Final report

Optimising heifer development and management to increase whole herd profit

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Abstract

Maternal productivity in southern beef breeder herds is driven by pasture production, utilisation and reproductive performance. A total of 14,229 heifers have been recorded across 25 contemporary groups on nine properties. The impact of heifer growth on reproductive performance demonstrated that joining weight and weight gain both prior to and during joining are key determinants of early pregnancy success. In most cases whole cohorts of heifers were joined and only 72% conceived following a 6-week joining; of those only 88% successfully reared a calf; and of those only 88% conceived within a 6-week joining so only 56% achieved being wet and pregnant early (WAPE). Tools that evaluate return on investment by accounting for feed cost, growth and reproductive performance have been developed and will form the basis of training material in a new project. The project should provide producers with greater confidence to increase productivity by managing pasture utilisation, heifer growth and cow body condition.

Executive summary

Background

In southern, temperate Australia beef systems a cow must produce a calf every year to maximise productivity and profitability. Reproductive performance is the key profit driver of a beef cow/calf enterprise. Nutrition, genetics and animal management play a key role in achieving this. Lifetime reproductive performance of a cow begins as a heifer, and to acquire maximum reproductive output the heifer should reach puberty as a yearling, conceive early in the breeding season, deliver a viable calf unassisted at two years, re-breed whilst lactating and support the calf through to weaning. A summary of the requirement of heifers to achieve being wet and pregnant early in the joining (WAPE). The MLA funded maternal productivity project through the Beef CRC addressed many of the components herein. However, there were concerns that due to the design, heifer growth targets for joining were higher than necessary. Thus, it was important to work with commercial herds across southern Australia to benchmark reproductive performance and develop targets for best practice. The research should lead to adoption programs to improve breeder herd productivity.

Objectives

1. Develop a comprehensive understanding of optimum growth path for modern phenotype heifers to achieve WAPE to increase whole enterprise profitability and improved risk management practices.
2. Develop knowledge of the farm profit impact for heifer and young cow management options depending on cost of management options and increased output (income).
3. Create information and extension package comprised of digital effort and small group engagement with producers, producer groups and advisors that is suitable for current genetics.
4. Develop a desktop study of current industry recommendations and benchmarks and delivered it to producers to inform and identify where to focus adoption of outputs.

Methodology

Nine commercial herds were enlisted in the project from across southeast southern Australia (SA), southwest slopes and Riverina New south Wales (NSW), central and western Victoria, and Tasmania (King Island). For each of the sites, location, average rainfall (mm) and calving season has been reported along with the total number of body composition measures including weight, height, BCS, fatness and pregnancy outcomes. Pasture samples were collected and analysed. To supplement this, green food on offer (FOO, kg DM/h) was estimated from satellite data. A total of 14,229 heifers have been recorded across four years, each site recorded data on two cohorts over two production cycles, i.e. cohort 1, the 2018 born heifer calves which calved in 2020/21, and cohort 2, the 2019 born heifer calves which calved in 2021/22 and 2022/23. At Farm 8 an additional three cohorts of approximately 3025 heifers born in 2020 (cohort 3), 1700 heifers born in 2021 (cohort 4) and 2200 heifers born in 2022 (cohort 5) has been measured from weaning through to the third, second and first pregnancy scan respectively.

The authors are indebted to the producers, managers, and consultants who worked tirelessly to collect the enormous amount of data for the project.

Results/key findings

There are significant challenges for industry in that the proportion of heifers conceiving within 6 weeks (72%); the number of those that successfully reared a calf (88%); and the number of those that successfully conceived again within a 6-week joining period (88%) were all lower than expected (average WAPE 56%). It is important to note that in most cases the whole heifer drop were joined

rather than selected for joining as this was a requirement for inclusion in the project. Growth paths of heifers in a range of commercial herds have been evaluated from soon after weaning to weaning of their second calf to determine the relationship between weight, condition and heifer pregnancy outcome. Growth rate (ADG) both leading up to and during joining is also important for early heifer conception and accounted for most of the difference between Autumn and Spring calving herds. Heifer weight at joining was most strongly associated with pregnancy success for lighter heifers (<300kg). To achieve 80% early conception (first two cycles), light weight heifers (<300kg) need to be growing at least 1.0 kg/day prior to joining and 2.0 kg/day during joining. If light weight heifers are not growing prior to joining (typically the case in Autumn calving herds), then during joining gain would need to be 2.5kg/day to achieve 80% conception rates and this is rarely achieved. In contrast heifers that are 350 – 400 kg at joining only need to be growing at 0.5 kg/day prior to joining and during joining to achieve 80% early conception. Other traits such as height, condition score and fat depth were less important.

The cost of being born later in the breeding season has also been quantified. Calves born to heifers scanned pregnant in the first cycle were between 9 and 13 kg heavier at weaning than those conceived in cycle 2, and 24 kg heavier than those conceived in the third cycle (approximately 0.5 kg/d). Heifers that conceived in the first cycle were 16 kg heavier than those conceived in the second cycle, and 28 kg heavier than those that conceived in the third cycle. While there are good premiums for well-bred pregnant heifers, there are good fall-back markets for empty heifers, joining times can be extended and cows that fail to raise a calf or re-breed can be sold into valuable manufacturing markets. Thus, for most herds the lower-than-expected maternal performance represents a productivity loss but not an economic disaster. A series of scientific publications will be submitted during 2024.

Benefits to industry

There is an opportunity to significantly increase breeder herd productivity in Southern Australia. Currently one of the biggest production gaps is the proportion of heifers getting in calf. Producers can achieve an increase in pregnancy rate of 10% by changing management to grow heifers to 350kg instead of 300kg at joining (average of group).

The project has recorded measurements on 14,229 heifers, if we could achieve a 10% increase in WAPE across those herds it would result in an extra 1422 PTIC heifers. The net benefit across the project herds would equate to an extra $898,416 net income or an extra $64/heifer joined.

Potential productivity losses have also been identified due to extended calving periods. Tighter calving patterns achieved through more heifers conceiving in the first cycle of joining will result in increased progeny weights at the same calendar day.

The target market is considerable with an estimated 500,000 heifers and 400,000 first calving cows developed each year across the target region. If 10% of all heifers and first-calving cows within the region were managed to increase WAPE by 10% there would be an increase of 7,920 calves weaned per year from the target region. When fully adopted this would represent an across region increase in farm gate production value of $5.68M/year.

Breeder herds are both resilient but have significant potential for increased productivity. Decision support tools have been developed to assist producers to make informed decisions about the value proposition of allocating greater feed to heifers. These should give greater confidence to those maximising productivity by balancing pasture utilisation and reproductive output. Many presentations have been given and producers have responded by calculating losses within their own production systems.

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1. Background

1.1 Heifer Conception

In southern Australian non-arid beef production systems a cow must produce a calf every year to maximise productivity and profitability. Reproductive performance is the key profit driver of a beef cow/calf enterprise. Nutrition and animal management play a key role in achieving this. Lifetime reproductive performance of a cow begins as a heifer, and to acquire maximum reproductive output the heifer should,

- Reach puberty early (14-15 months).
- Conceive early in the breeding season (first six weeks).
- Deliver a viable calf, unassisted (as a two-year-old).
- Re-breed early whilst lactating.
- Support the calf to weaning.

When a heifer does not conceive, produce, and wean a viable calf it is likely the loss in revenue will not be recovered (Mathews and Short 2001). Sufficient nutrition and early growth ensures the heifer has a greater chance to reach puberty prior to joining (Walmsley et al. 2018). Puberty attainment is a key driver of reproductive success in heifers. Heifers that reach puberty at an earlier age cycle multiple times prior to joining which increase conception rates (Byerley et al. 1987), and the likelihood of early conception (conceived in the first two cycles). This determines an early calving pattern that is replicated in subsequent years and can result in increased production and efficiency (Short and Bellows 1971, Lesmeister et al. 1973). In addition, calves that are born early in the season have additional days of growth and generally are heavier at weaning (Funston et al. 2012), thus can result in quicker turn off weights, increased carcass quality and quantity (Alexopoulos, unpublished) and or less feed to reach an adequate joining weight as a heifer replacement.

Joining weight is a key driver of heifer conception. Often target weights are used (e.g. 250-304 kg, Walmsley et al. 2018) or joining weight as a percentage of mature cow weight (MCW). Previous recommendations suggest that a heifer should reach 60-65% of MCW (Wiltbank et al. 1969, Ferrell 1982) 30 to 45 days pre-joining to achieve adequate conception rates greater than 85% (Ahmadzadeh et al. 2011, Hilton 2013). More recent studies have reported that attainment of 50 to 53% MCW has been seen with no detrimental effects on reproduction as well as reducing feed costs by $22 to $24/head (Martin et al. 2008, Freetly et al. 2011, Funston and Larson 2011). Funston and Deutscher (2004) grew heifers to 53 and 58% MCW and found that at 58% MCW 11% more heifers were pubertal at joining. However, this had no effect on pregnancy rates. Martin et al. (2008) also reported no difference in pregnancy rates and re-breeding rates when growing heifers to 55% MCW, although calf performance was greater than those heifers grown to 50% due to earlier calving and heavier weaning weights.

For optimum conception rates heifers also need to be in good condition at joining. Although this can be partly assessed by liveweight, body condition score (BCS) is a practical tool that can be used as an indicator of energy reserves and re-breeding performance post-partum (Randel 1990). Body condition score is a subjective measure of the fat cover over the short ribs and/or tail bone and is scored on a scale of 0 (emaciated) to 5 (obese; Graham 2006). A minimum BCS of 2.0 at calving is recommended for Spring calving cows and 2.5 for Autumn calving cows (Graham 2006). Body condition score at the first calving has a significant effect on the re-breeding success of the lactating heifer. As pre-partum BCS increases, re-breeding pregnancy rate increases (Selk et al. 1988). Jones et al. (2016) demonstrated the importance of fatness reporting 85% conception rates at 52% MCW with 8mm of rib fat. However, with only 4mm of rib fat the MCW needed to reach 69% to maintain 85% conception rates.

Understanding the intrinsic link between BCS at calving and rebreeding is a powerful management tool for producers, to improve herd efficiency and success. To improve BCS by one point on a 1-5 point scale a 70kg increase of bodyweight is required (Wright and Russell 1984).

1.2 Re-breeding

A cow must produce a calf every 365 days to increase productivity and profitability. An annual calving pattern means high energy demand during lactation must align with peak feed supply. To achieve this a cow must recover from calving and re-breed within 80 to 85 days post calving (Lalman et al. 2021). Directly following calving the heifer or cow enters a state of temporary infertility known as the post-partum anoestrus interval (PPAI; Short et al. 1990). PPAI is primarily regulated by body energy reserves (Diskin and Kenny 2016, Walmsley et al. 2018) thus, primiparous heifers have a longer PPAI than older, multiparous cows (Crowe et al. 2014, Rasby et al. 2014) due to the higher energy demand required for maintenance, lactation and continual growth. Houghton et al. (1990) found that as body condition score increased, PPAI decreased. At BCS of 2.0 (11.3% body fat), PPAI was 89 days while at a BCS of 3.3 (22.6% body fat) PPAI was reduced to 52 days. Heifers that conceive and calve early have a greater likelihood of early (conceived in the first two cycles) re-breeding success. After the heifer successfully has a second calf as a three-year-old she is well set to continue calving yearly and remaining in the herd (Day 2015). Females culled from a herd before producing 3 to 5 calves decrease profitability and sustainability of the cow calf operation (Cushman et al. 2013).

Anecdotally, producers in the project have reported their biggest issue is getting first calf lactating cows to re-breed. The maiden cow has not yet generated any income with a calf still at foot but has incurred a cost through management, feed and time to get her to this stage. Consequently, the cost of culling due to reproductive issues is felt keenly. A five-year study in Dakota found that heifers tended to calve on time as two-year olds but calve late as three-year olds or not get in calf at all (Boggs 1994). Improvement in female fertility that can be made through genetic selection is difficult due to the low heritability of reproductive traits (Dickinson et al. 2019) so implementation of management practices to increase the likelihood of early reproductive success in the lactating heifer is key to maintaining a productive and profitable beef enterprise.

1.3 WAPE

Heifer calving and re-breeding is key to a profitable beef enterprise (Grossi et al. 2008). The authors would like to introduce a new term: "Wet and Pregnant Early" (WAPE) to provide a value to measure the success of heifer reproductive performance at joining and re-breeding. WAPE encapsulates heifers that conceive early (conceive in the first two cycles), calve unassisted, raise a viable calf and re-breed early (conceive in the first two cycles). It has been estimated that only 65% of heifers joined in temperate production systems achieve this (Pitchford et al. 2017).

Target weights of 60-65% MCW that are provided to producers (e.g. through training courses such as Heifers for Profit, [Heifers for Profit | RIST]) are based on research done in the 1970s (Patterson et al. 1992). Over the last 50 years the modern Angus MCW has increased by more than 100 kg, and over the last 20 years Angus heifers on average are 15 kg heavier at 200 days of age, 34 kg heavier at 400 days and 48 kg heavier at 600 days of age (Angus Australia, 2024). There has also been almost five days genetic improvement in days to calving. These significant increases warrant updated recommendations for target weights, condition and growth paths.

An additional issue is that most earlier studies have been conducted with research herds. The aims of this study were to quantify commercial beef producers representing Autumn and late Winter/Spring calving production systems across southern Australia to identify optimum growth paths for heifers from weaning through to the first calving based on the relationship between weight, height, BCS, rib fat and early conception. Furthermore, the project aimed to identify relationships between body composition measures at the first and second joining and re-breeding conception rate, to evaluate WAPE and generate benchmarks that can be used to improve whole herd profitability

2. Objectives

Objective 1. Develop a comprehensive understanding of optimum growth path for modern phenotype heifers to achieve WAPE to increase whole enterprise profitability and improved risk management practices through increased knowledge of interactions between a:

- Heifer growth path, joining weight and joining season nutrition with heifer pregnancy conception rate and date for autumn and winter/spring calving herds.
- Growth path, maiden calving weight and condition, dystocia and calf survival for autumn and winter/spring calving herds.
- Growth path, subsequent re-breeding rates and weaning weight for autumn and winter/spring calving herds.

Measurement of heifer weight, condition, fat cover and height from pre-joining to third pregnancy scan has provided data to construct robust growth paths for modern phenotype heifers and identify a reasonable target for WAPE. Collection of feed quality and quantity has been incomplete. Data for dystocia, calf survival and calf weaning weight comes mainly from Farm 8.

Objective 2. Develop knowledge of the farm profit impact for heifer and young cow management options depending on cost of management options and increased output (income).

Economic modelling of the data from this project has demonstrated how farm profit is affected by changes in heifer conception. It examines herd profit under various scenarios including the costs and benefits of using supplementary feeding to get more heifers in calf and includes assessment of the relative salvage values of different age classes within the herd. It has also quantified the relationship between cow condition and pregnancy outcomes.

Objective 3. Created information and extension package comprised of digital effort and small group engagement with producers, producer groups and advisors that is suitable for current genetics and achieves high producer engagement and change of practice.

Detailed case studies from farms participating in the applied research: Farm 8 (can third cycle heifers re-breed successfully), Farm 3 (can heifer nutrition be restricted and not affect pregnancy rate) and Farm 4 (how conception is affected when heifers lose weight before and during joining). Updated industry benchmarks expected to be target heifer weight and/or condition with caveats (is animal *growing or not). Presentation material has been adopted and tested at various producer groups, further development of presentation material and spreadsheets will be a part of the 'Producing Profitable and Resilient Southern Beef Herds' project commencing July 2024. Further the findings from the report will be included in the Heifers for Profit course material. The information to be updated is found in Table 37 in the Appendix.*

Objective 4. Develop a desktop study of current industry recommendations and benchmarks and delivered it to producers to inform and identify where to focus adoption of outputs from R&D.

Current training material was recently reviewed (Eckermann et al. 2022). As the project material has been presented to producers the conclusions have been tested and have been supported by those in attendance. Over time the messages have remained consistent but the way in which it has been communicated has evolved significantly. In addition, the economics of feeding heifers spreadsheet tools have also been presented to multiple groups and has been well received. A small number of producers and consultants have trialled the tool and their feedback has been incorporated into the current version.

Objective 5. Complete 2 peer reviewed scientific publications submitted to "Animal Production Science" journal or similar.

A total of six papers from this project are planned (Appendix; Table 38), as part of a special edition of Animal Production Science. Two papers are currently in progress. The first paper covers heifer conception and includes a detailed description of the project, the effect of growth pre-joining and during joining, and a comparison of Autumn vs Spring calvings. The second paper examines the effect of getting in calf faster and will consider heifer conception (early vs late), weaning data of calves and economic modelling. This paper will include a tool for producers to use in decision making (see objectives 3 and 4). The aim is to have the two papers accepted by the time of final payment. The papers and publication plan are listed in the Appendix (Table 38).

Acknowledgements

Collecting data from over 14,000 heifers would not have been possible without the hard work, dedication and support of many individuals. The authors would like to express their sincere gratitude and appreciation to the producers, managers, farm staff and consultants for their enormous contribution to this project. There were a number of significant challenges presented during the project including fires, and COVID and the authors would like to thank Chris Blore and Nick Linden (Agriculture Victoria), Dr Josh Berryman and Dr Shane Thomson (Holbrook Veterinary Centre, James Pitchford and Jena Alexopoulos for collecting or facilitating the collection of data during some trying circumstances. The producers and farm managers have not been named to maintain confidentiality however the authors are indebted to them for the time and effort that they have given to the project and are extremely grateful for opportunity to work with them on such an important industry project. Finally, the authors would like to acknowledge the contribution of Dr Stephen Lee who successfully developed and lead the years of the project. Stephen's passion and enthusiasm for improving productivity in Southern-Australia led to the genesis of the project.

3. Methodology

3.1 Data Collection

Data were collected from nine commercial farming enterprises from southeast southern Australia (SA), southwest slopes and Riverina New south Wales (NSW), central and western Victoria, and Tasmania (King Island). For each of the research sites, location, average rainfall (mm) and calving season has been reported (Table 1) along with the total number of body composition measures including weight, height, BCS, fatness and pregnancy outcomes. A total of 14,229 heifers have been recorded across four years, each site recorded data on two cohorts over two production cycles (ethics number; S-2018-097), i.e. cohort 1, the 2018 born heifer calves which calved in 2020/21, and cohort 2, the 2019 born heifer calves which calved in 2021 and 2022. At Farm 8 an additional three cohorts of approximately 3025 heifers born in 2020 (cohort 3), 1700 heifers born in 2021 (cohort 4) and 2200 heifers born in 2022 (cohort 5) have been measured from weaning through to the third, second and first pregnancy scan respectively.

Table 1. A summary of the nine sites in the project including property, location, cattle breed, calving season, number of heifers (cohorts 1 & 2 combined), number of body composition measures (weight, height, BCS and fat) and pregnancy outcomes.

Property	Location	Rainfall (mm)	Calving	Breed	# Heifers	# Measures
Farm 1	Millicent, SA	750	Autumn	Angus	364	7,715
Farm 2	Western Vic.	800	Spring	Angus	223	3,713
Farm 3	Holbrook, NSW	825	Spring	Angus, Hereford and Shorthorn	575	8,643
Farm 4	Avenue Range, SA	550	Autumn		448	8,067
Farm 5	Central Vic.	1360	Autumn	Angus	226	2,863
Farm 6	Albury, NSW	650	Spring	Angus	304	6,427
Farm 7	Holbrook, NSW	780	Spring	Angus	335	6,415
Farm 8	King Island, Tas.	830	Spring	Angus	11,508	160,251
Farm 9	Western Vic.	610	Spring	Angus	246	3,903
Total					14,229	207,997

*Cohorts 1, 2, 3, 4 and 5

Each heifer had regular weight and body condition measurements with targeted recording of rib fat depth (mm) and hip height (cm). Heifers were measured at weaning (6 months), post weaning (9.4 months) and approximately 42 days before joining (13.2 months). Subsequently heifers/cows were measured at the start and end of mating for their first (14.6 months), second (26.7 months) and third joining (38.8 months). Some herds recorded weights at 30 days and/or 30 days before calving. In addition, pregnancy diagnoses and estimated conception dates/cycle were recorded for the first, second and third pregnancies. Height information was only collected periodically due to the extremely high repeatability of the trait. However, it became apparent throughout the project that the height measure was less accurate than anticipated, this in part due to collection days coinciding with production events thus a high number of heifers or cows needed to be processed, reducing the time to accurately measure height. This resulted in less than optimum positioning of heifers in the crush, in addition the measuring tape, and distance from the top to bottom of the crush varies between and within sites leaving a potential margin of error in the measure. Rib fat measures on heifers was difficult to obtain due to low (<2mm) readings, as heifers matured and fattened, rib fat was more easily recorded.

The proposed timing of measurement dates for Winter/Spring calving (Table 40) and Autumn calving herds (Table 41) are in the appendix. Not all cohorts were sampled at all events. A lot of the data collection occurred during 2020 and 2021 when COVID restrictions made farm visits difficult or impossible. In addition, it proved difficult to obtain extra measures outside annual production events i.e. additional mustering and yard work for producers, and so not all time points were able to be collected. Three of the participating herds withdrew before the completion of the project (Farm 3, Farm 5, Farm 9).

Dates were recorded for all measures and where possible key animal husbandry dates were recorded regardless of whether heifers were weighed i.e. joining/bull in dates, end of mating/bull out dates, artificial insemination dates, treatment dates (i.e. prostaglandin). A summary of terms used frequently in this document and their definitions and abbreviations is presented (Table 2).

The initial project proposal included genotyping to enable cow-calf units to be identified so that calf weaning weight could be matched with cows to enable quantification of maternal productivity. However, with limited budget, as the size of the herds grew the ability to be able to achieve this reduced. It was decided that it was better to have more heifers included and since pregnancy status was already known, that this would account for much of the variance in maternal productivity, so the genotyping was not justified and there was an associated amendment to the contract agreement. On the largest site (Farm 8), efforts were made to collect detailed calving records including parentage, calving date, calving difficulty, heifer and calf mortality, heifer slippage (one cohort) and weaning weights and rates for four cohorts. Second calving outcomes for one of these cohorts included parentage for a sub-set of heifers and weaning weights and rates were collected for the cohort.

Feed quality and quantity leading into, and during joining and calving has been recorded for heifers and re-breeders for some properties. Pasture was sampled and analysed for dry matter (DM, %), crude protein (CP, %) and metabolizable energy (ME, MJ /kg DM). Visual feed on offer (FOO, Kg DM/ha) was assessed. Pasture measurements ceased shortly after the project had commenced at most locations, this was in part due to COVID and in which interstate travel and farm entry was not permitted. In effort to overcome this issue, green FOO was estimated using satellite data from the Flurosense website (Regrow) and heifer weight and FOO were plotted over time.

Table 2. Frequently used terms, definitions, and abbreviations

Term	Abbreviation	Units	Definition
Heifer			Female bovine before she has had her first calf at ~2 years of age
Cow			Female bovine after she has had her first calf at ~2 years of age
Mature cow			Cow that has finished growing (particularly in height/frame) 4.5 years or older (5-year-old cow at calving)
Mature cow weight	MCW	kg	Weight of a mature cow
Project reference weight	PRW		Project reference weight is the regression of cow weight on body condition, at 3.5 years of age, the residuals of the regression were used to adjust individual weights to a standard condition score 3
Estimated reference weight	ERW		Where 7.5% of weight at BCS 3 at 3.5 years of age is added to the PRW to calculate ERW for 4.5 years of age being our best estimate of mature cow weight.
Body condition score	BCS	score	1 = emaciated, 5=obese (Graham , 2006)
Rib fat	Fat	mm	Fat depth at the 12/13th rib site using live animal ultrasound scanning.
Weight	Wt	kg	
Residual weight		kg	Weight adjusted for height or net of variation in height or frame which should reflect body condition
Average Daily Gain	ADG	kg/day	Rate of change in weight between two time points.
Hip height	Ht	mm	Measured at the hip bone while animal has back legs evenly spaced, on level ground and not moving. Measured while animal is standing on scales
Joining (Start of Mating)	SOM	Date	Date of introduction of bulls to heifers/cows or date of artificial insemination
End of Mating	EOM	Date	Date of removal of bulls from heifer/cow herd
Pregnancy Test/ Pregnancy Scan	PregScan		Conducted by qualified veterinarians. Pregnancy Tested in Calf (PTIC) or Empty (PTE) or fetal aged (see below).
Fetal Age	FA	Days, Weeks, Date	Fetal age was presented in various formats: age of fetus (days). Age of fetus (weeks), Conception Date. Calving Date. Descriptive of conception date: (Early or Late, Early, Medium or Late)

Cycle			The reproductive cycle that the heifer or cow conceived, 1st cycle – the first 3 weeks of the joining period, 2nd cycle – 2nd 3 weeks, 3rd cycle the last 3 weeks of a 9-week joining, PTE – pregnancy tested empty
Lactating		%	Defined as the proportion of cows which were scanned in calf as a heifer and were present at the second joining (this was used as a proxy for successfully rearing a calf)
Conception Rate		%	The number of heifers that conceive as a percentage of the number of heifers joined.
Wet and pregnant early	WAPE		Wet and pregnant early, calculated as cows that conceived in the first 2 cycles as a heifer, and conceived in the first 2 cycles of the rebreeding period
Heifer slippage (fetal loss)			Those heifers that were PTIC but did not deliver a calf
Dystocia			A difficult, long or abnormal delivery that requires assistance.
Contemporary Group	CG		Property (e.g. Farm1, Farm 2) by Management Group (e.g. standard or low) by year of birth (2018 or 2019 etc.)
Measurement Event	Event		Time of measurement of animals e.g. weaning, pre-joining, joining.

3.2 Contemporary Group Descriptions

Contemporary groups (CG) were defined by property, year of birth and any management group details from each property, i.e. different locations (north vs south) or feed on offer (high vs low). There were 26 contemporary groups from nine properties. Eight properties measured two drops of heifers, 2018 and 2019 born animals whilst at Farm 8 five drops were measured: 2018 - 2022 born heifers. Farm 3 ran an experiment on 2018 born heifers with two different post-weaning pasture systems and so had two cohorts that year. Farm 7 first cohort (7.1) heifers were artificially inseminated with no back-up bull. This resulted in an unusually low conception rate so was removed from all analyses, leaving 25 contemporary groups (Table 3).

Table 3. Summary statistics for heifer joining measures, number of animals and early conception rate in the first six weeks in each contemporary group

Farm	Cohort	Property / Treatment	Contemporary group	count	weight	ADG pre-joining	ADG during joining	height	BCS	fat	Conception rate
Farm 1	**Cohort 1**	**Property B**	**Farm 1.1.B**	72							68.1%
	Cohort 1	**Property M**	**Farm 1.1.M**	112	323	0.35					70.8%
	Cohort 2	**-**	**Farm 1.2**	179	314	0.34		1223	2.94	5.3	77.7%
Farm 2	**Cohort 1**	**-**	**Farm 2.1**	124	353	1.17	0.65		2.68	3.7	86.2%
	Cohort 2	**-**	**Farm 2.2**	99	310	1.67	0.80				80.2%
Farm 3	**Cohort 1**	**Std nutrition**	**Farm 3.1.H**	107	400	1.10					86.0%
	Cohort 1	**Low nutrition**	**Farm 3.1.L**	91	353	0.74					75.6%
	Cohort 2	**-**	**Farm 3.2**	377	375	0.76		1214	3.16	3.41	71.6%
Farm 4	**Cohort 1**	**-**	**Farm 4.1**	141							
	Cohort 2	**-**	**Farm 4.2**	307	294	-0.18	-0.18				50.2%
Farm 5	**Cohort 1**	**-**	**Farm 5.1**	90	328	1.00	-0.37			4.52	62.3%
	Cohort 1	**Property B**	**Farm 5.1.B**	37	317	0.90	-0.39			3.95	69.4%
	Cohort 2	**-**	**Farm 5.2**	99	327						84.7%
Farm 6	**Cohort 1**	**-**	**Farm 6.1**	170	431	1.34		1273	3.58	7.21	57.8%
	Cohort 2	**-**	**Farm 6.2**	134	420	1.34	0.67	1256	3.7	5.27	70.5%
Farm 7	**Cohort 2**	**-**	**Farm 7.2**	161	392	0.94	0.85	1224	3.46	3.93	65.4%
Farm 8	**Cohort 1**	**South**	**Farm 8.1.S**	1208							65.9%
	Cohort 2	**North**	**Farm 8.2.N**	1410					3.39		64.2%
	Cohort 2	**South**	**Farm 8.2.S**	1036	360			1246	3.39	4.13	66.8%
	Cohort 3	**North**	**Farm 8.3.N**	2068	320			1068			70.3%
	Cohort 3	**South**	**Farm 8.3.S**	957	321			1084			77.1%
	Cohort 4	**North**	**Farm 8.4.N**	1243	323	0.85	1.58	1188	3.38		85.5%
	Cohort 4	**South**	**Farm 8.4.S**	440	310	0.97	1.84	1150	3.29		85.2%
	Cohort 5	**-**	**Farm 8.5**	2538	336	1.74	0.93		3.23		68.0%
Farm 9	**Cohort 1**	**-**	**Farm 9.1**	124	355	1.40	0.40				74.0%
	Cohort 2	**-**	**Farm 9.2**	122	354	1.11	0.55		2.66	3.19	85.5%

3.3 Weight Group Descriptions

Weight groups were created to investigate the effect of weight on heifer conception. Weight groups were defined as less than 300 kg at joining (<300kg), between 300 and 350 kg (300-350kg), between 350 and 400 kg (350-400kg), and greater than 400 kg (>400 kg). A summary of the numbers of animals, average joining weight, variation and range is found in (Table 4).

Table 4. Summary of number of heifers, joining weight (kg), variation and range in joining weight for each of the weight groups created.

Weight Group	# Heifers	Mean	Min	Max	SD
<300kg	1695	281	215	299	15.2
300-350kg	4188	325	300	349	14.0
350-400kg	2324	370	350	399	13.8
>400kg	644	426	400	528	21.0

3.4 Residual Weight

Since the variation in fat in heifers at joining was low, residual weight was created as an additional trait. The residuals within each contemporary group were estimated from a regression of joining weight regressed on height. Residuals are the difference between the measured value for joining weight and the predicted value from the equation, where all the heifers that have weights above the line are heavier than predicted for their given weight, and all animals below the line lighter for a given joining weight (Figure 1). The units for residual weight are kg and indicate whether an animal is heavier (positive residual, above the line) and likely to be in better condition or lighter (negative residual, below the line) for their measured height.

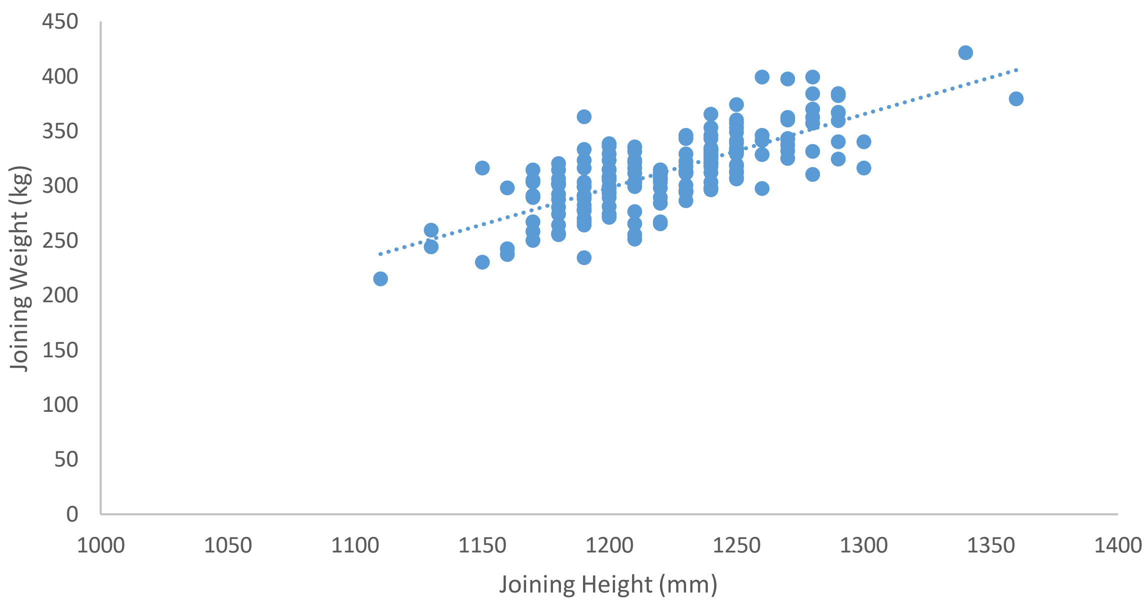

Figure 1. Regression of joining weight on joining height to determine the residual weight for Farm 2.1.

3.5 Average Daily Gain Pre-Joining Groups

Average daily gain (ADG) groups were created to further investigate the effect of ADG in the third trimester of gestation on heifer assistance. ADG groups were defined as less than 0.0kg/day (<0.0 kg/day), 0.0kg/day to 0.5kg/day (0.5 kg/day), 0.51kg/day to 1.0kg/day (1.0 kg/day) and >1.0kg/day (>1.0 kg/day). A summary of the numbers of animals, average ADG, variation and range is presented (Table 5).

Table 5. Summary of number of heifers, average ADG, variation and range in ADG for each of the ADG groups created.

ADG Group*	# Heifers	Mean	Min	Max	SD
<0.0 kg/day	204	-0.17	-0.50	-0.01	0.13
0.5 kg/day	672	0.25	0.00	0.50	0.14
1.0 kg/day	361	0.69	0.50	0.99	0.13
>1.0 kg/day	129	1.23	1.00	1.78	0.19

* Data provided are from Farm 8 (a Spring calving herd) only

3.6 Mature Cow Weight Traits

3.6.1 Project Reference Weight (PRW)

Angus Australia record the breeding value estimation for MCW at 5 years of age, measures on the majority of cows in the project ceased at the third pregnancy scan when cows were 3.5 years of age. Cow size within herds was relatively uniform so a new trait 'project reference weight' (PRW) was created as an indicator of MCW. Project reference weight estimated by taking the residuals from a regression of weight on body condition score at 3.5 years of age. The residuals of the regression were added to each animals predicted weight at condition score of 3. This gave an estimated weight at 3.5 years of age for each animal adjusted to a standard body condition score of 3.

3.6.2 Estimated Reference Weight (RW)

Cows continue to grow well beyond 3.5 so to further investigate and quantify cow growth two cohorts of cows (n = 555 and n = 989) from Farm 8, were re-measured at pregnancy scan 4 at 4.5 years of age. As per the PRW measure, weight was regressed on body condition, at 4.5 years of age, the residuals of the regression were used to adjust individual weights to a condition score 3. At this subsequent measure cows were not taller than from the year before but were an average of 7.5% heavier. A new trait was created 'estimated reference weight' (ERW) in which 7.5% was added to the project reference weight (PRW, weight at BCS 3 at 3.5 years of age).

3.7 Estimation of Green Feed On Offer

Pasture sampling early in the project included pasture sampling at key measurement points; calving and joining. This measurement included feed on offer (FOO), kg of dry matter per hectare and per head and measurement of quality by wet chemistry. As previously described, pasture measurements ceased shortly after the project had commenced at most locations due to difficulty especially during COVID restrictions limited support staff visits, so green FOO was estimated using satellite data from the Flurosense website (Regrow) and heifer weight and FOO were plotted over time.

The area of a farm or paddocks was selected on the map and submitted for the time the heifer project was running. The normalised difference vegetation index (NDVI) for that area was then downloaded. Green FOO for each day for a specific area was calculated from the NDVI using the following equation (Kahn 2017):

$$\text{Green FOO (kg DM/ha)} = \text{FOO}=71.35e^{4.88*\text{NDVI}}$$

3.8 Statistical Analyses

All analyses were performed using ASReml-R (version 4; Butler *et al.* 2017). Due to the binary nature of conception rate, lactating and WAPE, a generalised linear model was fit to the data with a logit link function, where the implicit residual variance is on the underlying scale $\pi^2/3$. The predicted means from the logit transformation are on the transformed scale that are then back transformed. Season was defined by three levels (Autumn, Spring calving herds and Farm 8, also a Spring calving). Farm 8 was included as an additional season factor level to prevent the large amount of data from a single farm overpowering the results for Spring calving herds.

3.8.1 Heifer Conception Analyses

Approach 1

The first two approaches analysed early heifer conception, which was defined as those animals that were scanned as pregnant within the first 6 weeks (2-cycles) of the heifer joining period. A univariate general linear model was used in the first approach used to determine the relationship between heifer conception rate and joining weight, body condition score (BCS), rib fat, height, and average daily gain pre-joining (ADG pre-join) and during joining (ADG join). All available data (i.e., across all sites) were used where season (Autumn, Spring and Farm 8), and contemporary group and any significant 2-way interactions were included as fixed factors and the covariate, and the interaction between season and covariate also included as fixed effects. A multiple linear regression was performed that included all significant covariates and interactions, however only 2336 heifers from five contemporary groups contained all data.

Approach 2

The second approach used the weight groups (Table 5) as a factor in a binary logistic regression. The fixed effects fit in the model included season, contemporary group and weight group, and the covariates (joining weight, height, BCS, ADG pre-join, ADG join) included in separate models. As in Approach 1, a multiple linear regression was run that included significant covariates and interactions from the individual analyses.

3.8.2 Re-Breeding Analyses

Approach 1

The first approach analysed project reference weight data in a binary logistic regression to determine the relationship between the proportion of project reference weight and heifer cycle. Contemporary group and the 2-way interaction were included as fixed effects.

Approach 2

The second approach was to quantify how much heavier a cow would be for every one increase in body condition score at 3.5 years of age. Data defined by a univariate general linear model to determine the relationship between weight and BCS at the third pregnancy scan. The fixed effects included CG; two-way interactions were included in the model if they were significant P<0.05.

3.8.3 Mature Cow Weight Analyses

Mature cow weight was analysed in two different ways. To determine if there was as significant difference between heifers that conceived early in the joining period (cycle 1 & 2) and those that conceived later (cycle 3) and whether this was the same across seasons (approach 1). The aim of the second approach was to determine if there was a relationship between MCW and BCS.

Approach 1

The first approach analysed project reference weight data in a binary logistic regression to determine the relationship between the proportion of project reference weight and heifer cycle. Contemporary group and the 2-way interaction were included as fixed effects.

Approach 2

The data were analysed using a univariate general linear model to determine the relationship between MCW and BCS at the third pregnancy scan. The fixed effects included CG, body condition score (included as a covariate) and the interaction between BCS and CG were included in the model if they were significant P<0.05.

3.8.4 Heifer Assistance Analyses (Farm 8 only)

Approach 1

The first approach analysed heifer assistance data defined by a univariate general linear model to determine the relationship between heifer assistance and joining weight, pre-calving weight, pre-calving BCS and ADG during the third trimester. Contemporary group and the 2-way interactions were included as fixed effects. A multiple linear regression was performed that included all significant covariates and interactions.

Approach 2

The second approach used the weight groups and ADG groups as described in (Table 17) as factors in a binary logistic regression. The model included the fixed effects of ADG group, CG and weight group.

3.8.5 Calf Weaning Weight Analyses

First Calving Outcomes

Approach 1

Weaning weight for Farm 1 and Farm 8 was analysed separately for each site. The first approach analysed calf weaning weight in a binary logistic regression to determine the relationship between calf weaning weight and heifer cycle. The fixed effects included CG, sex and heifer cycle. Two-way interactions were included in the model if they were significant (P<0.05).

Approach 2

The second approach was to quantify how much heavier a calf would be at weaning if it conceived earlier in the joining period. This approach was similar to approach 1 although heifer cycle was replaced with date of birth. Two-way interactions were included in the model if they were significant (P<0.05).

Approach 3

The third approach was only analysed for Farm 8 and was to determine if those heifer calves born to 1st cycle heifers maintained the weight advantage through to joining. This subset of data only included calf weaning weight for those that had a joining weight. The data were analysed with a binary logistic regression to determine the relationship between calf weaning weight and calf joining weight and heifer cycle. The fixed effects included CG and heifer cycle. Two-way interactions were included in the model if they were significant (P<0.05).

Second Calving Outcomes

Weaning weight of second calf was only analysed for Farm 8. The data analysed in a binary logistic regression to determine the relationship between second calf weaning weight and heifer cycle. The fixed effects included CG, sex and heifer cycle. Two-way interactions were included in the model if they were significant (P<0.05).

3.8.6 Correlation

The data were split into records that were recorded prior to first calving (heifers) and anything recorded post first calving (cows). A series of bivariate analyses were conducted to determine the correlations between heifer and cow weight, BCS, height and fat. The fixed effects in the model included CG, event (time of measurement of animals) days (from first joining) as fixed effects and ID as a random term.

3.9 Economic Analyses

The need for informative decision support tools that are easy-to-use, adaptable and informative has informed the approach taken to model southern Australia commercial beef enterprises productivity and profit. Based on discussions with collaborating producers the functionality includes:

a) Options for different levels of supplementary feed (total ME and cost)
b) Different sale prices (& differential) for cull stock, e.g. small vs. large differences in values of pregnant vs. not pregnant heifers
c) Different age profiles of herds

Four stages of development have been undertaken:

a) Building a stochastic model to simulate the biological component on a beef production system to weaning.
b) Taking the outputs from the stochastic model and informing a farm gross margin and stock trading statement. This has enabled various input changes to be evaluated.
c) Taking the relationships (results) from the cow performance and pasture data in this project and testing against the model.
d) Collectively building a pre-filled template for beef producers and their advisors to use to inform management practices.

The Excel based financial model of herd structure and value impacts has been developed to allow producers and advisors to test the financial implications of various herd management/production strategies associated with heifer pregnancy rates and maiden cow re-breeding rates. The Excel financial model is fully customisable, and individual businesses can enter their own data on business production, income, and costs into the model to predict outcomes.

The model has a single input page which allows producers and advisors to enter information in a series of sequential steps by firstly entering information on the herd structure and potential income, followed by feed costs:

1) set the property size, or area grazed by cattle

2) record the number of animals in each age group on hand at the start of calving

3) enter the expected numbers of animals sold from each age group

4) record the expected sale prices

5) enter the number of replacement heifers required

6) include the anticipated calving/weaning rate

7) enter the total cost associated with growing pasture (seed, fertiliser, chemicals, machinery costs)

8) include the quantity and cost of supplementary feed used

The herd health and marketing costs have been pre-entered into the model, as a standard set of practices, which are added to the gross margin calculation, on a per cow basis.

Total farm gross margin has been used as the measure of comparison as it captures income generated from all livestock sales, any change in inventory values associated with changing herd structure, and all variable costs for the enterprise.

Gross margins have been calculated using the financial model on each of the properties, for both cohorts (2018 and 2019 heifers). Calculations have been made based on the pregnancy rates achieved in heifers, and the re-breeding rates of first calvers to assess the effect of WAPE on overall business profit. Cost of pasture and supplementary feed have also been included for each of the individual properties. Total farm gross margin, gross margin per hectare and gross margin per cow have been calculated for each of the properties that have a WAPE result reported. The gross margins have all been calculated for two pricing scenarios 1) the current market prices, with a market premium of $500/head for mated heifers, and 2) the current market prices, with no premium for mated heifers.

4. Results

4.1 Growth Paths of Heifers

At the conclusion of this project data has been collected on over 14,000 heifers which far exceeds what was initially planned (9 producers x 2 cohorts x 100 heifers per cohort = 1800 heifers). Farms 1, 2, 3, 4, 5, 6, 7 & 9 contributed 220 to 570 heifers each while Farm 8 contributed 11,500 heifers (Table 1). One of the objectives of this project was develop a comprehensive understanding of the optimum growth path of the modern heifer phenotype to achieve WAPE. To evaluate the growth path of the modern heifer weight at key time points; weaning, pre-joining and joining, re-breeding and subsequent re-breeding were examined.

Growth paths demonstrate the change in body weight over time; from weaning through to 3.5 years of age. The average heifer growth path from weaning through to the third pregnancy scan varies between contemporary groups (Figure 2). It is evident that variation in body weight was significant between contemporary groups at the first joining, thus demonstrates various growth paths from weaning to 14 months of age.

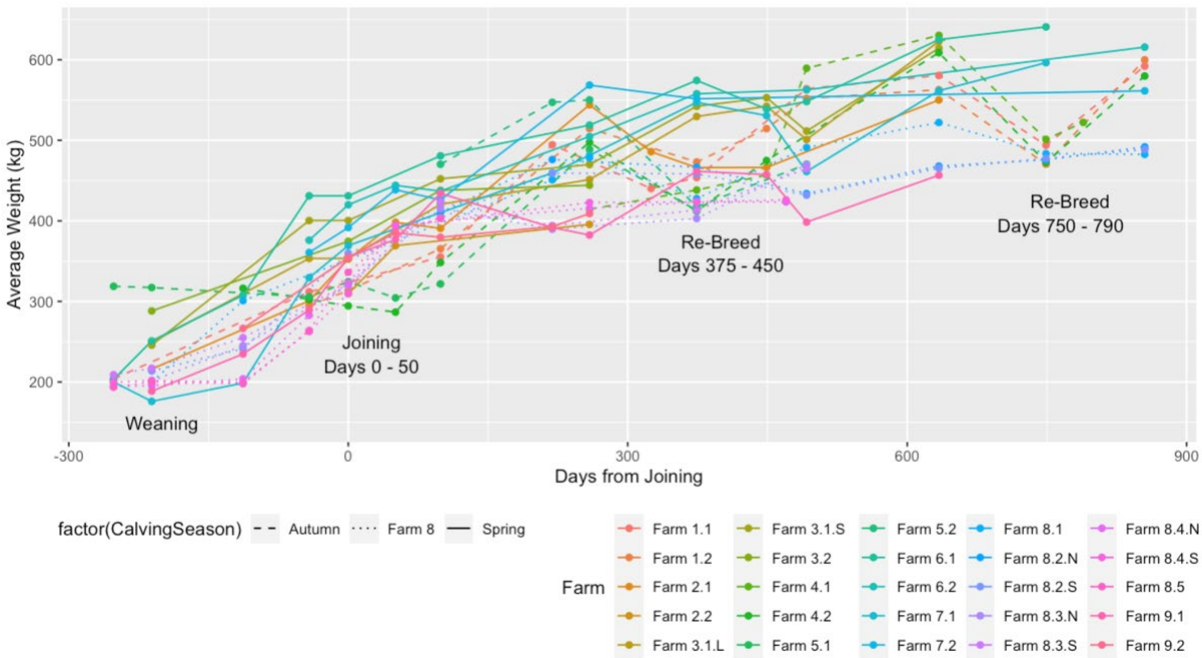

Figure 2. Variation in growth path of all animals by contemporary group

The average growth for Spring calving herds (Figure 3; orange line) compared to Autumn calving herds (Figure 4; blue line). Farm 8 (Figure 5; grey line, also a Spring calving herd) is presented due to its high number of heifers and unique climate and growing season. Estimated green FOO is also shown for Spring calving (orange columns), Autumn calving (blue columns) and Farm 8 (grey columns). Calves born in Spring were weaned as green FOO increased (orange bars) and experienced weight gain before and during joining (orange line). In contrast, calves born in Autumn are weaned as green FOO starts to decline (blue bars) and weight is maintained or declines until after joining (blue line). Calves born at Farm 8 follow a similar growth pattern (grey line) to other Spring calving herds except delayed by a month.

Analysis of the data summarised in these figures (growth pre- joining, growth during joining and joining weight) will help to establish the relative importance of reaching a target joining weight for joining or growth before/ during joining.

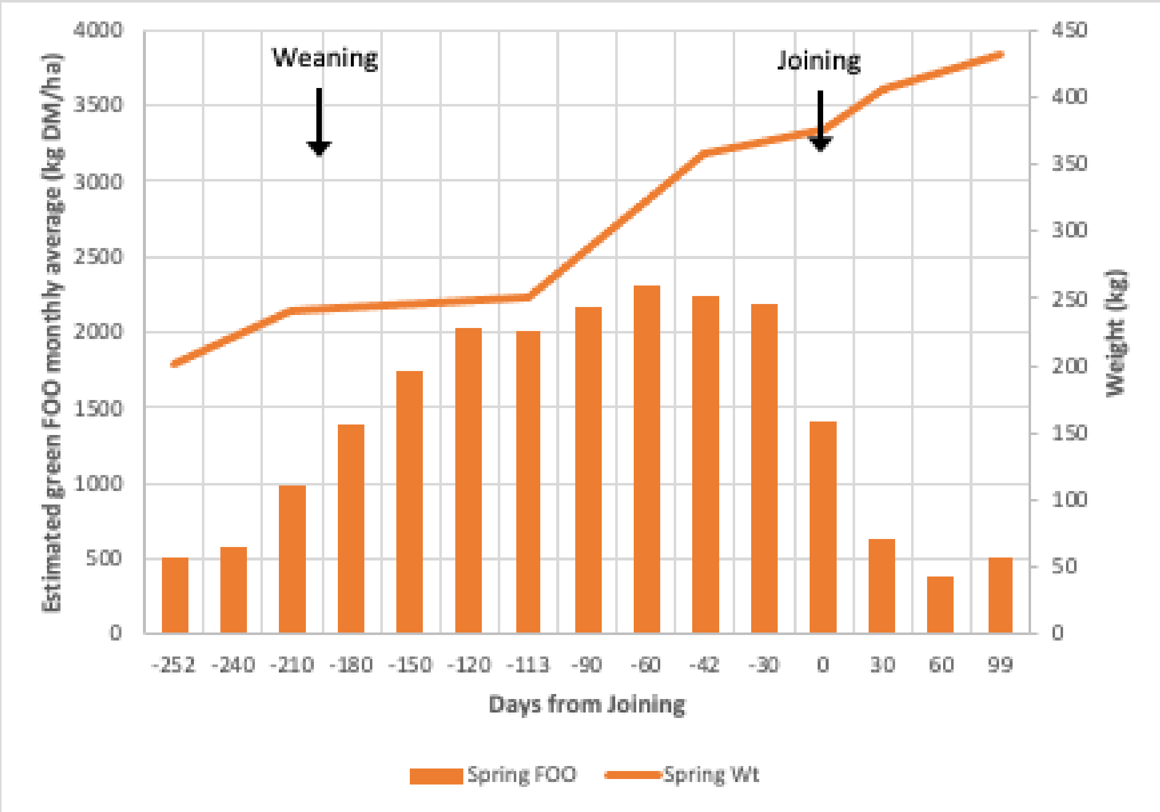

Figure 3. The average weight of spring calving herds (orange line) from weaning (-210 days before joining), through joining (0 to 50 days) to the first pregnancy scan (99 days after joining). The change in estimated green FOO for spring calving herds (orange columns) is also shown.

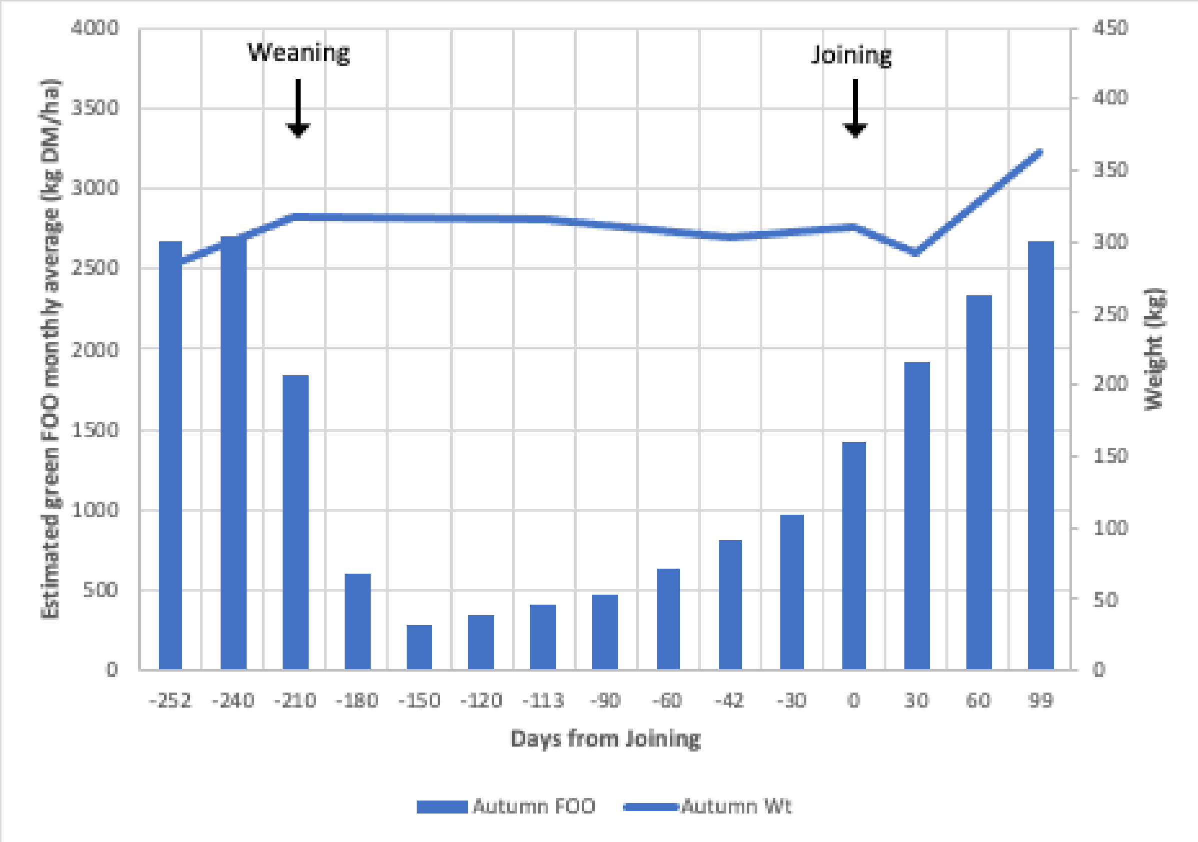

Figure 4. The average weight of autumn calving herds (blue line) from weaning (-210 days before joining), through joining (0 to 50 days) to the first pregnancy scan (99 days after joining). The change in estimated green FOO for spring calving herds (blue columns) is also shown.

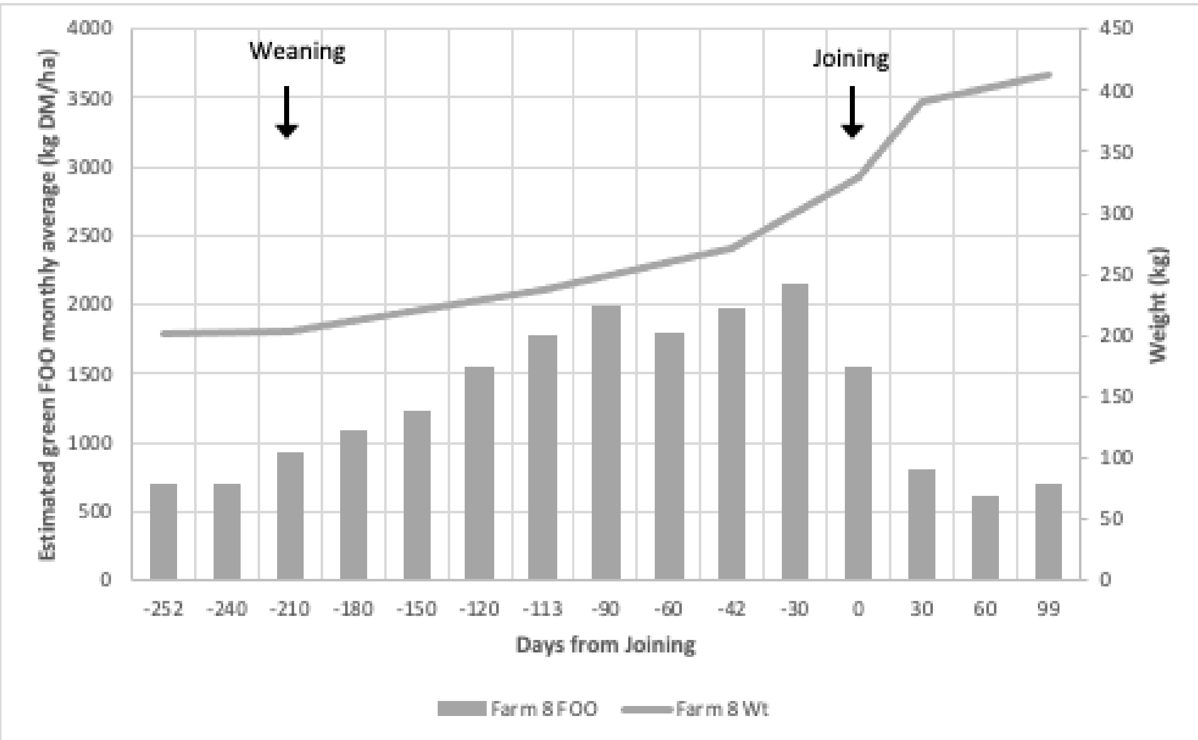

Figure 5. The average weight of Farm 8 heifers (grey line) from weaning (-210 days before joining), through joining (0 to 50 days) to the first pregnancy scan (99 days after joining). The change in estimated green FOO for spring calving herds (grey columns) is also shown.

4.2 Correlations Between Growth and Composition Traits

Based on work that was done in the Beef CRC (Donoghue et al. 2018 and De Faveri et al. 2018) and subsequent work on genetics of cow body composition, it is expected that correlations between composition measures for heifers are highly correlated with each other and also for cows. This means that the measures within heifers and within cows will be highly repeatable. However, the correlations between heifers and cows are less likely to be correlated with each other resulting from the large physiological impact of pregnancy and lactation. Thus, data was split into measurements taken pre-calving (first parity) and those subsequent.

Fitting individual as a random effect in the model allows for estimation of repeatability and the repeatable covariances between traits. Heifers varied more in height but less in weight than cows (Table 6). Cows also had slightly more variation in condition score and fat depth. The model fitted included fixed effects of contemporary group (CG, e.g. Farm 1), measurement event (e.g. joining), days from joining (NB pre-joining measures have negative days) and CG x Event and CG x days interactions.

Table 6. Phenotypic variance and repeatability (%) of measures. The repeatability demonstrates the accuracy of multiple measures within heifers or cows and the correlation between heifers and cows represents the substantial physiological effect of the first pregnancy and lactation.

	Heifers				H vs C	Cows			
	Anim #	Rec #	Pheno SD	Repeat (%)	Cor	Anim #	Rec #	Pheno SD	Repeat (%)
Wt (kg)	11193	15969	33	69	0.66 ±0.01	7508	20618	52	70
BCS	10802	28275	0.31	19	0.50 ±0.02	6367	18913	0.4	38
Ht (mm)	7829	15969	43	73	0.87 ±0.01	3881	8526	36	56
Fat (mm)	4852	8538	1.5	47		3143	6885	2	47

Both between animal and phenotypic correlations are reported in a similar manner to reporting genetic and phenotypic correlations. Between animal correlations based on repeated measures include additive genetic, non-additive genetic and permanent environmental effects. Often the additive genetic is the largest component. Weight and height were highly repeatable (>56%) with fat depth slightly less so (47%) and body condition score slightly less again in cows (38%) but poorly recorded in heifers (19%).

For heifers, weight and height were most highly correlated (Table 7). BCS and fat were moderately correlated with weight and each other. Not surprisingly, height was not correlated with fat depth. For cows, the correlations between weight, BCS and fat were stronger reflecting greater variation in condition than for heifers. There was a weak correlation between height and fat depth. The between animal correlations are less affected by measurement error and so were higher for all trait combinations. As expected, both the between animal and phenotypic correlations reported herein are very similar to the genetic and phenotypic correlations reported by Donoghue et al. (2018).

The results allow calculation of how much weight is associated with other traits which is especially of interest for cows. A 1 mm height was associated with just 0.7 kg heavier cows. A 1-score change in condition was associated with 69kg heavier weight and 2.9mm greater fat depth in cows. In heifers the equivalent values were roughly half (37kg and 1.4mm).

Table 7. Between animal (repeatable, below diagonal) and phenotypic (above diagonal) correlations between traits. Repeatable correlations represent correlations based on accurate measures whereas phenotypic includes measurement variation (or error).

	Heifers				Cows			
	Wt	BCS	Ht	Fat	Wt	BCS	Ht	Fat
Weight (kg)		0.35	0.51	0.28		0.53	0.46	0.48
Body condition score	0.62		0.15	0.30	0.75		0.18	0.57
Height (mm)	0.68	0.31		0.07	0.71	0.31		0.13
Fat (mm)	0.41	0.60	0.12		0.63	0.82	0.21	

4.3 Mature Cow Weight

Mature cow weight describes the weight of an individual cow at five-years-old. In this project the definition is extended to be at a standard intermediate condition score 3 (1-5 scale). There is a large variation in MCW within and between breeds so current industry recommendations suggest that heifers should reach 60-65% of their mature cow weight (MCW), 30-to-45-day pre-joining to achieve conception rates greater than 85%. This because of the relationship between weight, fatness and heifer conception rates. Larger framed types with heavier MCW have less fat cover at a given weight in comparison to moderate types. Fat is only stored as the animal begins to mature (Schumacher *et al.* 2022) and will not start to accrue until muscle and bone growth decreases (Berg and Butterfield 1968), and energy supply is greater than the demand (Nürnberg *et al.*1998). More recent studies have demonstrated heifers grown to just 50 to 53% of MCW with no detrimental effects on reproduction (Funston and Deutscher, 2004). Heifer measurements in the project ceased at the third pregnancy scan when heifers were 3.5 years of age. Cows with heavier mature cow weights are also heavier at 3.5 years of age so project reference weight (PRW) was used as an indicator of MCW.

Five of the nine sites supplied a weight and condition score at the third pregnancy scan (3.5 years of age), and therefore PRW was calculated for 10 contemporary groups (Table 8). The average PRW ranged from 506 kg (Farm 8) to 607 kg (Farm 6). The coefficient of variation was low and similar for all contemporary groups ranging from 6.9% to 9.1%.

Table 8. Average project reference weight (kg) for contemporary groups.

ContGrp	Mean	Min	Max	SD	CV	Count
Farm 1.1.B	551	423	627	44	8.0	36
Farm 1.1.M	540	454	646	43	8.0	66
Farm 1.2	572	573	715	52	9.1	111
Farm 4.2	565	465	705	43	7.6	107
Farm 6.2	607	522	760	48	7.9	62
Farm 8.1.S	507	374	656	43	8.5	677
Farm 8.2.N	512	373	647	40	7.8	806
Farm 8.2.S	511	322	719	44	8.6	555
Farm 8.3	511	373	651	40	7.8	758
Farm 7.2	534	450	622	37	6.9	55

Wright and Russell (1984) reported an 81 kg increase in body weight for every 1-score increase in BCS (1-5 scale) and herein the combined project data found an 87 kg increase for every BCS. The interaction between contemporary groups (CG) and BCS was significant (P=<0.0001) so that the increase per score varied between groups (Table 9) ranging from 25 kg (Farm 6) to 104 kg (Farm 8.3.S). This variation is likely the result of several factors; firstly, BCS is a subjective measure thus varies across multiple scorers and within a scorer i.e. when the herd average BCS is low it is possible that heifers with low condition scores are assigned a higher score, due to cognitive bias. Secondly, the range of weights between sites varied significantly (128 kg to 286 kg) across four BCS groups, and therefore the average weight per BCS varied significantly between sites. Similarly, sites that had significantly heavier minimum weights (602 kg Farm 6) and assigned a BCS of 2.5 were compared to heifers from sites with lighter minimum weights (459 kg Farm 8.3.S) assigned a BCS of 2.5. In addition, heifer numbers were low in low (<2.5) and high (>3.0) BCS groups. Farm 6.2 had just 55 heifers in the analysis, with less than 20 heifers in low and high BCS groups, similar heifer numbers were seen at Farm 7.2 and Farm 1. Regression coefficient across contemporary groups at Farm 8 were similar within cohort 1 and 2, cohort 3 had an additional 30 kg per 1-score increase in body condition score, this prediction is likely the result of the lower body weight (40 kg) of heifers in BCS 2.0 compared to earlier cohorts.

Table 9. Regression coefficient for increase in body weight per one increase in body condition score for contemporary groups.

Contemporary group	Regression coefficient (kg)
Farm 1.1.B	103
Farm 1.1.M	100
Farm 1.2	99
Farm 4.2	78
Farm 6.2	25
Farm 7.2	46
Farm 8.1.S	70
Farm 8.2.N	66
Farm 8.2.S	68
Farm 8.3.N	96
Farm 8.3.S	104

To further investigate MCW, height at 3.5 years of age was fit as a covariate effect in the model. Height was measured for just 3 contemporary groups and reduced the number of heifers in the model to 809. Height ranged from 120 cm to 150 cm, heifers from Farm 7 on average were shorter (125 cm) than those at Farms 4 and 8 (139 cm and 135 cm respectively). This is unlikely due to a breed effect as both Farms 7 and 8 are Angus with Farm 4 Angus, Hereford and Shorthorn. Height accounted for variation in the model, and when adjusted for the interaction between CG and BCS was less significant (P=0.04), however, when this smaller data was subset and height was removed from the model, the interaction between contemporary group and BCS was less significant (P=0.02) than in the combined data set (P=<0.0001). Weight increased by 4.8 kg for every 1 cm increase in height, therefore, the 30 cm range in height would see a 144 kg difference in body weight. Heifers that are taller are heavier than those shorter.

All herds except for Farm 5 were able to supply a MCW herd average estimate (Table 10). In some cases, producers were able to weigh and ideally condition score mature cows that were part of the project and get an average MCW for the herd, whilst others were able to provide a weight on project cows at 3.5 years of age. For those contemporary groups that PRW was able to be predicted and ERW was calculated (Table 10). Estimated reference weight calculations were similar (+/- 20kg) in those herds where producers were able to supply an estimated MCW.

Table 10. Average predicted reference weight (PRW) estimated reference weight (ERW) and mature cow weight for each property and or contemporary group.

ContGrp	PRW average	ERW average	Producer Estimate	Note
Farm 1.1.B	551	592	600	
Farm 1.1.M	540	581	600	
Farm 1.2	572	615	600	
Farm 4.2	565	607	618	Non-project cows, adjusted to condition score 3, 4 years of age and above
Farm 6.2	607	653		
Farm 8.1.S	507	555*	550	Project heifers, adjusted to condition score 3 at 4.5 years of age
Farm 8.2.N	512	544*		Data from project heifers, adjusted to condition score 3 4.5 years of age
Farm 8.3	511	549		
Farm 7.2	534	574	570	
Farm 3			595	Non-project cows, adjusted to condition score 3, 4 years of age and above
Farm 2			500	
Farm 6			620	
Farm 9			575	

*Actual weight at body condition score 3 at 4.5 years of age

Proportion of PRW was calculated for those heifers that had PRW and heifer joining weight recorded. There was a significant interaction (P=0.03) between season and cycle, this interaction describes the difference in proportion of PRW per cycle, between seasons. Spring calving herd and Farm 8 had a greater proportion of PRW in each cycle compared to Autumn calving herds (Figure 6). The significant interaction (P=0.03) between season and contemporary group describes the difference in PRW between contemporary groups. Given whole-herd genetic progress is slow, this result must reflect the variation in growth paths or measurement differences (e.g. assigning BCS) between contemporary groups (Figure 2).

It was expected that 1st cycle heifers would have had higher proportion of PRW at heifer joining when compared to later cycles and heifers that pregnancy tested empty (PTE). Predicted reference weight and ERW was not able to be calculated for those that did not conceive due to being culled. Cow weight at 3.5 years of age is just an indicator of MCW, thus predicted proportion of ERW was investigated. Similar to the PRW results, there was no difference in proportion of ERW between cycles, this result may be due to higher mature cow weight animals 'culling themselves' from the system i.e. those with higher MCW that get in calf in the 3rd cycle as a heifer and do not re-breed in subsequent pregnancies are culled thus not present in the data set at 3.5 or 4.5 years of age.

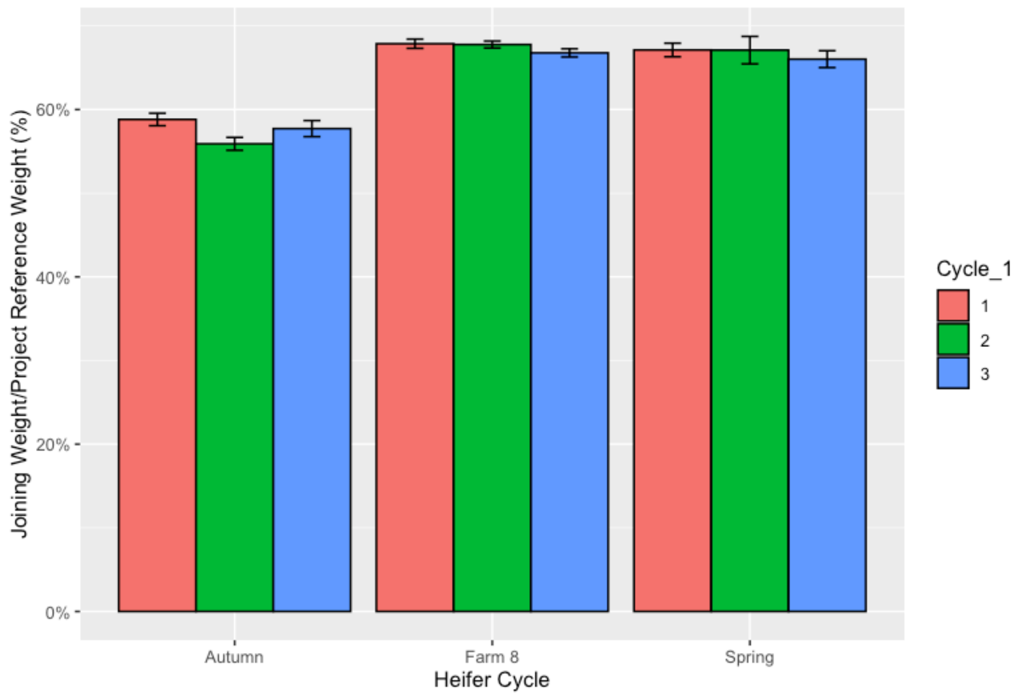

Figure 6. Joining weight as a percentage of project reference weight, for each heifer cycle (1 -3) in each season

4.4 Heifer Conception

4.4.1 Predictors of Heifer Conception

The first analysis approach included only 1 covariate (weight, height, body condition score, and rib fat at joining, and ADG pre-joining or ADG during joining) in the model with the fixed effect season and CG, to determine what covariates were significantly influencing early conception rate (conceived in the first two cycles) to be included in the multiple linear regression. Since only 2337 heifers from 5 contemporary groups contained all covariates (joining weight, height, condition score, ADG pre-joining and during joining), a series of analyses were performed to determine the effect of the covariates after removing the variation in conception rate that was explained by joining weight.

Near all body composition measures were significant (Table 11) as main effects or as part of an interaction with season. The main effect of season and the interaction between season and weight, residual weight, BCS and ADG during joining was significant. When weight was fitted as a fixed effect all covariates were not significant thus weight was better to describe the variation in conception.

Table 11. F-values for single covariate analyses of early conception rate (conceived in two cycles) when regressed against weight, height, body condition score, rib fat at joining, and average daily gain pre-joining and during mating.

	Weight	Height	Res_Wt	BCS	ADG Pre-Join	ADG Mating
Weight		11.30***		28.16***	45.08***	20.14***
Covariate	11.23***	2.28	14.31***	1.96	3.46	91.07***
Season	22.86***	42.48***	43.93***	7.73***	2.50	1.99
CGRP	19.30***	16.27***	15.29***	25.33***	11.89***	12.27***
Season x Weight		14.60***		14.15***	17.05***	7.43***
Season x Covariate	11.13***	1.63	1.47	6.63***	4.26*	
Den. DF	8751	4829	4817	5366	4831	4166

Den. DF = denominator degrees of freedom; * P<0.05; ** P<0.01 ;*** P<0.001

The graphs of the results from these analyses are presented below (Appendix 8.3). Briefly, joining weight was the key driver in predicting early heifer conception, and this relationship was stronger in Autumn where joining weights were lighter (Figure 7). The difference between Autumn and Spring calving herds in their response to joining weight is likely influenced by growth prior to and during joining. Compared to Autumn, spring calving herds were growing on average 4.8 times faster prior to joining (1.15 vs 0.24 kg/day; Table 38) and 2.3 times faster during joining (0.67 vs 0.30 kg/day). This resulted in heavier joining weights (around 350 kg) being more important in Autumn calving herds. The results from the analyses above are similar to that of the second analysis evaluating the impact of joining weight as defined by weight groups, and growth prior to and during joining on early heifer conception. However, Approach 2 is easier to interpret and communicate to producers and will be discussed in more detail below.

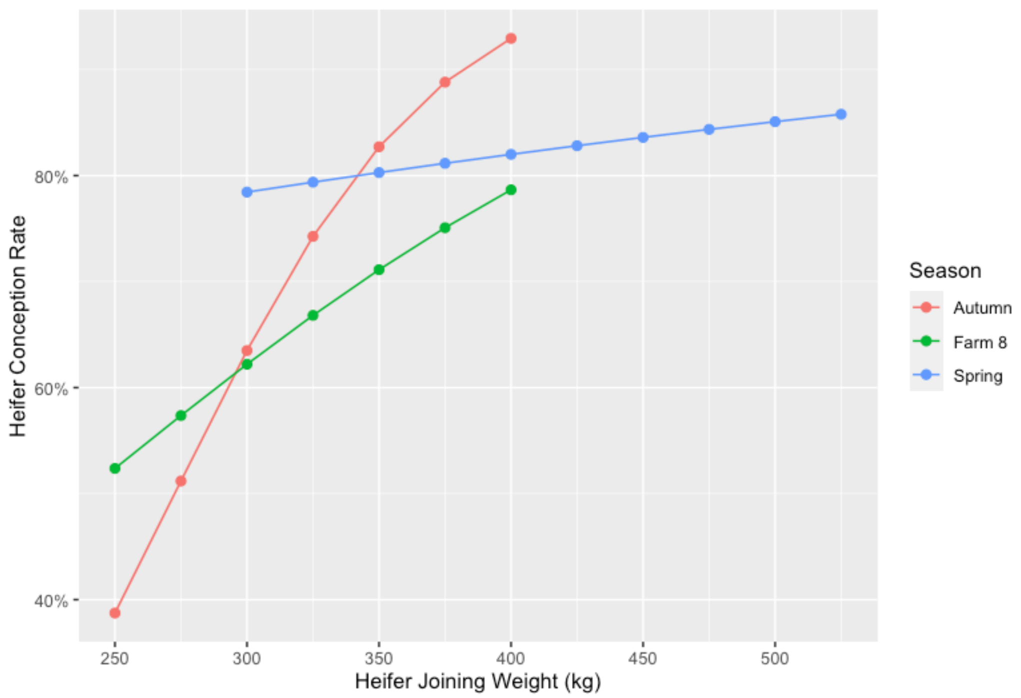

Figure 7. Heifer Conception predicted from Joining Weight

4.4.2 Weight Group

The second analysis approach (Approach 2) investigates the effect of weight on heifer conception in the first six weeks, weight was converted to a factor (weight group). As for the analysis with weight fit as a covariate, the initial analyses were conducted with only 1 covariate (height, body condition score, ADG pre-joining or ADG during joining), and included the fixed effects of weight group, CG and season, to determine what covariates were significantly influencing early conception rate (conceived in two cycles). There was a significant interaction between weight group and start of mating weight, for the light weight group (<300 kg) every extra 10 kg in joining weight was associated with an increase in conception rate of approximately 4.3%, relative to 1.5% for the 300-350 kg weight group, 0.5 % for the 350-400 kg weight group and -0.3% for the heavy (>400 kg group; Table 12;Figure 8).

Table 12. Tests of significance (F-values) for single covariate analyses of early conception rate (conceived in two cycles) when regressed against height, body condition score at joining, and average daily gain during joining.

	Weight	Height	BCS	ADG joining
Weight Group	12.14***	10.24***	4.62**	10.86***
Covariate		2.35	30.09***	90.54***
Season	14.16***	34.01***	11.29***	1.37
Weight Group x Covariate	8.52***	2.04	2.55*	2.08
Season x CGRP	17.63***	16.76***	25.72****	11.43***
Season x Covariate				
Denom. DF	8748	8747	5356	4161

Denom.DF – denominator degrees of freedom ; * P<0.05; ** P<0.01; *** P<0.001

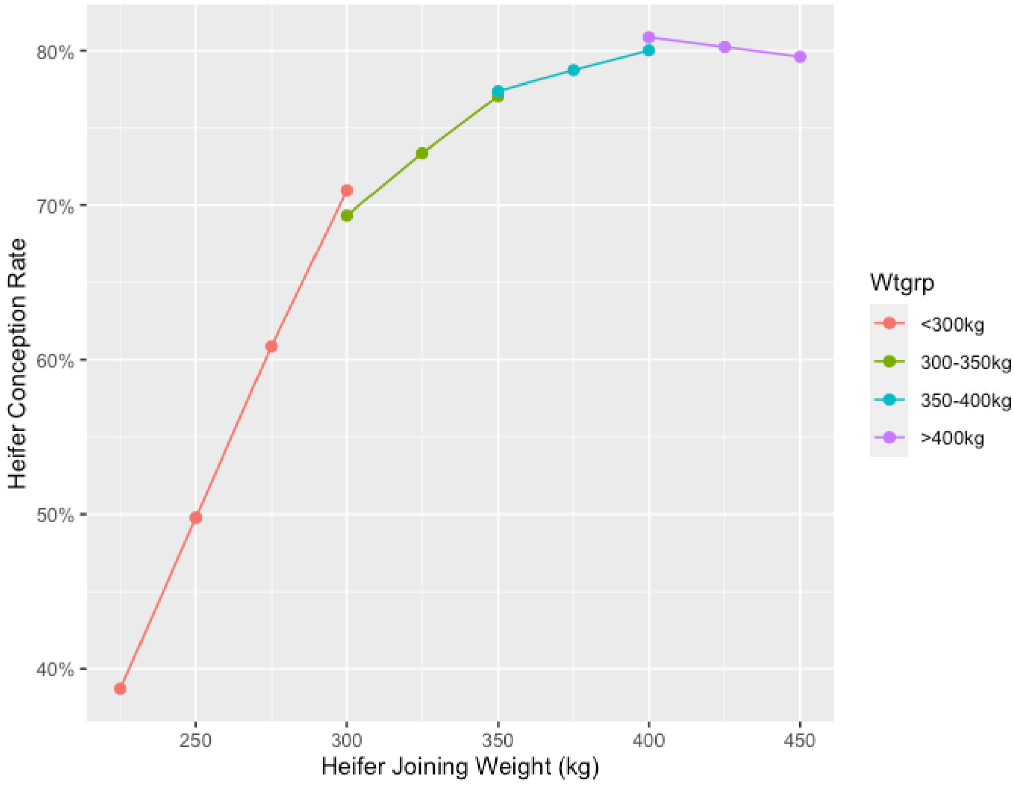

Figure 8. Relationship between heifer conception rate, joining weight within each weight group.

Height was difficult to measure accurately whilst the heifers were in the crush. It was not important for early conception when the model had adjusted for weight. Body condition score was more important for increasing heifer conception rate in the lightweight group (<300 kg) than in those that that were heavier (Figure 9). Weight and fat are key drivers of puberty attainment, thus those in better condition would have greater energy reserves stored in muscle and fat and therefore, had adequate energy to initiate the cascade of events leading to puberty prior to joining increasing early conception. The interaction between weight group and BCS suggests that within each weight group, heifers in greater condition had higher rates of early conception but this was most important for heifers under 300 kg.

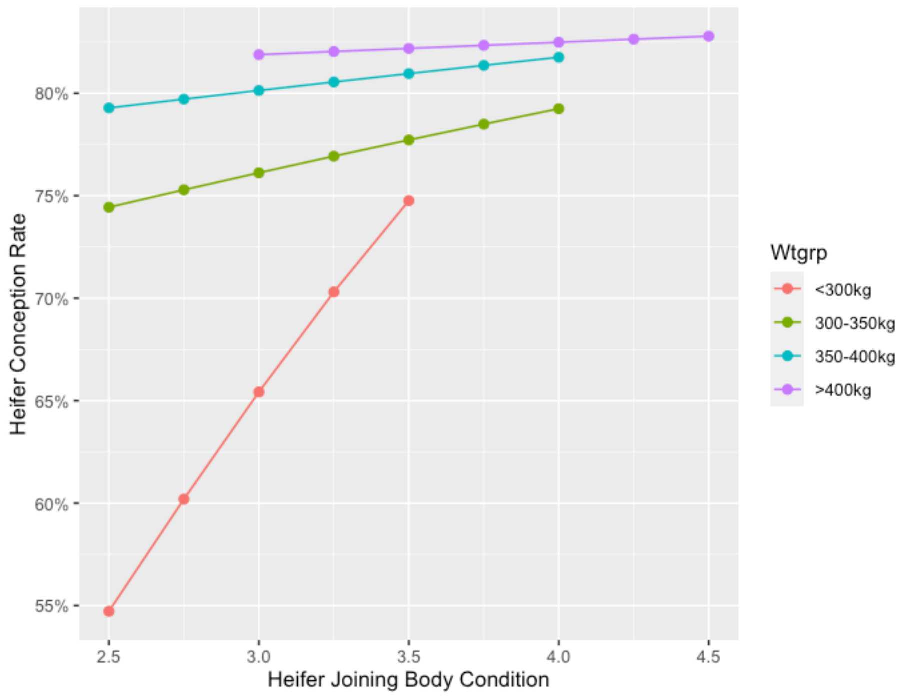

Figure 9. Relationship between heifer conception rate, joining body condition score within each weight groups

The multiple linear regression that included weight group, height, BCS, and ADG during joining, season and CG was fit as a fixed effect. This full model was reduced via stepwise backwards elimination (P<0.05). The final model (Table 13) included weight group, joining weight, and ADG pre-join and during joining. After accounting for differences between weight groups average daily gain during joining was the most important covariate, followed by ADG pre-joining. Both height and body condition score were not important over and above weight and growth. This is likely due to the difficulty in measuring body condition score accurately in young growing animals and the reduced variation compared to measuring body condition in cows. The heat maps of the relationship between early heifer conception and growth pre-joining and during joining for each weight group indicate that for heifers that are below 300 kg, that were not growing prior to joining, growth during joining needs to be at least 2.5 kg/day to obtain conception rates above 80% (Figure 10) which is unlikely to be achieved. During joining gain is also important for the two intermediate weight groups (300-350 kg and 350-400 kg).

Table 13 Tests of significance for multiple linear regression early conception rate (conceived in two cycles) with weight groups, joining body condition score,

Model Terms	DF	F-Value
Wtgrp	3	11.44***
Wtgrp x Weight	4	4.35**
Wtgrp x ADG_Join	4	22.83***
Wtgrp x ADG_PreJoin	4	7.90***

Den DF	3946

a

Average Daily Gain Pre-Joining \ Average Daily Gain During Joining	-0.50	0.00	0.50	1.00	1.50	2.00	2.50
-0.50	44						
0.00	44	52	59			79	84
0.50	45	52	60	67	74	79	84
1.00	45	53	61	68	74	80	84
1.50			61	68	74	80	
2.00				69			
2.50							

b

Average Daily Gain Pre-Joining \ Average Daily Gain During Joining	-0.50	0.00	0.50	1.00	1.50	2.00	2.50
-0.50	57						
0.00	62	78	82	85	88	90	92
0.50	67	74	78	82	85	88	90
1.00	71	69	74	78	82	85	88
1.50		64	69	74	78	82	
2.00			64	69	74		
2.50			59	64			

c

Average Daily Gain Pre-Joining \ Average Daily Gain During Joining	-0.50	0.00	0.50	1.00	1.50	2.00	2.50
-0.50							
0.00			79		84	85	87
0.50		77	80	82	84	86	88
1.00	76	78	80	83	85	86	88
1.50	76	79	81	83	85	87	
2.00	77	79	82	84	85		
2.50	78	80	82	84			

d

Average Daily Gain Pre-Joining \ Average Daily Gain During Joining	-0.50	0.00	0.50	1.00	1.50	2.00	2.50
-0.50							
0.00							
0.50				65			
1.00		66	68	69			
1.50		70	72	73			
2.00		74	75	77			
2.50			79	80			

Figure 10. Heat map of early heifer conception rates for average daily gain pre-joining and during joining for a) <300kg weight group, b) 300-350kg weight group, c) 350-400kg weight group, and d) >400kg weight group

The implication of these results could include alternative feed management options for lighter heifers coming into joining such as supplementary feeding or increased feed on offer during a season of high pasture growth. The costs associated with growing heifers to particular target joining weights are shown in Table 35. Additionally, in a poorer season or when supplementary feed is not an option producers may opt to not join lighter heifers. This result also highlights the importance of understanding the growth path of heifers within an enterprise, inclusion of an additional weight measure ~45 days pre-joining may be a valuable measurement tool for producers to aid important decisions for heifers.

4.5 Heifer Calving Outcomes

Detailed calving outcomes were unable to be collected due to budget constraints that resulted in termination of genomic testing to identify parentage. To partly amend this, on the largest site (Farm 8 a spring calving herd) detailed calving records including; heifer slippage, calving percent, heifer and calf mortality, calving day/pattern and parentage was recorded for four cohorts.

Calving outcomes were recorded for a total of 7,330 heifers that PTIC over four cohorts at Farm 8. There were 5,799 recorded births resulting in an average calving rate of 94%, this result is comparable to the 93.3% calving rate reported in southern beef herds (Stanger 2021; Project B.GBP.0048). Cohort 1 had the lowest calving rate (90.3%) and cohort 4 the greatest (97.2%;

Table 14). Calving rate was surprisingly high in cohort 4 when compared to earlier cohorts and is closer to the 96% calving rate reported by Morris et al. (1993). The lower calving rate seen in cohort 1 is due to management as in the initial year tagging calves at birth was not a management practice so the likelihood that calving events were not recorded was high. This was amended in the following three cohorts by tagging calves and recording dam identification tag at birth.

The majority (96%) of heifers that gave birth were present at the second joining measure, thus assumed to be lactating. The number of lactating heifers is marginally overestimated, due to those that "slipped the system", this includes heifers that had a stillbirth, early or late calf death or mismothered and were not culled prior to calf marking. Calf marking rate in this instance was a more accurate estimate of the number of lactating heifers. Cohort 4 recorded a total of 1395 calves at marking (November 2023) resulting in a marking rate of 93% (number of calves at marking/total births). Despite being a more accurate representation of lactating heifers, marking rate too was marginally overestimated because of calving management and intensive efforts towards fostering of mismothered calves, from older parity dams and heifers onto non-biological heifers that had lost a calf. Exact numbers have not been recorded. However, it is estimated that well over half of the mismothered calves are successfully fostered onto non-biological heifers, this would significantly reduce the number of cull heifers and poddy calves, thus increasing marking rates. Weaning rates were high and ranged from 90.6% to 92.3% (Table 14). Weaning rate attributed to describing calf mortality and is discussed in detail in the following section.

4.6 Heifer Mortality

Heifer mortality across the four cohorts was low, ranging from 0.1 to 0.5% (Table 14), this lower than 2.4% reported by Ring et al. (2018), however, project mortality losses only included mortality losses over the calving period (~3 months) thus heifer mortality was recorded over a smaller time frame. The majority of the heifer losses over the caving period occurred after assistance was provided, or after a uterine prolapse, the risk factor of mortality during the first week of lactation is higher in heifers than in older cows, and a heifer that requires assistance is at greater risk than heifers that do not require assistance (Ring et al. 2018).

Table 14. The number of heifers returning a positive pregnancy scan 1 and pregnancy scan 2, number of heifers scanned at the pre-calving (1) and joining (2) measure, number of calf births recorded, percentage of heifers lactating, number of calves weaned, heifer mortality, calving and weaning rate for cohorts 1, 2, 3 and 4 from Farm 8.

	Cohort 1	Cohort 2	Cohort 3	Cohort 4
Pregnancy scan (1)	1148	2457	2992	1686
PTIC (1)	1036	2038	2700	1556
Pre-calving (1)	955	2025	1535	1551
Births	935	1930	1421	1513
Calving [a] %	90.3%	94.7%	92.5[b]%	97.2%
Joining (2)	894	1856	1386	1434
Lactating %	95.6%	96.1%	97.5%	94.7%
# Weaned	847	1765	1298	1397
Weaning rate [c] %	90.6%	91.5%	91.3%	92.3%
Pregnancy scan (2)	863	1796	1221	1296
PTIC (2)	768	1585	961	1123
Heifer mortality	0.4%	0.3%	0.1%	0.5%

1. [a]Calving % calculation: Birth/Pregnancy scan (1) * 100
2. [b] Calving % calculation: Birth/Pre-calving (1) * 100 – this calculated was altered to account for 1st cycle heifers that were calved elsewhere.
3. [c]Weaning rate calculation: Weaned/Births * 100
4.

4.7 Fetal Loss and Slippage

Heifer slippage or loss of pregnancy significantly affects reproductive efficiency, this results in economic losses and increased costs. Pregnancy loss occurs in three stages, embryonic loss (15-17 days post conception), late embryonic loss (day 15-17 to 45 days post conception) and fetal loss or abortion (post 45 days conception). Embryonic and late embryonic losses generally go unnoticed as they mostly occur prior to pregnancy scanning, fetal losses account for 1 to 2.3% (Bellows et al. 1979, Bagley 1999). Heifer slippage in the current project describes those heifers that were PTIC but did not deliver a calf. Pregnancy scanning occurred ~40 days after the bulls were removed, thus heifers that lost/slipped a pregnancy after this measure were classified as an abortion. Calving percent (Table 14) provides an estimation of heifer slippage (avg. 94%), however, it should be noted that inaccuracies in calving records i.e. missed calving records, would present as lower calving percentages. Cohort 4, at Farm 8 attributed a status code to all PTIC heifers; calved (live or deceased), deceased or cull. Heifer slippage or fetal loss from pregnancy scan to calving was 2.8%, slightly higher than the average 1 to 2.3% previously reported (Bellows et al. 1979, Bagley 1999).

4.8 Dystocia

When a heifer or cow has maintained pregnancy full term, the next hurdle is parturition. A difficult, long (>2hrs) or abnormal delivery of a calf that requires assistance to complete the birthing process is labelled dystocia (Meijering 1984). This is undesirable for producers as it increases labour costs and is associated with negative affects to both dam and calf included but not limited to dam and calf performance and increased risk of disease associated with delayed and poor intake of colostrum (Hickson et al. 2006). Dystocia occurs at a higher incidence in heifers than in cows (Azzam et al. 1993, Nix et al. 1998) and the most common cause of dystocia is feto-maternal disproportion (Rice 1994), which is when the fetus is too big relative to the pelvic area of the dam.

BREEDPLAN calving ease (recording-calving-difficulty-scores.pdf (une.edu.au)) was recorded at Farm 1 on 73 calves from cohort 1 heifers. The range for calving ease is 1 for an unassisted birth to 5 malpresentation and 6 elective surgical. There were no major issues with calving ease recorded with only 2 calves recording a score of 2 which indicates an easy pull (no mechanical assistance required) or calf unassisted but cow and/or calf unit showing signs of a difficult birth. The remaining calves were all unassisted.

During calving at Farm 8 it was evident that dystocia was a challenge to measure as a large portion of heifers calve early in the morning and late in the evening. Thus those that had birthing durations over the average two hours (Gundelach et al. 2009) went unnoticed. In these cases, dystocia was assigned to the birth if the dam showed sign of paralysis and or significant tearing, or the calf had a swollen head. Dystocia was also investigated by monitoring the number of manual assists (Table 15). Heifer assistance was lower in cohort 1 and 2 (4.7 and 3.7% respectively) and was similar across cohorts 3 and 4 (7%), these results concur with previous reported manual assistance of 6% across beef herds (Nix et al. 1998). Cohorts 1 and 2 had less assistance and is likely the result of poor record keeping, this due to difficulty in ensuring multiple staff keep accurate records. More than 60% of calves that were assisted at birth were born live (Table 15) this result can be interpreted two ways; 1) assistance was provided too early into the calving duration or 2) assistance was provided in a timely manner.

Table 15. Heifer assistance and calf survival at Farm 8.

	Cohort 1	Cohort 2	Cohort 3	Cohort 4
Heifers assisted (proportion of total)	4.7%	3.7%	7.2%	7.0%
Calf survival (24 h) of assisted births (proportion of assisted)	61.4%	61.4%	69.9%	79.2%

Heifers that conceived in the first cycle had more assistance than those in later cycles in both cohort 1 and 2 (Table 16). The 1st cycle cohort 3 heifers were transported and calved at a distant site, so no data was recorded. However, cohort 3 heifers in the 2nd cycle had more assistance than those in the 3rd cycle. Higher assistance in those that calve in earlier cycles may be in part due to over assistance at the beginning of the calving period and declined record keeping over the calving period.

Heifers that conceived in the 1st cycle of cohort 4 had less assistance than later cycles. Cohort 4, 1st cycle heifers included both heifers that conceived to artificial insemination (AI) and natural mating. Interestingly, those that conceived to AI had a higher incidence of assistance (7.3%) compared to those that were naturally mated (4.4%). This was an unexpected result as it was assumed those that conceived to AI would have sires with better calving ease breeding values compared to the bull team exposed to the natural mated heifers.

Table 16. Proportion of assistance (per total births) per cycle for cohorts 1, 2, 3 and 4 at Farm 8.

	Cohort 1	Cohort 2	Cohort 3	Cohort 4
1st cycle	7.3%	4.9%		5.9%
2nd cycle	1.9%	3.0%	6.3%	7.5%
3rd Cycle	1.1%	1.9%	3.8%	7.9%

Calf growth occurs primarily in the third trimester (Prior and Laster 1979) therefore heifer nutrition and growth during this period is of interest. The effect of nutrition in late gestation and the incidence of dystocia is highly variable across literature, and neither low nor high feed allowances have consistently affected rates of dystocia (Hickson et al. 2006).

Third trimester growth was approximated by calculating ADG between two pre-calving time points. The first pre-calving measure was 77 and 86 days before the average calving date for cohort 1 and 4 respectively, and the second pre-calving measure occurred 20 and 40 days before the average calving date for cohort 1 and 4 respectively. Calving duration for cohort 1 and 4 was 69 and 61 days respectively, therefore the second pre-calving measure for the 1st cycle heifers occurred 1-2 weeks prior to calving, whereas this occurred 6-7 weeks prior to calving for 3rd cycle heifers. This issue was partly rectified in cohort 1 by weighing cycles closers to due dates.

To investigate the effect of late gestation nutrition on assistance, weight and average daily gain (in the third trimester) were converted to factors (weight group and ADG group). Weight group and ADG group and CG were included as fixed effects. Average daily gain in the third trimester was significant (P=0.01), however, weight at the first and second pre-calving measures were not. Heifers that had the greatest growth during the last trimester had the highest predicted assistance values (Table 17).

Table 17. Predictions of incidence of assistance for average daily gain groups during the third trimester at Farm 8.

	n=	% assist	s.e
ADGgrp -0.5	204	5.4%	0.014
ADGgrp 0.5	672	6.7%	0.0090
ADGgrp 1.0	361	4.4%	0.0097
ADGgrp 1.5	115	12.4%	0.026

The interaction between weight and ADG groups was not significant, although the predictions for manual assistance (Table 19) suggest that lighter heifers that are losing weight and heavier heifers that are gaining weight during the third trimester are at greater risk of dystocia, increasing manual assistance. However, these two problem categories have fewer animals per group, and as weight and ADG were treated as factors when one animal in the group is recorded as an assist there can be a large impact on predicted values.

It is expected that lighter, smaller framed heifers that are not growing would be more likely to incur a difficult calving, due to feto-maternal disproportion and the high energy demand of the fetus during the third trimester. However, lighter heifers with higher growth may be distributing more energy toward structural growth, and less into the pregnancy/fetal growth, giving birth to lighter/smaller calves reducing calving difficulty. On the contrary, heavier heifers that have little or no growth during the third trimester likely have adequate structure/size relative to calf birth weight minimising assistance, those heavy heifers that are growing are likely suppling ample energy to fetal growth as well as depositing fat increasing calving difficulty.

Table 18. Predicted assisted values for pre-calving weight groups and average daily gain groups in the third trimester at Farm 8.

	<0kg/day	count	0 - 0.5kg/day	count	0.51 – 1kg/day	count	1.1 - 1.5kg/day	count
WG400	9.6%	52	8.5%	117	6.5%	31		
WG450	5.4%	92	7.0%	273	4.9%	122	8.3%	21
WG500	2.0%	51	5.8%	191	3.1%	127	14.3%	44
WG550			5.3%	75	4.1%	74	13.0%	48

Arthur *et al.* (2000) reported greater incidence of dystocia in heifers with lower BCS pre-calving and so it was expected that those lighter heifers in poorer condition leading into calving would have required assistance more often. Interestingly at Farm 8 pre-calving body condition had no effect on incidence of assistance. However, this may be a result of adequate condition (avg. 2.8) and feed on offer leading into calving thus sufficient energy to utilise during parturition

To further investigate the effect of weight on assistance weight at joining was fit as a covariate with CG as a fixed effect. Heifer joining weight was statistically significant (P=0.04) for manual assistance, heifers that were lighter (<300kg) had a greater number of assists that those that were heavier (>350kg) at heifer joining (Table 19). It was interesting that weight at heifer joining had more of an effect on incidence of assistance than weight pre-calving.

Table 19. Predictions of incidence of assistance for weight at heifer joining at Farm 8.

weight (kg)	Assistance	s.e
250	8.2%	0.014
275	7.6%	0.010
300	7.0%	0.0066
325	6.5%	0.0053
350	6.0%	0.0063
375	5.5%	0.0080
400	5.1%	0.00898
425	4.8%	0.011

Heifer checks and assistance during heifer calving events it is common that these animals require a higher degree of supervision to ensure early detection of those that require assistance during the calving event (Lorenz et al. 2011). Most commonly calving events occur in the early morning or late evenings, it is a general practice for many producers to check heifers twice a day at these two time points. Heifer checks at Farm 8 occurred in the morning and afternoon at the beginning and the end of calving, as calving progressed a third check at midday occurred. There is insufficient data to conclude whether the additional check decreased dystocia, mortality or assistance. However, anecdotal evidence suggest that increased time spent in the paddock with heifers (midday check, or drifting cow and calf) resulted in disturbance, thus heifers that were in labour more frequently exhibited unwanted behaviours such as interrupted straining and increased standing to lying down. In addition, in peak calving periods, heifers appeared to be interrupted and distracted by other heifers and calves, multiple instances report that heifers in labour attempted to "calf steal" and cease straining resulting in assistance.

4.9 Calf Mortality

Stillborn calves contribute to calf mortality and increase the risk of dam mortality, premature culling, veterinary costs, treatment and labour (McDermott et al. 1992). Stillbirths include the expulsion of a full-term fetus that is considered viable, the calf may have died in utero or died shortly after birth (Holler 2012). In this study cohort 1 had the highest stillborn rate (5.7%). The number of stillbirths were similar across cohorts 2, 3 and 4 (3.2, 3.7 and 3.3% respectively), falling within ranges (2.7 to 3.6%) reported in literature (Woodward and Clark 1959, McDermott et al. 1992, Segura-Correa and Segura-Correa 2009, Waldner 2014).

Calf mortality data was collected at Farm 8 a spring calving herd, interestingly, stillbirths were greatest in 1st cycle heifers (Table 20) for cohorts 1 and 2, these results suggest that the increase in assistance seen in earlier cycles were likely warranted and not due to over assistance at the beginning of the calving season. Stillbirths in cohort 1, 1st cycle heifers comprised a staggering 9.4%, it was noted that this was a particularly wet/cold season when heifers began calving early August and high calf mortality was noted after extreme weather events. In addition, necropsy was not performed on calves thus it is likely that a portion of recorded stillbirths would have been attributed to exposure. Interestingly, the incidence of assist was greatest in the 3rd cycle cohort 4 heifers, this may be a result of increased Spring growth thus higher ADG in the third trimester, this growth would not have been captured accurately in the previous analyses due to later calving dates of third cycle heifers. In addition, the low number of heifers in the 3rd cycle meant less time was spent at the calving site thus assistance may have been provided unnecessarily when calving duration was unknown.

Table 20. Proportion of stillbirths per conception cycles for cohorts 1, 2 and 4 at Farm 8.

Cycle	Cohort 1	Cohort 2	Cohort 4
1st	9.4%	2.1%	1.6%
2nd	1.3%	0.7%	0.8%
3rd	5.7%	0.8%	4.0%

Mortality in the first seven days postpartum was highest in cohort 1 (6.7%) and similar across cohorts 2, 3 and 4 (5.4, 5.5 and 5.5% respectively; Table 21; Figure 11), these results were slightly higher than the 4.5% reported by Patterson et al. (1987) in the first three days post-partum. Calf losses between the first week of life and weaning accounted for 2.7, 3.9 and 3.7% of total calf mortality for cohorts 1, 2 and 3 respectively. These results higher than previously reported mortalities; 1.4 to 2.1%, within a similar timespan (Murray et al. 2016, Patterson et al. 1987).

Total pre-weaning mortality was highest in cohort 1 (9.4%) and was similar for cohorts 2 and 3 (8.5 and 8.7% respectively) and lowest in cohort 4 (7.7%; Table 21; Figure 11). Pre-weaning mortality for beef operations has been reported from 4.8% (Murray et al. 2016) to 6.7% (Patterson et al. 1987). At

Farm 8 pre-weaning mortality was higher and more closely aligned to those reported in the dairy industry (9.3%; Barry et al. 2020). There is little information on pre-weaning mortality in southern beef operations, Stanger (2021) quantified neonatal mortality and reproductive performance in Southern beef herds (Project B.GBP.0048) and reported acceptable neonatal mortality between 3 and 5%, much lower than observed in this study. However, it was acknowledged by Stanger (2021) that this figure may be understated due to inaccuracies in animal mortality records and the higher value reported in this project may be a more accurate representation of industry performance. These results warrant future investigation into quantifying calf loss in southern beef systems.

Table 21. Overall calf mortality by time, stillbirth, first 24 hours, first 7 days and day 7 to wean as proportion of total births at Farm 8.

Mortality	Cohort 1	Cohort 2	Cohort 3	Cohort 4
Stillborn	5.7%	3.2%	3.7%	3.3%
24 hours	1.1%	1.0%	1.3%	1.1%
7 days		0.5%	0.4%	1.0%
After 7 days	2.7%	3.9%	3.7%	2.3%
Total pre-weaning	9.5%	8.6%	9.1%	7.7%

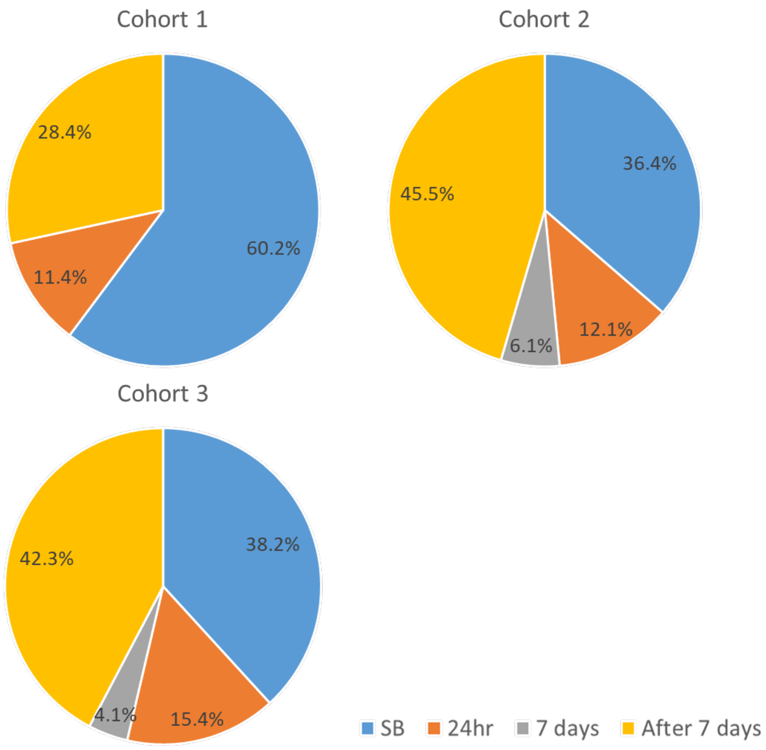

Figure 11. Overall calf mortality by time, stillbirth, first 24 hours, first 7 days and day 7 to wean at Farm 8.

4.9.1 Calf Mortality Causes

Due to calving management at Farm 8, calves remained at the calving location for ~seven days postpartum therefore any mortality that occurred in this period was recorded. Necropsy was not performed so a visual assessment was made to determine cause of death (Table 22). Stillbirths were recorded as those that were born dead (assist or in paddock) or those that died shortly after birth, this most commonly was accompanied by ingestion of birth fluid and or meconium. In addition to stillbirths, calf mortality that occurred in the first 24 hours of life included; exposure, suffocation, dystocia, viability, deformity and drownings. Calf mortality that was recorded as suffocation described those calves that had the placental bag over their head obstructing airways, or those calves that had fallen on their head/neck restricting their airways as a result of the heifer standing when the calf was expelled. Dystocia recorded mortalities described those calves that were alive but had signs of a difficult birth (assisted or natural), observed by excessive tearing, paralysis in the heifer, and or swollen head of the calf. There were three instances of low viability in cohort 4, this described calves that were live at birth with no visible signs of dystocia. Cohort 3 had a high number of drownings (8), these were in part a result of heifers calving into dams but also a result of full drains and a wet season. Other causes of death that occurred after 24 hours but within seven days postpartum included; bloat, prolapse (umbilical and rectal), starvation, destroyed due to injury, lost (calf left behind at muster), scours and unknown.

Table 22. Calf mortality causes within 7 days postpartum for cohorts 3 and 4 presented as counts and proportions of total peri-natal losses at Farm 8.

	Cohort 3	Cohort 4
Stillborn	47 (66%)	50 (60%)
Exposure*	2 (3%)	
Suffocated*	1 (1%)	4 (5%)
Dystocia*	8 (11%)	7 (8%)
Viability*		3 (4%)
Deformed*		3 (4%)
Drown*	8 (11%)	3 (4%)
Bloat		1 (1%)
Prolapse		2 (2%)
Starved		1 (1%)
Destroyed (injury)	2 (3%)	1 (1%)
Lost		1 (1%)
Scours		2 (2%)
Unknown	3 (4%)	5 (5%)
Total	71	83

*Deaths that occurred in the first 24 hours of life

4.10 Re-Breeding

4.10.1 Predictors of Re-Breeding Conception

A chi-squared test of independence was performed on the re-breeding conception rate data across all sites to examine the relationship between heifer cycle (cycle in which the heifer conceived, 1, 2 or 3) and cycle that those heifers conceived at their second joining. The association between the two variables was significant, χ^2 (6, 4623) = 97.0, P=<0.001. Heifers that conceived in the first 3-weeks of the breeding period were 9.5% and 17.9% more likely to conceive in the first cycle during the re-breeding period compared to heifers that got in calf in the second and third cycles respectively (Figure 12). When considering a 6-week joining 89.6% of heifers that conceived in the first cycle conceived in the first 2 cycles, compared with 85.1% in second cycle heifers, and 79.5% of the third cycle heifers, with 20.2% of heifers that conceived in the third cycle not getting calf during the re-breeding period. Therefore, there was a significant advantage of getting in calf early in the heifer breeding period.

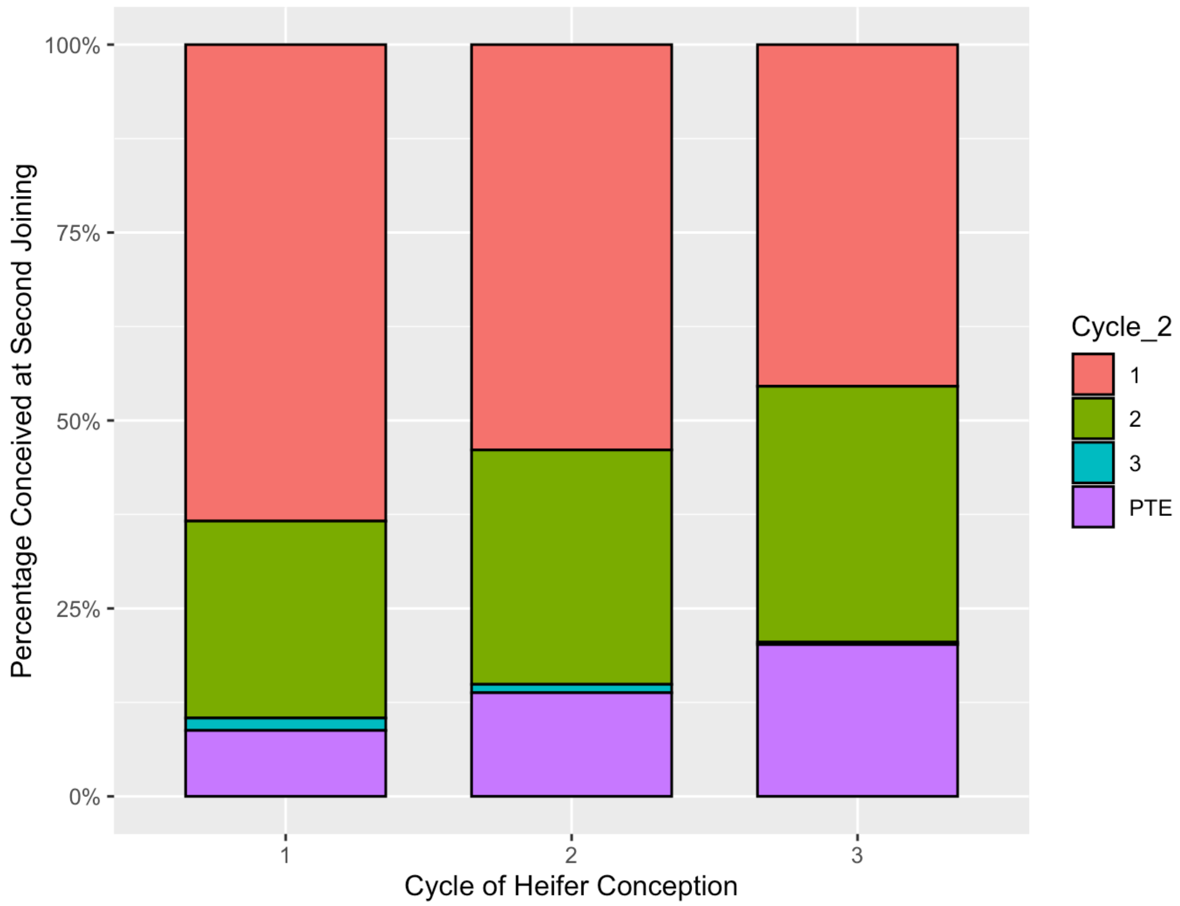

Figure 12. Stacked bar graph of the proportion of rebreeding first calvers based on the cycle conceived as a heifer (Heifer cycle 1 n = 1625, cycle 2 n = 1873, cycle 3 = 1135)

The impact of timing of heifer conception on rebreeding rate was further examined fitting a binary logistic regression accounting for heifer cycle and season, the interaction between heifer cycle and season as fixed effects and CG as a random term. The results were consistent across season where those born late in the heifer breeding period were less likely to conceive early (conceive in two cycles) of the re-breeding period (Figure 13; P=<0.001). When adjusting for start of second mating weight there was still a significant (P=0.001) effect of heifer cycle indicating that this difference was driven by more than just variation in start of second joining body weight.

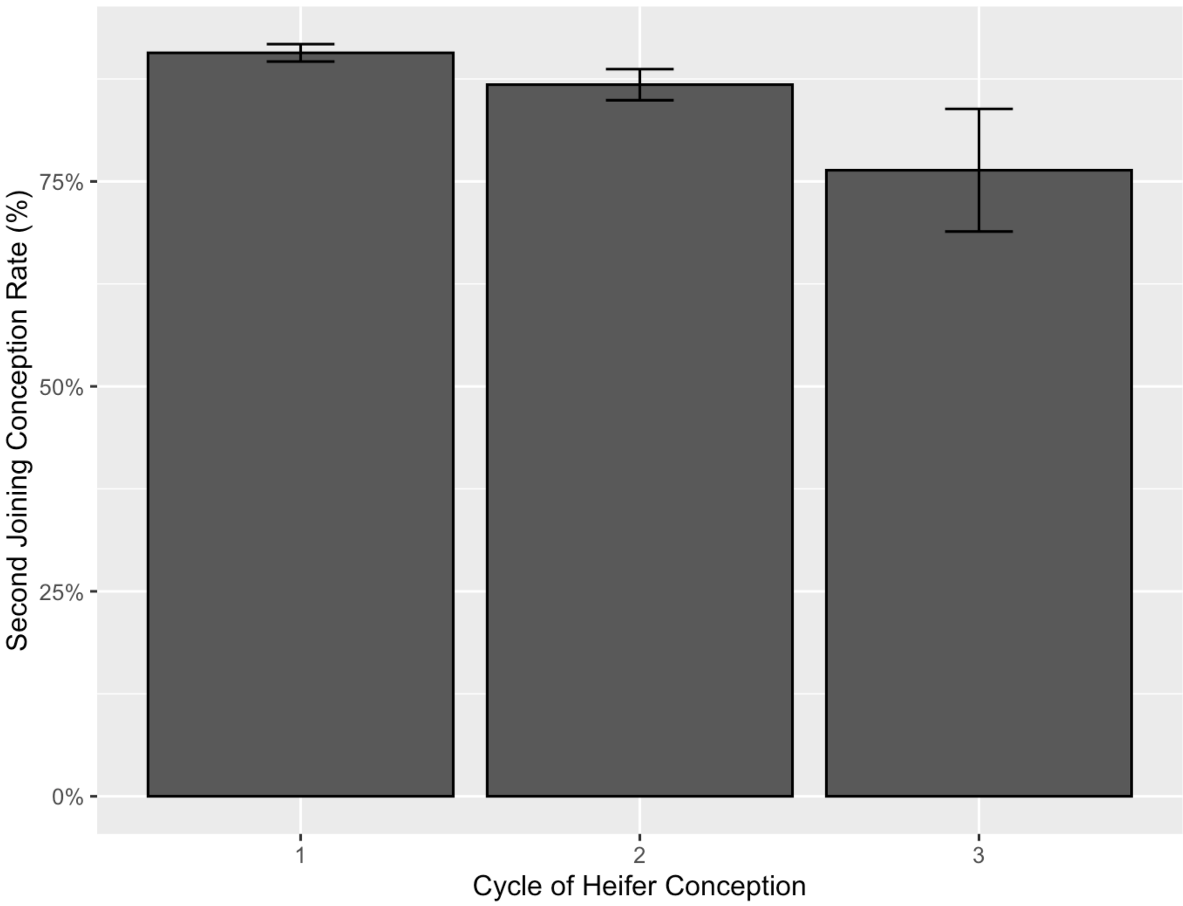

Figure 13. Second joining conception rate predicted means by cycle conceived as a heifer (1 = first 3-weeks, 2 = conceived in 6 weeks, 3 the last 3 weeks of the joining period).

It is expected that those that conceived early as a heifer would re-breed early. This is due firstly to the additional time to recover from calving (complete uterine involution) and secondly, after parturition the cow enters a state of infertility; the post-partum anoestrus interval (PPAI). PPAI is the period of sexual inactivity in the cow from parturition to the first oestrus (Short et al. 1990). PPAI can be affected by a number of biological factors such as parity, BCS at calving, nutrition, breed (Hickson et al. 2012, Short et al. 1990, Dunn and Kaltenbach 1980), suckling stimuli, season, presence of stimuli (bull) and effects of previous reproduction (Short et al. 1990, Crowe et al. 2014). Post-partum anoestrus interval is generally longer in primiparous cows than in multiparous cows (Blanc and Agabriel, 2008), in a review of literature Yavas and Walton (2000) reported PPAI lasting on average 1-4 weeks longer in the heifer than the cow, this is likely due to the additional demand for continual growth as well as lactation and maintenance (Spitzer et al. 1995). These results re-iterate the importance of early conception and calving to ensure an early re-breed, especially in those heifers that are in poorer condition and or on lower nutrition during calving. Poor nutrition can extend PPAI and decrease subsequent conception (Randel 1990, Banta et al. 2005, Diskin and Kenny 2016). DeRouen et al. (1994) reported that re-breeding conception rates in heifers that were 1 BCS higher (6 vs 7) by 4%, and this was even larger (6%) in heifers in poorer condition (4 vs 5). In addition to BCS, Spitzer et al. (1995) demonstrated the importance of nutrition, reporting increased conception rates (35%) in cows in higher BCS (6 vs 4) when fed a high nutrition diet.

4.10.2 Predictors of Re-Breeding Conception

There were 6,241 second joining records of those 81% were from Farm 8 (a Spring calving herd), 9% were from remaining Spring calving herds and 10% were from Autumn calving herds (Table 23). The coefficient of variation was similar for Autumn and Spring calving herds and Farm 8. Spring calving herds were 16% and 17% heavier than Autumn and Farm 8 cows respectively. In addition, Spring calving cows were half a condition score better than Autumn and Farm 8 cows. Nearly half (n=3009) of the cows had fat measured at this time, of those 77% were from Farm 8, 16% were from remaining Spring calving herds and 8% were from Autumn calving herds. Spring and Autumn calving cows had similar fat cover and were higher than Farm 8 cows. The variation in fat was similar and moderate in the Spring and Autumn calving cows and was highest in Farm 8 cows. Average daily gain during joining was only recorded on 766 cows as it was unable to be recorded at farm 8.

Table 23. Summary statistics for Autumn, Spring calving herds and Farm 8 for weight, height, body condition and rib fat at the start of the second mating, and average daily gain during joining, and conception rate (first 2 cycles).

Season	Weight (kg)	Height (mm)	BCS (1-5)	Rib Fat (mm)	Joining ADG (kg/day)
Autumn	610		349	247	339
average	438		2.76	4.96	0.520
range	300		2	11	3.116
SD	45.6		0.38	2.41	0.351
cv	10.4		13.8	48.6	67.5
Spring	551		564	485	427
average	521		3.37	5.50	0.007
range	334		3.5	14	4.360
SD	62.9		0.74	2.55	
cv	12.1		22.0	46.4	
Farm 8	5080	848	5186	2277	
average	433	1313	2.78	2.52	
range	357	220	3.5	10	
SD	49.9	34.1	0.39	1.90	
cv	11.5	2.6	14.0	75.4	

When analysed as a multiple linear regression, the start of joining weight was the most significant predictor of second joining conception (P=0.001) and was not significantly different between seasons. To achieve 90% re-breeding conception rate cows need to be approximately 500 kg (Figure 14). Using estimated reference weight as a proxy for MCW, 500 kg second joining weight is the equivalent of 84% MCW. These results align with recommendations that heifers should calve at 85% of MCW, this recommendation has been reported for dairy heifers (Fox et al. 1999) to maximise re-breeding fertility and milk production. More recently Stuttgen (2021) has reported 85% MCW at first calving in beef heifers. Re-breeding rates from the project indicate conception of 70% per cycle for a six-week breeding season, slightly higher than the average 60% reported by (Fordyce 2006; NBP.336). This highlights the engagement of the producers in the current projects and suggests that they are aware of the potentially difficulties associated with re-breeding fertility.

Body condition score (fit as a factor) was significant after adjusting for joining weight (P=0.0004), where the optimum condition score was 3.0 (conception rate = 90%) - 3.5 (conception rate = 89%; Figure 15. There was a significant decline in conception rate at the second joining at higher condition scores (4.0 and 4.5) where the estimated conception rates were 76 and 55% respectively. Body condition score is an adequate management tool to predict re-breeding conception outcomes, in contrast to heifers where BCS had low repeatability (Table 4). The increase in pregnancy rates in first calvers in greater condition (3.0 – 3.5) are due to adequate energy reserves thus, decreasing PPAI, resuming oestrus and conceiving. First calvers that are in BCS greater than 3.5 had lower re-breeding success, this likely due to being too fat, it has been reported that cows that have excessive fat cover have lower conception rates, milk production and increased calving difficulty.

Growth during joining was not significant after removing the variation explained by joining weight. To optimise re-breeding conception rates, cows should be approximately 500 kg at their second joining and in body condition score 3.0 (no greater that 3.5).

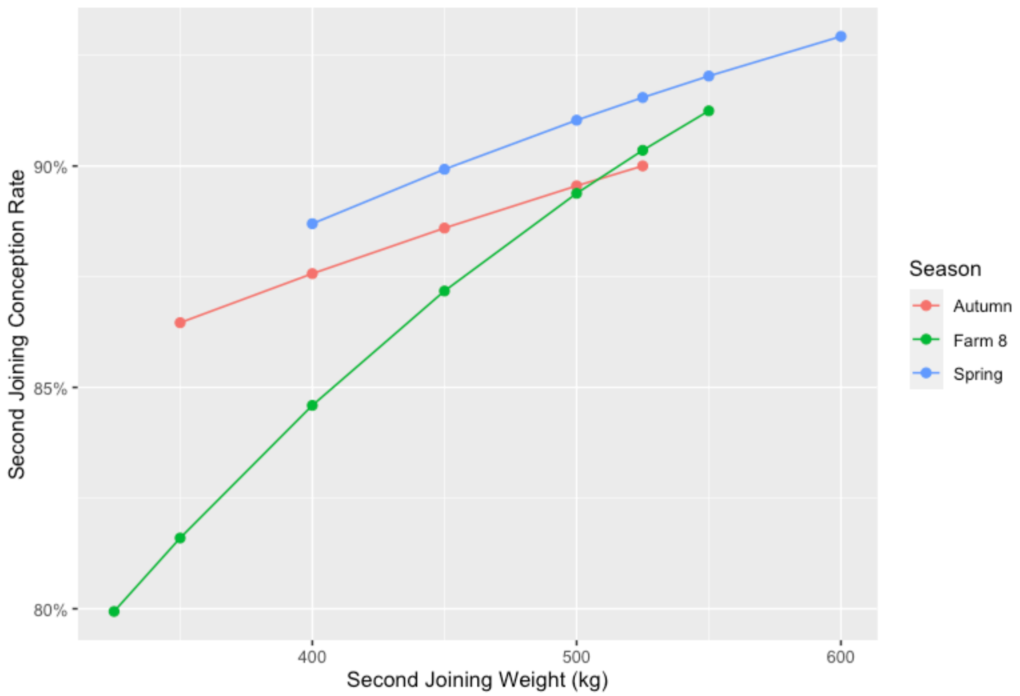

Figure 14. Second joining conception rate predictions from joining weight for each season

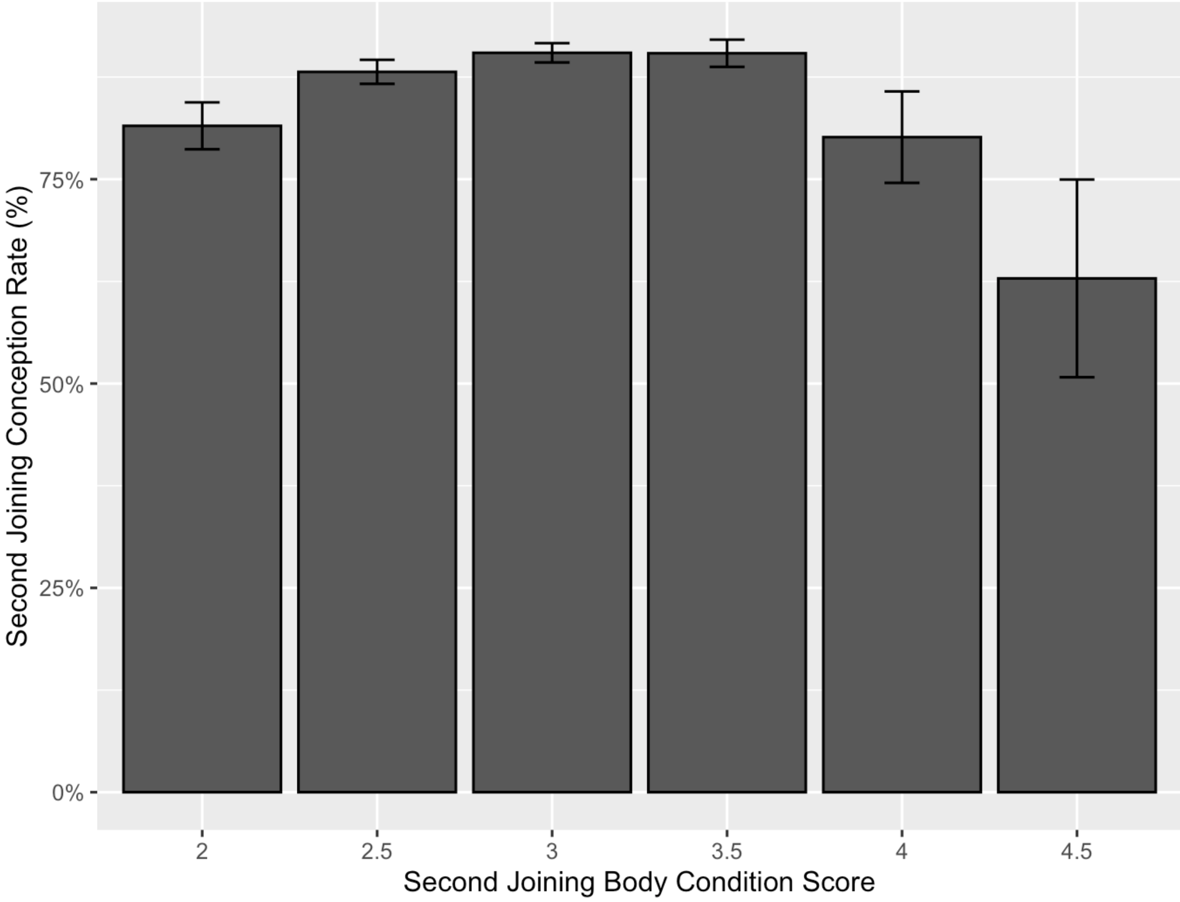

Figure 15. Average conception rate (second joining) at each joining body condition score

4.11 WAPE

WAPE as defined as heifers that get in calf early (first 6 weeks of the joining period), successfully raise a calf and rebreed early (get back in calf in the first 6 weeks of the rebreeding period), is made up of several component traits. These include early heifer conception, lactating (ability of the cow to raise the calf), and early re-breeding success. A summary of the variation observed at each site by CG can be found in Table 24. WAPE estimates ranged from 36.9 to 78.6, with the average 44% across CG. This is significantly lower than the predicted estimate of 65% based on Beef CRC Maternal Productivity data. The primary factor influencing heifer conception was joining weight, with growth pre-joining and during joining important at lower body weights. Since genotyping was removed from the project and mothering up was only done at Farm 8 a trait defined as lactating (the proportion of cows that were present at the start of rebreeding that were pregnant early (conceived in two cycles) of the heifer joining period. The proportion of heifers lactating was not significantly associated with growth during heifer joining, pre-calving weight or body condition Similarly to heifer conception the main driver of re-breeding conception was re-breeding joining weight, and in addition body condition. A multiple linear regression analysis was conducted to determine the key predictors of WAPE. The model included heifer joining weight, growth pre-joining and during joining, pre-calving weight, and re-breeding weight and body condition. After stepwise backwards elimination the only statistically significant association was with heifer joining weight. This was not surprising given that there was more variation in heifer conception than lactating or re-breeding conception.

Table 24. WAPE and WAPE component traits, heifer conception rate (conceived in two cycles), lactating, and re-breeding conception rate (conceived in two cycles)

Contemporary Group	Heifer Mating	Lactating‡	Re-Breeding	WAPE
Farm 1.1	69.7	86.6	76.1	46.5
Farm 1.2	76.9	86.5	93.5	61.8
Farm 2.1	86.2	87.7	84.0	64.5
Farm 2.2	80.2			
Farm 3.1.L	75.6	88.2	97.0	65.6
Farm 3.1.S	86.0	89.1	91.8	70.1
Farm 3.2	71.6			
Farm 4.1			73.2	
Farm 4.2	50.2	95	86.1	41.0
Farm 5.1	64.8	95.6		
Farm 5.2	84.7	94.0	98.7	78.6†
Farm 6.1	58.4	69.0	90.5	36.9
Farm 6.2	70.5	83.5	90.9	53.5
Farm 7.1	29.9*	100	90.2	
Farm 7.2	65.4	85.0	89.2	49.2
Farm 8.1	65.9	86.6	89.0	48.5
Farm 8.2	65.2	90.8	88.3	51.3

Farm 8.3	72.5	87.0	80.6	50.1
Farm 8.4	85.5	84.9	86.7	62.7
Farm 8.5	67.9			
Farm 9.1	74.0	83.8	87.8	56.0
Farm 9.2	85.5			

‡ % of heifers that were scanned in calf in the first 2 cycles that were scanned at re-breeding
†Farm 5.2 didn't fetal age at the re-breeding pregnancy scan and had joined for 8 weeks
*Farm 7.1 single AI with no back-up bull so not included in the WAPE measures

4.12 Weaning Outcomes (Heifers and Maiden Cows)

There was a significant difference (P=0.001) in weaning weight between calves that were born in the first and second cycle at Farm 1 (281 kg and 268 kg respectively; Table 25). The average weaning weight of calves from Farm 8 was 174 kg and ranged from 165 kg (cohort 2) to 182 kg (cohort 3). Calves were weaned from four cohorts of heifers in February/March from 2020-2024, those born to first cycle heifers were on average 9 kg heavier than those born to second cycle heifers, and 24 kg heavier than those born to third cycle heifers (Table 25). When age at weaning was included in the model rather than cycle there was increase in weaning weight for every day older a calf was at weaning, they were 0.5 kg heavier at Farm 1 and 0.6 kg heavier at Farm 8.

Table 25. Estimated predictions of heifer and steer progeny weights at weaning (WWt) by heifer cycle for Farm 1 and Farm 8.

	Farm 1			Farm 8		
Heifer cycle	**Count**	**WWt**	**s.e**	**Count**	**WWt**	**s.e**
1st cycle	47	281	3.39	1686	177	2.27
2nd cycle	31	268	4.98	1558	168	0.61
3rd cycle	NA			589	153	1.13

Calves that are born earlier in the season are generally lighter at birth (Funston et al. 2012). However, due to the additional days of growth are often heavier at weaning. Due to the longevity of the project at Farm 8, data from heifer calves born to earlier cohorts and were joined have been analysed. Heifer calves born to 1st cycle heifers were 9 kg heavier than those born to 2nd cycle heifers and 23 kg heavier than heifer calves born to 3rd cycle heifers at 5-6 months of age. By joining (12-14 months of age), heifer calves born to 1st cycle heifers maintained a 16 kg and 28 kg weight advantage compared to heifer calves born to 2nd and 3rd cycle heifers respectively (Table 26).

Table 26. Predicted average weaning weights (WWt) and joining weights (joining Wt) for progeny of cohort 1, 2 and 3 heifers by cycle that they were conceived at Farm 8.

	Count	WWt	s.e	Count	Joining Wt	s.e
1st cycle	485	191	1.03	472	332	1.61
2nd cycle	615	182	0.9	427	316	1.53
3rd cycle	322	168	1.17	234	304	1.96

Additional data from Angus Australia supports these findings in steer progeny. Steers that were heavier at weaning maintained the weight advantage at 400 and 600 days (1.0 kg and 1.1 kg heavier respectively). In addition, steers that were heavier at weaning had an extra 0.66 kg carcass weight for each 1.0 kg heavier at weaning, this result was greater than expected but is aligned to the 1.1kg 600-day weight advantage and if there was a 60% carcass dressing percentage of the lot-fed steers.

These results help further demonstrate the importance of early heifer conception and calving pattern, heifer and steer progeny that are heavier at weaning maintain the weight advantage through to joining and or slaughter potentially increasing reproductive success early in the season and or increased carcass weight.

4.13 Second Calving Outcomes

In the initial project application genomic testing was to be utilised to identify parentage and quantify second calving outcomes. However, due to budget constraints genomic testing was removed and most farms did not mother-up calves, so parentage was available for second calves. At most properties second calving cows were mixed with other mature cows with no mechanism of distinguishing calves born to first parity cows from calves born to older cows. This was evident in cohort 2 second calving outcomes at Farm 8, 730 cohort two cows were in a mixed mob with 139 mature cows (n=839) therefore at weaning calves that belonged to those older cows were unable to be detected and were included in the average weaning weight of the mob (181.4kg). To amend this outcome 700 2nd and 3rd cycle heifers were followed through to weaning of the second calf, average calf weaning weight was 181 kg and a 95% weaning rate. Two hundred lactating maiden cows were mothered up in the paddock, 150 of those had a recorded previous calving date and first calf weight. The average weaning weight of the first calf from the 2nd cycle heifers was on average 20 kg heavier than the first calf from the 3rd cycle heifer. However, there was no difference in weaning weight of the second calf between initial heifer cycles. When considering that there was no difference in re-breeding rates between these 2nd and 3rd cycle heifers, it was not unexpected that there was no difference in second calf weight.

Table 27. First and Second Calving Weaning Weights for Cohort 2 Heifers from Farm 8

	count	WWt1	s.e	count	WWt2	s.e
2nd Cycle	58	184	2.71	72	180	2.97
3rd Cycle	39	162	3.30	54	181	3.43

4.14 Female Attrition

Female attrition has been reported for most contemporary groups, from the post-weaning measure to the third pregnancy scan (Figure 16). The project has identified two aspects of attrition, firstly are those that in most instances are budgeted losses, such as failed conception and in most cases, those that do not wean a calf, likely due to abortion/fetal loss or early calf death. In addition, producer culling policies often involve culling heifers and cows for age, structure, temperament, and condition.

The second attrition, and this is what is presented to producer forums, is production attrition. This was defined as pregnant within a six-week joining and then successfully raising a calf, then pregnant within a six-week joining and so on. Thus, cows that are joined for longer than six-weeks can remain in herds, but not within our definitions. On average, just 56% of the project heifers that were weaned remained in the herd at the third pregnancy scan and achieved WAPE. This overall drop rate was 28% between weaning and the first pregnancy test, 8% between the first pregnancy scan and first calving (delivering a live calf), a further 5% between calving and the second pregnancy scan and 5% between the second pregnancy and third pregnancy scan. This snapshot of female loss throughout the first 3.5 years of a heifer's life has been presented to producers in a slide (Figure 17) which, after trialling many formats, seems to have been well understood by them.

Producer concern around the losses between heifer joining and re-breeding were a driving force of this project, however, the data has shown that female loss continues beyond this point, and that female drop out in mature cows are greater than realised. Data collection beyond the second pregnancy scan has proven crucial to understanding female retention and longevity in the herd. Nine cohorts (Figure 16) contributed pregnancy scan 3 results where a further 15% of the herd is lost from the system. This results in only 44% of the original heifers remaining in the herd at the third pregnancy. At farm 8 further attrition continued into later parities (4 and 5; Figure 16) which is of concern that 5–6-year-old cows are being lost from the herd when they are the most productive (weaning weights) of breeding stock.

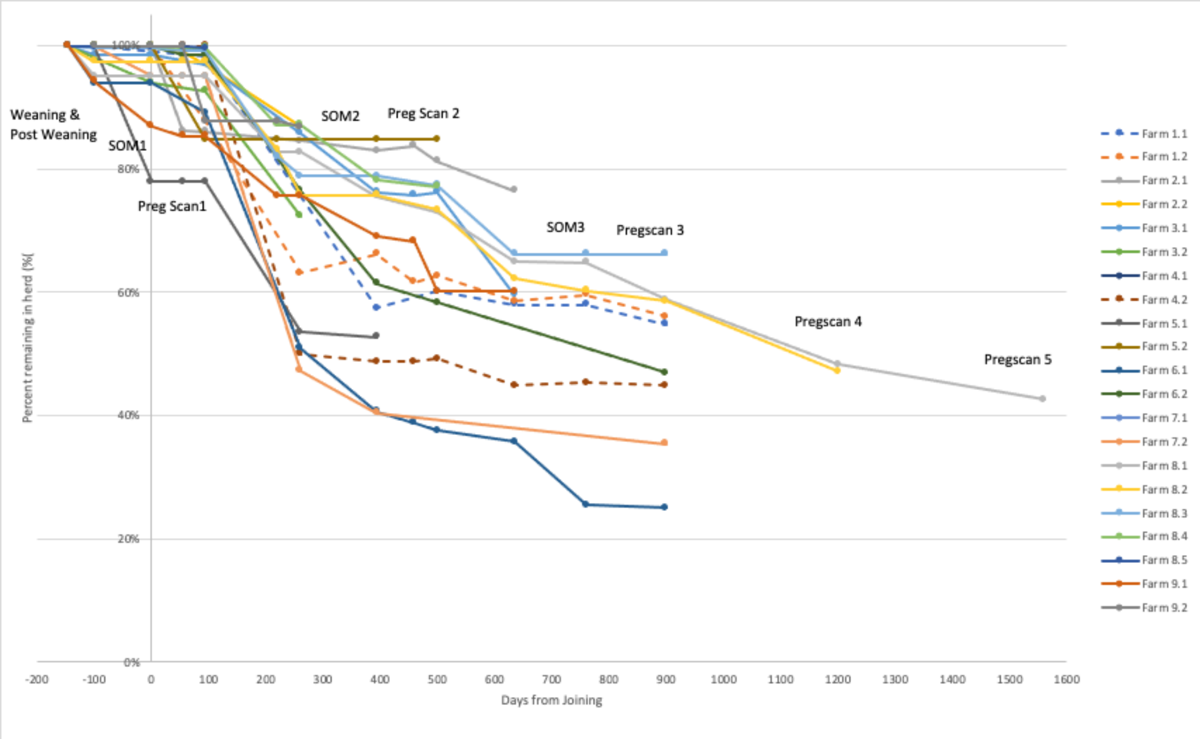

Figure 16. Herd attrition for each cohort of each property. Dashed lines are for autumn calving herds.

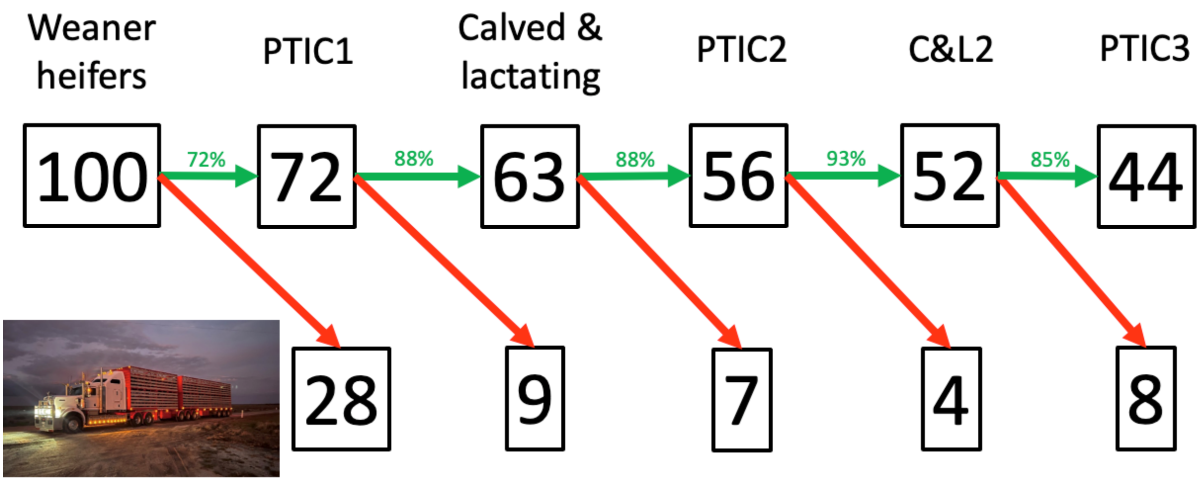

Figure 17. Example of data from the heifer project has been presented to producers to illustrate the loss of heifers/cows from the system.

4.15 Pasture Sampling

The project aimed to sample pasture at key time points calving and joining. Pasture was sampled from 5-10 randomly placed quadrats per paddock. The wet and dry weights were determined to calculate feed on offer (FOO, kg DM/h) and samples were sent for laboratory analysis. Samples were dried and ground to get dry matter (DM, %) and moisture (%). Further testing by near infra-red (NIR) feed analysis gave neutral detergent fibre (NDF, %), acid detergent fibre (ADF, %), crude protein (CP, %), inorganic ash (ASH, %), organic matter (OM, %) and water-soluble carbohydrate (WSC, %). Digestibility of dry matter (DMD, %) and organic matter (DOMD, %) were determined. Metabolisable energy (ME, MJ/kg DM) was calculated and where appropriate hay or silage grade was given (AFIA).

The two sites in South Australia had the most representative pasture sampling as COVID restrictions to travel were less restrictive than NSW and Vic (Table 28). Pasture sampling at the three Victorian sites, Farm 2, Farm 5 and Farm 9 was very limited due to COVID travel restrictions in Vic and is only available for cohort 1 (Table 29). The same was true for the NSW sites where COVID limited access to pasture sampling (Table 30). The results for pasture sampling and analysis for all properties except Farm 8 were presented in Milestone 7. Pasture analysis and supplementary feed analysis as well as visual estimation of FOO were collected for Farm 8 Cohorts 1, 2, 3 and 4 and were presented in Milestone 8 (Table 31).

Table 28. Pasture sampling at the SA sites.

Event	Farm 1.1	Farm 1.2	Farm 4.1	Farm 4.2
42 days PreJoin		✓		✓
SOM1		✓		
EOM 1		✓		✓
PregScan1 & FA		✓		✓
PreCalving1-60		✓		
PreCalving1-30	✓		✓	✓
SOM2	✓	✓		✓
EOM 2		✓	✓	✓
PregScan2 & FA	✓		✓	
PreCalving2-60				
PreCalving2-30			✓	
SOM3	✓	✓		✓
EOM3			✓	
PregScan3 & FA				✓

Table 29. Pasture sampling at the Vic sites.

Event	Farm 2.1	Farm 2.2	Farm 5.1	Farm 5.2	Farm 9.1	Farm 9.2
42 days PreJoin						
SOM1	✓				✓	
EOM 1	✓		✓		✓	
PregScan1 & FA						
PreCalving1-60					✓	
PreCalving1-30						
SOM2					✓	
EOM 2						
PregScan2 & FA						
PreCalving2-60						
PreCalving2-30						
SOM3						
EOM3						

Table 30. Pasture sampling at the NSW sites.

Event	Farm 3.1	Farm 3.2	Farm 6.1	Farm 6.2	Farm 7.1	Farm7.2
42 days PreJoin						
SOM1						
EOM 1				✓		✓
PregScan1 & FA						✓
PreCalving1-60					✓	
PreCalving1-30			✓	✓	✓	
SOM2	✓		✓	✓	✓	✓
EOM 2	✓				✓	
PregScan2 & FA	✓		✓			
PreCalving2-60						
PreCalving2-30						
SOM3					✓	
EOM3						
PregScan3 & FA						

Table 31. Pasture sampling at Farm 8 (Tas).

Event	Farm 8.1	Farm 8.2	Farm 8.3	Farm 8.4
42 days PreJoin		✓		✓
SOM1			✓	✓
EOM 1				✓
PregScan1 & FA				
PreCalving1-60		✓	✓	
PreCalving1-30	✓			
SOM2	✓		✓	
EOM 2		✓		
PregScan2 & FA			✓	
PreCalving2-60		✓		
PreCalving2-30				
SOM3		✓		
EOM3				
PregScan3 & FA				

4.16 Green FOO on Offer

To supplement pasture data that was received, green feed on offer (FOO) was estimated using satellite data from the Flurosense website (Regrow) and was presented in the previous milestone report as graphs where average monthly FOO and liveweight of heifers was plotted against time. An example is shown in Figure 18.

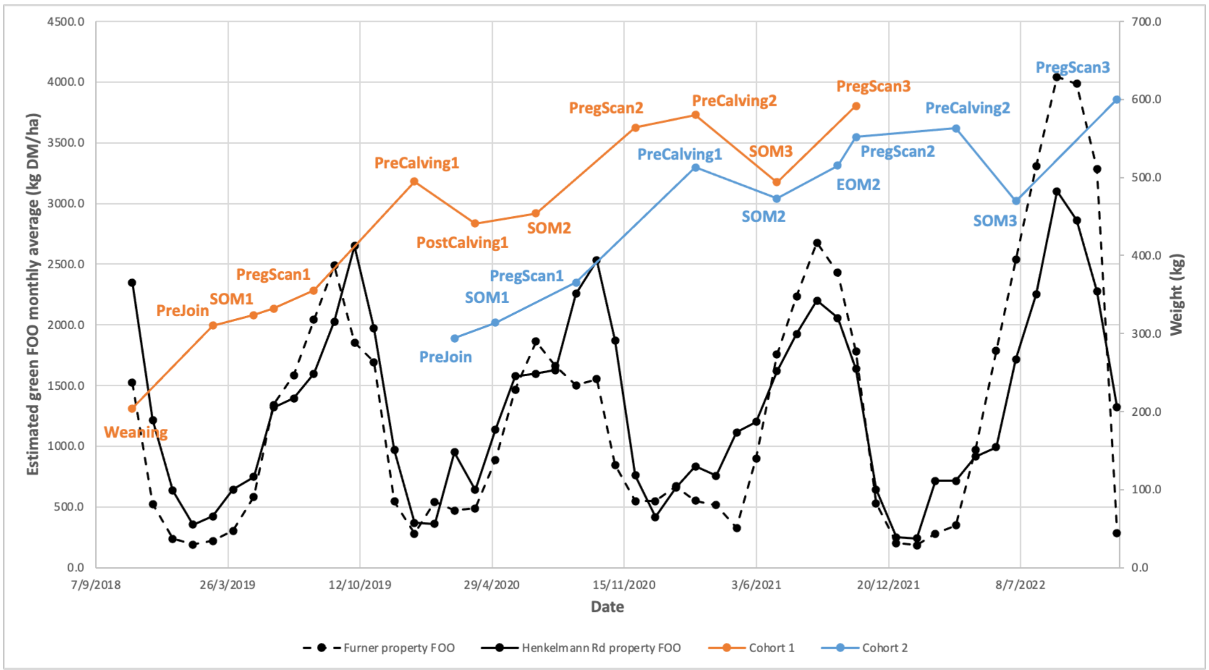

Figure 18. An example of average monthly FOO and liveweight of heifers plotted against time for Farm 1.

4.17 Economics

Farm business profit is clearly influenced by the ability to get heifers in calf and for those heifers to rebreed and remain in the herd, particularly for herds that can realise a premium for selling PTIC females (Table 32 and Table 33). In most cases the heifer conception was lower when compared to the rebreeding rates of the maiden cows for herds in this project, so heifer conception has a greater influence on the WAPE calculation than the rebreeding rates. In the project herein, maiden cow rebreeding rate not the major source of loss as expected by producers. Three factors that may be contributing to this: in project herds are, 1) the herds are large enough to manage the maiden cows as a separate group, 2) producers are already aware of this problem management group within the herd and have strategies in place to address this; or 3) given the investment in time into raising and calving down heifers, any loss is viewed as significant. For herds that have marketing strategies that do not include selling PTIC animals, as long as they can maintain enough PTIC females to maintain herd numbers, then profit is not greatly affected.

Table 32. Total Farm Gross Margins for cohort 1 heifers on properties achieving WAPE

Property	Heifer preg rate	Re-breed %	WAPE %	Total Gross Margin $500 PTIC premium	Total Gross Margin no PTIC premium
Farm 1	70	76	46.5	$518,400	$500,000
Farm 2	86	84	64.5	$536,800	$498,400
Farm 3	81	94	67.8	$534,400	$504,800
Farm 4		73			
Farm 5	65				
Farm 6	58	91	36.9	$511,200	$501,600
Farm 7	30	90			
Farm 8	66	89	48.5	$516,000	$502,400
Farm 9	74	88	56	$527,200	$504,000

Table 33. Total Farm Gross Margins for cohort 2 heifers achieving WAPE

Property	Heifer preg rate	Re-breed %	WAPE %	Total Gross Margin $500 PTIC premium	Total Gross Margin no PTIC premium
Farm 1	77	94	61.8	$530,400	$503,200
Farm 2	80				
Farm 3	72				
Farm 4	50	86	41.0	$502,400	$501,600
Farm 5	85	99	78.6	$539,200	$504,000
Farm 6	71	91	53.5	$524,000	$500,000
Farm 7	65	89	49.2	$518,400	$499,200
Farm 8	65	89	51.3	$517,600	$502,400
Farm 9	85				

Whilst the WAPE estimates from this dataset indicate that Southern breeder herd productivity is much lower than anticipated, the financial impact does not appear as bad as initially thought. The large variation in productivity did not translate to large variation in profit because there was a significant salvage value of cull heifers (because they have access to high quality pastures and therefore good growth) underpinned especially by the US manufacturing market. Low WAPE is more likely to become an issue during times when a herd rebuild is occurring due to loss of animals from natural disaster or building back from drought.

Heifer value and energy calculations

For each of the herds involved in the project calculations of the value of heifers were made at 18 months of age based on their weight, pregnancy test outcome and the associated sale value of the heifers as either PTIC heifers or unmated heifers (PT empty). In the following tables the daily energy requirements have been calculated based on growth rates necessary to achieve the respective joining weights and associated body condition scores, from a standard weaning weight of 180kg at six months of age. As previously described pasture samples have been used to estimate the energy requirements to grow the heifers from weaning to joining.

The cost of feed was calculated based on the energy requirements of the growing heifers, at a cost of 3 cents/ MJ ME, which takes into consideration the value of pasture and additional supplementary feed (the equivalent of cereal hay with 8MJ ME valued at $220/t) required to achieve the various heifer growth rates. A comparison Table 34 and Table 35 show the sensitivity to increased cost of supplementary feed ($320/t) which is in line with increases that can be experienced across southern Australia under varying seasonal conditions. Even with the price of supplementary feed rising by $100/t the rankings of the most profitable and least profitable heifer groups at Farm 4 remain the same.

Average heifer values were calculated using the current average southern Australian market values for PTIC heifers, and the current market values for unjoined females and were applied to each herd based on pregnancy test outcome. The net gain or loss of income for an individual animal is calculated based on weight, BCS and pregnancy outcome and is shown relative to a 300kg heifer in BCS 3. This reflects the variation in heifer values as weight changes and shows the relative salvage values when heifers are not in calf.

Farm 4

Pasture samples were collected at Farm 4 at various dates through 2020 and 2021 and feed on offer and feed quality are recorded in Table 34. Only data from the preliminary time point (20/03/2020) to pregnancy scanning (31/08/2020) were used for the economic analyses.

Table 34. Pasture samples collected at Farm 4.2.

	Sample date	DM (kg/Ha)	ME (MJ/kg DM)
Preliminary	27/03/2020	914.6	6.8
Pre-Joining	14/05/2020	397.5	-
End of Mating	22/07/2020	453.0	10.25
End of Mating	22/07/2020	821.3	7.9
Preg Test	31/08/2020	424.7	9.4
Preg Test	31/08/2020	634.5	9.5
Pre-Calving	19/02/21	536.5	5.4
Pre-Calving	19/02/21	991.8	5.0
Joining 2	24/06/21	544.2	6.0
Joining 2	24/06/21	1592.6	5.3
Post Join 2	21/09/21	620.9	9.7

The feed on offer and the energy measurements (MJ) were used to calculate the energy requirements for heifers from the point of weaning at 6 months of age to the end of mating. Calculations were based on growing heifers from a weaning weight of 180kg at 6 months to a joining weight of 300kg or 350kg. From each of the joining weights heifers either gained weight (0.5kg/day), maintained weight (0kg/day), or lost weight (-0.5kg/day) during mating. Based on the energy requirements the feed cost of growing the heifers to 300kg and 350kg was calculated. Feed costs were also calculated during mating for each of the scenarios.

Predicted heifer values were calculated on the sale value of the heifers based on the pregnancy test result. A PTIC heifer valued at $3,500 and an empty heifer valued at $2,000. Net heifer value was calculated at the sale value less the feed costs to grow the heifer from weaning to the end of joining. Results clearly show that profit margins are driven by getting heifers in calf (Table 35). Consistently the heaviest heifers at joining and those gaining weight during mating returned the highest profit margins.

Table 35. Energy requirement calculations for Farm 4.2 heifers from weaning to end of joining.

Pre joining weight (kg)	ADG joining (kg/day)	Post joining weight (kg)	Energy requir't joining MJ/day	Feed cost from weaning to joining	Feed cost though joining ($/hd)	Preg Rate *	Heifer $/hd	Net heifer value $/hd	Net gain $/hd
300	0.5	321	56.2	$307.80	$70.86	85%	$3,275	$2,896	$258
300	0	300	35.2	$307.80	$44.34	66%	$2,990	$2,638	$0.00
300	-0.5	279	32.4	$307.80	$40.80	42%	$2,630	$2,281	-$357
350	0.5	371	63.0	$372.00	$79.38	95%	$3,425	$2,974	$336
350	0	350	39.5	$372.00	$49.77	87%	$3,305	$2,883	$245
350	-0.5	329	36.8	$372.00	$46.35	56%	$2,840	$2,422	-$216

At Farm 4 there was a difference in the average gross margin/head of $692.22 between the most profitable group of heifers which were 350kg at joining and gaining weight through joining, compared to the least profitable group with a pre-joining weight of 300kg and an average daily gain through joining of -0.5 kg/day (Table 35). This data has helped to clarify the thinking around ideal mating weights. This is in line with the heap maps presented in Figure 10 which shows the relationship between early conception and growth pre-joining and during joining. As we better understand the optimum growth path of modern phenotype heifers it is clear that different management strategies can be used to achieve a similar outcome. Heifers can be fed from weaning to achieve a heavier weight prior to mating, which is a more important strategy for Autumn calving systems as the heifers are less likely to be gaining weight due to seasonal conditions at the time of joining. In Spring calving systems joining weights can be lower, as heifers will be gaining weight through the joining period.

Benefit to project herds

Currently one of the biggest production gaps across the project herds is the proportion of heifers getting in calf, if producers could modify management of heifers before and during joining to increase the number of heifers getting in calf it would have a positive effect on herd profit. The following calculations have been based on heifer calving rates. If we can achieve an increase in pregnancy rate of 10% by growing heifers to 350kg instead of 300kg (average of group). The associated extra cost of feed to grow heifers to 350kg instead of 300kg at the same age is $72/head (Table 35).

The project has recorded measurements on 14,229 heifers if we could achieve a 10% increase in WAPE across those herds it would result in an extra 1422 PTIC heifers. From the project data we would expect 88% of those heifers to rear a calf to weaning, resulting in an extra 1251 weaned calves. If the weaned calf is valued at $800 (250kg x $3/kg) the extra gross income achieved would be $1,000,800 across the project herds. Total cost of extra feed needed across the project herds to grow the heifers to 350kg instead of 300kg at joining would be $102,384, resulting in a net income across the project herds of $898,416 which equates to an extra $64/heifer joined.

4.18 Information and Extension Outputs

A number of (30) producer or consultant engagement activities have been attended by various members of the project team. Table 36 summarises the many occasions where information from the project has been presented and where possible gives the number of attendees.

Table 36 A summary of meetings, presentations and publications relating to this project.

When	Where	Who	Notes
Aug 2019	East Gippsland Beef conf.	Nick Linden	210 attendees
2019	Betterbeef Network	Tim Hollier, Chris Blore	50 attendees
2019	MLA media release	Stephen Lee	Extensive coverage in rural press
Jul & Dec 2020	SA Livestock Advisers update	SALC	
Nov 2020	Fleurieu Beef Group, Yundi, SA	Wayne Pitchford	
Jan 2021	Head Shepherd podcast	Wayne Pitchford	
Feb 2021	National Feed Efficiency workshops, Perth, WA	Wayne Pitchford	
Mar 2021	MeatUp Forum, Gawler, SA	Wayne Pitchford	
Mar 2021	Beef Genetics Central article	Wayne Pitchford	
Feb 2022	Barossa Improved Grazing Group, SA	Darren Koopman	80 attendees
Mar 2022	PIRSA forum 'Better decisions for business success', Murray Bridge, SA	Wayne Pitchford & Darren Koopman	17 attendees (producers, scientists, consultants)
May 2022	Aust. Limousin Breeders Assoc.	Wayne Pitchford	30-40 attendees
May 2022	MacKillop Farm Management Group PDS group	Wayne Pitchford	19 businesses
May 2022	Beef and Lamb NZ genetics update seminar	Wayne Pitchford	100 producers on webinar
Jul 2022	AAAS paper on cow composition	Wayne Pitchford	200 people at conference and APS publication
Jul 2022	Red meat updates Tasmania	Jena Alexopoulos	300 attendees
Aug 2022	King Island Beef Day	Jena Alexopoulos	
Aug 2022	Heterosis talk – David Brown BBB PGS group	Wayne Pitchford	10 beef businesses
Aug 2022	Presentations at Heifer Adoption workshop in Adelaide	Various	

Aug 2022	Zoom meetings with producers involved in project	Michelle Hebart, Wayne Pitchford, Darren Koopman, Jude Pitchford& Jena Alexopoulos	Included AgVic reps Chris Blore, Nick Linden, Kate McCue, Kirsty Anderson, Jennifer Alexander
Sep 2022	MLA Livestock Advisor updates	Wayne Pitchford, Darren Koopman	60 attendees
Sep 2022	SA Livestock Consultants Group Advisor updates	Wayne Pitchford, Darren Koopman	50 livestock advisors in attendance
Nov 2022	Fleurieu Beef Group	Wayne Pitchford	25 producers
Dec 2022	Chris Miram's group	Wayne Pitchford	10 beef businesses
Dec 2022	MacKillop Farm Management Group PDS group	Wayne Pitchford, Darren Koopman	19 businesses
Jun 2023	WALRC Livestock Matters, Nannup, WA	Wayne Pitchford	50 attendees
July 2023	AAABG conference, Perth, WA	Wayne Pitchford	
Nov 2023	Fleurieu Beef Group	Wayne Pitchford	
Oct 2023	King Island Beef Group	Jena Alexopoulos	55 producers

5. Conclusion

Maternal productivity in southern beef breeder herds is driven by pasture production, utilisation and reproductive performance. The key driver of early conception in the first six weeks is driven by joining weight and weight gain both prior to and during joining. On average, only 72% of heifers conceived following a 6-week joining; of those only 88% successfully reared a calf; and of those only 88% conceived within a 6-week joining so only 56% achieved being wet and pregnant early (WAPE). Body condition score is good predictor of re-breeding success in addition to 85% MCW target at the second joining. The project should provide producers with greater confidence to increase productivity by managing pasture utilisation, heifer growth and cow body condition.

5.1 Key findings

- Weight at heifer joining is the key driver of conception in the first six weeks of the breeding season. Previous recommendation suggest British breeds reach 300-330 kg by joining (60-65% mature cow weight). There has been a significant increase in MCW over the last 50 years and Beef CRC results indicated closer to 400kg as a target. The results from this project suggest obtaining adequate heifer conception (75-80%) in the first two cycles, heifers should be 350 kg at joining (Figure 4, equivalent to ~60% MCW). However, heifers that will grow rapidly during joining, as is common for Spring calving herds, can be joined at lighter weights.
- In addition to weight, growth rate (ADG) leading up to and during joining is also important and accounted for most of the difference between Autumn and Spring calving herds (Figure 6). In general, heavier is better especially for Autumn calving herds which are joined during winter and commonly have low weight gain during joining.
- Other body composition traits such as height, condition score and fat depth were less important for heifer conception.
- Body condition score is an adequate tool to predict re-breeding reproductive success (Figure 11). There were very few cows that were in low condition score at the second joining which prevents estimating robust relationships between condition score and reproduction. However, it does represent the majority of southern production systems experience.
- There are significant challenges for industry in that the proportion of heifers conceiving within 6 weeks (72%); the number of those that successfully reared a calf (88%); and the number of those that successfully conceived again within a 6-week joining period (88%) were all lower than expected (average WAPE 56%, Figure 13).
- Combined data (all heifers beyond WAPE) only 93% of heifers PTIC successfully raised a calf and of those only 85% got back in calf.
- Low WAPE values suggest that average herd fertility is lower than expected, reproductive traits have low heritability thus management strategies around heifer weight and growth and cow condition would aid to optimise early conception improving herd fertility.
- The cost of being born later in the breeding season has also been quantified. While there are good premiums for well-bred pregnant heifers, there are good fall-back markets for empty heifers, joining times can be extended and cows that fail to raise a calf or re-breed can be sold into valuable manufacturing markets.
- Data collection at each measurement time point across sites was a challenge to obtain. Measurements that did not align with annual production events were harder to obtain at all sites, this was due to the increased workload for the producer such as increased mustering and yards work. This was an important lesson learnt leading into future research in

commercial setting, measurement time points and recommendations should aim to align with the annual production cycle.

- Total pre-weaning mortality was higher (8.6%) than previously reported in southern beef herds (3-5%) and were more similar to mortality figures reported in the dairy industry. There is little information on pre-weaning mortality in southern beef operations and the results of this project warrant further investigation into quantifying calf loss.
- Quality feed on offer (FOO) measurements proved a challenge to collect. This was in part due to the COVID-19 restrictions i.e. unable to enter sites, but also collection of samples during key measurement point aligned with busy periods for producers. To amend this, Green FOO was estimated using satellite data from the FluroSense website and heifer weight and FOO were plotted over time and demonstrated the relationship between peak pasture growth and weigh gain.
- This project has trained 1 Honours (Kelly Wenham) 1 PhD student (Jena Alexopoulos)
- A series of scientific publications will be submitted during 2024.

5.2 Benefits to industry

Breeder herds are both resilient but have significant potential for increased productivity. This project has highlighted that one of the biggest production gaps is the proportion of heifers getting in calf. Producers can achieve an increase in pregnancy rate of 10% by changing management to grow heifers to 350kg instead of 300kg at joining (average of group). In this project measurements from 14,229 heifers were recorded. If we could achieve a 10% increase in WAPE across those herds, it would result in an extra 1422 PTIC heifers. The net benefit across the project herds would equate to an extra $898,416 net income or an extra $64/heifer joined.

The target market is considerable with an estimated 500,000 heifers and 400,000 first calving cows developed each year across the target region. If 10% of all heifers and first-calving cows within the region were managed to increase WAPE by 10% there would be an increase of 7,920 calves weaned per year from the target region. When fully adopted this would represent an across region increase in farm gate production value of $5.68M/year.

Decision support tools have been developed to assist producers to make informed decisions about the value proposition of allocating greater feed to heifers. These should give greater confidence to those maximising productivity by balancing pasture utilisation and reproductive output. Many presentations have been given and producers have responded by calculating losses within their own production systems.

6. Future research and recommendations

A large adoption project has been approved and is currently being contracted. This will build on the outcomes from the project herein. In addition, there will be ongoing data collection and research. The project herein has extended Beef CRC work from genetics focus to commercial herds. The next project will include a greater emphasis on reproductive disease losses which can prevent gains from well managed feeding strategies.

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8. Appendix

8.1 Information to be provided to Heifers for Profit course material

Table 37. Information to be provided to Heifers for Profit course material

Provide updated research to Heifers for Profit course	
1.1	Provide updated research on: - Relationships between cow weights and condition score and herd weight and weight per condition score - Adjustments for pregnancy weights - Heifer calving weight targets - Graph of preg rate vs joining weight and joining ADG - Puberty info. from Black Baldy can reach puberty during joining and get successful outcome and value of scrotal EBVs (pg. 27) - Need some real data from calving to joining weight and condition loss (pg. 52) - Data on economics around heifer time of joining vs time to recover etc. (pg. 60)
1.2	Dystocia - Check if we can help with dystocia (Black Baldy data) - Analyse relationship btw preg rate and pre calving wt. to add weight to argument re managing heifers to not only manage dystocia but also getting back in calf.
1.3	WAPE - Components of WAPE and should be % of heifers have joined, and not % of heifers weaned although both are useful measures.
1.4	Jena's PHD research - Mobilisation of reserves of relationship with weaning weight and re breeding rates - Condition score variation over annual production cycle.

8.2 Heifer Conception Results

Table 38. Proposed publications from the Heifer Development Project.

Paper	Topic	Main points
1	Heifer Conception Part 1	Descriptive – weight, condition score, fat cover Winter vs spring joining Pre-joining and joining growth
2	Heifer Conception Part 2: Early Conception	How to get heifers in calf faster Modelling data Economic evaluation
3	Rebreeding of Heifers	Target weights Case study from Farm 8 Economic evaluation
4	Wastage	Slippage, still born, dystocia, heifer loss Mainly Farm 8 data with compiled data from other herds
5	WAPE	Brings together heifer conception, wastage and rebreeding Reporting across herds Biological and economic KPIs for WAPE Herd structure
6	Mature cow data	The importance of the recent findings for productive losses in mature cows needs to be reported. We haven't yet decided whether to integrate that into papers 3, 4 and 5 or whether to have an additional separate paper.

8.3 Heifer Conception Results

The distribution and average heifer joining weight, height, body condition, rib fat, pre-join ADG and joining ADG for autumn and spring calving animals and Farm 8 are presented (Table 39), Farm 8 was fitted as a season due to high numbers of heifers, thus removing any dilution effect on the other spring calving herds.

Table 39. Summary statistics for Autumn, Spring calving herds and Farm 8 for joining weight, height, body condition and rib fat and average daily gain pre-joining, and during joining, and conception rate (first 2 cycles).

Season	Weight (kg)	Height (mm)	BCS (1-5)	Rib Fat (mm)	Pre-join ADG (kg/day)	Joining ADG (kg/day)
Autumn	703	583	486	255	604	686
average	312	1215	2.9	4.9	0.24	0.30
range	206	250	1	8	3.4	4.34
sd	30.2	36.5	0.27	1.8	0.5	0.78
cv	9.7	3.0	9.4	35.6	204	263
Spring	1579	986	1390	1166	1525	698
average	377	1203	3.2	4.4	1.15	0.67
range	308	370	2.5	11	4.15	4.08
sd	45.9	95.4	0.47	1.9	0.43	0.34
cv	11.9	7.9	14.9	42.9	37.7	50.1
Farm 8	6569	3224	3875	782	2775	2819
average	328	1170	3.4	4.1	1.24	1.34
range	326	490	2.5	8	3.78	5.31
sd	35.1	77.9	0.33	1.5	0.67	0.67
cv	10.7	6.6	9.9	36.1	53.8	49.6

8.3.1 Joining Weight

There were 8851 joining records, of those 74% were from Farm 8 (a spring calving herd), 18% were from remaining spring calving herds and 8% were from Autumn calving herds (Table 39). The coefficient of variation was similar for autumn and spring calving herds and Farm 8. Spring calving herds were heavier (4%) than Autumn calving herds at joining, interestingly, Farm 8 heifers were on average 50kg lighter than the average of the other spring calving herds closer resembling joining weights of Autumn calving herd.

Joining weight was important (P=<0.0001) for early heifer conception. Spring calving herds had higher predicted conception rates than Autumn calving herds (Table 11) as a result of higher weight at joining. Autumn calving heifers that were lighter at joining (250kg) and had much lower predicted conception rates (40%) than lighter heifers at Farm 8 (68%). This due to the seasonal differences in feed supply, where Farm 8 Spring calving heifers were supplied ample pasture thus energy leading into joining, this reflected by higher growth rates and therefore, were able to reach adequate weight and conceive within six weeks. Autumn calving heifers that are heavier (325kg or more) at joining had similar predicted conception rates to Spring calving and Farm 8 heifer, it is likely that these heifers were at an adequate weight at the joining and therefore able to conceive within six weeks.

The season by joining weight interaction was significant (P=<0.0001), heifers from Autumn calving herds on average were significantly lighter than those from Spring joining herds (Figure 7). This result is likely due to increased feed availability prior to joining for those Spring calving and Farm 8 heifers.

8.3.2 Joining Height

There were 4793 height records, 67% were from Farm 8 (a Spring calving herd), 21% were from remaining Spring calving herds and 12% were from autumn calving herds (Table 39). Spring calving herds had the tallest heifers on average and Farm 8 the shortest. The coefficient of variation was higher at Farm 8 but still low at 6.65%.

Heifer conception rates were higher for all categories of season for taller animals (P=<0.001), however, when the model was adjusted for weight, height was not significant meaning weight has a stronger association to conception than height

8.3.3 Joining Residual Weight

Further analyses of joining height and weight was done by investigating the effect of residual weight. The interaction between season and residual weight was significant (P=<0.0001). In general heifers that were heavier for a given height (positive residual weight) had higher conception rates (Figure 19) however this was more important in Autumn calving herds. Similarly, to weight, this is likely due to the increased feed availability and growth during joining seen in the Spring calving heifers.

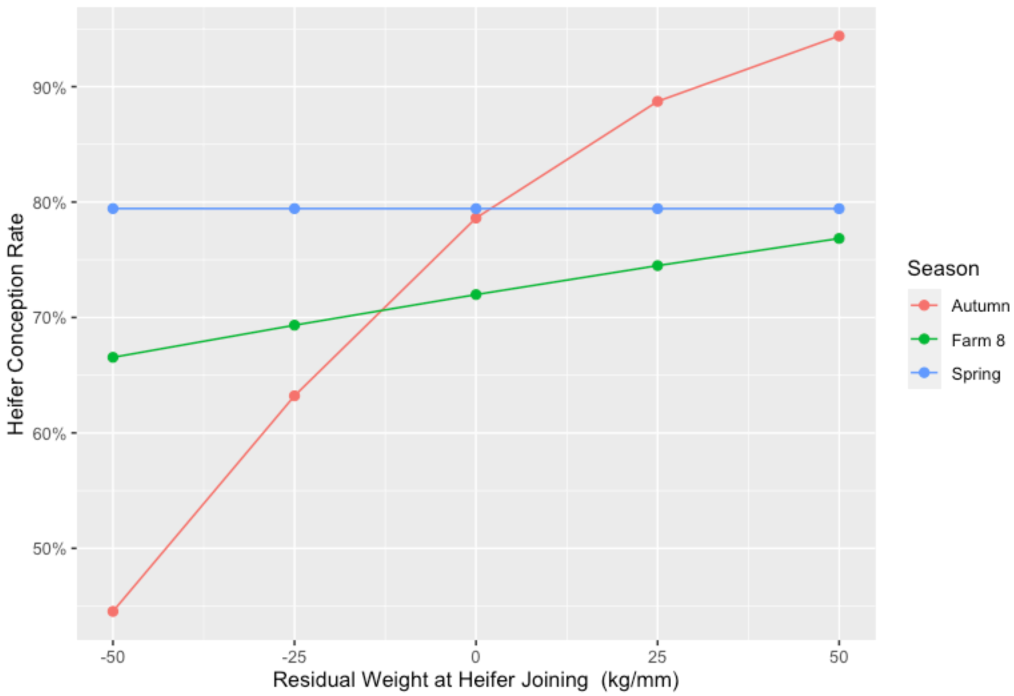

Figure 19. Heifer Conception predicted from Joining Residual Weight

8.3.4 Joining Body Condition Score

There were 5751 BCS records, 68% were from Farm 8 (a Spring calving herd), 23% were from remaining Spring calving herds and 9% were from Autumn calving herds (Table 39). Farm 8 heifers were in the best condition at joining, half a condition score greater than Autumn calving heifers. The coefficient of variation was higher in Spring calving herds but still low at 14.9%.

The interaction between body condition score and season was statically significant (P=<0.0001). The larger impact on conception within six weeks was observed in the Autumn calving herds, where those heifers that were in poorer condition (2.5) were less likely to achieve early conception (Figure 20), this likely due to the relationship between energy and fertility, those Autumn calving heifers did not have adequate energy reserves at joining to initiate the cascade of events leading to puberty and or successful conception. Those Spring calving or Farm 8 heifers that were in poorer condition at the start of joining likely had adequate nutrition leading into joining thus suppling enough energy for reproductive success.

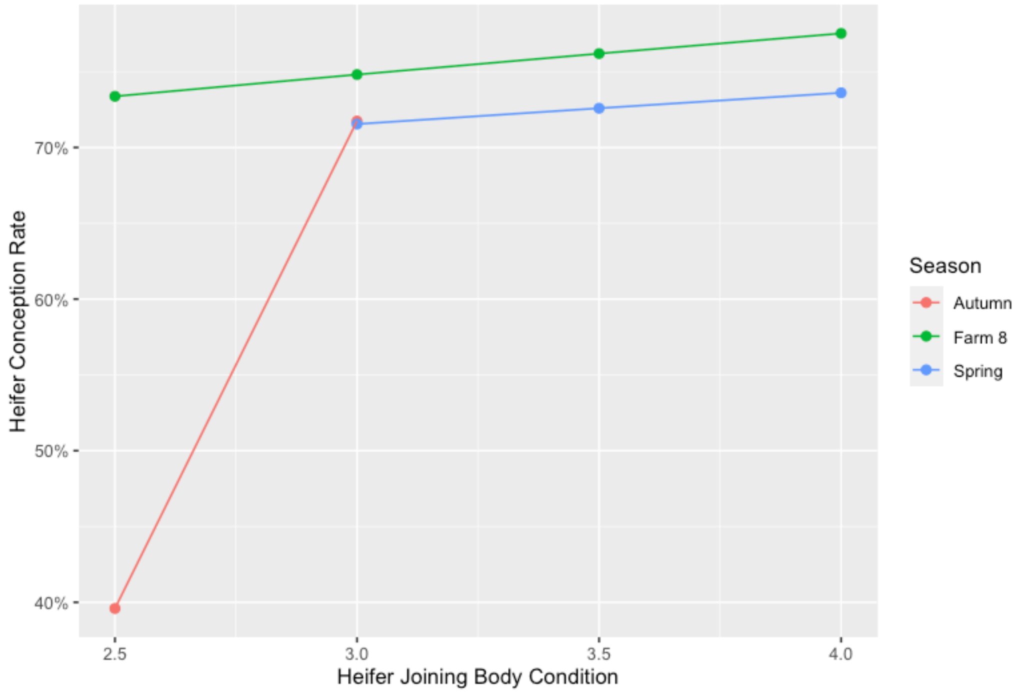

Figure 20.Heifer conception predicted from joining body condition by season.

8.3.5 Joining Rib Fat

There were 2203 rib fat depth records, 36% were from Farm 8 (a Spring calving herd), 53% were from remaining Spring calving herds and 12% were from Autumn calving herds (Table 39). The average rib fat depth was similar across Autumn and Spring calving herds and Farm 8. The coefficient of variation was higher in Spring calving herds (43.7%) with a minimum of 1mm and a maximum of 12mm and similar across autumn calving and Farm 8 heifers.

The main effect of rib fat suggested a trend (P=0.056) where fatter animals were more likely to get in calf in the first six weeks (Table 11). It is expected that those heifers that have greater fat coverage will get in calf earlier due to adequate energy reserves, and the relationship with earlier puberty onset. Jones et al. (2016) demonstrated the importance of fat coverage, reporting 85% conception rates at 52% MCW with 8mm of rib fat however, with only 4mm of rib fat the MCW needed to reach 69% to maintain 85% conception rates.

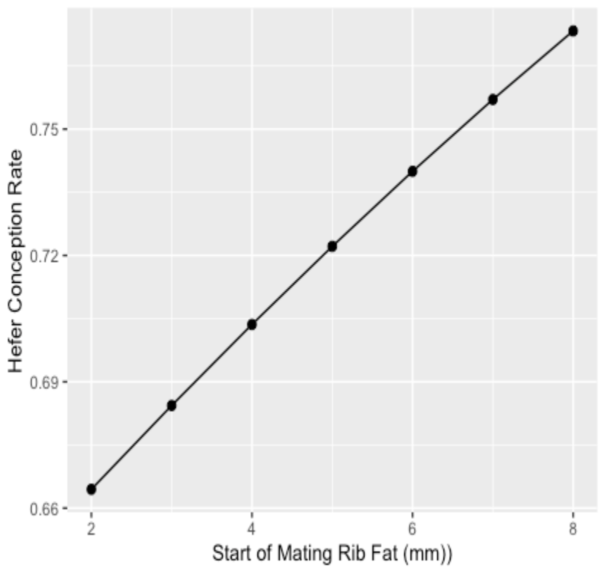

Figure 21.Heifer Conception predicted from Joining Rib Fat Depth.

8.3.6 Growth Pre-Joining

Growth for the month (approximately) leading up to joining was analysed where data were collected. At Farm 4 growth from 35 days pre-joining until the end of mating was included in the analyses. There were 4904 average daily gain (ADG) records pre-joining, 45% were from Farm 8 (a Spring calving herd), 38% were from remaining Spring calving herds and 17% were from autumn calving herds (Table 39). Spring calving heifers had the highest ADG pre-joining (1.09kg/day) and autumn calving heifers had the lowest (0.24kg/day). The coefficient of variation was higher in Farm 8 heifers (61.4%).

8.3.7 Growth During Joining

Growth during joining was analysed where data were collected. As with pre-joining growth, the growth rate at Farm 4 was included in this analysis and was measured from 35 days pre-joining until the end of mating. There were 2676 average daily gain (ADG) records during joining, 62% were from Farm 8 (a Spring calving herd), 26% were from remaining Spring calving herds and 12% were from autumn calving herds. Farm 8 heifers had the highest average daily growth during joining (1.65kg/day), and on average, autumn calving heifers were losing weight (-0.24kg/day). The coefficient of variation was higher in Spring calving heifers (50.1%), but still high in Farm 8 heifers.

8.4 Timing of Recording

Table 40. Timing of livestock and feed recording for late winter / spring calving system for 2018 born calves

Event	Approx. Date	Age in months	**Heifer and young cow records to be collected**				
Birth	1/08/2018	0.0					
Weaning	1/02/2019	6.0	weight				
Post weaning growth rate	13/05/2019	9.4	weight				
42 days prior to mating	8/09/2019	13.2	weight	fat depth	condition		
Start of mating (SOM) 1	20/10/2019	14.6	weight	fat depth	condition	height	
End of mating 1	1/12/2019	16.0	weight	fat depth	condition		
Pregnancy test and fetal age	1/02/2020	18.0	weight	fat depth	condition		
60 days prior to calving	1/06/2020	22.1	weight	fat depth	condition		
30 days prior to calving	1/07/2020	23.0	weight	fat depth	condition		
Start of calving 1 start	1/08/2020	24.0					calving difficulty
SOM2 & calf marking	20/10/2020	26.7	weight	fat depth	condition		
End of mating 2	1/12/2020	28.0	weight	fat depth	condition		
Preg test 2, fetal age, weaning 1	1/02/2021	30.0	weight	fat depth	condition	height	
60 days prior to calving	1/06/2021	34.1	weight	fat depth	condition		

30 days prior to calving	1/07/2021	35.0	weight	fat depth	condition		
Start calving 2 start	1/08/2021	36.0					calving difficulty
SOM3 and calf marking	20/10/2021	38.7	weight	fat depth	condition		
End of mating 3	1/12/2021	40.0	weight	fat depth	condition		
Preg test 3, fetal age, weaning 2	1/02/2022	42.0	weight	fat depth	condition	height	

Table 41. Recording timing for autumn calving system for 2018 born calves

Event	Approx. Date	Age in months	Heifer and young cow records				
Birth	1/04/2018	0.0					
Weaning	1/10/2018	6.0	weight				
Post weaning growth rate	11/01/2019	9.4	weight				
42 days prior to mating	9/05/2019	13.2	weight	fat depth	condition		
Start of mating (SOM) 1	20/06/2019	14.6	weight	fat depth	condition	height	
End of mating 1	1/08/2019	16.0	weight	fat depth	condition		
Pregnancy test and foetal age	1/10/2019	18.0	weight	fat depth	condition		
60 days prior to calving	1/02/2020	22.1	weight	fat depth	condition		
30 days prior to calving	1/03/2020	23.0	weight	fat depth	condition		

Start of calving 1 start	1/04/2020	24.0					calving difficulty
SOM2 & calf marking	20/06/2020	26.7	weight	fat depth	condition		
End of mating 2	1/08/2020	28.0	weight	fat depth	condition		
Preg test 2, foetal age, weaning 1	1/10/2020	30.0	weight	fat depth	condition	height	
60 days prior to calving	1/02/2021	34.1	weight	fat depth	condition		
30 days prior to calving	1/03/2021	35.0	weight	fat depth	condition		
Start calving 2 start	1/04/2021	36.0					calving difficulty
SOM3 and calf marking	20/06/2021	38.7	weight	fat depth	condition		
End of mating 3	1/08/2021	40.0	weight	fat depth	condition		
Preg test 3, foetal age, weaning 2	1/10/2021	42.0	weight	fat depth	condition	height	