# Factors associated with pregnancy and growth rates in New Zealand replacement dairy heifers

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# CHAPTER 1

## Introduction

Animal products from cattle and sheep are major contributors to New Zealand exports. Milk powder, butter, cheese, meat and edible offal constituted more than 35 per cent of the value of all exported commodities in 2011 rising from about 31 per cent in 2006 (Statistics New Zealand 2012a). Since 2013, New Zealand Government has undertaken the initiative of doubling the country's exports by 2025 (Ministry for Primary Industries 2013b;a). A sizeable part of this growth is expected to be coming from the meat and dairy industries. Geographical isolation, a temperate climate, a strategic focus on biosecurity, political support through building international relationships, and absence of some of the high-economic-impact animal diseases (such as foot and mouth disease) are important characteristics for sustainable livestock farming.

Replacement heifers are female calves that the farmer decides to keep for replacing cows that are going to be culled from the milking herd. Replacement heifers are also expected to increase the genetic potential for improved production and fertility. The criteria used to select replacement heifers include health, conformation, genetic breeding worth for milk production and calving ease, and high pre-weaning growth rate (Larson and Moser 1998). One of the main reasons for the removal of lactating cows is failure to conceive. Other reasons include low production, old age, lameness, bad temperament, mastitis, poor udder conformation, high somatic cell count, and other health problems. The decision to retain or cull is based on the cost of keeping a cow in the herd, the expected future production output, and the salvage value (Tozer and Heinrichs 2001). Nonetheless, farmers sometimes make voluntary culling decisions based on profit. Hence, the decision to cull or retain is based on economic considerations of expected future residual profitability and not because the cow has a current reproductive or health problem (Bach 2011). Replacement heifers are added to the herd in order to keep a constant herd size in accordance with farm resources.

Outsourcing the rearing of replacement heifers has become increasingly common in New Zealand (Penno 1997) and other parts of the world such as the USA (Wolf 2003). Replacement heifers are moved after weaning from the farm of origin to be raised on specialist grower farms. During this rearing period, heifers are weighed by some rearing enterprises to monitor their growth rate. Drenching, vaccination and other health management measures may also be implemented during this period. Efforts are made to maximise growth rate during this rearing period to achieve early puberty. This can consequently achieve a suitable mating weight by about 15 months of age and maximise the pregnancy rate. Heifers are returned to their farm of origin to calve with a target age at first calving of 24 months. Contracting the rearing of replacement heifers to specialist growers has advantages for both the dairy farmer and the heifer grower. In addition, there are some disadvantages. For the dairy producer, the main advantage is the increased availability of feed for the milking herd. Higher rearing cost and biosecurity risks are important disadvantages to the dairy farmer. On the other hand, heifer growers consider this practice as a potential for a profitable business opportunity that can utilise existing facilities, labour and management (Wolf 2003).

**Comment [HC1]:** Explain in more detail: at what age or how soon after weaning are heifer calves transferred to the rearing property? At what age do they return, are they always mated on the property, and are only pregnant heifers returned…?

Rearing heifers to first calving represents about 20% of total milk production costs (Donovan *et al.* 1986). Moreover, the return on the investment allocated from birth to first lactation is commonly not fully recovered until the second lactation (Cooke *et al.* 2013). The expected return on investment will not be realised if the heifer failed to calve as a rising 2 year old due to death, failure to get pregnant or abortion. Similarly, the return on investment will not be realised if the heifer failed to get in calf as a rising 3 year old and had to be culled or carried over. Macmillan found that only 81% of heifers tagged at birth actually calved as two year olds, while a further 14% were culled before calving as three year olds (Macmillan 1973). There are a number of traits in the replacement heifer that determine productivity and hence profitability. Some of these traits are correlated and can therefore not be considered individually without taking other traits into consideration. Correlated traits are weaning weight, post-weaning growth rate, onset of puberty, mating weight, age at conception and age at first calving. The ability of replacement heifers to reach puberty at a physiologically expected age, cycle normally, conceive at the desired time, sustain the pregnancy to term, calve normally, and subsequently commence their first lactation is a critical component of dairy enterprises (Velazquez *et al.* 2008). A profitable heifer would be a heifer that reaches first calving at about two years of age to realise her full lifetime potential, in terms of both productivity and profitability (Brickell *et al.* 2009a). In this study, a number of factors were examined for their association with pregnancy rate and average daily weight gain in the post-weaning period in replacements dairy heifers. The heifers in this study were reared in a heifer grower enterprise in the North Island of New Zealand.

# CHAPTER 2

## Factors associated with pregnancy rates in New Zealand replacement dairy heifers


### Abstract

AIMS: To investigate factors associated with pregnancy rate in a number of herds of contract rearing replacement dairy heifers. These factors included the average daily gain of a heifer mob, the average bodyweight of the mob at the start of grazing, the number of heifers in the mob, the length of the grazing period, the breed of heifers, the grazing season and the region from where the heifers originated.
METHODS: The data included 21,061 heifers from 111 farms in the five North Island regions of Hawke's Bay, Manawatu, Taranaki, Waikato and Wanganui. The heifers were part of a contract rearing programme where they were raised for a period of time on farms different to their farm of origin with a goal of obtaining high pregnancy rate and a maximum age at first calving of 24 months. Heifers were weighed at arrival post-weaning. A multivariate logistic regression model was fitted to predict mob-level pregnancy rates.
RESULTS: A significant association was observed between the odds of pregnancy and average daily gain and heifer breed. Pregnancy in Holstein-Jersey crossbreed was 2.1 (95% CI 1.9 – 3.2) times that of Ayrshire, 1.2 (95% CI 1.1 – 1.6) times that of Holstein and 1.3 (95% CI 1.1 – 1.5) times that of Jersey heifers. An increase of one standard deviation in the average daily weight gain of a replacement heifer mob increased average pregnancy rates by 3.3% equivalent to an OR of 2.5 (95% CI 1.3– 4.9).
CONCLUSIONS AND CLINICAL RELEVANCE: Post-weaning growth rate represents a major influence on the onset of puberty which in turn determines the suitability of heifers for mating when breeding starts. Improving the post-weaning average daily gain of replacement herds, especially Holstein-Jersey crossbred heifers, is therefore expected to improve pregnancy rate. Factors (e.g., management, environmental, etc.) associated with different grazing seasons should be investigated to determine potential associations with pregnancy rate.


KEY WORDS: *Average daily gain, heifer, logistic regression, New Zealand, pregnancy rate*


### Introduction

The New Zealand livestock farming system is one of the unique farming systems in the world. It is predominantly pasture-based all year round with a few exceptions. Seasonal production system occurs in New Zealand where the majority of calving occurs in late winter (August and September). Outsourcing the rearing of replacement heifers has become increasingly common in New Zealand (Penno 1997). Replacement heifers are moved after weaning from the farm of origin to be raised on specialist grower farms. During this rearing period, heifers are weighed by some rearing enterprises to monitor their growth rate. Drenching, vaccination and other health management measures may also be implemented during this period. Efforts are made to maximise growth rate during this rearing period to achieve early puberty. This can consequently achieve a suitable mating weight by about 15 months of age and maximise the pregnancy rate. Heifers are returned to their farm of origin to calve with a target age at first calving of 24 months.

The temperate climate of New Zealand is ideal for dairy farming. Additionally, the isolation of New Zealand was one of the factors that contributed to the absence of the majority of animal diseases of high economic impact. The dairy cattle population has increased from approximately 5.3 million in 2007 to 6.4 million in 2012, of which the replacement herd comprised almost 20 percent (Statistics New Zealand 2012b). On the other hand, the beef cattle population has declined by 15 percent since 2007 reaching 3.7 million in 2012. In 2011/12, the Holstein Friesian-Jersey crossbreed was the predominant breed in New Zealand representing 40.8% of the national dairy herd. This was followed by Holstein Friesian (38.2%), Jersey (12.1%), Ayrshire (0.7%) and other breeds (DairyNZ 2011/12).

Farmers strive to maximise pregnancy rates of their livestock. A number of elements can help enhance this rate. One of these elements is good nutrition. A high plane of nutrition and a high growth rate in the prepubertal period resulted in earlier puberty (Wiltbank *et al.* 1969; Wiltbank *et al.* 1985; Buskirk *et al.* 1995) and increased conception rates (Short and Bellows 1971; Patterson *et al.* 1989) compared with a low plane of nutrition and a low growth rate. Other factors include good farming practices, good sire selection, good heat detection and efficient animal health management (Donovan *et al.* 2003). In addition, oestrus induction, new methods for oestrus detection and pregnancy diagnosis using ultra-sound scanning all contributed to enhance pregnancy rates.

For pregnancy to be cost-effective, the age at first calving (AFC) is recommended not to exceed 24 months (Pirlo *et al.* 2000; Brickell *et al.* 2009b). However, higher AFC was reported in many countries (Pirlo *et al.* 2000; Mayne *et al.* 2002; Hare *et al.* 2006). High average daily gain will reduce the time required to reach mating weight with a consequent reduction in time to conception (Gardner *et al.* 1977; Little and Kay 1979; Van Amburgh *et al.* 1998). In addition, high first service conception rate depends on a number of factors, of which good oestrus detection, adequate nutrition and an efficient breeding programme are the main factors (Donovan *et al.* 2003; Brickell *et al.* 2009a). The benefits of calving at an average age of 24 months were reported to be more productive days, prolonged longevity and more lifetime calf production (Tibary *et al.* 1992; Wathes *et al.* 2008; Cooke *et al.* 2013).

Increasing global demand for milk and meat has been met by productivity increases achieved with more investment and more intensive farm management (Statistics New Zealand 2013). As a result, there has been a global trend towards farming intensification and more cost-efficient livestock enterprises. Enhancing the reproductive performance of livestock is one of the key pre-requisites. Some of the factors likely to be associated with pregnancy in replacement heifers are investigated in this study.

## Materials and methods

### Study design and data collection

The data was collected by a private veterinary practice in the North Island of New Zealand. The practice runs a contract rearing programme for replacement heifers. The data was edited to only include heifer contracts with a recorded pregnancy rate. The pregnancy rate was recorded at the herd, not individual heifer level. From the rearing season of 2006/07 to 2011/12, 21,061 heifers in 345 contract mobs were part of this rearing programme. Bodyweights were recorded at intervals for every participating heifer. Natural service was used in addition to the option of a synchronised artificial insemination programme. The heifers were then pregnancy-tested before returning to their farm of origin. The data obtained for this study was aggregated at the herd or contract level. The data included

**Comment [HC2]:** No, it was a private contract rearing operation.
Explain in detail how the operation works: at what age or how soon after weaning are heifer calves transferred to the rearing property? At what age do they return, are they always mated on the property, and are only pregnant heifers returned…?

the number of heifers per contract, the pregnancy rate at the mob level, the start and finish time of the rearing period, the breed of heifers, the average daily gain (ADG) and the average initial bodyweight. The latter represented the average bodyweight of the herd at the start of the grazing season. The farmer's name and address of the farm of origin were also available.

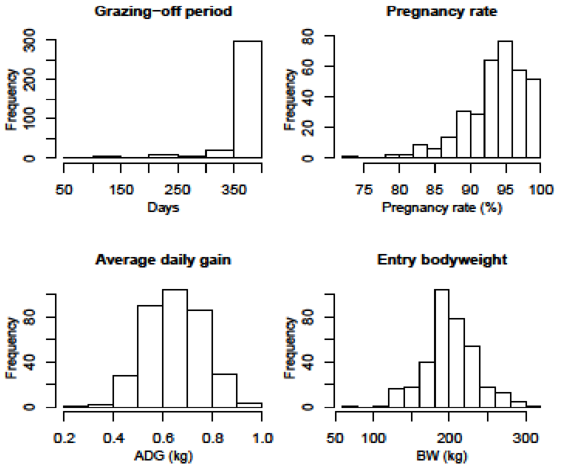


**Figure 2.1. Histograms of grazing-off duration, pregnancy rate, ADG and average entry bodyweight of heifers grazing from season 2006/07 to 2011/12 (n=21061)**

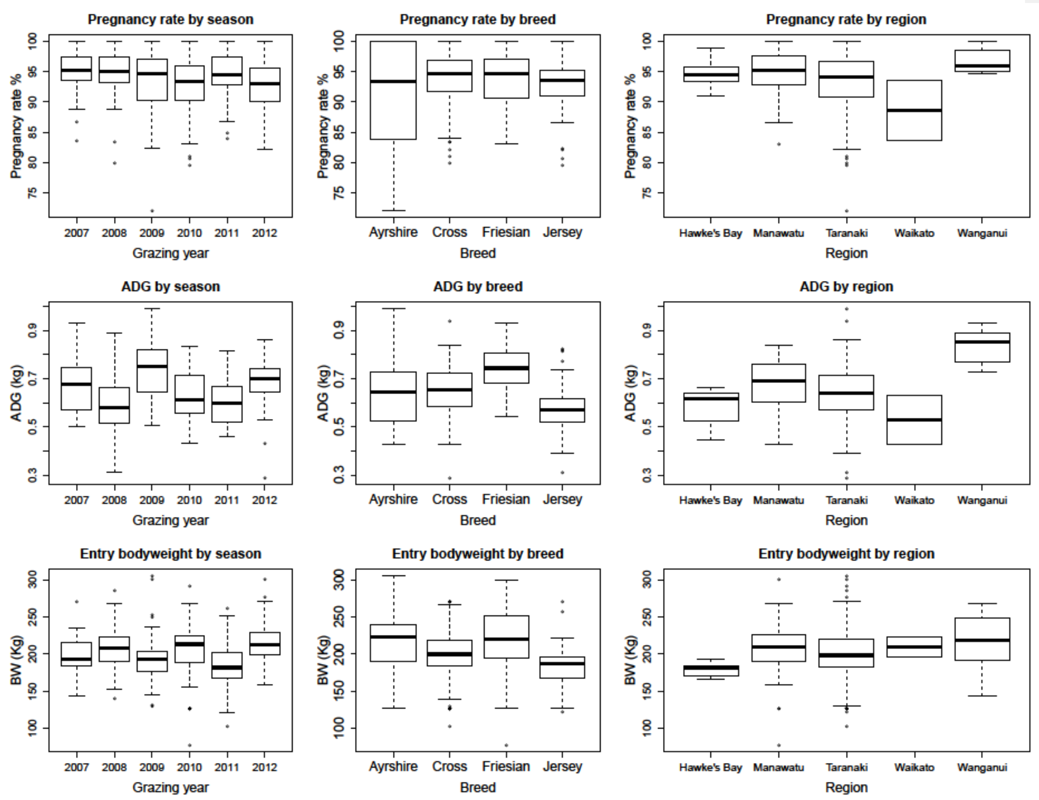


**Figure 2.2. Boxplots of pregnancy rate, ADG and average entry bodyweight stratified by the grazing season, breed of heifers and region of origin (n=21061)**

## Dependent variable

### *Pregnancy rate*

The chi-squared test for independence was used to examine the variability between the pregnant and empty heifer counts among the variables of the grazing seasons, the region of origin and the breed of heifers. Significant difference in pregnancy rate was found among the seasons, the regions and the breeds (Table 2.1).

**Comment [HC3]:** Like all output in M&M, table 2.1 is a result, relocate to Results section.

Table 2.1. Simple associations of ~~Pregnancy~~ pregnancy rate with~~,~~ ADG, average entry bodyweight and average grazing duration stratified by the variables of grazing season, region of origin ~~and~~ or breed of heifers (n=21061)

| Variable | Pregnancy rate (%) | ADG (kg) | Average BW (kg) | Average grazing-off period (days) |
|---|---|---|---|---|
| Grazing season | p<0.001[1] | p<0.001 | p<0.001 | p=0.20 |
| 2006/07 | 95.14[2] | 0.67[3] | 195.94 | 360.29 |
| 2007/08 | 95.04 | 0.58 | 207.06 | 353.17 |
| 2008/09 | 92.97 | 0.74 | 193.51 | 341.20 |
| 2009/10 | 92.88 | 0.62 | 203.09 | 339.41 |
| 2010/11 | 94.39 | 0.61 | 182.58 | 346.75 |
| 2011/12 | 93.16 | 0.68 | 217.38 | 352.83 |
| Region of origin | p<0.005[1] | p<0.001[4] | p=0.20[4] | p=0.89[4] |

| | | | | |
|---|---|---|---|---|
| Hawke's Bay | 94.52 | 0.58 | 178.30[5] | 363.57 |
| Manawatu | 94.28 | 0.69 | 205.54 | 349.19 |
| Taranaki | 93.66 | 0.64 | 199.98 | 347.97 |
| Waikato | 88.98 | 0.53 | 209.74 | 358.00 |
| Wanganui | 96.59 | 0.83 | 214.72 | 357.67 |
| Breed | p<0.001[1] | p<0.001[4] | p<0.001[4] | p=0.31[4] |
| Ayrshire | 87.71 | 0.64 | 212.81 | 325.08[6] |
| Crossbreed | 94.37 | 0.65 | 199.81 | 349.13 |
| Friesian | 93.64 | 0.74 | 220.14 | 354.48 |
| Jersey | 92.85 | 0.58 | 183.87 | 347.17 |

[1] Pearson's chi-squared test for independence: Significant difference existed between the number of pregnant and empty heifers among the grazing seasons, regions and breeds
[2] Pregnancy rate in the 2006/07 grazing season
[3] ADG achieved by herds grazing in the 2006/07 season
[4] *p*-value of the single factor ANOVA: Testing if a significant difference existed in ADG among different grazing seasons, regions and breeds, and the same test for average bodyweight and average length of grazing-off among the variables of season, region and breed
[5] The average bodyweight of herds originating from the Hawke's Bay region
[6] The average grazing-off duration of the Ayrshire herds

## Independent variables

### *Average daily weight gain*

The weighing dates were recorded for each participating heifer. These were used to calculate the difference between the first and last weighing date for every heifer. This difference was then used in conjunction with the difference between the first and last weight to calculate the ADG for every heifer. For contracts, the ADG of the group of heifers included in every contract was calculated. ADG was normally distributed among different contracts as illustrated in Figure 2.1. A significant difference in ADG existed among the grazing seasons and the heifer breeds (p<0.001), in addition to the regions of origin (p<0.005) as presented in Table 2.1.

### *Average initial bodyweight*

The heifer bodyweight at the start of the rearing period was used to calculate the average initial bodyweight of the herd. The average initial bodyweight was normally distributed among the contracts as shown in Figure 2.1. A significant difference in average initial bodyweight was only found among the grazing seasons and the heifer breeds (p<0.001) as presented in Table 2.1.

Table 2.2. Descriptive statistics of ADG, average entry bodyweight, average grazing-off duration, number of heifers per contract and pregnancy rate (n=21061)

| **Variable** | **Minimum** | **1st Quartile** | **Median** | **Mean** | **3rd Quartile** | **Maximum** | **SD** |
|---|---|---|---|---|---|---|---|
| ADG (kg) | 0.29[1] | 0.58 | 0.65 | 0.65 | 0.73 | 0.99 | 0.11[2] |
| BW (kg) | 78.00 | 183.10 | 199.30 | 200.80 | 220.40 | 305.20 | 33.61 |
| Grazing-off duration (days) | 54 | 357 | 363 | 348.8[3] | 367 | 376 | 48.55 |
| Number of heifers per contract | 5 | 40 | 51 | 61.05 | 75 | 275 | 34.66 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pregnancy rate (%) | 72.09 | 91.67 | 94.44 | 93.78 | 96.77 | 100 | 4.41 |

[1] Minimum average daily gain achieved in the study
[2] Standard deviation of ADG
[3] Average length of the grazing-off period

***Average grazing duration***

The contract rearing time spent by the majority of heifers (89%) was 350 days or more (Figure 2.1). There was no significant difference in the average grazing period among the grazing seasons, the heifer breeds or the regions of origin (Table 2.1).

***Number of heifers per contract***

Summary statistics of this variable is presented in Table 2.2. In 50% of the herds, the number of heifers in the herd ranged from 40 to 75 heifers producing an interquartile range of 35 heifers.

***Breed of heifers***

The majority of heifers were Holstein-Jersey crossbred (68%), followed by Jersey (15.9%), Friesian (13.3%) and Ayrshire (2.8%).

***Region of origin***

The heifers were sourced from the five regions of Hawke's Bay, Manawatu, Taranaki, Waikato and Wanganui in the North Island of New Zealand. The majority of heifers originated from the Taranaki region (75%), followed by the Manawatu region (17%).

Table 2.3. Bi-variate logistic regression analyses of the association between the odds of pregnancy occurrence at the herd level and the variables of ADG, entry bodyweight, length of the rearing period, rearing season, breed of heifer and region of origin (n=21061)

| **Variable** | **Coefficient** | **SE[1]** | **OR** | **95% CI** | **P-value** |
|---|---|---|---|---|---|
| Average daily gain (kg)[2] | 0.46 | 0.26 | 1.59[3] | 0.96 - 2.63[4] | 0.07[5] |
| Entry bodyweight (kg)[6] | -0.003 | 0.001 | 0.99 | 0.99 - 1 | 0.004[5] |
| Length of rearing period (days) | -0.001 | 0.001 | 1 | 0.99 - 1.01 | 0.98[5] |
| Rearing season | | | | | <0.001[7] |
| 2006/07 | Reference | | | | |
| 2007/08 | -0.02 | 0.12 | 0.98 | 0.77 - 1.24 | |
| 2008/09 | -0.39 | 0.11 | 0.68 | 0.54 - 0.84 | |
| 2009/10 | -0.4 | 0.11 | 0.67 | 0.54 - 0.82 | |
| 2010/11 | -0.15 | 0.11 | 0.86 | 0.69 - 1.07 | |
| 2011/12 | -0.36 | 0.10 | 0.70 | 0.57 - 0.85 | |
| Breed of heifers | | | | | <0.001[7] |
| Ayrshire | Reference | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Crossbreed | 0.85 | 0.13 | 2.35 | 1.82 - 3.03 | |
| Friesian | 0.72 | 0.15 | 2.06[8] | 1.55 - 2.75 | |
| Jersey | 0.60 | 0.14 | 1.82 | 1.38 - 2.40 | |
| Region of origin | | | | | 0.004[7] |
| Hawke's Bay | Reference | | | | |
| Manawatu | -0.045 | 0.17 | 0.96 | 0.68 - 1.34 | |
| Taranaki | -0.15 | 0.16 | 0.86 | 0.63 - 1.17 | |
| Waikato | -0.76 | 0.33 | 0.47 | 0.24 - 0.90 | |
| Wanganui | 0.496 | 0.28 | 1.64 | 0.95 - 2.85 | |

[1] Standard error
[2] The group average of ADG of the herd or contract
[3] The odds of pregnancy of the herd increased by a factor of 1.59 for every one kilogram increase in ADG of the herd
[4] The lower and upper limits of the 95% confidence interval of the odds ratio
[5] p-value based on Wald test
[6] The average bodyweight of the herd at the start of grazing-off
[7] p-value based on the likelihood ratio test
[8] The odds of pregnancy in Friesian herds was almost two times that in Ayrshire herds

### Statistical analysis

Descriptive analysis was done to visualise the data (Figures 2.1 & 2.2) and provide univariable statistics (Table 2.2). Only heifer contracts with a recorded pregnancy rate were included in the analysis. To account for correlation within heifer contracts, a generalised linear mixed model was fitted by maximum likelihood with a random effect for contract. Bi-variable logistic regression models were fitted to investigate the crude relationship between the odds of pregnancy as a dependent variable and the independent variables of squared ADG, number of heifers per contract, average initial bodyweight, grazing duration, heifer breed, grazing season and region of origin. Variables, with a likelihood ratio test p-value of <0.20 were retained for multivariate logistic regression analysis.

**Comment [HC4]:** As before → Results

Multivariate logistic regression was used to establish potential risk factors for pregnancy. To generate a preliminary multivariate model, stepwise backward elimination of the least significant variables was used while eliminated variables were assessed for confounding. The confounding effect was determined by a change of >20% in a variable coefficient in the model after another variable was dropped from or added to the model. Biologically plausible interactions between the variables were assessed to generate the final multivariate model. The variables were kept in the multivariable model if the likelihood ratio test statistic was significant at p<0.05. Improvement in the model by addition of variables was assessed by a reduction in the Akaike information criterion (AIC). Evaluation of the multivariable model was conducted by examining the significance of the full model, comparing the full and reduced models, Wald test and examining the goodness-of-fit. The latter was assessed by using the Pearson's and deviance chi-squared tests and exploring the predictive ability of the model. Deviance residuals were examined to identify potential outliers and leverage scores. All statistical analyses were conducted in R v3.0.2 (R Development Core Team, 2013; R Foundation for Statistical Computing, Vienna, Austria). Testing of statistical significance was carried out using the likelihood ratio test statistic (p<0.05).

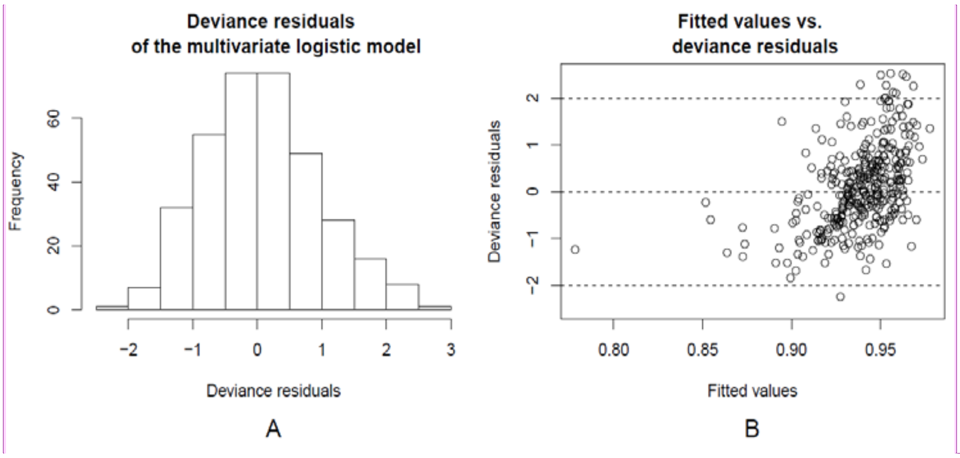


**Figure 2.3. A: Deviance residuals of the multivariate logistic model, B: Fitted values plotted against deviance residuals**

Significance of the model was examined using analysis of deviance. The full model with the candidate predictor variables was compared with the null model, with only the intercept. Furthermore, the full model was compared with reduced models with less predictor variables. The likelihood ratio test statistic was significant at p<0.05. This indicated that the predictor variables in the full model ~~a~~were significant predictors of the odds of pregnancy as they better explained deviance in the model than an analysis with less predictor variables. A Wald test was conducted individual categories of a ~~for the~~ categorical ~~independent~~ variables to examine their significance as a whole. The Wald test statistics for the grazing season and the breed of heifers were significant at p<0.05. In addition, improvement in AIC was evaluated ~~achieved with~~ by including those predictor variables in the final model. The deviance and Pearson's residuals showed normal distributions (Figure 2.3.A). The deviance residuals were plotted against the fitted values from the multivariable model. All the residuals were between +3 and -3 without showing any pattern (Figure 2.3.B). Deviance and Pearson's Chi-squared tests were both insignificant indicating a good fit. The predictive ability of the model was explored using a Receiver Operating Characteristic (ROC) curve. The area under the curve was 68%. This indicated that more information about the herds is required to enhance the prediction of the odds of pregnancy.

## Results

This study included 21,061 heifers sourced from 111 farms in the North Island of New Zealand. Those heifers comprised 345 rearing contracts in the period from 2006 to 2012. The results of the univariable logistic regression analysis are presented in Table 2.3. With the exception of the grazing duration variable, all predictor variables were accompanied by a likelihood ratio test p-value of less than 0.20. No significant correlation has been identified among the predictor variables. All the variables, with the exception of the grazing duration, were eligible to be included in the multivariable logistic regression model. Based on the previously mentioned criteria for confounding, none of the variables demonstrated the characteristics of being a confounder. In addition, interaction could not be detected when biologically plausible interactions between the variables were assessed to generate the final multivariable model. The multivariate logistic regression model was developed using the

**Comment [HC5]:** This looks blurred, try to insert a clear pic with higher resolution. You ignored the outlier of a mob with about 77% fitted pregnancy (B); was it influential?

**Comment [HC6]:** No individually, the LRT can be used to test variables with more than two levels.

**Comment [HC7]:** Relocate all results into this section.

predictor variables of ADG, rearing season and breed of heifers (Table 2.4).

Table 2.4. Multivariable logistic regression model of the association between the odds of pregnancy success (versus pregnancy failure) at the herd level and the explanatory variables of ADG, rearing season and breed of heifers (n=21061)

| Variable | Category | Coefficient | SE[1] | OR | 95% CI[2] | P-value[3] |
|---|---|---|---|---|---|---|
| Intercept | | 2.05 | | | | |
| ADG[4] | | 0.92 | 0.34 | 2.51[5] | 1.29 - 4.93 | <0.001 |
| Rearing season | 2006/07 | Reference | | | | <0.001 |
| | 2007/08 | 0.04 | 0.13 | 1.04 | 0.81 - 1.34 | |
| | 2008/09 | -0.44 | 0.12 | 0.64 | 0.48 - 0.76 | |
| | 2009/10 | -0.43 | 0.11 | 0.65 | 0.51 - 0.79 | |
| | 2010/11 | -0.16 | 0.11 | 0.85 | 0.66 - 1.04 | |
| | 2011/12 | -0.48 | 0.11 | 0.62 | 0.50 - 0.75 | |
| Breed | Ayrshire | Reference | | | | <0.001 |
| | Crossbreed | 0.73 | 0.13 | 2.08[6] | 1.88 - 3.18 | |
| | Friesian | 0.39 | 0.16 | 1.48 | 1.37 - 2.54 | |
| | Jersey | 0.46 | 0.14 | 1.58 | 1.43 - 2.50 | |

[1] Standard error
[2] The 95% confidence interval of the odds ratio
[3] p-value of the likelihood ratio test
[4] ADG (squared) achieved by a group of heifer comprising a contract or a herd
[5] The odds of pregnancy of the herd increased by a factor of 2.52 for every one kilogram increase in the ADG of the herd
[6] The odds of pregnancy in crossbred heifers was 2.44 times the odds of pregnancy in Ayrshire heifers

In the multivariable model, the odds of pregnancy success at the herd level (versus the odds of pregnancy failure) was significantly associated with the ADG of the herd, breed of heifers in the herd and grazing season. An increase of one standard deviation in the average daily weight gain of a replacement heifer mob increased average pregnancy rates by 3.3% equivalent to an OR of 2.5 (95% CI 1.3– 4.9). In terms of the breed of heifers, this study highlights the superiority of the Holstein-Jersey crossbreed which was associated with the highest pregnancy rate. Pregnancy in Holstein-Jersey crossbreed was 2.1 (95% CI 1.9 – 3.2) times that of Ayrshire, 1.2 (95% CI 1.1 – 1.6) times that of Holstein and 1.3 (95% CI 1.1 – 1.5) times that of Jersey heifers. Additionally, the odds of pregnancy in the Friesian and Jersey herds were similar, accounting for almost 1.5 times the odds of pregnancy in herds comprised of Ayrshire heifers. In addition, the 2007/08 grazing season was associated with the greatest odds of pregnancy success. The odds of pregnancy success in the 2007/08 grazing season was 1.05 (95% CI 0.81 – 1.34) times that in the grazing season of 2006/07, 1.73 ((95% CI 1.35 – 2.23) times that in the 2008/09 grazing season, 1.65 (95% CI 1.34 – 2.04) times that in the 2009/10 grazing season, 1.26 (95% CI 1.01 – 1.57) times that in the grazing season of 2010/11 and 1.71 (95% CI 1.37 – 2.15) times the odds of pregnancy in the grazing season of 2011/12. Moreover, the 2008/09 grazing season was associated with odds of pregnancy that was lesser than each of the other grazing seasons. For example, the odds of pregnancy in the 2006/07 grazing season was 1.66 (95% CI 1.32 – 2.08) times the odds of pregnancy in the 2008/09 grazing season.

**Comment [HC8]:** It would have been a lot better to show actual pregnancy rates in those strata; ORs are misleading as they overestimate RR which are the actual multipliers, however, mean PRs in breeds and seasons are better. Why don't you show line graphs of predicted PR over time and in relation to ADG? What about the long term trend, there seems to be a general decrease of PR over those years – did you test for that? I had asked this question in my 1st review already.

Post-weaning growth rate represents a major influence on the onset of puberty which in turn determines the suitability of heifers for mating when breeding starts. Improving the post-weaning average daily gain of replacement herds, especially Holstein-Jersey crossbred heifers, is therefore expected to improve pregnancy rate. Factors (e.g., management, environmental, etc.) associated with different grazing seasons should be investigated to determine potential associations with pregnancy rate.

**Comment [HC9]:** Sounds like an interaction, was there one? It is not in table 2.4

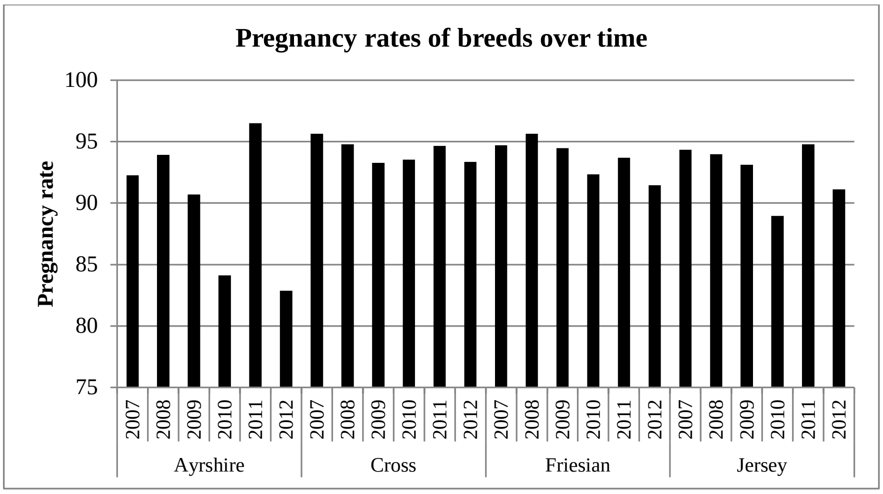


**Figure 2.4. Pregnancy rates of breeds over time**

## Discussion

Outsourcing the rearing of replacement heifers to specialist growers has become a common practice in New Zealand dairy farming (Penno 1997).This practice has become increasingly popular especially with studies showing that it is cost-effective to primarily utilise pasture grown on dairy farms for milk production (Bryant and McRobbie 1991). In the United States, the practice of subcontracting the rearing of replacement heifers is also prevalent in many parts of the country (Wolf 2003).

Dairy farmers maintain a constant size of their milking herds by keeping enough replacement heifers for this purpose. Excess heifers are usually sold if rearing them was more expensive than selling them. Several factors influence the size of the replacement herd kept by dairy farmers. Some of these factors are culling within the dairy herd, the calving interval, the live calving rate of the dairy herd, calf mortality rate, the age at first calving and the reproductive efficiency of the replacement heifers(Tozer and Heinrichs 2001). These factors can even extend to include nutrition and prepubertal growth rate. Since many of these factors are interrelated, it is difficult to consider one factor separately without considering other related factors.

***Post-weaning average daily gain***

Several studies investigated the association between post-weaning growth rate, prepubertal growth rate, pre-mating~~breeding~~ bodyweight and pregnancy rate in replacement heifers. Some of these studies found insignificant associations. Little et al. found that first service conception rate was not significantly different between groups of dairy heifers of different average daily weight gain (Little and Kay 1979). Van Amburgh et al. discussed this association in three groups of Holstein heifers with average daily gains of 0.6, 0.8 and 1 kg. The reproductive performance was recorded for every group.

The study showed that there was no significant difference in first service conception rate and the pregnancy rate among the three groups (Van Amburgh *et al.* 1998). Similar results were obtained in Holstein heifers where bodyweight and average daily gain in the prepubertal and prebreeding periods were not risk factors for first service conception (Donovan *et al.* 2003). In a New Zealand study, Macdonald et al. evaluated the effect of different levels of nutrition, with resultant different prepubertal average daily gains, on pregnancy rate in both Holstein and Jersey heifers. Estrus was synchronised in these heifers to allow for seasonal calving. No difference in pregnancy rate was noted between the heifer groups (Macdonald *et al.* 2005).

On the other hand, significant associations between prepubertal average daily gain, conception and pregnancy rate were found in other studies. Short et al. investigated the association between prepubertal growth rate and pregnancy rate in three groups of crossbred heifers with average daily gains of 0.23, 0.45 and 0.68 kg. Heifers from the lowest average daily gain group were the last to reach puberty. In addition, those heifers had the least pregnancy rate compared with the other two groups (Short and Bellows 1971). Patterson et al. noted significant associations between prepubertal growth rate, conception rate at first service and pregnancy rate in two groups of heifers that received two diets with different energy levels. In that study, to reach 55% and 65% of mature bodyweight before breeding, heifers received low and high energy diets, respectively. Heifers with higher average daily gain and heavier bodyweight before breeding had significantly higher conception rate at first service and pregnancy rate than heifers with lower average daily gain and lighter bodyweight (Patterson *et al.* 1989). Buskirk et al. concluded that increased postweaning weight gain in beef heifers enhanced fertility. The study found that increased weaning weight and postweaning gain was associated with increasing the probability of an early onset of puberty and increased first service conception (Buskirk *et al.* 1995). Wathes et al. found significant association between high prepubertal average daily gain and increased pregnancy rate in dairy heifers. The study concluded that poorly grown heifers had low pregnancy rate resulting in very poor lifetime productivity and were therefore uneconomic to keep. Wathes et al. also stated that heifers that have difficulty in conceiving are often poorly developed at 6 to 9 months(Wathes *et al.* 2008).Similar results were found in Holstein-Friesian heifers where high prebreeding average daily gain resulted in increasing first service conception rate and reducing age at first calving (Cooke *et al.* 2013). The results from the last five studies were in agreement with the results of the study in hand in that high prepubertal growth rate was significantly associated with increased pregnancy rate.

***Breed***

Many studies have discussed the differences in reproductive traits between different cattle breeds. Nonetheless, the difference in reproductive performance has not extensively been studied in the major New Zealand dairy cattle breeds of Holstein Friesian, Jersey and Holstein-Jersey crossbreed under New Zealand pasture-based seasonal production system. In a New Zealand study, the pregnancy rates at both 21 days and 42 days after the start of breeding were greater in Jersey heifers than Holstein Friesian heifers (Grosshans *et al.* 1997). In the United States, similar results were obtained (Washburn *et al.* 2002a; Norman *et al.* 2009). In another US study, South-eastern Jersey cows were characterised by significantly less days open than Holstein cows, whereas the breed had no significant effect on services per conception (Washburn *et al.* 2002b). On the other hand, some studies have found no significant difference in pregnancy rates between Holstein-Jersey crossbred and purebred Jersey and Holstein dairy herds. For example, Bjelland et al. studied the difference in reproduction traits between Holstein-Jersey crossbred heifers and Holstein heifers. The results suggested that crossbred heifers were not significantly different from purebred Holstein heifers in terms of reproductive efficiency (Bjelland *et al.* 2011).

All the other studies that have been reviewed have found that Holstein-Jersey crossbred herds were superior to either purebred Holstein or Jersey herds in terms of reproductive performance. Some of these studies discussed that difference in dairy herds raised in confinement production systems. Anderson et al. compared reproductive performance between Holstein and Holstein-Jersey crossbred first lactation dairy herds under confinement production system in Wisconsin, USA. Days to first breeding, services per conception and days open in Holstein-Jersey crossbred pens were significantly less than Holstein pens. In addition, pregnancy rate at 21 days after the start of breeding was significantly greater in crossbred pens than purebred Holstein pens (Anderson *et al.* 2007). Similar results were found by Heins et al. in another study that compared Holstein-Jersey crossbred cows with purebred Holstein cows at first lactation. Days open of crossbred cows were significantly less than purebred Holstein cows. Moreover, pregnancy rates of crossbred cows were significantly greater than purebred Holstein cows (Heins *et al.* 2008b). Another study was conducted in the USA to examine the differences in several physiological traits including reproductive performance among first and second lactation purebred Holstein and Holstein-Jersey crossbred cows (Brown *et al.* 2012). The results indicated that days open and the number of services per conception were significantly greater in purebred Holstein cows than crossbred cows.

Some also discussed differences in reproductive performance in seasonally calving pasture-based production systems. An Australian study examined the difference in reproductive performance between Holstein-Jersey crossbred cows and purebred Holstein cows in 4 pasture-based, seasonally calving dairy herds. First service conception rate and pregnancy rate at 6 and 14 weeks after the start of breeding were significantly higher in crossbred cows than in purebred Holstein cows (Auldist *et al.* 2007). Similar results were reported in an Irish study that compared reproductive performance and profitability between purebred Holstein, Jersey and Holstein-Jersey crossbred dairy cows under seasonal pasture-based management system (Prendiville *et al.* 2011). Prendiville et al. concluded that Jersey cows did not significantly differ from Holstein cows, whereas Holstein-Jersey crossbred cows were significantly superior to both breeds in terms of first service conception and pregnancy rate at 6 and 13 weeks after the start of breeding. Vance et al. reported results that supported the superiority of Holstein-Jersey dairy cows when compared to their Holstein contemporaries in terms of conception to first and second service and pregnancy rate at the end of breeding season in a seasonally calving management system (Vance *et al.* 2013). These results obtained by the several previous studies were in agreement with the results reached in the study in hand in that the Holstein-Jersey crossbred herds had significantly greater pregnancy rate than purebred Holstein and Jersey herds.

***Grazing season***

The grazing-off season of 2008/09 was associated with ~~the~~lowest pregnancy rates overall~~-~~ least odds of pregnancy occurrence, although it was associated with the highest ~~greatest~~ ADG amongst all the grazing-off season. Further information is required to investigate other factors in relation to the grazing-off seasons that can be potentially associated with the odds of pregnancy occurrence in replacement herds.

**Comment [HC10]:** What's that? The next season (2009/10) had the opposite combination, i.e. low PR/low ADG – this looks like an interaction season*ADG, was it significant?

CHAPTER 3

# Factors associated with growth rate in New Zealand replacement dairy heifers


## Abstract

AIMS: This study investigated the factors associated with growth rate in a number of replacement dairy heifers in the North Island of New Zealand. These factors included the length of the grazing period, entry bodyweight, heifer breed, grazing season and the region from which the heifers originated. Entry bodyweight is the heifer weight at the beginning of grazing on specialist rearing farms away from the farm of origin.

METHODS: The dataset consisted of 31,661 heifers in the seasons from 2006/07 to 2012/13. The heifers originated from the regions of Hawke's Bay, Manawatu, Taranaki, Waikato and Wanganui. Rearing the heifers was contracted to one specialist heifer rearing enterprise with a goal of obtaining high pregnancy rate and a target maximum age at first calving of 24 months. Multivariable linear models were fitted to test the hypothesis that the entry bodyweight, the breed, the region of origin, the length of the grazing period and the season of grazing were independently associated with the average daily weight gain.

RESULTS: The average daily gain (ADG) of heifers was 630 g (standard deviation sd: 150g). An increase of 1 sd ~~Unit increases~~ in heifer entry bodyweight increased the average daily gain by ~~0.45~~24 gram, equivalent to 3.9% ADG (p<0.001). ADG of Jersey heifers (398g) was ~~were associated with an ADG that was~~ significantly ~~less~~ lower than ADG ~~gained by each~~ of ~~the other breeds of~~ Holstein-Friesian (492g), Holstein-Jersey crossbreed (465g) and Ayrshire (479g; p<0.001). ~~, whilst Holstein heifers were associated with the greatest ADG amongst all breeds (p<0.001).~~ Heifer mobs sourced from ~~The region of~~ Wanganui had higher ~~was associated with an~~ ADG ~~that was significantly greater~~ than ~~the ADG achieved in each of the~~ other regions (p<0.001). ADG of heifers during ~~T~~the 2012/13 grazing season was ~~associated with an ADG that was~~ significantly lower~~ess~~ than ~~the ADG gained by heifers raised~~ in any ~~each~~ of the other seasons (p<0.001).

CONCLUSIONS AND CLINICAL RELEVANCE: ~~Monitoring of post-weaning average daily gain is crucial when raising replacement heifers.~~ Heifers that are ~~of~~ heavier ~~bodyweight~~ at weaning are expected to have higher ADG ~~more average weight gain~~ prior to mating~~before breeding~~. Although Holstein heifers fall in that category, Holstein-Jersey crossbred heifers can provide better functional traits. However, despite Holstein-Friesian heifers being heavier, Jersey-Friesian crossbreds had higher pregnancy rates (Chapter 2). Hence, high ADG may not be the only goal for heifer rearing. ~~These findings are important for informed decision making in rearing replacement heifers under New Zealand conditions.~~ Further information is required about other management factors (e.g. parasite burden, disease prevention).~~to investigate potential associations between different regions of New Zealand, grazing seasons and growth rate of replacement heifers~~.



KEY WORDS: *Average daily gain, linear regression, New Zealand, replacement heifers*


**Comment [HC11]:** What do you mean? Is this an opinion or a conclusion from the analysis? Crossbred had higher preg-rates in CH2.

**Comment [HC12]:** Try to avoid waffling, examiners hate it.

**Comment [HC13]:** These are the fators that you just looked at, so I would not suggest to do the same again, else your work was redundant.

## Introduction

Heifers with a low prepubertal average daily gain (ADG) need longer time to reach puberty and mating weight compared with heifers with a higher prepubertal ADG (Brickell *et al.* 2009a).

Consequently, these heifers are characterised by longer time to conception. Low prepubertal ADG and delayed onset of puberty can be caused by a number of factors of which sub-optimal nutrition is an important factor (Buskirk *et al.* 1995; Ettema and Santos 2004; Brickell *et al.* 2009a; Cooke *et al.* 2013). These heifers are predisposed to an increased risk of dystocia due to reduced skeletal growth. On the other hand, heifers with a high ADG need shorter time to reach mating weight (Gardner *et al.* 1977; Little and Kay 1979; Van Amburgh *et al.* 1998). In conjunction with good fertility, this can result in an age at first calving as young as 24 months and more productive days (Short and Bellows 1971; Heinrichs 1993; Donovan *et al.* 1998; Donovan *et al.* 2003; Wathes *et al.* 2008). This also means more lifetime calf production, more milk production and improved longevity (Lesmeist.Jl *et al.* 1973; Tibary *et al.* 1992; Buskirk *et al.* 1995; Wathes *et al.* 2008; Cooke *et al.* 2013). Given the presence of the favourable factors of sufficient nutrition, good heifer fertility and successful insemination, post-weaning growth rate would allow for puberty to be reached by 13 months of age and breeding and conception to be reached by 15 months of age (Wathes *et al.* 2008; Brickell *et al.* 2009a). Calving heifers at more than 24 months of age is costly due to higher overhead costs, increased feeding costs, increased overcrowding and increased number of unproductive days (Gardner *et al.* 1977; Losinger and Heinrichs 1997; Pirlo *et al.* 2000; Ettema and Santos 2004; Haworth *et al.* 2008; Brickell *et al.* 2009b).

Monitoring of ADG early in the life of heifers can be a powerful tool to predict survivability of those animals to second lactation (Bach 2011). Weighing animals at regular intervals is beneficial to establishing average daily gain between weaning and mating and again between mating and calving. It is unreliable and inefficient to guess growth rates and mating weights. The use of electronic scales is now an integral part of good management on modern farms. There are several studies that recommend optimum weights at mating and calving of Holstein Friesian, Jersey, Ayrshire and Holstein-Jersey crossbred heifers. Nonetheless, there is variation in average mature bodyweight from herd to herd and from one region to another, let alone variation between breeds. Additionally, optimum first calving bodyweight differs from one farming system to another. Holstein cows are recommended to weigh an average of 600 kg at first calving in feedlot systems (Heinrichs 1993; Hoffman 1997). On the other hand, the recommended average bodyweight at first calving is 520 kg for Holstein cows in pasture-based systems (Macdonald *et al.* 2005) and 450 – 500 kg for a New Zealand type Holstein cow (Penno 1997).

Outsourcing the rearing of replacement heifers to specialist growers has become common practice in New Zealand dairy farming (Penno 1997). This practice has become increasingly popular especially with studies showing that it is cost-effective to primarily utilise pasture grown on dairy farms for milk production (Bryant and McRobbie 1991; Heinrichs 1993). In the United States, the practice of subcontracting the rearing of replacement heifers is also prevalent in many parts of the country (Wolf 2003). However, the published literature about the factors affecting performance indicators of replacement heifers in New Zealand was limited. This study aims at examining the factors that are likely to be associated with growth rates of dairy heifers on one contract heifer rearing farm in New Zealand ~~replacement dairy heifers~~.

**Comment [HC14]:** Remember that the findings relate to only one contract rearer and do not represent all NZ heifers.

## Materials and methods

### Study design and data collection

The data was collected by a contract rearing heifer operation ~~veterinary private practice~~ in the North Island of New Zealand. The operation ~~practice~~ contracts ~~specialist grower~~ dairy farmers for grazing and mating replacement heifers. From the rearing season of 2006/07 to 2012/13, a total of 31,661 heifers were contracted by ~~part of~~ this rearing programme where they were raised for a period of time away from their farm of origin. Natural service was used in addition to the option of a synchronised artificial insemination programme. The heifers were then pregnancy-tested before returning to their farm of origin. The aim of the programme was maintaining a good health status for the heifers while achieving high pregnancy rate and a target age at first calving of 24 months of age. The data obtained for this study was at the individual heifer level. The data included rearing season, grazing-off duration, heifer breed ~~of heifer~~, average daily gain (ADG) ~~of the heifer~~, entry bodyweight ~~of the heifer~~ and the region from which ~~the~~ heifers originated. The entry bodyweight represented the heifer weight at the start of the grazing-off period.

**Comment [HC15]:** Again explain briefly how it works, i.e. age at which heifer calves are transferred to the rearing property, mating, and age when they return, are only pregnant heifers returned…?

**Comment [HC16]:** They also run a vet practice, coincidentally.

**Response variable**

***Average daily weight gain***

ADG was calculated by dividing the difference in bodyweight between the first and last weighing by the number of days between the first and last weighing. The average heifer weighing frequency was 6 weeks. Heifers were weighed on their entry to the rearing farms and a final weighing was done before returning to their farm of origin.

**Comment [HC17]:** Would it not be useful to also evaluate final pre-mating weight?

**Predictor variables**

***Entry bodyweight***

Entry bodyweight is the bodyweight of a heifer on arrival at the rearing farms. In this analysis, the association between entry bodyweight and average daily weight gain was investigated.

***Breed***

Four breeds were involved in this study; Holstein-Friesian (HF), Jersey (JJ), Holstein-Jersey (HJ) crossbreed and Ayrshire (AY). The association between the heifer breed and average daily weight gain was investigated in this study.

**Comment [HC18]:** Might be useful to use these acronyms

***Rearing season***

The rearing seasons ranged from 2006/07 to 2012/13. The relationships between average daily weight gain and ~~the~~ rearing season as well as longitudinal trend were~~as~~ examined. In addition, an interaction between starting weight and season was included to consider differences in rainfall and temperature dependent pasture quality between farm of origin and the contract rearing property.

***Region of origin***

The heifers originated from the regions of Hawke’s Bay, Manawatu, Taranaki, Waikato and Wanganui. The relationship between average daily weight gain and the region of origin was examined in this study.

**Statistical analysis**

Simple linear regression models were fitted to investigate the unadjusted relationship between the dependent variable of ADG and the independent variables of entry bodyweight, the duration of rearing, the heifer breed, the rearing season and the region of origin. Variables, with a significant F-test statistic at p<0.20 in bi-~~uni~~variable regression, were eligible to be included in the preliminary multivariable~~te~~ regression model used to predict average daily gain. In addition, the predictor variables were assessed for confounding. The confounding effect was determined by a change of >~~3~~2150~~0%~~ in a variable coefficient in the model after another variable was dropped from or added to the model. ~~Interaction was~~ Biologically plausible interactions were also evaluated in the multivariable model~~checked using biologically plausible scenarios~~. Variables with a significant F-test statistic at p<0.05 were retained in the final multivariable model. A linear mixed-effects model was fitted with a random effect~~s~~ for contract to account for correlation of ~~within~~ heifers within mobs~~s~~. A linear long term effect was tested ~~implemented~~ using rearing seasons as a continuous variable. Residual analysis was conducted as part of checking the assumptions of the final linear regression model. Linearity and homoscedasticity were examined. The presence of outliers, leverage and influence were also assessed. All analyses were conducted in R v3.0.2 (R Development Core Team, 2013; R Foundation for Statistical Computing, Vienna, Austria). Testing of statistical significance was carried out using a p-value of 0.05.

The significance of the multivariable model with all the predictor variables was compared ~~with the null model (a model with only the intercept) and~~ to a reduced model with less predictor variables using partial F-test. The test statistic in either case was significant at p<0.001. This indicated that the full model with all the predictor variables listed in Table 3.4 wa~~i~~s a good predictor of ADG. Raw and standardised residuals followed normal distribution (Figure 3.3.A). The standardised residuals were plotted against the fitted values from the multivariable model as presented in Figure 3.3.B. The majority of the residuals were homogenously spread between +3 and -3. Outliers were identified. Figure 3.3.C demonstrated the leverage score for every observation in this study. Additionally, heifers with high leverage scores were identified. There were no observations that could be considered influential (Figure 3.3.D). No significant change was noted in the model coefficients or the significance of the main effects when the multivariable model was re-fitted without the outlier and high leverage observations. Similarly, the partial F-test statistic was not significant at p<0.05 when this reduced model (without the outlier and high leverage observations) was compared with the full model with all the observations. Multiple R-squared was 0.40 indicating that the predictor variables of entry bodyweight, rearing duration, heifer breed, region of origin and grazing season explained 40% of variability in the data. This suggests that further information is required to better predict average daily gain at the individual heifer level.

**Comment [HC19]:** 30% is far too high, esp in a large dataset like this.

**Comment [HC20]:** No place for a null model here

**Comment [HC21]:** What's this, a result already? Or are you setting the level of significance for in-/excluding variables?

**Comment [HC22]:** Result again? And repeated further down – keep M&M and results apart as in CH2.

**Comment [HC23]:** Almost all of this is Results

## Results

The data consisted of 31,661 replacement heifers in the grazing seasons from 2006/07 to 2012/13.

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~~**Continuous variables**~~

The histograms of the continuous variables of the ADG, the entry bodyweight and the duration of the rearing period are displayed in Figure 3.1. Entry bodyweight is the heifer weight at the beginning of grazing on specialist grower farms away from the farm of origin. ADG was normally distributed. The mean daily bodyweight gain was 0.63 kg with a median of 0.64 kg. Half the heifers gained o~~a~~n average ~~daily gain~~ between 550 and 720 grams, weighed between 118 and 206 kg at joining the rearing programme and spent from 149 to 363 days grazing away from their farm of origin. About 40% of the heifers grazed for a period of 120 – 170 days (the first peak) and about another 43% of the heifers grazed for 350 to 395 days (the second peak) as presented in Figure 3.1. The descriptive statistics of the continuous variables are shown in Table 3.1.

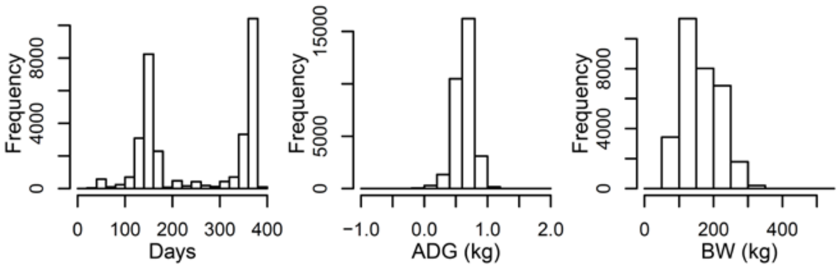


**Figure 3.1. Histograms of the grazing-off duration, the average daily gain and the entry bodyweight (n=31661)**

Table 3.1. Descriptive statistics of the continuous variables (n=31661)

| **Variable** | **Minimum** | **1st quartile** | **Median** | **Mean** | **3rd quartile** | **Maximum** | **SD** |
|---|---|---|---|---|---|---|---|
| Rearing period (days) group 1 Rearing period (days) group 2 | 15 | 149 | 222 | 250.1 | 363 | 395 | 108.72[1] |
| ADG (kg) | -0.87[2] | 0.55 | 0.64 | 0.63 | 0.72 | 1.85 | 0.15 |
| Entry BW (kg) | 49 | 118 | 159 | 164.1[3] | 206 | 520 | 54.04 |

[1] Standard deviation of the length of the rearing period
[2] Minimum average daily gain achieved in the study
[3] Average entry bodyweight

**~~Categorical variables~~**

The distribution of ADG, initial BW and duration of the grazing period ~~the continuous variables~~ stratified by the categorical variables of breed, ~~the~~ grazing season and ~~the~~ region of origin is demonstrated in Figure 3.2. Number of heifers, ADG, entry bodyweight and average length of the

**Comment [HC24]:** Remove this as it is not appropriate given that there were 2 groups. This needs to be explained – why these two groups? These must be different type of contracts, and this must be considered as a factor in the analysis!

rearing period are shown in Table 3.2 for every level of the categorical variables of breed, grazing season and region of origin.

The null hypothesis that there ~~is~~ was ~~a~~ no significant difference in the ADG between ~~among~~ heifer breeds, seasons and regions was tested using single factor analysis of variance (ANOVA). With a test statistic at $p<0.05$, the alternative hypothesis was~~can be~~ accepted, i.e. that there ~~i~~was a significant difference in ADG among those strata~~e heifer breeds~~. Single factor ANOVA was again used to test the null hypothesis of no difference in ADG among the grazing seasons and further among the regions of origin. With p-values less than 0.05, the null hypothesis can be rejected as the observed difference was unlikely to have occurred by chance alone. This was repeated for average entry bodyweight and average rearing duration with a significant difference among the levels of each categorical variable Results indicated that…. (Table 3.2).

**Comment [HC25]:** Explain what the main findings were from Fig 3.2 and Table 3.2.

**Comment [HC26]:** Now this is M&M, explain there.

**Comment [HC27]:** M&M

**Comment [HC28]:** Explain main findings

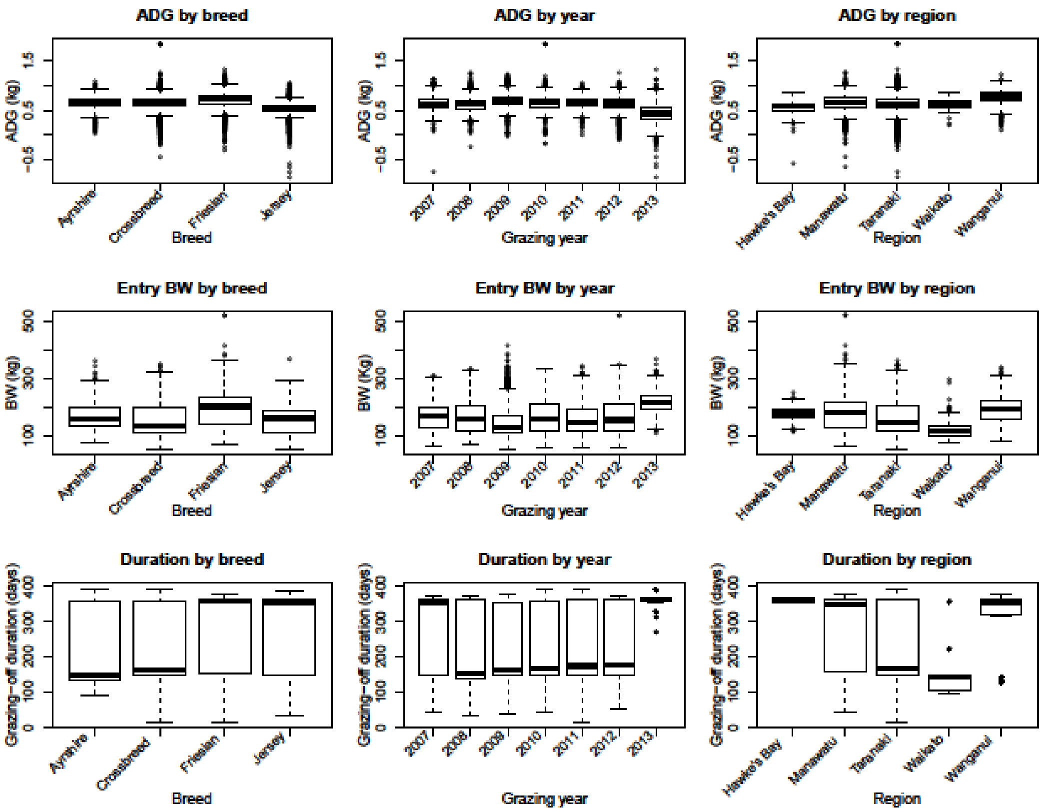


**Figure 3.2. Boxplots of the continuous variables of average daily gain, the entry bodyweight and the rearing duration stratified by the categorical variables of breed, the grazing season and the region of origin (n=31661)**

Table 3.2. Number of heifers, ADG, average entry bodyweight and average rearing duration stratified by the levels of the categorical variables

| Variable | Count | ADG (kg) | Average entry BW (kg) | Average rearing period (days) |
|---|---|---|---|---|
| **Breed** | | | | |
| Ayrshire | 8331[1] (3%) | 0.63 (p<0.05)[2] | 167.17 (p<0.05) | 223.56 (p<0.05) |
| Crossbreed | 14059 (44%)[3] | 0.64[4] | 152.55 | 222.32 |
| Friesian | 8878 (28%) | 0.70 | 193.56 | 281.45 |
| Jersey | 7891 (25%) | 0.54 | 151.16 | 267.31 |
| **Season** | | | | |
| 2006/07 | 3500[5] (11%) | 0.64 (p<0.05) | 166.03 (p<0.05) | 263.87 (p<0.05) |
| 2007/08 | 4463 (14%) | 0.62 | 163.15[6] | 227.72 |
| 2008/09 | 5132 (16%) | 0.69 | 143.3 | 218.17 |
| 2009/10 | 4073 (13%) | 0.66 | 162.82 | 236.21 |
| 2010/11 | 5035 (16%) | 0.65 | 156.78 | 249.55 |
| 2011/12 | 6731 (21%) | 0.64 | 163.96 | 245.11 |
| 2012/13 | 2727 (9%) | 0.44 | 217.94 | 363.71 |
| **Region** | | | | |
| Hawke's Bay | 894 (3%) | 0.56 (p<0.05) | 176.94 (p<0.05) | 363.61 (p<0.05)[7] |
| Manawatu | 5862 (18%)[8] | 0.65 | 175.39 | 273.1 |
| Taranaki | 23415 (74%) | 0.63 | 159.49 | 236.45 |
| Waikato | 122 (1%) | 0.63 | 124.16 | 159.4[9] |
| Wanganui | 1368 (4%) | 0.75 | 189.37 | 320.1 |

[1] Number of Ayrshire heifers in the study
[2] *p*-value of the anova test of the difference of ADG among breeds
[3] Percentage of crossbred heifers in the study
[4] ADG in crossbred heifers
[5] Number of heifers reared in 2006/07 season
[6] Average starting bodyweight in heifers reared in 2007/08 season
[7] *p*-value of the anova test of difference of the average rearing duration among the regions of origin
[8] Percentage of heifers originating from the Manawatu region
[9] Average length of the rearing period of the heifers originating from the region of Waikato

Table 3.3. Bi-variable linear regression analyses of the association between average daily gain (grams) and the variables of entry bodyweight, length of the rearing period, breed of heifer, region of origin and season of grazing (n=31661)

| Variable | Coefficient (g/d) | Standard Error | P-value |
|---|---|---|---|
| Entry bodyweight (kg) | 0.11[1] | 0.02 | <0.001[2] |
| Rearing duration (days) | -0.07[3] | 0.01 | <0.001 |
| Breed | | | <0.001 |
| Ayrshire (reference) | 629.29 | 4.63 | |
| Crossbreed (difference to reference) | 14.45 | 4.77 | |
| Friesian (difference to reference) | 72.62 | 4.85 | |
| Jersey (difference to reference) | -92.39[4] | 4.87 | |

**Comment [HC29]:** This is a mean whereas the coefficient is the rate of change, suggest to show them in separate columns

| | | | |
|---|---|---|---|
| Grazing season | | | <0.001 |
| 2006/07 (reference) | 640.72 | 2.24 | |
| 2007/08 (difference to reference) | -24.94 | 3.00 | |
| 2008/09 (difference to reference) | 50.9[5] | 2.91 | |
| 2009/10 (difference to reference) | 16.01 | 3.06 | |
| 2010/11 (difference to reference) | 14.07 | 2.92 | |
| 2011/12 (difference to reference) | 2.46 | 2.77 | |
| 2012/13 (difference to reference) | -200.05 | 3.39 | |
| Region of origin | | | <0.001 |
| Hawke's Bay (reference) | 561.68 | 4.82 | |
| Manawatu (difference to reference) | 87.67[6] | 5.17 | |
| Taranaki (difference to reference) | 63.38 | 4.91 | |
| Waikato (difference to reference) | 66.75 | 13.91 | |
| Wanganui (difference to reference) | 185.28 | 6.20 | |

[1] ADG increased by 11 grams for a 100 kg increase in entry bodyweight, holding other variables constant
[2] *p*-value of F-test
[3] ADG decreased by 7 grams for a 100 kg increase in the rearing duration, holding other variables constant
[4] ADG in Jersey heifers was less than ADG in Ayrshire heifers by about 92 grams, holding other variables constant
[5] ADG in 2008/09 season was more than ADG in the 2006/07 season by 50.9 grams, holding other variables constant
[6] ADG of heifers originating from the Manawatu region was more than ADG from the Hawke's Bay region by about 87 grams, holding other variables constant

Table 3.4. Multivariate linear regression model of average daily gain (gram/day) on entry bodyweight, breed of heifer, season of grazing and region of origin (n=31661)

| **Variable** | **Category** | **Coefficient (g/d)** | **Standard Error** | **95% CI** | **P-value[1]** |
|---|---|---|---|---|---|
| Intercept (kg) | | 324.25 | 26.98 | 271.37 – 377.13 | |
| Entry bodyweight (kg) | | 0.45[2] | 0.02 | 0.41 – 0.49 | <0.001 |
| Breed | Jersey | Reference | | | <0.001 |
| | Ayrshire | 80.95 | 5.83 | 69.52 – 92.38 | |
| | Crossbreed | 67.36 | 2.01 | 63.42 – 71.29 | |
| | Friesian | 93.96[3] | 2.42 | 89.22 – 98.69 | |
| Season | | | | | <0.001 |
| | 2006/07 | 261.99 | 19.39 | 223.89 – 300.09 | |
| | 2007/08 | 246.97 | 18.61 | 210.42 – 283.52 | |
| | 2008/09 | 332.07 | 18.03 | 296.66 – 367.48 | |
| | 2009/10 | 284.67 | 18.31 | 248.69 – 320.64 | |
| | 2010/11 | 282.01 | 18.25 | 246.16 – 317.86 | |
| | 2011/12 | 264.41[4] | 17.31 | 230.41 – 298.40 | |
| | 2012/13 | Reference | | | |

| | | | | | |
|---|---|---|---|---|---|
| Region of origin | Wanganui | Reference | | | <0.001 |
| | Hawke's Bay | -90.72 | 44.52 | (-178.15) - (-3.29) | |
| | Manawatu | -60.47 | 25.84 | (-111.21) - (-9.73) | |
| | Taranaki | -96.79[5] | 23.66 | (-143.26) - (-50.33) | |
| | Waikato | -90.87 | 50.79 | (-190.62) - (8.89) | |

[1] P-value of F-test
[2] ADG increased by about 45 grams for a 100 kg increase in heifer entry bodyweight, holding other variables constant
[3] ADG of Friesian heifers was about 94 grams more than Jersey heifers, after adjusting for other variables
[4] ADG of replacement heifers raised in the 2011/12 season was about 264 grams more than that of the 2012/13 season, holding other variables constant
[5] ADG of the heifers originating from the region of Taranaki was about 97 grams less than that of the region of Wanganui, holding other variables constant

~~The data consisted of 31661 replacement heifers in the grazing seasons from 2006/07 to 2012/13.~~ Results of the bi-variable linear regression analysis are presented in Table 3.3. The F-test statistics of the predictor variables were all significant at p<0.001. *explain here what you found…* Confounding was not identified using the aforementioned criteria. Interaction could not be detected in the interaction terms used. Multivariable regression was used to predict ADG using all the predictor variables except the rearing duration variable which was not significant in the final model (p>0.05). A linear mixed-effects model was fitted with random effects to account for correlation within heifer mobs and a long term effect was implemented using rearing seasons as a continuous variable.

**Comment [HC30]:** M&M, already explained there.

~~(~~Table 3.4 shows results of the multivariable analysis~~)~~. Unit increases in the heifer entry bodyweight in kilograms increased ADG by 0.45 (95% CI 0.09 – 0.16) gram (p<0.001). Jersey heifers were associated with an ADG that was significantly lower~~ess~~ than the ADG in each of the other breeds of Holstein, Holstein-Jersey crossbreed and Ayrshire (p<0.001). Crossbred heifers achieved an ADG that was significantly greater by 67.4 (95% CI 63.4 – 71.3) grams than that of Jersey heifers. This may be explained by the average entry bodyweight of Jersey heifers which was the lowest~~east~~ amongst all breeds (p<0.05) as presented in Table 3.2. Crossbred heifers did not differ significantly in ADG from Ayrshire heifers. In addition, Holstein heifers were associated with the greatest ADG amongst all breeds. The grazing season of 2012/13was associated with an ADG that was significantly less than ADG gained in each of the other grazing seasons (p<0.001). Moreover, the grazing season of 2008/09, which was associated with the least odds of pregnancy at the herd level, was associated with the greatest ADG amongst all grazing seasons. This indicated that investigation into other factors related to the rearing seasons would help identify other risk factors for pregnancy. The Wanganui region was associated with heifers that had a significantly greater ADG than the average daily gain achieved in each of the other regions (p<0.001). This may be attributed to the fact that the greatest average bodyweight at entering the rearing period occurred in the region of Wanganui.

**Comment [HC31]:** 1[st]BW of Jersey was almost as low as of Crossbreds that had much higher ADG, so this is no logical explanation.

Monitoring of post-weaning average daily gain is crucial when raising replacement heifers. Heifers of heavier bodyweight at weaning are expected to have more average weight gain before breeding. Although Holstein heifers fall in that category, Holstein-Jersey crossbred heifers can provide better functional traits. These findings are important for informed decision making in rearing replacement heifers under New Zealand conditions. Further information is required to investigate potential associations between different regions of New Zealand, grazing seasons and growth rate of replacement heifers.

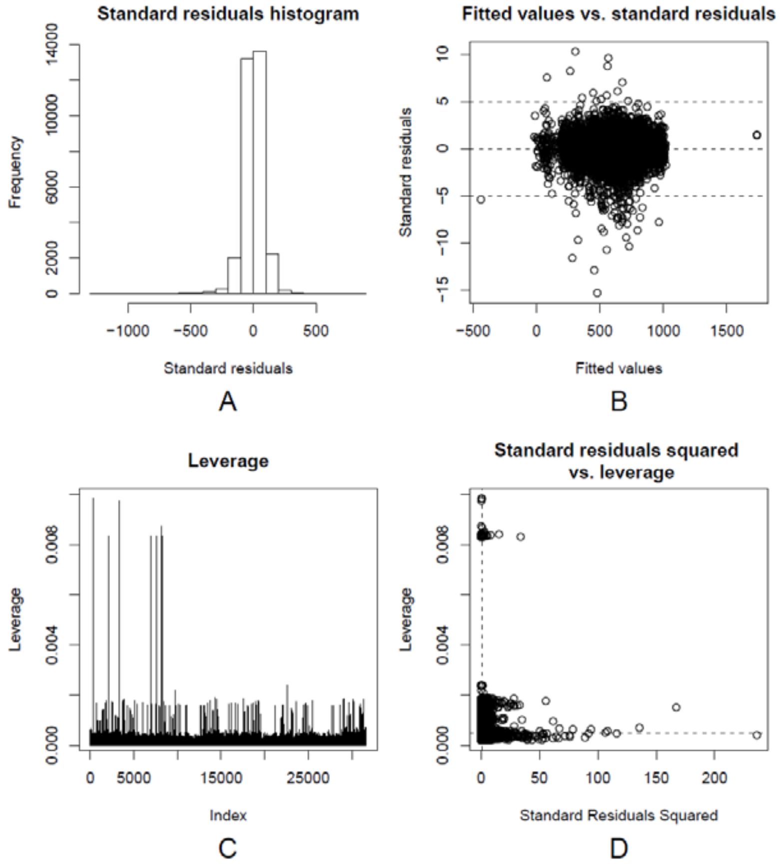


**Figure 3.3. Diagnostics of the multivariable linear regression model; A: Standard residuals histogram, B: Fitted values plotted against standard residuals, C: Leverage scores, D: Standard residuals squared plotted against leverage scores**

## Discussion

Heifers are recommended at mating to weigh at least 60% of the mature bodyweight of a cow in third lactation (Troccon 1993; Penno 1997; Coffey *et al.* 2006). In addition, the weight of heifers at first calving is recommended to be 90% of the mature bodyweight of a cow in third lactation (Troccon 1993; Penno 1997). The average weight of a third-lactation cow can be known by weighing a random selection of third-lactation cows in the herd. Once the latter is known, it is now straightforward to calculate the ballpark figure for the recommended heifer bodyweight at mating (at 15 months of age) and again at first calving (at 24 months of age). Bearing in mind the average bodyweight of a 12-week-old heifer, it is also straightforward to calculate the weight which that heifer needs to gain by mating and first calving, the time available to gain that weight, and the recommended average daily weight gain.

Average daily gain during the first two months of the life of dairy heifers was positively associated with the ability of those heifers to survive to second lactation (Bach 2011). Heifers that survived to second lactation had greater ADG in the first two months than heifers that did not. ADG was also reported in several studies to be associated with production parameters. Greater pre-weaning and prepubertal ADG will result in an earlier onset of puberty and earlier achievement of mating weight. The latter will subsequently result in achieving the recommended age at first calving of 24 months old and more lifetime productivity (Heinrichs 1993; Pirlo *et al.* 2000; Haworth *et al.* 2008; Wathes *et al.* 2008).

Numerous experiments were done to determine and achieve the optimum pre-weaning ADG during that critical period in the life of heifers. In New Zealand, there are four categories of calf feeding systems (DairyNZ). In restricted milk system, milk of about 5 litres per day is fed for 10 weeks. Rumen development occurs as leafy pasture is consumed in increasing quantities. The second category is unrestricted milk system. In this category, high levels of milk of about 8 litres per day are fed until about 6 weeks of age. Solid feed intake is kept to minimum during this period. After ceasing milk feeding, high quality concentrate meal is fed for 2 – 3 weeks. Restricted milk and ad lib meal system is the third category. In this category, milk is fed for 6 weeks of age at the restricted rate of about 5 litres per day with free access to meal and leafy pasture from the first week. Feeding meal continues until eating 1 – 1.5 kg per day then feeding meal is stopped. According to relative cost of milk and meal, this feeding system can be expensive. The fourth category is concentrated milk and high protein meal. Milk is fed once daily at a very restricted rate of about 2 – 3 litres per day. The daily milk is fed fortified with 200 – 300 milk powder for the first 4 – 5 weeks of age. Calves are fed indoors on ad lib 20% crude protein meal plus straw until 10 weeks of age. After that time, calves are turned out to pasture where meal feeding continues for another 1 – 2 weeks. At the end of this period, calves are weaned when a measured target weight is achieved. Weaning weight will depend on the rearing system used. Friesian calves reared on restricted milk and ad lib meal system can be weaned at a minimum of 63 kg. Calves reared on an unrestricted milk system can be weaned at a minimum of 75 – 80 kg.

***Bodyweight***

Bodyweight was associated with growth rate and ADG in several studies. Donovan et al. reported that calves with greater birth height, but with lower birth weight were significantly associated with greater ADG and pelvic height growth from birth to 6 months of age (Donovan *et al.* 1998). Brickell et al. found that greater ADG from 1 to 6 months of age occurred in calves with greater bodyweight indicators at one month of age, such as bodyweight, heart girth, crown-rump length and animal height (Brickell *et al.* 2009a). A New Zealand study discussed the effect of pre- and post-pubertal feeding level and bodyweight on growth rate and other performance indicators in grazing dairy cows (Macdonald *et al.* 2005).In that study, Holstein Friesian and Jersey calves, of less than 7 days of age, were sourced and fed to grow at different pre- and post-pubertal growth rates before being returned to their farm of origin at 22 months of age. Bodyweight at 15 and 22 months of age had a significantly positive and linear relationship with increasing growth rate during pre- and post-pubertal periods.

***Breed***

Several studies concluded that purebred Holstein Friesian cows were significantly heavier than Holstein-Jersey crossbred cows in the first lactation (Heins *et al.* 2008a). In addition, several studies noted that the bodyweight of purebred Holstein heifers was significantly greater than the bodyweight of Holstein-Jersey crossbred heifers (Bjelland *et al.* 2011). Anderson et al. reported that purebred Holstein cows were heavier than Jersey and Holstein-Jersey crossbred cows in a Wisconsin confinement dairy herd (Anderson *et al.* 2007).All those studies concurred with the results obtained in the study in hand in that the Holstein Friesian breed was associated with a significantly greater bodyweight and ADG than purebred Holstein, Jersey and Holstein-Jersey crossbreed.

Crossbreeding of the Jersey and Holstein breeds has been common in New Zealand where the Holstein-Jersey crossbreed accounts for over 40% of the national dairy herd in the 2011/12 season (DairyNZ 2011/12). Numerous studies have assessed the benefits of crossbreeding in pastoral systems. A New Zealand study reported that Holstein-Jersey crossbreed was superior to pure Holsteins in terms of milk fat production(Ahlbornbreier and Hohenboken 1991).In another study, it was concluded that the Holstein-Jersey crossbreed in New Zealand had greater fat and protein production than pure Holsteins (Bryant *et al.* 2007). In addition, crossbred calves were found to have lower birth weights, less calving difficulty, fewer stillbirths and lower incidence of scours when compared with purebred Holstein calves(Maltecca *et al.* 2006).

***Region of origin***

The greatest ADG was achieved in those heifers originating from the region of Wanganui. This was attributed to the fact the majority of the heifers originating from Wanganui were Holstein Friesian. Wanganui heifers also had the greatest entry bodyweight ($p<0.05$). In addition, the least ADG was gained in those heifers originating from Taranaki followed by Waikato. The majority of those heifers were crossbred followed by Jersey heifers. Both regions were associated with the least entry bodyweight and shortest grazing-off duration.

***Grazing-off season***

The rearing season of 2012/13 was associated with the greatest heifer entry bodyweight. In addition, the 2012/13 season was associated with the longest rearing duration where the majority of heifers were Holstein followed by Holstein-Jersey crossbreed. However, the 2012/13 season was associated with the least ADG amongst all seasons. Conversely, the heifers raised in the 2008/09 rearing season had the least entry bodyweight, the least rearing duration and the majority of them were crossbred or Jersey. However, the heifers raised in that season had the highest ADG amongst all seasons. The data provided for this study did not capture detailed information in relation to the different grazing seasons. Such information could have been beneficial in explaining some of the variation in growth rate of replacement heifers between the rearing seasons.

# CHAPTER 4

## General discussion

One of the main features of dairy herd management in New Zealand is a highly concentrated calving pattern in late winter(Macmillan *et al.* 1990). Such seasonal systems are highly dependent on cows achieving a high pregnancy rate within a short time interval following the start of the breeding period(Dillon *et al.* 2003).The decision of when to start the seasonal breeding programme is highly important as it determines the date when that herd will start calving in relation to the availability of pasture growth. Consequently, the cost of milk production is reduced as a result of utilising pasture grazing as the basis for the feeding system of seasonally calving herds.

As discussed before, the prepubertal growth rate of replacement heifers has a potential effect on age at first calving. Growth rate can vary according to many factors such as plane of nutrition, systemic diseases and helminthiasis. Variability was recorded in the ADG of calves up to 6 months old. ADG ranged from 0.5 to 1 kg/day between cohorts of calves and from 0.5 to 1.1 kg/day between individual calves within farms (Brickell *et al.* 2009a).Similar results were reported in another study (Donovan *et al.* 1998). Variability was also found in age at first calving. While the target AFC is 24 months of age, several countries reported differences between target and actual age at first calving. AFC averaged 29 months in China (Wu *et al.* 2012), 28 months in Italy (Pirlo *et al.* 2000), and 26 months in Ireland (Evans *et al.* 2006).In the USA, over 85% of the surveyed dairy operations reported an AFC of more than 25 months (Macdonald *et al.* 2005).

High average daily gain was introduced in this study as an important predictor of high pregnancy rate in replacement heifers. Several studies that have been cited discussed the strong relationship between prepubertal growth rate and fertility in replacement heifers. Prepubertal growth rate represents a major influence on the onset of puberty which in turn determines the suitability of heifers for mating when breeding starts. Several studies have also been presented where monitoring of growth rate was highly recommended in the critical stages of the pre-weaning and prepubertal periods. This study emphasises the importance of closely monitoring the growth rate of heifers during those periods and employing good management practices to achieve the recommended growth rate.

This study also highlights the benefits of Holstein and Jersey crossbreeding. New Zealand had adopted that breeding plan decades ago. Nowadays, the Holstein-Jersey crossbreed is the most common breed in New Zealand. That breed is not only superior in terms of pregnancy rate and reproductive performance in general (Auldist *et al.* 2007), but it also is characterised by high productivity in pasture-based systems, less calving difficulty and fewer stillbirths. In addition, crossbred calves have lower incidence of scours compared with purebred Holstein and Jersey calves. In addition, the Jersey breed has provided considerable benefit in crossbreeding with its high reproductive performance and concentration of milk solids(Prendiville *et al.* 2011).This study is in agreement with several studies that discussed the comparative growth rates among the breeds of Holstein, Jersey, Ayrshire and Holstein-Jersey crossbreed. Holstein herds were superior in terms of growth rate. However, due to the reasons mentioned above, the Holstein-Jersey crossbreed was the highest in terms of overall farm profitability in many studies (Prendiville *et al.* 2011).

Some grazing seasons were associated with low pregnancy rate although they were associated with high growth rate. The available records did not provide information about the variation between the grazing seasons. Similarly, the variation between the regions of origin could not be explained by the available records. Further investigation was recommended to provide additional information that could explain the variability between the grazing seasons and the regions of origin. Other factors in relation to pregnancy and growth rate of replacement heifers can be determined by such investigation.

# CHAPTER 5

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