AN EVALUATION OF GROWTH AND BODY COMPOSITION OF DROUGHTMASTER CATTLE IN NORTHERN QUEENSLAND

A Thesis

by

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ABSTRACT

The overall objective of this research was to evaluate impacts on growth of Droughtmaster cattle in northern Queensland based on four years (2009-2012) of repeated weight records from a single operation. Animals (total records n = 1,717) were identified by management group (n = 43). Gender consisted of females (n = 786), bulls (n = 386), and steers (n = 545).

Age at weight evaluation varied substantially across management groups and was therefore nested within each management group to create a 90-day window. Age, sire, and age of dam, impacted ($P < 0.001$) weights taken at branding, and, sire and age showed significance at every weight taken ($P < 0.001$). Age of dam was significant for weaning weight ($P = 0.002$), but became irrelevant for yearling ($P = 0.7252$) and final ($P = 0.1423$) weights.

Heritability values for branding, weaning, yearling, and final weight were calculated from estimates of sire variance to be 0.35, 0.42, 0.23, and 0.49, respectively. Heritability values of weight gain from birth to branding, branding to weaning, weaning to yearling, and yearling to final weights were estimated to be 0.23, 0.09, 0.26, and 0.29, respectively.

Simple correlations among these traits were evaluated within gender. Female, bull, and steer weights were moderate to highly correlated (0.53-0.77, 0.49-0.85, and 0.70-0.91 respectively). Ranges in correlations were mostly high depending on gender (females 0.68-0.92, bulls 0.53-0.81, and steers 0.70-0.91). Correlations between age and weight varied in strength depending on sex (females, 0.53-0.77; bulls, 0.24-0.79;, steers,

0.48-0.81). Correlations were stronger for traits measured closer in time, and for steers compared to bulls and females.

Results correspond to previous reports in numerous breeds. Sire, calf age, and age of dam significantly impact animals' growth during pre-weaning stages; however, influences of these effects were not identical across all genders. The last weight, which was closest to maturity, showed to be the most heritable in these data. Differences seen across genders for later weights can arise from different management strategies, including sire selection and supplementation, and it is possible shapes bend of growth curves may be manipulated, but there is a set mature size.

DEDICATION

I would like to dedicate this thesis to the future cattle producers everywhere. We can overcome the future struggle of supplying the world with enough food on less land.

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I would like to thank my committee members for helping me every step of the way, as this has progressed quickly. Drs. Herring, Skaggs, and Rayfield thank you for your diligence, your advice, and most importantly your time.

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INTRODUCTION

Animal growth is one of the most important concepts influencing the economic success and sustainability for the beef industry. Through defining the word growth and learning more about the heritability and correlations of growth traits producers will create a deeper understanding of beef cattle growth curves, which can be quite different across and within breeds. One of the most popular measures related to growth is weight. This is a very production oriented trait, because of the economic impact weight has on the industry. More specifically, producers typically sell cattle by weight. Observing growth curves that have already been established for other breeds and sires will help to explain the curves characteristics. Studying how the body grows and at which rates and understanding the correlations among body functions are important to make progress toward sustainability of the cattle industry. Since the world human population is increasing and the number of cattle finite or potentially decreasing, it is vital to understand the growth processes of beef cattle for improved food security.

The goals of this project were to evaluate relationships among weights and factors affecting weights in growing Droughtmaster cattle from a single herd in northern Queensland. The specific objectives of this thesis were to (1) evaluate the impacts of different production characteristics that will impact a growth, (2) evaluate the heritability of these growth traits, and (3) assess the relationships among weight, age, and gain.

LITERATURE REVIEW

History of Droughtmaster cattle

The following information about the Droughtmaster breed is summarized from the Australian Droughtmaster Society website (Droughtmaster Australia, 2011). In Northern Australia during the late 1800's beef cattle breeders bred cattle not paying attention to the cattle of other ranchers around them. The Droughtmaster breed was first recognized in the early 1900's when local farmers and ranchers realized their cattle looked similar (Droughtmaster Australia, 2011). The pioneers for this cattle breed wanted to establish a line of cattle that would be able to tolerate the rigors of northern Australia, where the climate can be similar to South Texas, with high temperatures and humidity, but with an annual rainfall below 500 mm (BOM, 2013). Cattle were selected for specific traits and who thrived for their geographic location. Today breeders have realized the breed consists of about one half *Bos indicus* and one half *Bos taurus.* The *Bos indicus* influence came from the American Brahman breed developed in the United States. Brahmans were first imported into Australia in the early 1900's but did not gain popularity until around 1933 (Droughtmaster Australia, 2011). Brahmans are known for their ability to withstand tropical and subtropical climates with natural insect and disease resistance and better sweat gland development (ABBA, 2014).

Shorthorn is believed to be the primary *Bos taurus* influence in Droughtmaster, and it was British breeds of cattle that were first imported into Australia when it was a British colony. The first Shorthorns arrived into Australia in 1825, and came from South

Wales. The breed gained in popularity quickly and is noted for upgrading in other breeds within Australia (Beef Shorthorns, 2013). These two breeds were used to create what is known today as the Droughtmaster breed. It was not until after the breed society had been established that it was known Shorthorn and Brahman were the original breeds combined to create a different composite breed. The organization first wanted to name the breed a Beefmaster, but discovered a breed with that name had already been created in the United States of America. The Droughtmaster name was used to describe solid red cattle while the blaze faced later became known as the Braford. Despite the regional preference, Droughtmasters have become one of the most dominant beef breeds throughout Australia (Droughtmaster Australia, 2011).

Defining growth in cattle

Growth and development have been studied in cattle throughout the years for various reasons. Producers and scientists have defined growth in a variety of ways including changes in: weight, height, muscle, fat thickness, and even body condition. Growth can have one of the biggest impacts on the profitability and sustainability in the cattle industry, and some of the terms associated with growth are discussed briefly here. Growth is defined as an increase in size and mass of structural tissue. Hyperplasia refers to growth through replication of cells, and hypertrophy refers to growth by expansion of cells, and, both are specific processes important in various types of growing animals (animals that have not yet reached maturity). Accretion is often associated with the growing concepts, but usually refers to the building of tissue, such as muscle tissue. For an individual animal, growth and development can be categorized into three main stages of prenatal, pre-weaning birth to weaning, and post weaning. The animal's body has different demands during these different stages, along with different management considerations (Herring, 2014).

Fitzhugh and Taylor (1971) defined size as a complex characteristic that is a weight relative to the animal's interval of maturity, degree of body composition, and sex. Cartwright (1979) argued this definition did not consider the degree of muscling. A thicker muscled steer will have a heavier weight compared to a light muscled steer if they are at the same frame (skeletal) size and body composition. By definition muscle will impact the animal's size through its weight. Mature weight and skeletal-muscular ratio, have been shown to be moderately to highly heritable (Brinks et al., 1962a; Smith et al., 1976; Kaps et al., 1999; Arrango et al., 2002). Changing weight and size by selection can be achieved without much difficulty (Petty and Cartwright, 1966; Berg and Butterfield, 1976).

When studying growth the first place to start is in the selection of sire and dam. The two ways cattle can impact their offspring (as parents) are genetically and through their phenotype. From a genotypic standpoint, parental selection provides a predetermined genetic probability for what the calf's genotype will be. Depending on the heterozygosity of genes in the parents, the same mating can produce multiple genotypes. If two animals are selected for two different ideal traits, the genes that impact an animal's growth curve can be different. It is obvious how different genetics will contribute to differences in a trait such as growth. For example an animal selected for lower birth weights will most likely have lighter weights compared to animals selected for high weaning and yearling weights.

An animal's phenotype refers to observed characteristics of the animal, which in turn are influenced by the animal's environment and genetics. Phenotype equals genotype plus environment. It is easy to see how genetics give an obvious contribution to these phenotypic traits of progeny, such as growth. It is harder to understand how a parents' phenotype will impact the same traits of their offspring. One easy way to measure growth is skeletal size. If both parents are considered tall, the progeny is expected to be tall. However this may not always be the case because of environment. For example, a calf may experience a lack of nutrition during growing stages of its life, and might only grow to 75% of its genetic potential. After maturity this animal as a parent could pass on high growth genetics to future offspring.

Depending on buyers' intentions, phenotype can be more important than genotype, unless the animal is used for breeding, then an estimate of genotype can become an important selection factor. The importance of phenotype and genotype can depend on the gender. A single mature sire can service about 25 females per breeding season. Sires will have little if any environmental influence on their progeny. In times of competition for food the sire could restrict a calf's intake. However many bulls are not in direct contact with their offspring. This creates more genetic interest in bulls since each bull produces so many more offspring than each cow. Producers can then select bulls for certain production levels to reach marketing goals (Cartwright, 1979).

The dam has a greater impact on her progeny's phenotype because she plays a crucial role in the environmental influences on her calves. This coupled with her genetic contribution means producers need to select for a tandem of genotype and phenotype when choosing females for their herd. Knowing that many traits are correlated it will also be more beneficial for producers not to select based on one single trait. An easy example of the phenotype impact on progeny a mature cow can have, is in the mammary system. If a cow has deformed teats and or very low milk production potential, this could result in minimal milk supply for her young, and restricting the calf growth potential through this environmental influence.

Selection for size is important for different reasons depending on production goals and their intended use. This means that producers wanting to produce bigger calves need to understand that bigger cows usually will require more supplementation resulting in an increase in cost. Therefore, mature cow size affects the maternal ability to be efficient, and also contributes half of the genetics passed on, creating more impact on a cow's progeny. In a production system the phenotype of the cow has a greater impact on offspring compared to the phenotype of the sire. This is because most breeding animals in the system are females, and producers need a larger quantity of females to reproduce than males. Simply stated, it cost less to maintain cattle with an overall smaller mature cow weight. However, selection for high growth rate will impact mature body weight. For example the mature body weight will increase if a herd is continuously selected for high growth rates between intermediate weights because of the extremely high correlations of growth rate to mature body weight (Mercadante et al., 2003).

Rate of maturity is often associated with the growth of animals. Maturity may have many definitions, but along with maturity comes a change in an animal's body composition. Koch et al. (1976) reports some impacts on carcass quality. Growth rate is associated with the breed type, creating a relationship with percent of retail cuts. Koch et al. (1976) also recorded evidence there was difference among different sire breeds for fat trim. Growth rate is also associated with breed. Growth rate has a negative association with fat trim (Koch et al., (1976). This is not surprising because as mentioned earlier, animals with lower growth rates will fatten sooner. Therefore, when producers select for growth, they sometimes inadvertently select for lower fat. In the 1950's market animals were heavily selected for earlier maturity. The concept behind this artificial selection for producers, was to obtain a carcass that was ready sooner (got fat earlier), and, animal fat was more commonly used as a cooking medium at this time. Early on this benefited the market by creating less time on feed, and lowering overall input cost into a single carcass. Today some producers still select for earlier maturing animals. These type of operations want to limit input cost. Often these producers will sell calves based on weight rather than age. Instead of selling a calf at 5 months or at weaning, a producer may sell his calves when they average 400 pounds. This will help reduce the potential loss the same producer may encounter if the calves were kept till 5 months of age. Others prefer later maturing cattle, as they typically produce heavier carcasses, weights, and rates of gain, creating a higher yield of meat (Nour and Thonney, 1987).

Estimated breeding values

Estimated breeding values are the predicted genetic values of animals. These values predict the parental ability of an individual, based solely on genetics, relative to another animal in the same breed. These figures cannot predict some production values, such as maternal instincts. The breeding value is different from the genotypic value. Genotypes are calculated into the phenotype of an individual ($P = \mu + G + E$). For example, many loci impact a single trait such as birth weight. Starting with independent genes, one locus can cause birth weight to increase or decrease depending on the gene at that particular locus. This independent effect is going to impact the genotype of the animal. Instead, breeding values explain the genetic value as a parent, meaning the sum of all the independent effects of the animal's loci that impact birth weight. An animal that is homozygous for the ideal gene at a specific locus, will have a higher (typically more desirable) breeding value. Most importantly breeding values are the genetic effects that are transmitted from parent to offspring. Estimated breeding values (EBV) are the prediction values of these estimates (Bourdon, 2000). Australian beef cattle associations (societies) report EBV for a variety of size and growth traits, such as 200 day growth, 400 day weight, and scrotal circumference (Breedplan, 2014). Progeny will receive one half of each parent's breeding value for each trait (Bourdon, 2000).

An animal's transmitting ability is one half of its breeding value. The transmitting ability can help predict some performance traits on an individual's progeny. This prediction is referred to as an expected progeny difference (EPD) in North American beef breed associations. If one can accurately predict the transmitting ability, then they can predict difference in offspring amongst different individuals. Unlike breeding values, the transmitting ability of an individual is not passed down from generation to generation (Bourdon, 2000). The same animal found in U.S. and Australian sire summaries will have different reported values (EPD vs. EBV).

Heritability considerations

Heritability refers to the ability of an animal to inherit certain traits from the sire and dam. It can also be observed through differences of one trait amongst a given population. Heritability determines that a calf from a Hereford parent and a solid-colored parent is expected to have a bald or white face, but also extends to traits affected by many gene loci. According to several studies (Brinks et al., 1962a; Smith et al., 1976; Kaps et al., 1999; Arrango et al., 2002) the heritability for weight in cattle ranges from 0.44 to 0.87. All of these studies represented different purebred and British crossbred cattle with a variety of ages when measurements were taken. The variability of weight inheritance can be attributed to observations at different stages of the animal's life including weaning weight, yearling weight and mature weight. These numbers can all be considered moderate to highly heritable, for these studies. A possible reason these studies are higher than others, could be explained by the cattle. In each study these cattle all showed to be contemporaries. If a heritability estimate is based off of one or just a few different treatments, the results may be skewed. These estimates do not account for some potential environmental influence that may be making the traits more uniform.

One study by Bullock et al. (1993) posted substantially different results for weaning and yearling weights. Out of 572,446 records from Polled Herefords the heritability was 0.24 and 0.30 for weaning weight and yearling weight, respectively, but was estimated at 0.52 for mature weight. In earlier studies of heritability, the results are very consistent showing weaning weight is less heritable than birth weight, and the amount of gain from birth to weaning could be categorized as a lowly heritable trait (Gregory et al., 1950; Koch et al., 1955a; Koch et al., 1955b; Koch et al., 1955c; Shelby et al., 1957; Koch et al., 1973; Woldehawariat et al., 1977; Nelson et al., 1979). With a combination of weight and height the heritability for growth is moderately high. Possible explanations for the drastic differences in these studies from Bullock et al. (1993) attributes this to the variety of the cattle. While this study does represent one breed, it also represents several producers. It is certain that producers manage cattle differently, which will create different contemporary groups. Adjustments can be made creating weights on a more even comparison. With this diversity these heritability estimates could closer reflect the true genetic values for specific traits that are inherited. Many of the values from these studies are summarized in Table 1.

Table 1. Summary of heritability estimates for growth and size traits in cattle

Name	Year	Cattle Type	Trait	h²
Arrango et al.	2002	Angus and Hereford Dams Age 2-6	Weight	0.48
			Hip Height	0.68
			Body Condition Score	0.16
Vargas et al.	2000	Charolais herd	Weaning Hip Height	0.73
			Post Weaning Hip Height Growth	0.13
			Hip Height 18 months	0.87
Marle Koster	2002	South African Hereford Cattle	Cannon Bone	0.24
			Weaning Hip Height	0.28
			Yearling Hip Height	0.33
			Body Length Weaning	0.22
			Body Length Yearling	0.14
Brinks et al.	1962	Hereford range cows	Weight in Spring	0.75
			Weight in Fall	0.73
Bullock et al.	1993	Polled Hereford cattle	Birth Weight	0.49
			Weaning Weight	0.24
			Yearling Gain	0.23
			Yearling Weight	0.30
			Yearling Height	0.59
			Mature Weight	0.52
Kaps et al.	1999	Angus	Weaning Weight	0.53
			Weaning Weight	0.59
			Mature Weight	0.44
			Mature Weight	0.52
			Mature Weight	0.53
Smith et al.	1976	Hereford, Angus, Shorthorn, Recip Crosses	Birth Weight	0.68
			200 day Weight	0.59
			396 day Weight	0.87
			550 day Weight	0.82
			3 and one third years	0.41
			Weight at puberty	0.44
			Age at puberty	0.64
Brinks et al.	1982	Red Angus, Angus, Herford	Birth Weight Heifers	0.37
			Birth Weight Bull	0.43
Gregory et al.	1950	Beef calves	Birth Weight	0.45
			Gain birth to weaning	0.45
			Weaning Weight	0.52

Table 1. (Continued)

Name	Year	Cattle Type	Trait	h²
Koch and Clark	1955a	Hereford	Birth Weight	0.35
			Gain birth to weaning	0.21
			Weaning Weight	0.24
Koch and Clark	1955b	Hereford	Birth Weight	0.35
			Gain birth to weaning	0.17
			Weaning Weight	0.25
Koch and Clark	1955c	Hereford	Birth Weight	0.42
			Gain birth to weaning	0.12
			Weaning Weight	0.19
Shelby et al.	1955	Hereford	Birth Weight	0.71
			Weaning Weight	0.23
			Gain	0.6
			Final Weight	0.84
			Efficiency	0.22
Nelson	1979	Angus and Hereford	Birth Weight	0.33-0.62
			Gain birth to weaning	0.15-.032
			Weaning Weight	0.15-0.33
Koch et al.	1973	Hereford	Birth Weight	0.49
			Gain birth to weaning	0.13
			Weaning Weight	0.15-0.25
Woldehawariat et al.	1977	Averages from multiple studies	Birth Weight	0.39
			Gain birth to weaning	0.25
			Weaning Weight	0.31

It should not be surprising that the mature weight has higher heritability than weaning and yearling weight. The mature weight is more indicative of the true weight compared to a weaning weight. True weight, meaning a weight that is less affected by management. Shelby et al. (1955) reported that a final weight was much more heritable than weights taken during a growing phase. This is logical because of the variability in treatments that are industry accepted. For example calves creep fed are expected to be heavier at weaning compared to no supplementation. However, both practices are typical for the beef industry. Heritability estimates ranging from 0.00-0.20 are low, 0.20-0.40 are moderate, and anything greater than 0.40 can be considered to be highly heritable (J. O. Sanders, Texas A&M University, Dept. of Animal Science, personal communication). Knowing one animal has the genetic potential to grow at a different rate compared to its contemporaries can be beneficial. Producers can select for better genetics, and if other sectors of the industry, such as the feedlot, knew the same information, animals could be fed as a contemporary group making them uniform, and more efficient. This could create problems if a pen of calves with a wide range of growth curves were fed together, because they would need different amounts of time on feed.

Genetic correlations among size traits

Genetic correlations refer to the shared variance of two traits caused by genetics; genetic correlation estimates the degree of association between breeding values of two traits (Bourdon 2000). Correlation estimates ranging from 0.00-0.20 are low, 0.20-0.40 are moderate, and anything greater than 0.40 can be considered to be highly correlated (J. O. Sanders, Texas A&M University, Dept. of Animal Science, personal communication).When considering growth, there are several correlations that should be evaluated. Selecting for higher yearling weights has potential to increase animal size throughout all stages of production. Different weight measurements may be two separate traits but they are genetically connected. Some are related over time or the lifespan of animals. Therefore one would expect a heifer with a heavier weaning weight to start at a bigger birth weight, assuming all other factors, such as nutrition, are on the same plane. Other traits may be related at the same point in time or stage of production, such as for traits such as yearling hip height and yearling weight. If cattle are selected for high yearling weight, hip height will tend to increase also (Vargas et al., 2000) unless there is selection pressure against it. On the other hand, not all measures of growth are correlated; Archer et al. (1998) stated that cattle maturity was not manipulated by the change in weight selections. When animals were selected for lighter or heavier ending weights, the rate of maturity is not changed in either direction. This being said animals that have been projected to have lighter ending weights, will reach those weights sooner than end weights from larger, mature weight animals (DeNise and Brinks, 1985). In order to create curve bending genetics, producers will have to select against correlations. This means producers could select for low birth weight, but high weaning and yearling weights. This will manipulated the animal's growth curve to give the producers an advantage of some expected results. (high weaning weight selection equals higher birth weights).

A few older studies recorded the correlation between birth weight and weaning weight ranged from 0.33-0.63. The degree of variability between these studies can be accounted for a few different reasons based on how the study was done, such as breed. (Gregory et al., 1950; Koch et al., 1955a; Koch et al., 1955b; Koch et al., 1955c; Shelby et al., 1957; Koch et al., 1973; Woldehawariat et al., 1977; Nelson et al., 1979). This range shows that although birth weight does help indicate weaning weight (and vice versa), one cannot rely on the birth weight to fully or accurately predict weaning weight.

In these same studies, many reported, weaning weight was highly correlated to the gain from birth to weaning, specifically a range of 0.82-0.99 (Gregory et al., 1950;

Koch et al., 1955a; Koch et al., 1955b; Koch et al., 1955c; Shelby et al., 1957; Koch et al., 1973; Woldehawariat et al., 1977; Nelson et al., 1979). These high correlations were expected because when the rate of gain is calculated it is the number essentially predicts the weight for that time. It will have minimal error in reflecting that weight. Therefore if an animal gains more weight per day, it would be expected to have an increased weaning weight, compared to its contemporaries.

Bullock et al. (1993) conducted a large study of Polled Herefords, and estimated the genetic correlation from mature weight to birth weight to be 0.64. Compared to other weight correlations this is lower. For this calculation a lower number is expected because of the diversity within the set. The large number of records can create a little more noise within the analysis simply because there is no way of putting such large numbers into contemporary groups.

In the same study Bullock et al. (1993) recorded a 0.80 genetic correlation between mature weight and weaning weight. Kaps et al. (1999) calculated the same measurements to have a 0.85 genetic correlation in an Angus study that used a repeated measures model. Both of these numbers are higher than correlation between mature weight and birth weight. Many factors impact birth weight besides just genetics that do not have as large of an impact on weaning.

Bullock et al. (1993) also posted a 0.89 genetic correlation when measuring yearling weight to mature weight. As expected this correlation showed to be higher compared to previous measurements recorded at earlier ages. Other possible reasons Bullock et al. (1993) discovered higher results is because the use of purebred and even possible linebred animals. These types of animals have increased homozygosity in their genes. This means animals that have the same or more similar genes, compared to another group or even composite breed, the breeding values are different. As the animals aged the correlations of the weights increased with each interval. For example the correlation between birth weight and weaning weight was lower than yearling weight and mature cow weight.

Similar results have been found by Meyer et al. (1991) in Zebu breeds. Results have differed in *Bos indicus* crosses. The correlations of reproductive traits and weight in straight bred cattle ranged from 0.24 to 0.52. There are stronger correlations for the crosses, 0.65 to 0.69. This is expected because of the hybrid vigor these types of crosses experience (Meyer et al., 1991).

Overall the relationships between measurements seem to be higher for measurements closer in time. Similar to heritability estimates, this is expected because many environmental factors can impact measurements at weaning or at an earlier age. Genetic correlations are important to understanding that selection for growth alters more than one single characteristic. This logically makes sense because there is not one single trait that can be the sole measurement of growth. Knowing these correlations can help select animals to benefit the livestock industry. Many of the reported correlations are provided in Table 2.

Table 2. Summary of correlation estimates for various traits

Name	Year	Cattle	Trait1	Trait2	Corr.
Bullock et al.	1993	Polled Hereford	Mature Weight	Birth weight	0.64
			Mature Weight	Weaning Weight	0.8
			Mature Weight	Yearling Gain	0.76
			Mature Weight	Yearling Weight	0.89
			Mature Weight	Yearling Height	0.73
			Mature Weight	Growth from Birth to Wean	-0.29
			Mature Weight	Growth from Wean to Yearling	0.35
Kaps et al.	1999	Angus	Mature Weight	Weaning Weight	0.85
Smith et al.	1976	Hereford, Angus, Shorthorn	Age	Weight	0.67
Koch and Clark	1955 a	Hereford	Birth Weight	Weaning Weight	0.63
			Gain birth to weaning	Weaning Weight	0.98
Brinks et al.	1962 b	Hereford	Birth Weight	Weaning Weight	0.42
			Gain birth to weaning	Weaning Weight	0.82

Table 2. (Continued)

Name	Year	Cattle	Trait1	Trait2	Corr.
Koch et al.	1973	Herford Bulls	Birth Weight	Weaning Weight	0.41
			Gain birth to weaning	Weaning Weight	0.95
		Hereford Heifers	Birth Weight	Weaning Weight	0.53
			Gain birth to weaning	Weaning Weight	0.96
Nelson et al.	1979	Angus and Hereford	Birth Weight	Weaning Weight	0.33-0.61
			Gain birth to weaning	Weaning Weight	0.94-0.99
Woldehawariat et al.	1977	Overall Averages	Birth Weight	Weaning Weight	0.55
			Gain birth to weaning	Weaning Weight	0.95
Bourdon	2000	Beef Cattle	Birth Weight	Weaning Weight	0.6
			Birth Weight	Yearling Weight	0.7
Meyer et al.	1991	Straight bred	Reproductive traits	Weight	0.24-0.52
		Zebu crosses	Reproductive traits	Weight	0.65-0.69

Growth curve considerations

A growth curve concept can be described in many ways, but all growth curves represent a repeated measure of growth recorded over a timespan. The rate at which an animal grows is different than the growth curve because the rate refers to the speed at which an animal grows over a particular period of time. A growth curve shows the differences in the repeated measurement. This difference can be observed by species, breed, sire line and age of the animal (DeNise and Brinks, 1985; Gilbert, 1993b).

Brody (1926), observed differences in growth curves relative to their composition and growth rates at a given time. One of the obvious differences between different growth curves is the inflection point. The time of inflection in cattle appears to be approximately after one third of the growth curve, based on a birth to mature weight curve. The speed of growth decreases after the sigmoid region. The concave shape results in a change of growth rate for the given variable. Younger animals experience more rapid growth and development (Mumford, 1926). Although the growth rate can be altered through artificial selection, this trend will minimally affect the growth curve model. This means it may take longer for an animal to reach a heavier weight, but it will not impact the slope of the growth curve or inflection points for that animal. More specifically the weights are changing but not the efficiency (Cartwright, 1979). A goal in selection strategy is to create curve bending genetics, which changes the curve. Curve benders can be made by selecting for animals that have higher ending weights, but lower birth weights. This will manipulated the curve to become steeper. In a study of Nellore cattle, Forni et al. (2007) fit a Von Bertalanffy function and found that selecting only for increased body weight will not change the shape of the growth curve. However, changing the curve is possible based on selection when done correctly. It is difficult and inefficient to select for an increasing growth rate, increase the slope of the growth curve, without changing mature size because of the genetic correlation between the traits. Simply selecting for body weight is easier than curve benders for producers because it is easily measured. If producers were to select sires based upon desired growth curves it could improve the efficiency for producers. Growth curves shift up and down, and change shapes according to sire groups based upon the Von Bertalanffy model in Nellore (Forni et al., 2007).

Brody (1926) said all animals have a genetic growth constant. This number may change individually but can be recorded by dividing a weight by a previously recorded weight. Over the span of time this rate will show the persistence of growth, as a weight. Another numerical form of growth discussed was the velocity of growth in which is explained by the weight gained over specific time, and the beef industry relies on this type of measure as average daily gain. These equations account for the decline in the rate of growth over time that animals experience since the velocity is not constant.

Goonewarde (1981) fit 4 different types of growth curves (Brody, Richards, Logistics and Von Bertalanffy) fitting animal weights from two different breeding groups (Hereford and a synthetic breed composed of Charolais, Angus and Galloway). All of the curves showed a sigmoid structure. The Von Bertalanffy and Logistics curves had a predetermined location for the inflection points for the model. The variability between the animals can make these models less accurate. In this study both curves over estimated birth weight, but under estimated mature weight. The fixed point for this model worked well throughout the growing stages of the animals, but struggled to maintain precision on starting and ending points. The Richards curve used the inflection points as another parameter, meaning the inflection points had a degree of variability, and provided the best fit to the data. This curve allowed for different inflection points, therefore it was not fixed.

The accuracy of the predicted inflection points can have a vast impact on the producer. As determined earlier that the velocity of growth decreases dramatically at these points. Therefore the value of gain for an animal will change drastically at this stage in its life. Therefore locating the time and age of these points can predict the economic value of a calf at a certain age. One single common denominator of this physiological process is puberty. This will make the inflection point difficult to judge in castrated animals. Now using simple equations such as the persistence growth equation one can relate numbers to this trend and observe times of higher growth rates, slower growth rates or even negative growth (Brody, 1945).

Based on multiple reports of genetic differences relating to growth curve characteristics in beef cattle, the objective of this thesis will be to evaluate potential growth curve components from repeated measures of weight relative to age in a purebred cattle population.

MATERIALS AND METHODS

Data were collected from a single cattle station located near Ayr in Queensland, Australia. Repeated weight measurements were available on purebred Droughtmaster (a stabilized composite developed in Queensland that is 50% Shorthorn, *Bos taurus*, and 50% Brahman, *Bos indicus*) cattle born in 2009 (n = 509), 2010 (n = 492), 2011 (n = 422), and 2012 (n = 514). These measurements were recorded at branding, weaning, and yearling ages, plus an additional weight recorded a short time after yearling weight that was designated as final weight. Initial summary statistics for these weights are provided in Table 3.

Table 3. Summary statistics of weights

Variable	N	Mean	Standard deviation	CV	Minimum	Maximum
Brand weight	1,664	153.642	32.621	21.23	41	271
Weaning weight	1,660	214.679	40.870	19.04	73	340
Yearling weight	1,583	302.909	45.918	15.16	152	548
Final weight	1,482	366.792	62.245	16.97	203	738

Records were sorted by management code to evaluate the distributions of weights and ages in days. It was discovered that some management codes provided in the data set were specific to sex and year, and others were not (provided confounding issues for these factors). Records varied substantially for the ages when the weights were taken. Therefore, each contemporary group was assigned a unique code to separate animals by gender and year, to prevent confounding results. Table 4 shows how the final number of records we obtained and used for this analysis. There was still variability in the ages of animals when the respective weights were recorded.

Table 4. Adjustments made for data

n_1	n_2	Reason
1937		All data
1934	3	Contemporary group is had less than 5
1933	1	Mistaken weights recorded
1929	4	breed composition was different
1924	5	Age of dam outlier
1664	260	90 day contemporary group for branding weight
1660	264	90 day contemporary group for weaning weight
1583	337	90 day contemporary group for final weight
1482	442	90 day contemporary group for yearling weight

n_1= number of records used; n_2= number of records removed from the data.

Total records (n = 1,937) were edited (n = 1,924) before separating into weight brackets, to generate tighter age groups (Table 4). According to Breedplan (2014) and BIF (2010) guidelines a group of animals must be in a 90-day window in age for consistent adjustments in weights due to age differences. In order to create a more meaningful approach, the average age that was associated with the mean of each contemporary group weight was deviated by adding and subtracting 45 days, and only these remaining animals falling within the 90-day age range were evaluated (illustrated in Table 4).

The variables considered in this study (brand weight, weaning weight, yearling weight, and a final weight) were analyzed through mixed model procedures of SAS (v 9.3, SAS Institute, Cary, NC). Effects modeled included age of dam, sire, and management code (which included calf gender and year effects). Least squares means were calculated for management group, and age of dam, and regressions on calf age were also evaluated. Paired *t*-tests were used to separate least squares means following significant *F*-tests. Heritability estimates were calculated using the equation (4 X sire variance)/(residual variance + sire variance) (σ^2A)/(σ^2p). Correlations among weights, ages, and gain values were also evaluated. Standard errors of these heritability estimates were not calculated.

RESULTS AND DISCUSSION

Results are presented in three different sections. First discussed are the results showing the significant factors impacting measurements of growth in Droughtmaster cattle. Second, the heritability values estimated in the various growth traits are provided and discussed. Last, correlations among the traits within gender are provided and discussed. Due to the presentation of the data, set the exact impact of gender or year could not be calculated and are tied into the management code effects.

Characteristics impacting weight

Table 5. Summary of significance traits in weight models.

Effect	Brand weight	Weaning weight	Yearling weight	Final weight
Management group	0.241	0.121	<0.001	<0.001
Sire	<0.001	<0.001	<0.001	<0.001
Age(management group)	<0.001	<0.001	<0.001	<0.001
Age of dam	<0.001	0.001	0.725	0.143

The significance levels of factors evaluated for the weights are shown in Table 5. Age of animal and sire showed important differences ($P < 0.001$) for all weights recorded. De Torre and Rankin (1978) observed results in Hereford and Brangus cattle that agreed with these where management groups showed substantial differences in weight. This similar result is not directly comparable though because of experimental design. Menchaca et al. (1996) showed in Brahman cattle that weights differed according to sex ($P < 0.05$). These results are typical and found in many studies. The standard difference in calf weaning weights due to sex are 2.72kg, 1.81kg, 0.91kg, 0kg, and 0.91kg, for the age of dams 2, 3, 4, 5-10, and older than 11 respectively (BIF, 2010). It is no surprise that age has a critical and obvious impact on weight ($P < 0.001$). As expected age of dam became less of an impact on the weights taken as the animals progressed in age after weaning (Table 5). Archer et al. (1998) reported similar results, showing no maternal effect on yearling weight.

Table 6. Least Square Means Estimates of weights

	Brand Weight	Weaning Weight	Yearling Weight	Final Weight
AOD	Estimate	Estimate	Estimate	Estimate
3	149.25 ± 1.662*	216.56 ± 2.088*	336.08 ± 5.772*	378.73 ± 3.976*
4	158.67 ± 1.670*	224.61 ± 2.085*	334.79 ± 5.766*	382.19 ± 4.069*
5	160.83 ± 1.743*	227.46 ± 2.135*	338.69 ± 5.842*	386.80 ± 4.201*
6	159.48 ± 1.940*	226.71 ± 2.343*	332.74 ± 5.877*	379.72 ± 4.503*
7	160.43 ± 2.283*	225.87 ± 2.777*	336.08 ± 6.303*	376.82 ± 5.218*
8	161.84 ± 2.760*	222.66 ± 3.304*	333.40 ± 6.910*	382.59 ± 5.913*
9	155.45 ± 3.260*	223.86 ± 3.945*	330.58 ± 7.652*	388.33 ± 6.837*
10	154.94 ± 3.430*	217.22 ± 4.057*	338.67 ± 8.675*	377.57 ± 7.054*
11	158.44 ± 3.442*	222.99 ± 4.102*	335.86 ± 8.477*	377.64 ± 7.054*
12	159.04 ± 3.551*	221.08 ± 4.266*	326.82 ± 8.232*	381.55 ± 7.453*
13	146.96 ± 3.374*	215.35 ± 4.023*	331.76 ± 8.130*	370.41 ± 7.019*

*Represents $P < 0.05$

Age of dam influenced brand weight ($P < 0.001$) and weaning weight ($P = 0.001$) (Table 5). The range in weights depending on age of dam are 14.88 kg., 12.11 kg., 8.11 kg., and 17.92 kg., for brand weight, weaning weight, yearling weight, and final weight respectively (Table 6). According to BIF (2010) for 3 year old dams, weaning weights for offspring should be adjusted up 27.22 kg., for males and 24.50 kg., for females. Male and female offspring should be adjusted up 18.15 kg., and 16.34 kg., respectively, for 4 year old dams. There is no adjustment for dams ranging from 5 to 10 years of age. Offspring from dams older than 10 years of age should be adjusted up 18.15 kg., and 16.34 kg., for males and females respectively (BIF, 2010). When age of dam increases, the standard error increases. Standard error also increased as the animals aged. Yearling weights do post the largest amount of variability, but this could have been emphasized by the lower number of records used. Compared to the BIF guidelines a similar trend is seen, but not the exact same. 3 and 4 year old dams did post lighter weights than the average. According to BIF guidelines, dams older than 10 years of age need to be adjusted. These results show on the average the older dams do need to be adjusted. In every weight category, the lowest average weight came from the dams older than 10 years. However, none of the 11 year olds gave averages lower than the 3 and 4 year old dams, which was expected (BIF, 2010) (Table 6). *Bos indicus* cattle are known for longevity. Therefore, the decrease in production may be a few years later than expected.

Regressions on age for all weights were determined according to each management code (Table 7). Speculation of why not all regressions are not significant is at least in part due to the numbers of animals in some groups. Therefore some averages have fewer animals and confidence in those estimates them. Each value represents the expected weight gain per day per animal, specific to each management code. This experimental design caused these regression coefficients to be unique to each year, sex, and management type. Therefore, these results show the producer the best type of management fitted to each sex (Table 7).

To better account for the wide differences in average ages across management groups the regressions on age was performed individually for each management code using age nested within management code; as a result, these regression coefficients are unique to year and gender (Table 7). The ranges in these regressions coefficients were from 0.35 to 1.84 kg/d for brand weight and 0.49 to 1.40 kg/d for weaning weight. The results here are different from those of Archer et al. (1998) who reported no differences between different lines of cattle for rate (age) of weight. There is not an expected interaction between an animal's genetic potential and age (not including gestation length), but management groups of different perceived genetic potential might have different management preferences. The range in regression coefficients for yearling weight on age were -.08 to 1.74 kg/d, and, the range in these coefficients of age on final weight went from -0.99 to 4.45 kg/d (Table 7).

Table 7. Regressions and standard error sorted by age(management code)

Man.	Branding weight	Man.	Weaning weight	Man.	Yearling weight	Man.	Final weight
Intercept	23.84±13.247†	Intercept	19.79±31.628	Intercept	-130.15±74.447†	Intercept	-152.03±114.40
BCF09	0.83±0.158*	BCF09	0.73±0.089*	BCF09	0.72±0.182*	BCF09	0.63±0.235*
BCF12	1.09±0.212*	BCF12	0.86±0.192*	BCLF09	0.14±0.280*	BCF12	0.44±0.302
BCHF10	1.13±0.244*	BCHF10	0.76±0.292*	BCM09	1.28±0.294*	BCLF09	0.53±0.384
BCHS09	0.78±0.221*	BCHS09	0.74±0.265*	BCM12	1.00±0.174*	BCLS09	0.06±0.452
BCM09	1.07±0.201*	BCM09	1.32±0.230*	BR1M10	1.06±0.498*	BCM12	1.35±0.190*
BCM12	0.91±0.079*	BCM12	0.49±0.148*	BRF09	0.81±0.192*	BCS09	1.30±0.563*
BCS09	0.74±0.221*	BCS09	0.89±0.181*	BRF11	0.54±0.154*	BCS12	1.25±0.263*
BCS12	1.04±0.256*	BCS12	0.94±0.163*	BRM11	-0.06±0.347	BH1F10	-0.17±0.698
BR0F10	0.73±0.094*	BR0F10	0.78±0.096*	BRS11	0.62±0.198*	BH1S10	0.87±0.637
BR0M10	0.35±0.325	BR0M10	0.53±0.409	FR0F11	0.54±0.287†	BR1F10	0.348±0.430
BR0S10	0.95±0.139*	BR0S10	1.02±0.167*	FR0M11	0.60±0.491	BR1M10	1.14±0.807
BRF09	1.12±0.129*	BRF09	1.10±0.154*	FR0S11	1.61±0.502*	BR1S10	1.34±0.521*
BRF11	0.83±0.099*	BRF11	0.72±0.126*	R10M09	-0.08±0.838	BR2F10	0.20±0.517
BRF12	0.87±0.114*	BRF12	0.75±0.137*	S1M12	0.85±0.407*	BR2S10	-0.99±1.259
BRM11	0.71±0.206*	BRM11	0.70±0.283*	SM1	1.01±0.485*	BRF09	0.91±0.244*
BRS09	1.02±0.127*	BRS09	1.08±0.153*	SM2M10	0.41±0.465	BRF11	0.39±0.193*
BRS12	1.00±0.132*	BRS11	0.61±0.159*	STF09	0.92±0.225*	BRF12	0.91±0.216*
EPIF10	1.84±0.759*	BRS12	0.57±0.163*	STF11	0.88±0.257*	BRM09	1.70±0.391*
EPIS10	0.39±0.416*	EPIF10	1.34±0.476*	STF12	0.77±0.161*	BRM11	-0.20±0.423
FR0F11	0.91±0.197	EPIS10	0.53±0.095	STM09	0.59±0.215*	BRS09	1.05±0.241*
FR0M11	0.89±0.317*	FR0F11	0.86±0.038*	STM11	1.74±0.262*	BRS12	0.61±0.262*
FR0S11	0.48±0.345*	FR0M11	0.65±0.096†	STM12	0.79±0.242*	EPIF10	0.26±1.442
STF09	1.08±0.150	FR0S11	1.50±0.414*	WN1M10	0.71±0.348*	EPIS10	-0.006±0.784
STF10	0.58±0.125*	STF09	1.06±0.180*	WNF09	0.55±0.183*	FR0F11	0.43±0.372

Table 7 (Continued)

Man.	Branding weight	Man.	Weaning weight	Man.	Yearling weight	Man.	Final weight
STF11	1.04±0.148*	STF10	0.49±0.151*	WNF12	0.64±0.134*	FR0M11	0.16±0.643
STF12	0.90±0.111*	STF11	1.01±0.182*	WNG	0.20±0.047*	FR0S11	1.89±0.651*
STM09	1.07±0.127*	STF12	0.73±0.133*	WNGS11	0.58±0.126*	R10M09	2.82±1.001*
STM10	0.76±0.159*	STM09	0.98±0.148*	WNM09	0.80±0.410†	SF1F10	0.55±0.752
STM11	1.27±0.179*	STM10	0.80±0.191*	WNM12	0.63±0.193*	SF2F10	0.65±1.465
STMS10	1.01±0.305*	STM11	1.40±0.215*	WNS12	0.89±0.162*	SM1M10	1.102±0.623†
STS12	0.83±0.228*	STM12	0.83±0.161*			SM1S10	0.457±0.593
WNF09	0.88±0.114*	STMS10	1.04±0.369*			SM2M10	0.13±0.600
WNF12	1.07±0.091*	STS12	0.53±0.274†			STF09	0.83±0.296*
WNGF10	0.75±0.096*	WNF09	0.88±0.137*			STF11	0.82±0.329*
WNGF11	0.79±0.091*	WNF12	0.90±0.110*			STF12	0.72±0.218*
WNGM10	0.78±0.142*	WNGF10	0.71±0.116*			STM09	0.48±0.261†
WNGM11	1.04±0.150*	WNGF11	0.69±0.109*			STM11	3.43±0.376*
WNGS10	0.68±0.085*	WNGM10	0.75±0.170*			STS12	0.17±0.431
WNGS11	0.89±0.067*	WNGM11	0.61±0.166*			WN1F10	0.91±0.391*
WNM09	1.12±0.275*	WNGS10	0.65±0.102*			WN1M10	0.44±0.441
WNM12	0.87±0.133*	WNGS11	0.77±0.100*			WN1S10	0.52±0.337
WNS09	0.93±0.096*	WNM09	1.19±0.329*			WN2F10	-0.07±0.680
WNS12	0.99±0.109*	WNM12	0.56±0.159*			WN2M10	4.45±1.419*
		WNS09	1.00±0.117*			WN2S10	0.24±0.94
		WNS12	0.90±0.134*			WNF09	0.47±0.216*
						WNF12	0.75±0.173*
						WNGF11	0.42±0.169*
						WNGM11	0.22±0.254
						WNGS11	0.54±0.132*
						WNM09	1.01±0.519†

Table 7 (Continued)

Man.	Branding weight	Man.	Weaning weight	Man.	Yearling weight	Man.	Final weight
						WNM12	0.48±0.254†
						WNS09	0.78±0.185*
						WNS12	0.95±0.211*

† Correlations are different at P < 0.10

* Correlations are different at P < 0.05

Heritability calculations

Heritability estimates were calculated on basic growth traits that producers could easily measure and were based on estimates of sire variance. These traits consisted of various weights taken (brand weight, weaning weight, yearling weight, and final weight, and gain between each interval), and these estimates are provided in Table 8. Standard errors of these estimates were not calculated.

Table 8. Summary of heritability estimates

	h^2
Weights	
Brand weight	0.35
Weaning weight	0.42
Yearling weight	0.23
Final weight	0.49
Gain	
Birth weight – brand weight	0.23
Brand weight – weaning weight	0.09
Weaning weight – yearling weight	0.26
Yearling weight – final weight	0.29

The lowest estimate of the weights taken, was expected to be the branding and weaning weight because of the number of other factors that could influence the weights of younger calves. However this did not show in the results. Yearling weight gave an estimate of 0.23. This number should be interpreted carefully. A large number of animals did not have yearling weights taken, therefore the reports could be slightly skewed depending on the distribution of sires, genders, and years amongst the animals that were recorded. Without the yearling weight estimate the upward trend of heritability agreed with Bullock et al. (1993) in evaluating Hereford cattle. This means the weights with younger weights seem to be less heritable than later weights taken. The brand weight heritability was 0.35 and weaning weight 0.42 (Table 8). These estimates fit within the ranges of previous studies of similar heritability estimates. Similar to Kriese et al. (1991), these heritability estimates showed to be higher in *Bos indicus* and *Bos indicus* crosses, compared to *Bos taurus*. It is no surprise the final weight had the highest heritability estimate among these weights at 0.49 (Table 8). These results support the trend, seen in other studies, weights taken at a later age are more heritable. This number can compare closest to mature weights in other studies. In this data set final weight cannot be considered a mature weight. Animals mature at different rates, therefore some animals may be closer to full maturity than others. The *Bos indicus* influence could certainly play a role in the age of maturity. This may also explain why on the average all of the weight heritability estimates seem lower compared to other calculations (such as Brinks et al., 1962; Smith et al., 1976; Bullock et al., 1993; Kaps et al., 1999; Arrango et al., 2002) that did not have *Bos indicus* influences in the data set.

The heritability of gain estimates were also calculated. Previous studies show very wide ranges. Overall the expectation was for all gain estimates were to be fairly low. The amount of gain from birth to brand weight gave a heritability of 0.23. Many historical studies do not report a weight recorded prior to weaning weight. Although a heritability for birth weight in this study was not calculated, due to the insufficient number of birth weights recorded, other studies have shown it to be between 0.35 and

0.71 (Gregory et al., 1950; Koch et al., 1955a; Koch et al., 1955b; Koch et al., 1955c; Shelby et al., 1957; Koch et al., 1973; Woldehawariat et al., 1977; Nelson et al., 1979; Brinks et al., 1982; Bullock et al., 1993). Except for mature cow weight (0.41-0.53), birth weight is one of the more heritable traits for weight (Smith et al., 1976; Bullock et al., 1993; Kaps et al., 1999). Fetal programming may play a role into birth weight, but weights taken at birth may have experienced less environmental influences compared to weights taken at weaning. Possible explanations for heritability of gain between birth and branding being so much lower compared to birth weight may be influenced by other factors in calves' lives such as available nutrients via milk or feed supplementation and health that may show more individual variability after birth.

The heritability of gain from brand weight to weaning showed to be quite low at 0.09. Potential reasons for this low estimate could be the actual ages recorded for the animals from branding to weaning, along with how the calves were managed. Each management code was restricted to a 90-day window of age, however that specific window was different for every group as average age was variable across groups. This created a very wide age for the trait across the entire dataset of when an animal's weaning weight was taken. This number is substantially lower than most other reports, which range from 0.12 to 0.45 (Gregory et al., 1950; Koch and Clark, 1955a; Koch and Clark, 1955b; Koch and Clark, 1955c; Shelby et al., 1955; Koch et al., 1973; Woldehawariat et al., 1977; Nelson et al., 1979). This estimate may not fully represent the heritability estimates of other reports because of the short time between branding and weaning, and possibly a potential interaction with the age at which the weights were recorded.

The heritability given for the gain from weaning to yearling was estimated at 0.26, and this was much higher compared to the previous time period gain. This is in the area of being low to moderately heritable. When considering growth curves, time of gain starts out steep, and depending on the rate of maturity some animals may be at the second point of inflection and leveling off their curve. Comparing this estimate to the 0.29 heritability given for the gain from yearling to final weight, it is slightly lower (Table 8). This small differences could either be impacted by the rate of maturity and each animals own inflection point (on their growth curve), and/or the short amount of time these two weights were taken within each other. Still the latest measurements taken gave the highest heritability. Some speculation could be these animals are approaching maturity, and levelling out their rate of gain, creating a more heritable trait.

Correlations among production traits

Many easily measured production traits are very important to producers as they influence value. Age and weight are both easy to record and are useful for production decisions. When weights are taken at two separate intervals the rate of gain can be calculated over the given period of time usually expressed in days, creating the term average daily gain. Simple correlations of these three different traits were calculated at different levels of production.

Droughtmaster females

Each correlation was broken down by gender, since the growth rates vary by sex. All of the correlations for Droughtmaster females of each weight gave $P < 0.05$, and could be classified has highly correlated (Table 9). Although brand weight has a strong correlation to final weight, the strongest correlations are presented on the diagonal. Simply stated all the weight comparisons showed to have the strongest correlations when compared to the weight taken before or after that specific weight. This relationship hold true to other studies that have measured the correlations of weights in cattle. More specifically, brand weight to weaning weight and weaning weight to yearling weight were correlated at 0.78 (Table 9). Among the weight correlations yearling weight to final weight had the highest correlation at 0.94 (Table 9). This significantly high figure could be contributed to the time each weight was taken. Another possible explanation is the levels of maturity are closer to each other for these two weights, and there are fewer factors that will impact the weights recorded. This concept is similar to why the heritability estimates show to be higher as cattle mature.

The correlations for the average daily gains for Droughtmaster females showed to be significant in several different ways. First, all gain correlations are significant to the weights of the ending weight, which the gain was calculated. For example, average daily gain 1 represents the amount of gain from birth weight to brand weight. It shows a significant correlation of 0.68 with brand weight (Table 9). The gain measurements did not show similar results to the weight correlations, meaning they were not correlated to consecutive measurements. However, each gain measurement was correlated in some way to at least one weight taken. In some cases these relationships had a negative correlation. These negative correlations were recoded when the weight measurement was taken before the gain was calculated (Table 9).

Table 9. Correlations of weights, gains, and ages for Droughtmaster females

Trait	Brand wt.	WW	YW	FW	ADG1	ADG2	ADG3	ADG4	ADG5	Brand age	WW age	YW age
WW	0.78*											
YW	0.70*	0.78*										
FW	0.63*	0.61*	0.94*									
ADG1	0.68*	0.37	0.18	0.16†								
ADG2	-0.11*	0.16*	0.16*	0.20*	-0.07							
ADG3	0.004	-0.11*	0.52*	0.36*	-0.27*	-0.05						
ADG4	-0.11*	-0.23*	-0.41*	-0.13*	0.29*	0.22*	-0.45*					
ADG5	-0.07†	-0.30*	0.38*	0.56*	-0.18*	0.02*	0.79*	0.10*				
Brand age	0.77*	0.55*	0.58*	0.48*	-0.11	-0.15*	0.13*	-0.24*	0.02			
WW age	0.53*	0.77*	0.55*	0.36*	-0.19*	-0.25*	-0.003	-0.44*	-0.30*	0.68*		
YW age	0.75*	0.67*	0.67*	0.62*	-0.13	-0.07†	0.11*	-0.23*	-0.02	0.94*	0.73*	
FW age	0.67*	0.72*	0.69*	0.58*	-0.18*	-0.16*	0.11*	-0.42*	-0.06	0.86*	0.87*	0.92*

WW = Weaning weight, kg; YW = Yearling weight, kg; FW = Final weight, kg; ADG1 = Average daily gain from birth weight to brand weight, kg/day; ADG2 = Average daily gain from brand weight to weaning weight, kg/day; ADG3 = Average daily gain from weaning weight to yearling weight, kg/day; ADG4 = Average daily gain from yearling weight to final weight, kg/day; ADG5 = Average daily gain from weaning weight to final weight, kg/day;
†Correlations at $0.05 < P < 0.10$.
*Correlations $P < 0.05$.

The age correlations of each weight, as expected were significantly correlated to every age. This is not surprising because the animal's age at one time is expected to be older as the weights progressed. These correlations ranged from 0.68 to 0.94 (Table 9). Overall, if an age measurement had a significant correlation to a gain measurement, that correlation showed to be low. However, every age taken was significant and highly correlated to every weight taken, with a range from 0.53 to 0.77 (Table 9). These figures are not as high as the correlations amongst ages, but this is expected because age was measured in days. Days are easily and accurately measured, since the world ran by a specific system (24 hours in one day). Still moderate to strong correlations are expected between age and weight because a possible definition of growth is the increase of weight over time.

Droughtmaster bulls

Droughtmaster bulls showed very similar results in terms of the correlations that are significant (Table 10). However the strength of correlations were different. First the weights when correlated to different weights ranged from 0.49 to 0.85 (Table 10). The only very strong correlation is between yearling and final weight. One possible reason the other figures show to be lower, could be the difference in when the bulls reached puberty or rate of maturity. Testosterone will impact to the growth in bulls. Therefore these figures are expected, to be higher in females and steers, and this is true for this data set. With the exception of the gain from branding to weaning compared to weaning weight, the same pattern of significant correlations is the same from females to bulls. The range of significant correlations of consecutive gain measurements are 0.35 to 0.87.

(Table 10). Age correlations for these bulls range from 0.53 to 0.81, and are all significant, with similar patterns as seen in the females. When the ages are compared to the weights, all correlations are significant and range from 0.24 to 0.79 (Table 10). As expected, the weakest correlations are the when the age and weight are farthest apart, but strengthen as the age and time the weight taken get closer. This is not surprising because age is aid in predicting the weight of growing cattle.

Droughtmaster steers

The correlation among weights of Droughtmaster steers was expected to be the highest among genders. With a range of 0.70 to 0.91, the average is strongest (Table 11). This is not surprising because among the genders the steers will have the least amount of variability for maturity. This means that bull and heifer weights can be impacted by the animal's physiology. Among the gain measurements, significant figures were calculated for consecutive gain measurements compared to their later weight measurement (gain birth to branding compared to branding weight). Similar to the bulls and females, there are no other patterns among correlations for the gain measurements. Correlations comparing the different ages for the steers also gave a stronger correlations on the average compared to the bulls and female. The age correlations ranged from 0.68 to 0.96 (Table 11). These high figures come as no surprise. Also expected, when these ages are compared to the weights, the correlation figures are stronger for steers, ranging from 0.48 to 0.81 (Table 11).

Table 10. Correlations of weights, gains, and ages in Droughtmaster bulls

Trait	Brand weight	WW	YW	FW	ADG1	ADG2	ADG3	ADG4	ADG5	Brand age	WW age	YW age
WW	0.64*											
YW	0.49*	0.60*										
FW	0.49*	0.64*	0.85*									
ADG1	0.69*	0.52*	-0.03	0.50*								
ADG2	-0.12*	0.07	0.05	0.23*	0.19							
ADG3	0.11*	0.10†	0.82*	0.63*	-0.36†	-0.08						
ADG4	-0.002	0.04	-0.15*	0.35*	0.42*	0.31*	-0.26*					
ADG5	0.15*	0.23*	0.69*	0.87*	0.28	0.16*	0.73*	0.44*				
Brand age	0.79*	0.42*	0.32*	0.24*	-0.04	-0.14*	0.06	-0.15*	-0.01			
WW age	0.45*	0.75*	0.37*	0.29*	-0.19	-0.43*	0.08	-0.22*	0.02	0.53*		
YW age	0.54*	0.49*	0.48*	0.37*	-0.25	-0.30*	0.20*	-0.02	0.14*	0.67*	0.63*	
FW age	0.65*	0.67*	0.57*	0.42*	-0.21	-0.32*	0.28*	-0.30*	0.12*	0.76*	0.81*	0.80*

WW = Weaning weight, kg; YW = Yearling weight, kg; FW = Final weight, kg; ADG1 = Average daily gain from birth weight to brand weight, kg/day; ADG2 = Average daily gain from brand weight to weaning weight, kg/day; ADG3 = Average daily gain from weaning weight to yearling weight, kg/day; ADG4 = Average daily gain from yearling weight to final weight, kg/day; ADG5 = Average daily gain from weaning weight to final weight, kg/day;
†Correlations at $0.05 < P < 0.10$.
*Correlations $P < 0.05$

Table 11. Correlations of weights, gains, and ages in Droughtmaster steers

Trait	**Brand weight**	**WW**	**YW**	**FW**	**ADG1**	**ADG2**	**ADG3**	**ADG4**	**ADG5**	**Brand age**	**WW age**	**YW age**
WW	0.81*											
YW	0.80*	0.82*										
FW	0.71*	0.70*	0.91*									
ADG1	0.76*	0.57*	0.64*	0.25*								
ADG2	-0.07	0.23*	0.20*	0.13*	-0.07							
ADG3	0.01	-0.17*	0.39*	0.36*	-0.25	-0.13*						
ADG4	-0.09	-0.02	-0.04	0.35*	0.01	0.04	-0.001					
ADG5	-0.03	-0.18*	0.17*	0.56*	-0.30*	-0.15*	0.77*	0.59*				
Brand age	0.81*	0.63*	0.67*	0.65*	0.22*	-0.05	0.11	-0.06	0.11*			
WW age	0.62*	0.81*	0.48*	0.58*	0.14	-0.10*	-0.02	0.03	-0.06	0.74*		
YW age	0.81*	0.64*	0.74*	0.60*	0.20	0.02	0.13†	-0.05	-0.08	0.94*	0.68*	
FW age	0.77*	0.76*	0.69*	0.73*	0.10	-0.04	0.08	0.01	0.11†	0.93*	0.88*	0.96*

WW = Weaning weight, kg; YW = Yearling weight, kg; FW = Final weight, kg; ADG1 = Average daily gain from birth weight to brand weight, kg/day; ADG2 = Average daily gain from brand weight to weaning weight, kg/day; ADG3 = Average daily gain from weaning weight to yearling weight, kg/day; ADG4 = Average daily gain from yearling weight to final weight, kg/day; ADG5 = Average daily gain from weaning weight to final weight, kg/day;

† Correlations are different at $P < 0.10$

* Correlations are different at $P < 0.05$.

Across all the correlations similarities are seen to some results of Forni et al. (2007) in Nelore cattle. The selection for a smaller weight at one stage of production and heavier growth at another stage of production would be in inefficient. This selection is difficult because of the correlation values from one weight to the next (Forni et al., 2007). DeNise and Brinks (1985) presented genetic correlations, and similar speculations may apply to the relationship between age and weight. Animals with lighter weights will reach a mature weight earlier in life (DeNise and Brinks, 1985). Hall (1991) reported that phenotypic correlations observed (height, cannon bone length, and weight) in Nigerian cattle appeared to be almost independent of the animal's environment. This means that while phenotypic traits maybe correlated to one another, and can show differences in different environments, the environment does not cause this correlation. This is important to note when discussing the relationship between weights. As previously determined weights are impacted by different environmental factors, but despite the conditions causing differences, there is still a correlation from one weight to the next (Hall, 1991).

On the average bulls and steers produced higher regression coefficients. Female groups were the least likely to post a significant regression. This is most likely because on the average females post lower average daily gains. Therefore the regression is less likely to be different from zero. There are some very high regression estimates. At first glance these estimates may seem unrealistic. However, some of the yearling weights were taken very close in time to the final weights in age. Therefore, some compensatory gain may have been inadvertently measured.

Not knowing the exact management conditions of each management code it is not clear which type of management is the most beneficial. Other factors such as body condition score, height, and production goals should be consider to determine the best option. Regardless, these regression coefficients explain the likelihood of expected weight gained per day sorted by management code.

SUMMARY AND CONCLUSION

The goals of this project were to evaluate relationships of weights and their influencing characteristics that impact growth in Droughtmaster cattle from northern Queensland. The objectives of this research were to (1) evaluate the impacts of different weights that could impact growth curves of cattle, (2) evaluate the heritability of these growth traits, and (3) assess the relationships among weight, age, and gain.

Analyses of variance and correlation analysis were used to calculate the impacts of different factors across management groups. Heritability estimates were calculated for different traits based on sire variance estimates. Regarding weight, sire and age showed to be significant factors for all animal ages. Age of dam only impacted early stages or pre-weaning production, showing significance in branding and weaning weights. This means the dam is an important environmental factor on calf size and growth, but does not influence later weights. Since the above factors impact weights taken during the growing stages, it means that they all could manipulate an animal's growth curve (possible to shifting left, or right, or changing slope).

Weights taken later in an animal's life showed to have higher heritability estimates compared to measurements taken in early stages of production. This also implies mature weights are more heritable than weaning weights, and therefore more responsive to selection. Producers may unknowingly manipulate mature weights more often than weaning weights. Producers need to know mature size for supplementation, and to help predict weights for offspring. However, very rarely, producers take weights of their mature cows. It would be more beneficial if mature weights were consistently taken for producers to better understand how to optimize production. Very often mature cattle are under or over fed during different stages of production. Instead most producers weigh their calves at weaning time because this is when most cow-calf producers sell calves.

Weights of the same animal taken at different stages of production should be and are correlated, and this was observed in these data. This makes sense because the weight at one stage should be indicative the weight of the next stage of production. The age at different stages of production are obviously correlated. While a producer's can chose when certain stages may occur, the actual age measured in days cannot be altered. Gain refers to the weight added over time. One way to explain gain is the interaction between weight and age. There are many more factors that impact gain, but gain is calculated by the difference weights over a period of time. The difference between weight and gain is that time is not considered into the weight factor. It is simply just a weight taken at a given time. Gain refers to the relationship weights have over time. In these data the relationships among weights were not the same across genders, and use of the same prediction models across all genders within the same breed or even family line may not be accurate.

Although pre-weaning weights may aid in predicting mature size, they do not seem to be the most accurate when used alone. There are simply too many ways to alter individual growth curves to determine a completely accurate weight. This being said, it is easier to predict mature weights as animals age. A producer should be able to more accurately predict mature weights opposed to branding and weaning weights. Age, gain, and weight correlations will help producers understand that selection for one trait will impact other traits as well. Although in this study birth weight was not evaluated, it should remain a concern for producers, specifically for heifers, or when producing bulls to be used on heifers. With improved knowledge of fetal programming influences producers will learn more about factors correlated to growth and size. Therefore producers can use a tandem selection of genetic and management strategy.

Future research should still be conducted with this data set. The ground work of determining the causes of differences of weights at different stages of production was laid from these analyses. Therefore, complete growth curve analyses could be evaluated on multiple levels with these data. DeNise and Brinks (1985) posted preliminary results discussing the heritability of parameters of a growth curve. Taking a similar approach could result in determining heritability of inflection points on animals' growth curves. Long term goals could consist of creating a way to discover a heritability estimate for a growth curve, and improved knowledge about mature size from traits evaluated earlier in life.

LITERATURE CITED

ABBA. 2014. History. Australian Brahman Breeders Association. Available at http://www.brahman.com.au/history.html. Accessed on 23, July 2014.

Archer, J.A., R.M. Herd, P.F. Arthur, and P.F. Parnell. 1998. Correlated responses in rate of maturation and mature size of cows and steers to divergent selection for yearling growth rate in Angus cattle. Livestock Production Science 54: 183–192.

BIF. 2010. Guidelines for uniform beef improvement programs. 9th ed. Beef Improvement Federation. North Carolina State Univ, Raleigh. 20-45.

Beef Shorthorns. 2013. About us. Available at http://www.beefshorthorn.org.au/about-us. Accessed on 23, July 2014.

Berg, R.T., and R.M. Butterfield. 1976. New concepts of cattle growth. Sydney University Press, Sydney, Australia.

BOM. 2013. Queensland in 2013: Record heat, dry in the west. Australian Government, Bureau of Meteorology. Available at http://www.bom.gov.au/climate/current/annual/qld/summary.shtml. Accessed on 23 July 2014.

Bourdon, R.M. 2000. Understanding animal breeding 2nd ed. Prentice-Hall, Inc. Upper Saddle River, NJ. p. 105-107, 279-291.

Breedplan. 2014. Overview. Breedplan. Available at http://breedplan.une.edu.au/index.php?option=com_content&task=view&id=5&Itemid=28. Accessed on 24 December 2014.

Brinks, J.S., R.T. Clark, N.M. Kieffer and J.R. Quesenberry. 1962a. Mature weight in Hereford range cows—heritability, repeatability, and relationship to calf performance. J. Anim. Sci. 21:501-504.

Brinks, J.S., R.T. Clark, N.M. Kieffer and J.R. Quesenberry. 1962b. Genetic and environmental factors affecting performance traits of Hereford bulls. J. Anim. Sci. 21:777-780.

Brody, S. 1926. Time relations of growth: Genetic growth constants of animals. The Journal of General Physiology. 8:248-251.

Brody, S. 1945. Bioenergetics and growth: with special reference to the efficiency complex in domestic animals. Reinhold Publishing Corp, New York, NY. pp. 1-738.

Bullock, K.D., J.K. Bertrand and L.L. Benyshek. 1993. Genetic and environmental parameters for mature weight and other growth measures in Polled Hereford cattle. J. Anim. Sci. 71:1737-1741.

Cartwright, T.C. 1979 Size as a component of beef production efficiency: cow-calf production1. J. Anim. Sci. 48:974-980.

DeNise, R.S., and J.S. Brinks. 1985. Genetic and environmental aspects of the growth curve parameters in beef cows. J. Anim. Sci. 61:1431-1440.

Droughtmaster Australia. 2011. Celebrating 50 Years of Droughtmaster. Droughtmaster. Available at http://droughtmaster.com.au/. Accessed on 5, June 2014.

Droughtmaster Australia. 2011b. History. Droughtmaster. Available at http://droughtmaster.com.au/history.html. Accessed on 5, June 2014.

Fitzhugh, H.A., Jr. 1976 Analysis of Growth curves and strategies for altering their shape. J. Anim. Sci. 42:1036-1051.

Fitzhugh, H.A., Jr., and St. C.S. Taylor. 1971. Genetic analysis of degree of maturity. J. Anim. Sci. 33:717-725.

Forni, S., M. Piles, A. Blasco, L. Varona, H.N. Oliveira, R,B. Lôbo, and L.G. Albuquerque. 2007. Analysis of beef cattle longitudinal data applying a nonlinear model. J. Anim. Sci. 85:3189-3197.

Forni, S., M. Piles, A. Blasco, L. Varona, H.N. Oliveira, R.B. Lôbo, and L.G. Albuquerque. 2009. Comparison of different nonlinear functions to describe Nelore cattle growth. J. Anim. Sci. 87:496-506.

Gilbert, RP., D.R. Bailey, and N.H. Shannon. 1993. Linear body measurements of cattle before and after 20 years of selection for postweaning gain when fed two different diets. J. Anim. Sci. 71:1712-1720.

Gilbert, R.P., D.R. Bailey, and N.H. Shannon 1993b. Body dimensions and carcass measurements of cattle selected for postweaning gain fed two different diets. J. Anim. Sci. 71:1688-1698.

Goonewardene, L.A., R.T. Berg, and R.T. Hardin. 1981. A growth study of beef cattle. J. Anim. Sci. 61:1041-1048.

Gregory, K.E., C.T. Blunn, and M.L. Baker. 1950. A study of some of the factors influencing the birth and weaning weights of beef calves. J. Anim. Sci. 9:338-346.

Herring, A.D. 2014. Beef cattle production systems.

Kaps M., W.O. Herring, and W.R. Lamberson. 1999. Genetic and environmental parameters for mature weight in Angus cattle. J. Anim. Sci. 77:569-574.

Koch, R.M., M.E. Dikeman, D.M. Allen, M. May, J.D. Crouse, and D.R. Campion. 1976. Characterization of biological types of cattle III. Carcass composition, quality and palatability. J. Anim. Sci. 43:48-62.

Koch, R.M., and R.T. Clark. 1955a. Genetic and environmental relationships among economic characters in beef cattle. I. Correlation among paternal and maternal half-sibs. J. Anim. Sci. 14:775-785.

Koch, R.M., and R.T. Clark. 1955b. Genetic and environmental relationships among economic characters in beef cattle. II Correlations between offspring and dam and offspring and sire. J. Anim. Sci. 14:786-791.

Koch, R.M., and R.T. Clark. 1955c. Genetic and environmental relationships among economic characters in beef cattle. III Evaluating maternal environment. J. Anim. Sci. 14:979-996.

Kriese, L.A., J.K. Bertrand, L.L. Benyshek. Genetic and environmental growth rait parameter estimates for Brahman and Brahman-derivative cattle. J. Anim. Sci. 69:2362-2370.

Mercadante, M.Z., I. U. Packer, A.G. Razook, J.N.S.G. Cyrillo and L.A. Figueiredo. 2003. Direct and correlated responses to selection for yearling weight on reproductive performance of Nelore Cows. J. Anim. Sci. 81:376-384.

Meyer, K., K. Hammond, M.J. Mackinnon, and P.F. Parnell. 1991. Estimates of covariance between reproduction and growth in Australian beef cattle. J. Anim. Sci. 69:3533-3543.

Nelson, T.C., and D.D. Kress. 1979. Estimates of heritabilities and correlations for production characters of Angus and Hereford calves. J. Anim. Sci. 48:286-292.

Nour, A.Y.M., and M.L. Thonney. 1987. Carcass, Soft tissue and bone composition of early maturing steers fed two diets in two housing types and serially slaughtered over a wide weight range. Journal of Agricultural Science. 109:345-355.(Abst.).

Petty, R. R., and T.C. Cartwright. 1966. A summary of genetic and environmental statistics for growth and conformation traits of young beef cattle. Texas A&M University. Dept. Tech.Rep. No. 5.

Shelby, C.E., R.T. Clark, and R.R. Woodward. 1955. The heritability of some economic characteristics of beef cattle. J. Anim. Sci. 14:372-385.

Smith, G.M., H.A. Fitzhugh, Jr., L.V. Cundiff, T. C. 1976. A genetic analysis of maturing patterns in straightbred and crossbred Hereford, Angus and Shorthorn Cattle. J. Anim. Sci. 43:389-395.

Vargas, C.A., M.A. Elzo, C.C. Chase, Jr, and T.A. Olson. 2000. Genetic parameters and relationships between hip height and weight in Brahman cattle. J. Anim. Sci. 78:3045-3052.

Woldehawariat, G., M.A. Talamantes, R.R. Petty, Jr, and T.C. Cartwright. 1977. A summary of genetic and environmental statistics for growth and conformation characters of beef cattle. Departmental Technical Report No. 103. TAES, Texas A&M University, College Station, TX.

APPENDIX

Table 12. Summary statistics for weights sorted by management code

Weaning Code	Variable	N	Mean	SD	CV	Minimum	Maximum
BCF09	Brand weight	27	121.296	27.949	23.042	69	170
	Weaning weight	35	149.543	37.905	25.347	80	212
	Yearling weight	35	225.343	27.541	12.222	152	282
	Final weight	33	276.242	30.341	10.983	203	331
BCF12	Brand weight	26	123.212	20.426	16.578	72	155.5
	Weaning weight	26	216.538	27.651	12.770	159	263
	Yearling weight	25	276.880	27.367	9.884	222	327
	Final weight	26	332.038	30.536	9.196	280	397
BCHF10	Brand weight	12	123.833	29.939	24.177	64	168
	Weaning weight	12	159.167	24.513	15.401	130	195
	Yearling weight	0	.	.	.	.	.
	Final weight	12	335.667	30.149	8.982	292	386
BCHS09	Brand weight	18	127.056	28.994	22.820	91	175
	Weaning weight	18	158.167	31.311	19.796	114	211
	Yearling weight	0	.	.	.	.	.
	Final weight	16	316.625	52.615	16.618	230	384

Table 12 (Continued).

Weaning Code	**Variable**	**N**	**Mean**	**SD**	**CV**	**Minimum**	**Maximum**
BCM09	Brand weight	34	164.088	23.320	14.212	121	196
	Weaning weight	35	222.000	30.860	13.901	160	264
	Yearling weight	31	277.129	29.023	10.473	210	321
	Final weight	31	411.226	51.010	12.404	271	488
BCM12	Brand weight	63	167.563	27.331	16.311	119.5	255
	Weaning weight	63	249.413	22.361	8.966	204	308
	Yearling weight	60	326.383	31.003	9.499	271	408
	Final weight	57	438.754	33.111	7.547	359	508
BCS09	Brand weight	16	83.188	19.319	23.224	49	122
	Weaning weight	18	127.500	35.224	27.627	73	235
	Yearling weight	0	.	.	.	.	.
	Final weight	17	263.765	31.893	12.092	210	355
BCS12	Brand weight	16	120.563	21.431	17.776	94.5	158
	Weaning weight	16	210.313	36.285	17.253	142	258
	Yearling weight	16	291.688	41.316	14.165	191	356
	Final weight	14	355.929	52.825	14.842	231	439
BR0F10	Brand weight	64	152.172	23.948	15.738	98	199
	Weaning weight	68	181.676	26.905	14.809	104	238
	Yearling weight	0	.	.	.	.	.
	Final weight	61	360.787	34.487	9.559	258	424

Table 12 (Continued).

Weaning Code	Variable	N	Mean	SD	CV	Minimum	Maximum
BR0M10	Brand weight	15	188.933	13.504	7.147	172	209
	Weaning weight	15	223.333	17.975	8.048	194	251
	Yearling weight	15	346.667	24.312	7.013	301	385
	Final weight	11	435.273	32.573	7.483	394	486
BR0S10	Brand weight	44	156.568	21.575	13.780	104	192
	Weaning weight	44	184.318	24.044	13.045	127	219
	Yearling weight	0	.	.	.	.	.
	Final weight	41	365.293	34.082	9.330	287	418
BRF09	Brand weight	54	138.389	25.703	18.573	86	189
	Weaning weight	54	193.296	25.737	13.315	140	252
	Yearling weight	52	261.135	23.820	9.122	211	324
	Final weight	52	315.385	29.591	9.383	248	399
BRF11	Brand weight	46	165.174	30.300	18.344	95.5	212
	Weaning weight	46	221.446	28.882	13.042	156.5	287
	Yearling weight	46	329.304	29.175	8.860	261	388
	Final weight	45	362.356	30.297	8.361	298	441
BRF12	Brand weight	68	162.949	27.845	17.088	94.5	229
	Weaning weight	68	226.985	28.700	12.644	148	309
	Yearling weight	68	294.132	28.969	9.849	230	358
	Final weight	68	342.206	33.851	9.892	261	415

Table 12 (Continued).

Weaning Code	**Variable**	**N**	**Mean**	**SD**	**CV**	**Minimum**	**Maximum**
BRM11	Brand weight	15	192.500	26.821	13.933	146.5	239
	Weaning weight	15	254.733	20.974	8.234	223	286
	Yearling weight	15	307.667	25.176	8.183	266	346
	Final weight	14	435.429	52.365	12.026	362	520
BRS09	Brand weight	52	134.212	26.920	20.058	74	180
	Weaning weight	52	188.712	32.069	16.994	110	241
	Yearling weight	0	.	.	.	.	.
	Final weight	49	310.551	33.311	10.726	219	384
BRS11	Brand weight	42	176.643	28.138	15.929	108	236
	Weaning weight	42	233.714	27.280	11.673	175.5	292
	Yearling weight	40	330.025	30.842	9.345	270	419
	Final weight	39	366.385	35.386	9.658	287	479
BRS12	Brand weight	33	153.561	31.532	20.534	100.5	212
	Weaning weight	31	218.516	30.766	14.079	172	274
	Yearling weight	29	295.414	34.429	11.654	228	349
	Final weight	29	348.172	31.885	9.158	292	413
EPIF10	Brand weight	17	147.412	18.964	12.865	108	178
	Weaning weight	17	228.471	23.899	10.460	176	259
	Yearling weight	0	.	.	.	.	.
	Final weight	16	403.875	32.012	7.926	326	448

Table 12 (Continued).

Weaning Code	Variable	N	Mean	SD	CV	Minimum	Maximum
EPIS10	Brand weight	26	148.615	17.154	11.542	115	185
	Weaning weight	26	229.731	18.419	8.017	190	257
	Yearling weight	0	.	.	.	.	.
	Final weight	26	398.923	22.287	5.587	322	434
FR0F11	Brand weight	28	158.089	24.905	15.754	101	215
	Weaning weight	28	212.214	25.478	12.006	152	276
	Yearling weight	28	321.821	31.150	9.679	239	398
	Final weight	28	357.571	34.644	9.689	261	445
FR0M11	Brand weight	21	182.595	18.890	10.345	145	213
	Weaning weight	20	245.850	19.937	8.110	198	284
	Yearling weight	19	318.105	21.566	6.780	271	364
	Final weight	19	456.895	33.594	7.353	392	512
FR0S11	Brand weight	7	157.357	42.283	26.871	108	223
	Weaning weight	7	223.429	41.999	18.798	158	271
	Yearling weight	7	322.143	48.533	15.066	248	384
	Final weight	7	365.000	56.374	15.445	272	432
STF09	Brand weight	36	173.806	27.929	16.069	124	234
	Weaning weight	36	214.000	29.188	13.639	154	275
	Yearling weight	35	274.371	28.069	10.230	215	333
	Final weight	34	328.529	30.205	9.194	253	400

Table 12 (Continued).

Weaning Code	Variable	N	Mean	SD	CV	Minimum	Maximum
STF10	Brand weight	25	133.440	30.197	22.629	76	181
	Weaning weight	25	179.840	33.355	18.547	104	242
	Yearling weight	0	.	.	.	.	.
	Final weight	24	380.083	35.452	9.327	322	440
STF11	Brand weight	23	166.283	29.724	17.876	111	216
	Weaning weight	21	221.619	33.878	15.287	152	278
	Yearling weight	18	345.333	32.863	9.516	288	412
	Final weight	18	380.444	29.892	7.857	332	438
STF12	Brand weight	39	148.000	30.001	20.271	92	215
	Weaning weight	38	244.579	30.214	12.354	191	322
	Yearling weight	38	295.789	33.968	11.484	233	384
	Final weight	35	354.829	37.393	10.538	280	425
STM09	Brand weight	29	168.069	34.267	20.389	114.5	230
	Weaning weight	30	222.200	34.162	15.375	164	287
	Yearling weight	27	301.074	77.928	25.883	216	456
	Final weight	30	438.967	65.132	14.838	358	606
STM10	Brand weight	18	140.556	23.545	16.752	105	179
	Weaning weight	18	200.944	25.847	12.863	158	247
	Yearling weight	18	335.944	20.792	6.189	286	373
	Final weight	17	439.235	26.037	5.928	402	488

Table 12 (Continued).

Weaning Code	**Variable**	**N**	**Mean**	**SD**	**CV**	**Minimum**	**Maximum**
STM11	Brand weight	15	184.867	36.366	19.671	125	271
	Weaning weight	15	248.600	39.502	15.890	180	340
	Yearling weight	15	341.000	63.605	18.652	248	458
	Final weight	12	496.667	117.724	23.703	358	738
STM12	Brand weight	32	158.250	27.209	17.193	108	229
	Weaning weight	32	266.188	31.423	11.805	198	336
	Yearling weight	31	356.871	88.827	24.890	245	548
	Final weight	30	492.000	106.588	21.664	334	706
STMS10	Brand weight	16	153.813	28.868	18.768	108	190
	Weaning weight	16	207.438	30.967	14.928	152	257
	Yearling weight	0	.	.	.	.	.
	Final weight	14	391.571	33.670	8.599	328	442
STS12	Brand weight	11	139.636	35.963	25.754	103	225
	Weaning weight	11	224.909	18.003	8.004	198	255
	Yearling weight	11	283.000	19.616	6.932	258	317
	Final weight	11	338.273	25.251	7.465	310	384
WNF09	Brand weight	78	141.615	23.253	16.420	86	188
	Weaning weight	78	196.795	24.481	12.440	146	251
	Yearling weight	76	261.618	26.041	9.954	210	325
	Final weight	73	317.123	31.159	9.826	255	397

Table 12 (Continued).

Weaning Code	Variable	N	Mean	SD	CV	Minimum	Maximum
WNF12	Brand weight	71	146.176	29.404	20.116	97	209
	Weaning weight	70	236.486	31.951	13.511	128	320
	Yearling weight	71	285.056	28.422	9.971	216	359
	Final weight	70	338.700	32.510	9.598	262	439
WNGF10	Brand weight	70	158.300	26.005	16.428	84	203
	Weaning weight	70	191.800	27.476	14.325	101	236
	Yearling weight	0	.	.	.	.	.
	Final weight	64	375.531	35.043	9.332	300	440
WNGF11	Brand weight	71	161.951	30.417	18.782	78.5	230
	Weaning weight	70	231.993	32.119	13.845	123	311
	Yearling weight	71	325.211	32.496	9.992	244	418
	Final weight	70	360.457	35.817	9.937	280	463
WNGM10	Brand weight	35	178.600	23.166	12.971	125	223
	Weaning weight	35	216.171	24.455	11.313	162	267
	Yearling weight	35	340.343	33.739	9.913	270	396
	Final weight	35	439.657	40.268	9.159	340	514
WNGM11	Brand weight	28	184.696	29.578	16.015	113.5	234
	Weaning weight	28	267.179	25.366	9.494	214	313
	Yearling weight	25	298.960	29.108	9.737	243	347
	Final weight	27	436.963	37.125	8.496	352	512

Table 12 (Continued).

Weaning Code	**Variable**	**N**	**Mean**	**SD**	**CV**	**Minimum**	**Maximum**
WNGS10	Brand weight	57	146.754	27.794	18.939	102	208
	Weaning weight	57	181.333	28.098	15.495	130	245
	Yearling weight	0	.	.	.	.	.
	Final weight	56	369.304	29.856	8.084	326	452
WNGS11	Brand weight	75	170.840	32.892	19.253	106.5	239
	Weaning weight	72	243.222	31.849	13.095	166.5	309
	Yearling weight	69	328.623	34.991	10.648	264	419
	Final weight	68	365.515	35.851	9.808	302	467
WNM09	Brand weight	18	166.722	18.817	11.287	120	188
	Weaning weight	18	228.500	20.712	9.064	185	271
	Yearling weight	18	273.278	24.906	9.114	233	324
	Final weight	17	426.824	34.328	8.043	383	526
WNM12	Brand weight	51	170.725	22.456	13.153	117	212
	Weaning weight	51	268.471	24.642	9.179	222	328
	Yearling weight	51	328.275	27.615	8.412	270	397
	Final weight	48	440.896	36.259	8.224	360	528
WNS09	Brand weight	71	129.859	27.796	21.405	56	184
	Weaning weight	71	183.394	31.996	17.446	95	265
	Yearling weight	0	.	.	.	.	.
	Final weight	71	302.056	34.386	11.384	218	376

Table 12 (Continued).

Weaning Code	**Variable**	**N**	**Mean**	**SD**	**CV**	**Minimum**	**Maximum**
WNS12	Brand weight	52	129.212	27.650	21.399	66.5	181.5
	Weaning weight	51	223.471	32.668	14.618	146	294
	Yearling weight	51	285.510	29.068	10.181	212	350
	Final weight	51	343.706	33.676	9.798	242	408