Final report

.

Increasing uptake of performance-recording genetics through automated livestock management systems (Phase 2)

Final Report

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Abstract

The use of genetic selection technologies remains limited in the Northern Australian beef industry. One of the key challenges limiting its uptake is thought to be the difficulty in collecting the accurate performance data. This project sought to develop and evaluate an Automated Livestock Management System (ALMS) that aimed to refine the collection of key reproductive and growth rate data for input into genetic evaluation programs. The project was undertaken as an integrated research, development and extension program across a central hub, Belmont Research Station and several commercial seed stock operations. The ALMS demonstrated ability to accurately collect liveweight data. The deployment of ALMS was found to be challenging in some situations with planning and producer effort required to get optimal results. Where the system was optimally deployed and maintained it was found to be able to detect the date of birth (DOB) to within 7 days for over 90% of cows. In sub-optimal deployment situations the ALMS was able to deliver growth trait data to a degree of accuracy and over the required proportion of cattle that would be suitable for inclusion into genetic evaluation programs such as BREEDPLAN. An extensive communication and engagement program suggest that the technology will be well received by the industry when commercially available systems become available that are well supported. The potential for automated collection of phenotypic data in Northern Australia could have profound impacts on adoption of genetic improvement programs and warrants further research and investigation.

Executive summary

Background

The uptake of performance-recorded genetic evaluation of beef cattle in extensive production systems of Northern Australia is currently low. Some seedstock producers do capture important information for genetic evaluation to generate estimated breeding values. However, the buying of bulls based on quantitative genetic traits has not been widely adopted by commercial producers. Reasons for the lack of industry participation in performance recording are multifaceted and industry anecdotes suggest there is a disconnect between seedstock and commercial producers. Commercial producers are not confident in the current methods used to derive estimates of genetic value. There are also challenges associated with collecting accurate performance data that is compliant with genetic evaluation systems. The future for genetic improvement in Northern Australian beef herds requires more cattle with more accurate, frequent and reliable performance measures. Future genetic improvement programs need to capture data with more autonomy, at lower costs and with less labour. This project explored new and emerging technologies that could fill this need.

Objectives

This project had several key objectives:

- Validation of an Automated Livestock Management System (ALMS) and implementation of these systems into northern seedstock and commercial breeding operations, including ensuring effectiveness of the algorithms, automation, and authentication of the system in all seasons.
- Development of understanding around the impact of paddock conditions on accuracy of the ALMS and provide guidelines for industry.
- Quantification of the economic feasibility of using ALMS to record phenotypic traits for submission into BREEDPLAN.

The research undertaken in this project and the current commercial development of ALMS has now positioned the industry to enable the ultimate objective of expanding the number of producers that provide detailed, and accurate data for industry genetics evaluations.

Methodology

This project was undertaken as an integrated research, development and extension program. The primary research site, Belmont Research Station provided the “hub” for concentrated testing and evaluation of the ALMS, while several commercial properties (“spokes”) provided further validation and the opportunity to better understand the user experience.

The project specifically explored the issues relating to ALMS utilisation by cattle to optimise data collection. It developed and refined algorithms for the detection of the key phenotypes of Date of Birth (DOB) and the 400 Day Weight trait, specifically exploring the challenge of deriving these from real-world data which is often incomplete. This analysis was undertaken in the context of developing data at an appropriate standard for inclusion in the BREEDPLAN program.

An economic analysis was based on a model seedstock operation to explore where on-farm value might best be derived from the deployment of ALMS.

An extensive communication program engaged with producers across the industry to understand the issues and develop a pathway to market for the technologies as they become commercially available.

Key Findings

The project demonstrated that an ALMS could be developed and applied to collect performance recording data in extensive grazing systems of Northern Australia. However, this is not a simple process and producers intending to implement ALMS to collect phenotypic data need be aware that property paddock plans and water resources need to be carefully considered. Animals also require an initial training phase involving organisation and time commitment.

A key phenotype of interest to the Northern beef industry is date of birth. When the ALMS was operating under good conditions and being well maintained, a date of birth could be accurately predicted within 7 days for more than 90% of cows.

One of the key challenges in using an ALMS to collect data for growth traits is the incomplete attendance of animals in the system. Under optimal conditions, where water was isolated, this project demonstrated that 400 Day Weights could be calculated for over 98% of the animals in a cohort using a simple in-paddock weighing approach. However, these optimal conditions are unlikely to be readily replicated in commercial and seedstock operations. This issue was particularly evident in a challenging, real-world case study based on Belmont Research Station (without isolated water). A data analysis framework was developed to maximise the number of animal assigned a 400 Day Weight. Utilising random regression, estimated 400 Day Weights were able to be calculated for cattle with up to 75% missing daily weight data. Although the total proportion of animals for which a 400 Day Weight could be estimated remained low in this cohort, the process developed has the potential for filling in data gaps where system utilisation is more reasonable.

An economic analysis of the potential benefits of an ALMS determined that the highest benefits would come through labour savings with the second highest benefit being ascribed to small increases in calf survival through reduced interaction with calving cows. For the model seedstock operator, the greatest benefits came through the automation of data collection around date of birth rather than the growth traits. The cost-benefit ratio of investing in ALMS was largely positive, ranging between 1.4 to 2.9 for the average estimated benefits considered to be accrued across the model seedstock operation.

An extensive communication and industry engagement program provided significant insights across the project. Producer use case studies explored the challenges and benefits of the system and identified the various points of value and challenges to implementation. The development of commercially available systems with good support is likely to be well received by the industry.

The three research higher degree student programs developed as part of this broader research project are currently ongoing. These students are focussed on sensor-based methods for capturing genetic evaluation traits and maximising their adoption in Northern Australia.

Benefits to industry

This project has demonstrated that systems can be developed to automatically collect performance recording data for genetic evaluation programs. It has identified the challenges associated with implementing these systems across commercial and seedstock operations and provided guidance for producers. An economic analysis has demonstrated that a positive return on investment is likely at a farm level, primarily through labour savings.

The ability to automatically collect key phenotypic data such as date of birth and growth traits will ultimately enable more producers to commence performance recording and increase the utilisation of genetic evaluation programs in the northern beef industry.

Future research and recommendations

This project was undertaken in collaboration with established seedstock producers who are already collecting phenotypic data. There is a clear opportunity to apply the outcomes of this project in seedstock production systems that are not currently collecting data or into commercial herds, to explore the potential value this would bring the individual breeders and industry more broadly.

Much of the focus of this project has been on the evaluation of the ALMS to provide data in a format that can be used in the current BREEDPLAN structure. There is an opportunity to explore the development of new traits that cannot currently be assessed using traditional means (e.g. compensatory gain, growth trajectories, calving ease & maternal investment). The further development of impossible/difficult to measure traits that are critical for the Northern beef industry could be the key to increasing uptake of genetic improvement technologies. The focus of the economic analysis in this project was around the potential impacts for the individual producer. Although there are likely to be benefits at this level, it is the potential for improved data collection to refine the process of genetic evaluation in Northern Australia and the perceived trust by the broader industry that could have a much greater economic impact across the sector. A much broader economic analysis, although significantly more complicated, would provide guidance on the likely return on investment of research efforts in this domain.

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1. Background

The uptake of performance-recorded genetic evaluation of beef cattle in extensive production systems of Northern Australia is currently low. Some seedstock producers capture important information for genetic evaluation to generate Estimated Breeding Values (EBVs). However, the purchase of bulls based on quantitative genetic traits has not been widely adopted by commercial producers (Agricultural Business Research Institute, 2015; Lee and Pitchford, 2015).

Reasons for the lack of industry participation in performance recording are multifaceted. Industry anecdotes suggest there is a disconnect between seedstock and commercial producers as commercial producers are not confident in the current methods used to derive estimates of genetic value. There are also challenges associated with collecting accurate performance data that is compliant with genetic evaluation systems (e.g. BREEDPLAN). Such challenges include labour availability, scale, terrain, and significant costs. The challenges are particularly acute for more difficult to measure traits, such as birth dates and birth weights. However, these traits have the greatest potential to have a significant positive impact on production.

The future for genetic improvement in Northern Australian beef herds requires more cattle with more accurate, frequent, and reliable performance measures. Future genetic improvement programs need to capture data with more autonomy, at lower costs, and with less labour. The Cooperative Research Centre for Beef Genetic Technologies (Beef CRC) put significant resources into supporting data capture for genetic improvement in Northern Australia up to 2012. While the data is valuable, it is challenging for producers to replicate and to maintain the quality and quantity of data capture that occurred during Beef CRC projects. It is critical that the Northern beef industry start to prepare to facilitate the incorporation of automated technologies, such as Automated Livestock Management Systems (ALMS), to support genetic evaluation. The opportunity to record performance traits more efficiently and economically using technology will not only increase the number of animals with recognised EBVs through BREEDPLAN but will also provide a greater number of cattle available as a reference population for genomic evaluation.

It was proposed that challenges with increasing the uptake of performance-recording genetics be addressed in a two-phase project. The project would build on the work that members of the CQUniversity Precision Livestock Management (PLM) team have previously published on growth rates and measures of reproductive performance using automated performance measures (Prayaga et al., 2007; Handcock et al., 2009; O'Neill et al., 2014; Menzies et al., 2017a, b). The goal was to refine and validate the use of ALMS to provide a more cost effective and accurate solution to collect critical performance data and aid greater adoption of performance recording and genetic evaluation in Northern Australia. Issues associated with the practical application of the technologies would need to be addressed for the beef industry to have confidence in using ALMS within genetic improvement programs. In particular, the importance of ensuring cattle regularly access the ALMS across varied landscapes and seasons. The previous work completed by the PLM team had shown differences in how cattle interact with ALMS under different environmental conditions. Certain management strategies, such as restricting access to surface water and the use of supplements to further entice cattle to interact with the technology, had the potential to overcome environmental impacts.

Phase 1 of the project (Swain et al., 2018) raised awareness of the potential for ALMS and to develop the infrastructure in the context of a seedstock operation in Northern Australia. The project developed an ALMS approach, integrating a range of technologies, algorithms, and data management processes, across an 1,100 head herd at Belmont Research Station, near Rockhampton. The project design was based on a 'hub and spoke' model, whereby Belmont Research Station would act as a 'hub' of intensive research activity for ongoing testing and progress towards establishing a whole of system ALMS approach. It would also provide the opportunity for cattle producers to see how emerging technologies could be incorporated within a whole of property operation to provide objective assessments of cattle performance. The 'hub' would be linked with a series of 'spoke' properties, owned by private cattle producers to implement, evaluate, and refine ALMS under a range of commercial conditions. The 'hub and spoke' model would ensure high quality research, direct participation with the target demographic (seedstock and commercial producers), and an efficient vehicle for extension to industry. Phase 1 of the project was completed in 2018 and laid the foundation for expansion of the research project into Phase 2.

This project (Phase 2) aimed to address challenges with capturing accurate and cost-effective phenotypes and extend the use of ALMS into seedstock and commercial beef operations. The project would focus on increasing the accuracy, reliability, and integrity of genetic data collection to reduce barriers to adoption. The project would also focus on the ability to deliver phenotypes that are compatible with BREEDPLAN to expand the number of producers that are providing complete, detailed, and accurate data for industry genetic evaluations. Emphasis would be placed on engagement and communication with producers, genetic evaluation systems (e.g. BREEDPLAN), genomic companies, and breed societies to facilitate the extension of potential new data collection tools developed by this project. In doing so, the project would explore the ease of collection, application, and use of objective genetic information, promote the uptake of genetic improvement programs, and demonstrate the feasibility of ALMS for genetic improvement programs. The project would therefore support the increase in rate of genetic gain and the number of animals with EBVs and Northern beef productivity growth.

This final report delivers a synopsis of all research undertaken during Phase 2 of the project, including final research results and economic analysis.

2. Objectives

The original stated objectives of the project outlined below (2.1 Original stated objectives) provided a very broad overview of the goals of the project. However, to fully understand the project, a schedule of objectives has been developed (2.2 Objectives for the purposes of reporting) to enable the reader to better understand the structure of the project and integrate several activities that were not explicitly outlined as objectives. All of the original objectives are reported on within the new proposed framework along with the additional material to provide context and demonstrate the overall program outcomes.

2.1. Original stated objectives

The original stated objectives of Phase 2 were:

- Validation of the ALMS and implementation of these systems into Northern seedstock and commercial breeding operations, including ensuring effectiveness of the algorithms, automation, and authentication of the system in all seasons
- Understand the impact of paddock conditions on accuracy of the ALMS and provide guidelines for industry
- Quantification of the economic feasibility of using ALMS to record phenotypic traits for submission into BREEDPLAN, including reproductive traits
- Expand the number of producers that are providing complete, detailed, and accurate data for industry genetic evaluations

2.2. Objectives for the purposes of reporting

The amended schedule of objectives provides the framework for this report, addresses all original objectives, and provides additional context to enable a better understanding of the structure of the project. These objectives are directly linked to each section in this report.

- Development and evaluation of ALMS across Northern seedstock and commercial breeding operations
    - Development of ALMS through the integration of the walk-over-weigh unit, DataHub, and DataMuster visualisation systems
    - Establishment of a research focused 'hub' at Belmont Research Station to enable high resolution testing and evaluation
    - Establishment of ALMS across partner 'spoke' properties and development of understanding of key challenges to adoption
- Analysis of variables impacting on ALMS performance and success, for example, paddock conditions, ephemeral water sources
    - Exploration of environmental and animal variables that influence system utilisation and data fidelity
    - Development of guidelines for the implementation of ALMS based on the limitations identified
- Development and refinement of algorithms for date of birth and growth traits and calibration to BREEDPLAN standards
    - Reporting on the development of basic daily and weekly weight algorithm from the ALMS

  - Validation of ALMS generated weights against static weights
  - Generating BREEDPLAN compliant date of birth data from the ALMS
  - Development of BREEDPLAN compliant growth trait data from the ALMS
- Quantification of the economic feasibility of using ALMS to record phenotypic traits for submission into genetic evaluation programs
- Communication and extension strategy to expand the number of producers providing complete, detailed, and accurate data for genetic evaluation
- General conclusions and future research

Table 1. Alignment of the original objectives against the amended objectives within this report.

Original objectives	Amended objectives
Validation of the ALMS and implementation of these systems into Northern seedstock and commercial breeding operations, including ensuring effectiveness of the algorithms, automation, and authentication of the system in all seasons.	• Development and evaluation of ALMS across Northern seedstock and commercial breeding operations • Analysis of variables impacting on ALMS performance and success, for example, paddock conditions, ephemeral water sources • Development and refinement of algorithms for date of birth and growth traits and calibration to BREEDPLAN standards
Understand the impact of paddock conditions on accuracy of the ALMS and provide guidelines for industry.	• Analysis of variables impacting on ALMS performance and success, for example, paddock conditions, ephemeral water sources
Quantification of the economic feasibility of using ALMS to record phenotypic traits for submission into BREEDPLAN, including reproductive traits.	• Quantification of the economic feasibility of using ALMS to record phenotypic traits for submission into genetic evaluation programs
Expand the number of producers that are providing complete, detailed, and accurate data for industry genetics evaluations.	• Communication and extension strategy to expand the number of producers providing complete, detailed, and accurate data for genetic evaluation

3. Development and evaluation of the Automated Livestock Management System (ALMS) across Northern seedstock and commercial breeding operations

This project was designed to address limitations and barriers in the capture of phenotypes in Northern Australia, with a focus on increasing the accuracy, reliability, and integrity of the data captured for inclusion into genetic evaluation programs. At the core of these activities is CQUniversity's Automated Livestock Management System (ALMS). The system was developed to facilitate autonomous and accurate data capture for incorporation into genetic improvement programs.

The project was undertaken using a 'hub and spoke' model initially developed under Phase 1 of the project. Belmont Research Station would act as a 'hub' of intensive research activity to be linked with a series of producer-owned 'spokes' to ensure high-quality research, direct engagement, participation with end-users, and an efficient vehicle for extension to producers and industry. The process strengthened the suitability and practicality of the technology for application on commercial properties and also provided an opportunity for the project team to identify areas where learning needed to take place.

3.1. Development of the CQUniversity Automated Livestock Management System (ALMS)

In-paddock weighing technologies are becoming more accessible to graziers as commercial suppliers enter the market. Uptake of the technologies is promising and anecdotal feedback suggests their value in extensive grazing systems is increasingly understood by the industry. This project aimed to extract greater value from these technologies, exploring how to generate automated phenotyping measures in-situ. In order to achieve this, CQUniversity developed its own custom Automated Livestock Management System (ALMS) which integrated a walk-over-weigh platform with EID reader, an in-situ data processing and communications system (DataHub), and data management and visualisation platform (DataMuster) (Figure 1).

Components of the Automated Livestock Management System

Walk-over-weigh | **DataHub** | **DataMuster**

Figure 1. The Automated Livestock Management System (ALMS) is made up of three key components – a walk-over-weigh unit, the DataHub, and the DataMuster data visualisation platform.

3.1.1. Development of the DataHub for use with ALMS

One of the key developments undertaken in this project was the DataHub (Figure 2). The DataHub acts as an edge-compute module and captures data from the EID reader and walk-over-weigh platform for transmission to the DataMuster server. The DataHub captures high resolution data at 15Hz as each animal moves over the platform, and utilises algorithms embedded on a miniature computer, known as a Raspberry Pi (Raspberry Pi Foundation, Cambridge, UK), within the system to automatically generate a single representative weight (Figure 3). Erroneous data points are removed at this stage. DataHubs were developed to be compatible with many livestock management hardware options, allowing graziers to remain loyal to their preferred brand during participation in the project or to use hardware that they already owned.

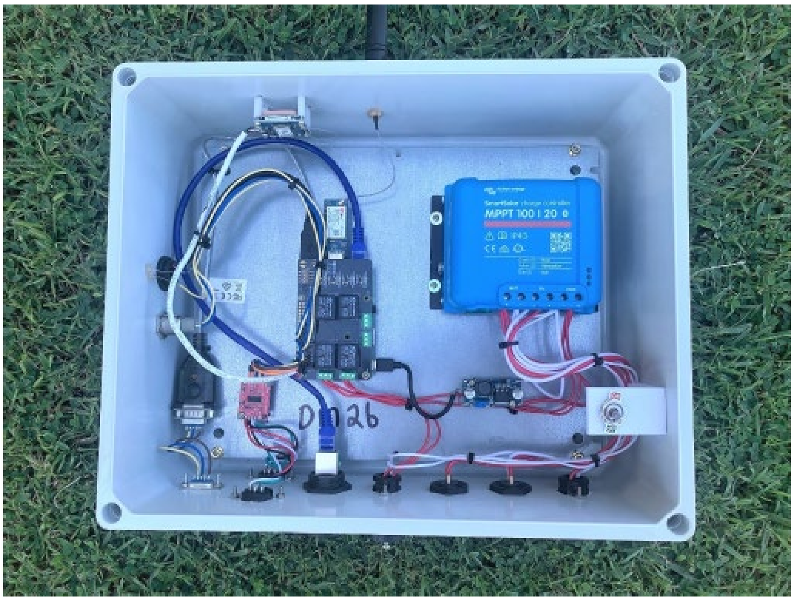


Figure 2. The DataHub was developed to facilitate the transmission of data from the walk-over-weigh system to the DataMuster visualisation platform. The DataHub is one component of the larger Automated Livestock Management System.

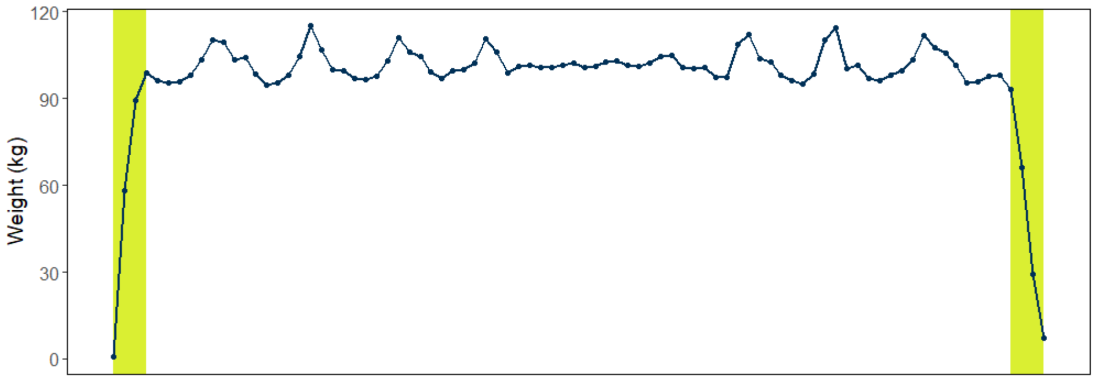


Figure 3. The DataHub will capture raw, 15Hz weight data as the animal traverses the walk-over-weigh unit. Green rectangles denote the animal stepping onto and off of the walk-over-weigh unit.

Over the life of the project, CQUniversity has developed and deployed 31 DataHubs across Northern Australia. Under this project, these devices have been used at Belmont Research Station, alongside four collaborator properties throughout Queensland and the Northern Territory.

3.1.2. Commercialisation of the CQUniversity developed ALMS and related intellectual property

CQUniversity owns intellectual property related to existing ALMS algorithms that are embedded into the DataHub and the DataMuster visualisation platform. These algorithms deliver the cattle weight data and links to electronic identification via RFID, date, and time. The focus of this project was to develop algorithms that provide summary data identifying optimal phenotypes aligned to existing genetic improvement tools, such as growth traits and dates of birth. Such algorithms would have commercial value particularly for seedstock producers that want more efficient tools to measure phenotypes. Value in the algorithms might also be seen by commercial beef producers who are interested in better connecting herd performance based on individual animals, with data showing breeding values and the associated herd genetic potential.

Discussions were initially held between CQUniversity and MLA to explore commercialisation options. The outcome of these discussions indicated that the algorithms would require deployment via commercialisation to maximise value for beef producers, given the potentially broad range of end-users. The algorithms should also align with current performance recording standards and provide a roadmap for future genetic evaluation opportunities based on new remote automated monitoring technologies. In principle the algorithmic IP should be validated, secure, easily accessible, and deliver data that is consistent with the expectations of any genetic improvement program.

At the time of writing this final report, a licensing opportunity proposal is being prepared for GrowAG to provide technology developers with the opportunity to integrate the IP developed within the project into their commercial systems.

3.2. Establishment of ALMS at Belmont Research Station

The establishment of ALMS at Belmont Research Station formed the 'hub' of the 'hub and spoke' model. The focus for Belmont Research Station was to plan, implement, and test the automated cattle monitoring infrastructure and to develop and evaluate algorithms.

A total of 21 ALMS were installed at Belmont Research Station across the life of the project, recording data on 2,717 breeding and growing animals, and generating 202,181 weights (Table 2, Figure 4). Each ALMS used different layouts and infrastructure, but all incorporated portable panels formed into a compound, surrounding a watering point, with a race leading cattle past an EID reader and over a weighing platform. Spear gates were installed on the entry and exit of the compound, ensuring the one-way flow of traffic.

A 15 day training protocol was designed to ensure cattle were accustomed to walking through a race, over the weigh platform, and through the entry spear gates (10. Appendix A). Limited meaningful weight data is recorded during the training program, however, following completion of the 15 day period typically all animals are recording weight data.

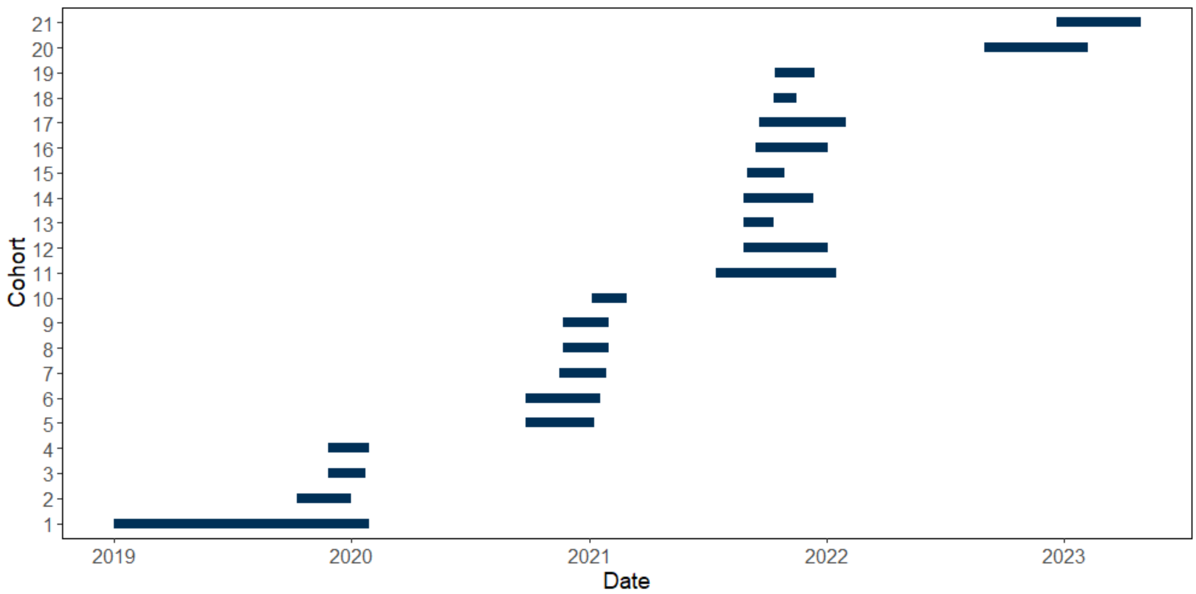


Figure 4. A total of 21 cohorts were monitored at Belmont Research Station using ALMS.

Initial cohorts at Belmont Research Station had high percentages of daily weights that were zero, due to perceived or real erroneous weights detected by the DataHub (Table 2). The algorithm on the DataHub underwent continuous refinement between January and November 2019, resulting in a decreasing percentage of zero weights over time. By the beginning of 2021, nearly all cohorts had less than 1% zero weights (Table 2). Despite the improved daily weight capture across time, there was still substantial variation observed in the percentage of the herd recording a weekly weight, with a range of 45.9% to 98.4% observed (Table 2). This could suggest that the quality of the daily weight data, despite the improvement in zero daily weights, is fluctuating. Further exploration and validation of the daily and weekly weight values can be found in 4.5.2 Validation of the data captured using ALMS: comparing static weights to daily and weekly weights.

Table 2. A total of 21 cohorts were monitored at Belmont Research Station using ALMS.

Cohort	**Start**	**End**	**Weeks on ALMS**	**Number of cattle**	**Total daily weights**	**Percentage of zero daily weights**	**Percentage of herd recording a daily weight**	**Total weekly weights**	**Percentage of herd recording a weekly weight**
1	01/01/2019	30/01/2020	56	105	36,317	46.3%	36.3%	1,988	58.1%
2	10/10/2019	02/01/2020	12	164	10,519	53.5%	22.8%	430	67.7%
3	28/11/2019	23/01/2020	8	131	3,113	19.2%	34.6%	248	45.9%
4	28/11/2019	29/01/2020	8	121	10,588	0.5%	76.6%	847	92.6%
5	26/09/2020	10/01/2021	15	47	4,011	9.6%	42.0%	216	48.9%
6	26/09/2020	19/01/2021	16	50	4,955	0.6%	54.6%	374	54.0%
7	17/11/2020	28/01/2021	10	252	34,231	0.6%	61.4%	1,654	97.2%
8	23/11/2020	31/01/2021	9	65	3,594	0.4%	48.0%	245	50.0%
9	23/11/2020	01/02/2021	10	69	2,839	1.5%	41.3%	225	47.8%
10	06/01/2021	28/02/2021	7	83	7,279	1.1%	60.8%	341	60.2%

11	15/07/2021	17/01/2022	26	193	25,417	7.1%	53.4%	2,333	98.4%
12	26/08/2021	03/01/2022	18	105	4,461	0.04%	29.7%	448	54.1%
13	26/08/2021	13/10/2021	6	472	12,163	1.6%	46.4%	1,217	83.7%
14	27/08/2021	12/12/2021	15	101	5,088	0.1%	34.7%	452	85.8%
15	01/09/2021	28/10/2021	8	61	3,950	0.5%	64.9%	332	71.2%
16	14/09/2021	04/01/2022	16	99	5,292	0.2%	33.2%	415	68.4%
17	20/09/2021	01/02/2022	19	59	6,059	0.3%	47.6%	379	56.4%
18	12/10/2021	17/11/2021	5	65	2,035	0.2%	51.9%	161	86.8%
19	14/10/2021	15/12/2021	8	143	4,708	0.3%	34.6%	376	49.1%
20	02/09/2022	07/02/2023	22	147	2,141	0.3%	16.1%	158	61.2%
21	22/12/2022	29/04/2023	18	185	13,421	0.1%	32.9%	1,078	80.6%%
		Total	312	2,717	202,181				

3.3. Establishment of ALMS at collaborator 'spoke' properties

The establishment of ALMS at producer-owned properties formed the 'spokes' of the 'hub and spoke' model. The focus for the 'spoke' properties was to develop the processes and procedures for the successful implementation of the hardware on-farm, increase producer participation in the project, maximise quality research outputs, and capture producer feedback on technology performance and adoption barriers.

A customised product research and development agreement was developed to manage the collaborator-CQUniversity relationship. The research agreement was effected for 12 months, after which the collaborator could choose to continue involvement in the research or cease to renew the contract and return the DataHub.

Included in the agreement was an outline of the equipment required for ALMS. CQUniversity would lease the collaborator a DataHub unit to collate and transit ALMS data. The CQUniversity project team would support collaborator access to the DataMuster software and access to the data collected on their property. The collaborator was responsible for supplying all other ALMS infrastructure, aside from the DataHub. Table 3 details a standard list of equipment required. The DataHub was developed to integrate with commercial weighing infrastructure regardless of brand. Thus, collaborators could choose to purchase new items, use existing infrastructure and equipment, or purchase a custom-designed integrated unit manufactured by Stark Engineering Pty Ltd. If the collaborator chose to use their own equipment, the research team provided advice about specific product strengths and limitations. At the end of the agreement period the collaborator retained all infrastructure except the DataHub.

Table 3. Two models of ALMS installation and purchase were available to participating producers.

<table>
<tr><th>Option 1: commercially available ALMS components</th><th>Option 2: pre-fabricated walk-over-weigh unit (manufactured by Stark Engineering[1])</th></tr>
<tr><td>● Walk-over-weigh platform
● Solar panel
● Solar panel mount
● Deep cycle battery
● Loadbars
● EID tag reader
● EID tag reader antenna
● Portable panel, including pins
● Portable panel, including pins and modified with timber inserts
● Race bows (2)
● Spear gates (2)</td><td>● Walk-over-weigh integrated system
● Solar panel
● Deep cycle battery
● EID tag reader controller
● EID tag reader antenna panel
● Spear gates (2)</td></tr>
<tr><td colspan="2">Additional components (dependent on site specific requirements)</td></tr>
<tr><td>● Enclosure fencing around water point
● Enclosure fencing around ALMS</td><td>● Enclosure fencing around water point
● Enclosure fencing around ALMS</td></tr>
</table>

● Pole and fixtures for solar panel mount	

[1] *Stark Engineering and Hardware Pty Ltd., Forest Hill, QLD, 4342*

In addition, CQUniversity provided collaborators with the necessary service to effectively implement the technology as part of the agreement. A member of the project team conducted regular site visits to assist with establishment of the infrastructure, including assistance to maximise cattle training (10. Appendix A). The project team liaised with the collaborator to determine the most efficient placement of the ALMS depending on their property layout and purpose for installing the technology. A detailed map of the property showing access points, water courses, and fences was developed and used to form the foundation of the DataMuster data management software delivery platform (Figure 5).

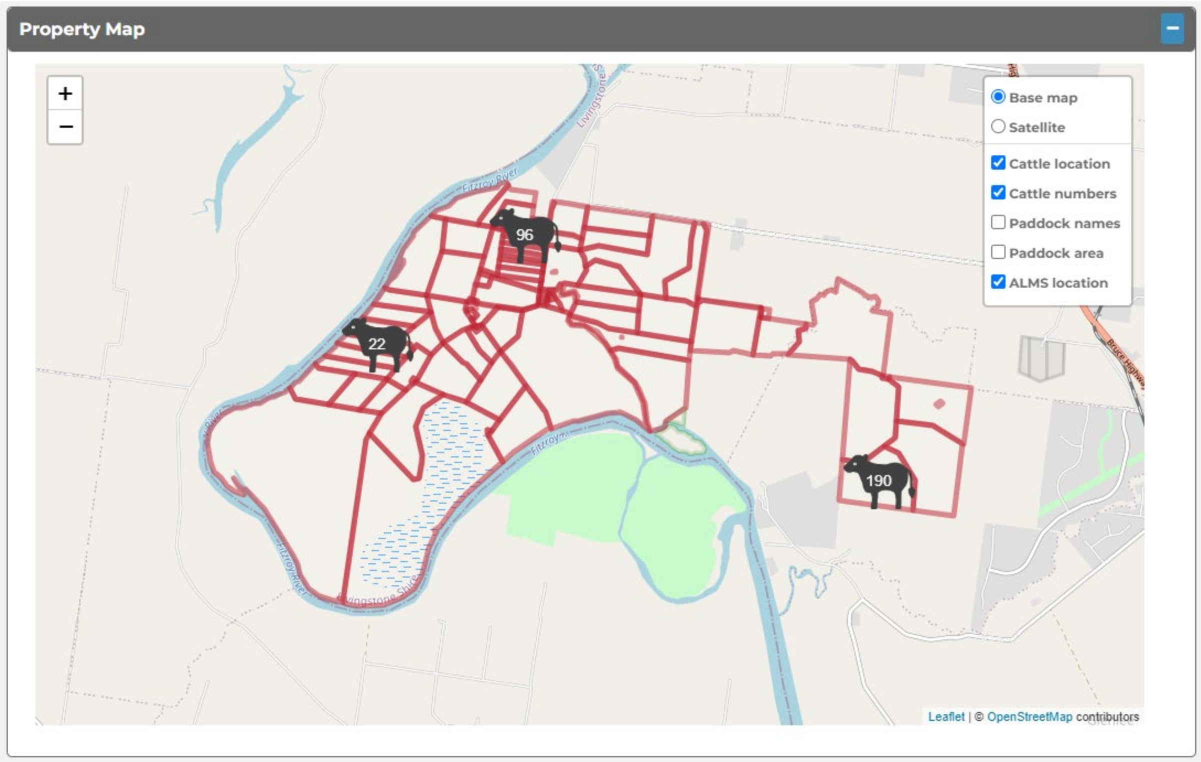


Figure 5. A map of the property, with paddocks, fences, and watercourses mapped out, is available for visualisation on the DataMuster platform.

Following installation of the ALMS, the project implemented a development and evaluation cycle. Ongoing producer consultation was provided to continuously refine, test, and evaluate the system and improve data capture and transmission. Consultation primarily consisted of contact being made with the collaborating producer to identify any key limitations, report on data capture, and develop strategies to mitigate the described issues. New developments were again tested and evaluated and the development-evaluation cycle continued, with feedback from the collaborator on how the system would best be used on their property. Collaborator involvement in this phase of the project allowed the ALMS technology to be tested and evaluated under commercial conditions whilst also providing an opportunity to test the data management and delivery, as collaborators were also involved in viewing and interpreting data from their herd.

Final evaluation of the success of the implementation occurred once the sites had been established for a 12-month period. This period of time allowed for true evaluation of the technology under commercial conditions as well as the process of service delivery to collaborators, such as developing and refining a contract between CQUniversity and collaborators and conducting tutorials on how to use the software and interpret data.

A detailed account of the installation and performance of the ALMS at the first producer 'spoke' property can be found in 11. Appendix B.

3.3.1. Overview of data captured from 'spoke' properties

Four 'spoke' properties were recruited to the project – Carisma Station, Killara, Mathison, and Tremere Pastoral (Table 4). A total of 272,528 data points were generated for 3,040 animals across 10 different cohorts (Table 5).

Compared to the data captured from the ALMS at Belmont Research Station, the data captured from the 'spoke' properties had a higher proportion of zero weights, indicating that there were a greater number of incidences of erroneous weight capture on the system (Table 5). The algorithm situated on the Raspberry Pi within the DataHub was consequently refined to improve the accuracy of data capture and reduce the instances of erroneous weight capture. For the properties with two or more cohorts (Killara and Tremere Pastoral), there were decreases in the percentage of zero weights captured and increases in the percentage of the herd recording daily weights over time, indicating improvements in the data captured and ALMS usage (Table 5).

Interestingly, the 'spoke' properties showed a greater percentage of each herd recording a weekly weight (range: 57.6% – 99.0%) compared to Belmont Research Station, with three cohorts achieving more than 90% of their herd having recorded a weekly weight (Table 5).

Table 4. Four 'spoke' properties were recruited to the project. Two properties had more than one cohort and spanned two or more years of participation in the project.

Property	Number of cohorts	Total number of cattle	Total daily weights captured
Carisma Station	1	489	28,484
Killara	2	735	52,466
Mathison	1	301	6,839
Tremere Pastoral	6	1,515	184,559

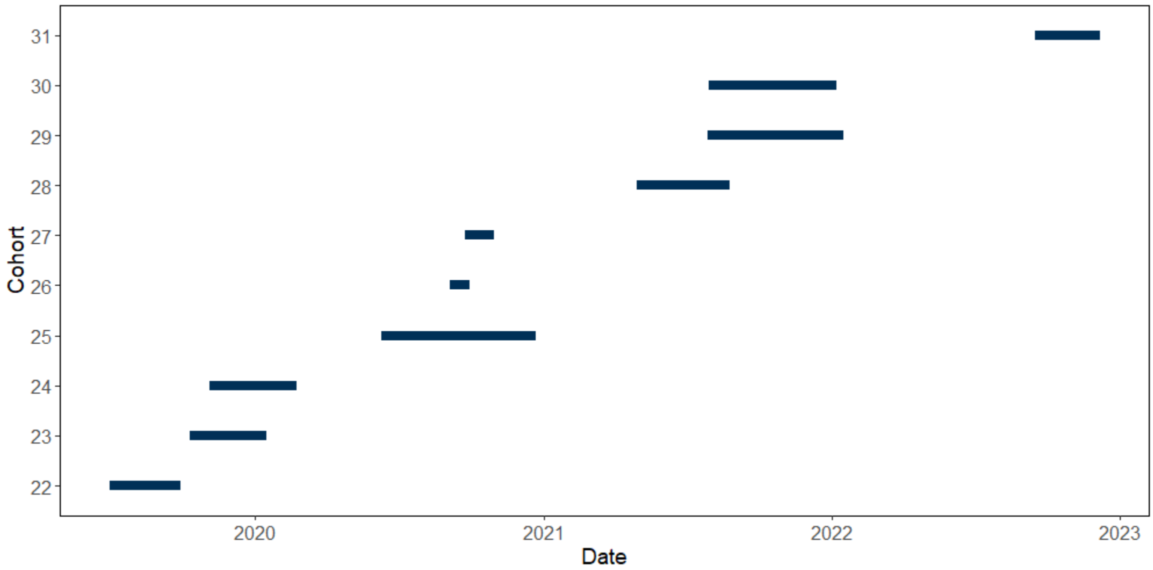


Figure 6. A total of 10 cohorts were monitored at the four ‘spoke’ properties using ALMS.

Table 5. A total of 10 cohorts were monitored at four different 'spoke' properties across the life of the project.

Property	Cohort number	Start	End	Weeks on ALMS	Number of cattle	Total daily weights	Percentage of zero daily weights	Percentage of herd recording a daily weight	Total weekly weights	Percentage of herd recording a weekly weight
Killara	22	30/06/2019	28/09/2019	12	712	45,276	66.5%	36.7%	1,933	98.0%
Tremere Pastoral	23	10/10/2019	15/01/2020	13	293	21,719	3.7%	59.2%	1,329	57.6%
Tremere Pastoral	24	04/11/2019	22/02/2020	15	292	10,660	0.2%	35.0%	843	59.5%
Tremere Pastoral	25	09/06/2020	21/12/2020	27	299	57,801	4.5%	60.5%	4,706	58.6%
Killara	26	03/09/2020	29/09/2020	3	23	7,190	17.3%	55.9%	38	65.2%
Mathison	27	23/09/2020	30/10/2020	5	301	6,839	0.2%	49.8%	429	74.1%
Carisma Station	28	29/04/2021	24/08/2021	16	489	28,484	3.1%	40.9%	2,174	96.1%
Tremere Pastoral	29	28/07/2021	15/01/2022	24	214	41,645	4.0%	75.8%	3,543	77.7%
Tremere Pastoral	30	29/07/2021	06/01/2022	23	220	35,487	0.03%	71.9%	3,566	73.3%
Tremere Pastoral	31	15/09/2022	06/12/2022	11	197	17,427	0.2%	72.4%	1,581	99.0%
			Total	149	3,040	272,528				

3.3.2. Challenges to the adoption of ALMS on 'spoke' properties

The project team engaged with producers across Queensland and the Northern Territory via email to explore options to deploy ALMS technology. More than 30 producers expressed interest in hosting 'spoke' sites on their properties following the initial project launch at Beef Australia 2018 (see 7. Communication and extension strategy to expand the number of producers providing complete, detailed, and accurate data for genetic evaluation). Of these, 10 progressed to the point of equipment purchase and installation. The process of on-boarding producers and installing ALMS on their properties provided valuable insights into the adoption challenge that will face technology providers in the future:

- All 10 producers purchased ALMS hardware.
- Follow up support was provided in the form of phone conversations, provision of implementation guides, and the offer of a farm visit to assist with installation.
- Seven of the 10 producers operationalised the equipment, however, the remaining 3 producers were unable to organise implementation on their properties due to competing production priorities. As of 2023, only one producer continues to utilise the system.
- Three producers ceased using the equipment due to hardware issues, lack of property infrastructure/connectivity, and lack of use due to their herd and land management system.
- Interest in the research remains strong. The three producers who purchased equipment, but have not yet utilised it, have signalled their intent to activate the technology in 2023 and a desire to remain part of future research in this field.

Finding the time to implement change and commit to persisting with change appeared to be the major barrier between the point of commitment to participate and the implementation of the technology on farm. The successful installation and operation of ALMS is not simply a 'plug-and-play' scenario but relies on a staged process. Awareness and understanding that using ALMS equipment requires investment in understanding how to deploy and maintain the equipment is critical. Identifying the correct placement of the ALMS within the paddock landscape, pre-training of the cattle, monitoring and validation of the hardware and software in place, and checking the website to track progress are all important elements to consider.

4. Analysis of variables impacting on ALMS performance and success

Over the course of the monitoring period, several animal and environmental variables impacted ALMS visitation. This section investigates the different animal characteristics and environmental variables that impact visitation and describes observed visitation trends in response to these factors. The usage metric used in this section is specified as the number of days per week where at least one visit occurred. This metric does not consider multiple visits within one day. Therefore, the greatest number of days in the week that could have recorded a weight was seven.

4.1. Impact of animal variables on uptake and use of ALMS

4.1.1. Time on ALMS

An animal's familiarity with an ALMS is expected to affect usage of the system. The time spent on an ALMS was examined as a product of total time spent on the ALMS across an animal's lifetime and the current time spent on the ALMS. In both situations, a broad trend was observed where increased time spent on an ALMS resulted in greater usage (Figure 7, Figure 8). This is unsurprising as animals require time to acclimate to the system. In addition, the commencement of the use of the ALMS often coincided with the movement of animals into a new paddock, which requires additional acclimation to identify water sources and explore the feed base.

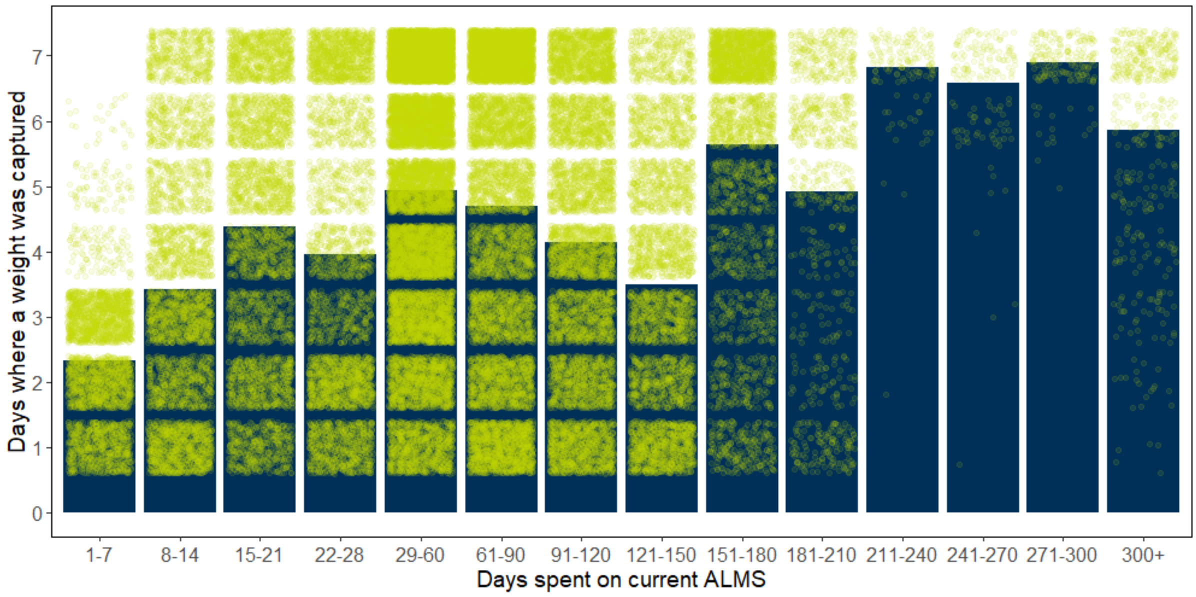


Figure 7. Time spent on the current ALMS compared to days where a weight was captured. Green dots represent individual datapoints, while blue bars represent the average for the cohort.

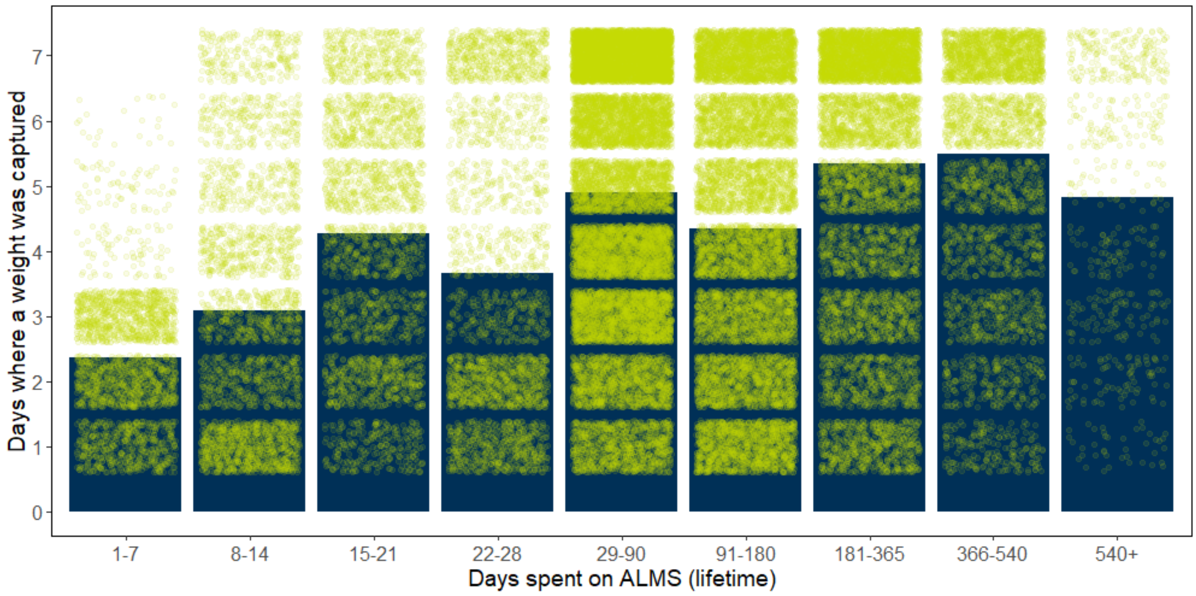


Figure 8. Time spent on an ALMS across the lifetime of the animal compared to days where a weight was captured. Green dots represent individual datapoints, while blue bars represent the average for the cohort.

4.1.2. Age of cattle

ALMS usage increased as cattle aged, with maximum usage observed when cattle reached 4 years of age and lowest usage rates observed in cattle under 1 year (Figure 9). The earliest instance of ALMS usage by a calf was on the day of birth (n = 1) and peak usage following birth but prior to weaning occurred 13 days after birth (n = 46) (Figure 10).

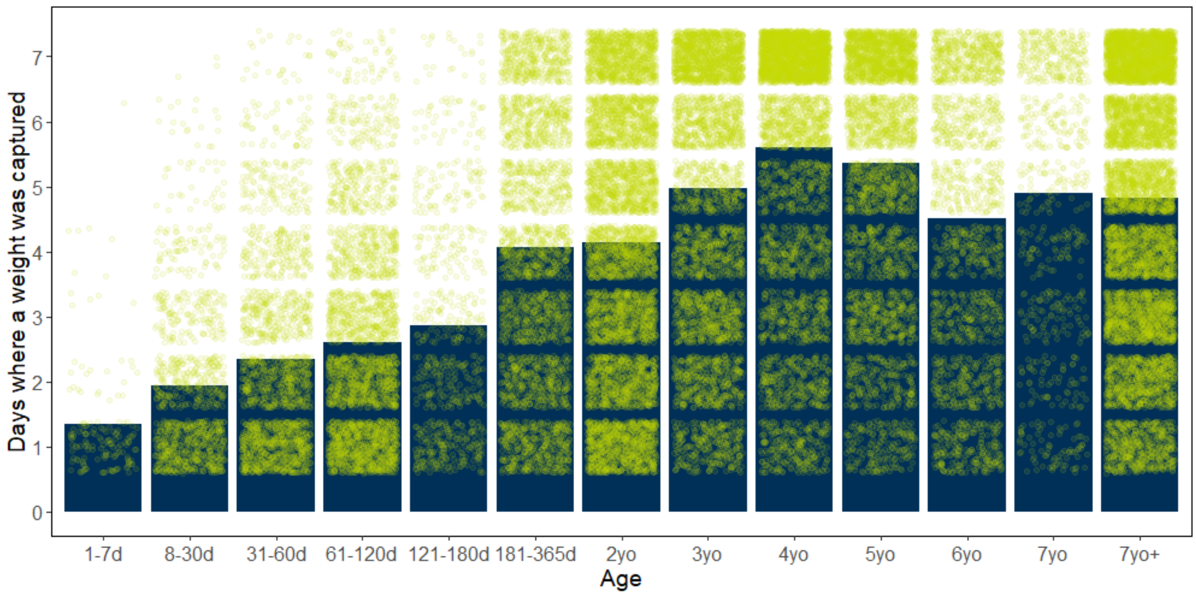


Figure 9. Age of the animal on the day of ALMS use compared to days where a weight was captured. Green dots represent individual datapoints, while blue bars represent the average for the cohort.

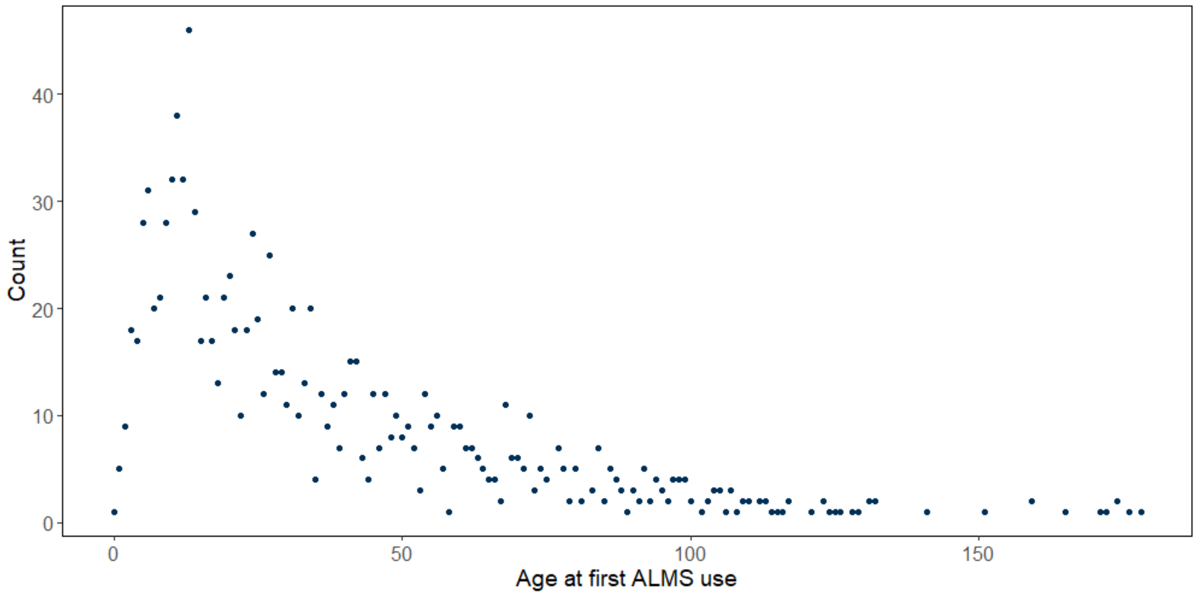


Figure 10. The age of the cattle at first ALMS use.

4.2. Impact of environmental variables on uptake and use of ALMS

4.2.1. Property and paddock

The paddock in which animals were housed was expected to affect ALMS use. Paddock characteristics are highly variable across and between properties within the project. The number of water sources, paddock size, and paddock topography were all anticipated to affect ALMS usage. Variation in the paddocks used showed differences in ALMS usage, even between paddocks on the same property, indicating that some paddocks were better suited to ALMS compared to others (Figure 11, Figure 12). As a result, a whole of property management plan and forecasting framework was developed for Belmont Research Station to ensure that animals were utilising paddocks more suited to ALMS data capture during key periods, such as during calving or 200 Day Growth and 400 Day and 600 Day Weight measurement.

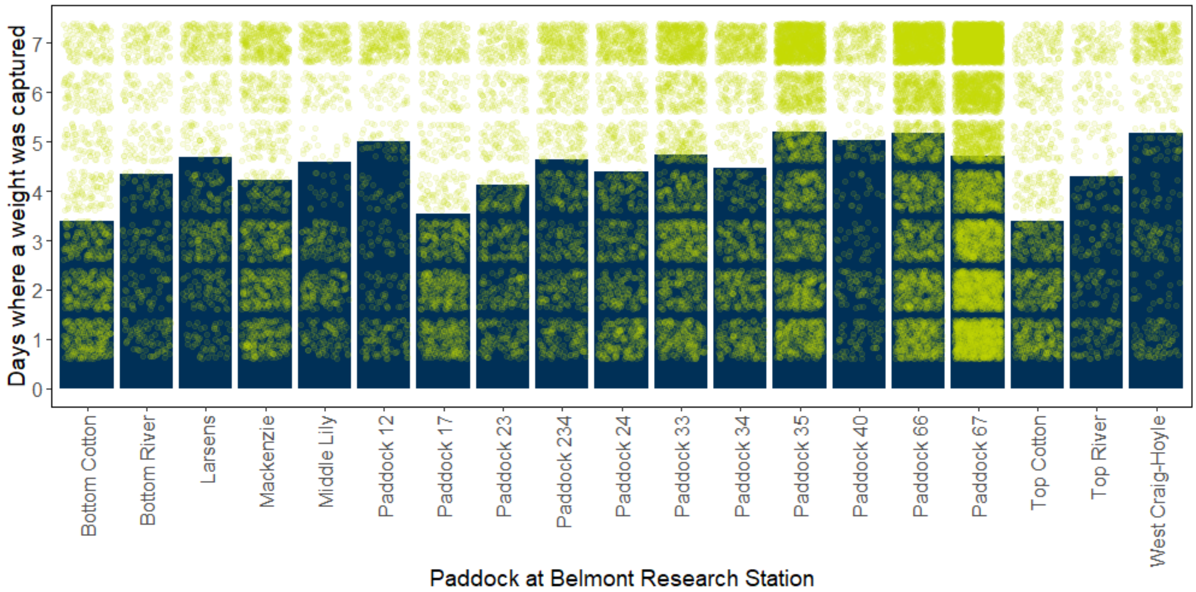


Figure 11. Paddock at Belmont Research Station compared to days where a weight was captured. Green dots represent individual datapoints, while blue bars represent the average for the cohort.

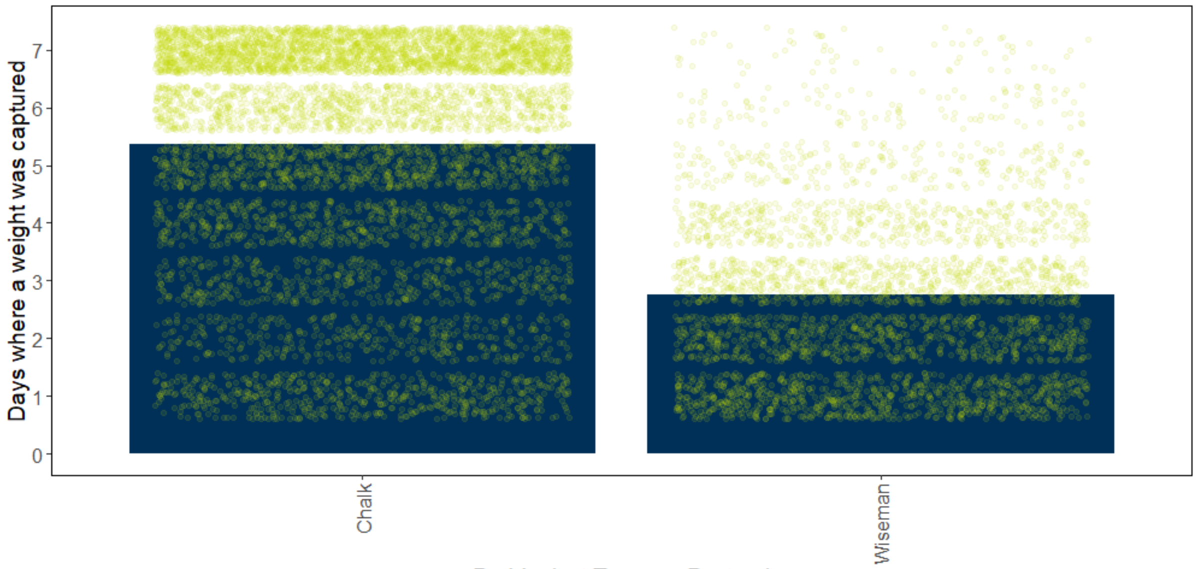


Figure 12. Paddock at Tremere Pastoral compared to days where a weight was captured. Green dots represent individual datapoints, while blue bars represent the average for the cohort.

4.2.2. Paddock size

A broad trend exists between paddock size and ALMS usage, with a decrease in usage observed in larger paddocks (Figure 13). This is likely due to increased opportunities for surface water accumulation and multiple water sources, which in turn will reduce usage of the ALMS in situations where water is used to incentivise ALMS use. Where more than one water source is available, cattle will frequently divide water consumption between several sources, thus reducing overall ALMS usage.

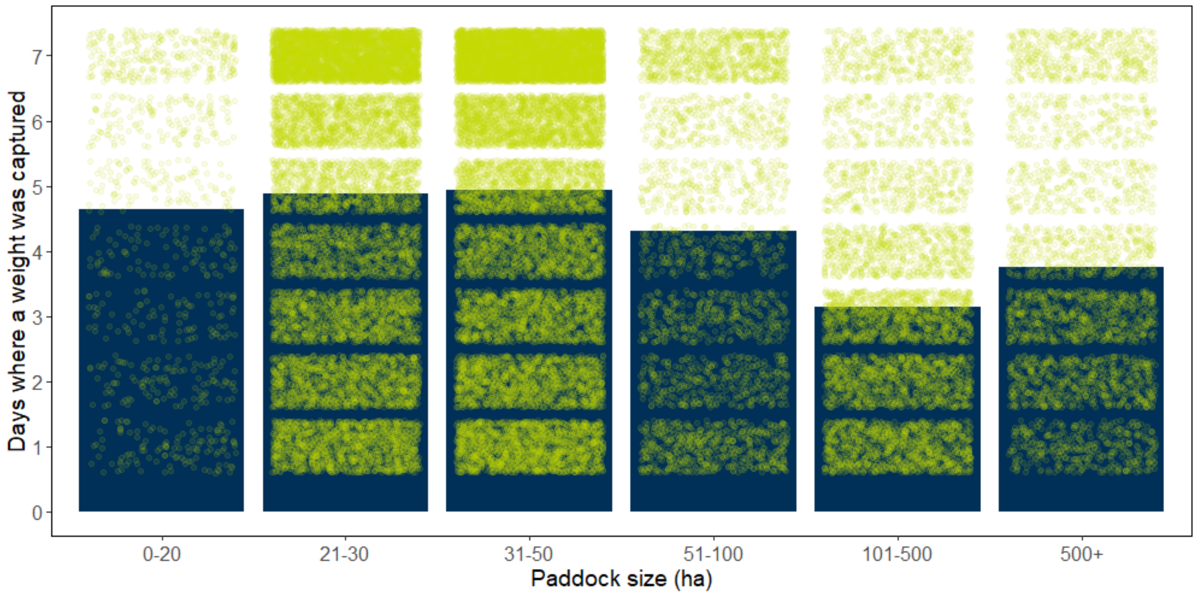


Figure 13. Paddock size in hectares compared to days where a weight was captured. Green dots represent individual datapoints, while blue bars represent the average for the cohort.

4.2.3. Herd size

A relationship was identified between herd size and ALMS usage, whereby increased herd sizes were associated with decreased ALMS use (Figure 14). Larger herd sizes are frequently associated with housing in larger paddocks and this may explain, in part, the association. As discussed in 4.2.2 Paddock size, larger paddock sizes provide greater opportunities for surface water accumulation and are often associated with multiple water sources, diluting the usage of ALMS systems where water incentivises use.

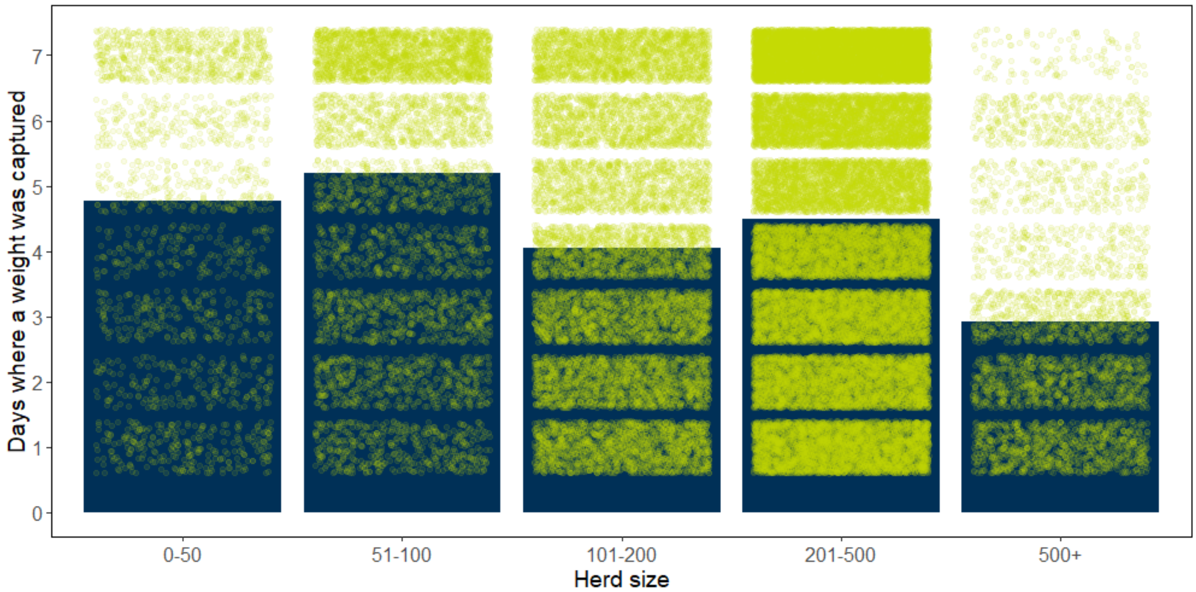


Figure 14. The herd size (number of animals also residing in the same paddock and using the same ALMS unit) was compared to the ALMS usage.

4.2.4. Rainfall

Rainfall data was retrieved from the Bureau of Meteorology website for the participating properties (Table 6) (Bureau of Meteorology) over the period of the project. The rainfall was amalgamated for the week in which ALMS usage was examined. Higher rainfall was associated with decreases in ALMS usage (Figure 15). This is unsurprising as all of the ALMS were installed with water as the incentive to encourage utilisation. Access to water as a result of rainfall, therefore, resulted in a decrease as cattle were able to access water without entering the ALMS.

Table 6. Historical rainfall data for each experimental property from the Bureau of Meteorology website.

Property	Bureau of Meteorology station
Belmont Research Station	033310: South Yaamba TM, QLD
Carisma Station	039151: Gonyelinka, QLD

Killara Station	040671: Killara, QLD
Mathison Station	014974: Mathison, NT
Tremere Pastoral	039071: Moura Post Office, QLD

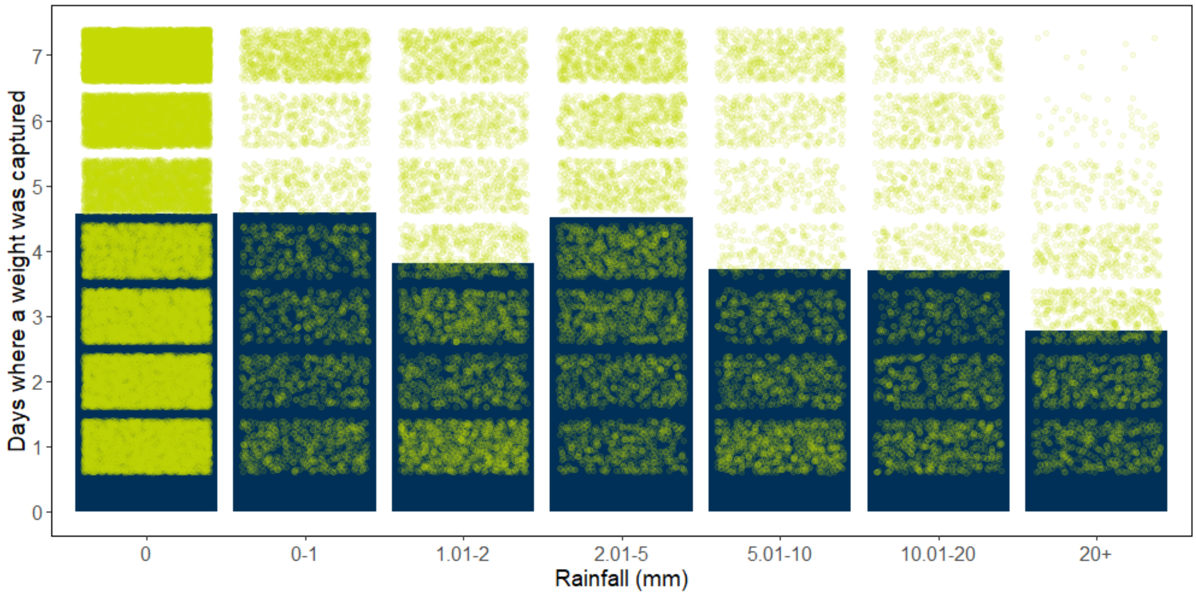


Figure 15. Rainfall accumulated over the week was compared to ALMS usage at both the ‘hub’ and ‘spoke’ properties.

4.2.5. Time of day

Time of day was not expected to, and didn't, impact on the utilisation of ALMS units and the ability to capture daily weights. It was, however, an opportunity to explore other data streams recorded by walk-over-weigh technologies, such as visitation characteristics. Visitation characteristics may prove useful in some phenotypic predictions, for example, inclusion in calving date or mothering up algorithms. Over the course of 24 hours, the greatest utilisation is observed at 8:00am (Figure 16). Following this, utilisation throughout the day decreases slightly before plateauing, then dropping to low rates throughout the night (Figure 16).

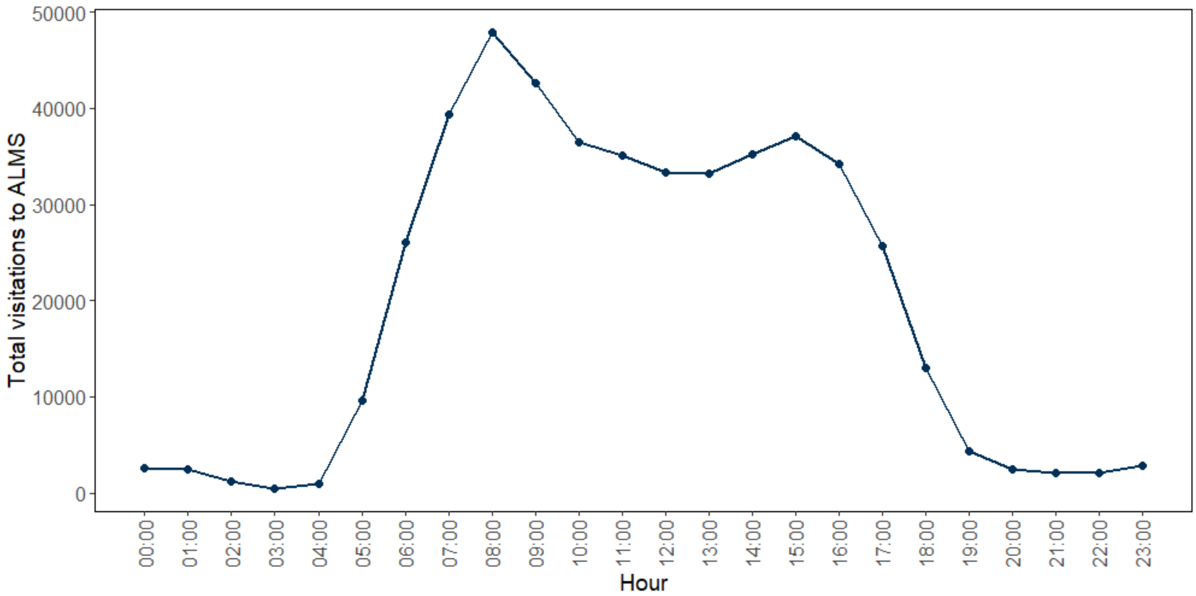


Figure 16. The time of the day in which animals utilised the ALMS was identified. Increased usage was observed during the day.

4.3. Guidelines and conclusions arising from variable analysis

Examination of a variety of environmental and animal variables have identified some key guidelines and considerations when implementing ALMS.

The key driver encouraging ALMS usage is water. All of the ALMS deployed as part of this project utilised water as an incentive to encourage usage of the system. As such, any variable that impacted on water availability was found to have an influence on the use of the ALMS. Paddock topography can allow for the accumulation of surface water during rainfall events reducing the need for animals to use the ALMS to access water. Similarly, animals that have access to other water sources, may also choose to drink from these other sources, as opposed to the one within the compound of the ALMS. Additional research is required to investigate the use of other incentives, such as supplementation, during periods where there may be access to ephemeral water or in paddocks where multiple water sources are available. Some preliminary research, as detailed in 5.4.4 Part 2B – Establishing a BREEDPLAN compliant reporting format for weight traits, has indicated that supplementation does not increase utilisation and data capture remains generally unsatisfactory; however, significant rainfall prior to supplementation may have improved pasture quality, resulting in a decrease in molasses attraction. Repeated trials are warranted to validate this finding and explore how supplementation usage in environments with multiple water sources with lower pasture quality.

The findings of the variable analysis indicate that animals take some time to become accustomed to the ALMS. Peak utilisation was not observed to have occurred until over six months following implementation, with particularly low usage in the first month. As such, in order to use the ALMS to capture high quality data in line with genetic evaluation programs, early installation and exposure is critical. This is a key factor when considering the use of ALMS for key data capture periods, such as during calving. Additional research is needed to determine whether early exposure to the ALMS, for example, being born in a paddock with an ALMS, will influence on the trainability of an animal to the system later in life.

5. Development and refinement of algorithms for date of birth and growth traits and calibration to BREEDPLAN standards

5.1. Daily weights and weekly weights

The raw weight data captured by the ALMS can be subject to variation, for many reasons due to gut fill, or error. For example, if multiple animals attempt to use the system at once error occurs. Several automated scripts sitting in the background of the DataMuster system are designed to manage this daily weight variation and identify erroneous data points. One key metric derived from the raw weights is the weekly weight value. The weekly weight first calculates the average weight captured for the day. A minimum of four individual daily weights is required to calculate the average. Weights that are greater than a standard deviation of 25kg are then excluded. The diagram below illustrates how a single average weekly weight is calculated from the raw daily weight data (Figure 17).

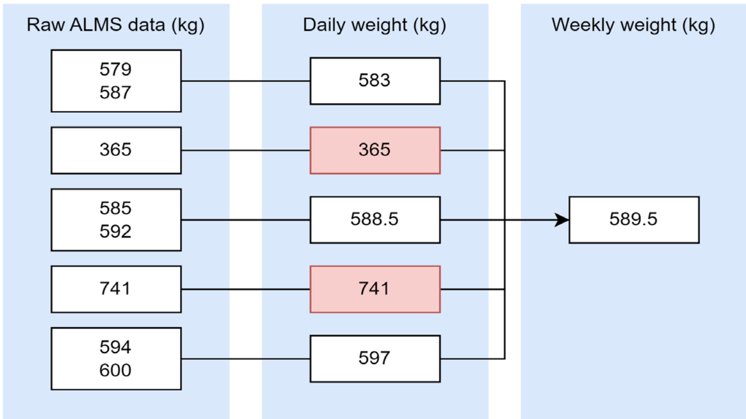


Figure 17. Flowchart depicting how raw ALMS data is transformed into daily weight data and weekly weight data. Daily weights highlighted in red indicate outliers that are removed for the weekly weight calculation.

The weekly weight value is used in both the date of birth and weight trait algorithms and is a focal point for data visualisation on the DataMuster platform (Figure 18). Emphasis is placed on the use of weekly weights for decision making, due to its increased accuracy compared to raw or daily weights captured by the ALMS (see 4.5.2 Validation of the data captured using ALMS: comparing static weights to daily and weekly weights).

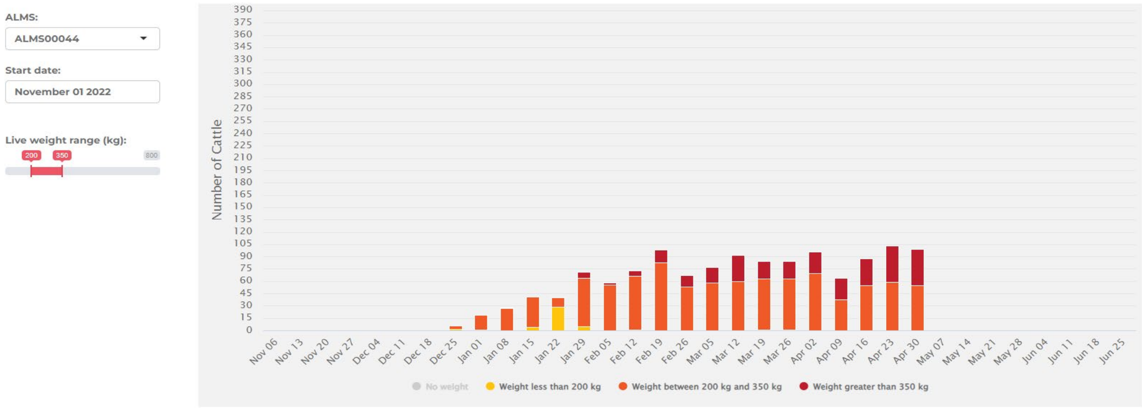


Figure 18. The DataMuster platform provides most visualisation metrics using the weekly weight, due to the increased accuracy of the value compared to daily weights.

5.2. Validation of the data captured using ALMS: comparing static weights to daily and weekly weights

A total of 10,354 static weights were captured manually, using scales within a cattle crush, across the entirety of the experimental period. These weights were used to validate the accuracy of the daily and weekly weights captured using the ALMS. The closest daily and weekly weights, within four weeks of the static weight, were compared and a coefficient of determination (R^2) value was calculated.

The daily weight model performed more poorly compared to the weekly weight model, with R^2 values of 0.77 and 0.95, respectively, despite the greater time between measurements in the weekly weight model (Table 7, Figure 19, Figure 20). This indicates that the weekly weight value is more accurate compared to the daily weight model.

Table 7. The daily weight and weekly weight values produced by the ALMS were compared to static weights captured within four weeks of the ALMS weight.

	Daily weight	**Weekly weight**
Number of weights within 4 weeks of a static weight	2,547	1,851
Coefficient of determination (R^2)	0.77	0.95
Average time between measurements	7.4	10.6

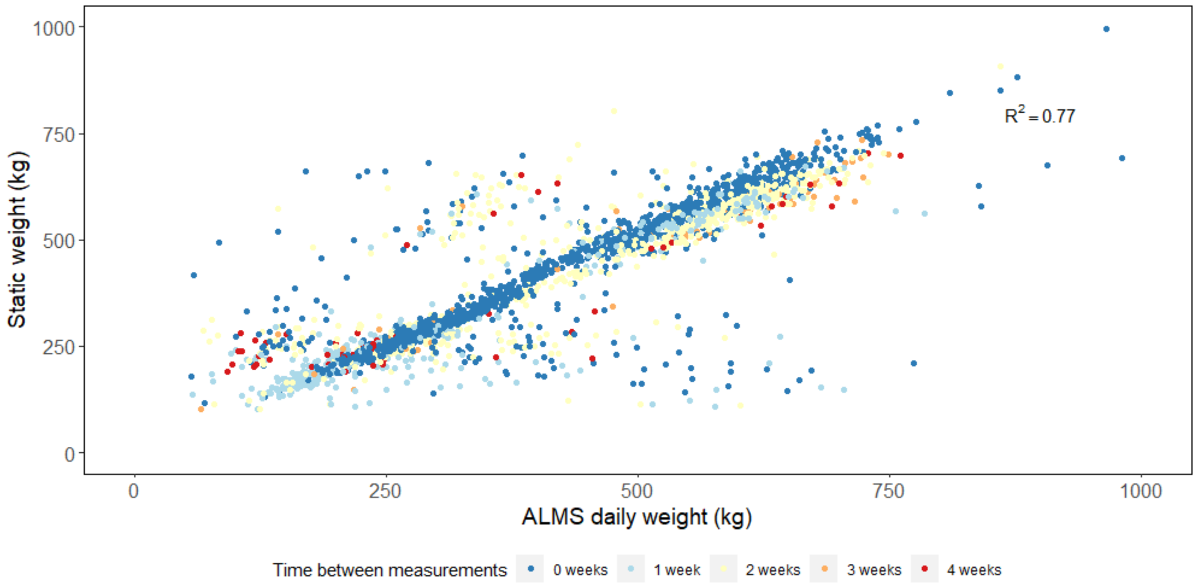


Figure 19. The daily weight captured by the ALMS was compared to static weights within a four week period of the initial data.

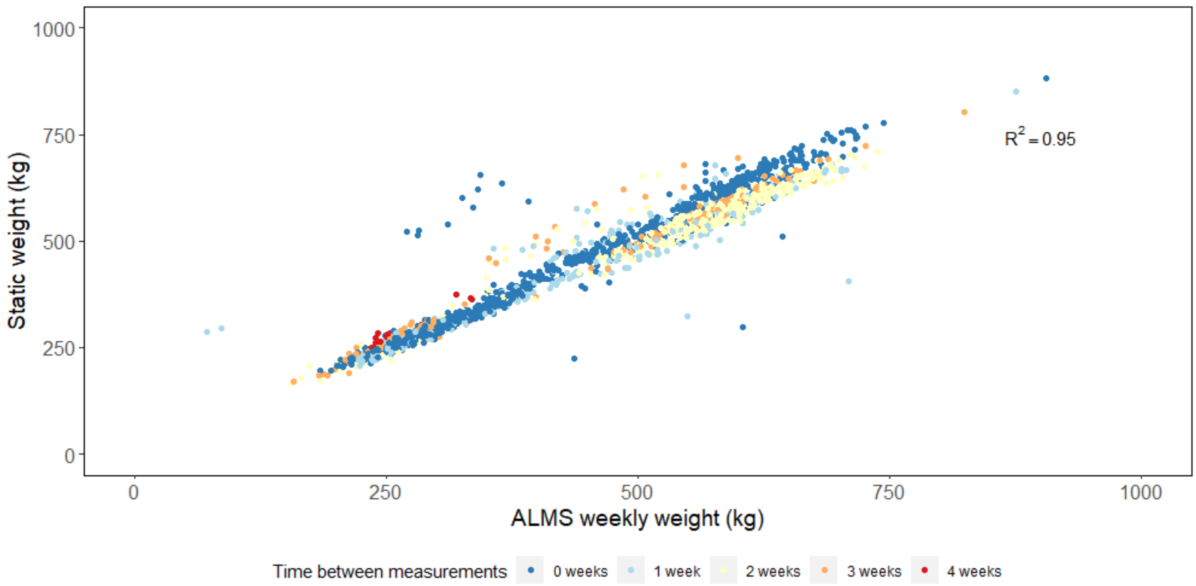


Figure 20. The weekly weight calculated by the ALMS was compared to the static weights captured within four weeks of the ALMS derived weight.

5.3. Dates of birth

Dates of birth are acutely difficult and costly to record in extensive grazing environments and many traits used for genetic evaluation require an animal's date of birth. The date of birth algorithm has been developed and refined over the life of the project. Various challenges, including manure build up under the scales, became apparent in several calving seasons, leading to the refinement and further development of the algorithm to overcome these issues. A total of two iterations of the date of birth algorithm were developed and evaluated using data from 152,340 individual weights from 848 cows over four calving seasons (2018/19, 2019/20, 2020/21, 2021/22) and two properties (Belmont Research Station, Tremere Pastoral). Belmont Research Station, as the 'hub' property, was used for algorithm development and refinement, while Tremere Pastoral, as the 'spoke' property, was focussed on algorithm application in a commercial setting. Learnings from the algorithm application on Tremere Pastoral were also incorporated into algorithm development.

5.3.1. DoB1 algorithm development – Belmont Research Station 2018/19

The first date of birth algorithm (DoB1) was developed following a heuristic methodology on historical data from 112 cattle during the 2018/19 calving season at Belmont Research Station. DoB1 relies on the daily weight data captured using the ALMS unit, as well as the weekly weights, which are autonomously calculated post hoc using background scripts stored on the DMMongoDB Google Cloud server. The weekly weight algorithm will determine the standard deviation for the week, remove any outliers, and calculate the average weight for the week. If there are fewer than four weights per week, the weekly weight is discarded. The weekly weight algorithm is designed to provide a more accurate representation of an animal's weight, accounting for variations in weight, for example, due to rumen fill, whilst also discarding inaccurate weights that may have been generated, for example, if a calf walks over the scale while the cow is also using the system.

DoB1 will search the autonomously calculated weekly weights to identify a week where a weight difference of 30kg to 120kg was observed – this week is classified as the calving week. The algorithm will then search through the calving week to identify the date on which a substantial decrease in weight is observed.

Table 8 provides a summary of the weekly weight data captured across the three calving paddocks that were used for DoB1 development. This data was captured between 1 August 2018 and 1 February 2019. The percentage of daily weights retained for the weekly weight calculation was greater than 90% for two of the paddocks (Paddock 19 and Paddock 66), however, was lower in Paddock 17, averaging 85.0%. Consistently high daily weights were identified across each week for all paddocks (Table 8).

Table 8. Summary of the weekly weight data captured at Belmont Research Station during 2018/19.

Paddock name	Number of cows	Average number of daily weights per week	Average percentage of daily weights retained	Average weekly weight standard deviation
Paddock 17	34	8.6	85.0%	10.7

Paddock 19	36	10.8	92.8%	9.8
Paddock 66	42	8.3	92.3%	9.5
Total	112	8.3	87.3%	9.3

When reapplied over the data from the 2018/19 calving season at Belmont Research Station, DoB1 predicted a total of 110 dates of birth. There were no dates of birth predicted for two cows, as they did not meet the criteria for DoB1 algorithm and thus were not predicted to have calved during the experimental period. Overall, Paddock 17 showed the lowest performance compared to the other paddocks, while Paddock 19 had the highest average accuracies (Table 9). The R^2 value during the 2018/19 calving season at Belmont Research Station for the dates of birth predicted using DoB1 against the observed calving dates was 0.93 (Figure 21).

Table 9. Results from the application of DoB1 over the ALMS data from Belmont Research Station in the 2018/19 calving season.

Paddock name	**Percent predicted on the same day as calving**	**Percent predicted within 1 day of calving**	**Percent predicted within 2 days of calving**	**Percent predicted within 7 days of calving**
Paddock 17	29.4%	55.9%	64.7	88.2%
Paddock 19	55.6%	80.6%	91.7%	97.2%
Paddock 66	55.0%	85.0%	85.0%	95.0%
Total	46.7%	73.8%	80.5%	93.5%

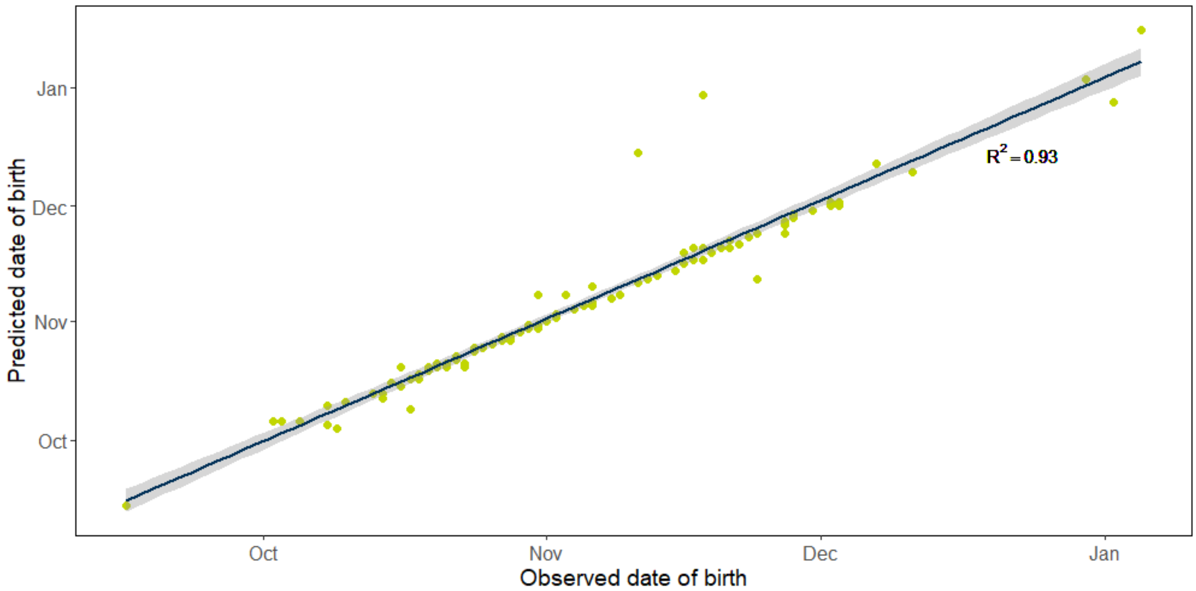


Figure 21. Observed date of birth captured through manual calf catching compared to predicted dates of birth generated using the ALMS data and DoB1.

5.3.2. Application of DoB1 under commercial breeding conditions – Tremere Pastoral 2019/20

DoB1 was tested under commercial breeding conditions at Tremere Pastoral, near Moura in Queensland, during the 2019/20 calving season. A total of 291 cows were initially recruited to the experimental group for the period between 10 October 2019 and 22 December 2019. DoB1 was applied over the weight data captured by the ALMS to predict dates of birth. Table 10 provides an overview of the weekly weight data captured from the ALMS at Tremere Pastoral during the calving period.

Table 10. Summary of the data captured by the ALMS at Tremere Pastoral during the 2019/20 calving season.

Number of cows	Average number of daily weights per week	Average percentage of daily weights retained	Average weekly weight standard deviation
291	7.2	78.9%	18.2

A number of challenges occurred during the 2019/20 calving season at Tremere Pastoral and as a result, DoB1 was only able to predict 35 dates of birth. Of the 291 cows that were originally recruited to the experimental group, 125 calved prior to the ALMS installation date on 10 October 2019. Additionally, a load bar calibration issue rendered the data for the period of 10 October 2019 to 8 November 2019 unusable, as these erroneous weights would have resulted in inaccurate date of birth predictions by DoB1. Consequently, the 46 cows that calved during this period and the 17 cows that calved immediately following the uncalibrated period were excluded from further analysis (Table 11). A further 69 cows did not have dates of birth observed by the producer and therefore the accuracy of DoB1 could not be determined for these animals (Table 11).

A series of guidelines were developed in response to the challenges encountered at Tremere Pastoral. These guidelines have been described in greater detail in 4.5.3.5 Guidelines and recommendations for improving the accuracy and success of date of birth predictions.

Table 11. Data for 257 out of 291 cows was excluded.

Number of cows	Reason for exclusion
125	Calved prior to ALMS installation
46	Calved during the period where load bar calibration resulted in erroneous weights
17	Calved immediately following the period where load bar calibration resulted in erroneous weights - insufficient pre-calving baseline data

69	Did not have an accurate observed date of birth

Of the 35 cows that had sufficient, accurate data, DoB1 was able to predict dates of birth for all animals. The results are comparable to that of Paddock 17 at Belmont Research Station during the 2018/19 calving season. Overall, however, DoB1 performed more poorly at Tremere Pastoral in 2019/20 compared to Belmont Research Station in 2018/19 (Table 12, Figure 22). This is likely due to the lower frequency of use at Tremere Pastoral, with an average of 7.2 captured weights per week and 78.9% retention rate, compared to an average of 8.3 weights and 87.3% retention rate at Belmont Research Station (Table 12, Table 9). In order to capture accurate dates of birth, it is essential that animals utilise the ALMS system frequently. DoB1 will attribute the date of birth to the first use of the ALMS following calving. For example, if an animal uses the ALMS on 08/09/2019, calves on 09/09/2019, and then returns to the ALMS on 11/09/2019, the predicted date of birth will be attributed to 11/09/2019.

Table 12. Results from the application of DoB1 over the ALMS data from Tremere Pastoral in the 2019/20 calving season

Percent predicted on the same day as calving	**Percent predicted within 1 day of calving**	**Percent predicted within 3 days of calving**	**Percent predicted within 7 days of calving**
31.4%	57.1%	68.6%	94.3%

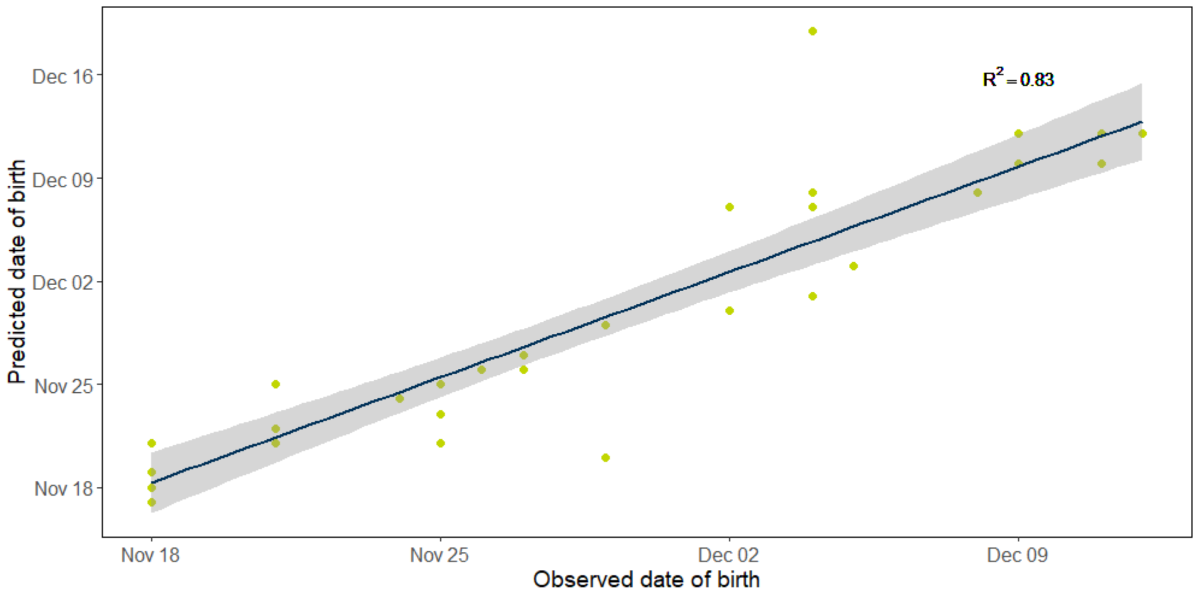


Figure 22. Observed date of birth captured through manual calf catching compared to predicted dates of birth generated using the ALMS data and DoB1 at Tremere Pastoral.

5.3.3. DoB2 algorithm development and evaluation – Belmont Research Station 2020/21

Wide scale ALMS deployment was conducted on seven paddocks at Belmont Research Station in the 2020/21 calving season. A total of 306 animals were recruited to the experimental group and were sub-grouped based on their breed and estimated calving date (Table 13).

Table 13. Seven cohorts were used for the development of DoB2 at Belmont Research Station.

Paddock name	Number of cows	Breed	Date on	Date off
Paddock 17	40	Brahman	08/09/2020	11/02/2021
Paddock 23	24	Composite	26/09/2020	10/01/2021
Paddock 24	26	Composite	26/09/2020	11/01/2021
Paddock 33	34	Composite	23/11/2020	31/01/2021
Paddock 34	33	Composite	23/11/2020	01/02/2021
Paddock 40	50	Composite	06/01/2021	28/02/2021
Top Cotton	99	Brahman	26/09/2020	28/01/2021

Table 14 provides summary of the weekly weight data captured across the seven calving paddocks. The number of daily weights captured per week and the average percentage of daily weights retained were substantially lower compared to the 2018/19 calving season at Belmont Research Station (4.0 versus 8.3 and 38.7% versus 87.3%, respectively). The average standard deviation of the weekly weights captured, however, was lower in the 2020/21 calving season compared to the 2018/19 season, suggesting that the data incorporated into the weekly weights is more consistent (5.7 versus 9.3, respectively) (Table 14, Table 8).

Table 14. Summary of the data captured for each cohort at Belmont Research Station.

Paddock name	Average number of daily weights per week	Average percentage of daily weights retained	Average weekly weight standard deviation
Paddock 17	4.5	49.1%	6.7
Paddock 23	2.7	33.5%	5.0

Paddock 24	3.2	39.3%	4.4
Paddock 33	2.4	22.4%	3.7
Paddock 34	2.2	20.6%	3.1
Paddock 40	8.9	59.8%	11.6
Top Cotton	3.9	46.1%	5.7
Total	4.0	38.7%	5.7

DoB1 was initially applied over the ALMS data, however, this yielded few predictions – in four paddocks, no date of birth predictions could be made (Table 15). The highest percentage of DoB1 date of birth predictions occurred in Paddock 40, where predictions were made for 74% of the herd (Table 15). Due to the poor performance of DoB1, the algorithm was redeveloped and refined using data from Paddock 17. The subsequent version of the algorithm, DoB2, was able to generate predictions for every calving paddock at Belmont Research Station, and a total of 246 predictions overall (Table 15). DoB2 was designed to maximise the number of predictions made, however, was less accurate compared to DoB1 (R^2 value of 0.59 vs. 0.87 respectively). In order to address this, confidence intervals were developed to provide a level of confidence around the predictions made.

Table 15. Two date of birth algorithms were generated and compared.

Paddock name	Number of cows	DoB1 predictions	DoB2 predictions
Paddock 17	40	0	38
Paddock 23	24	0	21
Paddock 24	26	14	25
Paddock 33	34	0	30
Paddock 34	33	0	30
Paddock 40	50	37	36
Top Cotton	99	1	66

Total	306	52	246

Compared to DoB1, DoB2 will autonomously determine periods where ALMS data may be unreliable, for example, due to manure build up under the system. DoB2 will first identify animals that are in the top quartile of ALMS usage across the experimental period, then use their calculated weekly weights to develop a herd weight average. Weeks where significant changes in weight, greater than 20kg, are identified and flagged as periods where data is likely to be unreliable, potentially due to ALMS failure. Any predictions made during these periods of unreliable data are assigned a low confidence interval.

DoB2 will calculate a weekly weight using the daily weights by excluding outliers less than two standard deviations away from the median weight of the week. The difference between weekly weights is calculated, and weeks with a weekly weight decrease greater than 20kg are further examined. The daily weights for the two weeks prior to and following the weekly weight decrease are investigated. The weight difference between days is calculated, alongside a rolling weight difference to identify a sustained decrease in weight. These values are ranked and used to determine the most likely day on which calving may have occurred. Confidence intervals are attributed based on the fit to a number of criteria that contribute to the final prediction (Table 16). If two or more high confidence predictions are initially identified, both are overridden, and a medium confidence interval is assigned to the greater weight difference instead. This ensures that the integrity of the high confidence interval is maintained.

Table 16. DoB2 will generate a confidence interval (high, medium, low) for each date of birth prediction, based on a set criteria.

Confidence interval	Criteria
High	● Less than one day between daily weights ● Weight difference between days greater than 40kg ● Sustained weight loss of greater than 30kg ● Prediction does not occur during a week where unreliable data may have been collected ● Prediction is not within the first 14 days or last 14 days of the daily weights captured ● Atleast 14 weights captured over the two weeks prior to and following the prediction date
Medium	● Less than one day between daily weights ● Weight difference between days greater than 30kg ● Sustained weight loss of greater than 20kg ● Prediction does not occur during a week where unreliable data may have been collected ● Prediction is not within the first 14 days or last 14 days of the daily weights captured ● Atleast 14 weights captured over the two weeks prior to and following the prediction date
Low	● Does not meet one or more of the criteria described for the high/medium categories

The results of the application of DoB2 over the paddocks at Belmont Research Station during the 2020/21 calving season can be seen in Table 17. Overall, DoB2 performed more poorly during this season compared to DoB1 in the 2018/19 calving season at Belmont Research Station (Table 17, Table 9). The average percent of predictions that were made on the same day was 10.5% compared to 46.7% in 2018/19 (Table 17, Table 9). Likewise, where DoB1 was able to predict on average 93.5% of dates of birth within a week of calving in 2018/19, DoB2 was only able to predict 45.6% of dates of birth within a week of calving in 2020/21 (Table 17).

Table 17. Results from the application of DoB2 over the ALMS data at Belmont Research Station.

Paddock name	Percent predicted on the same day as calving	Percent predicted within 1 day of calving	Percent predicted within 2 days of calving	Percent predicted within 7 days of calving
Paddock 17	13.2%	26.3%	36.8%	36.8%
Paddock 23	9.5%	23.8%	28.9%	42.9%
Paddock 24	20.0%	32.0%	56.0%	68.0%
Paddock 33	6.7%	16.7%	20.0%	43.3%
Paddock 34	6.7%	26.7%	33.3%	56.7%
Paddock 40	11.1%	25.0%	33.3%	50.0%
Top Cotton	6.1%	15.2%	22.7%	31.8%
Total	10.5%	23.7%	33.0%	45.6%

Examination of the ALMS data from the 2020/21 calving season revealed a number of periods with substantial decreases in weight, along with periods with no ALMS use or weight decreases due to ALMS failure (Figure 23). Periods of decreased ALMS use coincided with periods of rainfall, likely due to the presence of standing water, thereby reducing the need to access water via the ALMS system (Figure 23). Interestingly, no such rainfall influence was observed in the 2018/19 calving season at Belmont Research Station and instead, high ALMS use was sustained throughout the trial period. Additionally, decreases in average herd weight were observed in Paddock 17, Paddock 23, and Top Cotton due to manure and dirt accumulation under the ALMS unit (Figure 24). Following cleaning of the system, average herd weights returned to baseline values.

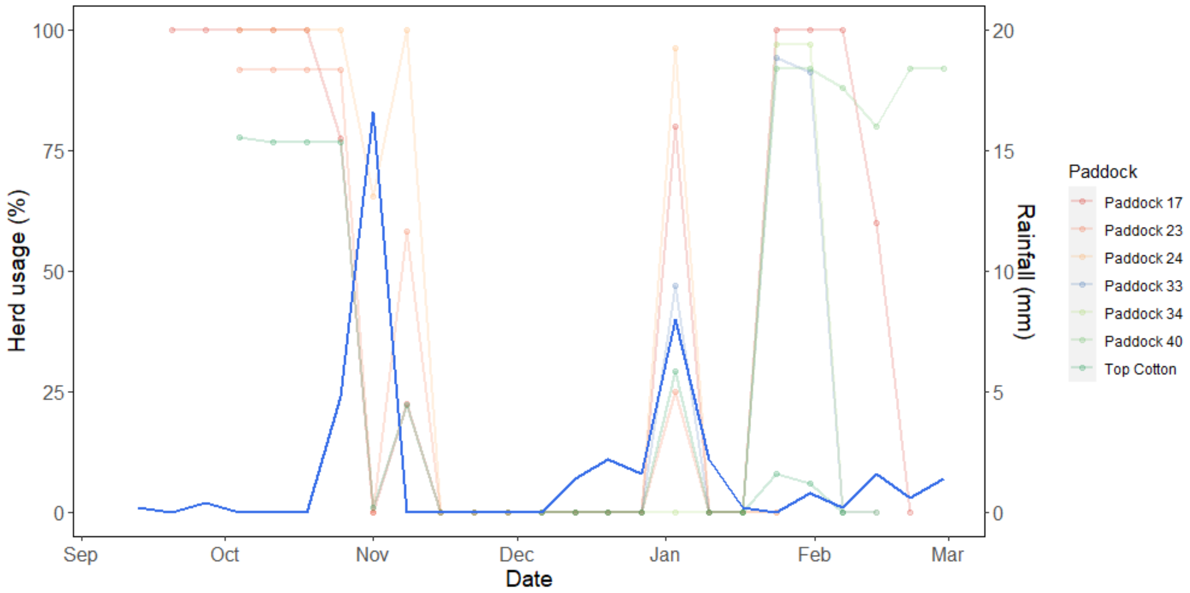


Figure 23. Historical rainfall data was captured across the calving period to investigate its impact on ALMS usage at Belmont Research Station.

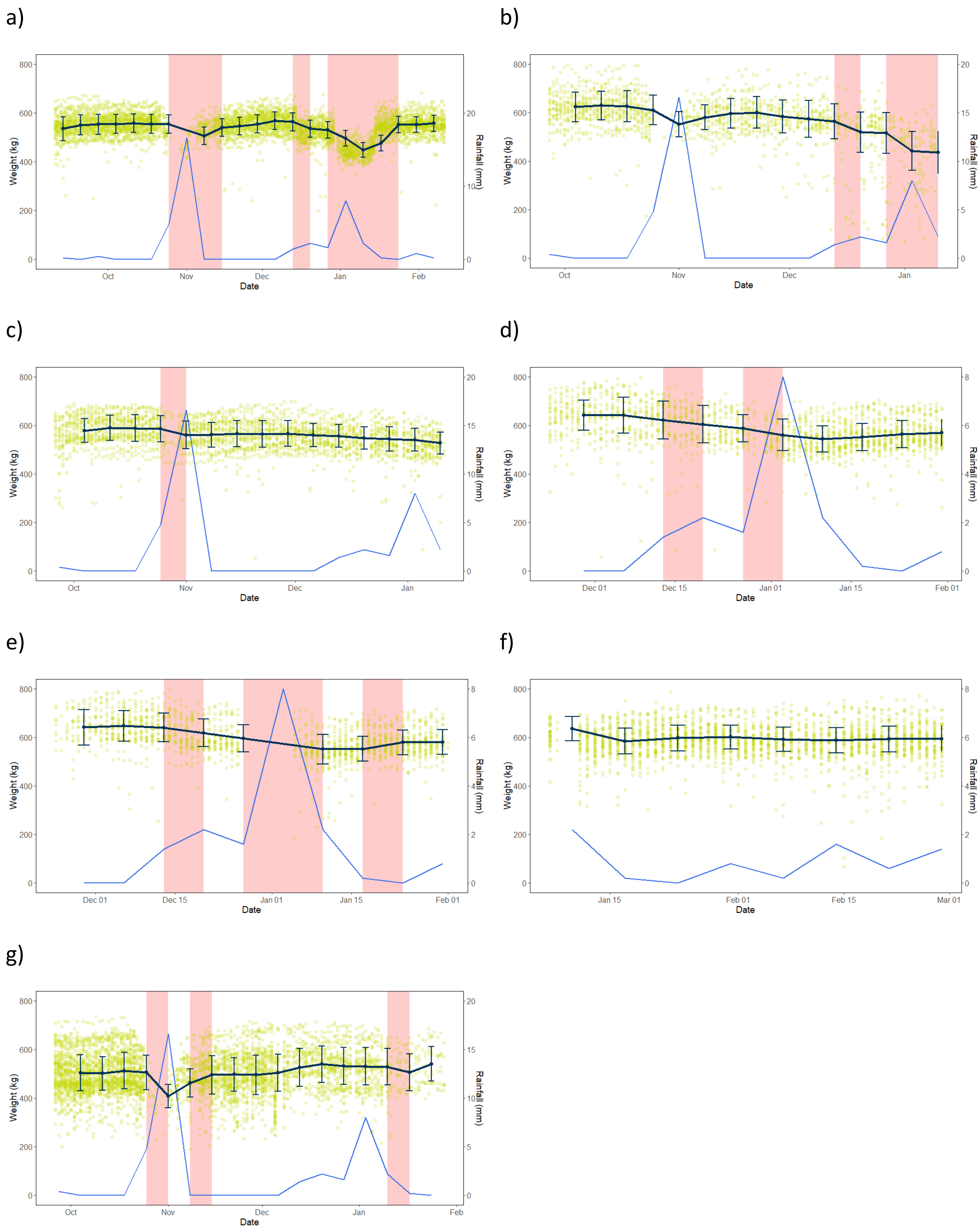


Figure 24. Average herd weekly weight for calving paddocks: a) Paddock 17, b) Paddock 23, c) Paddock 24, d) Paddock 33, e) Paddock 34, f) Paddock 40, and g) Top Cotton, at Belmont Research Station. Alert periods were identified where the average weight of the most frequent visitors to the ALMS decreased by more than 20kg (red shaded areas). These periods frequently coincided with periods of rainfall.

The R^2 value of the predicted dates of birth compared to the observed dates of birth is 0.59 (Figure 25). This value is lower compared to the R^2 value generated in the 2018/19 calving season (Figure 21).

On average, more than 70% of the date of birth predictions, however, were generated with a low confidence interval, while high confidence predictions only occurred on average 9.8% of the time (Table 18). The vast majority of low confidence predictions were due to irregular usage of the ALMS system, alongside predictions made within the weeks where unreliable data was captured.

When only considering high confidence predictions, however, the R^2 value of the predictions made is 0.94, which is comparable to the R^2 value of 0.93 attained during the 2018/19 calving season (Figure 26). As anticipated, the low confidence predictions had the lowest R2 value of 0.49 and medium confidence predictions had the second highest R2 value of 0.74 (Figure 26). Therefore, the confidence levels have improved accuracy associated with more confident predictions.

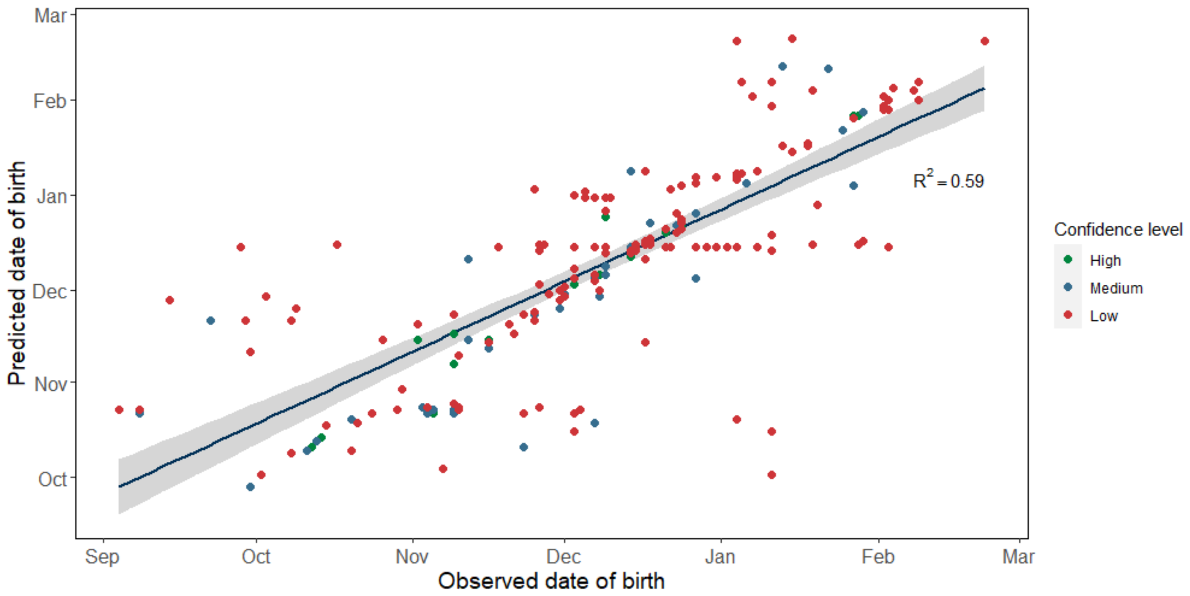


Figure 25. Observed date of birth captured through manual calf catching compared to predicted dates of birth generated using the ALMS data and DoB2 at Belmont Research Station. High, medium, and low confidence predictions of the dates of birth are presented.

Table 18. Percentage of high, medium, and low confidence predictions made for each cohort at Belmont Research Station in the 2020/21 calving season.

Paddock name	Percent of high confidence predictions	Percent medium confidence predictions	Percent low confidence predictions
Paddock 17	5.2%	18.4%	76.3%
Paddock 23	4.8%	23.8%	71.4%
Paddock 24	36.0%	28.0%	36.0%
Paddock 33	3.3%	3.3%	93.3%

Paddock 34	3.3%	3.3%	93.3%
Paddock 40	8.3%	16.7%	75.0%
Top Cotton	7.6%	30.3%	62.1%
Total	9.8%	17.7%	72.5%

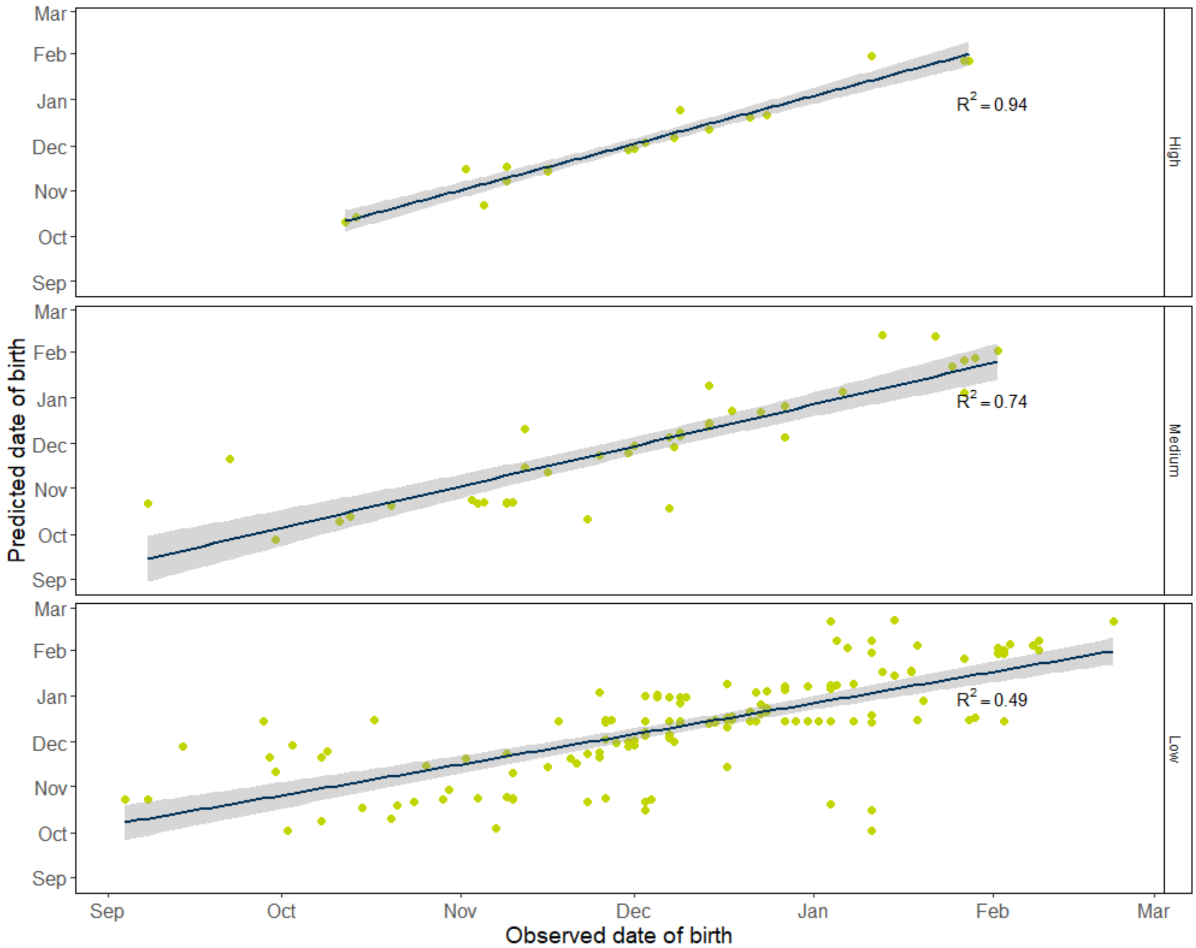


Figure 26. Observed date of birth captured through manual calf catching compared to predicted dates of birth, categorised according to the confidence level of each prediction.

5.3.4. Application of DoB2 under commercial breeding conditions – Tremere Pastoral 2021/22

A total of 139 cows were recruited to the two experimental groups at Tremere Pastoral in the 2021/22 calving season to evaluate DoB2 under commercial breeding conditions. Table 19 describes the ALMS data captured over the period spanning between 29 July 2021 and 23 October 2021. High daily weight retention, averaging 95.0%, was observed in both cohorts across the entire experimental period, indicating that the weights captured by the ALMS were reliable (Table 19). The average percentage of daily weights retained was substantially higher compared to the 2019/20 calving season at Tremere Pastoral (95.0% versus 78.9%, respectively) (Table 19, Table 10). Additionally, the average standard deviation of the weekly weights captured was lower compared to previous years (10.4 versus 18.2), suggesting that the data captured is more consistent. There was, however, a decrease in overall usage of the ALMS system, with an average of 5.9 in the 2021/22 calving season, compared to 7.2 in the 2019/20 season (Table 19, Table 10).

Table 19. Summary of the ALMS data captured at Tremere Pastoral in the 2021/22 calving season.

Paddock name	Number of cows	Average number of daily weights per week	Average percentage of daily weights retained	Average weekly weight standard deviation
Wiseman	51	6.5	94.6%	12.2
Chalk	88	5.2	95.3%	8.6
Total	139	5.9	95.0%	10.4

Weekly and daily weights remained relatively stable in both paddocks across the entirety of the experimental period (Figure 27). There was, however, one week where a decrease of 24.5kg was observed across the herd in Wiseman (Figure 27). This period coincides with the movement of the ALMS and animals to another paddock, and can likely be attributed to a combination of decreased usage following re-establishment in another paddock and reduced feed intake associated with mustering and paddock movement. No such suboptimal data week was observed in Chalk (Figure 27).

a) b)

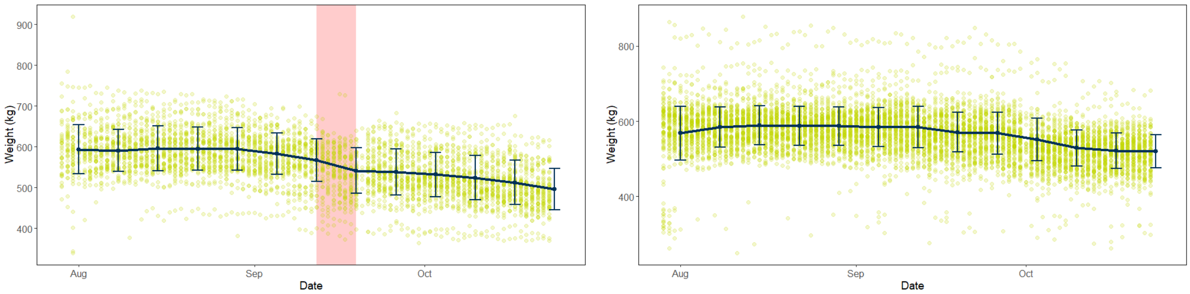


Figure 27. Average herd weekly weight for a) Wiseman and b) Chalk paddock at Tremere Pastoral. Alert periods were identified where the average weight of the most frequent visitors to the ALMS decreased by more than 20kg (red shaded areas).

A total of 132 date of birth predictions were made using DoB2 for the 139 animals that were recruited to the experimental group (Table 20). Over 40% of the date of birth predictions were made on the same day as the observed date of birth and over 90% of the date of birth predictions were accurate within a week of the observed date of birth (Table 20) These results are comparable to those captured in the 2019/20 calving season at Tremere Pastoral (31.4% within one day, 94.3% within one week). However, DoB2 was more successful at capturing dates of birth for a greater proportion of the animals recruited to the study compared to DoB1 in the 2019/20 season (95.0% of 2021/22 cohort versus 12.0% of 2019/20 cohort) (Table 20, Table 12).

Table 20. Results from the application of DoB2 over the ALMS data from Tremere Pastoral in 2021/22.

Paddock name	Number of predictions made	Percent predicted on the same day as calving	Percent predicted within 1 day of calving	Percent predicted within 2 days of calving	Percent predicted within 7 days of calving
Wiseman	50	48.0%	72.0%	80.0%	94.0%
Chalk	82	36.3%	62.2%	72.0%	86.6%
Total	132	42.2%	67.1%	76.0%	90.3%

The vast majority of the date of birth predictions made by DoB2 were high confidence (Table 21). A total of 25 low confidence predictions were also made in Wiseman – the majority of which were due to predictions made during the week where the herd experienced a decrease in weight (Table 21).

Table 21. High, medium, and low confidence predictions were made by DoB2 for each cohort at Tremere Pastoral.

Paddock name	Percent of high confidence predictions	Percent medium confidence predictions	Percent low confidence predictions
Wiseman	40.0%	10.0%	50.0%
Barney	53.7%	29.3%	17.1%
Total	46.9%	19.7%	33.6%

The overall R^2 value for the date of birth predictions made by DoB2 against the observed dates of birth was 0.59 (Figure 28). Although lower compared to the predictions made by DoB1 at Tremere Pastoral in 2019/20, the R^2 values of the high confidence predictions are comparable (0.83 in 2019/20 versus

0.86 in 2021/22) (Figure 28, Figure 22). As with the results observed at Belmont Research Station in 2020/21, increasing confidence levels were associated with improved accuracy and higher R^2 values (Figure 29).

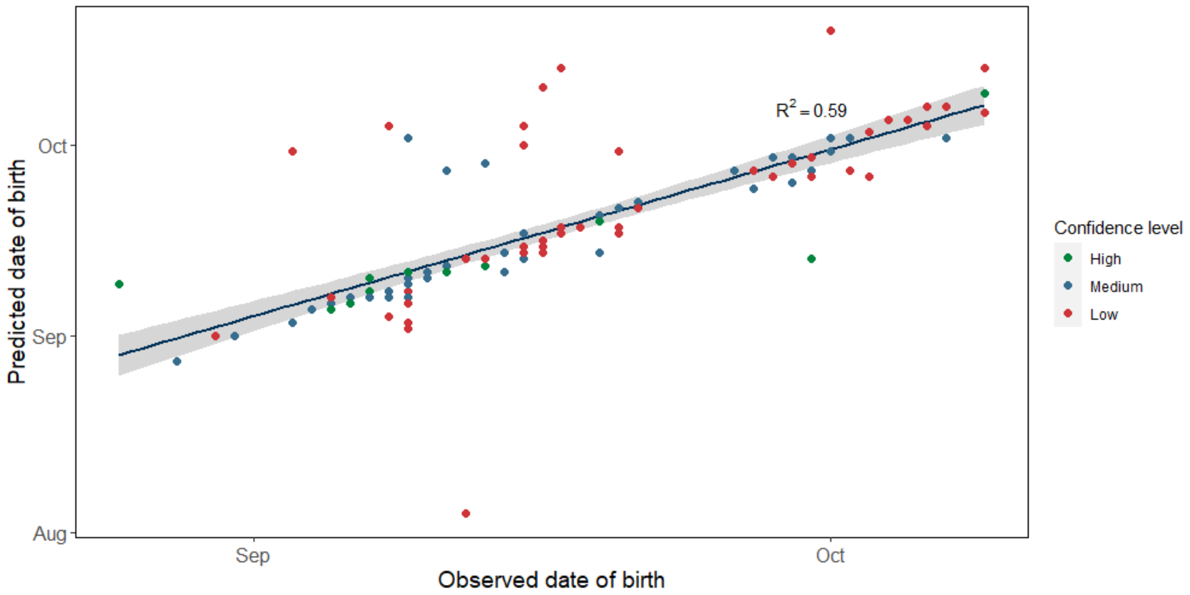


Figure 28. Observed date of birth captured through manual calf catching compared to predicted dates of birth generated using the ALMS data and DoB2 at Tremere Pastoral. High, medium, and low confidence predictions of the dates of birth are presented.

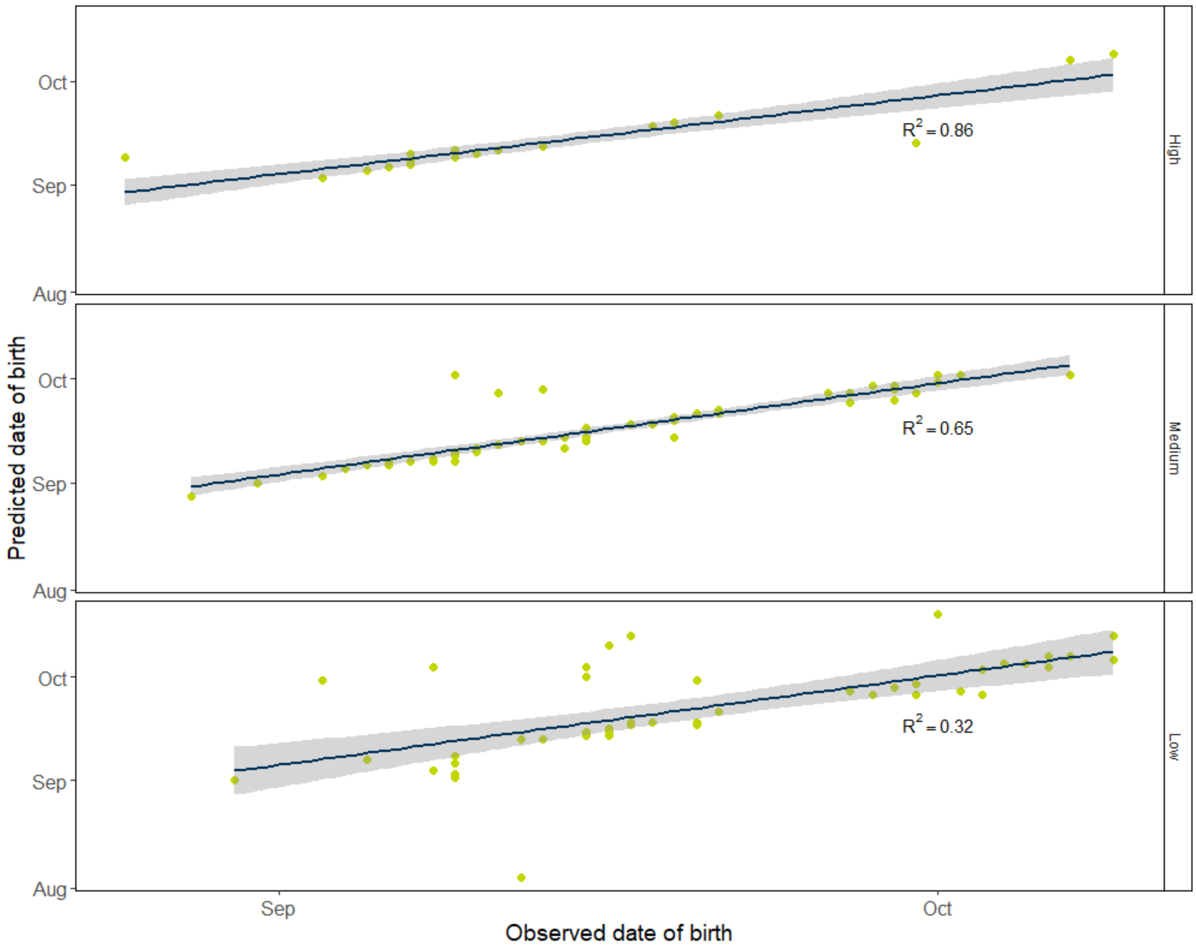


Figure 29. Observed date of birth captured through manual calf catching compared to predicted dates of birth, categorised according to the confidence level of each prediction.

5.3.5. Guidelines and recommendations for improving the accuracy and success of date of birth predictions

Over the life of the project, several challenges were encountered that limited the accuracy and success of the date of birth algorithm. A series of guidelines and recommendations have been developed to improve the performance of both versions of the date of birth algorithm. These guidelines revolve around two main themes:

- Maximising the number of daily and weekly weights captured
- Accurately capturing ALMS data

<u>Maximising the number of daily and weekly weights captured</u>

Both iterations of the date of birth algorithm are reliant upon differences in the weekly weights to first identify potential calving weeks, before exploring the daily weight data to identify the exact date of calving. As such, gaps in the weekly or daily weight data can significantly impact on the accuracy of the date of birth algorithm.

At least one month prior to the calving season, the cattle must first be trained to use the ALMS unit to ensure that they are familiar with and comfortable with using the unit. The typical training protocol involves the progressive enclosure of some incentive, typically a water point, with portable panels.

Rushed or poor training can result in significant animal welfare issues, particularly if the ALMS unit is placed on the sole watering point in the paddock. Cattle may become stressed if they are unfamiliar with the system, and rush over the scales, resulting in poor and unreliable data capture.

The ALMS unit needs to surround an incentive. Enclosing the sole waterpoint within the paddock can increase usage of the ALMS system, however, accumulation of ephemeral groundwater during wet periods can lead to a sudden decrease in usage, as seen at Belmont Research Station in the 2020/21 calving season. Selection of flatter paddocks, without areas where water could be trapped, can help to minimise the duration of standing water following rain. The use of other incentives, such as mineral supplementation, within the ALMS compound could also be used to encourage continual use of the system, however this was not used in this project. A mixed methods system could also be used, where the ALMS system is used during periods of low rainfall and there is a greater reliance on manual data collection during periods of higher rainfall or system failure. A low use alert email can be used to determine when manual data collection should commence (Figure 30).

Good morning,

There are 8 cattle that have not been recorded by an ALMS unit during the previous 3 days. The table below shows the details of the cattle. These animals should be checked if a cause for the warning is unknown, there may be issues associated with the animal or with the RFID tag. If there are many cattle listed for a particular ALMS unit there may be a hardware or a communication issue and the unit should be checked.

Regards,

The DataMuster Team

ALMS00006

RFID	Tag	Category	Sex	Paddock	Last record	Days since last record
982 123737117499	90158	breeding	female	Wiseman	2021-08-02 23:49:42	**62**
982 123531903956090118		breeding	female	Wiseman	Never	**NA**

Figure 30. Example of an email alert used to identify where there is insufficient use of the ALMS.

Cattle movement between paddocks should be minimised across the calving period. Cattle require time to refamiliarise themselves with new paddocks, and ALMS usage often remains low in the first week of introduction to a new paddock (Figure 7). Where possible, animals should remain in the same paddock for the duration of the calving period and at least one month prior to the expected calving date.

<u>Accurately capturing ALMS data</u>

The ALMS unit requires maintenance across the course of the calving season. Build-up of dirt or manure under the ALMS scales can reduce the accuracy of the captured weights, with cattle appearing lighter. As a result, the date of birth algorithm may attribute the decrease in weight to a calving event. The accumulation of manure and dirt at Belmont Research Station in the 2020/21 calving season coincided with an extended period of rainfall, where the increased rainfall led to more pliable soil, which could be kicked under the ALMS scale as cattle utilised the system. Routine maintenance should be used to rectify this issue.

Similarly, other hardware failures, such as faulty solar regulators or dirty solar panels, may impact on the ALMS' ability to capture and transmit weight data. Hardware failure alert emails could be used to identify any issues and ensure that the unit is fully operational. Figure 31 depicts an example of an email that was sent to a producer in one calving season when a thunderstorm caused operational issues.

Hello!

There is 1 walk-over-weighing units that have not sent a telemetry signal in the last 3 hours. Please review the units below and alert the appropriate individuals to resolve the issue.

Regards,

The DataMuster Team

Property	Asset ID	File name	Paddock	Last signal
Tremere	ALMS00006	Trem	Wiseman	2020-10-20 19:07:02

Figure 31. Example of an email alert used to identify hardware failure**.**

5.4. Weight traits

The research conducted on the ability of ALMS to deliver BREEDPLAN compatible weight trait phenotypes was performed in two parts. Simulation models were used in Part 1 to provide insight into the suitability of ALMS as a tool for generating genetic weight data and identify potential issues, such as missing data. Part 1A explored the potential differences between using continuous ALMS data to generate a measured weight for age versus the current practice. Part 1B illustrated the ability for ALMS to successfully capture data that meets the BREEDPLAN weight trait requirements, considering animal and environmental variables. The research outcomes and proposed data handling techniques from Part 1 were reviewed with the providers of BREEDPLAN prior to any experimental work involving cattle.

Part 2 then applied the research to real ALMS data and developed methods for generating potential BREEDPLAN compliant weight data under practical conditions. The research was conducted over two trials, using data collected at Belmont Research Station. Part 2A used three years of data to generate ALMS derived cattle weights suitable for the 400 Day Weight trait. Part 2B generated ALMS derived data for the 400 Day Weight trait and predicted weights for individual animals who did not achieve an ALMS weight.

The decision to initially focus on the 400 Day Weight trait was based mainly on the highest perceived benefit to automating the collection of this data. Typically, animals are mustered and weighed solely for the purpose of collecting 400 Day Weights, whereas the 200 Day Growth and 600 Day Weight traits are usually recorded in conjunction with mustering for other purposes, such as weaning and other husbandry practices. Additionally, minimal ALMS data has been recorded for 200 Day Weight, as calves often do not accompany their mothers to water, and the data for the 600 Day Weight can be complicated by cattle pregnancy status and stage of pregnancy. An automated solution for the 200 Day Growth and 600 Day Weight traits, and other genetic traits, may be addressed in the future.

The results from this research demonstrate that high numbers of potential BREEDPLAN compliant cattle weights can be reliability generated in the paddock and under practical conditions using ALMS. Predicted weekly weights can provide an accurate substitution for missing datapoints if sub-optimal cattle utilisation impacts a dataset (up to 75% of missing daily weight data). The results of the activities conducted to determine the ability of ALMS to deliver BREEDPLAN compatible weight trait phenotypes are described in detail below.

5.4.1. Part 1A – Modelling growth rate data to determine accuracy of multiple measures versus a single measure

The aim of this research activity was to develop a cattle growth simulator to generate daily cattle growth values. The data could then be used to explore how different measuring protocols are indicative of individual animal performance. In particular, the goal was to explore the difference between two methods of capturing data for the 200 Day Growth trait – method 1 utilises continuous weight data (representative of ALMS data), while method 2 utilises a single daily weight and corrects the weight for age (representative of current industry measuring methods).

A Monte Carlo simulation framework was used to simulate individual daily cattle growth from birth through to 600 days of age. The stochastic simulation allowed for the variability in daily growth rates typical of that produced using ALMS. The simulated data considered three variables that impact on performance recording through the ALMS cattle weight data – genetic potential, environment, and ALMS data capture. The focus of the activity was not to derive high level accuracy predictions of daily growth rates. Instead, the model was employed to investigate how fluctuations in these three factors (genetic, environment, and data capture) might influence the ultimate cattle weight data being submitted to genetic evaluation programs, consequently affecting the resulting EBVs generated. The central research question was whether data derived from ALMS could be treated comparably to data collected through existing recording methods upon submission to genetic evaluation platforms, such as BREEDPLAN.

For the purposes of the simulation, a set optimal daily growth rate was assumed. A linear response in the daily mean growth rate between optimal and sub-optimal conditions was set with no difference in the standard deviation. It should be noted that this is an over-simplification of reality. The genetic potential of an animal for growth is set at birth and is reflected across the herd via an optimal daily weight gain trait following a normal distribution. The herd variation is reflected in the standard deviation and is subject to changes in the environmental conditions, or feed base, over time reflecting natural seasonal variability. However, for the purposes of testing differences between continuous and intermittent weight recording the model provides a useful starting point.

The model was designed to take the following inputs:

- Number of individual animals to simulate
- Number of days for each individual to simulate growth rate over (note, the model needed to run for at least 700 days to capture 200 Day Growth and 400 Day and 600 Day Weight traits)
- Calving patter n
- Distribution in optimal growth genetic potential
- Variation in growth genetic potential

The model was built on a set of nested functions with a set of pre-set variables. There is opportunity to change the values of the variables to simulate different outcomes if required. As reproductive traits were not the focus of this activity, the model assumed that all calves had a nominal birth weight of 60kg. This value was assumed as the extreme upper limit of birth weights expected in the monitored cattle production systems. Monthly feed resources were inputted as a list of 12 values (one for each month of the year) that considered the amount of feed available for the month to optimise the genetic growth parameter. The individual daily growth was therefore determined by the genetic potential (this includes natural variation around the optimal mean daily growth rate), and time of the year based on the seasonal value that moderated the daily growth. The overall population values were determined by the herd (number of individuals in the simulation), time of calving (this connects to the seasonal variable), and the distribution of the individual genetic daily mean growth values. The herd genetic value used a normal distribution with a mean value for the overall herd and standard deviation to represent the variation. The timing of calving was calculated using a deterministic sampling approach, which generated a date of birth for each individual. This method took into consideration the natural variability found in inter-calving intervals within a contemporary group.

The cattle growth simulator was used to generate weight data that represented ALMS weekly mean weights of individual animals when they turned 200 days of age. The ALMS weight was compared to the live weight recorded when the group averaged 200 days, and was then adjusted for age. The latter weight adjustment method is currently used in mixed model analyses of growth data submitted by industry to BREEDPLAN.

Figure 32 presents histograms of simulated weights for each sampling method. The distribution of actual (ALMS) 200 Day Growth conformed typically to the bell-shaped curve of a normally distributed continuous variable. By contrast, the age adjusted 200 Day Growth indicated many outliers beyond two standard deviations from the mean. The result suggests that ALMS weights recorded at 200 days of age would provide a suitable measure for genetic evaluation of growth data. These traits would need to be modelled differently to the current age adjustment models used by BREEDPLAN. The data could be treated similarly to models currently used for traits not measured in contemporary groups, such as birth weight and gestation length.

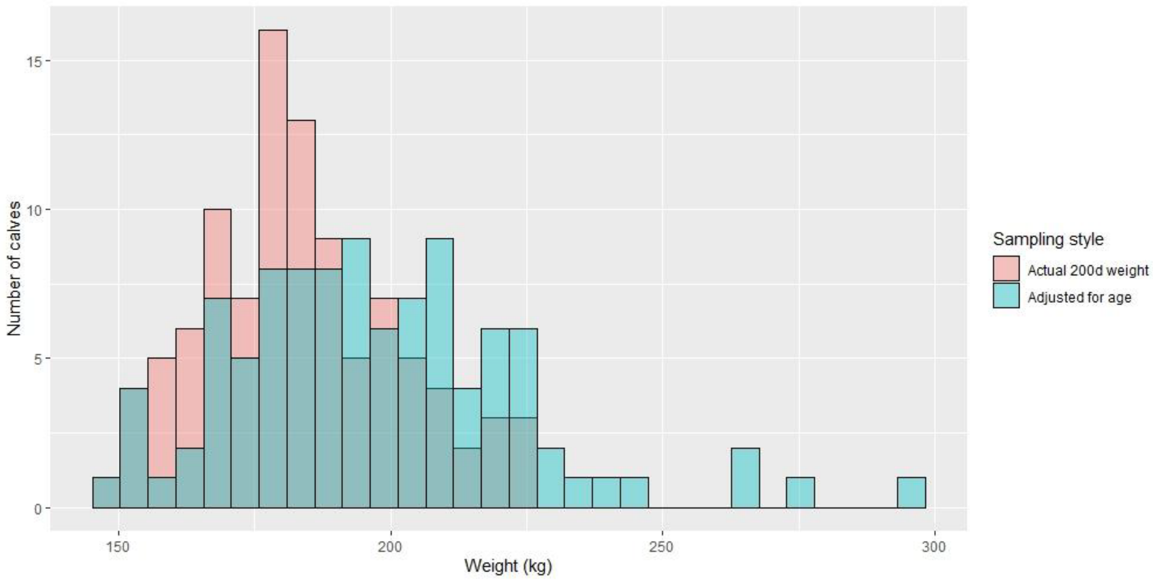


Figure 32. Distribution of simulated 200 Day Growth data.

5.4.2. Part1B – Simulating the effects of cattle ALMS utilisation and prediction of missing data points

Growth Estimated Breeding Values (EBVs) are calculated from the liveweight performance of cattle between 80 and 900 days of age. Within this age range, BREEDPLAN uses the age of a cohort at weighing to determine what trait the captured weights should be defined as. Windows for weight traits are between 200 – 220 days for each 200 Day Growth and 400 Day and 600 Day Weights (for example, 200 Day Growth = 80 – 300 days of age) (Agricultural Business Research Institute, 2011). The age windows allow producers flexibility to capture appropriate liveweight data within their unique production system. The large window also provides ample opportunity to capture the same required data using ALMS, without the need for significant intervention. In this activity, cattle ALMS visitation behaviours were explored to assess impact on the capture accuracy of each weight trait.

A demonstration model was developed to illustrate the ability for ALMS to successfully capture data that meets the X Day Weight trait requirements for submission to BREEDPLAN. Daily weight data was simulated for 100 cattle until each animal reached 900 days of age. To increase the difficulty of capturing adequate data for each weight trait submission to BREEDPLAN, the range of birthdates for the 100 animal cohort was set to 203 days (07/09/2020 – 29/03/2021).

The date of birth feature was intentionally set to an extended period for two primary purposes: to significantly limit the time frame during which all animals would concurrently fall within a specified weight trait range (e.g., 301–500 days for 400 Day Weight), and to more reflect potential conditions encountered in extensive northern production systems, where wide date of birth ranges can be observed.

The final data set was subsampled using a pseudorandom method to reflect varying levels of missing daily weight data, reflecting variation in animal utilisation of ALMS. The resulting output represented ALMS datasets where 2.5 – 50% of daily weight data were missing for each animal. This range, although large, was reflective of ALMS data recorded on Belmont Research Station and producer partner properties throughout the project, and reflected varying seasonal conditions. Weekly weights were then calculated for each day of an animal's lifetime (0 – 900 days) using the previously described algorithm. Future modelling could better represent visitation data based on other variables, including weather, cattle experience using ALMS technologies, and cattle class. A key finding from this project has been the influence of these features on cattle use of ALMS. Each calculated weekly weight value represented a modified mean of all daily weight values captured in the previous seven days. The resulting weekly weight values have greater accuracy (R^2 = 0.98) than any single daily weights (R^2 = 0.079) and are therefore recommended for submission to genetic evaluation platforms.

Simulations were replicated 100 times to assess variability at each level of missing data. In total, 9 million simulated weekly weight values were calculated to assess the impact of missing data. To identify the “best” recorded weight for submission to BREEDPLAN, automated algorithms were developed that interrogate all possible opportunities within the weight trait window to identify a day where 100% of cattle had recorded weights. Where more than one day satisfies the criteria, the algorithm selects the day where the cohort’s median age is closest to the specified weight trait. Outputs were separated into results where 100% of cattle were assigned a weekly weight on the same day within the specified window of opportunity (total), and results where there were no days where 100% of cattle were assigned a weekly weight (partial). For total results, means and nonparametric bootstrap confidence intervals were calculated for the number of days where 100% of cattle were assigned a weekly weight. For partial results, means and nonparametric bootstrap confidence intervals were calculated for the maximum percentage of cattle, then the diminishing number of cattle with valid weekly weight values as data were removed from the whole-of-life data set.

For the purposes of this report, a 200 Day Growth scenario was selected to illustrate the capacity of ALMS to capture adequate data for submission to BREEDPLAN. The window of opportunity was 17 days. Similar trends are observed for 400 Day and 600 Day Weights.

Prediction techniques could then be employed to maximise the use of datasets where data points are missing. The nature of time series data sets such as those captured by ALMS technologies makes them suitable for use in random regression models. A fitted model incorporating animal and cohort performance could be used to provide accurate estimates of liveweight (estimated marginal mean) on specified dates where data is unavailable for 100% of a cohort. Using this approach, accurate cohort data could be captured for all livestock, allowing 100% of the cohort to have weight trait values submitted to BREEDPLAN. The accuracy of these estimated values would be influenced by visitation behaviours and subsequent patterns in the daily weight data. As such, a measure of confidence would be required to inform BREEDPLAN heritability models.

A linear mixed-effects model was developed and fitted to the dataset including the 30 days before and after the specified window of opportunity. Weekly weight values were fitted as the response variable and 'Date' and 'ID' as fixed effects. Individual animals within the cohort were included in the model as random effects to account for temporal repeat measures and a first order autoregressive structure was specified for the errors to account for correlations between repeated measures. Estimated marginal means and standard errors were calculated for the individual with missing weekly weight data.

The varying outputs of ALMS datasets where 2.5% – 50% of daily weight data were missing for each animal were assessed. When 2.5% – 27.5% of data were missing, at least one day met the requirements of BREEDPLAN submission with 100% of livestock having a weekly weight recorded (Figure 33). The number of suitable days decreased as the amount of missing data increased, with 27.5% being the last subset before ALMS derived data would no longer meet BREEDPLAN requirements for 100% of cattle in this scenario. When the amount of missing data exceeded 30% for a cohort, no days were identified as suitable within the 17 day window of opportunity (Figure 34). The percentage of cattle captured on any given day decreased as more daily weights were removed from the data set. At the extreme, when 50% of data was removed, the maximum number of cattle captured within the specified 17 day window was 72%. Although this would be considered unacceptable for submission to BREEDPLAN, the likelihood of having 50% of data missing is low and commercial offerings of ALMS products should include features that alert producers to low utilisation events.

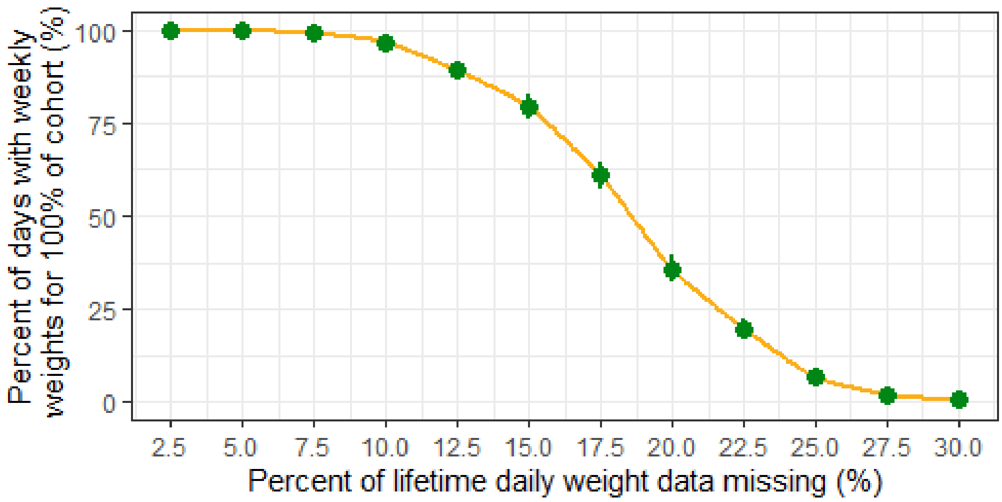


Figure 33. Percent of opportunities to capture weekly weights for 100% of cattle within a 17-day window of opportunity as the number of missing data points increases.

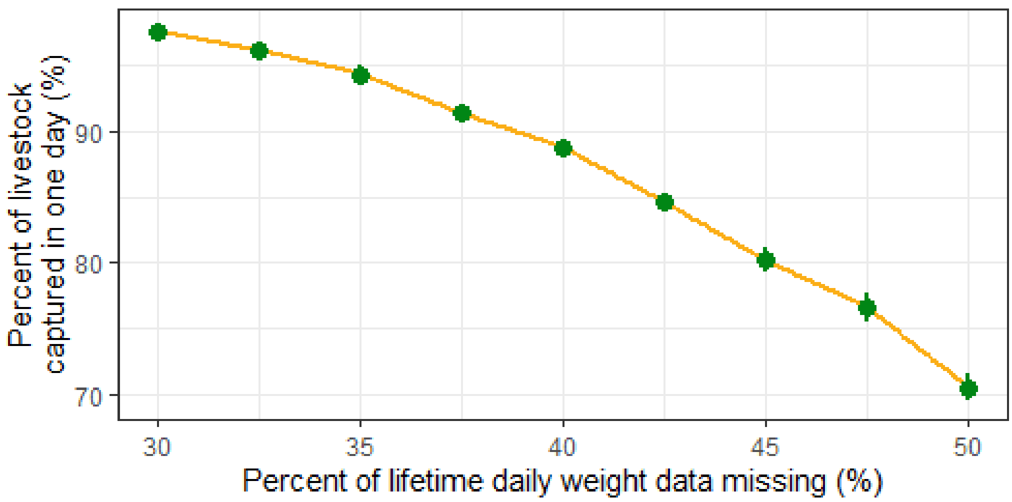


Figure 34. Maximum percent of livestock captured in one day as the number of missing data points increases.

A prediction example was undertaken using one of the simulated cohorts. The maximum number of cattle with weekly weight values on any given day for this cohort was 91 (out of the possible 100). The nine missing animals had weekly weight values in the days surrounding the specified 200 Day Growth submission date, making the individuals ideal candidates for prediction (Figure 35). The data was fitted to the mixed-effects model and compared back to a simulated dataset where no data points were removed (Figure 36). The results indicate that an accurate weight estimate could be predicted within a cohort using ALMS liveweight trajectories. All missing data points were predicted within 2.01 kg ($\bar{x}$ = 1.21 kg) of the actual (modelled) weight, and all within the specified standard error range. These results warrant further research to explore the capacity of ALMS data analysis to estimate missing weights when cattle performance and behaviour impact dataset variance.

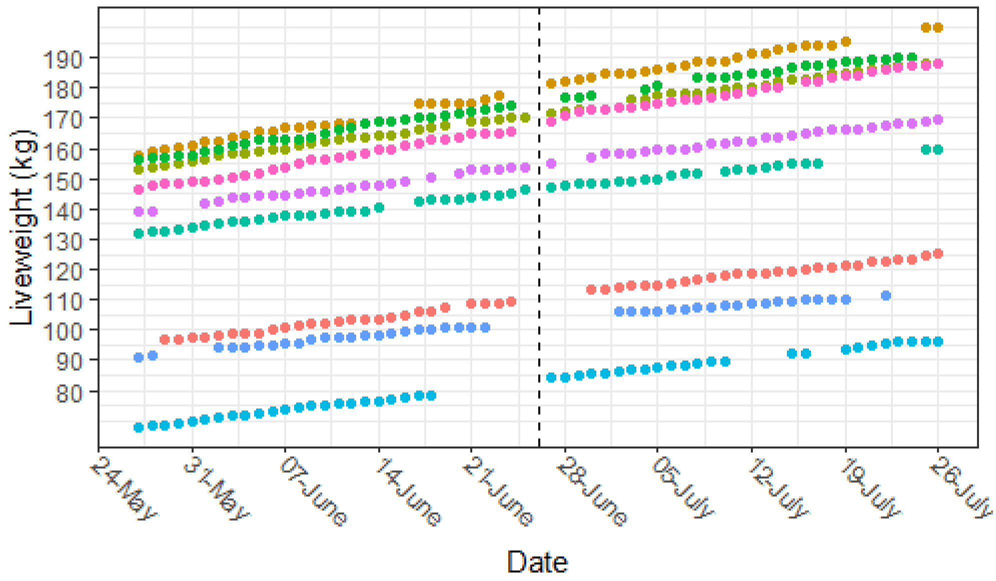


Figure 35. Weekly weight values calculated for livestock in the weeks surrounding the specified 200 Day Growth submission date. Dashed line denotes submission date.

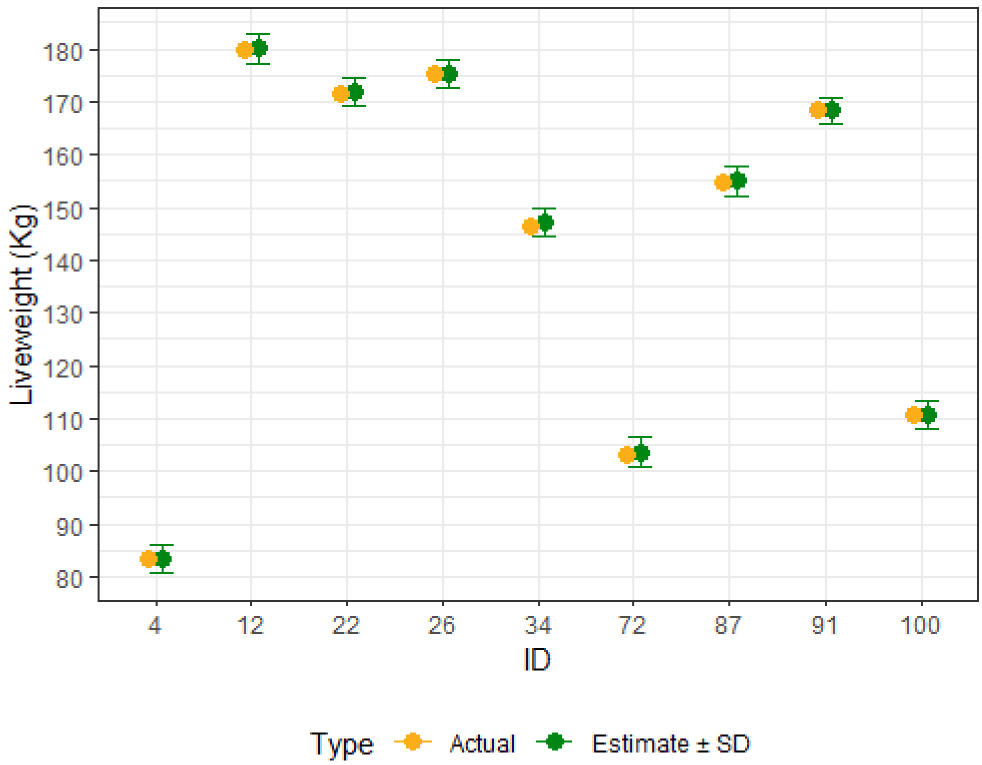


Figure 36. Predicted live weight versus actual liveweight on a specified 200 Day Growth submission date.

An example 200 Day Growth, 400 Day Weight, or 600 Day Weight trait report that could be presented to genetic evaluation platforms such as BREEDPLAN is shown in 13. Appendix D. The report uses the dataset previously described with 27.5% of ALMS data points missing. For the sake of clarity and readability, the final figure excludes sixty cattle with actual (modelled) weights. In this particular example, on the optional sample date (where the majority of cattle had valid weekly weight records), 91 cattle had actual recorded weights, while nine cattle required predicted weights for submission. Consequently, estimated values are provided for each of these platforms.

5.4.3. Part 2A – Evidence of the ability of ALMS to accurately record weight traits

The previous activities have explored the ability for ALMS to successfully capture weight trait data considering animal and environmental variables in this method using modelling techniques. This section explores real ALMS data and develops a data processing method for generating BREEDPLAN compliant weight data under practical conditions. The specific goal of this section was to generate potential BREEDPLAN compliant cattle weights derived using ALMS.

A scoping study was conducted to review existing ALMS data that had been collected during the previous five years of this project at Belmont Research Station. The CQUniversity database was searched for cohorts with ALMS data when aged between 80 and 900 days, which is the eligible age range for BREEDPLAN weight traits (Agricultural Business Research Institute, 2011). A total of 10 potential cohorts were found with data available for each of the weight traits (Table 22).

Table 22. Summary of cattle cohorts from Belmont Research Station with ALMS data when aged within the eligible age range for BREEDPLAN weight traits.

Cohort	Animal class	Number of animals	Age range (days)	Potential trait
1	Calves (2018 drop)	67	80 – 252	200 Day Growth
2	Calves (2019 drop)	79	82 – 228	200 Day Growth
3	Calves (2021 drop)	45	103 – 200	200 Day Growth
4	Calves (2022 drop)	34	85 – 179	200 Day Growth
5	Female heifers (2021 drop)	190	164 – 467	200 Day Growth
6	Bulls (2019 drop)	122	318 – 502	400 Day Weight
7	Heifers (2020 drop)	235	349 – 565	400 Day Weight
8	Heifers (2021 drop)	179	164 – 467	400 Day Weight
9	Pregnant heifers (2016 drop)	40	775 – 897	600 Day Weight
10	Pregnant heifers and bull (2019 drop)	29	662 – 864	600 Day Weight

Upon preliminary investigation of each cohort it was decided to first focus on the data for the 400 Day Weight trait for the following reasons:

- These three cohorts contained the largest number of cattle
- There is minimal ALMS data for 200 Day Growth, as calves often do not accompany their mothers to water (Menzies et al., 2017a), therefore it is less likely to be collected and submitted.
- The data for the 600 Day Weight is complicated by cattle pregnancy status and stage of pregnancy (Agricultural Business Research Institute, 2011)

The ALMS weekly weights for each of the cohorts with 400 Day Weight data were retrieved and a method to verify each weight, to increase the certainty that the data was a good estimate of the animals' liveweight at that time, was developed. The ALMS weekly weight is an average of individual daily weights collected each week. The ALMS weekly average weight is a more reliable estimate of live weight (R^2 = 0.98) than individual ALMS weights (R^2 = 0.079). Individual weights that are captured each time an animal walks through an ALMS can be susceptible to inaccuracies if an animal walks through too quickly or too closely with another animal for example.

The verification method assigned each ALMS weight as 'verified', 'unverified', or 'removed' (Table 23). Weights were removed if identified as an outlier by statistical tests. Weights were 'verified' if within 60 kg of two or more weights collected four weeks before or after the weight under analysis. The weight margin allowed for high cattle growth (1 kg/day) on pasture over the comparison period and some error. Weights were 'unverified' if they failed the verification check, usually due to a lack of comparable weights.

Table 23. Example ALMS data for one animal with weekly weights assigned as "verified", "unverified" or "removed" according to the verification method.

Weight	Date	Filter
406	2021-08-08	removed
251	2021-08-22	verified
255	2021-08-29	verified
241	2021-09-05	verified
250	2021-09-12	verified
252	2021-09-19	verified
259	2021-09-26	verified
252	2021-10-03	verified
247	2021-10-10	verified
242	2021-10-17	verified
242	2021-10-24	verified
255	2021-10-31	verified
257	2021-11-14	verified
258	2021-12-12	unverified
257	2022-01-16	unverified

When it came to selecting the most suitable data, the selection method was aligned as best as possible to the current BREEDPLAN requirements. It is understood that there are two important BREEDPLAN data requirements for weights traits: 1) the maximum number of animals from a management group are to be weighed on the same day and, 2) the management group can be split if weighing does occur on different days. In line with this understanding, each cohort was separated into breed-based sub-cohorts and the week where the highest number of animals from each sub-cohort had a 'verified' weight was identified. The sub-cohort data were then searched for a second week, where the highest number of animals that were missed, or had an 'unverified' weight, in the first week, had a weight recorded to try to maximise the number of animals with weight data. The data from the two weeks were assembled into a single dataset. Occasionally, if the weight from the first week was 'unverified' an animal would have two weights, one from each week. In this instance, one of the weights was removed, with priority given to ‘verified’ weights over ‘unverified’ weights or to the weight from the first week if both weights were ‘unverified’.

It was intended to compare the ALMS derived weight data to manual weights that were collected for submission to BREEDPLAN. However, there were time differences between the two datasets. For example, the optimal week of ALMS data might have been obtained three to four weeks prior to the date that the cattle were mustered and weighed. Therefore, the two datasets could not be directly compared. Instead, similarities between the two datasets were demonstrated.

A summary of the cohort data used to generate potential BREEDPLAN compliant ALMS derived 400 Day Weight data is shown in Table 24. All cohorts were managed as a single mob from weaning and were a mix of Composites and Brahmans. Animals without a recorded date of birth were excluded from analysis (33 #19 bulls, 45 #20 heifers and 47 #21 heifers). Manual 400 Day Weights for submission to BREEDPLAN were recorded on 4/02/20, 11/02/21, and 18/01/22 respectively.

Table 24. Summary of the cohorts and data periods used to generate potential BREEDPLAN compliant 400 Day Weight data.

Cohort	Total number of animals (post-exclusion)	Number of Composites	Number of Brahmans	ALMS data period
Bulls (2019 drop)	89	46	43	28/11/29 – 29/01/20 (52 days)
Heifers (2020 drop)	190	152	38	17/11/20 – 28/01/21 (72 days)
Heifers (2021 drop)	132	94	38	15/07/21 – 15/01/22 (184 days)

BREEDPLAN suggests that the average age of cohorts for the 400 Day Weight trait should be between 301 and 500 days (Agricultural Business Research Institute, 2011). The mean age of the cohorts at the start and finish of the ALMS data period were within the specified age criteria except for the #21 heifers, which were younger at the start of the data period (Table 25). The ALMS data period for this cohort started earlier in the year compared to the other two cohorts but continued through until the cohort reached a suitable age.

Table 25. Summary of cohort age statistics during the ALMS data period

Cohort	Mean start age (days)	Min start age (days)	Mean finish age (days)	Max finish age (days)	Cohort age range (days)
Bulls (2019 drop)	386	315	454	542	159
Heifers (2020 drop)	366	286	467	576	188
Heifers (2021 drop)	207	142	408	497	154

A high proportion (>82%) of potential ALMS-derived 400 Day Weight traits were produced for each breed-based sub-cohort (Table 26). Only a small number of weights were not able to be verified. Most weights were obtained from the first selection week, where the highest number of animals had a ‘verified’ weight.

Table 26. Summary of potential BREEDPLAN compliant 400 Day Weight data derived from ALMS data.

Cohort	Sub-cohort	Percentage total weights	Number of unverified weights	ALMS weight dates	Number of second week weights
Bulls (2019 drop)	Composites	85% (39/46)	1	8/12/29 29/12/19	1
Bulls (2019 drop)	Brahmans	95% (41/43)	1	8/12/19	0
Heifers (2020 drop)	Composites	92% (140/152)	1	20/12/20 17/01/21	7
Heifers (2020 drop)	Brahmans	82% (31/38)	0	20/12/20 24/01/21	1
Heifers (2021 drop)	Composites	98% (92/94)	4	10/10/21 19/12/21	5
Heifers (2021 drop)	Brahmans	97% (37/38)	1	10/10/21 26/12/21	1

The mean age of the #19 bulls and the #20 heifers at the ALMS weight was closer to 400 days than the age of these cohorts at the manual weight (Table 27). The mean age of the #21 heifers at the ALMS weight date was younger (Table 27). The weather during the 2021 data period was wetter than the previous two seasons, which could have been reason why most of the ALMS weights were derived during October rather than December/January as per the other cohorts (Table 26). The mean age of the #21 heifers remained within the BREEDPLAN specified age criteria.

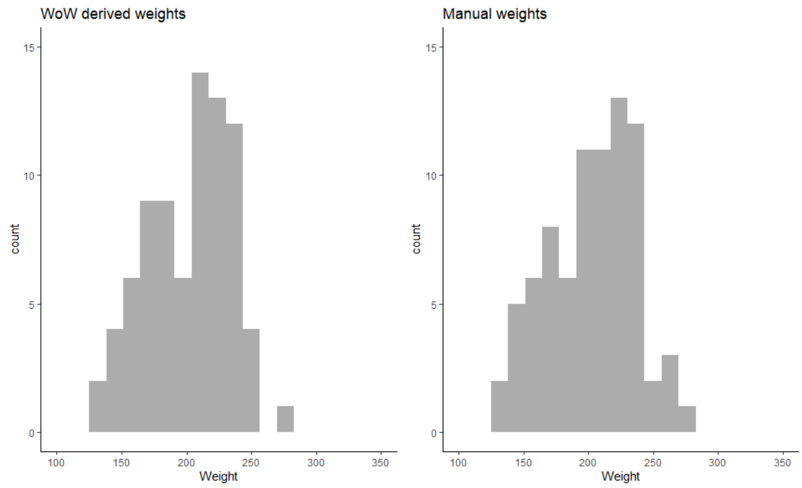
Table 27. Summary of age statistics of sub-cohorts relating to the ALMS weight compared to the manual weight.

Cohort	Sub-cohort	ALMS weight mean age	ALMS weight age range	Manual weight mean age	Manual weight age range
Bulls (2019 drop)	Composites	401	362 – 474	448	399 – 542
Bulls (2019 drop)	Brahmans	406	325 – 432	464	383 – 490
Heifers (2020 drop)	Composites	442	385 – 551	468	412 – 576

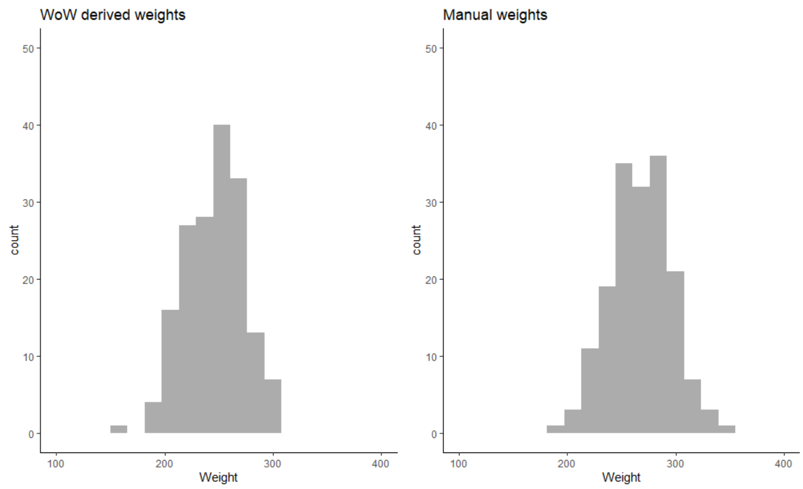
Heifers (2020 drop)	Brahmans	447	370 – 494	466	388 – 512
Heifers (2021 drop)	Composites	305	243 – 415	401	343 – 469
Heifers (2021 drop)	Brahmans	327	255 – 397	424	348 – 497

Histograms of the ALMS weight data and the manual weight data for each cohort demonstrate similar distributions between the two datasets (Figure 37). A shift to the left in the distribution of the ALMS weights compared to the manual weights is evident in Figure 37c, due to the larger time difference between the two weights.

a)



b)



c)

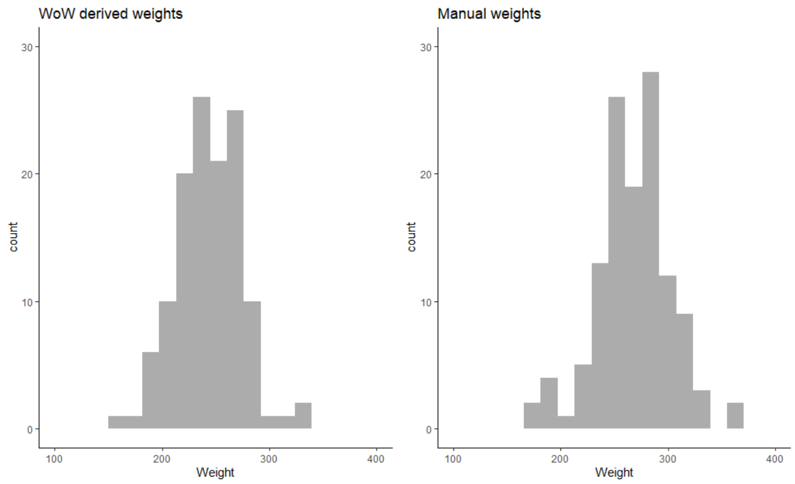


Figure 37. Histograms comparison weights captured using the ALMS and manually captured weights for a) bulls (#19s), b) heifers (#20s), and c) heifers (#20s).

This scoping study demonstrates that high numbers of potential BREEDPLAN compliant cattle weights can be reliability generated in the paddock and under practical conditions using ALMS. No special conditions were put into place for collecting the data presented in this report. Across all cohorts there were issues associated with the equipment, animals, and environment that impacted the data.

Further trials to understand more about the ideal timing of data collection within the year, ideal time frame of data collection and monitoring cattle ALMS use during data collection periods would be beneficial to increase the number of weights generated closer to 100%. Future collaboration with MLA, ABRI, and other organisations involved with BREEDPLAN will also help to finesse data processing and selection techniques and agree on a reporting format.

5.4.4. Part 2B – Establishing a BREEDPLAN compliant reporting format for weight traits

Engagement and consultation between the research team and the providers of the industry genetic evaluation systems has been an important aspect of the project to ensure calibration of research outputs to BREEDPLAN standards. Several meetings involving CQUniversity, MLA, ABRI, and AGBU were held throughout the life of the project (July 2021, April 2022, August 2022, and November 2023). During the meetings, CQUniversity presented the results of the growth trait research activities to date and sought feedback on the proposed methods to discern performance data, the obtained results and further validation and enhancement of ALMS data to pass into performance evaluation pipelines. The feedback received from each meeting was positive from all parties. CQUniversity was supported in their initiative of reviewing the current ways that performance data is collected for genetic assessment and proposing new data collection practices. Some key discussion points concerning the previous research activities include:

- The results of the simulation experiment and the scoping trial showed that 100% of herd performance data may not be obtained using ALMS. The use of predictive methods to discern performance data was agreed as a potential suitable tool pending further investigation.
- There are strategies that can be implemented 'on ground' to maximise the percentage of ALMS compliant data such as the strategic timing of data capture, intensive monitoring of animal ALMS utilisation and supplementation to increase ALMS utilisation. However, it was agreed that 70 – 80% of the herd is sufficient under many commercial circumstances, especially where the use of new data collection methods will allow engagement from producers who otherwise would not or could not engage with BREEDPLAN.
- The BREEDPLAN method of splitting management groups into sub-groups based on age and other parameters was discussed. There is potential to incorporate this information when selecting ALMS data to maximise the percentage of the herd with performance data and avoid further splitting of management group due to different ALMS weight dates.
- The average age of the management group needs to be between 301 and 500 days at the 400 Day Weight weighing. CQUniversity can provide data for individuals that fall outside of this age range, if the average age of the group is within the BREEDPLAN age criteria.
- CQUniversity has done substantial work to align the research to fit within the existing BREEDPLAN requirements. There may be scope for ABRI to review and modify current BREEDPLAN procedures to allow for new data collection methods.

Following previous discussions, a final experiment was conducted to generate real ALMS weight data and continue to establish a BREEDPLAN compliant reporting format for weight traits. The aim of the trial was to achieve 95%+ of ALMS derived 400 Day Weights for the cohort. ALMS data on 190 heifers eligible for the 400 Day Weight trait were collected at Belmont Research Station between 22 December 2022 and 2 April 2023 (101 days). The heifers were mustered and manually weighed for the 400 Day Weight trait by the Belmont management team on 9 February 2023 (week 8). The heifers were managed as a single mob consisting of Brahmans and Composites.

Cattle ALMS utilisation was intensively monitored via the online DataMuster dashboard throughout the data collection period and predicted 400 Day Weights would be generated for individuals who did not achieve an ALMS weight. Regular manual live weights were collected throughout the trial to cross-validate predicted weights against manual weights and test the model for accuracy and repeatability. The heifers were mustered and manually weighed for the 400 Day Weight trait by the Belmont management team on 9 February 2023 (week 8). The paddock environment was not conducive to regular mustering, usually requiring a helicopter muster, and so a spear trapping method was used to collect further weights during weeks 11 – 15. The 'exit' spear gates on the ALMS yard were turned early in the morning (around 5am) so that once the heifers voluntarily accessed the ALMS yard they were prevented from exiting. The trapped heifers were then manually weighed at around 10am and allowed to return to the paddock. The heifers had access to water, supplement, and shade while held in the yard. A total of 227 manual weights were collected using this method during weeks 11 – 15. This quantity was considered sufficient for testing and validation purposes.

An ALMS, and associated infrastructure, had been operational in the paddock since the heifers arrived at the beginning of September 2022. It was quickly identified that ALMS utilisation was low due to the presence of surface water in the paddock. Only about one quarter of the heifers had accessed the ALMS during the first few weeks. At the start of the experiment period (December 2022), a wet supplement (molasses) was made available within the ALMS yard via two wheel lick troughs for the heifers to access *ad libitum* and encourage utilisation (Figure 38). A gate to the ALMS yard was opened for the first week of supplement delivery to entice the heifers to access the supplement. The gate was then closed to coerce the heifers to access the yard via the ALMS. Data collection continued and *ad libitum* supplementation was maintained. The heifers were moved into an adjoining paddock, maintaining access to the ALMS, after being weighed for the 400 Day Weight trait. The main paddock surface water sources in this paddock (two dams and one gully) were fenced to exclude cattle access in an attempt to further improve ALMS utilisation. Data collection was extended for an additional seven weeks to maximise the quantity of data available for analysis. However, rainfall continued throughout the experiment period, totalling 250mm. Cattle utilisation of the ALMS remained largely unsatisfactory.

Figure 38. Image showing the ALMS compound used to collect data for the 400 Day Weight trait at Belmont Research Station between December 2022 and April 2023. The two supplement lick wheel feeders, water trough and manual weighing race and platform are visible. The entry to the yard containing the ALMS is situated to the right of the supplement pod (behind the water trough) and the exit to the left (out of sight).

A summary of the cohort data used to generate potential BREEDPLAN compliant ALMS derived 400 Day Weight data is shown in Table 28. Heifers without a recorded date of birth or identified breed (n = 20) were excluded from analysis. A total of 170 heifers remained in the analysis.

Table 28. Summary of the cohort data used to generate potential BREEDPLAN compliant 400 Day Weight data.

Experiment Week	Percentage of herd that achieved an ALMS weekly weight	Percentage of herd that recorded a manual weight
1	3% (5)	-
2	10% (17)	-
3	14% (24)	-
4	21% (35)	-
5	20% (34)	-
6	38% (64)	-
7	31% (52)	-
8	39% (66)	98% (166)
9	52% (88)	-
10	35% (59)	-
11	41% (70)	41% (69)
12	49% (84)	28% (48)
13	45% (77)	46% (78)
14	45% (76)	5% (9)
15	51% (86)	14% (23)

Unfortunately, a high (98%+) proportion of ALMS derived 400 Day Weights per week across the herd could not be achieved in this experiment using the standard approach. Herd ALMS utilisation remained low despite proactive monitoring and additional efforts made to entice the cattle to the ALMS yard (excluding cattle from surface waters and providing supplementation). Should these circumstances have been experienced under a commercial situation, manual collection of 400 Day Weights would have been recommended rather than relying on ALMS data.

However, variation in individual animal utilisation of the ALMS was noticed within the herd. A proportion of the herd utilised the ALMS regularly (daily or multiple times per day), a further proportion every second or third day and the remainder utilised the ALMS poorly. The variation in the dataset provided an opportunity to examine the data further and generate a further understanding of the data requirements for BREEDPLAN compliance. Following on from 5.4.2 Part1B – Simulating the effects of cattle ALMS utilisation and prediction of missing data points, datasets where an iterative amount of daily weight data were missing for each animal could be assessed. The likelihood of capturing suitable weights for submission to BREEDPLAN with varying quantities of ALMS data could then be examined. The research question was: what percentage of BREEDPLAN suitable weights (actual and predicted) might be achieved for a cohort with *x* amount of missing ALMS daily data (e.g. 25%, 50%, or 75%).

The weekly ALMS data from the second half of the experiment (weeks 8 to 15) was used to explore the research question. Herd ALMS utilisation was highest during these weeks and manual weights were available to compare against the ALMS data. A minimum of 10.9% of daily ALMS data, and a maximum of 100% of daily weight data were missing for individual animals in this experimental dataset. The percentage of missing data for each animal was calculated from the number of days during the 55 day period where no ALMS weights were recorded. Each animal in the herd was categorised by the missing data percentage from 0% – 100% in increments of 12.5% (Figure 39). For example, the animal with 10.9% of missing data was allocated to the category of 0% – 12.5% of issing data. Each group of animals was treated hereon as a separate cohort.

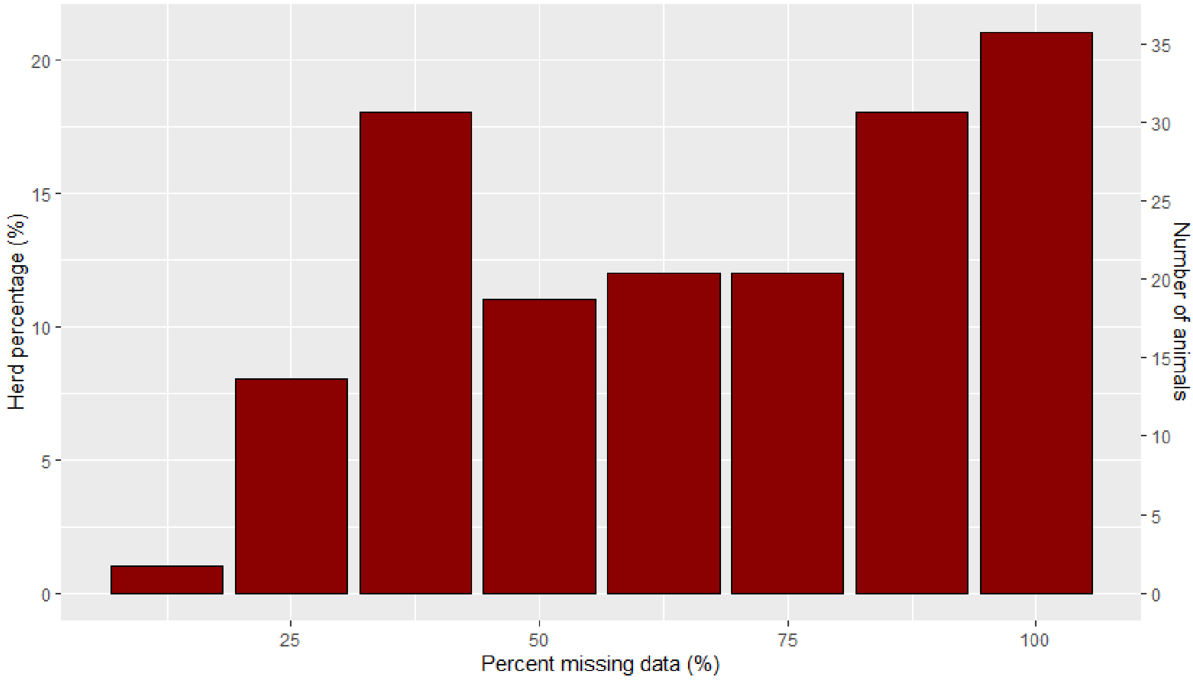


Figure 39. Distribution of ALMS daily weight data when grouped by missing data percentages from 12.5% – 100% of data in steps of 12.5%

For each week, the ALMS weekly weight data (if available) was compared to the manual weight data (if available). Any missing weekly weights were computed using the linear mixed-effects prediction model developed in the previous experiment and compared to the manual weight data (if available). The model was fitted to the ALMS weekly weight dataset using available data from the 30 days before and after the specified missing weight date. One weekly weight before and after each missing weight date was required to be included in the model. Estimated marginal means and standard errors were calculated for the missing weekly weight data and confidence measures around each available comparative weight dataset (ALMS weekly weight vs. manual weight or predicted ALMS weekly weight vs. manual weight) were computed. The week with the highest number of combined ALMS weights (actual and predicted) was then extracted to demonstrate the percentage of BREEDPLAN suitable weights achieved for each cohort.

The data showed that weekly ALMS recorded weights could be achieved for 100% of the cohort when up to 37.5% of the daily data were missing (Table 29, cohorts 1–3). The individual in cohort 1 (0% – 12.5%) achieved an ALMS weekly weight across all eight weeks. All animals in cohort 2 (12.5% – 25.0%) achieved an ALMS weekly weight during seven weeks and the animals in cohort 3 (25.0% – 37.5%) during one week. The previous experiment had estimated a cut off value of 30% of missing daily data to achieve a weekly weight for all animals. The ALMS data from this experiment appears to be more forgiving than simulated, which could be attributed to multiple daily weights being collected when animals access the ALMS multiple times per day. The likelihood of achieving weekly ALMS weights for a high (90%+) proportion of the herd dropped when more than 50% of daily weight data was missing and became unachievable when more than 62.5% of daily weight data was missing. The accuracy of ALMS weekly weights when compared to static weights remained high across all datasets ($r > 0.94$, $P < 0.001$).

Table 29. Opportunities to capture herd weekly ALMS weights for submission to BREEDPLAN with an increasing quantity of missing daily weight data. * denotes an insufficient number of comparisons for analysis.

Percent missing daily weight data (%)	**Number of cattle**	**Percent of weeks with all animals attaining an ALMS weekly weight (%)**	**Percent of herd attaining an ALMS weekly weight per week (%)**	**ALMS weekly weights vs. manual weights**	
				No. comparisons	**R value**
12.5	1	100	100	4*	
25	13	87.5	92-100	49	0.94
37.5	30	12.5	77-100	94	0.99
50	19	0	47-95	44	0.97
62.5	21	0	24-76	23	0.98
75	21	0	10-43	14	0.98
87.5	30	0	7-33	11	0.98
100	35	0	3-6	3*	

The results of the predicted ALMS weekly weight data for each iteration of missing data are shown in Table 30. Conforming to the previous experiment, the results indicate that accurate weight estimates can be predicted within a cohort using ALMS liveweight trajectories (Table 30). More than 80% of missing ALMS weekly weights were able to be fulfilled by predicted weights when up to 75% of daily weight data was missing (cohorts 1–6). The prediction model failed with more than 75% of missing daily weight data (cohorts 7 and 8) due to the lack of available weight data. The predicted weights compared strongly to manual weights across all cohorts ($r > 0.95$, $P < 0.001$).

Table 30. Predicted ALMS weekly weight data with an increasing quantity of missing daily weight data. * denotes an insufficient number of comparisons for analysis. The prediction model failed once more than 75% of daily weight data was missing.

Percent missing daily weight data (%)	Number of missing ALMS weekly weights	Number of predicted weekly weights	ALMS weekly weights vs. manual weights	
			No. comparisons	R value
12.5	0	0	0*	
25	1	1	0*	
37.5	22	20	8	0.98
50	39	37	14	0.95
62.5	86	79	22	0.98
75	124	116	22	0.99
87.5	206	0	0*	
100	276	0	0*	

Graphical representations of the predicted ALMS weekly weight data are shown in Figure 40 and Figure 41. The mean difference between the predicted weights and the manual weights was -4.0kg, which was similar to the difference between the ALMS weekly weights and manual weights (-3.6kg). The small variance can be attributed to differences between weighing platforms, weighing curfews, and mustering or handling procedures.

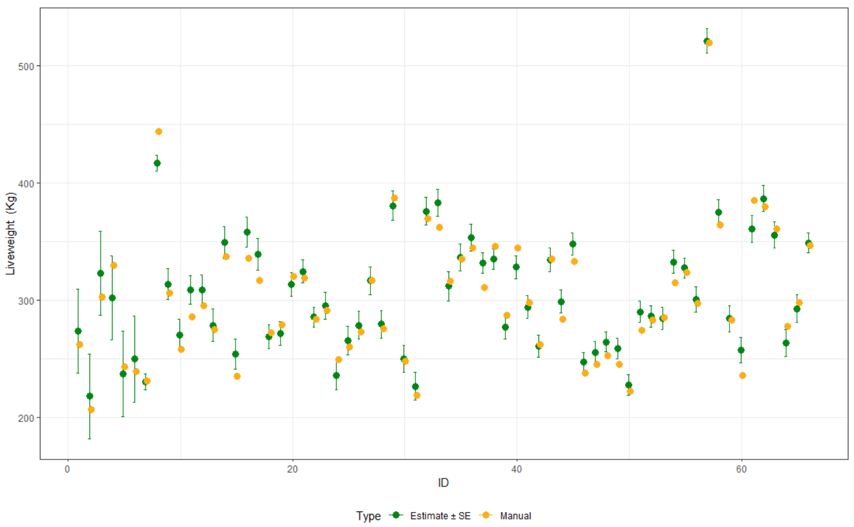
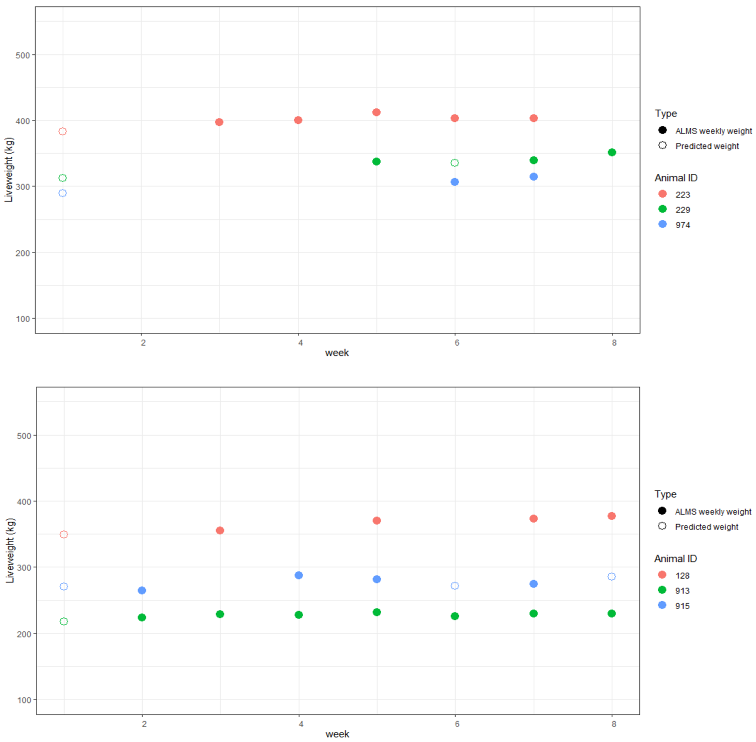


Figure 40. Predicted live weight derived from ALMS weekly weight data versus manual live weight.



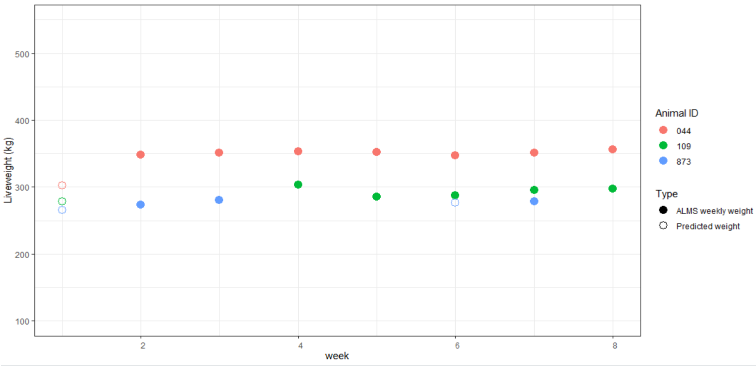


Figure 41. Live weight trajectories of 12 randomly selected heifers showing ALMS weekly weights and predicted weekly weights.

Potentially suitable BREEDPLAN weights were achieved for 95% – 100% of cohorts 1–6 when the actual and predicted ALMS weights were combined and tallied by week (Table 31). A lack of available weight data prevented the generation of predicted weights when more than 75% of daily weight data was missing (cohorts 7 and 8).

Table 31. Percentage of potentially suitable BREEDPLAN weights (actual and predicted) achieved for cohorts with increasing quantities of missing ALMS daily weights. The prediction model did not improve weight tallies once more than 75% of daily weight data was missing.

Cohort	Percent missing daily weight data (%)	Percent of ALMS derived weekly weights (%)	Percent of predicted weights (%)	Total percent of weights (actual + predicted, %)
1	12.5	100	0	100
2	25	100	0	100
3	37.5	100	0	100
4	50	95	5	100
5	62.5	76	19	95
6	75	33	62	95
7	87.5	33	-	33
8	100	6	-	-

The results of this experiment show that good ALMS derived weight data can still be achieved even when herd ALMS utilisation appears unsatisfactory and a high (95+%) proportion of ALMS derived 400 Day Weights per week across the herd cannot be achieved. Currently, BREEDPLAN requires all individuals within a cohort to have a 400 Day Weight recorded on the same day. This requirement may be achieved with ALMS datasets missing up to 50% of daily weight data by using a combination of actual and predicted ALMS derived weight data. A high (95+%) proportion of weights for a cohort might similarly be achieved with datasets missing up to 75% of daily weight data. Manual collection of 400 Day Weights would be recommended for poorer datasets (where more than 75% of data is missing). Future collaboration with BREEDPLAN associated organisations is required to discuss the acceptability of predicted weights, in place of actual ALMS weekly weights, the satisfactory proportion of actual and predicted ALMS weights for a cohort and a suitable reporting format.

5.5. BREEDPLAN feedback on the integration of algorithms and ongoing developments

At the time of writing, there have been significant interactions and collaborative efforts between the research team and BREEDPLAN. These interactions have focused on understanding how the developed algorithms might integrate into BREEDPLAN's system, considering the existing EBV constraints and opportunities for novel methods, and discussing ongoing developments. This section outlines the key outcomes from these engagements and describes the progress and future directions. The research team have engaged with BREEDPLAN throughout the project with key updates in July 2021 and November 2023.

5.5.1. Liveweight traits

In July 2021, following preliminary presentation of the project findings, BREEDPLAN requested a case study to assess the agreement between weekly weights obtained automatically and manual weights in a real-world grazing environment. The findings, presented in later meetings, affirmed the effectiveness of an ALMS in accurately recording animal weights. It was concluded that, especially in favourable seasons, ALMS can reliably monitor a contemporary group of cattle and record an accurate liveweight trait value (i.e. 400 Day Weight) for an individual animal with a degree of accuracy that is sufficient for submission to genetic evaluation platforms.

The discussion also highlighted a key challenge: ensuring every animal in a group accesses the ALMS and registers a weekly weight within a designated window for weight trait collection (for example, between 301 – 500 days for 400 Day Weight). Despite best planning, it is common that a small percentage of animals might either miss accessing the WoW or record inaccurate weights during this optimal sampling period. In response to this, BREEDPLAN positively received the suggestion of using random regression models to estimate the weights of cattle where actual weights were unavailable. They further suggested that applying this method to provide estimated weights for the entire contemporary group could be the most effective way to handle all data recorded by ALMS.

Another point of concern discussed was the utilisation of ALMS under unfavourable conditions, such as in the presence of surface water, which could notably reduce the number of weights available for submission. Considering this, BREEDPLAN acknowledged the merit in submitting weights for at least some animals in a group, as opposed to none. Additionally, it was noted that ALMS technologies are likely sourcing data from producers who have not previously engaged in performance recording. This contribution is enhancing the scope and robustness of the performance data collected for seedstock in Australia.

5.5.2. Date of birth

In a meeting held in July 2021 with representatives from CQUniversity, MLA, ABRI, and AGBU, the presentation focused on the DoB1 algorithm's effectiveness. The algorithm had been applied at Belmont Research Station during 2018/19 and Tremere Pastoral in 2019/20. The stakeholders provided positive feedback, particularly noting the algorithm's ability to accurately determine cattle dates of birth (DoBs) within a one-week period of calving. This initial positive reception was further supported in a later meeting with ABRI in November 2023, where additional data on both the DoB1 and DoB2 algorithms was presented. In summary, the level of algorithm accuracy, coupled with the algorithm's conservative yet effective approach within a 7-day window, led BREEDPLAN to express satisfaction with the use of ALMS for recording DoBs.

The meeting also addressed the variability in existing DoB recording methods, observing that not all producers adhere to the recommendations set by BREEDPLAN. In certain cases, the DoBs estimated by the algorithm could match or even surpass the accuracy of traditional recording methods.

5.5.3. Moving forward

Moving forward, the collaboration between CQUniversity and BREEDPLAN is entering a crucial phase, focusing on demonstrating how data from Automated Livestock Management Systems (ALMS) can be integrated into genetic evaluation platforms. During the November 2023 meeting, it was proposed that creating a new trait code, such as ALMS_DOB, would be the most effective method for integrating ALMS-derived traits into the BREEDPLAN platform.

The next phase of this collaborative effort will explore several key areas. One primary question is how to submit data effectively, particularly whether walk-over weigh (WoW) data can be aggregated with existing data for 200 Day Growth, 400 Day Weight, 600 Day Weight, and Date of Birth (DOB). Although this project has identified a consensus between ALMS-derived and traditional traits, there is a need for investigative work to confirm this is true for BREEDPLAN platform. This alignment will be a primary focus in the subsequent steps of the collaboration.

CQUniversity and BREEDPLAN plan to engage in exploratory work to understand the practical aspects of this integration. CQUniversity will take an active role in working with BREEDPLAN to pipe ALMS-derived information into the BREEDPLAN database. Initially, the focus will be on the Tropical Composite breed, collaborating with Tremere Belmont Reds and 5 Star Senepol. The initial emphasis will be on integrating DOB data, followed by an examination of weight traits.

This ongoing collaboration marks a significant step towards enhancing the accuracy and efficacy of genetic evaluations in livestock breeding, leveraging the ALMS technology developed in this project.

The discussions also touched on the most suitable entity to handle the computation required for generating ALMS-derived traits. This involves condensing the high-frequency data from ALMS into the single-point data format that BREEDPLAN requires. It was recognised that although BREEDPLAN currently lacks this specific capability, they have the potential to develop it within their operations. However, the possibility of engaging a third-party mediator was considered more advantageous. Such a mediator would be responsible for processing ALMS data, computing the necessary values, and then providing this information to BREEDPLAN.

This approach could also expand BREEDPLAN's capacity to incorporate traits from various vendors (such as Datamars, Optiweigh, etc.) and integrate emerging precision livestock phenotypes into their platforms. While it was agreed that CQUniversity would continue to play a role in this process as BREEDPLAN evaluates the new ALMS-derived traits, there exists a potential opportunity for an external party to fulfill this computational and mediatory function in the future.

5.5.4. Future opportunities

During discussions with BREEDPLAN, several key themes emerged, reflecting the evolving priorities and innovative strategies in livestock breeding. A prominent theme was the emphasis on sustainability traits, highlighting the need to align livestock production with environmental and societal sustainability goals. This focus underscores a growing awareness of the broader impact of livestock breeding practices.

Another significant theme was the efficiency of the breeding cow herd, specifically concerning mature cow weight. Recognising that the breeding cow herd is often the least efficient component in the grazing system, the discussions centred on strategies to enhance cattle efficiency, which is crucial for optimising overall system productivity.

Behaviour traits also emerged as a topic of interest, focusing on understanding which animals are accessing various systems. This area is gaining attention for its potential to provide deeper insights into herd management and animal welfare, indicating a shift towards more holistic management practices.

Lastly, the integration of technologies such as GPS, accelerometers, and front-foot weighing systems was a significant topic of discussion. These tools, which are gaining prominence in the Australian beef sector, hold the potential to accelerate data collection. They can provide invaluable new phenotypic information for genetic evaluation platforms, including insights into landscape utilisation and heat stress resilience. Additionally, these technologies can expand national reference populations by automating data collection, thereby enhancing both the scope and efficiency of data gathering processes.

6. Quantification of the economic feasibility of using ALMS to record phenotypic traits for submission into genetic evaluation programs

An economic analysis of a model seedstock operation in Northern Australia was undertaken to explore the viability of implementing automated phenotyping technologies at the property level. Based on a range of key assumptions around the likely benefits that might be achieved through the deployment of ALMS, the cost-benefit was assessed over different investment levels in two scenarios. The first scenario involved a producer who did not collect calf weights while the second explored the value for a producer who required calf catching. In most of the investment levels in the two scenarios proposed the analysis suggests a positive return on investment (ranging between 1.40 and 2.9), with some negative or marginal returns identified where high-cost implementation and low-benefit sensitivity models occurred.

Much of the value in implementing these systems would be derived from labour savings, and further to this much of the value came around collecting data at calving time. Producers would need to carefully consider how this would interact with the available labour resource on their property – for some producers who hire in additional labour for calving season it may be particularly useful, however, those with fixed labour units may find it more challenging.

This analysis has focused on the on-property benefits of automated phenotyping technologies and has not considered the value to the broader industry of improved accuracy and trust in data, as well as improvements to productivity through increased genetic information. Future studies should explore how these factors might make an economic impact across the entire northern beef industry.

6.1. Introduction

The broader project has explored the technical feasibility of ALMS to provide key data for integration into genetic evaluation programs. There is, however, little value in this if the economics around the use of these emerging technologies doesn't provide a compelling argument for adoption. This part of the project sought to understand the impact that adopting automated phenotyping technologies might have in terms of cost savings and revenue increases. The primary focus of this analysis was based on the on-farm economic benefits of these technologies, with much of this coming in the form of labour savings. This does, however, ignore the potential benefits at a broader industry level if the collection of phenotypic data improves the accuracy of genetic selection programs and delivers a greater overall impact to the northern herd. This side of the economic evaluation cannot currently be addressed in this project due to significantly more complex modelling than is currently resourced, however, it is worth considering the benefits that might be gained by seedstock producers to facilitate the adoption of these technologies at a farm level.

The specific objective of this activity is to undertake a cost-benefit analysis of using automated phenotyping technologies as opposed to labour intensive and less accurate manual performance recording measures currently used by industry.

6.2. Methodology

This economic analysis is based on the development of hypothetical case study properties and followed the techniques described in MLA Report P.PSH.0835 (Trotter et al., 2018). This analysis technique was specifically developed by CQUniversity and Acil Allen Consulting to evaluate the impact of new and emerging technologies on extensive grazing livestock industries. The technique involves the development of a case study property which broadly represents a typical production system. In this case, two representative case study operations were developed:

- Property 1: A more intensive seedstock production system in the southern areas of Northern Australia, for example, around Central Queensland
- Property 2: A more extensive seedstock production system in the upper areas of Northern Australia, for example, in Katherine, Northern Territory

The method involves estimating the potential benefits as either costs savings (e.g., hours of reduced labour) or revenue gains (e.g., increased animal sales through improved calf survival) on an annual basis. A third factor, Catastrophic or Unusual Events (CUEs) seeks to estimate the costs or benefits of incidents that occur only infrequently (e.g., a labour unit being hurt while calf catching). These costs savings and revenue gains are then applied to the case study business model developed to determine the final impact of the technology in terms of total costs and revenue. The economic returns calculated above are then finally compared to the costs of implementing the technology to provide a simple cost:benefit analysis.

One of the critical considerations undertaken in this study was the determination of true benefits over perceived benefits. This is best explained in an example. An ALMS system can be used to collect data on 200 Day Growth and 400 Day and 600 Day Weights. However, in many seedstock production systems these periodic weights are collected as part of other regular animal management (e.g., weaning for 200 Day Growth). In this study, the conservative route was taken and only the benefits of automating one of the regular weights was calculated, as this is considered a more genuine assessment of the technology's value. In time, it may be proven that the increased accuracy of the data collected by ALMS systems warrants their use across all day weights (200 Day Growth and 400 Day and 600 Day Weights) which would obviously improve the return on investment of these systems.

One key limitation of this process is that the complexity of farm labour, either being employed staff or imputed family, is treated as a similar cost. This does provide a true economic picture of the benefits and costs of implementing this technology but does not truly consider the impact on a property where some labour units are fixed. In some cases, while a labour saving might be achieved by a technology, it cannot be truly reflected as a true cost saving on the farm as the labour units are fixed in whole units. In-depth analysis of this issue is beyond the scope of this project and for the purposes of this study, any labour savings can be reassigned to bring value to the operation in other areas.

6.3.1. Data inputs and assumptions

The data underpinning these case studies was derived from the experience of the research team in conjunction with discussions with industry leaders and seedstock producers involved in the North Australian genetics industry. The key assumptions derived from these opinions are outlined as the primary drivers of economic returns. As discussed later, there is likely to be debate around the specific values input into the modelling process as seedstock producers are highly variable in how they run their operations. The differences between producers translates into significant variability in impacts on the likely costs saved through the implementation of technology, thus a hypothetical seed stock operation model was chosen to provide a more general understanding of the likely impacts across the sector. This variability is also dealt with by simulating low-, average-, and high-benefit scenarios which further provides a sensitivity analysis across the case study.

6.3.2. Basic case study property parameters

The basic parameters of the case study properties (i.e., herd size, productivity, and revenue) were derived from discussions with producers and industry experts (Table 32). For the purposes of this analysis, a seedstock producer case study has been developed, based on a 500 cow herd selling 95 bulls. The basic financial parameters of this operation are described in Table 33. The estimation of operating costs is notoriously complicated and the process developed in Trotter et al. (2018) was followed. In this case, operating costs were based on ABARES survey data (2019 – 2022) for general commercial beef operations across Queensland and estimated at 73%. These operating figures include all business costs, along with depreciation and interest, but exclude both employed labour and operator and family labour, which is dealt with separately because of the significant impact of labour savings of the technologies in question. The additional costs associated with managing and selling seedstock animals (which are not captured in these standard expense estimates for commercial operations) were included as a proportional cost of sales (detailed below). A cash cost for each FTE labour unit was estimated by applying the Pastoral Award (2020) Farm and Livestock Hand Level 6 Award with on-costs and superannuation of 29%. This meant that all labour used on the properties was valued equally at $30.34 per hour or $230 per day or $59,953 per year. Labour utilisation was set at 2.5 FTE for the case study property. Vehicle costs were assumed to be covered in an estimate of $0.60 per kilometre. Livestock sale prices were estimated from five-year average values taken from the MLA NLRS data base for steer/heifer and cull cow sales. A multiplier of 1.25 (25% higher premium) was applied to heifer sale prices due to perceived higher demand for better-bred cull heifers. Bull sale prices were set at a nominal $13,239 per animal. This value was calculated from bull sale summaries for *Bos indicus* type (Brahman, Santa Gertrudis, and Droughtmaster) over the past two years as reported on Beef Central. A nominal extra cost of 5% of bull sales was added to expenditure to account for the additional expenses associated with seedstock bull sales (for example, custom feeding).

Table 32. Basic herd parameters of case study seedstock operation.

Breeder herd (cow numbers)	500
Weaning rate	90%
Mortality rate	2.5%
Heifers retained	50%

Bulls kept entire for sale	45%

Table 33. Basic farm profit and loss of case study seedstock operation.

	Numbers	Weight	Price/kg or unit price	TOTAL
Bulls sold	95		$13,240/hd	$1,257,784
Steers sold	120	380	$4.48/kg	$204,288
Heifers sold	120	350	$4.66/kg	$195,825
Cull cows sold	50	450	$2.78/kg	$62,550
Total Revenue				**$1,720,447**
Farm operating costs (exc. labour)				$1,255,926
Additional costs associated with bull sales				$62,889
Farm labour costs (hired and imputed)				$149,884
Total Costs				**$1,468,699**
Profit/loss				**$251,748**

6.3.3. Estimating annual cost savings

Cost savings, and particularly labour savings, make up the largest value components of the analysis. The values were calculated by apportioning an estimate of the time saved by the technology against the annualised, weekly, or daily labour costs described above. In some situations, savings come from more than one source (for example, labour savings and reduced vehicle costs from avoiding a mustering event) and are considered additive.

6.3.4. Estimating revenue gains

In some situations, it was considered viable that small revenue increases might be achieved through the application of the technology (for example, very minor increase in calf survival because of avoidance of interfering with newly calved cows). In these cases, the value of the animal was carried through to it final sale at the more conservative red meat value (i.e., not as a bull sale).

6.3.5. Estimating costs/lost revenue savings from Catastrophic or Unusual Events (CUEs)

A key feature of the analysis was the attempt to capture information around the value and impact of Catastrophic or Unusual Events (CUEs). These events do not necessarily occur on an annual basis but have a significant impact on the operation when they do. The technique used to calculate the value of these events apportions the impact when it does occur over its perceived frequency. This is a relatively simple way of calculating value and whilst other complex means could have been applied, this provides the most readily understandable way of standardising the value across technologies. In this analysis the primary CUE identified was that of injury to labour while calf catching (several producers have reported OHS risks associated with this activity as cows become more aggressive around newborn calves).

6.3.6. Costs of implementing technology

The costs of implementing technology were estimated based on the experience of the research team and current commercially available ALMS. In addition to the initial investment in the purchase of equipment, a producer also needs to invest in yard panels to surround the water and may need to adjust fencing to accommodate the system. There is also some investment of time in initially learning to set up and operate the system. The ongoing maintenance/checking of the system is generally low and can be achieved as part of regular water run and therefore is not separately budgeted for.

Two separate costs of implementation were modelled in this analysis. The high-cost deployment reflects a larger-scale investment into two ALMS units, while the low-cost deployment reflects investment into only one unit. The acquisition of a single ALMS unit is associated with higher labour costs, as this system would need to be moved between paddocks to achieve the same result as having multiple units. In reality, there is likely to be a large degree of variation in the required investment across individual seedstock operations with some already having fencing infrastructure suitable for integration and others requiring significant additional investment. The estimates provided provide an upper and lower boundary on what is assumed to be the average costs of adopting this technology in this environment.

6.3. Scenario 1 and Scenario 2 – Using ALMS to collect data on key reproduction and liveweight traits

This section explores the economic benefits of using ALMS to automate the collection of key data around birth dates, maternal parentage, and key liveweight traits. The section has been divided into two scenarios based on the necessity to collect calf birth weight data: Scenario 1 represents a situation where a producer is not seeking to collect calf weight data. Scenario 2 represents a situation where a producer requires calf weight data within 48 hours of birth, which has traditionally required calf catching, which can be made more efficient by knowing exactly which animals have calved in the last 48 hours.

The ALMS has been demonstrated to provide key data on a range of key behaviours and characteristics of cattle that can be used to either directly inform or infer performance records. In this scenario the ALMS will be assumed to be able to deliver the data on several key traits with the required degree of accuracy, the assumptions behind each are described in detail below.

6.3.1. Detection of the calving event for date of birth (DOB)

The ALMS has been demonstrated to provide an accurate estimate of date of birth (DOB) down to a day level (see 4.5.3 Dates of birth). When provided in near real-time this information enables investigation of adverse calving events and improved scheduling of field inspections for other traits of interest – these are discussed in more detail below.

6.3.2. Increasing efficiency in recording of birth weights

Walk-over-weigh systems have so far proven unable to accurately detect calf birth weight. Initial attempts have been made to explore pre and post-birth event cow weights to estimate calf weight but variation in body fluids and expelled reproductive tissue (such as placenta) associated with the calving event appears to confound this (Chang et al., 2021). Further research is being undertaken to explore the potential for calf birth weight to be detected directly if the animal crosses the platform early in life, however the outcome of this remains in question.

The only method that enables collection of calf birth weight remains the physical catching of the animal. In this situation, some of the efficiency of the ALMS is lost as labour is required to visit the paddock to undertake this activity. However, there would be some refinement of these visits based on the data generated by the system which would make the producer aware of which animal had calved and when, so that a much more targeted approach to calf catching could be developed.

This situation is the focus of Scenario 2 where calf catching is undertaken every second day with a small reduction in labour use as the operation can more efficiently target animals that are known to have calved.

6.3.3. Maternal parentage

Once calves have been ear tagged it is feasible to use the visitation of cow/calf pairs to the ALMS to identify maternal parentage (Menzies et al., 2018). As maternal parentage is generally recorded if the calf is caught to be weighed, this application is only relevant to Scenario 1. There is a small labour saving in not having to mother up calves either in the yards or paddock.

6.3.4. Periodic live weight (200 Day Growth and 400 Day and 600 Day Weights)

The recording of periodic liveweights is often aligned with other management activities on the property. This means that any labour saving (through reduced mustering events) cannot be applied across all three of these key weight measures. In the case study we have developed we have assumed that the 200 Day Growth is taken at the time of weaning and the 600 Day Weight is collected during a normal animal management event. In this case study we have not included any reduced costs for these two events. We have assigned the 400 Day Weight as that which would normally require additional mustering and handling to enable collection, with the costs incurred by the implementation of an ALMS. In reality, there is a great deal of variability in seedstock production systems with some producers potentially gaining benefit from using an ALMS to collect more than one of the key day weights. We have taken a more conservative approach in only attributing the benefits for the one weighing event.

6.4. Key assumptions

The assumptions underpinning the economic modelling process are the key determinants of the final outcomes and are clearly outlined in Table 34 and Table 35. These estimates have been developed through discussion with producers and industry experts and reflect the best estimate of value provided at each point. Like all estimates these figures are open to critique, however, to provide some degree of sensitivity analysis a simple high and low-range multiplier was developed and applied. The high multiplier represents the maximum likely value that a seedstock producer might get from an impact point. For example, some producers might have much higher vehicle costs for calving runs based on the size and terrain of their property, and so the maximum multiplier was set at four times for this impact point; others are likely to have a lower cost and so the minimum estimated benefits multiplier was set to 0.5.

The key assumptions around the cost of deployment are outlined in Table 36. Two separate deployment models based on a high and low investment are considered to provide some sensitivity in the analysis of cost:benefit.

Most of the assumptions are similar across the two scenarios with a few notable exceptions. Scenario 1 includes a benefit around reduced labour for manually recording maternal parentage (mothering up) as the ALMS is able to provide this service after branding when calves have NLIS tags fitted. The avoided calf loss from reduced interference with calving cows was estimated at a low 0.5% for Scenario 1, but a higher 1% for Scenario 2. The justification is that those producers who do not currently catch calves would naturally have a lower impact in terms of cow/calf interference compared to those who are calf catching. For those who are calf catching, the potential to schedule and target cows for calf catching at key points in time is thought to enable better cow-calf bonding and reduced mismothering. The percentages estimated here are likely to vary considerably between seedstock operations, with some reporting very little if any impact while others have suggested much higher rates of loss.

Table 34. Scenario 1 key assumptions behind economic value of automated phenotyping where no calf weights are recorded.

		Average estimated benefits			Maximum estimated benefits		Minimum estimated benefits	
Impact	**Justification**	**Cost saving**	**Revenue gain**	**CUE loss avoidance**	**Multiplier**	**Value**	**Multiplier**	**Value**
Labour utilisation to check calving cows to record DOB	Monitoring reduced to 2 times per week from daily (1 FTE * 3 hours a day * 4 months)	$7,802	$0	$0	1.50	$11,703	0.50	$3,901
Vehicle costs associated with monitoring calving cows	Reduced to 2 trips per week from 7 (5days * 20 km)	$960	$0	$0	4.00	$3,840	0.50	$480
Labour utilisation for mustering and yardwork for 400 Day Weight	4 FTE for 1 day mustering and yardwork	$922	$0	$0	3.00	$2,767	0.75	$692
Vehicle costs associated with mustering event	Vehicle savings of 300km (over multiple vehicles/bikes/buggies)	$180	$0	$0	2.00	$360	0.75	$135
Labour used to identify maternal parentage	2 full days of labour	$461	$0	$0	1.25	$576	0.50	$231
Avoided liveweight loss from mustering event	Liveweight loss of 2kg (excludes compensatory gain)	$0	$667	$0	2.00	$1,334	0.25	$167
Avoided calf loss from reduced interference with calving cows	0.5% reduction in calf loss from reduced calving runs	$0	$3,031	$0	2.00	$6,061	0.50	$1,515
On-farm data collation and reporting	10 minutes per day saved	$607	$0	$0	1.25	$759	0.50	$303

Table 35. Scenario 2 key assumptions behind economic value of automated phenotyping where calf weights are recorded every second day and guided by alert to which animals have calved.

		Average estimated benefits			Maximum estimated benefits		Minimum estimated benefits	
Impact	**Justification**	**Cost saving**	**Revenue gain**	**CUE loss avoidance**	**Multiplier**	**Value**	**Multiplier**	**Value**
Labour utilisation to check calving cows to record DOB and catch calves for weight	Monitoring reduced to every second day (2 FTE * 3 hours a day * 3.5 days per week * 4 months)	$10,923	$0	$0	1.50	$16,384	0.50	$5,461
Vehicle costs associated with monitoring calving cows	Reduced to a trip every second day (3.5 days/week * 20 km)	$672	$0	$0	4.00	$2,688	0.50	$336
Labour utilisation for mustering and yardwork for 400 Day Weight	4 FTE for 1 day mustering and yardwork	$922	$0	$0	3.00	$2,767	0.75	$692
Vehicle costs associated with mustering event	Vehicle savings of 300km (over multiple vehicles/bikes/buggies)	$180	$0	$0	2.00	$360	0.75	$135
Avoided liveweight loss from mustering event	Liveweight loss of 2kg (excludes compensatory gain)	$0	$667	$0	2.00	$1,334	0.25	$167
Avoided calf loss from reduced interference with calving cows	1.0% reduction in calf loss from reduced calving runs	$0	$6,061	$0	1.50	$9,092	0.50	$3,031
On-farm data collation and reporting	10 minutes per day saved	$607	$0	$0	1.25	$759	0.50	$303

Table 36. Key assumptions around the cost of implementing automated phenotyping technologies under two deployment modes: high-cost where two systems are deployed or low-cost where one system is deployed.

		High-cost deployment		Low-cost deployment	
	Per unit price	**Units**	**Total**	**Units**	**Total**
Capital costs					
Walk-over-Weigh Platform	$15,000	2	$30,000	1	$15,000
Yards for immediate around water	$2,550	2	$5,100	1	$2,550
Fencing investment	$1,500	2	$3,000	1	$1,500
Labour (days) for initial learning and set up phase	$231	3	$692	3	$692
TOTAL			$38,100		$19,050
Annual cost (amortised over 5 years)			$7,620		$3,810
Maintenance expenses					
Annual service charges	$600	2	$1,200	1	$600
Labour (days) for set up and maintenance	$231	3	$692	6	$1,384
Repairs to system & yards	$455	2	$910	1	$455
Total maintenance costs	$1,286		$2,802		$2,439
TOTAL Annualised Costs			**$10,422**		**$6,249**

6.5. Results and discussion

The results presented provide a summary of the cost savings and revenue gains across the two proposed scenarios. Scenario 1 represents a situation in which a seedstock producer is not interested in collecting birth weights but does want to use the system to identify birth dates and collect at least one of the key live weights. Scenario 2 represents a seedstock producer who currently calf-catches to record birth weight and wishes to continue to do so using the system to refine the scheduling of this activity and targeting of cows specifically known to have calved in the last 48 hours.

6.5.1. Which impacts matter?

By far the biggest impact comes through labour savings. Across both scenarios presented, labour savings made up between 62% and 67% of the total value (across all cost savings and revenue gains). The next biggest gains, 21 – 30%, were based around the potential benefits that could be achieved through reduced calf loss caused by accidental injury to calves or mismothering due to the increased amount of traffic in calving paddocks. While the potential for using this system to help in the collection of the key live weight traits is likely to develop over time, the immediate benefits were more apparent through refining the way cow calving data was collected with most of the value (81 – 88%) based on this aspect.

6.5.2. Scenario 1 – Is there value for a seed stock producer who doesn’t record calf weight?

The average estimated benefit of implementing an ALMS under Scenario 1 was $14,630 per year (Table 37). Some 75% of this value is made up of cost savings ($10,932) with potential revenue gains contributing 25% ($3,698). The net financial benefit after the annualised costs of implementing an ALMS were removed suggests that a positive cash return can be achieved in most scenarios. The exception to this is under a high-cost deployment where the minimum likely estimated benefits were modelled. In this situation it is unlikely a producer would implement a high-cost deployment model anyway, as most of the benefit is being accrued by the detection of calving events which could feasibly be based around the utilisation of a single system.

The cost:benefit ratio ranged between 1.40 and 2.34 for the average estimated benefits (Table 39), demonstrating a viable return for the investment in this technology for this theoretical case study property. As previously described, there is a vast amount of variation in how seedstock properties are managed across Northern Australia and so the results are likely to show a similar variation when considering real properties. The marginal cost:benefit ratio shown for the low-cost deployment under the minimum estimated benefits (1.19) reflects a situation where the vast majority of value is coming from labour savings around the checking of cows for collection of birth dates ($3,901) and avoidance of calf loss ($1,515). Together they represent 73% of the value generated in this situation and although there is still a positive return on investment it is marginal. There is clearly a situation in which a high-cost deployment and low-generated value result in a cost:benefit ratio of less than one. In this scenario there is no incentive for the adoption of the automated phenotyping technologies on this hypothetical case study property and reflects the need for prudent consideration of an individual properties situation before investments like this should be made.

Table 37. The expected annual financial benefits of implementing an ALMS to enable automated phenotyping at three levels across Scenario 1.

	Cost saving	Revenue gain	CUE loss avoidance	TOTAL
Average estimated benefits	$10,932	$3,698	$0	$14,630
Maximum estimated benefits	$20,005	$7,396	$0	$27,401
Minimum estimated benefits	$5,742	$1,682	$0	$7,424

Table 38. The expected annual financial benefit after costs of implementing the ALMS across two levels of investment (a high cost and low cost system) across the case study seedstock operation across Scenario 1.

	High-cost deployment	Low-cost deployment
Average estimated benefits	$4,208	$8,382
Maximum estimated benefits	$16,979	$21,152
Minimum estimated benefits	-$2,998	$1,175

Table 39 The cost benefit ratio of implementing the ALMS across two levels of investment (a high cost and low cost system) across the case study seedstock operation across Scenario 1.

	High-cost deployment	Low-cost deployment
Average estimated benefits	1.40	2.34
Maximum estimated benefits	2.63	4.39
Minimum estimated benefits	0.71	1.19

6.5.3. Scenario 2 – is there value for a seedstock producer who is still required to catch calves to record weight?

The average annual benefit of implementing an ALMS under Scenario 2 was $20,032 (Table 40). Of this value, 66% was made up of cost savings ($13,304) and 34% was derived from revenue increases ($6,728). This is a higher value overall compared to Scenario 1 (37% higher) and is the result of two key assumptions: the first is the reduced labour required from 2 FTE catching calves (if the activity is reduced to occurring every second day); and the second is an increase in calf survival. This factor is probably the most difficult to validate; the assumption that there will be less calf loss in this system compared to Scenario 1 is based on a reduction in the more intensive activity of calf catching (as opposed to cow/calf checking in Scenario 1). If these gains could not be realised by an individual producer, it's worth noting that the sensitivity analysis offered through the minimum estimated benefits reports a positive cash benefit after costs for the low-cost deployment and is around breakeven under a high-cost deployment situation (Table 41).

The cost:benefit ratio ranged between 1.80 and 2.89 for the average estimated benefits situation and only fell marginally below 1:1 under the high costs and minimum estimated benefits scenario. This suggest that the implementation of this technology would bring economic benefit in most circumstances for this hypothetical seed stock operation.

In a similar way to Scenario 1, labour made up the vast majority of the total value (62%) to be gained from implementing an ALMS. In reality, labour pools on property are often fixed and careful consideration would need to be given to investments made on this cost saving as reassignment of these resources would potentially be required to generate real value.

One of the key challenges in increasing the value of these systems is the development of technology to enable automated weighing of calves so that calf catching is no longer required. If this could be integrated alongside the currently achievable benefits, the case for automated phenotyping technologies would be significantly strengthened.

Table 40. The expected annual financial benefits of implementing an ALMS to enable automated phenotyping at three levels across Scenario 2.

	Cost saving	Revenue gain	CUE loss avoidance	TOTAL
Average estimated benefits	$13,304	$6,728	$0	$20,032
Maximum estimated benefits	$22,958	$10,426	$0	$33,384
Minimum estimated benefits	$6,928	$3,197	$0	$10,125

Table 41. The expected annual financial benefit after costs of implementing the ALMS across two levels of investment (a high cost and low cost system) across the case study seed stock operation across Scenario 2.

	High-cost deployment	Low-cost deployment
Average estimated benefits	$9,611	$13,784
Maximum estimated benefits	$22,962	$27,135

Minimum estimated benefits	-$297	$3,876

Table 42. The cost benefit ratio of implementing the ALMS across two levels of investment (a high cost and low cost system) across the case study seed stock operation across Scenario 2.

	High cost deployment	Low cost deployment
Average estimated benefits	1.80	2.89
Maximum estimated benefits	3.00	4.81
Minimum estimated benefits	0.91	1.46

6.6. General conclusions

This analysis undertaken on a hypothetical model farm has demonstrated that implementing automated phenotyping technologies is economically viable for northern seedstock producers. However, the analysis has highlighted that much of the value is derived from the activities undertaken to collect data at calving time as opposed to the regular live weights. The other clearly identified driver of value is labour savings. The challenge in realising these labour savings is not simple on seedstock operations. For some producers, the ability to reduce labour requirements at calving may be highly attractive as they are required to hire additional support which is often difficult to find on a seasonal basis. For other producers with a fixed labour pool, value in reassigning this resource would need to be achieved.

One of the key limitations of this economic analysis is that it has not considered the broader economic value of improved data recording across the entire Northern beef industry. To some extent, the automation of data collection will improve the accuracy of data collection increasing the usefulness and degree of industry trust in genetic evaluation technologies. It is this value proposition that stands to provide the greatest economic benefit to the entire Northern beef industry. However, the modelling of this is beyond the scope of this study and requires further empirical evidence to support any assumptions and social science research into explore how the industry would receive these developments.

7. Communication and extension strategy to expand the number of producers providing complete, detailed, and accurate data for genetic evaluation

7.1. Background

The capture of phenotypes for genetic improvement in Northern Australia is limited by a number of challenges, including expansive properties that limit the capacity to record accurate, BREEDPLAN compliant, performance data. The use of ALMS could provide an opportunity to autonomously capture phenotypic data, such as weight traits, whilst bypassing some of the limitations associated with farming in Northern Australia. This section will describe the communication and extension strategy designed to extend and support the awareness of ALMS and the algorithms developed by the research team.

The aim of the communication and strategy extension was threefold – to increase awareness around the project methods and outcomes, build capacity and provide support to producers involved in the project to facilitate peer-to-peer engagement, and demonstrate the value of the technology.

The following communication strategy was developed in consultation with MLA’s National Adoption Manager – Genetics, David Packer, to ensure that communication activities and key messages aligned with MLA’s strategic plan to promote objective breeding tools. It was also aligned with the communications strategy for the DataMuster brand, which was established by CQUniversity to provide a touchpoint for producers seeking ALMS hardware and software.

7.2. Extension approach using the ‘hub and spoke’ design

End-user engagement was at the core of the project, via a ‘hub and spoke’ design. The technology trials were primarily undertaken at the research ‘hub’, Belmont Research Station, while the research ‘spokes’ provided commercial properties on which the research activities could be trialled and evaluated. This approach enabled direct engagement and participation with prospective end-users of the ALMS. These ‘spoke’ properties were also vehicles for peer-to-peer engagement in various cattle producing communities, with participating producers acting as technology champions.

The target audience for the extension activities included seedstock breeders and commercial producers in Northern Australia. Secondary audiences were also targeted as a means of influencing the primary audiences. These included breed societies, stock and station agents, farm advisors and consultants, technology providers, and livestock genetic researchers.

7.3. Key messages integrated into the communication and extension strategy

A series of key messages were developed to explain how ALMS could be used to overcome cost and labour barrier to participation in genetic improvement programs, the research methods developed as part of this project, and the associated value propositions (Table 43).

Table 43. Key messages developed as part of the communication and extension strategy.

Key message	Message purpose
The future for genetic improvement in Northern Australian beef herds requires more cattle to have more accurate, more frequent, and more reliable performance measures	Detail the background to project
ALMS can capture objective performance recording data at lower costs and with less labour	Describe value proposition of the project outcomes
ALMS will allow more producers to participate in genetic evaluation by enabling detailed performance recording in the most remote locations	Describe value proposition of the project outcomes
This project will play an important role in developing and showcasing new technology for recording objective breeding measurements	Increase awareness of project methods and objectives
This project consolidates a range of technologies, algorithms, and data management systems that have the potential to be used to automatically record cattle performance	Increase awareness of project methods and objectives
ALMS have the potential to gather difficult to record data such as birth dates and birth weights	Increase awareness of project methods and objectives
This project will deliver immediate benefits to industry by adding to the cohorts of cattle that have detailed and accurate phenotype information through both the 'hub' (Belmont) and the 'spoke' properties (collaborating producers). This data will be used to enhance the estimated breeding values produced by BREEDPLAN	Increase awareness of project methods and objectives
This project will provide immediate benefits to the wider industry by lifting the number of cattle that contribute to a broader reference population that is available for genomic	Describe value proposition of the project outcomes

evaluation and thereby lift the accuracy of estimated breeding values	
EBVs are a proven method for improving the genetic selection decisions and accelerating the rates of genetic gain in a herd	Detail the background to project

The key messages were delivered in conjunction with generic industry messages to promote the uptake of objective selection tools (Table 44). The purpose of this messaging was to encourage the increase and expansion of the number of producers providing complete, detailed, and accurate data for industry genetics evaluation.

Table 44. Generic industry messages that have been incorporated into the communication and extension strategy.

Generic industry messages
When making genetic selection decisions, producers should focus on what they are trying to achieve in their breeding program and ensure that this is addressed in the traits they are selecting for. This should be expressed in clear breeding objectives that reflect the target market specifications.
Genetic improvement is cumulative and occurs over many generations. Well considered breeding objectives are essential to maintaining and directing ongoing genetic improvement within a herd.
BREEDPLAN uses the world's most advanced genetic evaluation system to produce EBVs of recorded cattle for a range of important production traits (e.g. weight, carcase, fertility).
The larger the population of cattle being evaluated the higher the chance of finding elite genetic material which can then be rapidly disseminated using modern artificial breeding techniques.
Objective assessment uses actual measurements to assess the relative worth of an animal to an enterprise. One form of objective assessment is genetic evaluation which provides an insight into the genetic makeup of animals.
Selecting breeding stock is one of the most important decisions a producer makes each year and will impact the farm business productivity for years to come.
Genetic selection decisions are made easier and more precise through EBVs.
Breeding values are calculated using information from each animal's own performance and from the performance of its relatives. This information can help select and breed livestock that will achieve performance targets and improve profitability.

7.4. Tools and channels used to disseminate the key messages

Several tools and distribution channels have been selected for engaging with producers and industry, and for disseminating the key messages developed as part of the communication and extension strategy (Table 45). These were used on an ad hoc basis depending on available content – i.e., emails and media releases were only distributed when new information became available regarding project delivery, trial results, or implementation advice.

Table 45. Distribution tools and channels for the dissemination of key messages developed as part of the communication and extension strategy.

Tool	Channel
Email	● Direct email to producers who have expressed interest in the project ● AgForce Action 11 (state-wide) and CQ member updates
Media release	● AgForce Envoy magazine ● Breed society publications, such as Brahman News, Droughtmaster Digest ● CQUniversity Facebook, Twitter, and Instagram accounts ● MLA's Feedback magazine ● MLA's Friday Feedback ● MLA's social media accounts ● CQUni News and partner publications

7.5. Results

Beef Australia 2018 acted as the initial launch platform for the activities outlined in the communication and extension strategy. Collateral and messaging were developed to support MLA and CQUniversity staff in articulating the project's purpose and anticipated benefits. The event generated significant awareness of ALMS technology and interest from producers in participating in the project. As the project progressed, the focus shifted to supporting these producers and demonstrating the efficacy of ALMS and the DataMuster platform through field days and media. In the final stages of the project, and following commercial interest in the ALMS from Gallagher, there was a shift in the emphasis of the communications activities away from producer recruitment for the project and towards consolidating messaging around value proposition.

7.5.1. Increasing awareness of the project methods and outcomes

Three key channels were used across the life of the project to increase awareness of the project methods and outcomes – media engagement, newsletters, and social media.

Media was used throughout the project to promote research findings, producer experiences, and events where industry could learn more about the technology. Rural and regional media were the primary targets in alignment with the target audiences defined in the communications and extension strategy. Coverage was obtained from outlets including Queensland Country Life, The Land, North Queensland Register, ABC Radio, and BeefCentral, as well as mainstream regional media outlets, such as WIN,7 Central Queensland television news, and Rockhampton's Morning Bulletin. Over the course of the project, more than 170 media articles were published by these outlets.

Newsletters were used to update interested followers via email and connect them with the latest news, blogs, videos, and event information. The email distribution list was built via the face-to-face engagement with producers at industry events and field days (Table 46), as well as via voluntary sign up through the DataMuster website. In total, more than 270 people subscribed to the newsletter.

Social media was used throughout the year as a method of building understanding of both use of ALMS and the research project objectives. The DataMuster and CQUniAg channels on Facebook, Twitter, LinkedIn, YouTube, and Instagram were used (Table 46), including MLA and industry stakeholders, such as AgForce wherever possible. Social media posts were frequently linked back to the DataMuster website and the user guidebook and live software demonstration. In addition, followers were frequently connected to relevant blogs, media releases, and videos relating to project activities. Photos and videos were used to demonstrate the 'how to' aspects of ALMS, such as the construction of a compound around a watering point, animal training, and equipment troubleshooting. Videos also included producer testimonials and 'how to' clips for setting up compounds, training animals, and troubleshooting any hardware issues. 'Tiles' were regularly used for 'FAQ Friday' social posts, with a simple graphic providing explanations to common questions surrounding use of ALMS and DataMuster. The result of the social media campaign was the development of a significant following and engagement with the project.

Table 46. Summary of the social media channels used to engage with producers and industry stakeholders.

Social media	Website URL	Engagement levels

Facebook	www.facebook.com/DataMuster	553 followers
Twitter	www.twitter.com/Data_Muster	267 followers
YouTube	www.youtube.com/@datamuster7778	11 videos published and a combined 1,244 video views

7.5.2. Capacity building to support producers of 'spoke' properties

The awareness raising activities, designed to stimulate interest in ALMS, were linked with materials and events designed to build knowledge among producers. These activities and materials were primarily promoted through the DataMuster website, brochures and handbooks, and peer-to-peer engagement and support.

The DataMuster website acted as a demonstration point for the software system and provided training materials to explain the hardware and software requirements for setting up an ALMS. A total of 12 blogs were published to explain practical tips for setting up and using the ALMS and DataMuster software, training of animals, and how prospective new users could engage with the research team to participate in the project. A gatefold brochure was developed for distribution at industry events, carrying high-level messages advertising the benefits of ALMS, DataMuster, and the project objectives. The brochure worked in conjunction with a longer booklet, providing more detailed information around the equipment required to set up an ALMS, how to set up the compound around a watering system, and how to train animals to use the unit. As the project evolved and knowledge grew, this handbook was revised, with the three editions growing in length to capture the knowledge generated by the project.

A producer WhatsApp group was created to encourage support and conversations between participating producers. CQUniversity has also worked through established support networks with DAF Qld and Southern Gulf NRM key players in order to promote awareness and adoption of the technology.

7.5.3. Demonstration of the project methods and outcomes and the ALMS

A key component of the communication and extension strategy was focussed on connecting with producers and stakeholders to extend the project methods and outcomes and demonstrate the value of the ALMS. A number of opportunities and activities were conducted to increase networking opportunities and facilitate engagement with industry – these are described in greater detail in Table 47.

Table 47. CQUniversity attended a number of events in order to promote the project and demonstrate the ALMS hardware and software.

Event	Activities	Media coverage	Industry engagement
Beef Australia 2018, Belmont Property Tour	• Presentation to the symposium by Professor Dave Swain (CQUniversity), outlining the value proposition, data accuracy, and investment opportunity available to industry through ALMS • Demonstration of the ALMS hardware and DataMuster visualisation tool at the CQUniversity stand • Demonstration of the ALMS hardware and DataMuster visualisation tool at the Belmont Property Tour (attended by approximately 150 people). The tour commenced at CQUniversity's Central Queensland Innovation and Research Precinct, where the software and data insights were presented, before continuing to the 'hub' of the research activities, Belmont Research Station, where the hardware was demonstrated	Significant media attention was achieved, including a live broadcast by ABC Rural Radio, live from the Belmont property Tour	• Attendance of approximately 150 individuals, including producers, extension officers, and researchers, at the Belmont Property Tour
May 2020 webinar	• Presentation by Dr. Nicholas Corbet (CQUniversity) on the project to date and progress being made on advancing ALMS to provide phenotyping to BREEDPLAN standards • Presentation by Dr. Lauren O'Connor (CQUniversity) on the technical aspects relating to the date of birth algorithm and validation of ALMS data against manual data collection	The event was advertised via media release and on the social media platforms of CQUniversity, MLA, and DataMuster, as well as on FarmOnline websites, including Queensland Country Life and	• 85 individuals registered to attend the webinar, including commercial producers, stud breeders, extension officers, farm business advisors, and government, industry, and media representatives

	● Presentation by Swin Hudson (Tremere Pastoral) on his experience as a cattle producer testing the technology, including the lessons learned on how to maximise the performance of ALMS in a real-world, commercial environment	The Land, and News Ltd's Rural Weekly publications. Post-event media coverage included FarmOnline websites and Channel 7 Central Queensland News.	● A total of 49 people attended the webinar, with nearly all individuals staying for the entire 1¼ hour presentation - it should be noted that several individuals that initially registered indicated that they could not attend on the day and would watch a recording of the event at a later date ● A video of the webinar has been uploaded to YouTube (https://www.youtube.com/watch?v=H6e_mKkZRdU), where it has been viewed 220 times
2021 Barfield DAF field day	● Promotion of DataMuster following a presentation by Tru-Test, Gallagher, and DAF on ALMS		● 20 producers attended the day, and after networking with 80% of the crowd, five producers were identified as interested in DataMuster. These were added to the DataMuster email distribution list and provided follow up information. None have adopted the technology as yet.
Callide Dawson beef carcase	● Promotion of the project and ALMS via a display		

competition field day			
ICMJ Northern Conference	• Presentation by Dr. Anita Chang and Ms. Hannah Jasperson on the DataMuster visualisation platform and insights from the embedded algorithms, including the date of birth algorithm • Demonstration of the ALMS by Dr. Thomas Williams		• Three groups of approximately 25 people were rotated between the groups. During and after the session, there was engagement with the attendees
Beef 2021, Belmont Property Tour	• Demonstration of the ALMS hardware and DataMuster visualisation tool at the CQUniversity stand • Presentations by Dr. Anita Chang and Dr. Thomas Williams providing an update on the project findings, including the status of the developed algorithms, and demonstrating the ALMS software and hardware		• Attendance of approximately 50 producers, advisors, researchers, and industry leaders. It should be noted that attendance at Beef Australia 2021 was lower compared to previous years due to the absence of international delegates and the disruption to local participation caused by COVID-19
Beef 2021 producer meet and greet	• Networking with producers participating in the project, along with any interested or potential producers and industry supporters, to build relationships and increase the confidence and visibility of the project		• Several producers interested in participating in the project attended the event, along with industry partners from NRM and DAF

2022 ICMJ Northern Conference	• Presentation of the ALMS hardware, its data gathering abilities, and the importance of this information for breeding programs and supply chains		• Approximately 100 people were in attendance of the event and the presentation
2022 August MLA/QAAFI Genomics Field Day at Belmont Research Station	• Presentation by Dr. Anita Chang on the results of the automated phenotyping research and the accuracies obtained in detecting date of birth, the performance of the ALMS in meeting BREEDPLAN data standards, and the potential for the technology to capture reference population information for genetic testing • Presentation by Geoff Maynard regarding his participation in the project and his support for ongoing research into automated phenotyping and genomic tools		• Approximately 150 people were in attendance, including producers, researchers, advisors, and industry leaders • This event stimulated further discussions with MLA and BREEDPLAN representatives to determine how to achieve further improvements to enable recognition of data gathering techniques within the BREEDPLAN framework
MLA Updates Toowoomba	• Demonstration of the ALMS hardware and software and video testimonials from participating producers via a display • Engaged with producers and industry		
Trade fairs (2018 Global Forum for Innovations in Agriculture Brisbane, 2019 Rabobank Farm to	• Promotion of commercial investment in ALMS and the DataMuster platform		

Fork conference and trade fair Sydney , 2019 Northern Beef Research Updates Conference Brisbane)			

7.6. Case studies on the adoption of the ALMS by 'spoke' properties: understanding attitudes towards automated phenotyping

Although 35 producers initially showed interest in participating in the project, the conversion of interest to implementation was lower than hoped. As such, three semi-structured interviews were conducted in 2022 with producers of 'spoke' properties to understand and identify barriers to adoption. The semi-structured interviews examined perceived or real barriers, including price, technology performance, data needs, animal training, and ongoing customer support. Interview transcripts can be found in 14. Appendix E.

The producers interviewed were:

- Geoff Maynard (Maynard Cattle Co.) and Phil Orchard (Belmont Research Station), who run a seedstock operation and require intensive data and have observed the research activities and algorithm development conducted at Belmont Research Station.
- Swin Hudson (Tremere Pastoral), who was an early participant in the project and has been involved in the development of the date of birth algorithm and in turn has expanded to two ALMS units.
- Carl Anderson (Carisma Station), who has started using an ALMS but ceased to continue due to issues with paddock management and the prioritisation of other business activities.

These interviews identified a number of barriers to adoption, including the need for personal and ongoing support to assist with the implementation of the technology on farm. As a result, CQUniversity have provided additional support measures to reduce the intimidation factor associated with the adoption of new technology. A series of simple, instructional videos have been developed, detailing how to gain value from the DataMuster software capabilities and how to troubleshoot disruptions to hardware performance, for example battery failure or modem disconnection. Other identified challenges included the need for mobility and improved durability in the hardware to reduce damage from animals and transport between paddocks and connectivity.

Participating producers identified that training the animals to use the ALMS was the hardest and most labour intensive step of the installation process. The knowledge of ALMS usage, however, was passed onto progeny and the process does not need to be repeated for calves born into paddocks with ALMS. Additional research is needed to understand how early exposure to ALMS may be retained to allow for easier training later in life.

The connection of auto-drafting to the ALMS was identified as highly appealing to participating producers. These interviewees indicated that the auto-drafting would reduce labour costs at mustering, could be used to facilitate targeted supplementation, particularly in addition to the animal weight and growth monitoring currently available via the ALMS, and for catching cow-calf pairs.

8. Conclusions, recommendations, and future research

This project has developed and evaluated the ALMS focused on delivering data for integration into genetic evaluation programs. The ALMS developed integrates a walk-over-weigh platform, edge computing enabled in-situ data management, analysis, and communications system (the DataHub), and a visualisation platform (DataMuster).

The system was established on Belmont Research Station and a number of producer partner sites, and evaluation across numerous seasons and animal types demonstrated that despite some challenges, data can be automatically collected that would be compliant with BREEDPLAN requirements.

8.1. Key findings

- Setting up an ALMS to collect data for genetic evaluation programs needs to take into account the overall property characteristics and resources. If data is to be sought for specific traits, then paddocks will need to be identified that are designed appropriately. One of the most critical factors is the animal's ability to source water outside the ALMS compound. Unless other water supplies in the paddock can be isolated or controlled optimal results will not be achieved.
- Producers intending to implement ALMS to collect phenotypic data need be aware that animals will require an initial training phase and this will involve organisation and time commitment.
- The relationship between static weights and the data generated by ALMS is excellent with a correlation coefficient of > 0.95. The increased regularity of data collected by ALMS is likely to overcome any sources of error that might occur during traditional muster and weighing events.
- A key phenotype of interest to the northern beef industry is date of birth. When the ALMS is operating under good conditions and being well maintained, a date of birth could be accurately predicted within 7 days for more than 90% of cows.
- Under optimal conditions, where water was isolated, this project demonstrated that 400 Day Weights can be calculated for over 98% of animals in a cohort using a simple in-paddock measurement approach.
- In a challenging, real-world case study at Belmont Research Station, during a period without isolated water, 400 Day Weights could be achieved for 52% of the herd using a simple in-paddock measurement approach. Liveweight trajectories were generated using random regression of animals with up to 75% missing daily weight data. Utilising this method, 400 Day Weights were achieved for an additional 10% of the herd. At the conclusion of this case study, 400 Day Weights were achieved for 62% of the herd. This case study demonstrates the capability of ALMS to capture accurate data for genetic evaluation programs, even in situations where the ALMS and environment are not optimised.
- An economic analysis of the potential benefits of an ALMS determined that the highest benefits would come through labour savings with the second highest benefit being ascribed to small increases in calf survival through reduced interaction with calving cows. For the model seedstock operator analysed, the greatest benefits came through the automation of data collection around date of birth rather than the growth traits.

- The benefit cost ratio of investing in ALMS was largely positive, ranging between 1.4 to 2.9 for the average estimated benefits considered to be accrued across the model seedstock operation.
- An extensive communication and industry engagement program provided significant insights across the project. Producer use case studies explored the challenges and benefits of the system and identified the various points of value and challenges to implementation. The development of commercially available systems with good support is likely to be well received by the industry.
- The research higher degree student program continues to develop key research leadership for the industry. These students are focused on area of significant potential impact for genetics in Northern Australia.

8.2. Future research

Like most research projects this diverse program of activities has identified several key points of interest that warrant further investigation.

One of the key challenges identified by producers involved in the project was the issue of training animals to use the equipment. Further research needs to explore ways of refining this process. Of particular interest is the potential for animals having been exposed earlier in their life to the ALMS to be more cooperative in its use in later years. If this is the case, then the overall investment in training would be isolated to the first few years as subsequent generations are essentially self-trained after this.

This research project focused on the development of the ALMS as no reliable commercial offerings were available at the time. Recently, commercial systems have entered the market that would potentially provide the required hardware and software to facilitate the data collection demonstrated throughout this project. Further research would be worthwhile in exploring how these particular systems might apply the research outcomes from this project to enable collection of suitable data for genetic evaluation programs.

This project was undertaken in collaboration with established seedstock producers who are already collecting phenotypic data. There is a clear opportunity to apply the outcomes of this project into production systems that are not currently collecting data to explore the potential value this would bring the individual breeders and the industry more broadly. The potential development of commercial herds as reference populations for quantitative and genomic evaluation could provide critical mass to the acceptance of genetic evaluation in Northern Australia.

A key focus of this project has been on the evaluation of the ALMS to provide data in a format that can be used in the current BREEDPLAN structure. There is an obvious opportunity to explore the development of new traits that cannot currently be assessed using traditional means. Examples of this would be body weight change over time to understand individual animal variation in compensatory gain and the refinement of key reproductive traits such as age at puberty or days post-partum before first oestrus. The need to catch calves to obtain weight data to inform calving ease EBVs remains a critical challenge for the Northern Australian beef industry, the development of alternative strategies to measure this more directly (the direct difficulty of birth experienced by the cow) would dramatically reduce the costs of data collection for seedstock producers. The development of impossible/difficult to measure traits that are critical for the northern beef industry could be the key to increasing uptake of this technology. Some of these will continue to be explored within the RHD program of this project (e.g., oestrus detection), while others are being explored in related research projects (e.g., ease of calving) but further research in this domain could reap significant rewards.

The focus of the economic analysis in this project was around the potential impacts for the individual producer. Although there are likely to be benefits at this level, it is the potential for improved data collection to refine the process of genetic evaluation in Northern Australia and the perceived trust by the broader industry that could have a much greater economic impact across the sector. A much broader economic analysis, although significantly more complicated, would provide guidance on the likely return on investment of research efforts in this domain.

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10. Appendix A

A 15 day training guide is available to producers, detailing how to train animals to use the ALMS.

TRAINING ANIMALS

DAY	ACTIVITY
1	Open the last panel in the force just prior to the race so that cattle have easy access to the water compound. Place the top spears in the exit spear so as to discourage cattle from entering through this point. Muster cattle to the WoW compound and allow them free entry to water. Leave panel open for two days to enable stock to sniff around the system without any fear.
3	Reduce the width of the gap in the portable panel that is open but ensure cattle can still enter through the gap. Place the second from the top set of spears in the exit spear. Place an incentive such as a weaner ration on the ground leading through the WoW race. Muster cattle to WoW compound. Gradually allow animals to enter the compound hopefully encouraging some animals to cross the platform.
5	Close the gap in the open portable panel so that only one animal can enter at a time. Place the third from the top set of spears in the exit spear. Place an incentive on the ground leading through the WoW race. Muster cattle to WoW compound. Gradually allow animals to enter the compound hopefully encouraging some animals to cross the platform.
7	Close portable panel so all animals have to enter via WoW platform. Place the final set of spears in the exit spear. Place an incentive on the ground leading through the WoW race. Muster animals to the compound. If animals won't freely enter the race you may need to place some pressure on them by entering their flight zone. This may require 3 or 4 of staff members and is were having a wing or fence extending from the compound is crucial.

8

TO ACCESS WOW SYSTEM

DAY	ACTIVITY
9	Muster animals to the compound and apply some pressure to the mob if they are reluctant to cross the WoW platform. The use of an incentive may be required if the mob is reluctant to start leading over the WoW platform. If by this stage all animals are walking over the platform and into the compound begin adding spears to the entry spear gate starting from the top set. Whereas, if animals are still baulking at entering the WoW compound leave spears out of entry spear gate.
11	By this time you should be getting a reasonable count (roll call) of RFID tags crossing the platform. Muster animals to the compound and observe whether they will enter the compound without applying any pressure. If so, add the second set of spears from the top down to the entry spear gate.
13	Check roll call information and if all animals have been recorded within the previous 48 hours the third set of spears can be added to the entry spear. If there are some animals still reluctant to enter the compound, muster the mob and apply some pressure to the hesitant animals.
15	Check roll call information to see if all animals are watering between 48 and 72 hours. If all animals are watering and final set of spears haven't yet been added, do so.

11. Appendix B

An ALMS was installed at the first ‘spoke’ property in October 2019. The ALMS was installed surrounding a single watering point on a 285 hectare paddock. Cattle were required to traverse the system prior to accessing water before then pushing through a spear gate to exit the compound. The ALMS was formed using existing equipment on the property then connecting the DataHub. Initially, 230 breeding cattle were trained to use the system, with the intention for a further 60 first calf heifers to be trained later. There were 139 calves born prior to the ALMS being installed, with a further 37 born after installation.

Cattle training was undertaken by the collaborator with the assistance of the project team over a 7 day period. The cattle were passively trained using a gentle and consistent approach that allowed them to become accustomed to the compound infrastructure without any fear or hesitation. The compound was gradually established once the cattle were familiar with each of the components, first starting with the race, followed by the surrounding compound, exit spears, then lastly adding the weighing platform (Figure 43). The entrance race was placed in front of an area where the cattle were used to accessing water to work with their natural spatial patterns. The entrance race spanned five portable panels in length (approximately 12m long) to reduce the speed that the cattle traversed the weigh platform. The RFID panel reader was located 1 metre before the end of the weigh platform, which is deemed the optimal distance to record the animals ID and weight when their entire body weight is on the platform. Training the cattle to traverse slowly over the platform results in a greater quantity and quality of data than cattle moving too quickly. Cattle are required to traverse the weigh platform for a minimum of four seconds for their RFID and weight to be accurately recorded.

Figure 42. A compound was gradually formed around a watering point, as per the CQUniversity training protocol.

Accurately recording calf data as they used the system was challenging. Calves can move over the weigh platform too quickly to obtain an accurate read. In addition, they also often hold their head at a lower position compared to an adult, and thus they may be out of range of the RFID reader. Additionally, calves were found to follow closely behind the cow, such that they RFID tag is unable to be detected, or they traverse between two cows, who either push them over too quickly or obscure their RFID tag from being read. The ALMS data at this property demonstrated the same issues. Calf data gradually improved over time but was still low compared to the cows (Figure 44).

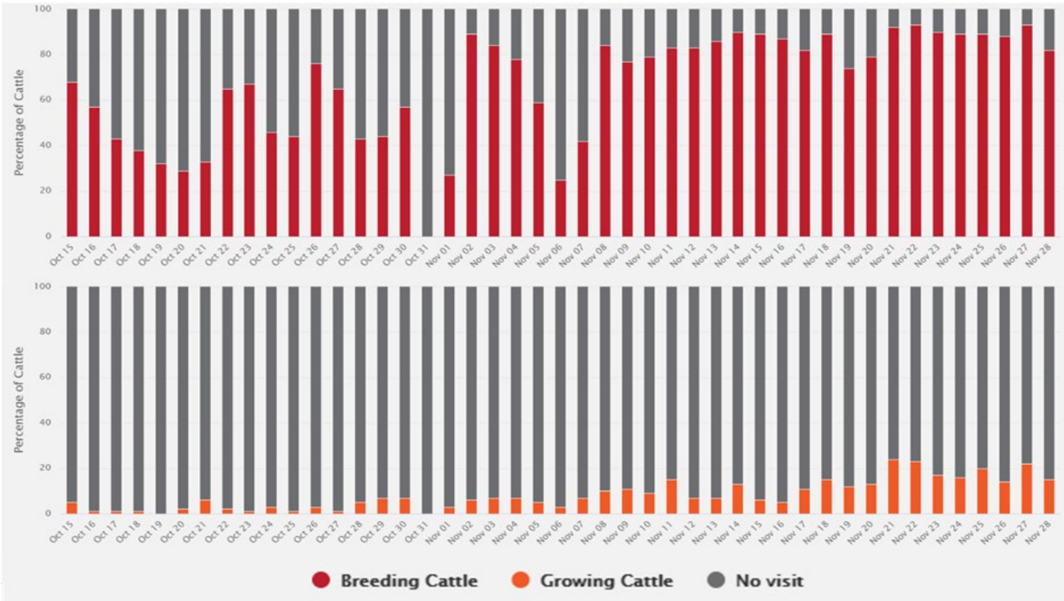

Figure 43. Daily use of the ALMS at the 'spoke' property since installation, categorised by cow (top) or calf (bottom) status.

The automatically recorded data did not initially align with manual observations of the number of cattle using the system. It was suspected that the metal panels were amplifying the RFID reader's read range and the layout was adjusted to avoid any metal contacting the reader. However, the issue persisted. A second weigh platform and associated electronics was installed using equipment that had previously been validated by the project team to identify the cause of the issue. The second unit was placed in front of the exit spear using a similarly long exit race. The intention was to compare the data between the two units to evaluate the quality of both systems. The two systems recorded all the cattle that were accessing the system (Figure 44). Initial investigations suggested that different brands of platforms and readers result in different read ranges, and thus some are more efficient at assigning a RFID to a weight than others. It is also thought that cattle move slower through the exit race after consuming water, and thus the exit reader may result in more accurate data due to cattle spending longer on the exit weigh platform than upon entry.

Unexpected patterns in the data also occurred during the establishment period, which could be explained by factors external to the ALMS infrastructure, such as weather, pasture availability, and activities such as mustering. While these activities are natural or necessary events, the system does not allow for these events to be detected or accounted for automatically. To track local conditions and align them with patterns in the data, the collaborator was provided a diary template to document significant events and activities, such as hail storms and diminishing pasture or paddock movements so that any data anomalies can either be accounted for or investigated.

Ongoing assistance was provided to the collaborator as they continued to use the system including support when they inducted new animals, the issuing of daily data reports, regular communication and site visits, and access to data and its interpretation to assist with management decisions. While automated data is a powerful management support system with a multitude of benefits, the technology does not take away from routine manual observation of the health and welfare of cattle and their environment.

12. Appendix C

It is important to understand the impact paddock conditions have on the accuracy of ALMS data and provide guidelines for industry. Beef cattle are managed across landscapes of varying terrain, pastures, soil types, trees and water availability. The ALMS primarily relies on cattle using the system to access water on a daily basis. However, maintaining the attraction for cattle to use the ALMS can be difficult in many paddocks due to persistent water courses or ephemeral water particularly during the wet season. While some cattle will continue to use the ALMS once trained, many will take the path of least resistance and will drink from alternate water sources. Some paddocks are therefore more suitable for ALMS installation than others. However, the location and/or carrying capacity of these paddocks may not suit when individual animal data is most needed. For example, regular access to ALMS is required during calving to record dates of birth or at specific times of the year to record 200 Day Growth, 400 Day Weight, and/or 600 Day Weight. Thus, the idea to develop a whole of system management plan to optimise the use of ALMS on a property was created.

The aim was to understand paddock suitability for ALMS at different times throughout the year and create a management plan that stipulates when and where cattle should be located to optimise ALMS data collection whilst maximising production. The innovative approach is vastly different from traditional beef businesses management. The intention was to develop a forecasting framework to assist producers plan their cattle management at least 12 months in advance, so they were equipped to deal with a range of environmental conditions, for example, average rainfall, above average rainfall to flood events, below average rainfall leading to periods of drought. The framework would also allow producers to monitor the state of their property to make informed decisions, such as identifying when to provide cattle with nutritional supplements based on cattle weight and the level of nutrients in the pasture. Nutrient budgets could be calculated for each paddock by knowing the number of cattle that had been in that paddock and for how long to estimate the amount of nutrients that had been both removed and added to the paddock. Such information would allow proactive planning according to localised paddock information, rather than reactive management decisions in response to infrequent observations of pasture or cattle.

An approach was designed for Belmont Research Station to test the development, implementation, and evaluation of an ALMS centred management strategy on a property with varied landscapes that were equivalent to a range of paddock types across many beef properties in northern Australia. The results would therefore be applicable to a large proportion of stakeholders. The framework considered a range of factors that contribute to cattle and pasture productivity including feed budgeting, deployment of ALMS units based on paddock suitability, the number of cattle per class and their nutritional and management requirements, the number of expected calves and the timing of ALMS data requirements, for example, during calving or for targeted weight traits, which require adequate data on either side of the event of interest.

Management considerations were required to allow for continuous data recording periods such as having enough feed base for cattle to remain in a paddock with an ALMS unit for the duration of the required period. For example, pregnant cattle are required to record an average weekly weight for 6-8 weeks before and after calving to accurately record an ALMS derived calving date. This period has been determined as the ideal date range to identify the decrease in weight that occurs during the week of calving. Thus, a cow would need to regularly access an ALMS a minimum of three times per week over a 12-16-week period centred around calving. For a September calving period, the location of cattle in paddocks needs to be established in mid-July, or earlier if the cattle are naive to ALMS and require training. Inconsistent data is usually recorded during training, while cattle are familiarising with the system, and is unable to be used for monitoring purposes. Thus, training needs to begin approximately 4 weeks prior to the commencement of baseline recording to ensure cattle are using the system seamlessly and accurate data is being recorded. Pregnancy testing is recommended as a tool to group animals based on estimated birth date and assign groups to ALMS units based on expected calving periods.

To accurately record weights at specific dates, for example, 200 Day Growth and 400 Day and 600 Day Weights, calves born into a single group with a 3 month calving spread may be required to access an ALMS for 12 weeks prior to a 200 Day Growth being recorded. It was estimated that approximately 12 weeks of weekly weight data would be required to record accurate 200 Day Growth data for more than 95% of calves with a 100 day calving period. Managing calves to maintain ALMS access during this period of time requires planning of husbandry routines such as branding, castration, and dehorning around the ALMS recording period so that their behaviour and subsequent ALMS use is not affected. Weaning practices that require calves to be away from the paddock, such as yard training, and nutritional requirements for growth post-weaning also need to be considered. Despite the various considerations, following branding (recognising the need for an NLIS tag in each calf) calves are observed using the ALMS independently of the cow, thereby allowing the ALMS to reliably capture weight data for 200 Day Growth.

Objective climate and pasture data was incorporated into the management plan framework using Queensland Government's 'The Long Paddock' website to compliment ALMS data patterns that may reflect environmental conditions. The Long Paddock database provides historic data on climate and pasture conditions in areas across Australia using satellite imagery and local variables to create predictive models to forecast future weather patterns and regional conditions. Freely accessible reports are generated monthly for specified agricultural lots, providing information tailored specifically for the Australian agricultural industry, and graziers in particular, to inform decision-making and tailor management practices in line with current and expected seasonal conditions.

In addition to understanding the local regional climate and pastoral information, information on individual paddocks and categorising their suitability for ALMS use was a critical component of the management plan framework to determine the most appropriate paddock for cattle each month. The framework prioritises cattle location based on obtaining reliable data for productivity recording, which may be different to how cattle have been traditionally managed, for example, based on pasture availability, location to yards or rotation schedules.

A paddock ranking system was developed to characterise paddocks and determine the suitability of a paddock to install an ALMS. The system considers the availability of permanent and ephemeral water, the ease of restricting cattle access to ephemeral water during the wet season as well as terrain type and level of shade. The ranking system starts with 1 for a paddock that is perfectly suited to recording accurate ALMS data due to the presence of no additional water as an attractant. A paddock ranking of 4 describes an area with many water sources, challenging terrain and a difficult to fence landscape (Table 48). Photograph examples of high- and low-ranking paddocks are shown in Figure 45.

Table 48. The ranking system used to determine a paddock's suitability to install an ALMS.

Rank	**Number of permanent water sources**	**Ephemeral water**	**Option to exclude**	**Influence of shade**	**Terrain**	**ALMS suitability**

			ephemeral water	on daily ALMS use		
1	1	None	Not required	Nil	Flat	High
2	1	Minimal	Yes	Nil to mild	Flat to undulating	Medium
3	1	Present in wet season	Yes	Nil to mild	Flat to undulating	Medium
4	>1	Persistent	Not economical or practical	Major	Difficult	Low

Figure 44. An example of paddocks types defined by the ranking system used to determine a paddock's suitability for an ALMS. Left: A paddock with a ranking of 1 (most suitable) is flat with one permanent water source and shade available. Right: An example of a paddock with a ranking of 4 (least suitable) exhibiting hilly terrain, heavy woodland and permanent ephemeral water that would be difficult and expensive to fence.

The combination of The Long Paddock data with individual animal weights, calving dates, and ALMS visitation frequency is one step towards creating a holistic model of cattle productivity with environmental factors. Consolidating this information can be used to develop an accurate and reliable whole of property management plan and will progress industry towards understanding cattle response to the environment through ALMS use and weight trajectories. This will also assist in determining the accuracy of ALMS data both with and without integration with environmental sensor data.

The capability to review and analyse historical data from each season allows the models developed to be evaluated for their accuracy and modifications made to improve the predictability of future. The framework considers reviewing data on a seasonal or monthly basis to determine the most accurate level of evaluation periods.

Developing a management plan framework for Belmont Research station has included ranking each paddock on its suitability of ALMS installation, as well as detailing the overall cattle management strategy currently in place. This information provides the foundational knowledge on what activities happen and when, thereby allowing specific dates to be entered into the framework to plan for ALMS use; pasture and nutrient predictions based on cattle use and The Long Paddock historic and predictive data.

The historic Belmont Research Station cattle management plan begins in September at the start of calving. This accounts for calves entering the system at the time of birth and reflects increments in each age class of cattle. Table 49 details the annual schedule of cattle management, identifying the paddocks that are normally utilised at this time of year and their characteristics. The suitability of each of these paddocks to effective ALMS installation is shown in Figure 46.

Table 49. Annual activities and paddock rotations at Belmont Research Station.

Month	Activity	Paddock's utilised and characteristics			
		Number	*Size (hectares)*	*Name*	*ALMS suitability*
September – December	Calving	As per pre-calving			
December – March	Mating 750-800 breeders Brahman and Belmont Red Composite breeds	***Multi sire mating:***			
		60	514	McKenzie	Lengthy river frontages, not practical to fence. Presence of semi-permanent and temporary surface water
		69	443	Bottom Cotton	
		75	275	Campbells	
		65	79	Top Cotton	
		80	91	Bottom Selection	
		Single sire mating:			
		66	28		ALMS unit installed central to three paddocks
		67	39		
		35	22		
		25	30		
		19	30		
		20	32		
		32	19		
		13	69		
		17	34		ALMS unit installed central to two paddocks
		18	31		
		58	39	West Craig-Hoyle	
		86	105	Etna Creek	
		26	39	Quarantine	
		81	47	Top Selection	
		Artificial insemination groups:			
		71	53		
		72	59	Bottom River	
January - February	Branding	***Holding paddocks:***			
		60			
		69			
May - June	Weaning - Heifers relocated, approx. 250 bulls remain	***Weaner bulls:***			
		93	105	One Tree	
		94	86	Hut	
		95	88	New	
		96	115	Peach	ALMS unit installed

Table 3 continued.

Month	Activity	Paddock's utilised and characteristics			
		Number	***Size (hectares)***	***Name***	***ALMS suitability***
May - June	Pregnancy testing and foetal aging - Form calving groups	***Early calving groups:***			
		(a) Riparian fenced			
		22	20		
		23	23		
		24	23		ALMS unit installed
		33	22		ALMS unit installed
		34	25		
		35	22		
		(b) Easily accessible paddocks			
		21	20		
		40	40		
		12	51		
		14	23		
		15	22		
		1	6		
		(c) Brahman designated			
		17	34		
		18	31		
		19	30		
		20	32		
		(d) Irrigated paddocks			
		2a	7		
		2b	7		
		3a	7		
		3b	7		
		3c	4		
		4a	9		
		4b	10		
		234	16		
		Mid calving groups:			Inaccessible terrain for vehicles, presence of semi-permanent water. Cows move into the above calving paddocks as early calving groups calve
		41	14	Top Lilly	
		42	27	Middle Lilly	
		43	53	Bottom Lilly	
		71	53	Top River	
		Late calving groups:			Cows progress towards the above paddocks as earlier calving groups calve
		92	144	Larsens	
		52	77	West Craig-Hoyle	
		56	37	East Craig-Hoyle	

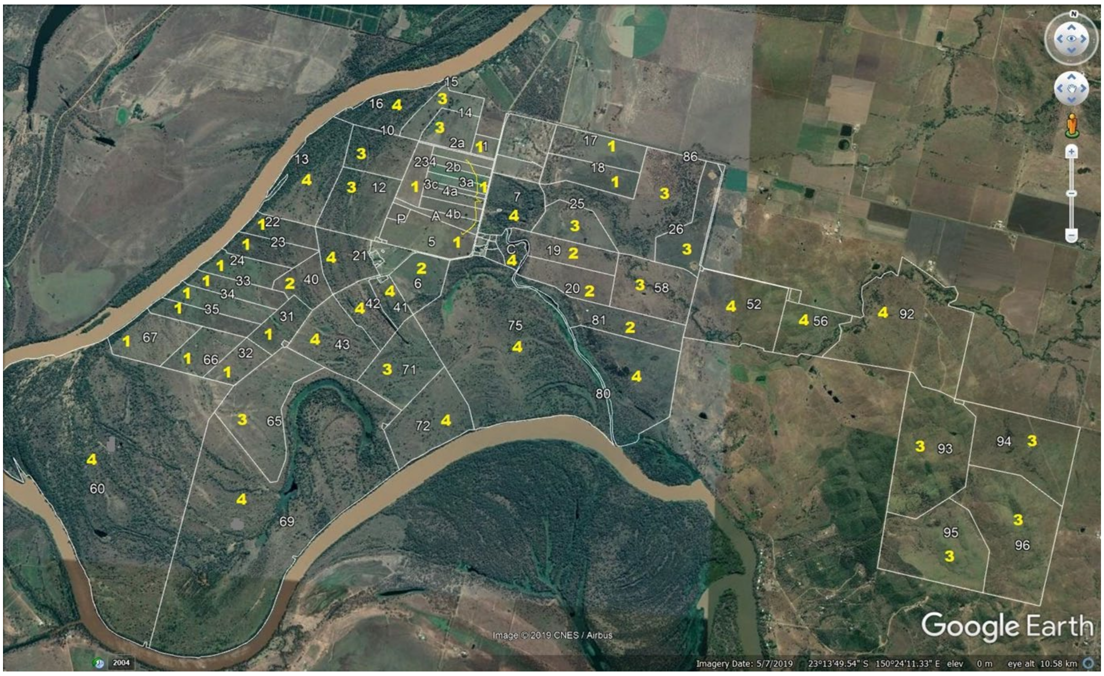

Figure 45. Suitability of Belmont Research Station paddocks for ALMS unit installation, where a rank of 1 indicates highly suitable paddock characteristics while 4 indicates a paddock has highly unsuitable paddock characteristics.

Many parts of Queensland are experiencing drier and hotter than average conditions. Belmont's rainfall from 2018 through to 2019 has totalled 347mm and simulated pasture growth was 669 kg/ha; these values are well below the 10^{th} percentile for the expected averages of 741 mm and 2,693 kg/ha, respectively. These conditions have meant that cattle have been rotated through paddocks quicker than usual, often not allowing enough time to record baseline ALMS data. Because of this, determining calf birth dates for this season may be subject to errors caused by inadequate information required for the algorithms to calculate birth date with the level of accuracy obtained during previous years. Conversely, higher rainfall has been observed to negatively impact utilisation, as the ALMS uses water as an attractant to the system. Standing water throughout the paddock can thus reduce the use of the system. Weather appears to be a significant factor contributing to the success of the system. While weather itself cannot be directly managed, the systems described in this appendix can be used to reduce their impact on the data captured using the ALMS.

In late August 2020, 218 PTIC Tropical Composite cows were weighed and drafted three ways on stage of pregnancy. The early calving group (expected to calve during November) and the mid calving group (expected to calve during December) were then split into six calving paddocks (ranging from 22ha to 25ha) holding between 25 and 35 cows in each paddock. Forage budgets and predicted carrying capacity of the paddocks were conducted. The smaller groups of cows were designed to be kept intact for the length of the calving period and hopefully through to the end of the joining period. Previous management of the calving groups involved rotating larger groups of cows through the calving paddocks and conducting bi-monthly "cleaning out" of cows that had calved to relieve stocking pressure of the main group on the calving paddocks. The new system of having smaller groups in more paddocks allowed for retrieval of intact cow growth paths prior to and after birth events. The late calving group (52 cows expected to calve during January 2021) were monitored with ALMS from December 2020.

13. Appendix D

The below is a proposed reporting format to supply genetic evaluation programs with a visual representation of ALMS submissions.

BREEDPLAN 200-DW Report

2021-11-01

To identify the best recorded weight for submission to BREEDPLAN, the developed algorithms interrogate all possible opportunities within the trait window where weekly weights were recorded for 100% of cattle, then selects the date closes to the appropriate cohort median age. Where no dates are available with 100% coverage, accurate predictions can be utilised to ensure 100% of a cohort have values able to be submitted to BREEDPLAN.

In this cohort, the birth date range was 203, leading to a 200-DW sampling window of 17. The median 200 Day date was 2021-06-05 (Fig. 1).

A total of zero dates were available where the weekly weights were captured for 100% of cattle (Fig. 2). The best candidate for a submission date was 2021-06-26 which had 91% coverage. Estimated means and standard errors were computed for the missing data points.

Cohort variability over the window of opportunity was low liveweights mostly increased throughout the sampling period (Fig. 3). Observed liveweights ranged from 162.5–174 kg.

Submitted liveweight values

Estimates have been included for 9 cattle. This is due to weekly weight values being unavailable for all cattle on at least one day within the specified window of opportunity. Where weights were available (n = 91) they have been reported as a modified mean weekly weight, comprised of available daily weights within a seven day period, standard deviation, and the number of daily weights used (Table 1). Estimates are reported as an estimated marginal mean and standard error (Table 2). Available weekly weights are provided for cattle where estimates were produced to support submitted predictions (Fig. 4).

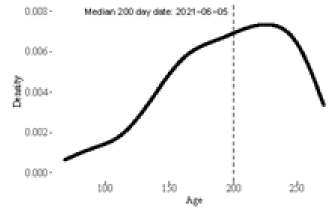

Figure 1: Age distribution at 200 days

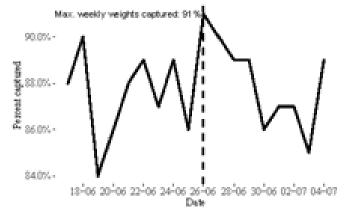

Figure 2: Weekly weights captured in 200-DW period

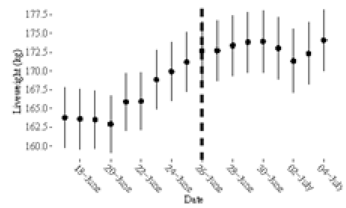

Figure 3: Mean cohort growth over during the specified 200-DW window of opportunity. Dashed line denotes sampling day.

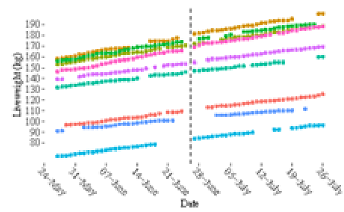

Figure 4: Trends in weekly weights for livestock where submission values were estimated

Table 1) Liveweights of cattle with weekly weight values associated with specified 200-DW date. 'N' denotes the number of daily weights associated with a weekly weight value.

ID	Weight (kg)	SD	N
7	211.55	2.24	7
69	131.02	1.27	4
92	198.34	0.81	4
75	182.39	2.20	5
57	218.33	1.99	5
67	137.43	1.32	7
49	230.09	2.28	6
41	133.06	0.75	8
16	144.60	0.88	5
71	200.99	2.09	6
2	134.96	1.25	4
93	168.91	1.65	5
29	195.35	1.88	5
73	101.33	1.10	5
98	137.42	1.32	5
90	189.19	2.07	6
74	118.32	1.02	6
15	187.31	1.96	7
14	129.46	1.15	4
64	192.80	2.16	4

Table 2) Liveweights of cattle with estimated weekly weights associated with specified 200-DW date

ID	Weight (kg)	SE
4	83.42	2.77
12	180.04	2.74
22	171.82	2.66
26	175.21	2.71
34	147.08	2.73
72	103.60	2.84
87	155.00	2.69
91	168.27	2.63
100	110.80	2.69

14. Appendix E

14.1. Geoff & Alison Maynard

ALMS training pays unexpected dividends for Maynard Cattle Co.

Producers: Geoff and Alison Maynard, Maynard Cattle Co. (MCC), Jambin, Qld, and property manager Phil Orchard, Belmont Station.

Breeding profile: Belmont Station is owned by AgForce Queensland and leased by CQUniversity for research purposes, with cattle provided for use in Research by Maynard Cattle Co. The 3200-hectare property runs an average of 1000 adult equivalents. The breeding herd is comprised of Belmont Red, Tropical Composite and Brahman stud cows, which are performance recorded for inclusion in BREEDPLAN.

Data Objective: Maternal parentage, dates of calving and birth weights are currently manually recorded by calf catching. Weights at 200, 400 and 600 days are captured crush side in the yards at mustering. The objective of MCC's participation in the project is to capture increased data at higher levels of accuracy in a more efficient manner. There is recognition this may take some time to achieve and therefore MCC is supporting the project by providing comparative validation data by continuing the use of traditional, manual data capture techniques.

User experience: For Geoff Maynard the experience with the walk-over-weigh and DataMuster system has been hands off – supportive of the research and the data it could deliver for his business, with implementation undertaken by property manager Phil Orchard.

"We've always been involved in performance recording of animals and the genetics world, and there's difficulties, as everybody knows, in the physical collection of that data. So anything that makes that easier and more accurate is a good thing," Geoff said.

He is excited by the prospect of including the data from ALMS in BREEDPLAN, believing the extra data gathered each day can only improve the genetic evaluation process.

"We are at risk of just one snapshot at the moment. So at 400 days, and if that animal had been sick for three or four days beforehand, it could be 50 kilos lighter. So you have the risk of individual differences," he said.

"Over time, obviously BREEDPLAN with the sire lines and dam lines, that will probably be washed out, but you do still pick individuals to use. And we are at higher risk with 200-, 400-, 600-day weights only taking just one weighing of the animal.

"So I'd be interested to know if BREEDPLAN with X amount of weights every day or whatever can get from walk over weigh will get the averaging more accurate."

For Phil Orchard, the initial expectations of the system were low, but it has since proven itself useful and effective, and he now checks the animal data 3-4 times each week via the DataMuster website.

Phil said the initial training, which took 2-3 weeks, was the hardest part of the process.

"You had to train everything. You do still have some that won't walk over it. If at any time I noticed something wasn't going in, then I'd remove the spears and let them go in or open the panels up so they could go in there and get a drink. And if that happened repeatedly then that cow go removed from the herd," he said.

"That first lot of training was the first generation using it and it took longer. But because the calves then learnt to walk through it as calves, then they don't to have any more training; you can wean cattle and throw them straight in a paddock they'll use it."

When the system was first introduced he estimates 70% would walk over. For the other 30% panels would be left open until they were comfortable going in, before later closing the panels up.

"98% would walk over the scales without spears in there and then adding the spears in they were pretty good," he said. "Everything now walks straight over because they all experienced it as a calf."

Mr Orchard found the equipment generally quite reliable, and any technical issues were dealt with by the CQU research staff.

One unexpected benefit of the ALMS compounds has been in aiding the catching of calves for assignment of maternal parentage or capturing birth weights.

"Cow and calf get in there and you get someone to stand on the other side. You could go in there and catch the calf. And if you had a cranky cow you could let her out and not let her back in while you caught the calf."

Phil found the software easy to use, with changes included by the research team – such as adding a new feature to record any animal deaths – to assist with herd recording.

He said the pricing of DataMuster at $200/month was not expensive when compared to other herd management software systems on the market.

"I think walk-over-weighing is good especially with the auto-draft. I think that has a lot of potential and using the walk over weigh with an auto-drafter, I can see that going a long way and cut down on management and labour costs."

While Geoff Maynard had been interested in walk-over-weighing for some prior to the project, he said he would have been "50:50" as to whether to implement it without the support provided by CQU as part of the research.

"I suppose being an older demographic, you are not familiar with the technology, so that probably would bring about hesitancy. Also, say if it was at our home property, our connectivity has been terrible, really terrible – like we can't get any phone service in half the house. Solving those connectivity issues would probably slip that balance the other way in favour of adoption."

14.2. Swin Hudson

Support brings ALMS success a step closer at Tremere

Producers: Swin & Kathy Hudson, Tremere Pastoral, Moura QLD

Breeding profile: Swin and Kathy Hudson run a family operated beef breeding business providing tropically adapted Bos Taurus genetics. Stud bulls sold at an annual auction and the commercial steers are marketed to the EU trade.

Data Objective: Swin's initial interest in the DataMuster technology was the consistent access to daily weights on his dry stock herd, which would assist him in identifying when he was running out of pasture, and meeting market specs for sale. However, the key factor which made Swin decide to participate in the research project was the possibility of monitoring calving cows. He joined with the goal of lengthening out the period between a cow calving and having to intervene in the mothering process by catching and tagging the calf.

User experience: With exposure to walk-over-weighing technology as far back as the early 2000s through CSIRO research, Swin has patiently waited for the right time to begin using the technology.

He held off from investing in the equipment knowing that support would be a key factor to his successful adoption.

“If something can go wrong, it goes wrong with me. And I think that was probably a good experience for the researchers to experience,” he said.

His expectations entering this project were high, with the main focus on being able to tell the exact day a calf was born, along with an approximate birth weight based on the loss of weight of the cow. And although he knew support would be a factor in successful implementation, he also hoped that the technology would be set and forget.

“I must admit that I kind of expected there to be less troubleshooting because the researchers had been using it out at Belmont. So I must admit that that sort of surprised me a little bit,” Swin said. “But we learned together and I ended up with something that worked and the researchers ended up with information that they can take on and make work elsewhere.”

Unexpected challenges and obstacles that Swin encountered included connectivity and transmission interference, coping with larger cattle numbers using the scales, and the mob utilising multiple watering points.

Swin said the most stressful part of the project was training the herd to use the DataMuster system, with his biggest fear that of cattle perishing due to lack of water.

This increased his labour by checking the system daily for the first 3-4 weeks, mustering and pushing cattle over the scales to ensure every cow was getting access to water.

“The cows would try and break it down, they'd try and circumvent it, they’d tried to avoid using it, and some still do,” he said. “And that's been a challenge with it. You can't you can't make the system work with flimsy fencing, it has to be substantial fencing.

“To a large extent, the older cows are more difficult to get to do new things. Then young stock are more curious. But now, they're used to it and you introduce it and turn it back on again.”

While finding the training on how to use the DataMuster website clear and easy to understand, Swin admitted to not exploring the website to its full potential, as he uses another software program for animal records and did not want to duplicate the work.

He believes the cost of the hardware and installation is reasonable, as is the $200 month software access fee.

“I mean, there's got to be some sort of service fee and that’s $12 a head per year for the amount of animals that I'm using on it.”

Swin said if his focus was more on weight gain to meet market specs for sale he would have used the walk over weigh unit more frequently.

And while it still lacks some of the information is seeking chasing on his cow and calf units, he said the progress had been significant.

“I do see that we're getting to the day of calving and getting that narrowed right down quite quickly and quite well,” he said.

Swin feels like he is still on the journey but is definitely getting closer to achieving his original objectives and has grown more confidence in the system to record correct automated data to be sent directly through to BREEDPLAN.

A fundamental point Swin made throughout his interview was the proactiveness in the support provided by CQU, describing it as crucial for the success and continuance of the project out at Tremere.

14.3. Carl Anderson

Unrealised potential at Carisma

Producers: Carl and Monica Anderson, 'Carisma', Banana, Qld

Breeding profile: Carl and Monica Anderson run a family operated business running 700-900 head of commercial growing stock, targeting both organic and non-organic markets.

Data Objective: Carl's interest in the DataMuster technology to identity earlier the cattle in his organic beef fattening operation that were ready to sell at a specific weight. He hoped this would make life easier by reducing the labour required to collect data that could aid in management decisions and having access to information to identify problems arising within his herd.

User experience: Carl's initial expectations for the ALMS were low, knowing it was a research project that was still developing the technology.

However, he wanted to see the technology grow and evolve based on any problems that occurred on his property.

His hope was that through the project his business would benefit from be able to leave his cattle in the paddock with little interference while still being able to monitor their weights and readiness for sale.

"I was trying to use the system in the same way as I manage the herd now, so trapping cattle on water for mastering and things like that," Carl said. "So utilising it in that sense, it was more of a way to not actually have to change too much in the whole running of everything."

After initially installing the walk-over-weigh hardware, including a paddock-based auto-drafter, and training animals, the data provided through the DataMuster software exceeded Carl's expectations.

"The way it was able to draft cattle via the parameters we put in – that was when it was going to start being very useful to myself," he said.

The herd took to the system quite well, only taking a couple of days to adjust to it as they were already used to walking through trap gates.

"There were a few that would stand off, but they would end up joining with a group that went over. There was only one that I know of that didn't like it, but he was taken out of the herd only because he was crook as well," Carl said.

However, some unexpected obstacles have prevented the Andersons from capturing the equipment's full potential for their business.

"With a paddock change, an infrastructure wasn't in that paddock, we lost out on it. We had a problem where cattle did take off with one of the systems and destroyed a few things.

"It was quite easy to get the help to fix that system and get it back up and running or but we ended up changing it right out because there were other things the research team wanted to check on."

Installing the infrastructure to support the weighing hardware and locating it in way to maximise use in the new paddock with multiple water sources were major obstacles. With water easy to come by the research team considered other attractants, but with lick not on the menu at Carisma this challenge was not overcome

Connectivity was another issue due to problems with the mobile tower at Banana. No data was lost from the DataMuster system when the tower connection was down, and all animal data was uploaded as soon as it was reconnected, which Carl found to be a big positive with the technology.

Carl found the software training satisfactory and was interested to see range the capabilities it has. He found the website easy to navigate through to get an overall view of the herd and also to pull out more detailed and targeted reports.

Using the system weekly at the least to check target weight ranges and as he got closer to an upcoming sale he would look multiple times over the week.

Alerts were helpful and the timing convenient arriving overnight for Carl to view first thing in the morning and then check on animals if needed.

Overall, while not quite achieving the original objectives set out in the beginning, Carl is keen to see where the project can go in future.

Carl saw value for money in the DataMuster system and although he may yet purchase a commercially available unit, he would prefer to work with the university based on the support he receives, the hardware already purchased and being able to learn with people who have similar interests.