred each season during the last 10 years. During the last two decades the number of active broodmares decreased by 36 %, and the number of live foals reduced by 45%. The number of active sires decreased as well, from 265 in 1990 to 124 in 2004. However, the number of mares served by these sires increased by 1 mare per year per stallion. The mean number of mares covered by 1 stallion was 50, but some stallions covered more than 227 mares (Rogers *et al.* 2007, Rogers *et al.* 2009). These changes require addressing urgently, as the reduced numbers of mares being bred each season mean the industry will have to minimise reproductive losses to provide sufficient foals for the racing and export sectors of the industry.
The aim of this project is to utilise existing breeding records to identify biological risk factors within the New Zealand commercial Thoroughbred horse breeding industry for reproductive losses. The associations between mare age, parity and the mares’ reproductive status will be the primary variables of interest.

3.1 NZ racing
Thoroughbred horses are primarily bred for flat racing. The racing industries (Thoroughbred, Standardbred and Greyhounds) are responsible for 1.3% of New Zealand’s total Gross Domestic Product. The Thoroughbred breeding industry is the largest of the commercial horse enterprises and generates NZ$1.093 million a year, 0.95% of the GDP.
23,000 people are involved with the Thoroughbred breeding and racing industries, equal to 13,567 Full Time Equivalent jobs. In 2003 there were 286 race meetings with 609,900 visitors, spending NZ$21.8 million on course.
New Zealand is the seventh largest producer of Thoroughbred foals with 4.2% of the international foal crop. More than 3000 breeders spend NZ$394 million annually on foal production. At least one third of annual foal crop is exported, which generates over NZ$120 million per year. The majority of the horses (64.8%) are exported to Australia. (Rogers *et al.* 2009; Size and Scope of New Zealand Racing Industry 2004)

3.2 Stud farm management
The Thoroughbred studbook is the largest equine studbook in New Zealand with ~6,500 broodmares (Rogers *et al.* 2009).
Equine production systems in New Zealand have a greater pastoral focus than contemporary industries in the Northern hemisphere. This generates subtle differences in management of the mare and the early neonate (Morel *et al.* 2007; Rogers *et al.* 2007*)*. The pastoral management of horses in New Zealand means that horses may be exposed to a greater variation in herd health and nutritional management during pregancy (Hanlon 2008). Most horses are grown at pasture all year round and grass is the main diet. The challenge for stud masters is to provide quality pasture each breeding season, as horses are selective grazers. The stocking rate can be very high during the height of the breeding season in spring and summer. This increases the pressure to maintain good quality pasture. The high stocking density can also affect the animal health negatively, for example caused by the necessity to graze near faeces, what increases the risk of ingesting large numbers of infective larvae. (Rogers *et al.* 2007)
The majority of the literature relating to reproductive loss, risk factors for reproductive loss and morbidity in the early neonate are generated from Northern hemisphere production systems. Studies from the Northern hemisphere do not necessarily apply directly to the industry in New Zealand, because of the mentioned differences in management and nutrition.
Equine reproductive epidemiology has historically been conducted at a relatively superficial level, possibly because of the difficulty in integrating on-farm data and industry records. The relatively small and cohesive nature of the New Zealand Thoroughbred industry is a valuable research opportunity.
During the last 30 years there has been a substantial increase in intensity of Thoroughbred broodmare management. Nevertheless, compared with other livestock industries as sheep and beef cattle, there is less standardising, defining and analysing of the reproductive performance. The only measures are based on annual mare returns. Effects of different management or treatments are not assessed. (Hanlon 2008). This may cause the relatively poor reproductive efficiency of the Thoroughbred breeding industry (Morris *et al.* 2007). Bruck *et al.* (1993) showed that the pregnancy rate for Thoroughbred mares was 85%, and only 69.3% of them gave birth to life foals. So despite their high pregnancy rates, Thoroughbred mares have a low reproductive efficiency.
Reproductive dysfunction is linked to improper care and maintenance and hormonal and genital disorders (Yang and Cho 2007). Another possible reason of the reduced reproduction capability can be the fact that reproductive capacity has not been the focus of genetic improvement. Mares and stallions are selected on a combination of pedigree and performance on the racetracks, not on fertility traits (Morris *et al.* 2007; Rogers *et al.* 2009; Asbury 1987). Mare ownership is often undertaken for other reasons than profit, sush as a recreational hobby or sentiment for a certain mare (Bosh *et al.* 2009).
The breeding season of the Thoroughbred horses runs from 1 September until 1 December, as the aim of the breeders is to produce a foal as close to the official Southern Hemisphere birth date of 1 Augustus as possible. This is a very short period. Most breeders try to breed their mares as early as possible in the season, so closest to 1 September. This applies mainly for large stud farms. Some farms use lights or hormone therapy to advance the onset of oestrous cyclicity in dry mares. The breeders aim to have horses foaling as soon as possible after the first of August, to maximize time for growth and ensure optimal body size at the time of sale as yearlings. (Brown-Douglas *et al.*  2005; Rogers *et al.* 2007) Mares that foal late in the year may not be re-bred that season and the resultant foal may be considered too late, resulting in financial losses. Off season breeding may be an opportunity (Brown-Douglas *et al.* 2005*)* although this has not been adopted by the Thoroughbred industry in New Zealand.
The Thoroughbred studbooks are closed studbooks, so there are increasing limits of inbreeding, this may limit the reproduction. Artificial insemination is prohibited. This may decrease conception rates, and there are more sires needed to maintain the population. There is also a careful management of the stallions and of the reproductive cyclic activity of the mares needed. Shuttle stallions, stallions that are stud at both Northern and Southern Hemisphere, are frequently used. The number of shuttle stallions has increased from 2 in 1993 to 17 in 2007, covering 18.7% of the mares breed. The use of only natural service means that there are frequent movements of mares and stallions, between national borders as well as international. This poses a bio security risk. It can facilitate the spread of endemic infectious diseases and introduce new diseases. *et al.*(Rogers and Cogger 2010)
There is a wide variation in reproduction performance of Thoroughbred mares on a farm-by-farm basis. Areas that seem to have major impacts on reproduction performance include dry mare management, management of foaling mares, management of problem mares, ovulation induction, pregnancy loss and management of these mares. To improve the reproduction performance and financial performance of the stud farm, these areas of reproductive wastage need to be identified. Other effects that may have influence are the mare age, parity and moment of covering (early versus late in season) (Hanlon, 2008).

3.3 Equine pregnancy
Normal placentation is essential for foetal health and development. Throughout gestation, the placenta provides a pathway for the exchange of essential nutrients, gases and waste products between maternal and foetal vascular systems. Therefore, deficiencies in placental functions may be reflected in deficits of foetal growth and maturation. (Wilsher and Allen 2003) For a proper understanding of pregnancy losses a summary of equine pregnancy is given in this chapter, mainly based on a detailed review by Ginther in 1998.

3.3.1. Early pregnancy (<40 days)
Until day 40 (day 0=ovulation) the conceptus is called embryo and from day 40 to parturition, the term foetus will be used.
The embryonic placenta consists of three germ layers; ectoderm, mesoderm and endoderm. Unlike other farm animals, equine species develop a capsule. The capsule of the blastocyst is located between the trophoblast and zona pellucida, and will become the outer layer in a few days after the blastocyst enters the uterus. The capsule is thin but tough and thickens at least until day 11. It provides a supportive wrapping during the embryo mobility phase. Around day 21 the capsule disappears, its role seems completed. (Ginther 1998)
The embryo becomes a blastocyst soon after or by the time it enters a uterine horn on day 6. (Allen 1987; Ginther, 1998) This means that a central cavity is formed, and the inner cell mass is established at one pole. The inner cell mass will form the eventual foal. (Ginther 1998)
The blastocyst cavity is encircled by endodermal cells, what is completed by approximately day 12. The mesoderm starts growing from the embryonic disc into the area between yolk sac (blastocyst) and trophoblast on day 15. This results in a three-layered wall. The mesoderm differentiates into blood vessels and connective tissue. (Ginther 1998)
The embryo first reaches the uterine body on day 8 and then starts an intra-uterine mobility phase. This phase continues until day 15-17. During these days, the embryo can be anywhere in the uterine lumen from the tips of either horn to the cervix. On day 9-11 the embryo is frequently (60%) found in the uterine body. The embryo moves from one horn to the other 10 to 20 times per day during the phase of maximal mobility (day 11-15). This causes pressure on the embryo by uterine contractions which are the propulsive force. The mobility is maximized because of the spherical form of the vesicle and the anti-adhesive quality of the capsule and the longitudinal folds in the uterine lumen. (Ginther 1998)
When the mare is not pregnant the uterus produces prostaglandin F2α, which is a luteolysin. PGF2α travels through the systemic circulation to the ovary, in contrast with the local route in cattle. When an embryo is present the luteolysis must be blocked, because the hormone progesterone produced by the corpus luteum is vital to embryonic development. The mobility of the embryo allows it to contact the whole uterine lumen so it is able to block luteolysis through the relatively large uterus. There are indications that the embryo produces an antiluteolysin substance and releases this substance directly on the endometrium as it passes by. Earlier experiments demonstrated that there must be a viable embryo in the uterus on day 14 after ovulation to prevent the luteolysin release. (Allen 1987; Ginther 1998)
After the mobile phase the embryo is fixated on mean day 15 in ponies and 16 in horses. Fixation is defined as the ceasing of mobility. This fixation occurs most of the time in the caudal portion of a horn near a flexure. There is no connection between the side of ovulation and the side of fixation. On the day of fixation less than half of the yolk-sac has developed the mesoderm layer, and blood vessels have begun to start growing near the embryo proper. Within the mesoderm a cavity is formed, which is the exocoelom. The amnion is developed out of folds of ectoderm and mesoderm. The membrane consisting of ecto- and mesoderm is called the chorion. (Ginther 1998)
If the mare is pregnant, the uterus increases in tone after day 11 and becomes turgid on day 16. At the same time the diameter of the uterine lumen decreases, what results in the fixation of the conceptus. Estradiol may contribute to tone stimulation.
When luteolysis occurs after fixation, the uterus loses its turgidity and the embryo leaves the fixation side. Embryonic death is inevitable. (Ginther 1998)
After fixation a phase of orientation takes place. The embryonic vesicle rotates so that the embryo proper is on the ventral aspect of the yolk sac. The yolk sac becomes an efficient supplier of nutrients to the embryo proper, which is rapidly developing. After fixation and orientation, the horn turgidity increases caudal and cranial to the vesicle, preventing the vesicle form moving in a longitudinal direction. (Ginther 1998)
The amniotic cavity is completely formed on day 21. The allantois becomes prominent by day 24. During day 30 to 36, the size of the allantoic sac increases, moving the embryo farther away from the vesicle floor. The chorion and the allantois unite, forming the beginning of the allantochorionic placenta. The allantochorion and amniochorion are vascularised by blood vessels in the mesoderm.
By the beginning of the foetal stage (day 40), the amnion is vascularised. The umbilical cord will be formed. (Ginther 1998)

3.3.2. Foetal stage (>40 days)
The foetus will reach the lower wall of the allantoic sac by day 48. Movements of the head are first detected at day 40 by ultrasound examination. The foetal activity increases with limb movements by mean day 46 and whole body activity at day 48. (Allen 1987)
At day 65, the fluid-filled allantochorionic sac involves the entire uterus. During months 2-4, the length of the umbilical cord increases, as well as the volume ratio of allantoic fluid to foetal mass. This provides the foal to move around in a large pool of fluid, tethered only by the umbilical cord. The foetus changes presentation (caudal vs. cranial) a mean of five times/hour during the third month. The foetus at term is in cranial position in >99% of the cases with the hind limbs in one uterine horn, with a small volume of amniotic fluid compared to the foetal mass. (Ginther 1998)
At the beginning of the foetal stage endometrial cups are formed. These are unique structures originating from cells of both maternal and foetal origin. The endometrial cups produce equine chorionic gonadotropin (eCG), which is excreted into the mare’s systemic circulation in high quantities during the first one-third of gestation. The role of this excretion is not clear. It is known that eCG rejuvenates the primary CL, which causes an increased and extended production of progesterone and estrogen. This may serve as a transient source of these steroids until the fetoplacental production is adequate. The cups begin to degenerate at approximate day 80 and the hormone disappears entirely between day 100 and 150. (Ginther 1998; Allen 1987) In mares that abort prior to day 100-150 after ovulation, the endometrial cups and corpora lutea do not spontaneously regress. This makes it difficult to successfully rebreed these mares in the same season (Morehead *et al.* 2001)
The age and parity of the mare seems to influence the development of the micro cotyledons. The density of the micro cotyledon surface was the lowest in aged multiparous mares. This is presumably caused by degenerative changes in their endometrium. Significantly lower values are also showed by primiparous mares. This suggests a priming effect. The foal birth weight increases after the first foal. (Wilsher *et al.*2003)

3.4 Pregnancy Loss
The maintenance of pregnancy involves a complex interchange of hormonal, biochemical and immunological signals between the mare and the foal. (Allen 1987) Embryonic and foetal death in mares is associated with genetic and environmental factors as vaginal infections and uterine abnormalities. This has an impact on premature pregnancy loss by failing to meet the metabolic needs of pregnancy. Irregular and unbalanced nutrition and stress can also cause embryonic end foetal death. (Yang and Cho *et al.* 2007)
Previous studies have identified differing prevalence and conflicting risk factors for pregnancy losses in thoroughbred mares.
Bruck *et al.* (1993) reported a pregnancy rate of 83.9%, with a pregnancy test done between day 12 and 100 after the date of last service. The foaling rate was 69.3%. The pregnancy rate for mares 3-10 years old was significantly higher than for older mares. No significant difference was found between the pregnancy rates of maiden mares, barren mares or foaling mares. Also the foaling rates were significantly higher for mares 3-10 years old than for older mares. Maiden mares had a significantly higher foaling rate than barren or foaling mars. Of all diagnosed pregnancies 19.5 % were lost. In mares aged 3-5 years pregnancy loss occurred significantly less than in older mares.
Morris *et al.* (2003) found a pregnancy rate of 94.8% at day 15 after ovulation, which fell to 89.7% at day 35 after ovulation. Only 5.2% had never been diagnosed pregnant and 17.3 % of the pregnancies diagnosed at around day 15 were subsequently lost. Of those pregnancy losses 59.7% occurred before day 35; 82.7% of the mares gave birth to a life foal at term. The lowest pregnancy rates occurred in mares aged >14 and in mares that were not served the season before. Age had a significant effect on the proportions pregnancies that were lost. Young mares (3-8 years old) lost fewer pregnancies before day 35, but they lost more pregnancies after day 35 than older mares (9-13). Maiden mares lost fewer pregnancies before day 35. Overall pregnancy lost was highest in mares that aborted the year before.
In Sweden, a small research project by Hemberg et al. (2004) reported a pregnancy rate of 90.9% and a foaling rate of 79.8%. The age of the mare had a significant effect on the foaling rate, but not on the pregnancy rate. Associated with this, the pregnancy loss rate from the first pregnancy diagnosis was the highest in mares older than 13 years. Barren mares and aborted mares showed a significantly higher pregnancy loss rate than maiden and foaling mares.
Yang and Cho *et al.* (2007) reported a pregnancy rate of 97.9% when pregnancy was confirmed 15 days post ovulation; 12.2% of the mares lost their embryos within 45 days post ovulation. The prevalence of
early embryonic death was higher in barren mares (17.2%), mares older than 15 years (15.4%) and mares with a parity higher than 10 (18.2%). The lowest embryonic death rate of 9.8% occurred in mares that experienced abortion or stillbirth during the previous breeding season. Three-quarters of the number of embryonic deaths were detected within 25 days after ovulation, so between day 15 and 26.
More recently Nath *et al. (2010)* reported a pregnancy rate of 68.8%, when pregnancy was diagnosed at day 13-21 using ultrasound. The highest pregnancy rates were found in maiden mares. Mares 2-13 years old had a significantly higher pregnancy rate than mares >13 years old. 7.1% of the mares lost their pregnancy between day 13 and day 45 after ovulation, with the lowest incidence in mares 2-8 years old.

3.4.1. ’Missed’ mares
It is likely that the major pregnancy loss takes place before the detection of pregnancy. Nevertheless the loss of an identifiable foal is more distressing. (Asbury, 1987)
Barren mares, those that ‘miss’, are the ‘problem breeding mares’ and a source of frustration for the studmaster. It might take several cycles to establish pregnancy in those problem mares, and they have a high chance to pregnancy failure. In the New Zealand Thoroughbred Studbook (The New Zealand Studbook, Wellington, 2008) mares that are not detected pregnant at day 45 after covering, are listed as missed. A summary of the causes of mare subfertility are presented in table 1.

Table Causes of mare subfertility (Pycock 2008)

|  |  |  |
| --- | --- | --- |
| **Anatomical** | **Functional** | **Infectious Endometritis** |
| Defective vulvaDefective vestibulovaginal constructionVesicovaginal refluxVaginal bleedingPersistent hymenAbnormal cervix1. Uterine cysts
2. Partial dilatation of the uterus

Abnormal oviductsPituitary abnormalities | Anestrus1. Seasonal (winter/early spring)
2. Poor body condition
3. Disease
4. Chromosome abnormality
5. Lactation related
6. Prolonged luteal function
7. Pregnancy/pseudopregnancy
8. Silent heat

Irregular or prolonged oestrus1. Transitional (‘spring’) oestrus

Ovarian and ovulatory dysfunctionPregnancy failure1. Early embryonic death
2. Abortion: twins, uterine body pregnancy, placental abnormalities
 | Bacterial Fungal |

3.4.2. Slipping mares
Pregnancy loss during the foetal period of gestation (abortion) is a major economic concern to horse breeders. This is defined as slipping in the New Zealand Thoroughbred Studbook (The New Zealand Studbook, Wellington, 2008) Because of the economic impact equine chorionic gonadotropin the focus is on abortion storms due to stress or infectious agents. Isolated incidents are of far greater significance. (Asbury, 1987)
Varied causes of pregnancy loss exist. Examples are endometritis, luteal insufficiency, external factors as stress and nutrition and chromosomal and genetic factors. (Le Blanc 1997) Julian summarized the causes of abortion in New Zealand in 1993. He found *Streptococcus group* C and *equine herpesvirus* 1 as the most common infectious causes. (Julian 1992)

# Materials and methods

4.1 Dataset
Summary data were collected from the Registers of Thoroughbred Stallions of New Zealand 2003-2009. From these records an overview was created of 2001/02 to 2006/07 breeding seasons. This data included number of stallions, number of mares covered, number of foals living, number of foals dead or slipped, number of mares missed, number of dead mares, number of exported mares, number of no returns and fertility. Only the stallions that had covered 10 or more mares are considered commercially active stallions in the Register of Thoroughbred Stallions of New Zealand.

From the Register of Thoroughbred Stallions of New Zealand 2005 (New Zealand Thoroughbred Breeders Association) 16 stallions were randomly chosen after being grouped by stud fee. These categories were:
- Cheap: <$5000,-
- Medium: $5001-$10000
- Expensive: >$10000
- Shuttle: At Stud at both hemispheres during 2005

Using the online Thoroughbred stud book (www.nzracing.co.nz), a summary of the career of all the mares covered by these stallions in 2005 was collated within Microsoft Excel 2006. The 2005/06 breeding season (foaling year 2006) was the reference year. From this year the career was followed four years retrospectively (2001/02-2004/05) and three years prospectively (2006/07-2008/09). The age and parity of the mare in 2005 was recorded, as well as the last date of service and date of foaling and mare status (foaling, dead foal, missed, slipped, maiden, not served). Reproductive outcomes were defined as live foal (having a foal at foot) or dead foal; a full term born foal that is born dead or is killed/died shortly post partum. Data was also provided if the mare had missed or slipped. Within this study a mare is deemed to have slipped when:
(a) she has been observed to abort a foetus.
(b) she has not been observed to abort a foetus but did not deliver a foal after having a 45 day positive pregnancy test.1
A missed mare is a mare that was covered, but was not detected pregnant at day 45 post ovulation within that breeding season. A mare that was not bred at all was categorised as not served. A maiden mare is defined as a mare that has not been served ever before. Dead mares and mares that ceased breeding were also recorded.
The parity in 2005 was counted as the total number of live foals and dead foals for each mare. The number of active breeding mares is calculated as the number of total mares minus dead mares, exported mares, not returned mares and mares that had ceased breeding. The mare fertility rate was calculated as the number of live foals, dead foals and slipped foals, divided by the total number of active breeding mares. Stallion fertility is calculated as the number of life foals, dead foals and slipped foals divided by all the mares covered. Pregnancy is detected on day 45 after day of ovulation. Foaling rate is calculated as the number of live foals and dead foals divided by number of active breeding mares. Early pregnancy loss is calculated as the number of misses divided by the number of active breeding mares. Late pregnancy loss is calculated as the number of slips divided by the number of pregnant mares since a mare that had missed has no chance to slip. The term slips and late pregnancy loss are both used and similar, meaning the loss after day 45. The term miss can be confusing and is not necessarily early pregnancy loss, as mares that have never been pregnant were also categorised as missed mares.

4.2. Statistical analysis
Collated data were imported into SPSS Statistics 17.0 (SPSS, Chicago, Il, USA) for statistical analysis. Outcome variables were coded as binary outcomes for analysis. Logistic regression was used to identify management and biological risk factors for a miss or slip in the 2005/06 breeding season. Data were initially screened using a univariate model. Variables with a P<0.2 were included in the final multivariate model.
For distribution data a Chi Square test was used and continuous data were compared using a general linear model with a Bonferroni post hoc test. Survival analysis (Kaplan Meier with the log rank test) was used to identify the prospective value of missing or slipping for the following reproductive career of the broodmare. The significance level for all analyses was set at P<0.05 unless otherwise stated.

1The New Zealand Studbook 2008, Wellington

# Results

5.1. Breeding records
Table 2 provides an overview of the breeding records of all the thoroughbred stallions standing at stud for the 2001-2006 breeding seasons. Data were available on a stallion if it had covered 10 or more mares in that season. The general trend is for a reduction in the number of stallions at stud per season and a reduction in the total number of mares covered. The fertility of the stallions remained constant over the years. In the reference year (2005) there were 112 active stallions that had covered 6043 mares. Those 6043 mares produced 3778 live foals, 488 dead or slipped foals, and 991 mares ‘missed’, with a mean stallion fertility of 81.15%, as reported by NZTR.

**Table 2 Summary of breeding records for commerical Thoroughbred stallions at stud in New Zealand for the 2001 – 2006 breeding season**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **2001 cov** | **2002 cov** | **2003 cov** | **2004 cov** | **2005 cov** | **2006 cov** |
| **N Stallions** | 132 | 133 | 126 | 125 | 112 | 111 |
| **Mares covered** | 7162 | 6769 | 6446 | 6458 | 6043 | 6099 |
| **Foals Living** | 4496 | 4110 | 4061 | 3965 | 3778 | 3908 |
| **Foals Dead + Slipped** | 662 | 621 | 557 | 518 | 488 | 497 |
| **Mares Exported** | 121 | 131 | 172 | 229 | 252 | 183 |
| **No returns** | 503 | 597 | 448 | 498 | 397 | 402 |
| **Mares Dead** | 205 | 203 | 159 | 164 | 127 | 95 |
| **Missed Mares** | 1153 | 1089 | 1033 | 1076 | 991 | 1004 |
| **Indeterminate Results** | 22 | 18 | 17 | 8 | 10 | 10 |
| **Stallion Fertility1** | 81.73 | 81.28 | 81.28 | 80.64 | 81.15 | 81.44 |

1 These values are mean fertility values for the season as reported by NZTR.

The breeding records of the 16 selected stallions are shown in Table 3. As the 16 stallions used were randomly chosen, there is a difference in number of mares covered in each category. The stallions covered 1270 mares in total, which is 21% of all the mares covered in 2005. The four stallions in the cheap, medium, expensive and shuttle category had covered 186, 350, 445 and 314 mares, respectively. The miss prevalence was similar and only slightly higher with the cheaper sires (17.2%). There is no significant difference in miss and slip prevalence between the categories. (p=0.148)
The fertility of the 16 stallions was 81.75% on average, versus a stallion fertility of 81.15% in the whole population for 2005.

Table Breeding records selected stallions (n=16) for the 2005 breeding season

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Cheap** | **Medium** | **Expensive** | **Shuttle** | **Total** |
| **Mares Covered** | 186 | 325 | 445 | 314 | 1270 |
| **Mean Stallion Fertility** | 79.93±6.8 | 82.58±5.8 | 82.91±3.6 | 81.58±14.9 | 81.75±1.3 |
| **Number of Slips** | 6 | 20 | 13 | 7 | 46 |
| **Number of Misses** | 32 | 55 | 68 | 48 | 203 |
| **Prevalence Slips (%)** | 3.23 | 6.2 | 2.92 | 2.23 | 3.55 |
| **Prevalence Misses (%)** | 17.2 | 16.9 | 15.28 | 15.29 | 15.68 |
| **Mean Mare Age** | 10.32±4.4 | 10.23±4.2 | 9.58±4.2 | 9.88±4.2 | 9.9±4.22 |
| **Mean Mare Parity** | 4.2±2.8 | 4.48±2.8 | 4.09±2.8 | 4.13±2.9 | 4.23±2.8 |

There were no significant differences in mare age, parity and fertility through the four stallion categories in the used model. Post hoc tests (Bonferroni) confirmed this.

To compare age and parity, the mares were divided in two groups based on age. Group 1 contained the mares from 3 years old to 12 years old, this was the young category. Group 0 included the mares from an age of 13, the old category. Scatter plots of these two groups are shown in Figure 4 and Figure 5. There was a high correlation between age and parity in the young category, but this seemed to end in the old category. Because of this different pattern, most of the further calculations were completed for both groups separately.

Figure Correlation parity vs. age young mares (3-12) for the 2005 breeding season

Figure Correlation parity vs. age old mares (>13) for the 2005 breeding season

5.2. Pregnancy loss
The distribution of number of mares and miss and slip prevalence for each mare age is showed in table 4.

Table Prevalences misses and slips within age in all mares (n=1270) for the 2005 breeding season

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **age** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
| **Number of mares (n)****% of total mares** | 151.2% | 514.0% | 1149.0% | 14311.3% | 1249.8% | 1169.1% | 957.5% | 947.4% | 1078.4% | 725.7% | 665.2% | 665.2% |
| **% misses within age** | .0% | 13.0% | 9.4% | 12.5% | 9.0% | 12.8% | 21.7% | 23.0% | 19.6% | 23.2% | 23.4% | 17.2% |
| **%slips within age** | .0% | 4.3% | .9% | 2.2% | .9% | 4.6% | 2.4% | 1.1% | 2.9% | 10.1% | 1.6% | 1.7% |
| **age** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **total** |
| **Number of mares (n)****% of total mares** | 493.9% | 604.7% | 302.4% | 231.8% | 141.1% | 141.1% | 12.9% | 3.2% | 00.0% | 10.1% | 1.1% | 1270100.0% |
| **% misses within age** | 18.2% | 19.0% | 14.3% | 19.0% | 27.3% | 50.0% | 66.7% | .0% | 0.0% | 0.0% | 100.0% | 17.1% |
| **%slips within age** | 11.4% | 6.9% | 3.6% | 4.8% | 9.1% | 7.1% | .0% | .0% | 0.0% | 0.0% | .0% | 3.4% |

These results are shown graphically in Figure 6. Most of the served mares are 5-11 years old. The number of misses seemed to increase until an age of 9, when it became a plateau. The miss and slip prevalence differed greatly after the age of 18, probably due to fewer mares served in this age class. In further statistical analysis only the mares <18 years old were used.

Figure Prevalence of a miss or slip within age category for thoroughbred mares (n=1270) during the 2005 breeding season

A summary of the career of the mares covered by the 16 used stallions is shown in Table 5. In the reference year 2005 there were 1135 mares defined as active breeding mares. The remaining mares of the total 1270 mares surveyed were dead (2%), exported (4%) or no return was received (1%). The number of active breeding mares decreased when examining the data retrospectively. In 2001 only 593 of the 1135 mares were at stud. Prospectively by 2008 only 700 of the mares were still active breeding mares. The percentage misses and slips varied across years. The career of the mares is graphically shown in Figure 4.

Table Breeding records active breeding mares (n=1135) for the 2001-2008 breeding seasons

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** |
|  **Active breeding mares (n)** | 593 | 675 | 802 | 956 | 1135 | 901 | 839 | 700 |
| **Misses (n)** | 77 | 107 | 114 | 180 | 183 | 170 | 185 | 145 |
| **Miss prevalence** | 13% | 16% | 14% | 19% | 16% | 19% | 22% | 21% |
| **Slips (n)** | 19 | 29 | 26 | 26 | 38 | 27 | 27 | 24 |
| **Slip prevalence (of all mares)** | 3.20% | 4.30% | 3.20% | 2.70% | 3.30% | 3.00% | 3.20% | 3.40% |
| **Slip prevalence (of pregnant mares)** | 3.70% | 5.10% | 3.80% | 3.40% | 4.00% | 3.70% | 4.10% | 4.30% |
| **Life Foals** | 464 | 506 | 615 | 709 | 829 | 653 | 570 | 485 |
| **Foal Dead** | 33 | 33 | 47 | 41 | 85 | 51 | 57 | 46 |
| **Foal Dead prev** | 5.60% | 4.90% | 5.90% | 4.30% | 7.50% | 5.70% | 6.80% | 6.60% |
| **Fertility** | 87% | 84% | 86% | 81% | 84% | 81% | 81% | 79% |
|  |  |
|  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |

Figure Prevalence of misses, slips and dead foals of the active breeding mares (n=1135) for the 2001-2008 breeding seasons

* 1. Risks for pregnancy losses

Univariate effects of mare age, parity and status on the breeding outcome in 2005 are shown in Table 6. The slip prevalence was calculated with the denominator as percentage slips within pregnant mares. In 2005 847 mares gave birth to a live foal, 85 mares had a dead foal and 40 mares were detected pregnant but had not given birth. The mean mare fertility rate was 83.9%. The foaling rate was 80.5%. Misses and late pregnancy losses occurred in 16.1% and 4.0% of the active breeding and pregnant mares, respectively. This resulted in a total pregnancy loss of 19.5%.

5.3.1. Age
There was a significantly higher foaling rate in young mares compared with old mares(p=0.038). Associated with this, young mares had a significantly lower total pregnancy loss than older mares (p=0.038). The same trends were seen in the pregnancy rate (p=0.132) and misses (p=0.132) and slips (p=0.101) separated.
Analysis across all ages identified an increase in the prevalence of a miss of 6.8% for each year of mare age (p=0.001). This risk was 16.7% higher for every increasing year in the mares aged 3-12 (p=0.000) and no significant effect of age was reported in the old category (p=0.475).
The slip prevalence followed the same pattern, with an increasing late pregnancy loss of 12.5% (p=0.005) for every year of age in the whole group, 23.5% in the young category (p=0.015) and no significant age effect in the old category (p=0.277).
When looking at the overall reproductive inefficiency, misses and slips together, the results were similar. In the whole group the reproductive inefficiency rate increased with 8.2% for every year the mare got older (p=0.000). This is 18.2% if only the young category was used in the calculation (p=0.000), and age was not significant in the old category (p=0.938).

Table Breeding records active breeding mares (n=1135) based on age category for the 2005 breeding season

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Age* | *N mares* | *Pregnancy rate (%)a* | *Foaling rate**(%)b* | *Misses <day 45 (%)c* | *Late pregnancy loss > day 45 (slips) (%)d* | *Total pregnancy loss(misses+slips) (%)e* |
| **3-12** | 862 | 84.8α(731/862) | 81.91(706/862) | 15.1α(131/862) | 3.4α(25/731) | 18.11(156/862) |
| **13-18** | 273 | 80.9β(221/273) | 76.12(208/273) | 19.0β(52/273) | 5.9β(13/221) | 23.82(65/1135) |
| **Total** | 1135 | 83.9(952/1135) | 80.5(914/1135) | 16.1(183/1135) | 4.0(38/952) | 19.5(221/1135) |

1. Number of mares pregnant at day 45/number of mares covered
2. Number of mares foaling/ number of mares covered
3. Number of mares not pregnant at day 45/ number of mares covered
4. Number of mares not foaling/pregnant mares
5. Number of mares not foaling/number number of mares covered

1,2 Values with different superscripts within columns differ significantly (p<0.05)
α, β Different superscript are trends in difference between categories (p<0.2)

5.3.2. Parity
Mares with parity 0-4 had a significantly higher foaling rate (p=0.023), lower late pregnancy loss (p=0.023) and a lower total pregnancy loss (p=0.049) than mares with parity 5-9. Too few mares with parity >10 were examined to provide a valid comparison (Table 7).
For every increasing year of parity in category old, the miss prevalence decreased with 15.9%. (p=0.015). No effect was reported when the young category or all ages were examined.
There was no significant effect of parity on slip prevalence in the whole group, young category and old category (p=0.313; p=0.407; p=0.257).
Parity significantly influenced the total pregnancy loss rate in old mares with a decreasing rate of 16.2% for every increase in parity (p=0.008). Parity was not significantly influencing in the whole group and the young category (p=0.711; p=0.371).

Table Breeding records active breeding mares (n=1135) based on parity category for the 2005 breeding season

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Parity* | *N mares* | *Pregnancy rate (%)a* | *Foaling rate**(%)b* | *Misses <day 45 (%)c* | *Late pregnancy loss > day 45 (slips) (%)d* | *Total pregnancy loss(misses+slips) (%)e* |
| **0-4** | 694 | 84.6(587/694) | 82.01(569/694) | 15.4(107/694) | 3.01(18/587) | 18.01(125/694) |
| **5-9** | 392 | 82.1(322/392) | 77.02(302/392) | 17.9(70/392) | 6.22(20/322) | 23.02(90/392) |
| **10-14** | 49 | 87.8(43/49) | 87.8(43/49) | 12.2(6/49) | 0.0(0/43) | 12.2(6/49) |
| **Total** | 1135 | 83.9(952/1135) | 80.5(914/1135) | 16.1(183/1135) | 4.0(38/952) | 19.5(221/1135) |

1. Number of mares pregnant at day 45/number of mares covered
2. Number of mares foaling/ number of mares covered
3. Number of mares not pregnant at day 45/ number of mares covered
4. Number of mares not foaling/pregnant mares
5. Number of mares not foaling/number number of mares covered

1,2 Values with different superscripts within columns differ significantly (p<0.05)

5.3.3. Breeding Status 2004
The effect of the breeding status of the mare is shown in Table 8. Highest pregnancy rate was found in the mares that were not served the year before and with maiden mares. The lowest pregnancy rate occurred in the mares with a dead foal the previous year. Late pregnancy losses occurred the most in mares with a dead foal, and were not observed in the maiden mares. Mares with a dead foal in 2004 had a total pregnancy loss of 39.5%
5.3.3.1. Dead foal
Mares with a dead foal in 2004 had a significantly lower pregnancy rate and so significant more misses than maiden (p=0.002), not served (p=0.001) and missed (p=0.038) mares. Compared with the slipped mares, and mares with a live foal, a trend of a lower pregnancy rate was reported (p=0.061 and p=0.124 respectively). There was a trend for the mares with a dead foal in 2004, which had 1.9 times (OR) more misses than mares with a live foal or mares that had slipped or missed in 2004 (p=0.084). In the young category a very close trend was seen, with an increasing risk of missing of 2.2 times (p=0.057). However, there was no significant effect of these within the old category. (p=0.826)
The foaling rate of mares with a dead foal in the previous year was significantly lower than the foaling rate of maiden mares (p=0.000), missed mares (p=0.015), not served mares (p=0.047) and foaling mares (0.021). Again there was a trend reported in the slipped mares (p=0.065). Associated with this was the higher prevalence of slips in the mares with a dead foal in 2004. In the whole group, there were 3.9 times (or 95% CI; 1.256 – 11.869, p=0.018) more slips found in mares with a dead foal in 2004. If only looking at the young category, 4.0 times (or 95% CI; 1.088 – 14.588, p=0.037) more slips were reported. There was no significant effect in category old.
The total pregnancy loss was significantly higher in mares with a dead foal, compared with all the other statuses. Reproductive inefficiency was 2.4 times higher in mares with a dead foal in the whole population (p=0.01) and 2.7 times higher in the young category (p=0.01). Again there was no effect in the old category (p=0.464)

5.3.3.2. Missed
A mare that had missed in 2004 seemed to miss 27.1% less than a mare that became pregnant in 2004, but this was not significant (p=0.202). The same trend was seen when only the old category was examined, with a decrease of 52.2% (p=0.079). Category young showed no statistical significant effect (p=0.648).
Again no significant effect was found when the slips are being looked at (p=0.438; p=0.683; p=0.612).
A trend was observed when we looked at the effect of having a miss in 2004 and the reproductive inefficiency in 2005, with a decrease of 28.1% in the whole population (p=0.139). No significant effect was reported in category young (p=0.490) and a decrease of 51.1% was reported in category old (p=0.064).
5.3.3.3. Slipped
A slip in 2004 gave no significant increased or decreased risk for a miss or a slip in 2005 (p>0.2).
5.3.3.4. Not served
Mares that were not served in 2004, due to various reasons, had a significant higher pregnancy rate and less misses than mares that had a life foal (p=0.005) or a dead foal (p=0.001). When a mare was not served she had 63.6% less misses than a mare that was served the year before, looking at all the mare records (p=0.009). This decreasing prevalence is highest in the old category, with an 83% lower miss prevalence (p=0.017). A trend was found in the young category with 54.5% less misses (p=0.17). The total pregnancy loss rate was lower as well. (p=0.010). Reproductive inefficiency decreased with 53.9% in all ages (p=0.015), which was only a trend of 49.1% decrease in the young mares (p=0.102) and was the highest in category old again, namely a decrease of 63.9% (p=0.041)
5.3.3.5. Maiden
Maiden mares showed a significantly higher pregnancy rate and less misses than mares with a live foal (p=0.007) and mares with a dead foal (p=0.002). Maiden mares had a significantly lower miss prevalence of 52.7% compared with mares with parity >2 (p=0.011). The prevalence decreased with 48.4% in category young (p=0.027). There were no maiden mares within category old. Pregnancy rates were higher in maiden mares compared with foaling mares (p=0.011), mares with a dead foal (p=0.000), missed mares (p=0.03) and not served mares (p=0.018).
59.5% less reproductive inefficiency was found within maiden mares in category young (p=0.004).

Table Breeding records active breeding mares (n-1135) based on mare status for the 2005 breeding season

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Mare status* | *N mares* | *Pregnancy rate (%)a* | *Foaling rate**(%)b* | *Misses <day 45 (%)c* | *Late pregnancy loss > day 45 (slips) (%)d* | *Total pregnancy loss(misses+slips) (%)e* |
| **Life foal** | 654 | 81.213,4(531/654) | 77.32,3(506/654) | 18.83,4(123/654) | 4.72,3(25/531) | 22.65(148/654) |
| **Dead foal** | 38 | 71.14(27/38) | 60.54(23/38) | 28.94(11/38) | 14.84(4/27) | 39.51(15/38) |
| **Missed** | 169 | 85.22,3(144/169) | 82.22(139/169) | 14.82,3(25/169) | 3.52(5/144) | 17.82,5(30/169) |
| **Slipped** | 23 | 91.3(21/23) | 91.3(21/23) | 8.7(2/23) | 0.0(0/21) | 8.72,4,5(2/23) |
| **Not served** | 104 | 92.3 1,2(96/104) | 88.52(92/104) | 7.711,2(8/104) | 4.22(4/96) | 11.52,4(12/104) |
| **Maiden** | 147 | 90.51(133/147) | 90.51(133/147) | 9.51(14/147) | 0.01(0/133) | 9.53,4(14/147) |
| **Total** | 1135 | 83.9(952/1135) | 80.5(914/1135) | 16.1(183/1135) | 4.0(38/952) | 19.5(221/1135) |

Number of mares pregnant at day 45/number of mares covered

1. Number of mares foaling/ number of mares covered
2. Number of mares not pregnant at day 45/ number of mares covered
3. Number of mares not foaling/pregnant mares
4. Number of mares not foaling/number number of mares covered

1,2 Values with different superscripts (numeric) within columns differ significantly (p<0.05)

Table Univariate screening for the effect of mare status on miss, slip and reproductive inefficiency prevalence

|  |  |  |  |
| --- | --- | --- | --- |
|  | **All ages** | **3-12** | **13-18** |
| **Misses <day 45**  | *OR [0.95 CI]* | *Sig.* | *OR [0.95 CI]* | *Sig.* | *OR [0.95 CI]* | *Sig.* |
| Age | 1.068 [1.026-1.114] | 0.001 | 1.167 [1.080-1.262] | 0.000 | x | NS |
| Parity | x | NS | 0.929 [0.838-1.031] | 0.166 | 0.841 [0.730-0.967] | 0.015 |
| 2004 dead foal | 1.890 [0.917-3.895] | 0.084 | 2.197 [0.978-4.936] | 0.057 | x | NS |
| 2004 not served | 0.374 [0.178-0.785] | 0.009 | 0.545 [0.229-1.297] | 0.17 | 0.17 [0.040-0.729] | 0.017 |
| 2004 missed | 0.739 [0.465-1.175] | 0.202 | x | NS | 0.478 [0.210-1.088] | 0.079 |
| 2004 slipped | x | NS | x | NS | x | NS |
| 2004 maiden | 0.473 [0.266-0.841] | 0.011 | 0.516 [0.287-0.928] | 0.027 | - | - |
| Missed ever | 1.299 [0.940-1.796] | 0.113 | 1.278 [0.880-1.857] | 0.197 | x | NS |
| Slipped ever | x | NS | x | NS | x | NS |
|  |  |
| **Late pregnancy loss > day 45 (slips)** | *OR [0.95 CI]* | *Sig.* | *OR [0.95 CI]* | *Sig.* | *OR [0.95 CI]* | *Sig.* |
| Age | 1.125 [1.037-1.221] | 0.005 | 1.235 [1.042-1.464] | 0.015 | x | NS |
| Parity | x | NS | x | NS | x | NS |
| 2004 dead foal | 3.861 [1.256-11.869] | 0.018 | 3.984 [1.088-14.588] | 0.037 | x | NS |
| 2004 not served | x | NS | x | NS | x | NS |
| 2004 missed | x | NS | x | NS | x | NS |
| 2004 slipped | x | NS | x | NS | x | NS |
| 2004 maiden | x | NS | x | NS | - | - |
| Missed ever | x | NS | x | NS | x | NS |
| Slipped ever | 1.944 [0.869-4.348] | 0.105 | x | NS | 2.343 [0.681-8.059] | 0.177 |
|  |
| **Total pregnancy loss (misses+slips)** | *OR [0.95 CI]* | *Sig.* | *OR [0.95 CI]* | *Sig.* | *OR [0.95 CI]* | *Sig.* |
| age | 1.082 [1.043-1.127] | 0.000 | 1.186 [1.102-1.276] | 0.000 | x | NS |
| Parity | x | NS | x | NS | 0.838 [0.735-0.955] | 0.008 |
| 2004 dead foal | 2.413 [1.234-4.720] | 0.01 | 2.721 [1.277-5.798] | 0.01 | x | NS |
| 2004 not served | 0.461 [0.247-0.859] | 0.015 | 0.509 [0.226-1.144] | 0.102 | 0.361 [0.136-0.959] | 0.041 |
| 2004 missed | 0.719 [0.467-1.107] | 0.139 | x | NS | 0.49 [0.230-1.043] | 0.064 |
| 2004 slipped | 0.309 [0.072-1.332] | 0.115 | x | NS | x | NS |
| 2004 maiden | 0.372 [0.210-0.660] | 0.002 | 0.405 [0.226-0.726] | 0.004 | - | - |
| Missed ever | 1.275 [0.945-1.721] | 0.112 | x | NS | 1.3 [0.918-1.842] | 0.14 |
| Slipped ever | x | NS | x | NS | x | NS |

5.4. Multivariate analysis
For a representative picture of the risks for pregnancy losses, a multivariate screening was conducted, correcting for the age or parity effect. Table 9 shows the effect of the mare status on the misses, late and total pregnancy losses in the whole population, corrected for the age effect.
When corrected for age, being not served in 2004 gave a reduction in misses of 66.9% (p=0.004). There was a trend for a 1.8 times higher miss prevalence when the mare had a dead foal the year before (p=0.099). Late pregnancy losses were significantly influenced by having a dead foal the previous year, with a 3.74 times higher chance of slipping (p=0.022). Also the total pregnancy loss increased 2.4 times when a mare had a dead foal the previous year (0.013). Being not served decreased the risk of losing a pregnancy with 60% (p=0.004).

Table Multivariate screening all ages

|  |  |  |
| --- | --- | --- |
|  | **All ages** |  |
| **Misses <day 45** | *OR [0.95 CI]* | *Sig.* |
| **Age +** 2004 dead foal | 1.843 [0.891-3.810] | 0.099 |
| **Age +** 2004 not served | 0.331 [0.157-0.700] | 0.004 |
| **Age +** 2004 miss | 0.682 [0.427-1.091] | 0.111 |
| **Age +** 2004 maiden | 0.684 [0.365-1.281] | 0.235 |
|  |  |  |
| **Late pregnancy loss > day 45 (slips)** | *OR [0.95 CI]* | *Sig.* |
| **Age +** 2004 dead foal | 3.740 [1.210-11.556] | 0.022 |
|  |  |  |
| **Total pregnancy loss (misses+slips)** | *OR [0.95 CI]* | *Sig.* |
| **Age +** 2004 dead foal | 2.356 [1.199-4.628] | 0.013 |
| **Age +** 2004 not served | 0.401 [0.214-0.753] | 0.004 |
| **Age +** 2004 miss | 0.659 [0.425-1.020] | 0.061 |
| **Age +** 2004 slip | 0.291 [0.067-1.263] | 0.099 |
|  |  |  |

Table 10 shows the effect of the mare status on the misses, late and total pregnancy losses in the young mares, corrected for the age effect. The only significant effect occurred for having a dead foal in 2004, on the risk for overall pregnancy loss in 2005, with an increased risk of 2.4 times (p=0.041). Only trends were reported for the other mare statuses.

Table Multivariate screening young mares

|  |  |  |
| --- | --- | --- |
|  | **3-12** |  |
| **Misses <day 45** | *OR [0.95 CI]* | *Sig.* |
| **Age +** 2004 dead foal | 1.909 [0.840-4.340] | 0.123 |
| **Age +** 2004 not served | 0.460 [0.191-1.104] | 0.082 |
| **Age +** 2004 maiden | 0.886 [0.456-1.723] | 0.721 |
|  |  |  |
| **Late pregnancy loss > day 45 (slips)** | *OR [0.95 CI]* | *Sig.* |
| **Age +** 2004 dead foal | 3.541 [0.952-13.136] | 0.059 |
|  |  |  |
| **Total pregnancy loss (misses+slips)** | *OR [0.95 CI]* | *Sig.* |
| **Age +** 2004 dead foal | 2.367 [1.067-1.270] | 0.028 |
| **Age +** 2004 not served | 0.426 [0.188-0.966] | 0.041 |

Table 11 shows the interaction between mare status and the misses and total pregnancy losses in the old mares (no significant effects were found for the late pregnancy losses), corrected for the parity effect. Being not served the year before gave a high reduction of 85% for missing (p=0.011). Late pregnancy losses reduced by 68% (p=0.024) in that case. A similar effect occurred when a mare had missed the year before, with a reduction of 59% (p=0.041) for misses, and a reduction of 58% late pregnancy losses.

Table Multivariate screening old mares

|  |  |  |
| --- | --- | --- |
|  | **13-18** |  |
| **Misses <day 45** | *OR [0.95 CI]* | *Sig.* |
| **Parity+** 2004 not served | 0.150 [0.035-0.650] | 0.011 |
| **Parity+** 2004 miss | 0.416 [0.179-0.964] | 0.041 |
|  |  |  |
| **Total pregnancy loss (misses+slips)** | *OR [0.95 CI]* | *Sig.* |
| **Parity+** 2004 not served | 0.320 [0.119-0.862] | 0.024 |
| **Parity+** 2004 miss | 0.423 [0.195-0.920] | 0.030 |

5.5. Prospective value
Mares that had missed ever in the analysed years, seemed to have an increased chance of having missed in 2005 of 29.9% (p=0.113), if looked at all ages. On the other hand, mares that had slipped ever during the analysed, seemed to have in increased chance of almost 2 times of having slipped in 2005 (p=0.112).

Figure 8 shows the survival plot of all mares for having a miss (n=661). There was no statistically significant evidence that having a miss in one year increased the chance of having a miss in the next years (p=0.436).
The same model was used for the slips (Figure 9) (n=646), and again no significant prospective value is reported. (p=0.889).

Figure Survival analysis miss prevalence 3 years prospective

Figure Survival analysis slip prevalence 3 years prospective


# Discussion

This survey was limited to the breeding records of mares covered by 16 stallions. The stallions were chosen after being blocked by stud fee, to provide a representative sample of the Thoroughbred sires at stud in New Zealand. Only stallions that had covered a reasonable number of mares were used (≥10 mares) in an attempt to minimise bias. The surveyed stallions stood at different stud farms spread over New Zealand. Of all the Thoroughbred mares covered by stallions in New Zealand in 2005, 21% was examined in this investigation. It is highly likely that the data presented in this report is representative of the breeding records of the overall population.

Data were collected from the online Thoroughbred Studbook. The breeding records in the Studbook were the annual returns of the breeders and so there is a possibility of variation in interpretation of the reproductive outcome despite guidelines being provided by the studbook. However, the definitions provided by NZTR are relatively robust and so there is expected there should be minimal variation in interpretation of definitions.

Pregnancy rates are highly dependent on stallion fertility. The mean stallion fertility in this research was similar to the mean population stallion fertility. Also different breeding management of stud farms will influence the breeding records of a mare. This factor was not included in the calculations. For future studies it could be useful to examine the mares at stud, and include several management factors like time of mating (early vs. late in season), uterine treatments, use of hormone and light therapy, management of twin pregnancies and attending veterinary clinicians.

Several factors can cause early embryonic death in mares, including genetic causes, hormone deficiencies, uterine infections, lactational stress and twin pregnancy. Late embryonic death can be triggered by failure of normal placentation, stress due to infection, twin pregnancy and endocrine dysfunction (Yang and Cho *et al.* 2007). Different studies reported an early pregnancy loss rate in Thoroughbred mares from 7.1% (Nath *et al.* 2010) to 12.2% (Yang and Cho *et al.* 2007). Morris *et al.* (2010) reported that 6.98% of the pregnancies are lost in the foetal stage.

The pregnancy rate was 83.9% in the present study, so 16.1% of all mares were not detected pregnant at day 45. This is in close agreement with most of the previous studies. The pregnancy rate is calculated on day 45, so cases of embryonic death before this day are not reported. Yang and Cho et al (2007) described that three-quarters of the total number of embryonic deaths occurred between day 16 and day 25 after ovulation. Morris Equine abortions in New ZealandEquine abortions in New Zealand *et al.* (2003) reported that the majority of the pregnancy losses (59.7%) occurred between days 15 and 35 of gestation. The pregnancy rate in the present study does not reflect these losses. Early pregnancy results are not reported in this database (around day 15). Effectively all mares that were not been pregnant at 45 days are categorized as missed mares (even though they may have suffered from embryonic loss). Most farms will scan around day 14 to 18 for an early pregnancy indication (and detection of twins), but this data is not recorded nationally. A suggestion for future research is to use on farm data to include this early pregnancy rate, and collect data regarding number of cycles before a mare is detected pregnant, first cycle rate and incidence of twin pregnancies.
The foaling rate of 80.5% in the present study is similar to reported foaling rates in previous studies (Bruck *et al.,*1993;Morris *et al.* 2003; Hemberg *et al.* 2004). Because of the low slip prevalence, statistical significance for effects on slipping was not easy to generate.

Age is a significant factor in the reproductive life of a broodmare, with an increasing risk of missing or slipping when a mare is older. Hemberg *et al.* (2004), Bruck *et al.* (1993), Morris *et al.* (2003)and Nath *et al.* (2010) found similar age effects. However, there was no significant age effect when we only examined the mares older than 12, so the risk of missing or slipping did not increase with increasing mare age after they reach 12 years. One reason for this could be that a problem mare is not bred anymore after an age of 12. An economic model by Bosh *et al.* (2009) showed the highest profitability among mares that were bred for 7 years consistently, assuming mares were barren once. These 7 years are a traditional investment period in the Thoroughbred breeding industry. Only the mares with the best breeding records (‘easy breeders’) stay in the population and are being bred at an older age. Older mares have a greater risk of missing and a lower pregnancy rate due to reduced oocyte viability. This supports the hypothesis that embryos of older mares may already be compromised before they enter the uterus. Other degenerative changes in the uterus are caused by repeated pregnancy, particularly reduction of myometrial activity and loosened uterine ligaments and a higher incidence of endometritis occurs in older mares (Yang and Cho *et al.* 2007; Bruck *et al.* 1993; Nath *et al.* 2010).

Mares with parity 0 to 4 have a significantly higher foaling rate, less late pregnancy losses and a lower overall pregnancy loss than mares with parity 5-9. There is no difference in pregnancy rate between the categories. Age and parity is highly correlated in young mares (mares with a low parity are usually the younger mares). When breeders buy new mares they will look for younger mares to maximise their breeding careers. These younger mares are likely to have a better uterine environment and oocyte viability so the better breeding performance can be related more to an age effect instead of a parity effect.
When a mare is older than 12, the risk for a miss seems to decrease for every increasing year of parity. This can be caused by the same selection bias as mentioned earlier; only the mares with the best breeding records stay in the population and reach a high parity.

The highest pregnancy rate is found in mares that were not served the year before and maiden mares. For maiden mares this was probably related to their relatively lower age, which is associated with a better condition of the reproductive tract (Yang and Cho *et al.* 2007; Bruck *et al.* 1993; Nath *et al.* 2010). Being not served a year may give the uterus time to recover from the previous pregnancy. Because these mares are not lactating, they can be bred as early as possible in the season, often being put under lights to induce early onset of the spring transition, and reproductively managed more aggressively. In effect there is more time to cover these mares over more cycles. Bosh *et al.* (2010) reported that an early foaling date increased odds of producing a registered foal in the subsequent year. When mares foaled in consecutive years, the mean ± s.d. drift in foaling date was 13.4 ± 23.2 days later. This can result from failure to establish pregnancy or from delay in mating the mare post foaling. (Bosh *et al.* 2009)
Nath *et al.* (2010) reported the highest pregnancy rates in maiden mares. Morris *et al.* (2003) described the lowest early pregnancy loss rate in maiden mares, as compared to foaling mares. He also reported that the lowest pregnancy rate occurred in the mares that were not served the year before, which is conflicting with the results in the present study and with the results from Hemberg *et al.* (2004) who also found a high pregnancy rate in mares that were not served the year before.

Mares with a dead foal the year before showed the lowest pregnancy rate in 2005. A low foaling rate of 60.5% happened in the mares that had a dead foal the year before. Having a dead foal the previous year increases the risk for a slip with 4.0 times in young mares. This could be an indication the uterus environment is influenced by the dead foal. The mares with a dead foal could include a lot of distocia mares. Manipulation during the partus can cause damage to the cervix, which is associated with difficulty maintaining pregnancies.

Foaling rate was the highest in slipped mares the year before, but no significance difference was found between this group and the other statuses, probably because of the low slip prevalence. A significant higher foaling rate occurred in the maiden mares.
Yang and Cho *et al.* (2007) found a significantly higher total pregnancy loss in mares that missed the season before, but that is not confirmed in the present study. Hereported the lowest total pregnancy loss rate in slipped mares. Slipped mares show the lowest total pregnancy loss rate in the present study as well, but no significant difference is found when we compare it to mares with a life foal the previous year. The opposite is described by Morris *et al.*, who found a high total pregnancy loss rate of 33.3 % in slipped mares and Hemberg *et al.* (2004). Bruck *et al.* (1993) reported a lower total pregnancy loss in maiden mares, which is consistent with the results in the present study. Hemberg *et al.* (2004) reported that the total pregnancy loss was numerically higher for missed mares and slipped mares than maiden and foaling mares.

Having a miss one year does not increase the risk of missing in the next years, within this dataset. However, having a miss ever seems to increase the risk of missing in one year, but this is only a trend. Only 661 mares and three years are examined in this survival analysis, so this might be different if looking at a bigger dataset. However, mares that have a history of missing may be removed from the population.
No prospective value is given to having a slip in one year, though having a slip ever shows a trend of more chance having a slip in one year.

It appears that the persistence of a high incidence of pregnancy failure before day 45 represents the major loss in to the Thoroughbred breeding industry worldwide. To decrease the numbers of misses and slips, it can be useful to carefully examine mares that gave birth to a dead foal, and treat them if necessary. Also older mares need to be inspected thoroughly to minimise embryonic loss.

In summary, reproductive inefficiency in New Zealand Thoroughbred broodmares can be caused by a wide range of factors, directly or indirectly. These factors include biological factors as age, parity and reproductive status, but management factors also contribute to the reproductive performance. The biological factors are examined in this study, but breeding condition, stud farm management, reproductive history, postpartum breeding timing, embryonic condition and uterine environment are contributing as well. The role of veterinarians seems very important to reach optimum breeding condition, and more integrated research is needed to specify the risks. Stud masters must be aware of the risks of having a dead foal, and need to react adequately to minimise the reproductive wastage. A more intensive breeding management is necessarily when a mare gets older.

# References

ALLEN, W.R. (1987) Endocrinological and immunological aspects of pregnancy and pregnancy loss. *Proceedings of the Bain Fallon Memorial Lectures,* Vol. 9, 61-74

ASBURY, A.C. (1987) Abortion in mares. *Proceedings of the Bain Fallon Memorial Lectures*, Vol. 9, 117-120

BLANC, le, M. (1997) An approach to the diagnosis of infertility in the mare. *Proceedings of the Bain Fallon Memorial Lectures,* Vol. 19, 139-151

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

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,* Vol. 53, 326-331

BRUCK, I., ANDERSON, G.A., HYLAND, J.H. (1993) Reproductive performance of Thoroughbred mares on six commercial stud farms. *Australian Veterinary Journal,* Vol. 70, 299-303

GINTHER, O.J. (1998) Equine pregnancy: Physical interactions between the uterus and conceptus, *AAEP*, Vol. 44, 73-104

HANLON, D. (2008)Current strategies to maximise the reproductive performance of Thoroughbred mares. [*Proceedings of the Annual Seminar of the Equine Branch of the New Zealand Veterinary Association*](http://www.sciquest.org.nz/elibrary/publication/102), [Annual Conference, FCE Publication number 272](http://www.sciquest.org.nz/elibrary/edition/4511), 61-62

HEMBERG, E., LUNDEHEIM, N., ENARSSON, S. (2004) Reproductive performance of Thoroughbred mares in Sweden. *Reproduction Domestic Animals,* Vol. 39, 81-85

JULIAN, A.F. (1992) Equine abortions in New Zealand.  *Surveillance,* Vol. 19, 24-25

MOREHEAD, J.P., BLANCHARD, T.L., THOMPSON, J.A., BRINSKO, S.P. (2001) Evaluation of early foetal losses on four equine farms in central Kentucky. *Journal of American Veterinary Medicine Association*, Vol. 220, 1828-1830

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

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

NATH, L.C., ANDERSON, G.A., MCKINNON, A.O. (2010) Reproductive efficiency of Thoroughbred and Standardbred horses in north-east Victoria. *Australian Veterinary Journal,* Vol. 88, 169-175

PYCOCK, J.F. (2008) Proceedings of the 30th Bain Fallon Memorial Lectures, Cairns. Equine Veterinarians Australia.

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

ROGERS, C.W., GEE, E.K., 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,* Vol. 69, 126-131

ROGERS, C.W.; GEE, E.K.; FIRTH, E.C. (2007) A cross-sectional survey of Thoroughbred stud farm management in the North Island of New Zealand. *New Zealand Veterinary Journal,* Vol. 55, 302-307

WILSHER, S. ALLEN, W.R. (2003) The effects of maternal age and parity on placental and foetal development in the mare. *Equine Veterinary Journal,* Vol. 35, 476-483

YANG AND CHO, Y., CHO, G. (2007) Factors concerning early embryonic death in Thoroughbred Mares in South Korea. *Journal of Veterinary Medicine Science*, Vol. 69, 787-792

Size and Scope of New Zealand Racing Industry. Economic Impacts & Community Social Benefit. June 2004. New Zealand Racing Board