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Prepared by: Alastair Henderson[1], Nigel Perkins[2] and Steve Banney[3].

1. Mirroong Pty Ltd,
2. AusVet Animal Health Services Pty. Ltd,
3. Steve Banney Agribusiness.

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Determining property-level rates of breeder cow mortality in northern Australia

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Abstract

Breeder cow mortality rates in extensive north Australian cattle herds at the property and regional levels are not accurately known. By working with 36 properties across nine regions of northern Australia, sufficient herd records (mainly from data for the period 2006-2011) were collected to allow estimates to be made of total female, breeder and male death rates. When a static herd model was found to be inappropriate for this task, a rigorous livestock inventory approach was developed such that deaths and death rates could be calculated over several years. Average regional death rate in the total female component of a herd ranged from 2.7% to 11.8%, while average breeder cow mortality rate ranged from 3.0% to 17.8%. Using univariable and multivariable analysis, factors with significant associations with mortality rate included the age of females at last joining, the age of females at last weaning, the age at which cows were culled, wet season phosphorus supplementation, dry season segregation of breeders, and continuous versus controlled mating. A mortality calculator tool has been developed which will enable producers to use their own property records to determine levels of breeder mortality in their herds and the associated financial losses. A reliable standard of herd record keeping is necessary to effectively utilise the mortality calculator tool.

Executive summary

Currently, there is no reliable information about on-property levels of breeder cow mortality in extensive areas of northern Australia. This is a consequence of incomplete or inaccurate property herd records and the extensive nature of the properties, which makes a count of all deaths impossible. These deaths represent a loss in income and, above certain levels, these losses may be reduced by implementing proven strategies.

The aim of this project was to determine breeder cow death rates on properties in northern Australia on a regional basis, speculate on causal factors, and develop a method of determining death rates over time at a property and regional level. The project team worked with 45 properties over nine regions and was able to extract useful information from 36 of these properties to produce data that covered periods varying from three to nine years. The regions included in the analysis were:

1. Queensland southern Gulf
2. Queensland northern Gulf
3. Northern Territory Barkly Tableland
4. NT Gulf/Katherine/Sturt Plateau
5. NT Alice Springs
6. NT Victoria River district
7. Kimberley East
8. Kimberley West
9. Pilbara.

From a list of all properties in each region, properties were randomly selected and, if they met certain selection criteria such as herd size, these properties were contacted to confirm they met all the selection criteria and were willing to cooperate. The data were mostly collected during property visits, using a pre-determined template of questions which would allow the data and management practices described to be analysed to determine associations between management practices, rainfall, climatic events and rates of female and male mortality. During property visits, the team members were able to interrogate management on the validity of the data, seasonal conditions, land types and property management practices.

Initially, the BCOWPLUS herd model was used with retrospective herd records to calculate breeder mortality rates. BCOWPLUS works on the principles of a static, self-replacing herd and as the majority of extensive northern herds are not steady state, i.e. significant numbers of both female and male cattle move in and out of the herd over time, an alternative method was developed.

The alternative method was to populate a livestock inventory schedule over a number of consecutive years. The required herd records are simple and generally available from most properties. To validate this alternative method, desk-top studies of herd data supplied by two large pastoral companies involving six northern breeding properties were used. Agreement was obtained from the companies that the methodology produced a fair representation of their herds. From the livestock inventory approach, a livestock mortality calculator was developed for use by industry.

Following a random process for the selection of properties, each property was contacted to request their co-operation and to ensure they met several selection criteria including running at least 1,000 breeders, a willingness to cooperate, managing a self-replacing herd and holding adequate herd records. To ensure full co-operation, the project team made a commitment to keep the identity of each property and its records confidential. As a result, the information and analysis contained in this report is consolidated and regional in nature. All property visits took place during 2011 and while records were generally collected for the years 2006 to 2011, for some properties the years 2009 to 2011 met data requirements.

The data were collated and analysed using univariable (a single explanatory factor) and multivariable (many explanatory factors) screening to arrive at mortality rate estimates for total females, breeders and males. Variables including rainfall and management practices commonly employed on northern cattle properties were analysed for associations with mortality. This allowed the identification of likely causal factors. The unreliability of some of the property herd data was a constraint during the assembling and analysis of the data.

Given the variable accuracy of available records, the most suitable indicator of breeder cow mortality was the total female death rate. The total female death rate includes non-breeding and breeding females and is a rational proxy for the breeder death rate. In most cases, the breeder death rate will be slightly higher than the total female death rate due to the stress associated with pregnancy, calving and lactation. The total female death rate, using univariable screening, ranged from 2.7% in the Queensland southern Gulf (QLD SthGulf) to 11.8% in the Alice Springs region over the years of interest. By assuming the mortality rate in non-breeding females is 3%, the breeder death rates were calculated to range from 3.0% in the QLD SthGulf to 17.8% in the QLD NthGulf for the same period. If the non-breeder death rate is higher than the assumed 3%, then the breeder mortality rate will be proportionately lower.

The overall steer mortality rate was 8.8% per year (region specific estimates ranged from a low of 4.2% to a high of 24.9%).

The median[1] total female mortality rate for all the regions was 3.8%, while the median breeder mortality rate was 5.7% and the median steer mortality rate was 5.9%.

The strongest statistical associations with female mortality rate were with the following variables:

1. The age of females at last joining, at last weaning and age at culling,
2. Wet season phosphorous supplementation,
3. Wet season phosphorous supplementation of aged females,
4. Dry season segregation of breeders, and
5. Continuous vs. controlled mating.

The contribution or otherwise of other variables such as Botulism vaccination, dry season nitrogen supplementation, male turnoff age and extreme events like drought, flood and fire are discussed.

[1] The median is the middle value in a sample sorted into ascending order.

If the northern industry as a whole is to recognize the actual death rates that are occurring annually, much more accurate property records are required. Basic herd records can allow mortality rates to be determined when used with the mortality calculator tool. These same records will also allow management to benchmark other herd performance indicators.

The following recommendations are made in this report:

1. *Make available the mortality calculator tools to the beef industry along with material on how to use them and interpret the findings.*
2. *Consider incorporating the findings from this research into existing extension material concerning best practice for beef cattle properties in northern Australia.*
3. *Consider further prospective research to apply the mortality tool to beef properties and allow further validation and refinement using data collected specifically to ensure that all of the tool's capabilities are utilised.*
4. *Further investigate causes of mortality in regions with the highest rates.*
5. *Consider additional research to specifically understand the management practices that may be contributing to statistical associations between variables in this study and mortality outcomes, such as segregation of breeders in the dry season, P-supplementation, age of cows at last joining/weaning/culling.*
6. *Further investigate the indicative male mortality rates, explore explanations for any elevated mortality in steers, and identify strategies that may be applied to reduce steer mortality.*

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1 Background

Breeder mortality and reproduction rates directly influence herd productivity and enterprise profit. Past R&D and producer experience have demonstrated that annual breeder mortality rates in extensive pastoral regions can often exceed 10% (O'Rourke *et al.* 1995, Dixon *et al.* 1998). However these levels can be reduced to below 5% with strategies such as early weaning, botulism vaccination, wet season phosphorus (P), dry season urea (NPN) and conservative stocking rates (Holroyd *et al.* 1990, McCosker *et al.* 1991, Petty *et al.* 1994, O'Rourke *et al.* 1995, Sullivan *et al.* 1992.).

Despite the potential of improved cattle management, there is evidence which suggests breeder mortality rates in the Northern Territory (NT), Kimberley and Pilbara regions of Western Australia (WA) and possibly the north-west and north of Queensland (Qld) could be much higher than recent estimates by producers. For example, recent analysis of property benchmarking data suggests that breeder death rates are a major factor limiting profitability for many properties in the Alice Springs, Katherine and Pilbara regions (McCosker, McLean and Holmes (2010), MLA report B.NBP.0518). In the Northern Territory an assessment of regional turn-off data between 2002 and 2008 (Niethe 2010) suggested mortality rates could be 8-9%. However, beef producers estimate average breeder and heifer mortality rates at 3% (2006 NT Pastoral Survey).

In the Pilbara and Kimberley, Niethe & Quirk (2008) estimated regional breeder cow mortality was greater than 10%, however losses reported to the Pastoral Lands Board in West Australia average 3.6% for the period from 1985 to 2007. Property-level mortality rates are particularly difficult, if not impossible to measure directly, which may partially explain the disparity between general industry estimates and emerging regional evidence. In large extensive properties where 100% musters are seldom accomplished and where paddock security is expensive to maintain, it is difficult to establish if animals haven't been mustered, have escaped or have indeed died in the paddock. Aerial surveys and counting of unmustered stock (as was routinely performed in the TB eradication era) is usually only practised when a property is offered for sale. This is an expensive exercise that adds little to the bottom line of a property's profitability. A typical scenario is that management starts with an opening stock number, adds in calves branded and stock purchased and deducts sales and rations and a rather conservative estimate of losses to derive a closing number of stock. If the number counted at the final muster of the year does not match the closing book numbers, it is usually assumed that the muster was not as good as expected or that stock have wandered onto the neighbouring property. While bang tail musters are commonly practised, there are very few properties which follow up with a random survey of long tails in the herd 4-6 weeks after the initial muster to establish accurate estimates of the stock present on a property. Visible stock losses that occur at watering points and along property tracks usually only represent a small portion of the calculated deaths and, where surface waters are plentiful, most stock losses can go undetected.

Because of difficulties in identifying and counting dead animals on extensive beef properties, a number of alternative methods have been used in the past as indirect measures of herd and breeder mortalities. These indirect measures typically use data that most properties are routinely recording such as branding or weaning rates and counts of animals turned off. For example, an increase in breeder mortalities is expected to be associated with a decline in the proportion of female turn-off (e.g. <40%), an increase in proportion of heifers retained as replacement breeders (e.g. >50%) and a decrease in the proportion of total turn-off to calves weaned (<80%).

Preliminary investigations during the pilot phase of this project explored the use of several approaches to estimation of mortalities and the approach selected was to use a simple, robust, indirect method of retrospectively estimating breeder mortality over a period of at least 3 years using property-level herd and turnoff data combined with simple inventory analysis. Data were collected from a random sample of at least five properties identified from each of 3 regions in the NT, Kimberley and Pilbara regions of WA, and southern and northern Gulf regions of Qld.

This project required direct collaboration with participating beef producers and individual property visits. Confidentiality of property data was maintained at all times. The study design required the collection of annual property-level male and female herd turnoff, total cattle numbers and weaning rate data over a period of at least 3 years.

2 Project objectives

1. Develop and test an indirect method and measures for estimating breeder mortality and possible contributing causes, retrospectively over a period of 3-5 years using readily available property herd and turn-off data combined with simple herd modelling.

2. Collect and analyse data necessary to quantify and document property level breeder cow mortality rates retrospectively over a period of at least 3 years from at least 5 properties in each of the following pastoral regions: Pilbara, Kimberley, Katherine, Barkly Tablelands, Alice Springs and the Gulf region of Queensland.

3. Collect property-level data on management practices and meteorological data over the same period which may explain some of the variation detected.

4. Report on breeder cow mortality in each of the six regions, speculate on causal influences, provide recommendations for future research, development or extension activities to cost-efficiently reduce mortality rates and make recommendations for improvements to data collection and monitoring systems so that property and industry level performance can be more systematically monitored and evaluated.

3 Methodology

The project team considered a number of approaches for analysing retrospective property data relating to cattle numbers and a decision was made to use a simple livestock scheduling approach based on estimates of opening and closing numbers and estimates of sales and purchases for cattle in each of several major livestock classes.

A number of alternative approaches were considered and not progressed and these are described briefly at the end of this section.

3.1 Livestock schedule approach

The livestock scheduling approach was developed by the project team with assistance from Mr Fred Chudleigh (agricultural economist from Queensland Department of Agriculture, Fisheries and Forestry).

3.1.1 Background

The approach is based on opening and closing numbers in each of multiple classes (calves, weaners, heifers, steers, cows, bulls) and sales and purchases. Animals can then be transferred internally (weaners moving to unjoined heifers or steers, heifers moving to cows and so on). Balancing numbers in this way can allow estimates of mortality by class. This approach requires accurate estimates of numbers in each of several classes in order to be able to track internal transfers as animals age. If estimates can be generated using this approach then it can be possible to directly estimate mortalities as the discrepancy between opening and closing numbers after adjusting for sales and purchases. The benefits of this approach are that it is intuitively understandable and is relatively easily set up using modifications of existing schedule approaches or setting up in a spread sheet.

A simplistic flow diagram is provided below to illustrate the concept, based on an understanding of a northern beef property that may conduct two rounds of musters per year.

The diagram outlines an approach for all female animals but can be easily adapted to breeders or steers. Most properties will start the year with an opening count of females (including branded heifers from previous year, and all older females on the property from the previous year). During the year there will be various animal movements both off the property (sales) and onto the property (purchases) and movements of animals into the recorded female herd (heifers branded during the year). The mustering rounds will also provide an estimate of all females on the property during the year (assuming all animals are mustered during the year).

The diagram shows two separate interim closing counts. One is outlined under the heading of **book entries** and is the opening count adjusted by actual estimates of animal movements (sales, purchases and branded heifers). The closing count (book) does not incorporate any adjustment for deaths and therefore is an over-estimate of the actual number of animals on the property at the end of the year.

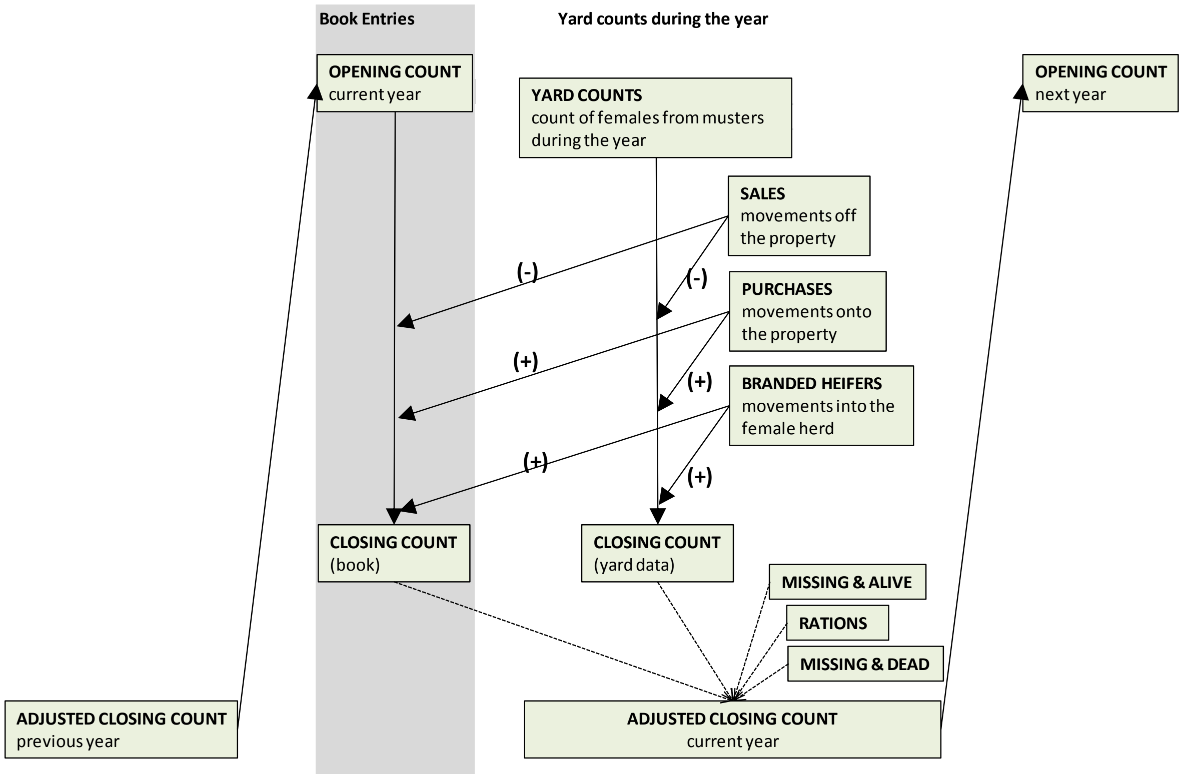

Figure 1: Flow chart of livestock scheduling approach for female cattle

The second interim closing count is derived from **yard counts** during the year and incorporates the exact same adjustments for animal movements (sales, purchases and branded heifers). The closing count derived from yard data is always expected to be lower than the closing count derived from book entries because of missing animals (missing & alive, and missing & dead) that cannot be counted in the yard counts because they were not yarded. The closing count (yard data) can be considered to be an under-estimate of the actual number of females on the property with the level of under-estimation directly dependent on the number of missing and alive (which is related to mustering efficiency). There may also be a number of animals killed for rations through the year that should be separately recorded so they are not recorded as deaths.

The numeric difference between the two interim closing counts is an estimate of the sum of missing & alive plus missing & dead.

CLOSING COUNT (book) - CLOSING COUNT (yard data) = MISSING & ALIVE + MISSING & DEAD + RATIONS

If mustering efficiency is 100% and there are effectively no animals that are missing and alive, then the difference between the two interim closing counts can be considered to be a direct estimate of the number of dead females.

If mustering efficiency is less than 100% then the difference between the two interim closing counts is an over-estimate of the number of dead females with the level of over-estimation dependent on the mustering efficiency.

It is expected that most properties will then use some form of adjustment based on estimation of the number of animals that may be missing and alive or on estimation of the number missing and dead, or both. In some cases these adjustments take place through the year as data are collected on each mustering round and in others the adjustments may take place at the end of the year. The result is an adjusted closing count which is intended to reflect as closely as possible the number of live females on the property at the end of the year.

The difference between the opening count and the adjusted closing count is then a direct estimate of the number of deaths through the year.

This approach is the basis of the livestock scheduling approach derived for this project.

3.1.2 Development of excel template

Many property owners and managers do not have accurate information on numbers of animals in different stock classes on an annual basis. A modified scheduling approach was developed to allow estimation of mortality in several classes of cattle on an annual basis and over multiple years for each property. Table 1 illustrates example data and calculations for one property over a five year period.

The following descriptions provide a definition of each variable in Table 1. The shaded cells present data collected directly from properties during the data collection phase of the project. Other cells are derived using spread sheet formulae.

- **Opening female:** Estimate of the closing number of females on the property from the end of the previous year – serves as the opening number for the next year. Represents all females that have been branded prior to opening estimates (includes weaners, unjoined heifers, joined heifers and cows).
    - does not include the **Branded** figure since these are animals that are branded through the course of the current year.
- **Opening breeder**: all animals that were mated in the current year
    - Includes the **Opening 2-3 yr. heifers** (data not shown)
- **Branded:** all animals that were branded in the current year.
    - Includes animals that were branded and weaned and animals that are branded and left on the cows
    - Assume that 50% of branded animals are heifers and 50% are steers
    - Warning - The branding % in this model is calves branded from opening females. This is different from an estimate of branding % that may be calculated as calves branded from females joined the previous season.

Table 1: Example data and calculations for one property and covering a five-year period

Mortality Calculator	Year 1	Year 2	Year 3	Year 4	Year 5	ALL
Opening female	25505	29311	32799	22836	22425	132959
Opening breeder	18293	16331	17896	18860	18920	90300
Branded	11527	10183	9194	9238	12375	52517
Est'd branded heifers	5764	5092	4597	4619	6188	26259
At-risk non-breeding females	10094	15526	17202	6286	6599	55788
At-risk_females (open_fem+0.5*brd_heif+0.5*purchase)	28387	31857	35098	25146	25519	146088
Proportion branded=male	0.5	0.5	0.5	0.5	0.5	0.5
Female sales	1698	1248	8173	5020	3526	19665
Female purchases	0	0	0	0	0	0
Closing females (adjusted count)	29311	32799	22836	22425	23624	130995
Closing females (book count)	29571	33155	29223	22435	25087	139553
Estimated deaths in all females (difference)	260	356	6387	10	1463	8558
Female deaths as % of At-risk females	**0.91%**	**1.12%**	**18.20%**	**0.04%**	**5.73%**	**5.86%**
Assumed death rate in non-breeding females						**0.03**
Estimated deaths in non-breeding females						1674
Estimated deaths in breeding females						6884
Estimated % deaths in breeders						**7.6%**
Opening males	6686	11101	16339	2135	1850	38111
Sales of males	864	2520	17272	3250	5664	29570
Purchase of males	0	2666	0	0	0	2666
Closing males (adjusted count)	11101	15850	2135	1850	1962	32898
Est'd branded males	5764	5092	4597	4619	6188	26259
Closing males (book count)	11586	16339	3664	2167	2374	37466

Estimated male deaths	485	489	1529	317	412	4568
At-risk_males (open_males+0.5*brd_steers+0.5*purchase)	9568	14980	18638	4445	4944	52573
Est'd % steer deaths using At-risk males	5.1%	3.3%	8.2%	7.1%	8.3%	8.7%

- **Est'd branded heifers:** Calculated as an integer equal to 50% of the **Branded**
- **At-risk non-breeding females:** Calculated as
    - Opening females – Opening breeders + 0.5*(Est'd branded heifers)
- **At-risk females:**
    - Opening female + **(**0.5*Est'd branded heifers) + (0.5*Female purchases)
    - Provides an epidemiological estimate of females at risk of mortality on the property that can serve as a denominator to calculate % mortality.
    - Young animals are only counted as part of the denominator once they are branded (mortalities are only counted in branded females). Young animals are branded during the year – they are not all eligible for death from the start of the year. Since we do not have accurate measures of when calves were branded, the most unbiased way to measure the contribution to time at risk is to assume that they became eligible half way through the year.
    - Purchases can come on to the property at any time of the year. Since we don't know when they arrived, the most unbiased estimate is to assume they came at half way through the year. This means that we can add half the purchases to the denominator to represent the increased animals at risk of dying during the year.
    - After some deliberation and interim modelling, a decision was made to not adjust the denominator for sales. During the interim modelling process, adjustment had also incorporated adjusting the denominator by subtracting 0.5*sales. When this is done, it adjusts the total females at risk downward (makes the denominator smaller) and this generally results in an increase in estimates of % mortality. Since it was less common for large numbers of females to be sold, these adjustments were generally relatively small compared to the total number of breeding females. However, on the male side, since it was common for relatively large numbers of male animals to be sold, adjustment for sales often appeared to reduce the denominator by a large amount and resulted in estimates of mortality that were unrealistic (20% to 30% or higher). After some consideration, a decision was made to eliminate all adjustment for sales and to estimate the total females at risk as shown above. The final formula produces a denominator that is considered to be an estimate of the opening number at risk and is considered appropriate for cumulative mortality estimates.

- **Proportion branded=male**: Assumed to be 0.5. The formula used returns an integer. This means that the number of females and number of males may not be exactly equal depending on whether the Branded can be divided by 2 into two whole numbers or not.

- **Female sales:** this figure includes any female (any female that is branded or older) that was sold that year. There is no way of determining accurately the number of animals in any component class that were sold from these data (weaners, branded calves, heifers or cows), or of knowing whether any older females that were sold were bred, pregnant/empty or had calves at foot or not.

- **Females purchased**: Similarly this is simply an overall estimate of anything that was branded and female and that was purchased in the current year. There is no accurate way of determining whether these arrivals were calves, weaners, heifers or cows or whether they were mated/pregnant or had calves at foot.

    - the impact of these constraints is that while we can track and reconcile total numbers of females (any animal that is branded and female), we really cannot accurately track component class numbers.

- **Closing females (adjusted count)**: This is the estimate of closing females provided by the owner/manager. Also serves as the opening number of females for the following year. It is assumed that this estimate has been adjusted to reflect missing and alive, and missing and dead animals.

- **Closing females from book entries**: calculated as follows

    - opening females + Est'd branded heifers – sales + purchases

- **Estimated deaths in all females**: Calculated as the difference between the above two estimates of closing females.

    - Is actually an estimate of difference.

    - Depending on the quality of property records this difference may include some animals that could be missing & alive and rations as well as animal deaths.

- **Total deaths as % of all females**: Deaths (above) divided by Total females at start and expressed as a %.

    - not adjusted for sales and purchases so is a biased estimate

- **Deaths as a % of at-risk females**: Deaths (above) divided by at-risk females & expressed as a %.

    - Is adjusted for purchases and incoming females (branded heifers) so is an unbiased estimate

- **Assumed death rate in non-breeding females:** It may be reasonable to assume that non-breeding females (branded calves, weaners and unjoined heifers) have a lower death rate than breeding females. This estimate can be directly entered as a proportion (0.05, 0.03) and the number can be changed as a way of trying different scenarios.

- **Estimated deaths in non-breeding females:** Using the above proportion, can directly estimate the expected number of deaths in non-breeding females by multiplying the proportion by the total number of non-breeding females.
- **Estimated deaths in breeding females:** Since we have an estimate of the total number of female deaths and we can estimate the expected number of non-breeder deaths for an assumed death rate in non-breeders, we can then calculate the number of deaths in breeders as
    - Estimated deaths in all females – Estimated deaths in non-breeding females
- **Estimated % deaths in breeding females:**
    - Estimated deaths in breeding females divided by opening breeders
    - This is not adjusted for sales and purchases. Adjustment can be done but requires an assumption about the proportion of sales and purchases that represent breeders vs. non-breeders.
- **Opening steers**: Count obtained from owner/manager
- **Est'd branded steers**: 50% of Branded expressed as an integer
- **Sales of steers**: all steers sold (may be any age but are assumed to have been branded)
- **Purchase of steers**: Count of purchases
- **Closing steers (adjusted count)**: estimate from owner/manager
- **Closing steers (book entries):** calculated field
    - opening steers + Est'd branded steers – sales + purchases
- **Estimated steer deaths**: the calculated difference between the two closing counts (book entries minus adjusted count)
- **Estimated % steer deaths:** Uses a denominator based on opening steers + est'd branded steers
- **At-risk steers:**
    - Opening male + **(**0.5*Est'd branded steers) + (0.5*Male purchases)
    - Provides an epidemiological estimate of males at risk of mortality on the property that can serve as a denominator to calculate % mortality.
    - See At-risk females section above for more detailed discussion
- **Est'd deaths using at-risk:** Uses the at-risk males as the denominator.

3.2 Other approaches

3.2.1 BCOWPLUS and DYNAMA

BCOWPLUS and DYNAMA are examples of steady state and dynamic herd modelling programs used for herd budgeting for extensive beef production systems.

The project team initially worked on defining inputs to populate the steady state BCOWPLUS model. The project team had prior experience in using BCOWPLUS and underwent additional training by Bill Holmes. Preliminary findings from discussions with participating properties indicated that there were very few properties that could be considered to be in a steady state and it appeared more common for cattle numbers to vary widely from year to year as a result of decisions concerning sales, purchases and animal transfers in general.

The DYNAMA program offered a more complicated modelling approach that allowed incorporation of year-to-year changes in stock numbers but required additional assumptions about various input parameters.

Both BCOWPLUS and DYNAMA required an iterative set-up process where assumptions about input parameters were changed until the model output appeared to be reflecting what property managers expected.

A decision was made to use the simpler livestock scheduling approach that allowed a very simple and clear set of assumptions and calculations to underpin the mortality estimates.

3.2.2 Alternative measures of mortality

The proportion of female sales as a percentage of total sales is sometimes used as an indirect measure of female mortality and is reported as an output in BCOWPLUS. Other, indirect, candidate measures include the total turnoff expressed as a proportion or ratio to the number of animals weaned.

These measures were considered likely to be most useful as indicators of female mortality when the herd was self-replacing and stable. Where there were large movements of females and males into and out of the herd, the ratio of female sales to total sales, and the ratio of cattle turnoff to calves weaned were not considered to be a reliable indicator of female death rates.

As a result of these issues, the project team decided to not use percentage female sales and turnoff as a proportion of numbers weaned as indicators of female mortality.

3.2.3 Northern Territory (N.T.) waybill data

Preliminary discussions with stakeholders raised the possibility of using waybill records in an attempt to determine the proportion of female sales to total sales. Initial discussions suggested that waybill records from cattle originating on properties in the N.T might be available in electronic form from a central database. However, subsequent discussions indicated that waybill data were not routinely entered into a central database, meaning that the completeness of any record set might be difficult to assess. Additional issues were identified related to accessibility of records and these issues coupled with the lack of confidence in percentage female sales for properties that were not in a steady state, resulted in the project team deciding not to pursue an attempt to source waybill records as part of this project.

3.3 Pilot studies - modelling and validation of methodology.

One of the first steps in the conduct of the pilot study was to spend a training day with Bill Holmes of DAFF Qld on the use of BCOWPLUS and how the modelling could be used effectively within the context of this project. Further to this another session was held with Fred Chudleigh (DAFF Qld) on various working aspects of BCOWPLUS.

The next step was to contact two large pastoral companies with extensive land holdings and breeding operations in northern Australia, seeking their cooperation in using some of their property data in the pilot study. Both companies agreed to supply breeding property herd data on a confidential basis.

Company 1 supplied nine consecutive years of data for three of its Barkly Tableland and southern Queensland Gulf properties. Company 2 supplied five years of data for one each of their Victoria River District, Barkly Tableland and southern Queensland Gulf properties.

Company records were initially used to develop BCOWPLUS models which were further refined in consultation with company representatives until the models were producing outputs that were felt to be a fair representation of each property as a static herd.

Preliminary experiences with BCOWPLUS led the project team to move towards the livestock schedule approach and company records were then used in developing the livestock schedule template, again in discussion with company representatives to ensure that outputs were reflecting property performance.

The pilot study process allowed the project team to become familiar with BCOWPLUS and reinforced the decision to avoid using BCOWPLUS as the primary modelling tool for the full dataset. The pilot process also allowed the project team to better understand data requirements and opportunities for gathering supporting information in the main part of the data collection process. There were refinements made in the design of the template and survey questionnaire used in collecting data and information as a result of feedback gathered during the pilot stage.

3.4 Collection of data from study properties

A data collection template was developed which included the relevant herd data to be collected and a check list of questions addressing all aspects of property management and seasonal conditions relating to the years of investigation. See Appendix 8.1.

Details of the property selection methodology are contained in Appendix 8.2. The selection process included compiling of property names for each region, production of sampling frames comprising all eligible properties from regions within Queensland, Northern Territory and Western Australia, and finally a modified random selection process with a target of 36 properties from the defined regions.

The first step in collection of property data involved telephone calls to randomly selected properties, explaining the purpose of the project, discussing the criteria for eligibility, seeking agreement to be involved and negotiating a tentative date for a property visit.

These arrangements were confirmed in a letter which included the selection criteria, a list of the data to be collected, and a copy of an article describing the project taken from MLA's Feedback magazine.

In order to ensure development of a consistent approach to the property visits, the team members responsible for data collection visited the southern Alice Springs co-operators together. Following this, the two team members completed the remainder of the property visits individually with one team member completing visits in northern Alice Springs, Kimberley and Pilbara, while the other team member visited properties in the northern and southern Queensland Gulf, the Barkly Tableland, Katherine/Sturt Plateau/Gulf and the Victoria River district.

The property visits took several hours during which the required herd data was collected; numbers which appeared inconsistent with related numbers were challenged; property cattle returns, waybills, and sales and purchases documents checked and records validated; rainfall records collected; and management practices and seasonal conditions for each year discussed and noted. This same procedure was repeated on all property visits

3.5 Statistical analyses and terminology

Information on cattle numbers over several years was collected from properties and recorded as counts of animals by class. A variety of additional information was collected from property managers about management procedures (such as age of cows at last weaning, nutritional supplementation, botulism vaccination and others). Rainfall records were also sourced from properties directly or from the internet for the years covering the same period as the cattle records.

It is important to note that while the project collected multiple years of data from each property, these records were used to generate an overall estimate of property performance based on the aggregation of data across all years for each property. This was felt to be important because in any one year some cattle might be missed in one or more musters thus the aggregated performance over several years was felt to be a more valid measure of property performance. It is acknowledged that this approach also meant that individual years, when mortality counts were low or high, were likely to be averaged out to some extent when the data were aggregated over several years. The project therefore provides a better indication of longer term performance rather than a measure of extremes in any one year.

In the dataset, the main outcome of interest was annual mortality rate (expressed as the count of deaths – numerator – and the count of animals at risk of dying – denominator). Mortality rates were presented as deaths per 100 animal years. These estimates can be represented as percentage deaths per year for general usage.

The first step in the analytical process was to complete simple descriptive analyses of collected data to produce summary measures of performance (average counts of cattle, annual rainfall, mortalities) expressed at either property or region levels. These figures provide a description of the range in performance measures in each region.

The next approach was called univariable screening or modelling. Univariable modelling means a single outcome (mortality rate) and a single explanatory factor. It provides a simple and unadjusted (or crude) measure of association between explanatory factors and the outcome of interest.

A simplistic way of interpreting the p-value is to assume that if the p-value for a test of association is >0.05, then the measured effect could have occurred due to chance alone and is unlikely to be really meaningful. In contrast, if the p-value is <0.05, then the association is unlikely to have occurred by chance alone and there is likely to be a relationship between the explanatory factor and the outcome of interest.

Multivariable modelling was also performed and this refers to a statistical model with the same outcome (mortality rate) but where many explanatory variables were considered at the same time. Multivariable models were conducted using negative binomial regression. Negative binomial regression is a method commonly used to analyse count data (such as deaths or other events) particularly where some measure of exposure or animal-time-at-risk can be provided as well as counts of deaths. Negative binomial regression is particularly useful for count data where over-dispersion might be an issue and preliminary analyses of the data in the current project indicated that there was evidence of over- dispersion. Results of negative binomial regression are presented as incidence rates (deaths per 100 animal years) in this report. A robust standard error term was also used in statistical models to account for unmeasured clustering at the regional level.

Candidate explanatory variables were those variables that were significant on univariable screening and that were deemed to be not highly correlated with each other. A model building process was applied where all candidate variables were added initially and non-significant variables removed one at a time until the final model contained only significant explanatory factors. In some cases, biologically plausible two-way interactions were then considered and retained in the model only if statistically significant. An example was the interaction between phosphorus supplementation and cow age, where it appeared that the beneficial effects of P-supplementation on reducing mortality may be larger in older animals. Multivariable statistical models provide the most powerful approach to testing associations between explanatory factors and outcomes of interest. Some explanatory factors may be significant on univariable screening and then not be significant on multivariable modelling. This is often the case when there are more complex causal patterns and the underlying association may be due to some other explanatory factors. All analyses were conducted using commercial statistical software (www.stata.com).

4 Results

4.1 Reviewed literature

A literature review relating to property level rates of breeder cow mortality in northern Australia has been completed as a separate report under this project. Numerous publications support the view that breeder mortality may be the single most important factor limiting profitability of cattle enterprises in the more extensive areas of northern Australia. The mortality rates reported range from less than 2% to more than 20%, and in aged cows (13 years old) on Kidman Springs Research Station in the Victoria River district of the Northern Territory, during the years 1981 to 1990, the rate was 38%. In contrast, state-wide surveys of producers' estimates of breeder mortality rates found estimates of less than 5% were common.

Reasons for the difficulty in obtaining accurate mortality rates in extensive areas include, amongst other factors, the inability to obtain clean musters due to topography and vegetation, drought, flood, fire damaged fences, botulism, cattle missing between musters, and the simple failure to keep records. The Smart Manager project of the QDPI identified the poor level of record keeping as a major constraint to estimating breeder mortality, and a contributor to producer reluctance to accept that breeder mortalities are likely to be higher than 'guesstimated'. Across northern Queensland, producers underestimated mortalities and overestimated brandings. In a Pilbara survey, sales records were found to be the most reliable records available using rolling averages; weaning and breeder numbers were less reliable.

Given that some mortalities are inevitable in any herd regardless of the level of management, the significant and basic factors contributing to higher than acceptable breeder mortalities and low brandings are the age of the breeder, the stage of pregnancy combined with the effect of seasonal conditions and nutritional status of pastures.

BCOWPLUS has been used extensively to assess the level of herd breeder mortality and to examine the economic impact of improving income from cow sales on enterprise operating surplus. In an analysis across north Western Australian herds, comparing the effects individually of 1% decrease in breeder mortality, 1% increase in weaning rate, and 1% increase in liveweight gain, the reduction in mortality gave the greatest improvement in gross margin per adult equivalent (Niethe and Holmes, 2008).

Since direct measures of breeder mortality are difficult to obtain, some indirect measures are relevant to the task. These have included: annual female sales as a proportion of total sales (Wicksteed, 1986; Niethe, 1996); sex turn off differences (Jubb, Kerr and Bolam, 1997); heifer retention rates (Niethe and Quirk, 2008); the number of females sold annually (Niethe, 1996); total sales as a percentage of total calves; and a breeder performance score based on sales (Wicksteed, 1986).

A number of recommendations are supported in the literature as measures to reduce breeder mortality. These include strategic protein and phosphorus supplementation, vaccination against known infectious diseases, weaner management, sustainable pasture management and appropriate stocking rates, pregnancy diagnosis and ageing of the foetus.

All management options have a cost which must be exceeded by the benefits, both operational and cash. A three level system of management options which meets these requirements can be introduced sequentially into breeding herds to improve fertility and survival (Holroyd and Fordyce 2001). These options include:

1. First-level management options of appropriate stocking rates, genotype, supplementation, weaning and weaning management, and botulism control.
2. Second-level management options of heifer management, selecting breeding cattle, efficient culling, disease control and bull soundness.
3. Third-level management options of controlled mating, spike feeding, dry season segregation of cows and artificial breeding.

4.2 Calculation of mortality rates

A mortality rate estimation has three components:

- numerator – count of the number of deaths that occurred in a defined time period
- denominator – count of the number of animals that were eligible to die or at risk of dying during the period
- time period – definition of the time period (the current project used a one year period or 12 months)

The resulting mortality rate is expressed as deaths per 100 animals per year. It may also be expressed as deaths per 100 animal-years. Note that 100 animal years could be represented by a paddock containing 100 animals covering a one year period (each animal contributes one animal-year of time at risk), or it could be represented by a paddock of 50 animals covering a 2-year period, or 200 animals covering a 6-month period. In each situation the total amount of animal-time in the paddock is 100 animal-years.

The rate estimation requires a numerator (count of deaths) and a denominator (number of animals considered to be eligible to die during the year). Both the numerator and denominator in extensive production systems are problematic and require approximation.

Very few properties were able to provide an accurate count of numbers of deaths. An estimate of deaths was based on the difference between the expected number of animals (based on book entries) and the actual number of animals based on mustering counts. The difference between these two estimates then provided a measure of missing animals. Missing animals might be alive and not able to be mustered that year (still on the property but not yarded, or relocated to another paddock or property) or dead. For the purposes of these analyses, missing animals were assumed to be dead. This approach produced an estimate of total deaths in females. The estimate is likely to be an over-estimate of mortality since it will include some animals that are missing but not dead.

Because the project was developed to study breeder deaths, it was necessary to estimate a numerator and denominator for breeders.

A breeder was defined as any animal that was eligible to be bred or capable of being bred and was represented by the number of animals presented for breeding on each property in a given year (opening breeders = closing number of breeding cows from previous year plus any maiden heifers being joined for the first time).

Non-breeding animals were those females that were not eligible to be bred (branded animals and weaners or heifers that were too young or small to be bred and spayed females). An unbiased estimate of total non-breeding females was calculated as:

opening total females – opening breeders + 0.5*(branded heifers)

Multiplying the branded heifers by 0.5 was intended to allow for the fact that heifers may be branded at any mustering occasion at different times of the year. Multiplying the total by 0.5 is applying a mathematical assumption that the average animal may be branded about half way through the year (some will be branded earlier and some will be branded later).

The death rate in non-breeding females was assumed to be 3% and was treated as a constant. Multiplying the estimate of non-breeding females by 0.03 produced an estimate of deaths in non-breeding females. The death rate in non-breeding females will vary with region and management.

The mortality calculator developed as part of this project allows the death rate for non-breeding females to be varied.

Subtracting the estimated deaths in non-breeding females from the total female deaths produced an estimate of deaths in breeding females.

The approach resulted in two estimates of mortalities in female animals: one was total deaths in all females, and the other was an estimate of deaths in breeders only. The mortality estimates provided the numerator for rate calculation.

The denominator in a rate calculation may be described as the number of animals that were eligible to die in a one year period. While this concept is relatively simple to grasp in a closed herd situation, it is more complex in a dynamic herd and requires some explanation. A simple example is used to illustrate the concept.

- *Imagine a herd that starts the year with 1000 females. The animals are monitored over one year. During the year no animals are purchased and none are sold. The only reason for any change in the number of females is through deaths. This is called a closed herd system. At the start of the year, all 1000 animals were alive and therefore eligible to die. At the end of the year, 70 animals had died.*
- *The simplest measure of the denominator for a mortality rate is the starting number in a closed system. In this case it is 1000 animal-years (or animals followed for a one-year period).*
- *The numerator is the count of deaths (70).*
- *The annual mortality rate is 70/1000 per animal-year = 0.07 deaths per animal-year.*
- *If we want to express this as deaths per 100 animal-years, the rate is multiplied by 100.*
- *i.e. 7 deaths per 100 animal-years.*
- *This means that for every 100 animals that are at risk (present on the property and eligible to die), we expect 7 deaths through the course of one year.*

This approach is appropriate but in real life, properties may add new animals (branding or purchase) and sell others. This is a dynamic system. While an animal is present on the property (and alive) it is eligible to die. While present and alive, it should be contributing to the denominator animal time (the time at risk). If the animal dies, it contributes to the numerator.

- *Imagine that the same property starts the year with 1000 females. After 6 months, it sells 300 females. At the beginning of the 8th month, 200 female calves are branded and weaned and these animals then join the count of females on the property. Estimating the denominator of animal time at risk of death is now more complicated.*
- *There are 700 females that start the year alive and are present for the whole year, so they contribute 700*1=700 animal years to the denominator of animal time at risk.*
- *The 300 animals that are sold half way through the year are eligible to die up until they leave the property. They have contributed 300*0.5 = 150 animal years to the denominator.*

- *The 200 female calves that are branded and become eligible to be counted from the 8th month, will contribute 4 months each to the denominator: 200*(4/12) = 200*0.33= 66 animal years to the denominator.*
- *The total number of animal years at risk is then the sum of the contributing bits:*
    - *700 + 150 + 66 = 916 animal years.*
- *If 70 animals died during the year, the mortality rate is now:*
    - *70/916 per animal year = 0.076 deaths per animal-year*

  or
    - *7.6 deaths per 100 animal-years.*

The last illustration of this concept is the situation where animals are known to have joined the herd or left the herd at multiple time periods through the year but there is no information on when these changes occurred. The only information available is that the starting count was 1000, that multiple purchases were made totalling 300 animals, and a total of 200 females were branded but there is no information on how many were branded and when. If changes could have occurred on any month of the year and there is no reason to think that any one month is more or less likely than any other month, then the simplest and mathematically least biased approach is to treat them as if they occurred at the half-way point. All this requires is an assumption that the changes could have occurred either before half way or after half way during the year.

- *Start with 1000 animals*
- *Add 300 animals at half way. These animal contribute 300*0.5 animal years = 150*
- *Add 200 animals branded at half way. These animals contribute 200*0.5 animal years = 100*
- *Total animal years at risk = 1000 + 150 + 100 = 1250 animal-years*
- *70 deaths occurred during the year.*
- *Mortality rate = 70/1250 = 0.056 deaths per animal-year= 5.6 deaths per 100 animal years.*

It is important to note that data collected from properties included opening and closing counts for various classes of cattle (total females, breeders, steers). The number of animals branded each year was recorded and it was assumed that 50% of these would be male and 50% female. Sales and purchases were recorded by sex (male and female) but female movements (sales and purchases) were generally not differentiated as breeders or non-breeders.

Counts of sales and purchases were often relatively large numbers in the dataset, in comparison to opening counts. This was particularly noticeable for steers where a large proportion of animals could be sold in a given year. In some years and on some properties there were relatively large movements on or off for females as well. Failing to appropriately adjust a denominator to account for these movements could produce very biased rate estimates.

The most unbiased denominator for use in estimating female death rates was therefore based on estimation of at-risk female animal-years:

*At-risk adjusted total females = opening females + 0.5*branded heifers + 0.5*female purchases.*

This number is an estimate of the number of females that are at risk of dying during the period. Adjusting by half the number of female brandings and purchases reflects the fact that these movements (branded animals and purchases into the herd) can take place at any time through the year. In an open population where animals can enter (purchases and branded) or leave (sales) at any time through the risk period, the method described above is commonly recommended as an unbiased way to estimate animal time at risk.

In theory it should be appropriate to also incorporate adjustment for sales as well, by subtracting half the female sales from the right hand side of the above equation. When preliminary estimates were generated and discussed with property managers, in particular with pastoral company management generally possessing reliable records, the resulting numbers were considered to be less consistent with long term experiences than the numbers produced without any adjustment for sales. Not adjusting for sales is mathematically making the assumption that most sales occurred towards the end of the 12 month period, meaning that sale cattle were present on the property for most of the year and therefore eligible to die. In situations where sale cattle may have been shifted off the property before the end of the 12 month period, failing to adjust the denominator to account for this will have the effect of making the denominator bigger than it should be and this will consequently reduce the mathematical value of the calculated mortality rate. This means that the estimated mortality rates produced while using a denominator that is not adjusted for sales, may have some risk of under-representing the true mortality rate.

At the same time there is also inherent potential bias in the numerator (count of deaths) since the numerator may be described as a count of missing animals. If there is bias in the numerator it will be to over- represent the true death rate. The same approach was used for steers.

Accurate data on how many heifers and cows were spayed each year was not available from property records. It is expected the death rate in spays is higher than other females of the same age in the year they are spayed, so if the inventory analysis was able to separate spay deaths and number spayed, the likely outcome would be a slightly lower average total female and breeder death rate. This is probably something that could be looked at more closely into the future with a view to accommodating spayed females as a separate class into an inventory tool (mortality calculator). This is provisional upon any additional accuracy outweighing the added complexity.

4.3 How to interpret results

Statistical models provided two forms of output. One is a direct estimate of mortality rate (deaths per 100 animal years) for the levels of an explanatory factor. The other was a measure of relative risk (RR). Relative risk is a way of comparing one level of an explanatory factor to another level.

For example, Table 43 is based on comparing the female mortality rate based on categories of age of cow at last weaning. The explanatory factor is *age of cow at last weaning*. It has two levels (*up to 11 yrs.* and *>11 yrs.*). The female mortality rate for those properties where cows were last weaned at ages up to 11yrs was 4.67 deaths per 100 females per year. The female mortality rate for those properties where cows were last weaned at >11 yrs. was 7.36 deaths per 100 females per year.

The relative risk is estimated by 7.36/4.67 = 1.57. It provides a measure of the relative strength of the association and is stating that the female mortality rate on those properties where cows are last weaned at >11yrs, is 1.57 times higher than the mortality rate on those properties where cows are last weaned at ages up to 11yrs.

Most model output also generates standard errors and 95% confidence intervals. The 95% confidence interval provides a measure of the precision in the estimate. The average mortality rate for properties that last weaned younger cows was 4.67 but the 95% confidence interval ranged from 3.46 to 5.88. A reasonable way to interpret this is to assume that because these results were based on a relatively small sample (fewer than 40 properties), the estimates are uncertain. The estimated mean female mortality rate was 5.64 but if we were to repeat this study numerous times with the same underlying patterns in the data, we could expect the measured mortality rate to vary between about 3.46 and 5.88 deaths per 100 females per year.

Finally, the explanatory factors that were contained in the final models were then used to estimate population attributable fractions or PAFs. The PAF provides a measure of the proportional reduction in average mortality rate that would be achieved by eliminating the effects of one particular explanatory factor, while leaving the effects of other risk factors unchanged. Within a given multivariable model the PAF measures allow comparison of the relative importance of the different explanatory factors to answer questions such as: *which explanatory factor is most important* and *how much of a reduction in mortality rate might be expected if the effects of one explanatory factor were able to be eliminated*. Again, these estimates are provided with 95% confidence intervals to reflect the uncertainty arising from the small sample sizes.

4.4 General descriptive results

The project was designed to collect data and information from a target of 36 properties selected in a modified random selection process from nine regions across northern QLD, NT and northern WA. The project enrolled a total of 45 properties that agreed to participate (Table 2).

Table 2: Summary of target selections and numbers of properties that provided data for the project

State	Region	Total	Selection target	Data collected from
NT	Barkly	32	6	7
NT	Gulf + Roper	26	1	1
NT	Katherine	6	1	1
NT	Sturt Plateau	26	1	1
NT	VRD	25	3	4
NT	Nth Alice Springs, Tenn. Creek, Plenty	51	4	3
NT	Southern Alice Springs	25	2	4
NT	Subtotals	190	18	21
WA_Kimb	Halls Creek, Wyndham-East Kimberley	53	4	3
WA_Kimb	Broome, Derby-West Kimberley	42	2	6
WA_Kimb	Subtotals	95	6	9
WA_Pilb	East Pilbara, Port Headland, Roebourne	34	3	3
WA_Pilb	Ashburton	30	3	3
WA_Pilb	Subtotals	64	6	6
QLD	QLD southern gulf	336	3	6
QLD	QLD northern gulf	146	3	3
QLD	Subtotals	482	6	9
TOTALS		831	36	45

The project began with six properties being enrolled in a pilot phase as a way of developing and validating data collection and methods of estimating breeder mortality. These six properties were chosen in a non-random manner by contacting two pastoral companies and asking for their participation in developing and validating the methods. The random selection process then involved selection of additional properties in each region where required to ensure that target numbers were achieved. More detail on the selection process is provided in the Appendix 8.2.

A total of 6 properties were unable to provide estimates of all of the input parameters required to be able to populate the template. This was mainly due to lack of available records, in some cases because the properties had recently changed hands.

Table 3: Summary of properties providing data, including those that failed to provide sufficient data for any estimates to be produced (n=6) and those that provided data generating negative estimates for mortalities.

Region	Count of stations	Insufficient data to analyse	negative mortality female	negative mortality breeder	negative mortality steers
QLD South Gulf	6			1	1
Qld North Gulf	3		1	1*	1*
NT Barkly	7		1	1	
NT Gulf	1				
NT Katherine	1				
NT Sturt Plateau	1			1	
Alice Springs North	3	1			
Alice Springs South	4	2			
NT Victoria River	4				1
Kimberley East	3				1
Kimberley West	6	1		1	1
Pilbara East	3	1	1	1*	1*
Pilbara West	3	1			1
Total count	45	6	3	6	7
Used for analyses			36	33	32

* the same station excluded from female, breeder & male analyses

In a number of cases the data generated negative mortality estimates, meaning that actual yard counts for closing figures were consistently higher than opening counts. Statistical modelling of mortality rates does not allow negative rates to be expressed. These properties were therefore removed from analyses of rates. This meant that analyses of female mortality were conducted on a total of 36 properties (45-3-6) while breeder mortality involved 34 properties and steer mortality involved 33 properties (Table 3).

Most properties provided 5 years of data, starting in either 2006 or 2007 (Table 4).

Table 4: Count of number of properties providing data by start year and number of years of data

	Number of years of data				
Start year	**3**	**4**	**5**	**9**	**Total**
2002			1	3	4
2003			1		1
2005			1		1
2006			11		11
2007		1	13		14
2008		2			2
2009	6				6
Total	6	3	27	3	39

There was a total of seven (7) properties that had a negative mortality estimate for either steers or females or both. Of these, only two properties had negative estimates for all three outcomes. There was one property that reported negative estimates for female and breeder deaths, and one property reported negative estimates for breeder and steer deaths. There were a further six properties that reported a negative estimate for a single outcome only.

When annual estimates from the 36 properties contributing data to analysis of female mortality were combined, they accounted for about 528,000 females in any given year, providing an indication of the coverage of the study. Summary statistics for average annual opening female count are shown in Table 5.

Table 5: Summary statistics for average of annual opening female count for each region. se = standard error, n=number of properties contributing data

		Count of opening females			
Region	**n**	**Average**	**Se**	**Minimum**	**Maximum**
QLD SG	6	13,649	4,318	1,339	30,233
QLD NG	2	14,598	11,993	2,605	26,592
NT Barkly	6	27,598	6,700	7,749	53,148
NT GKS	3	8,304	3,955	4,214	16,212
NT ASpr	4	3,555	553	1,976	4,557
NT VRD	4	19,927	4,100	9,299	27,304
WA EKimb	3	21,742	8,252	5,240	30,222
WA WKimb	5	11,425	1,642	6,269	14,998
WA Pilb	3	4,954	1,459	2,232	7,225
Total	36	14,798	2,029	1,339	53,148

Table 6 shows the final count and region coding for those properties that were used in the analyses. The revised region coding was used to ensure that a minimum of two properties were included in each region to generate a mean and variance for various outcomes of interest. There were a total of 36 properties with non-negative mortality estimates for females and 32 for steers.

Table 6: Summary of properties providing data that could be used for analyses and showing re-coding of regions used in analyses

Region	Region coding for analyses	available for female mort	available for male mort
QLD South Gulf	1	6	5
Qld North Gulf	2	2	2
NT Barkly	3	6	7
NT GKSt	4	3	3
Alice Springs	5	4	4
NT VRD	6	4	3
Kimberley E	7	3	2
Kimberley W	8	5	4
Pilbara	9	3	2
		36	32

4.5 Results for female mortality

Descriptive statistics, results from univariable screening and the model coefficients from the final multivariable statistical model are all presented in Appendix 8.3. The following sections of the main report present the descriptive summary results and the findings from the final multivariable model.

The following section is limited to the 36 properties with non-negative female mortality rates.

4.5.1 Descriptive summary of female mortality rate

Female mortality for each region is shown in The region specific mortality estimates were calculated using an approach equivalent to a least squares mean from a linear regression model, meaning that they may be considered to be equivalent to the mean of the property mortality estimates for each property within that region. This is an unbiased approach to estimating region means since it is not influenced by the number of cattle contributed by any one property but instead weights each property equally.

Table 7. The overall female mortality rate may be interpreted as an overall population level estimate of annual expected female mortalities.

The region specific mortality estimates were calculated using an approach equivalent to a least squares mean from a linear regression model, meaning that they may be considered to be equivalent to the mean of the property mortality estimates for each property within that region. This is an unbiased approach to estimating region means since it is not influenced by the number of cattle contributed by any one property but instead weights each property equally.

Table 7: Female mortality (deaths per 100 females per year) and 95% confidence interval for each region and overall

		No of	Mortality rate	95% Confidence interval	
Region	**Region**	**properties**	**%**	**Lower**	**Upper**
1	QLD SGulf	6	2.68	0.99	4.37
2	QLD NGulf	2	11.14	2.65	19.64
3	NT Barkly	6	3.74	2.59	4.88
4	NT GKSt	3	5.86	0.83	10.89
5	NT ASpr	4	11.80	2.30	21.31
6	NT VRD	4	6.09	3.73	8.46
7	WA EKimb	3	5.46	2.37	8.55
8	WA WKimb	5	3.08	1.48	4.68
9	WA Pilb	3	7.14	3.32	10.97
	Total	36	5.64	3.93	7.35

Figure 2 presents the overall female mortality rate for each region, expressed as the percentage deaths in females (female deaths per 100 females at risk per year). Figure 3 presents mortality rate estimates for each property, ordered from lowest to highest.

Figure 2 indicates that there were wide confidence intervals for mortality estimates, in particular for the Queensland Northern Gulf and the NT Alice Springs regions. The wide confidence intervals indicate increased variability between the property specific estimates that make up the region estimates and are exacerbated by the small sample size for the Queensland Northern Gulf in particular. These two region estimates were associated with the two individual properties with the highest property-specific estimates for female mortality as shown in Figure 3 (the two properties on the right side of the chart with the highest rank for female mortality). Similarly, the extremely low value for a Katherine-Gulf-Sturt Plateau property has ranked this district lower than the VRD region.

As an indication of the effect of the two properties with the highest mortality estimates (one from QLD nthGulf and one from NT ASpr), if the calculations are repeated with these two properties omitted, the overall estimate for female mortality drops from 5.64% to 4.7% and the two region specific estimates drop to 5.11% (QLD NGulf) and 6.51% (NT ASpr).

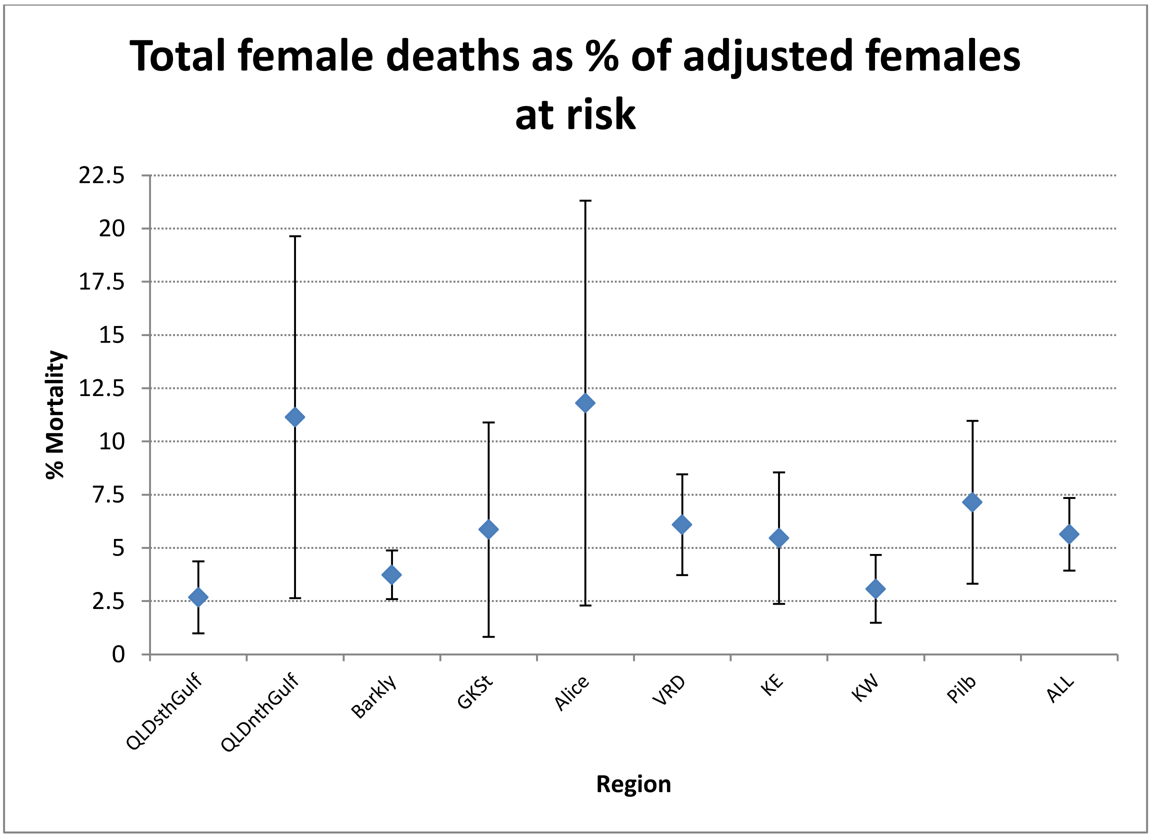

Figure 2: Plot of percentage female deaths by region (deaths per 100 females per year). Each estimate is the percentage calculated as total female deaths divided by total (adjusted) females at risk. Bars represent a 95% confidence interval generated from a negative binomial regression model.

It is only appropriate to discard extreme values if they can logically be considered as outliers meaning that they are unlikely to be representative of broader population or plausible values, or if the values can be confidently considered to be associated with errors in data collection or data entry. Every effort was made during the data collection process to check all input values and to go over interim results with property managers or owners. The effort undertaken in the data collection exercise meant that we were confident that there were no errors in data entry. In addition, the multivariable statistical modelling involved specific assessment of model residuals as a way of assessing whether any particular property might be such a poor fit to the model to be classified as an outlier. Inspection of model residuals indicated that there were no concerns about any properties behaving as outliers and therefore all property data were retained in the analyses.

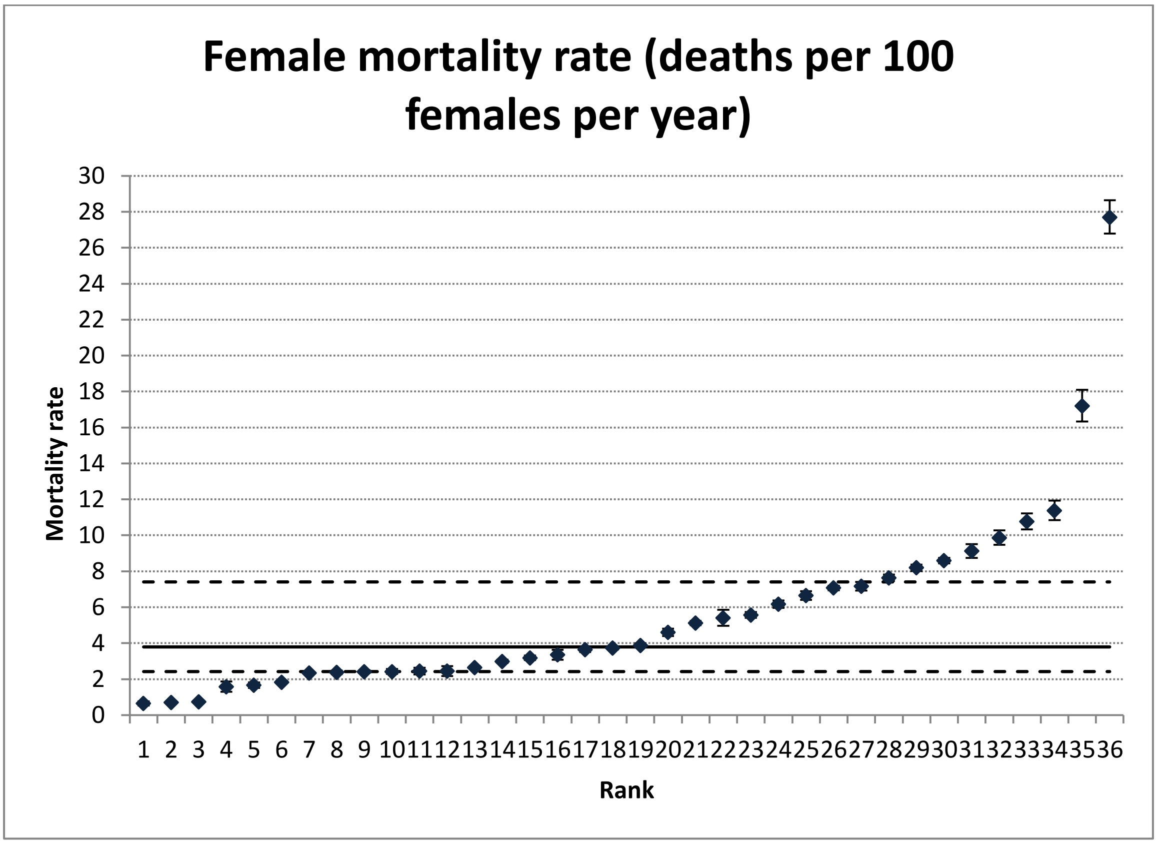

Figure 3: Separate estimates of percentage female deaths estimated for each property, ordered from smallest to largest. Bars represent 95% confidence intervals. The lower and upper dotted lines represent the 25th (2.4%) and 75th percentiles (7.4%) and the solid line represents the median (3.8%) mortality rate. 10% mortality rate represents about the 87th percentile.

4.5.2 Results of multivariable modelling for female mortality

Explanatory variables that were significant in the screening process were then considered for inclusion in a multivariable model using female mortality as the outcome. Region was retained in all models as a fixed effect. Candidate variables for the starting model included age at last joining, age at last weaning, age when cull for age cows were sold, P-supplementation, botulism vaccination, segregation of breeders during the dry, and continuous mating of cows.

Age at last joining and age at last weaning were considered to be correlated and a decision was made to include only one or the other of these variables. Both variables were tried and the best fitting variable was retained if significant in the final model.

A manual backwards stepwise model building process was used where all candidate variables were included in the model initially and non-significant variables then removed one at a time until the final model contained only significant factors. Plausible two-way interaction terms were then considered and retained only if they were significant.

Inspection of model residuals plotted against fitted values did not identify any abnormal patterns or ill-fitting or overly influential records. There was no indication that any of the properties with relatively larger or smaller female mortality values were outliers and therefore all records were retained for analysis.

The final model included the following terms:

- Region: QLD Sth Gulf, QLD N Gulf, NT Barkly, NT GKSt, NT Alice Spr, NT VRD, Kimberley E, Kimberley W, Pilbara
- Age at last weaning: <11yrs, 11+ yrs
- Supplementary phosphorous over wet season: No, Whole herd, Part of herd
- Segregation of breeders during dry: Yes, No
- Interaction between age at last weaning and supplementary phosphorous over wet.

It is important to note that the value of the multivariable models is in identifying those factors that are likely to be influencing mortality. Some factors such as region were included in the models in order to adjust models for unmeasured variability at the region level and to ensure more valid measures of effects for other factors in the model. Other factors such as age of cows at last weaning, dry season segregation of cows, and wet season P-supplementation are of particular interest because they may inform future management strategies designed to reduce female mortality.

Measures of performance (percent female mortality estimates for each region) are presented in the descriptive summary in section 4.5.1 and in Figure 2. There are a number of interesting findings from the multivariable modelling exercise (Table 8).

Region was included in the model to ensure adjustment of the effect of other factors for any unmeasured effects of region. The estimated percentage deaths for each region are estimates that are adjusted for the effects of all other factors in the model. While the estimates are generally similar with those presented earlier (The region specific mortality estimates were calculated using an approach equivalent to a least squares mean from a linear regression model, meaning that they may be considered to be equivalent to the mean of the property mortality estimates for each property within that region. This is an unbiased approach to estimating region means since it is not influenced by the number of cattle contributed by any one property but instead weights each property equally.

Table 7 and Figure 2), there appears to be a discrepancy for the NT VRD estimate. It is not clear why the predicted value from the multivariable model may be so much higher than the descriptive measure for female deaths. It is possible that the properties in the NT VRD may have differed from most of the other properties in other regions in some factors that were related to female deaths. As an example, review of the descriptive summaries and univariable analyses presented in Appendix 8.3 indicated that NT VRD appeared to have cows with a younger age at last joining than almost all other regions. Table 8 provides estimates of predicted percentage death for each region that are averaged over all other factors in the model. If the NT VRD properties were different from other regions in some of these factors then this could contribute to a difference between the predicted percentage death (averaged across all factors) and the observed or descriptive summary of percentage female death. The presence of significant variation between regions in the final model, even once adjusted for other factors in the model, indicates that there is remaining variation in female mortality risk at the region level after adjusting for other factors. Further work is required to investigate possible causal factors that may explain more of the region effects and the intriguing difference between the two measures for the NT VRD.

Table 8: Adjusted predictions of female mortality rate (deaths per 100 females per year) for each factor in the multivariable model. All means are adjusted for other factors included in the model.

				95% CI	
Variable	**Level**	**Mort rate**	**se**	**Lower**	**Upper**
Region					
	QLD S Gulf	5.68	1.60	2.55	8.81
	Qld N Gulf	17.95	3.50	11.08	24.82
	NT Barkly	6.40	1.58	3.30	9.51
	NT GKSt	3.74	0.84	2.09	5.39
	NT Alice Spr	8.38	1.91	4.64	12.12
	NT VRD	23.85	6.23	11.63	36.07
	Kimberley E	7.27	1.37	4.59	9.96
	Kimberley W	2.86	0.87	1.14	4.57
	Pilbara	2.82	0.91	1.03	4.61
Segregation of dry breeders					
	Yes	2.74	0.31	2.12	3.35
	No	8.26	0.79	6.71	9.81
Age at which cows are last weaned					
	<11 yrs	4.58	0.38	3.83	5.33
	11+ yrs	8.00	1.17	5.70	10.30
West season supplementation with P					
	No	6.77	1.13	4.56	8.98
	Whole herd	5.75	1.04	3.71	7.79
	Part herd only	4.96	0.89	3.22	6.70
Interaction: Age last weaned # P-supplementation					
Age wean	P-suppl				
<11yrs	No	3.60	0.59	2.44	4.75
<11yrs	Whole herd	6.23	1.58	3.14	9.33
<11yrs	Part herd	4.59	0.56	3.49	5.69
11+ yrs	No	12.93	3.41	6.25	19.61
11+ yrs	Whole herd	4.81	1.05	2.76	6.86
11+ yrs	Part herd	5.67	2.10	1.55	9.79

Properties that practised segregation of breeders during the dry season had a 67% reduction in female mortality compared to those properties that did not segregate (reduction from 8.26% death to 2.74% death). This effect is attributed not to segregation per se but to the fact that properties that do segregate were likely to accompany this with additional strategies such as targeted supplementation or management of pastures to ensure optimal nutrition is provided to groups of animals with higher needs.

Properties where the age of cows at last weaning was <11 years, had a 43% reduction in female mortality compared to those properties where the age of cows at last weaning was 11 years or older (reduction from 8% deaths to 4.6% deaths). Age of cows at last weaning was correlated with age at last joining when they are most likely to be culled for age. All three variables are expressing dimensions related to how properties manage older cows.

The effects of phosphorous (P) supplementation were difficult to interpret. There was a significant interaction between age of cows at last weaning and P-supplementation. For those properties where cows were last weaned at <11 years, there was no difference between the three categories of P-supplementation ($p>0.05$).

However, there was a larger benefit of P-supplementation for properties where age at last weaning was 11 years or greater. The reduction in these properties from non P-supplementation to whole-herd supplementation had a tendency towards significance ($p=0.079$) but there was no difference between no supplementation and part herd supplementation ($p=0.3$) or between part and whole herd supplementation ($p=0.2$).

The results suggested that properties that applied P-supplementation and that retained older cows, may be able to reduce their female mortality by as much as 63% when looking at the maximal reduction (from 12.93% to 4.81% female mortality). This is an area that requires further investigation.

A number of factors were dropped during the model building process because they were found to be non-significant when included in the multivariable model (age of cows at culling, botulism vaccination). Again some caution is urged in interpreting these findings.

For example, botulism vaccination is considered likely to have an important potential impact on animal health and survival. It was not retained in the final model but this was considered to be largely because almost all properties vaccinated (only two properties indicated they did not vaccinate against botulism), providing less opportunity to assess the effects of this variable in a multivariable model.

An attempt was also made to compare the relative importance of the three factors in the final model (age at last weaning, segregation of dry breeders and P-supplementation), using population attributable fractions (PAF).

There are two common interpretations that are applied to the PAF. The first is the proportion of a particular outcome being studied (risk of female mortality) that may be attributable to a particular factor. The second is the proportion (or percentage) of disease risk that could be eliminated from the population if effects of the exposure (particular risk factor) were to be eliminated. Both interpretations are valid. At its simplest the PAF estimates can be considered as a measure of the relative importance of particular risk factors for that outcome.

In this case we are using the PAF as an estimate of the proportional reduction in average mortality risk that would be achieved by eliminating the effects of one particular factor, while leaving the effects of other risk factors unchanged. A simple Poisson model (describes the occurrence of events in a large number of independent repeated trials) was run with the four factors added as fixed effects without any interactions. Population attributable fractions were then estimated with 95% confidence intervals (Figure 4).

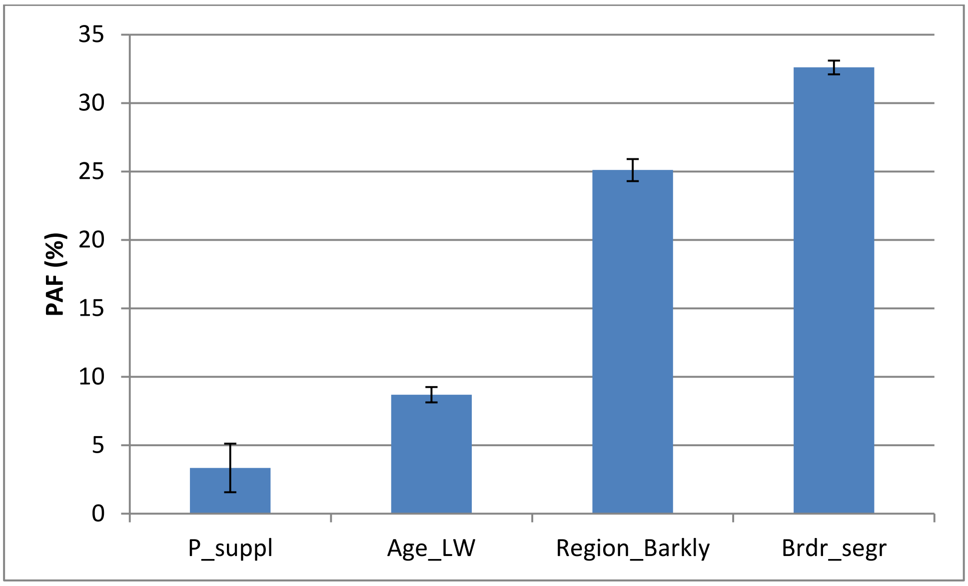

Figure 4: Population attributable fractions (PAF) for each of the four factors in the final model: age at last weaning, P-supplementation, breeder segregation when dry and region.

Interpretation of the PAF values requires an understanding of the reference or baseline level. With respect to age at last weaning, the reference level was the lower age group (<11 yrs.). The exposure level of interest was the older age group (11+ yrs.). If the exposure could be completely eliminated (meaning that if all properties were to adjust their weaning practices such that the age at last weaning on all properties was <11 yrs., then the expected impact would be a 9% reduction in female mortality across the population of beef properties.

In contrast, if all properties adopted P-supplementation at a level equivalent to the effect seen for part herd supplementation, then the effect would be expected to result in a 3% decline in female mortality across the population of beef properties.

If all properties were to implement segregation of breeders during the dry (presumably accompanied by other management decisions such as better access to feed or targeted group supplementation), then the expected effect would be to reduce female mortality by 32% across the population of beef properties.

There was no immediately identifiable reference level for region so the approach used was to assume that all properties implemented changes such that their performance was made equivalent to the NT Barkly performance. This is basically using an arbitrary baseline level to assess the impact on female mortality if all of the effects associated with region were removed. The result (reduction in female mortality of more than 33%) indicates that factors operating at the regional level (other than the 3 factors included in the model) continue to provide an important contribution to female mortality. It is important to note that unmeasured factors operating at the regional level may include things associated with environmental factors (land and pasture quality) but also other factors such as regional variation in property management.

These findings suggest that the most important intervention that properties may wish to consider is related to segregation of breeders in the dry season and presumably associated with additional management factors such as nutritional supplementation of animals that may be at higher risk. Other unmeasured regional effects may also be important and may include things that potentially can be corrected but were not measured in the current project.

It was frequently reported by managers that the implementation of one particular strategy to reduce breeder mortality required a change in other aspects of overall management. The consequences of these less direct changes no doubt contributed to the improvement in performance.

Results for breeder mortality

Descriptive statistics, results from univariable screening and the model coefficients from the final multivariable statistical model are all presented in Appendix.8.4. The following sections of the main report present the descriptive summary results and the findings from the final multivariable model.

4.5.3 Breeders vs. total females

The motivation in performing this study was an attempt to describe mortality rates in breeders. Breeders may be considered to be represented by female cattle that are eligible to be bred (old enough or mature to mate, unspayed, etc.).

Non-breeding females will include females that are too young to mate (calves, heifers prior to first joining) and possibly spayed females. The major distinction between breeding and non-breeding females is that non-breeding females do not have to deal with pregnancy and lactation. Non-breeding females may be assumed therefore to have lower mortality rates than breeding females.

As data collection proceeded for the project it became apparent that there were problems in collecting data that were sufficiently detailed to allow clear distinction between breeding and non-breeding females. It was generally possible to collect data on total females (opening numbers, number branded, sales and purchases), but it was often not possible to assign these numbers to either breeding or non-breeding females.

The prior section of this report was based on total female mortality (including both breeding animals and non-breeding animals). It was expected that non-breeding animals would contribute a lower proportion of total female mortality and that the patterns of mortality and statistical associations with risk factors would be dominated by factors associated with breeder mortality.

The following section provides an estimate of breeder-specific mortality (breeder mortality).

Each participating property provided an estimate of the following:

- opening female count (female weaners, unjoined heifers, joined heifers, cows, spayed heifers/cows).
- opening breeder count (all females that were joined at the start of the current year)
- number branded in the current year
    - Estimated branded heifers = 0.5*number branded

The total number of non-breeding females was then estimated as:

- opening female – opening breeder + 0.5*(estimated branded heifers)

No data were generally available to allow a direct estimate of mortality rates in non-breeding females. In the current project, a more direct estimate of total female deaths was available: this was the difference between book estimates and yard counts for total females over the course of the year. This is an approximation and may include some missing animals that are not dead as well as some ration animals.

All respondents were asked to indicate their estimated death rate in non-breeding females during the data collection process and rates ranged from about 2 to 5% per annum. For this report it was assumed that the overall expected annual rate of death in non-breeding females was 3 deaths per 100 animals per year (3%). For each property, an estimate was then made of the total deaths in non-breeders (0.03*opening non-breeder count). This was then subtracted from the estimated total female deaths, leaving a residual which was the estimated count of deaths in breeders.

There was a total of five properties that had negative estimates of breeder deaths. Three of these had also produced negative estimates of total female deaths. These three properties were excluded from all analyses performed on total female deaths. For the purposes of analyses performed on estimated breeder deaths, all five properties with negative estimates of breeder deaths were excluded from the analyses. This dropped the number of properties contributing data for analyses to a total of 34.

4.5.4 Descriptive summary of breeder mortality

Breeder mortality for each region is shown in Table 9.

Table 9: Descriptive summary of breeder mortality rates for each region

Region	Region	No of properties	Mortality rate %	95% Confidence interval Lower	Upper
1	QLD SGulf	5	3.01	0.59	5.43
2	QLD NGulf	2	17.84	2.42	33.26
3	NT Barkly	6	4.04	2.45	5.63
4	NT GKS	2	11.30	5.73	16.88
5	NT ASpr	4	15.85	1.81	29.90
6	NT VRD	4	8.58	4.24	12.93
7	WA EKimb	3	7.58	2.05	13.12
8	WA WKimb	4	3.70	1.82	5.59
9	WA Pilb	3	10.68	3.40	17.97
	Total	33	8.03	5.21	10.85

Figure 5 illustrates the average breeder death rate for each region and compares this to the total female death rate for each region. Figure 5 indicates that there were wide confidence intervals for mortality estimates in the Queensland Northern Gulf and the NT Alice Springs regions in particular. The wide confidence intervals indicate increased variability between the property specific estimates that make up the region estimates as discussed in the previous section on female mortality. The most useful descriptive measures of percentage breeder mortality for each region are presented in Table 9 and Figure 5.

Figure 6 shows the breeder mortality rate for each property ordered from smallest to largest with a median breeder mortality rate of 5.7%. Lower and upper dashed lines represent the 25th (2.2% mortality) and 75th (11.7% mortality) percentiles and the solid line represents the median (5.7% mortality). A 10% mortality rate is at the 70th percentile. This plot provides a visual summary of property performance, and the lower threshold (25^{th} percentile) may represent a candidate target mortality level for properties to benchmark against and aspire to.

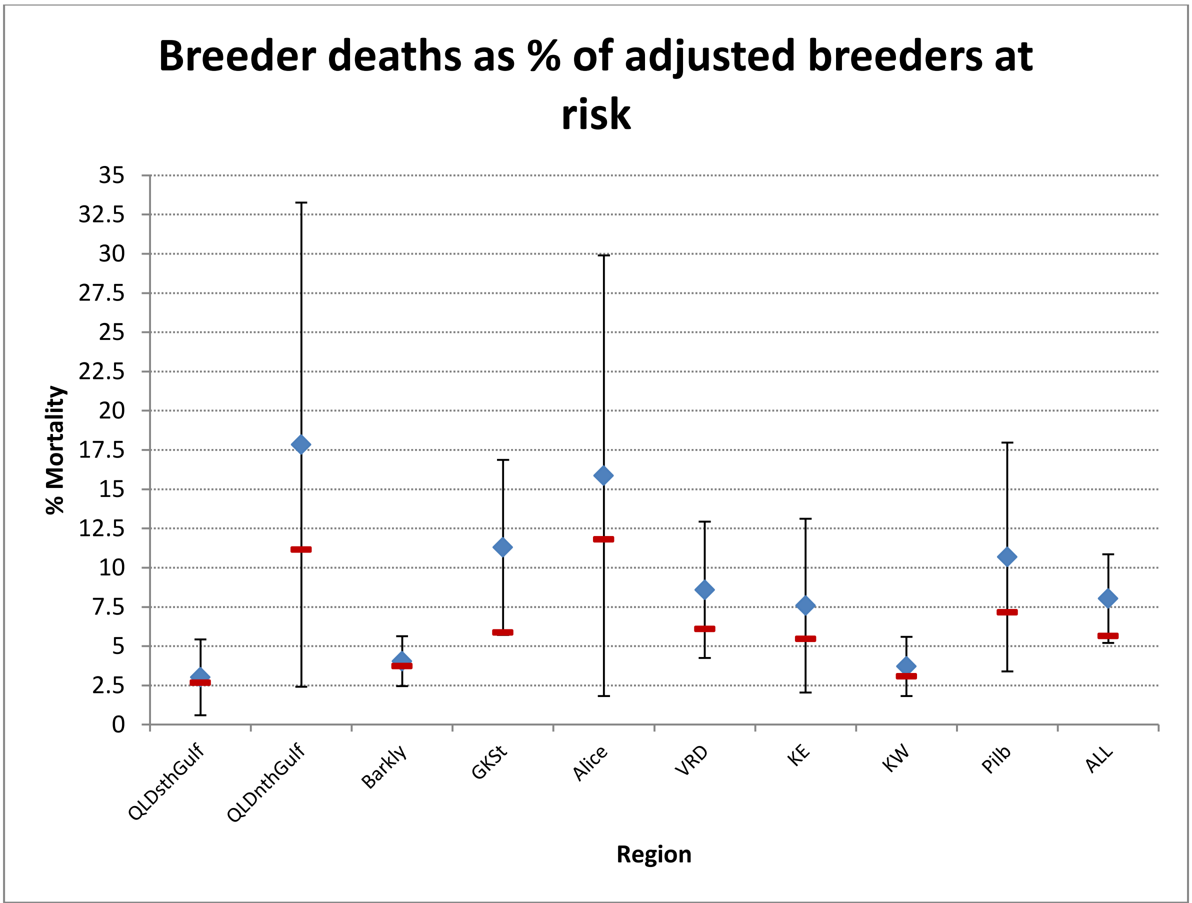

Figure 5: Plot of percentage breeder deaths by region (breeder deaths per 100 breeders per year). Based on 33 properties with positive estimates of breeder deaths. Bars represent 95% confidence limits. The red lines represent percentage female deaths for each region (incorporating breeder deaths and non-breeder female deaths).

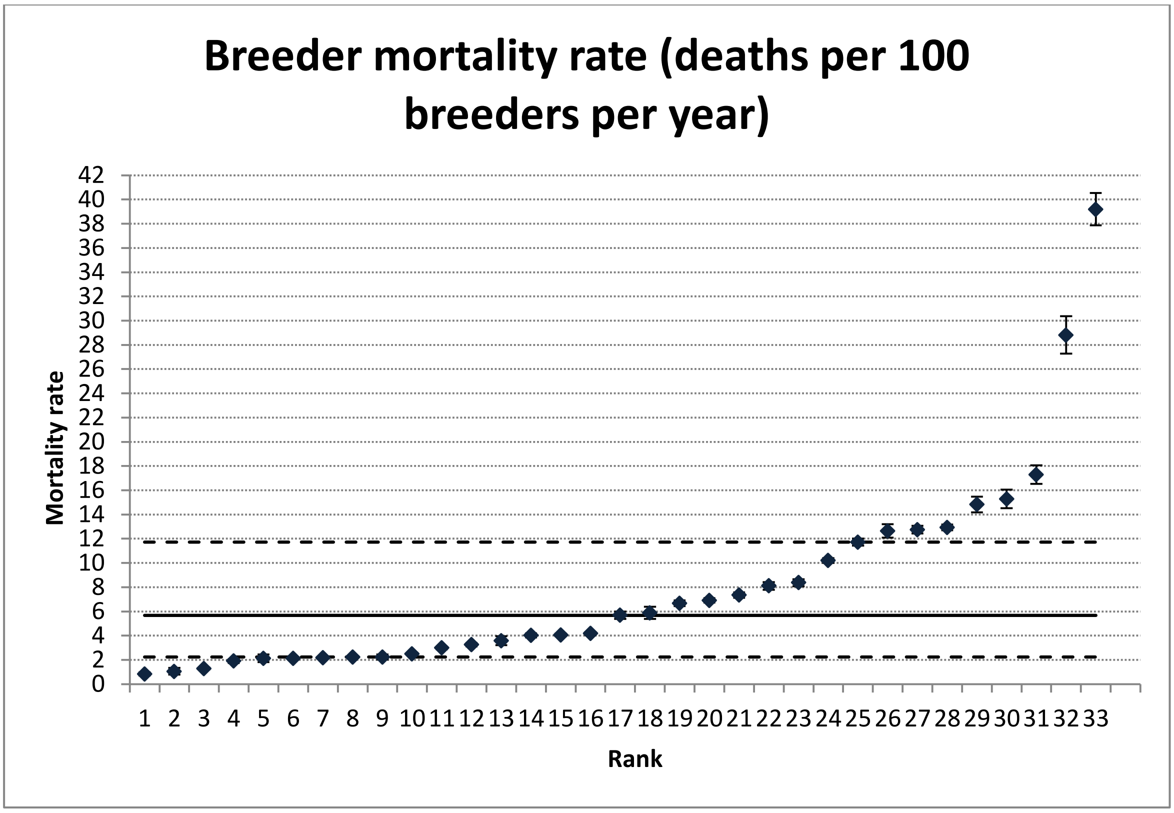

Figure 6: Separate estimates of percentage breeder deaths estimated for each property, ordered from smallest to largest. Bars represent 95% confidence intervals. Lower and upper dashed lines represent the 25th (2.2%) and 75th (11.7%) percentiles and the solid line represents the median (5.7%). A 10% mortality rate is at the 70th percentile.

4.5.5 Results from multivariable modelling of breeder mortality

The same model building approach was used as has been described for female mortality. The final model included the following terms:

- Region: QLD Sth Gulf, QLD N Gulf, NT Barkly, NT GKSt, NT Alice Spr, NT VRD, Kimberley E, Kimberley W, Pilbara
- Age at last weaning: <11yrs, 11+ yrs
- Supplementary wet season phosphorous: No, Whole herd, Part of herd
- Segregation of breeders during dry: Yes, No
- Interaction between age at last weaning and supplementary P during wet.

Table 10 provides estimates of mean female mortality rate for each of the variables in the multivariable model. All estimates are therefore adjusted for all other factors in the final model.

Table 10: Mean breeder mortality rate (deaths per 100 breeders per year) for each factor in the multivariable model. All means are adjusted for other factors included in the model.

				95% CI	
Variable	**Level**	**Mort**	**se**	**Lower**	**Upper**
Region					
	QLD S Gulf	7.10	2.75	1.70	12.50
	Qld N Gulf	41.95	9.39	23.55	60.35
	NT Barkly	6.54	1.54	3.53	9.56
	NT GKSt	7.85	1.53	4.85	10.85
	NT Alice Spr	11.22	3.14	5.06	17.38
	NT VRD	40.24	12.66	15.43	65.06
	Kimberley E	8.52	2.00	4.60	12.43
	Kimberley W	2.77	0.95	0.91	4.64
	Pilbara	4.66	1.82	1.08	8.23
Segregation of dry breeders					
	Yes	3.31	0.49	2.34	4.27
	No	13.07	1.81	9.52	16.63
Cow age when cows are last weaned					
	<11 yrs	6.15	0.47	5.22	7.08
	11+ yrs	12.17	1.94	8.37	15.97
West season P-supplementation					
	No	8.40	1.26	5.93	10.88
	Whole herd	7.22	0.83	5.60	8.83
	Part herd	8.22	1.81	4.67	11.78
Interaction: Age last weaned # P-supplementation					
Age wean	P-suppl				
<11yrs	No	4.30	0.76	2.81	5.79
<11yrs	Whole herd	6.18	1.27	3.70	8.67
<11yrs	Part herd	7.82	1.21	5.44	10.20
11+ yrs	No	17.50	4.22	9.23	25.76
11+ yrs	Whole herd	9.50	1.85	5.87	13.14
11+ yrs	Part herd	9.12	4.30	0.70	17.54

The final model for breeder mortality had similar variables to the final model for female mortality and the initial discussion of findings is also very similar. There was significant variation between regions, even once adjusted for other factors in the model, indicating that there is remaining variation in breeder mortality risk at the region level after adjusting for other factors. The biggest change from the descriptive estimates for region (Table 9 and Figure 5) and those generated from the multivariable model (Table 10) was observed for the NT VRD region. Further work is needed to explore why the NT VRD might be predicted to have a higher mortality than was observed. This was discussed in more detail in the previous section.

Properties that practised segregation of breeders during the dry season had a 75% reduction in breeder mortality compared to those properties that did not segregate breeders in the dry season (reduction from 13.07% deaths to 3.31% deaths). Properties where the age of cows at last weaning was younger than 11 years had a 50% reduction in breeder mortality rate compared with properties where the age of cows at last weaning was older (reduction in breeder mortality from 12.2% to 6.2%).

The effects of phosphorous (P) supplementation were difficult to interpret and involved consideration of an interaction between P-supplementation and age of cows at last weaning. For those properties where age of cows at last weaning was <11 years, there was a lower breeder mortality estimate in properties that did not use P-supplement compared to those properties that did use P-supplement. The effect was only significant when comparing no supplement (breeder mortality=4.3%) to part herd supplement (breeder mortality= 7.82%, p=0.01).

In contrast, for those properties that last weaned cows at ages of 11 years or older, there appeared to be a beneficial impact of P-supplementation. The effect was associated with a tendency towards significance for the comparison between no supplementation (breeder mortality=17.5%) and whole herd supplementation (breeder mortality=9.5%, p=0.087). In this group, P-supplementation reduced breeder mortality by 46%. There was no difference between no supplementation and part herd (p=0.3) or between part and whole herd supplementation (p=0.9).

The interaction between age at last weaning and P-supplementation indicated that the benefit of wet season P-supplementation was most apparent in those properties that also were retaining cows for longer (older cows at time of last weaning), suggesting that benefits may be most apparent in older cows.

An attempt was also made to compare the relative importance across the entire beef population of the three factors in the final model (age at last weaning, segregation of dry breeders and P-supplementation), using population attributable fractions (PAF) (Figure 7). Interpretation of the PAF values requires an understanding of the reference or baseline level.

With respect to age at last weaning, the reference level was the younger age group (<11 yrs.). The exposure level of interest was the older age group (11+ yrs.). If the exposure could be completely eliminated (meaning that if all properties were to adjust their weaning practices such that the age at last weaning on all properties was <11 yrs., then the expected impact would be a 12% reduction in breeder mortality across all beef properties. In contrast, if all properties adopted P-supplementation at a level equivalent to the effect seen for part herd supplementation, then the effect would be expected to result in a 2.5% decline in breeder mortality across all beef properties.

If all properties were to implement segregation of breeders during the dry (presumably accompanied by other management decisions such as better access to feed or targeted group supplementation), then the expected effect would be to reduce breeder mortality by 38% across all beef properties.

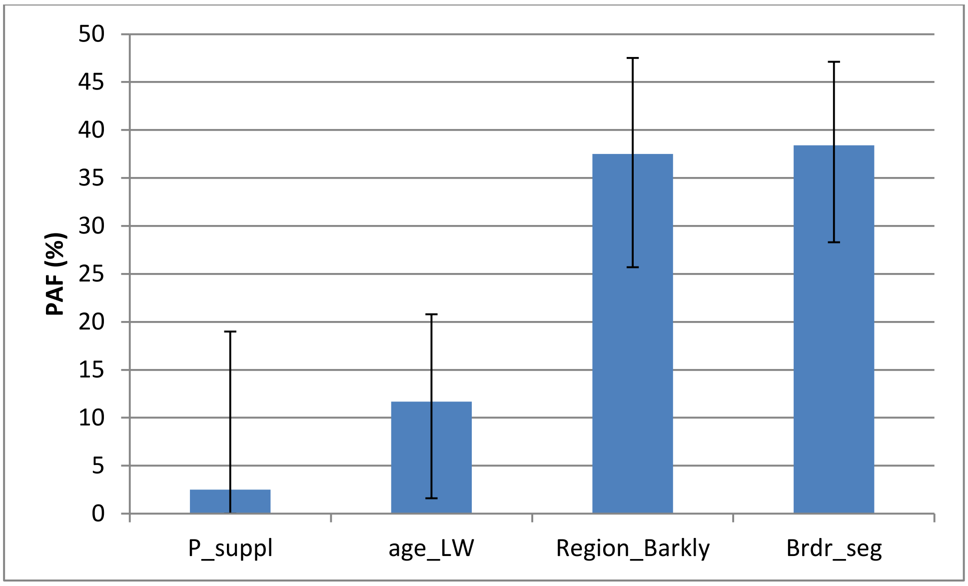

Figure 7: Population attributable fractions (PAF) for each of the four factors in the final model: age at last weaning, P-supplementation, breeder segregation when dry and region

There was no immediately identifiable reference level for region so the approach used was to assume that all properties implemented changes such that their performance was made equivalent to the NT Barkly performance. This is basically using an arbitrary baseline level to assess the impact on breeder mortality if all of the effects associated with region were removed. The result (reduction in breeder mortality of more than 38%) indicates that factors operating at the regional level (other than the three other fixed effects included in the model) continue to provide an important contribution to breeder mortality. This is interpreted as a simple measure of the relative importance of regional effects on breeder mortality.

These findings suggest that the most important intervention that property managers may wish to consider are related to segregation of breeders in the dry season, presumably associated with better nutritional management of breeders.

It was frequently reported by managers that the implementation of one particular strategy to reduce breeder mortality required a change in other aspects of overall management. The consequences of these less direct changes likely contributed to the improvement in performance.

Results for steer mortality

Descriptive statistics, results from univariable screening and the model coefficients from the final multivariable statistical model are all presented in Appendix 8.5. The following sections of the main report present the descriptive summary results and the findings from the final multivariable model.

4.5.6 Descriptive summary of steer mortality

A summary of mortality rate estimates for steers is shown in Table 11.

Table 11: Summary estimates of steer mortality rate (deaths per 100 steers per year) by region

Region	Region	No of properties	Mortality rate %	95% Confidence interval Lower	Upper
1	QLD SGulf	5	6.71	1.54	11.89
2	QLD NGulf	2	24.89	0.00	51.48
3	NT Barkly	7	6.25	1.80	10.70
4	NT GKS	3	13.93	0.00	29.69
5	NT ASpr	4	5.48	1.05	9.91
6	NT VRD	3	7.75	3.89	11.61
7	WA EKimb	2	7.52	5.19	9.86
8	WA WKimb	4	4.17	2.16	6.18
9	WA Pilb	2	17.97	15.41	20.53
	Total	32	8.80	5.51	12.09

The average steer mortality rates for each region, and associated 95% confidence interval, are shown in Figure 8. Figure 9 presents mortality rate estimates for each property, ordered from lowest to highest. Inspection of Figure 8 indicates that there were wide confidence intervals for mortality estimates indicating less confidence in the generality and reliability of the average values. This is particularly so for the Queensland Northern Gulf and the NT GKSt regions. The wide confidence intervals simply indicate increased variability between the property specific estimates that make up the region estimates, and these are exacerbated by the small sample size for the QLD Northern Gulf sample in particular. The estimates for the Queensland Northern Gulf and the NT GKSt regions were associated with the two individual properties with the highest property-specific estimates for steer mortality as shown in Figure 9 (the two properties on the right side of Figure 9, with the highest rank for steer mortality).

If the calculations are repeated with these two properties omitted, the overall estimate for steer mortality drops from 8.8% to 6.8% and the two region specific estimates drop to 6.1% (QLD NGulf) and 4.5% (NT GKSt).

Inspection of residuals from the statistical model did not indicate any property values that were behaving as statistical outliers and the rigorous interview process associated with data collection meant that the authors were confident that there were no data entry errors. As a result there were no grounds on which any property values could be discarded and results were therefore generated from analyses applied to the complete dataset.

There was interest in the estimates for steer mortality since they indicate that steer mortality estimates are higher than overall female mortality and breeder mortality estimates. More information is needed to confirm these findings and to explore both biological explanations for an elevated mortality in steers and to identify strategies that may be applied to reduce steer mortality.

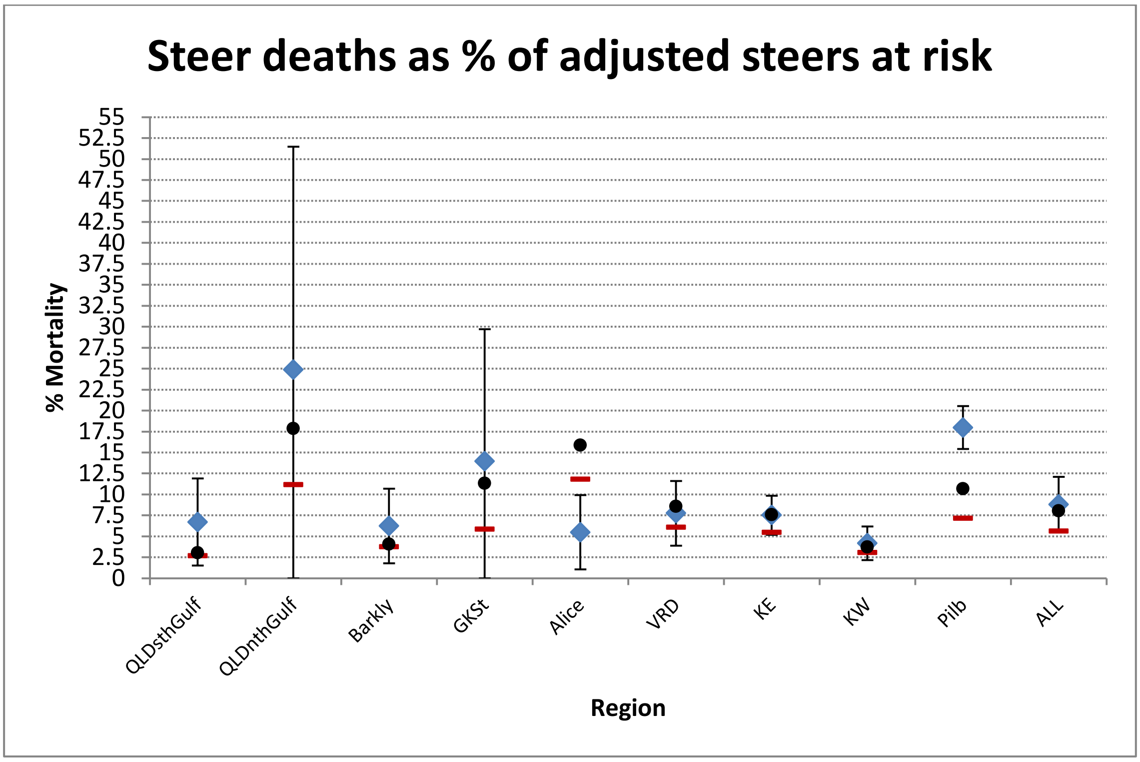

Figure 8: Plot of percentage steer deaths by region (steer deaths per 100 steers per year). Based on 32 properties with positive estimates of steer deaths. Bars represent 95% confidence limits. The red lines represent percentage female deaths for each region and the black circles represent percentage breeder deaths.

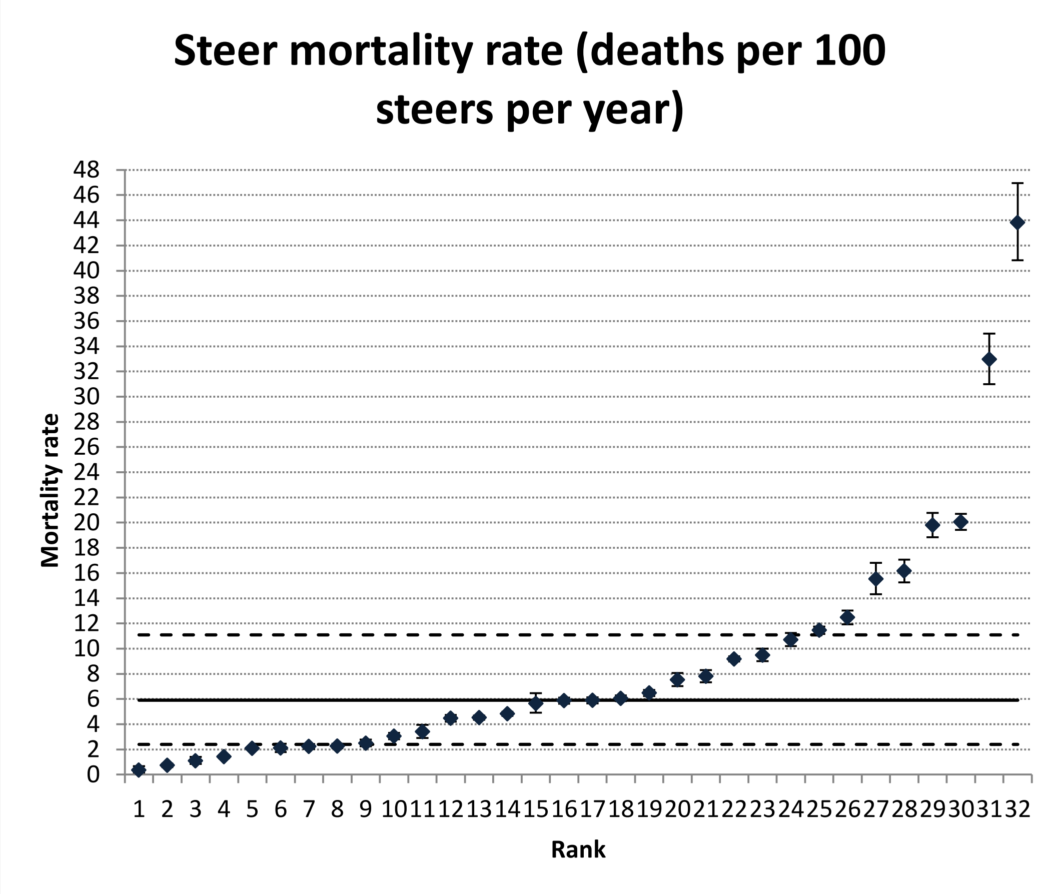

Figure 9: Separate percentage steer deaths estimated for each property, ordered from smallest to largest. Bars represent 95% confidence intervals. Lower and upper dashed lines represent the 25th (2.4%) and 75th (11.1%) percentiles and the solid line represents the median (5.9%). A 10% mortality rate is at the 71st percentile.

4.5.7 Results from multivariable modelling of steer mortality

The same model building approach was used as has been described for female and breeder mortality. The final model included the following terms:

- Region: QLD Sth Gulf, QLD N Gulf, NT Barkly, NT GKSt, NT Alice Spr, NT VRD, Kimberley E, Kimberley W, Pilbara
- Age when most steers are sold: up to 1yr, 1-2 yrs, >2 yrs
- Segregation of breeders during dry season: Yes, No
- Age when most cull for age cows are culled: up to 11 yrs, >11 yrs

The final model for steer mortality included two explanatory factors that related to aspects of female management (segregation of breeders during the dry season, and age when most cull-for-age cows are culled). Both of these factors are not directly measuring attributes that relate to steer management but both are considered likely to be proxies for aspects of general property management. This is the only reason that these variables have been considered for the steer model.

Inspection of model residuals plotted against fitted values did not identify any abnormal patterns or ill-fitting or overly influential records. There was no indication that the two properties with relatively larger steer mortality values were outliers and therefore all records were retained for analysis.

There are a number of interesting findings from the multivariable modelling exercise (Table 12). The mean mortality rate estimates derived from the multivariable model for each region are different to the univariable or screening results reported earlier in this report (Table 11 and Figure 8). The biggest changes were seen for QLD North Gulf and NT VRD where the predicted percentage steer deaths was higher than the observed percentage deaths. This issue was discussed in earlier sections and may be related to the quality of the underlying property data, the limited number of properties in these regions and the fact that these properties did experience 'mortality episodes' during the period of interest. It is interesting to note the findings from descriptive summaries and univariable screening (see Appendices 8.3 to 8.5). The QLD North Gulf and the NT VRD did appear to be selling steers at a younger age than other regions (**Error! Reference source not found.**). Additional research ay be required to investigate these differences.

Table 12: Mean percentage steer deaths (deaths per 100 steers per year) for each factor in the multivariable model. All means are adjusted for other factors included in the model.

Variable	**Level**	**Mort**	**se**	**95% CI Lower**	**Upper**
Region					
	QLD S Gulf	5.64	1.13	3.43	7.85
	Qld N Gulf	93.17	24.19	45.76	0.00
	NT Barkly	11.19	2.69	5.91	16.46
	NT GKSt	34.50	16.04	3.05	65.95
	NT Alice Spr	6.94	2.73	1.59	12.29
	NT VRD	47.55	13.70	20.69	74.40
	Kimberley E	4.08	0.67	2.76	5.40
	Kimberley W	3.54	0.96	1.67	5.42
	Pilbara	6.68	0.74	5.24	8.13
Age when most steers are sold					
	up to 1 yr	4.66	0.52	3.63	5.69
	1-2 yrs	9.96	2.36	5.33	14.59
	>2 yrs	21.68	5.28	11.33	32.02
Segregation of dry breeders					
	Yes	4.33	0.88	2.60	6.06
	No	11.79	1.08	9.66	13.91
Age when most cull for age cows are culled					
	Up to 11 yrs	5.04	0.85	3.37	6.70
	>11 yrs	14.68	1.97	10.82	18.55

There was increasing mortality risk as steers were kept for longer on properties. This is not solely due to steers having additional time during which the same mortality rate might be operating. A total of 100 steers kept for two years may be expected to have more total mortalities than 100 steers kept for one year even when the same mortality rate is operating, but they would still produce the same mortality rate when expressed as deaths per 100 steers per year. The results of the multivariable model suggest that the mortality rate is rising as steers age. It is not clear why this might be occurring.

An attempt was also made to compare the relative importance of the three factors in the final model (age when steers are sold, age when cull cows are culled for age, segregation of dry breeders), using population attributable fractions (PAF) (Figure 10). PAF is defined as the proportional reduction in average mortality risk that would be achieved by eliminating the effects of one particular factor, while leaving the effects of other risk factors unchanged.

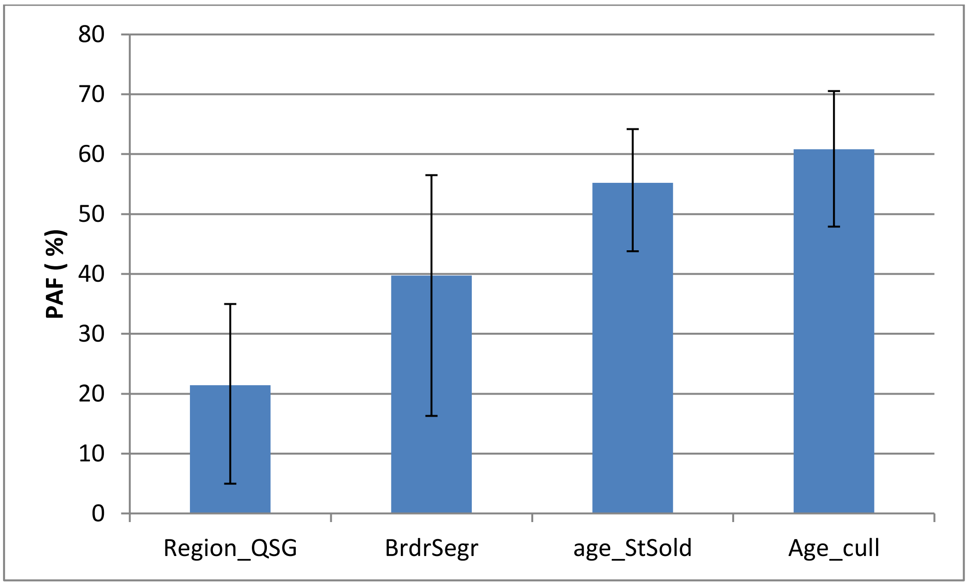

Figure 10: Population attributable fractions (PAF) for each of the five factors in the final model: region, breeder segregation in the dry season, age when most steers are sold and age when most cull cows are sold. Bars represent 95% confidence intervals.

Interpretation of the PAF values requires an understanding of the reference or baseline level. There was no immediately identifiable reference level for region so the approach used was to assume that all properties implemented changes such that their performance was made equivalent to the QLD Sth Gulf performance (one of the lower regional estimates for steer mortality). This is basically using an arbitrary baseline level to assess the impact on steer mortality if all of the effects associated with region were removed. The result (reduction in steer mortality of 21.4%) indicates that factors operating at the regional level (other than the 4 other fixed effects included in the model) continue to provide the most important contribution to steer mortality. This is interpreted as a simple measure of the relative importance of regional effects on steer mortality.

For age when steers were sold, those properties that sold steers at up to 1 yr. of age had the lowest steer mortality. If the effect of this variable was removed, then the impact would be an expected 55% reduction in steer mortality. The PAF measures for breeder segregation during the dry and for the age at which cull-for-age cows are culled, are not considered to represent factors related to steers. They are more likely to represent unmeasured factors related to general property management and reflect the likelihood that two similar properties may have different steer mortality rates because of some differences in management. It is not possible to identify what these factors might be from the dataset and analyses used in this report. The value of this finding is more general in indicating that unmeasured management factors have the potential to influence steer mortality risk and therefore more effort should be directed at understanding the differences between properties with respect to steer management practices that might explain some of the variability in steer mortality risk.

4.6 Tool for estimation of breeder mortality

The calculations used to generate estimates of mortality were implemented in Microsoft Excel®. The approach then used was to develop a spread sheet template into which producers could enter their own livestock scheduling data. The built-in formulae will then perform the calculations to generate mortality estimates. The template, once fully tested, would be a useful tool for producers to access.

Two forms of the tool have been produced.

4.6.1 Mortality tool version 1

The first is a simpler tool that has the same structure as was developed and applied in all estimations used in this report. The tool has two worksheets. The first worksheet is labelled ***Data Entry*** and producers can directly enter their own assumptions and livestock counts.

The upper part of the data entry sheet requires answers to three questions:-

1. Number of years of data. There is capacity to manage up to 10 years of data.
2. Proportion of branded calves as female.
3. Expected death rate in non- breeding females. The default value is 0.03 (3%).

The lower part of the data entry sheet allows producers to input actual stock numbers – Opening numbers of females, breeders, steers, sales, purchases, natural increases and closing numbers for each category. Table 13 shows the first two years of data from an example file but the tool has the capacity to allow users to enter up to 10 years of data.

Table 13: Layout of the data entry worksheet from the mortality tool

Enter data and assumptions here	***please enter your data below***	
1. How many years of data are you going to enter?	5	
2. Proportion of branded animals that are expected to be female?	0.5	
3. Expected proportion of deaths per year in non-breeding females	0.03	
5. ENTER ANIMAL COUNTS BELOW FOR EACH YEAR		
Livestock schedule	**Year 1**	**Year 2**
Opening females	25,505	29,311
Opening breeders	18,293	16,331
Female sales	1,698	1,248
Female purchases	0	0
Closing females (adjusted count)	29,311	32,799
Rations - females	0	0
Closing females (adjusted count) + rations (female)	29,311	32,799
Branded count during year	11,527	10,183
Opening steers	6,686	11,101
Sales of steers	864	3,324
Purchase of steers	0	2,666
Closing steers (adjusted count)	11,101	16,264
Rations - males	20	18
Closing steers (adjusted count) + Rations (male)	11,121	16,282

Adjusted counts represent the best estimate for the number of live animals on the property at the end of the year. Conceptually this can be approached in different ways and alternative pathways are outlined here for females:

- yard counts of females through the year – sales + purchases + branded heifers + estimate of missing & alive females
- opening count of females (book entry) – sales + purchases + branded heifers – estimate of dead females

Rations represent known losses that should not be included in estimates of mortalities. It is assumed that properties will not include rations in the closing counts for females and males (adjusted counts). If rations are specified separately, then these are added to the closing count to produce a closing count + rations. This ensures that they are not included in the estimate of mortalities.

The second worksheet in the mortality tool then performs all the calculations and provides summary reports. See Table 14.

Table 14: Summary statistics derived from entered data for five consecutive years – 'inputs'

Summary from entered data	
Number of years of records	**5**
Opening females	132,959
Opening breeders	90,300
Female sales	20,674
Female purchases	0
Closing females (adjusted + rations)	131,078
Branded during year	52,517
Opening steers	35,145
Sales of steers	31,867
Purchase of steers	2,666
Closing steers (adjusted + rations)	29,349

The first output table provides a summary of the total animal counts (sums of all years of inputted data) entered by the user. The second output table provides further results including mortality estimates. See Table 15.

Table 15: Second output table from the mortality tool – 'outputs'

Calculations using entered data to derive additional estimates	
26,259	Count of branded heifers (Branded during year*0.5)
138,544	Closing females from schedule counts (Opening females+female purchases+brandings*0.5–female sales)
146,088	Adj'd females at risk #1 (Opening females+0.5*branded heifers+0.5*female purchases)
55,788	Adj'd count non-breeding females (Opening females-opening breeders+0.5*branded heifers)
7,466	Deaths in all females (Closing females from schedule counts- closing female number)
1,674	Deaths in non-breeding females (Adj'd non-breeding females*0.03)
5,792	Deaths in breeding females (Deaths all females-deaths non-breeding females)
26,259	Count of branded steers (Branded*0.5)
32,203	Closing steers from schedule counts (Opening steers+male purchases+brandings*0.5-male sales
49,607	Adj'd steers at risk #1 (Opening steers+0.5*branded steers + 0.5*steer purchases)
2,854	Estimated steer deaths (Closing steers from schedule counts-closing steer number)
135,751	Adj'd females at risk #2 (Opening females+0.5*branded heifers+0.5*female purchase-0.5*female sales)
33,674	Adj'd steers at risk #2 (Opening steers+0.5*branded steers+0.5*steer purchases-0.5*steer sales)
Mortality rate estimates	
5.11	female deaths per 100 females per year, using adjusted count #1 (not adjusted for sales)
6.41	breeder deaths per 100 breeders per year
5.75	steer deaths per 100 steers per year, using adjusted count #1 (not adjusted for sales)
Mortality rate estimates using adjusted denominators that incorporate adjustment for sales (#2)	
5.50	female deaths per 100 females per year, using adjusted count #1 (adjusted for sales)
8.47	steer deaths per 100 steers per year, using adjusted count #1 (adjusted for sales)

4.6.2 Mortality tool version 2

The second version of the mortality tool has additional refinements to allow more accurate adjustment of the denominator for each mortality estimate to account for movements of animal into and out of the herd. The approach involves asking users to indicate counts of animals that are sold, purchased or branded by month of the year for each year. More information on version 2 of the mortality tool and a detailed user manual on the use of both versions of the tool are included in Appendices 8.6 and 8.7 respectively.

5 Discussion

Some caution should be exercised in interpreting these results for a number of reasons. Firstly, it should be noted that data was used from a relatively small number of northern properties. It should also be noted that although this project used a random process to select co-operating properties, it was reliant on those producers who were interested and had sufficient records to be able to participate. This illustrates an element of bias in the data collected. It could reasonably be assumed that the mortality rates presented for the properties in this study may be representative of better managed commercial beef properties across the regions under study and may therefore be lower than any whole-of-industry estimate. It cannot be disputed that data from more properties would add value to what is presented here. The reliability of records is also cause for caution. Despite these cautionary notes, this report does provide a useful source of information for industry.

Generally, the extent of coverage and accuracy of property herd records were not uniformly high. Some properties had excellent records starting with templates for yard sheets and progressing to either book or computer records. Often yard counts were not recorded in a uniform way which made accurate transcribing to storage in an office book or computer haphazard. A simple and consistent method is essential and the absence of this reliable yard record makes interpretation and analysis of records difficult.

5.1 Summary of model results

The results from the multivariable models are considered to provide the most important indications of drivers or explanatory factors that may be contributing to risk of mortality (Table 16 and Table 17). Because of the limitations associated with the relatively small sample size, the significant explanatory factors from the univariable screening process may also offer insight into such factors.

Table 16: Relative risk estimates from the three multivariable models (female, breeder and steer mortality). More detailed results (standard errors, confidence intervals and p-values) are reported in the tables presented in earlier sections of this report.

		Relative risk estimates		
Variable	**Level**	**Females**	**Breeders**	**Steers**
Region	QLD S Gulf	reference	reference	reference
	Qld N Gulf	3.16	5.91	16.51
	NT Barkly	2.13	0.92	1.98
	NT GKSt	0.66	1.11	6.12
	NT Alice Spr	1.48	1.58	1.23
	NT VRD	4.20	5.67	8.43
	Kimberley E	1.28	1.20	0.72
	Kimberley W	0.50	0.39	0.63
	Pilbara	0.50	0.66	1.18
Age at last weaning				
	<11 yrs	reference	reference	not included
	11+ yrs	3.60	4.07	
Supplementary P				
	No	reference	reference	not included
	Whole herd	1.73	1.44	
	Part herd	1.28	1.82	
Segregation of dry breeders				
	Yes	reference	reference	reference
	No	3.02	3.95	2.72
Age at last weaning # Supplementary P				
Age wean	Suppl P			not included
11+ yrs	Whole herd	0.21	0.38	
11+ yrs	Part herd	0.34	0.29	
Age when steers are sold				
	up to 1yrs	not included	not included	reference
	1-2 yrs			2.14
	>2 yrs			4.65
Age when most cull for age cows are culled				
	Up to 11 yrs	not included	not included	reference
	>11 yrs			2.91

Table 17: Mean percentage death estimates (deaths per 100 animals per year) derived from multivariable models for females, breeders and steers. Female deaths are expressed as deaths per 100 females per year, breeder deaths as deaths per 100 breeders and steer deaths as deaths per 100 steers.

		Mortality rates		
Variable	**Level**	**Females**	**Breeders**	**Steers**
Region	QLD S Gulf	5.68	7.10	5.64
	Qld N Gulf	17.95	41.95	93.17
	NT Barkly	6.40	6.54	11.19
	NT GKSt	3.74	7.85	34.50
	NT Alice Spr	8.38	11.22	6.94
	NT VRD	23.85	40.24	47.55
	Kimberley E	7.27	8.52	4.08
	Kimberley W	2.86	2.77	3.54
	Pilbara	2.82	4.66	6.68
Age at last weaning	<11 yrs	4.58	6.15	Not
	11+ yrs	8.00	12.17	Included
Supplementary P	No	6.77	8.40	
	Whole herd	5.75	7.22	Not
	Part herd	4.96	8.22	Included
Segregation of dry breeders	Yes	4.58	3.31	4.33
	No	8.00	13.07	11.79
Age last weaned # P-supplementation				
Age wean	P-suppl			Not
<11yrs	No	3.60	4.30	Included
<11yrs	Whole herd	6.23	6.18	
<11yrs	Part herd	4.59	7.82	
11+ yrs	No	12.93	17.50	
11+ yrs	Whole herd	4.81	9.50	
11+ yrs	Part herd	5.67	9.12	
Age when most steers are sold	up to 1 yr	not	not	4.66
	1-2 yrs	included	included	9.96
	>2 yrs			21.68
Age when cull for age cows are culled	Up to 11 yrs	not	not	5.04
	>11 yrs	included	included	14.68

When the results from the three multivariable models are presented side-by-side (see above) the findings are consistent. There were some variables included in the steer mortality model that were not included in the two other models and vice versa. This is to be expected given the potential for some factors to be influencing female deaths and not steer deaths or vice versa.

It is important to note that the inclusion of female management factors in the steer mortality model (segregation of breeders in the dry season and age when most cull-for-age cows are sold), was only because these variables were considered likely to be indirectly representing unmeasured management factors at the property level that may be expected to have impacts on all cattle on the property. For example, properties that routinely segregate their breeders in the dry season may also be more likely to provide supplementary feed or generally apply a higher level of scrutiny and intervention into animal management.

5.2 Comparison of the three outcomes

Using the livestock inventory approach described in this report, the total female mortality rate is considered to be a more valid and less biased estimate of mortality than the breeder mortality estimate because the total female mortality rate required fewer assumptions in its calculation. As earlier mentioned, these assumptions revolve around not being able to accurately differentiate between non-breeders and breeders in all the supplied property data and the assumption that the non-breeder mortality rate is 3%.

It seems plausible that breeder mortality is higher than mortality in non-breeding females because of the additional stresses and risks associated with pregnancy and lactation. Most females on beef producing properties will be in the breeding population and therefore it is also reasonable to assume that breeder mortality is likely to be the major driver of overall female mortality. However, the livestock scheduling approach has more difficulty in measuring breeder mortality than female mortality, mainly because it is difficult to track animal transfers by breeder and non-breeder. In contrast it is relatively easier to track animal transfers (movement between age classes, sales and purchases) as females without consideration for whether they may be breeders or non-breeders. As a result, even though there may be more interest in breeder mortality, it is likely to be easier to estimate female mortality and female mortality is likely to be an indirect measure of breeder mortality. If female mortality rates are higher than benchmarks or targets then it seems reasonable to assume that this will be due mainly to elevated breeder mortality and that strategies may be required to address breeder mortality and perhaps to a lesser extent mortality in non-breeder females.

The overall steer mortality rates were higher than the rates reported for breeders and females and the region-specific steer mortality rates were higher than those for breeders and females in most but not all regions (Table **18**).

Table 18: Summary measures of unadjusted mortality rate for females, breeders and steers, presented for each region and overall. Derived from descriptive analysis.

	Mortality rate (deaths per 100 animals per yr)		
Region	**Female**	**Breeder**	**Steer**
QLD SthGulf	2.68	3.01	6.71
QLD NthGulf	11.14	17.84	24.89
NT Barkly	3.74	4.04	6.25
NT GKSt	5.86	11.30	13.93
NT Alice Spr	11.80	15.85	5.48
NT VRD	6.09	8.58	7.75
WA KE	5.46	7.58	7.52
WA KW	3.08	3.70	4.17
WA Pilb	7.14	10.68	17.97
ALL	5.64	8.03	8.80

The authors have some concern that steers may have more movement (sales and purchases) onto and off properties and that these movements may interfere with accurate estimation of denominators (animals at risk for mortality). There were also some concerns about whether properties may not routinely invest as much effort in keeping accurate records for steer numbers because steers may not be handled as much as breeding females. The combination of these factors means that there may be some increased level of uncertainty associated with the results reported in this report for steer mortality compared with female mortality. Further work is required to more accurately define steer mortality and associated causal factors.

There are a number of possible explanations for higher mortality rates in steers compared to females. Young male cattle as calves or weaners are believed to be at greater mortality risk than young female cattle because of management factors such as castration and dehorning and associated complications arising from poor hygiene, blood loss and Clostridial diseases. Another observation made during property visits was that often steers including male weaners were moved onto ‘river’ country to grow and finish before transfer or sale. Several property managers recalled mortality episodes where young male cattle in particular would bog and die in river systems or at the other extreme were lost during flood events.

From an epidemiological perspective, it would be more accurate to adjust the denominator in calculating death rates by including both purchases and sales and to do this to replicate the timing of these movements during each year. For example, females or steers that are sold in the first quarter of the year are at a lower risk of property mortality than those sold in the last quarter of the year. A similar effect on mortality occurs with purchases throughout the year. The formulae used in the mortality calculator do incorporate adjustment for female and male sales to determine the number of at-risk females and males.

5.3 Risk factors in the final models

5.3.1 Region

The region-specific mortality rate estimates are widely divergent. As noted previously the region specific estimates for mortality rate that were presented in the descriptive summaries are considered to offer the most valid summary measure of overall performance (Table **18**).

The unadjusted measures provide a useful measurement that can be used as a measure of performance for the regions. The highest mortality rates for females and breeders are in the QLD Northern Gulf and the Alice Springs regions, followed by the Northern Territory VRD and Western Australian Pilbara regions (female mortality) and the NT Gulf-Katherine-Sturt and WA Pilbara (breeder mortality). The steer results are similar with the highest mortalities reported in the QLD Northern Gulf and the WA Pilbara regions, followed by the NT Gulf-Katherine-Sturt region and the NT VRD.

The region specific estimates derived from the multivariable models may differ from the descriptive summaries. As indicated previously, region was included in the multivariable models partly in order to provide adjustment to other explanatory factors in the models. It is likely that region may be a proxy for a range of unmeasured factors that could be operating at either property or regional levels. The regional estimates for mortality that are derived from the multivariable model are adjusted for the effects of other factors included in the model (P-supplementation, dry season segregation of breeders, age of cows at culling or last weaning etc.). The variation between regions and the fact that some regions have elevated mortality rates is consistent with the suggestion that mortality rate problems may be more severe in some regions than others and that further work may be required to investigate reasons for higher mortality, with particular focus on identifying explanatory factors that may be amenable to interventions that can mitigate or reduce risk.

Another way to look at the mortality results is by using the median and percentile results as shown in Table 19. For example, using the female mortality rate as an indicator of breeder mortality rate, a mortality rate of 2.4% on a northern breeding property would signal to management that their breeder mortality rate is lower than the industry median for the north, and perhaps suggest that time and money spent on reducing breeder mortality further may be better spent in other areas of the business. Similarly if management found their female mortality rate to be 7.4% or higher, this would suggest more focus be directed at lowering mortality. Each situation should be looked at on an individual basis to consider the benefit/cost of lowering mortality.

Table 19: Summary of median, upper 25th percentile and lower 25th percentile mortality rates for all females, breeders and steers (deaths per 100 per year) based on adjusted counts at risk. Extracted from data in Figures 2, 5 and 8.

ALL	Female mortality rate	Breeder mortality rate	Steer mortality rate
Upper 25th percentile	7.4	11.7	11.1
Median	3.8	5.7	5.9
Lower 25th	2.4	2.2	2.4

5.3.2 Cow age

Cow age was represented by either age of cows when last weaned or the age of cows when they are most likely to be culled-for-age. It is argued that age of last joining, age at last weaning and age at culling are all related measures of cow age. Increasing cow age is generally associated with an increase in mortality risk.

A policy of last joining of cows at or under 10 years of age would appear to be sound policy if female mortality rates are to be minimised. Often property management will cite these females as their best breeders and 'in the prime of their life'. The analysis shows that breeding females over this age present the biggest mortality risk. This risk is likely to be accentuated when seasonal conditions are unfavourable.

With such a policy on the age at last joining, the analysis also supports the policy of weaning these cows the next year, under 11 years of age and subsequently culling those cows from the herd within the next 12 months, i.e. under 12 years of age.

Many northern properties already have such a policy in place and use this system to generate income from female sales and to accelerate the upgrading of their herd performance through superior genetics in their replacement heifers.

5.3.3 West season phosphorous supplementation

The evidence in this report suggests that wet season phosphorous supplementation has the potential to lower female and male death rates. An underlying message may be that supplementation with phosphorous should efficiently target females on the most phosphorus deficient country and the most susceptible cattle as opposed to attempting to supplement the whole herd. Ensuring adequate consumption of phosphorous during wet seasons on extensive properties can be problematic and may be the primary reason why wet season phosphorous supplementation is not more widely practised.

There was also an association between P-supplementation and lower death rates in older cows (properties where the age at last weaning was 11 yrs or higher), suggesting that there may be a larger benefit to feeding supplemental P in older cows. There were some inconsistencies in the results surrounding phosphorous supplementation and particularly the finding that properties that supplemented the whole herd appeared to have slightly higher mortality than properties where only part of the herd was supplemented.

There may be some indirect effects of management incorporated into this variable. Those properties where phosphorous supplementation is only provided for part of the herd may have either a higher level of supplementation or may have different methods of determining where and when phosphorous supplementation might be implemented when compared to those properties that indicated that they supplemented all cattle. In some instances, management had identified the most deficient phosphorous country on the property and supplemented only cattle running in these areas. The balance of the property may be only marginally less deficient in phosphorous or not deficient at all.

5.3.4 Segregation of breeders in the dry season

The segregation of breeders during the dry season was a significant factor associated with reduced mortality rates in females and males. Note that this factor was only included in the steer model because it was considered likely to be a proxy for general management.

This is considered likely to be a proxy variable and there may be a number of potentially different underlying factors associated with this variable. Properties that segregate breeders in the dry season are presumably also likely to be managing cattle differently and possibly managing land and pastures differently. More work is required to investigate possible explanations for why this variable might be contributing to reduced mortality rates.

When property managers were asked about segregation practices it was apparent that there was considerable variation. Some managers drafted pregnant dry breeders according to the stage of gestation determined at pregnancy diagnosis and either paddocked them onto favourable pasture or provided supplements. Some managers drafted breeders on their lactation status and/or body condition score. Our observations were that on some properties segregation did not occur every year and that it was dependent on season.

The management of the more at-risk breeders following segregation was also variable. Generally speaking, the higher risk breeders would be paddocked separately on superior pasture and supplemented with a nitrogen source.

5.3.5 Age when steers are sold

There appears to be a marked elevation in steer mortality for those properties that do not sell steers until >2 yrs. of age. There are wide confidence intervals associated with this estimate so the true impact may be variable. It seems plausible that this may also be associated with management and also environment in that properties that are in harsh environments may not turn off steers until they are older and it may be the harsh environment rather than the age of steers at run off that is the true driver of elevated mortality. It was not always clear from management whether all male and female cattle were vaccinated for Botulism to maintain immunity. Some managers reported not vaccinating cattle in their planned year of sale which may increase the risk of mortality in these animals. This risk would be further increased when sale cattle are missed in the sale muster.

5.3.6 Other variables

There were a number of other variables that were considered likely to be related to mortality in some situations and that were not retained in the final models. Only two of the co-operating properties did not vaccinate against Botulism and for this reason statistical analysis was not possible for this variable. Therefore, the results of this project in no way reduce the well-established importance of Botulism vaccination to help minimise cattle deaths across northern Australia.

There were no significant associations between nitrogen supplementation during the dry season and female or male mortality rates. This is surprising considering the available industry and research evidence to support the benefits of nitrogen supplementation during the dry season.

There was also no significant effect on female and male mortality associated with fire, flood and drought events. This is most likely due to the fact that management practices were in place to largely counter these effects, e.g. segregation of breeders during the dry season and early sales or transfers. Some property managers however did recall huge episodic deaths due to floods in the northern regions and drought in the more southern regions.

5.4 Mortality calculator

A simple tool was produced by developing a template in Microsoft Excel® that contained built-in formulae with cells where users (producers or consultants) may enter data relating to standardised inputs and the tool can then estimate mortality for various classes of cattle. The template may be made available to stakeholders as a downloadable file from the MLA web site.

It is suggested that the mortality calculator tool offers a useful tool for the northern industry that may contribute in turn to interest in improved record keeping and potentially to improved productivity through lowered mortality rates. To use the breeder cow mortality calculator as recommended in this report, the minimum inputs must be accurate if there are to be meaningful mortality estimates over time. These minimum inputs are:

- Opening total female number
- Opening breeder number
- Branded number
- Female sales
- Female purchases
- Closing book female number.

A consistent approach to determining the number of breeders at the start of the year is essential. This is best achieved on the basis of age alone rather than on whether heifers and cows are actually joined to the bull. Differentiation between non-breeders (entire females and spays) and breeders is useful. Recording purchases and sales by month or quarter will allow the application of formulae to more accurately estimate at risk animals and as a result more accurately measure mortality.

Similar basic records are required to calculate steer or male death rates:

- Opening male number (excluding herd bulls)
- Male sales (excluding herd bulls)
- Male purchases (excluding herd bulls)
- Closing book male number (excluding herd bulls).

On some properties male calves are not castrated and remain entire until transferred or sold, hence it is preferable to record these as male calves and to avoid the terminology of steers.

5.5 Comparison to the literature

During a 1987 survey in the Northern Territory (GRM International, 1987), producer estimates of breeder cow mortality were 4.9% (Alice Springs region), 6.7% (Darwin and Gulf districts), and 7.1% (Victoria River district). The level of confidence in these records is questionable, given the accuracy of property record keeping. These producer estimates are considerably lower than this project's indicative breeder mortality rates of 15.85%, 11.3% and 8.58% for the Alice Springs, Gulf/Katherine/Sturt Plateau and Victoria River District regions respectively despite the fact that there have been massive changes to the genotype, level of supplementation and vaccination programs in the past 25 years.

Twenty years later, producers in the Northern Territory estimated breeder mortality at 3% in an NT survey (Oxley et al, 2006). The results from this survey point to producers generally under-estimating their breeder mortality rates. The Northern Territory breeder mortality rates from this project ranged from 4.04% in the Barkly region to 15.85% in the Alice Springs region.

Pratchett (1989) measured branding rates, breeder mortality and steer mortality in an extensively managed, low input herd in the East Kimberley from 1980 to 1988. The herd was mustered once per year in some years and twice per year in other years. Calves were not weaned. The average breeder mortality rate was 11%. The average steer mortality rate was 8%. The indicative breeder mortality rate in the East Kimberley as part of this project was found to be 7.58%. Breeds, management practices and property infrastructure has changed greatly since the 1980s, so given the nature of the country and the low level of management in a herd of Shorthorn cows with Brahman bulls, caution is warranted in comparing the average breeder mortality rates.

Pratchett also looked at the impact of three different management systems on production outcomes in a smaller controlled trial. Of interest was that controlled mating gave no advantage in reducing breeder mortality rates and resulted in lower weaning rates compared to uncontrolled mating. This is in contrast to the significant association found as part of this project between controlled mating and lower breeder mortality. Mean breeder mortality rates of 9% were found in herds that were mustered twice per annum, weaned to 140 kg twice per annum and continuously mated. The mean mortality rate increased to 18% when the herd was mustered twice per annum, there was no weaning and the herd was continuously mated.

Work by McCosker et al (1991) in the Darwin region and by Sullivan et al (1992) in the lower Gulf region of the Northern Territory recorded an average breeder mortality rate of 11.5% over nine years in a herd subjected to seasonal mating, weaning and year-round supplementation. Again this is comparable to the indicative mortality rate of 11.3% from this project for the Gulf/Katherine/Sturt Plateau region.

The breeder herd at Kidman Springs in the Victoria River District of the Northern Territory recorded an average mortality rate of 11.5% over an 11 year period ranging from 5.7- 24.8% (Jayawardhana et al, 1992). This is comparable to an indicative breeder mortality rate of 8.58% from this project for the Victoria River District. In cows aged 9-13 years at Kidman Springs over the same time frame, the mortality rate was 38%.

Brown et al (1994) provided data from a trial to assess wet season supplementation on a Gulf property in the Northern Territory between 1984 and 1990. Reproductive and mortality rates were recorded in a herd of around 570 Brahman breeders with a continuous mating system, weaning once a year with generally only one muster per year. The breeder cow mortality rate ranged between 11% and 28%. In 1987 and 1989 with just under average annual rainfall, the recorded mortalities were 11% and 13%. In 1986 and 1988 when less than half the average annual rainfall was recorded, the breeder mortality was 19% and 28%. These results can be compared to this project's breeder mortality rate of 11.3% for the Gulf/Katherine/Sturt Plateau region.

Work by O'Rourke et al (1995) between 1981 and 1990 on Kidman Springs with a herd of 542 Droughtmaster/Shorthorn cross cows involved weaning at least once per year at the weaning weight of 100 kg. The breeders were mustered three times per year. Breeder age, calving and yearly seasonal conditions had significant associations with mortality and branding rate. Age-associated annual mortality rates were similar at 9-12% for breeders aged 2-9 years, and then sharply increased from 10.3% to 37.9% between the ages of 9 and 13 years.

The average annual cow mortality rate of 11.5% was much higher than in similar work at Swans Lagoon where cow mortality was 1-2%. The authors speculated that the difference in mortality was due to a number of factors at Kidman Springs including:

- Less favourable environment,
- Less property subdivision,
- Year round mating,
- Limited culling for age,
- No strategic supplementation during poor seasons.

The results from this project support these factors as being associated with higher breeder mortality rates.

Cobiac (2006) reported the results of a trial at the Kidman Springs Research Station during 1995 to 2001 to evaluate the breeding efficiency of several *Bos indicus* and *Bos indicus*-cross beef cattle herds when run under a customised management system (The Best Bet Management System or BBMS). Seasons and pasture production during the trial period were reported to be favourable. Mortality averaged 2.1% per annum across all herds, indicating that best bet management system for the region successfully minimised the stresses associated with the environment. This mortality rate is low in comparison to this project's indicative breeder mortality rate of 8.58% for the Victoria River District. In addition, 52% of cows that died as part of this trial were nine years or older. Older cows (nine plus years) had twice the risk of dying than did younger cows (four to eight years). This last result is consistent with this project's finding that the relative breeder mortality risk for those properties where cows were last weaned at ages greater than 11 years, was 1.98 times higher than the risk of mortality in properties where cows were last weaned at ages up to 11 years.

Pastoral returns completed by producers in northern Western Australia suggested an average annual breeder mortality of 3.6% over a period from 1985 to 2007 (Niethe et al, 2008). The results from this project show the breeder mortality rates of 10.68% (Pilbara), 7.58% (East Kimberley) and 3.7% (West Kimberley).

Dray et al (2011) in a survey of the Pilbara and Kimberley, asked pastoralists to estimate their 2009 and 2010 mortality and weaning rates. Estimated breeder and old cow mortality rates over the two years ranged around 4% to 8% per annum. Old cows were nominated as over 9 years old. These results should be interpreted with some caution since many pastoralists did not have accurate cattle inventory records.

From a north Queensland perspective, O'Rourke et al (1995) analysed long-term records at the Swan's Lagoon research station in coastal north Queensland and found that in two different cohorts, the mean cow mortality rate was 1.7% and 1.2%. In poor seasons this increased to up to 30-40%. In comparison, this project found the breeder mortality rate in the southern Gulf of Queensland and northern Gulf of Queensland to be 3.01% and 17.84% respectively. As earlier noted, the confidence interval for the northern Gulf is large, making this result less reliable. The level of management in coastal northern Queensland is substantially more intensive than in the Queensland Gulf.

In the Smart Manager project, Kernot (2004) used data and information provided by producers predominately in the northern Queensland Gulf, to create herd and business benchmarks so that individual producers could measure their improvement in performance. Producers were considered to invariably over-inflate branding rates and significantly under-estimate death rates. Smart Manager utilised the BCOWPLUS stable herd model as the platform for estimation of property level production outcomes between 1998 and 2000. The female death rate ranges from 2-9%. Given concerns over accuracy of producer estimates of some key inputs and the relatively extensive nature and poor fertility of some of the districts benchmarked, the breeder death rates are lower than expected. The authors speculate that these results are due to husbandry practices such as early weaning and supplementation in predominantly *Bos indicus* herds. The results from this project indicated a breeder mortality rate of 17.84% with a 95% confidence interval ranging from 2.42% to 33.26%

Fordyce, Tyler, and Anderson (1990) reported that 21% of cows died in a herd of 802 Brahman cross cows in a 7,000 ha paddock in the Charters Towers district with twice-yearly handling during the severe drought of 1982-83. According to the authors, cows more advanced in pregnancy and those in poorer condition in the early stages of the drought had lower survival probabilities. Cows aged over 7 years also generally had a reduced probability of survival. These findings are consistent with the results of this project.

Overall, it appears producers under-estimate breeder mortality rates, while the available research supports the indicative breeder mortality rates found in this project.

5.6 Industry implications

First and foremost, industry needs to recognise that breeder mortality rates are considerably higher than estimated by many producers. This recognition will be assisted by improved record keeping which will enhance estimates of not only mortality rates but other important herd benchmarks. The mortality calculator tool developed as part of this project should form the platform for what records need to be kept at the property level. Consideration was given to producing templates for record keeping to be used in the cattle yard and in the office. However, discussions with property managers and our own experience tells us that no single template would be suitable for all properties. Devising standalone templates is further complicated by the use of the National Livestock Inventory System (NLIS) and its associated electronic record keeping and reporting for management purposes which should greatly enhance animal records and productivity. The adoption of good record keeping and the mortality calculator will allow the managers of extensive northern properties to more accurately assess their mortality rates in all females, breeders and male cattle. This is turn will lead to improvements in herd and financial performance.

It was apparent that there was a wide variation in management policy towards age of last joining, at last weaning and age at culling. Many property managers had a firm policy of culling aged cows at around 10 years of age, while others saw no sense in culling what they perceived to be their most fertile and productive breeders. The outcomes of this project support previous findings and best practice recommendations that breeders are culled under 12 years of age. This means joining cows for the last time at no older than 10 years of age and their calves weaned no older than 11 years of age. This project and other work confirms that this age group of breeders are the highest at-risk of death class of animals on extensive northern cattle properties.

The dry season segregation of breeders appears to be a well adopted practice in some regions and not others. This is probably a reflection of the individual stage of property development rather than a regional influence. This is an aspect of management which appears not to have been widely investigated under commercial research conditions. Segregation of large numbers of breeders during the dry season requires careful planning, a high level of operational ability and a certain level of fencing and water infrastructure. Critical components for success include meeting breeder nutritional requirements with pasture management, supplementary feeding, and culling of empty dry females. Although there is no obvious direct link, there was a strong association between controlled mating and lower female mortality rates. It is speculated that this outcome is linked to more intensive management of which controlled mating is one component.

More information is required to provide clarity on the association between P-supplementation and mortality risk. There does appear to be a benefit of P-supplementation but there are concerns over why there might be a difference between part herd supplementation and whole herd supplementation. More detailed work may be required to understand this discrepancy.

An Excel spread sheet tool has been developed as part of this project that producers can use to enter counts of livestock over several years in order to generate estimates of mortality rate. The tool has been produced in two versions. Version 1 is a simpler version and is based directly on the approach used in this report. Version 2 has a more detailed approach to collection of data from users and in particular asks users to enter month-by-month counts for animal sales, purchases and brandings. This enhancement has been implemented in an attempt to ensure that accurate estimates of rate denominators can be produced. The authors are confident that this more detailed tool has the potential to produce unbiased estimates of mortality.

Although not one of the stated objectives of this project, it is important to reflect on the economics of changing management practices in order to lower breeder cow mortality rates. Examination of the potential benefit/cost of reducing mortality can be complex and should ideally be examined on a property by property basis. This is because each property has its own starting point in terms of location, operational scale, land capability, climate, herd performance and existing management practices. Reducing mortality rates alone may not be sufficient to justify extra costs, however it is normal for management interventions which reduce mortality to have multiple beneficial effects on reproduction efficiency, weight gains and age of turnoff.

Recommendations

1. *Make available the mortality calculator tools to the beef industry along with material on how to use them and interpret the findings.*

   Those properties with limited herd records could use the basic level calculator (version 1). Properties where animal movements can be recorded month-by-month, the more detailed calculator (version 2) provides the most accurate and valid estimate of mortality rates.

   The mortality tool could be available as a downloadable tool and/or offered to extension personnel who can collect raw data and manage the use of the tool for the property owner/manager. Two issues need to be addressed: these are validating the raw data, and maintaining confidentiality of the data and results. Validating the raw data should involve interrogating management on their record keeping and management practices. Most producers are extremely wary of presenting herd records outside their immediate business.

2. *Consider incorporating the findings from this research into existing extension material concerning best practice for beef cattle properties in northern Australia.*

3. *Consider further prospective research to apply the mortality tool to beef properties and allow further validation and refinement using data collected specifically to ensure that all of the tool's capabilities are utilised.*

   It is suggested that further research will be required before the mortality tool could be used with confidence to support extension activities intended to lower mortality.

   It should be possible to incorporate additional modelling in any future research project by ensuring collection of data that could allow application of tools such as BCOWPLUS and DYNAMA. These tools may then allow quantification of benefit/cost of management practices to lower herd death rates.

4. *Further investigate causes of mortality in regions with the highest mortality.*

This may be achieved by inviting a number of properties in these regions to co-operate over a five year period to monitor cattle records, management practices and resulting mortality and fertility outcomes.

5. *Consider additional research to specifically understand the management practices that may be contributing to statistical associations between variables in this study and mortality outcomes, such as segregation of breeders in the dry season, P-supplementation, age of cows at last joining/weaning/culling.*

6. *Further investigate the indicative male mortality rates and explore explanations for an elevated mortality in steers and to identify strategies that may be applied to reduce steer mortality.*

   This may be achieved by working with a number of properties in several regions with highest mortality over a five year period to monitor cattle records, management practices and resulting mortality outcomes.

6 Conclusion

By adapting a livestock inventory approach and using actual property records, indicative mortality rates for all females, breeders and male cattle have been calculated for a sample of extensive northern properties between the years 2006 and 2011. The results confirm that many northern producers underestimate the mortality rates in their herds. The analysis of the data shows strong statistical associations between mortality rate and a number of management practices. A mortality calculator has been devised to allow producers to calculate their mortality rates over time. Knowing these mortality rates, producers can make informed management decisions on the implications to productivity and profitability by lowering mortalities. If the extensive northern industry is to benefit from these findings, there generally needs to be a much improved level of herd record keeping.

7 Bibliography

Bortolussi G, McIvor J, Hogkinson J, et al: The northern Australian beef industry, a snapshot. 2. Breeding herd performance and management. Australian Journal of Experimental Agriculture 45:1075-1091, 2005.

Brown A, Schlink T, Carpenter M: Production parameters of Brahman cross cattle in the Gulf area of the NT over 5 years. Technical Bulletin of the Northern Territory Department of Primary Industries and Fisheries 217:1-15, 1994.

Burns B, Fordyce G, Holroyd R: A review of factors that impact on the capacity of beef cattle females to conceive, maintain a pregnancy and wean a calf - Implications for reproductive efficiency in northern Australia. Animal Reproduction Science 122:1-22, 2010.

Buxton R, Stafford-Smith M: Managing drought in Australia's rangelands: Four weddings and a funeral. Australian Rangeland Journal 18:292-308, 1996.

Cobiac M: Productivity consequences of incorporating late maturing genes into a tropically adapted breeding herd in the Victoria River district, NT - The Kidman Springs genotype trial, 1995-2001. Technical Bulletin of the Northern Territory Department of Primary Industries and Fisheries 324:1-70, 2006.

Coventry J: Herd health and performance on Westside Mount Riddock Station, NT: A report on a five-year study (1991-1996), Department of Primary Industries, Fisheries and Mines, NT, 2007, pp 1-44.

Dixon R: Improving cost-effectiveness of supplementation systems for breeder herds in northern Australia. Project number DAQ.098. Meat & Livestock Australia, Sydney. 1998.

Dixon R, Coates D, Holmes B, English B. and Rolfe J: Phosphorous nutrition and management – overcoming constraints to wider adoption. Proceedings, Northern Beef Research Update Conference, 2011.

Dray R, Huey AM, Fletcher M, Stockdale M, Smith PC (2010) Final report B.NBP.0628 – Pastoral Industry Survey of the Kimberley and Pilbara regions, Western Australia – 2010. Meat & Livestock Australia, North Sydney, 2010.

Fordyce G, Tyler R, Anderson V: Effect of reproductive status, body condition and age of *Bos indicus* cross cows early in a drought on survival and subsequent reproductive performance. Australian Journal of Experimental Agriculture 30:315-322, 1990.

GRM International: Northern Territory Pastoral Industry Study, Darwin, Northern Territory Government, 1987.

Holmes P, Stockdale M, Smith P, et al: Sustainable Commercial Beef Production in Pilbara Region of Western Australia, in Vol. 2010, p 45.

Holmes W, Sullivan M, Best M, et al: Representative Herds Templates for Northern Australia V1.00 – data files for Breedcow and Dynama herd budgeting software., in Vol. 2010.

Holroyd R, Fordyce G: Cost effective strategies for improved fertility in extensive and semi-extensive management conditions in northern Australia, Available at www.brahman.com.au, 1990.

Holroyd, R.G. and Fordyce, G. Cost effective strategies for improved fertility in extensive and semi–extensive management conditions in northern Australia. In: Range female management and fertility. 4th International Symposium on Animal Reproduction, Huerta Grande, Cordoba, Argentina, pp 39–60, 2001.

Jayawardhana G, McCool C: The effect of stocking rate on breeder productivity in the Victoria River district, Proceedings, NW Australia Pastoral Conference, Katherine, 1992 (available from NTDPIF).

Jubb T, Kerr J, Bolam M: Problem definition for veterinarians working with extensive beef herds, Proceedings, The Australian Association of Cattle Veterinarians, Brisbane, 1997 (available from The Australian Association of Cattle Veterinarians)

Jubb T, Vassallo R, Annand T: Estimating deaths in breeder-age female cattle in the Kimberley region of Western Australia. Australian Veterinary Journal 73:152-153, 1996.

Kernot J: Smart Manager, Project number NAP3.107. Meat & Livestock Australia, Sydney 2004.

McCosker T, O'Rourke P, Eggington A: Effects of providing supplements during the wet season on beef production in the Darwin district of the Northern Territory. Rangeland Journal 13:3-13, 1991.

McCosker T, McLean D and Holmes P: Northern beef situation analysis 2009. Meat & Livestock Australia, B.NBP.0518. 2010.

Niethe G, Holmes W: Modelled female sale options demonstrate improved profitability in northern beef herds. Australian Veterinary Journal 86:458-464, 2008.

Niethe G, Quirk M: A scoping study on potential beef production from the northern rangelands of Western Australia in relation to the supply chain. A report to the Department of Agriculture and Food, Western Australia, 2008, p 40.

Niethe G: New R and D for better herd health and productivity, Proceedings, Northern Beef Research and Update Conference (NBRUC), Darwin, 2011 (available from Meat and Livestock Australia).

O'Rourke P, Fordyce G, Holroyd R, et al: Mortality, wastage and lifetime productivity of *Bos indicus* cows under extensive grazing in northern Australia 1. Seasonal mating in the speargrass region. Australian Journal of Experimental Agriculture 35:285-295, 1995.

O'Rourke P, Fordyce G, Holroyd R, et al: Mortality, wastage and lifetime productivity of *Bos indicus* cows under extensive grazing in northern Australia 3. Comparison of culling strategies. Australian Journal of Experimental Agriculture 35:307-316, 1995.

O'Rourke P, Sullivan R, Neale J: Mortality, wastage and lifetime productivity of *Bos indicus* cows under extensive grazing in northern Australia 2. Continuous mating in the semi-arid tropics. Australian Journal of Experimental Agriculture 35:297-305, 1995.

Oxley T, Leigo S, Hausler P, et al: N.T. wide industry survey 2004., Katherine, Department of Primary Industry, Fisheries and Mines, 2006, p 49.

Petty S: The impact of once a year weaning of calves to 60 kg on breeder fertility and mortality in the Kimberley - Preliminary results. Proceedings of the Australian Society for Animal Production, 1994 (available from Australian Society for Animal Production).

Pratchett D: The benefits of weaning on cows in the Kimberley region of Western Australia. WA Journal of Agriculture 30:56-57, 1989.

Stockwell T, Smith P, Stafford-Smith D, et al: Sustaining productive pastures in the tropics. Managing cattle. Tropical Grasslands 25, 1991.

Sullivan R, O'Rourke P, Robertson D, et al: Effects of once-yearly weaning on some aspects of herd productivity in an extensive herd in the semi-arid tropics of northern Australia. Australian Journal of Experimental Agriculture 32:149-156, 1992.

Wicksteed L: The ability to sell cull cows and heifers - The key to profitable cattle production in the extensive country of north Queensland, Proceedings, Field Day Proceedings, North Queensland Branch of the Australian Society of Animal Production, Byrne Valley, Home Hill, December 1986.

8 Appendices

8.1 Template used to collect property data

Table 20: Template used to collect data during property visits

Breeder Cow Mortality Project							
Property Name:				**Property Code:**			
Property Manager:							
Date:							
Permission to access Waybills (NT only)		YES	NO	(Need written authority & PICs)			
Describe season:							
Cattle numbers:	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Average**	**L.O.C.**
All steers out/sold	0	0	0	0	0	0	
All steers in/purchased	0	0	0	0	0	0	
Net steer movement	0	0	0	0	0	0	
All females out/sold	0	0	0	0	0	0	
All females in/purchased	0	0	0	0	0	0	
Net female movement	0	0	0	0	0	0	
Opening breeders	0	0	0	0	0	0	
Branded	0	0	0	0	0	0	
Branding Percent	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
Total opening number	0	0	0	0	0	0	
Total closing number	0	0	0	0	0	0	
Average total herd number	0	0	0	0	0	0	

Steer opening number	0	0	0	0	0	0	
Steer closing number	0	0	0	0	0	0	
Female opening number	0	0	0	0	0	0	
Female closing number	0	0	0	0	0	0	
Opening 2-3 yr. heifers	0	0	0	0	0	0	
Opening bulls	0	0	0	0	0	0	
Bull Percent	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
All bulls out/sold	0	0	0	0	0	0	
All bulls in/purchased	0	0	0	0	0	0	
Other							

L.O.C.= Level of Confidence: (1: accurate, 2: approximate, 3: best guess)

Breeder Cow Mortality Project	
Questions to ask	**Units**
Herd management:	
Joining age	years
Percentage of 1-2 yr. heifers joined	%
Percentage of 2-3 yr. heifers joined	%
Heifer retention rate (%)	i.e. Cows mated at 2-3 yrs./Heifers weaned
Peak calving month	

Age cows last joined	years	
Age cows last weaned	years	
Age most cull for age cows sold	years	(Year branded or mouthed?)
Female culling policy		
Spaying policy		
Pregnancy testing policy		
Age most steers transferred/sold	years	
Annual mustering efficiency	%	
Frequency of bang tail counts	years	
Effective property area grazed	hectares	(100 ha=1km2)
Annual, monthly, average rainfall records	mm	
Number of weaning rounds		
Supplementation program - P and N		
Genetics of herd		
Botulism vaccination		
Vibrio vaccination - bulls/heifers		
Heifer management		
Selection of breeders		
Bull physical examination		
Bull semen morphology test		
Controlled or continuous mating		
Dry season segregation of breeders		
Spike feeding		
Bulls age at first mating		
Bulls age at last mating		
Cattle number recording system		
Average cattle weights - see AECALC		

Average turnoff months - see AECALC

Wild dog control

Record fire/flood/drought events (describe seasons)

Tick prevalence

Number of paddocks, distance between waters. Land type and vegetation, pasture spp

8.2 Property selection

The following section outlines the methodology behind the selection of properties or the sampling procedure.

8.2.1.1 Pilot phase

Two pastoral companies were approached during the pilot phase and asked to participate by providing data from several properties for use in developing and validating the methods for data collection and estimation of animal mortality. These properties were not randomly selected.

A decision was made to retain these six pilot properties in the main part of the study because they had participated in the pilot work and because these properties were felt to be representative of many of the company properties across the regions of interest.

Additional properties were selected using a modified random process described in the following sections. Modifications to the random process reflected the eligibility criteria that were used to screen properties.

Sampling frame

Lists of property names were obtained for each of the regions of interest. These lists were then reviewed by a steering committee and sampling frames produced. A sampling frame is a list of eligible properties from which a random selection may be chosen. A target sample size was also identified for each region of interest.

In the Northern Territory, pastoral properties were arranged by NT pastoral districts and these were then aggregated into one of seven regions of interest for the purposes of this project. Some properties were removed from the denominator list because they were considered to not meet the eligibility criteria.

A similar review of property lists obtained for the Kimberley and Pilbara regions of WA resulted in two project regions being identified in each of these larger regions.

Property lists obtained for the northern or Gulf region of Queensland included properties within the boundaries of the two QLD Natural Resource Management bodies that together were considered to best represent the Gulf region of Queensland. These were the Northern Gulf Resource Management Group and the Southern Gulf Catchments.

In order to be eligible for inclusion in the sampling frame a decision was made to restrict the list to those properties that were 15,000 ha or larger. This step was necessary because the area of interest covered a wide part of northern Queensland from the western edge of the Queensland Gulf almost to the eastern coastline near Cairns. There were a large number of small properties included within an initial list and the choice of a 15,000ha cut off was made in an attempt to limit the sampling frame to extensive properties that were considered highly likely to be running larger scale beef enterprises and where breeder mortality might be more likely to be an important issue. In contrast it was considered that smaller scale enterprises may be more intensively managed and not be representative of the extensive enterprises being sought for inclusion in the project.

Properties were then assigned to a northern project region (Carpentaria, Croydon, Etheridge and Tablelands shires) and a southern project region (Burke, Cloncurry, Flinders, McKinlay, Mt Isa and Richmond shires).

This process resulted in a sampling frame covering 13 defined project regions from three states, with a total of 831 pastoral properties listed in this sampling frame. The selection target shown below is the targeted number of properties intended to be enrolled in the project from each of the project regions. See Table 21.

Table 21: Sampling framework and selection targets for each region.

State	Region	Total	Selection target	%
NT	Barkly	32	6	18.8
NT	Gulf + Roper	26	1	3.8
NT	Katherine	6	1	16.7
NT	Sturt Plateau	26	1	3.8
NT	VRD	25	3	12.0
NT	Nth Alice Springs, Tnt.Creek, Plenty	51	4	7.8
NT	Southern Alice Springs	25	2	8.0
NT	Subtotals	190	18	9.5
WA_Kimb	Halls Creek, Wyndham-East Kimberley	53	4	7.5
WA_Kimb	Broome, Derby-West Kimberley	42	2	4.8
WA_Kimb	Subtotals	95	6	6.3
WA_Pilb	East Pilbara, Port Headland, Roebourne	34	3	8.8
WA_Pilb	Ashburton	30	3	10.0
WA_Pilb	Subtotals	64	6	9.4
QLD	QLD southern part of the northern areas	336	3	0.9
QLD	QLD northern parts of the northern areas	146	3	2.1
QLD	Subtotals	482	6	1.2
TOTALS		831	36	4.3

8.2.2 Random selection

A column of random numbers was generated in Excel in an adjacent column to the sampling frame (list of eligible properties). Properties were arranged in separate lists for each region. The random number column was then sorted in ascending order (smallest to largest) to create a list of property names that was randomly ordered within each region such that the selection process could be started with the first property in each region and continue until the target was reached.

A number of properties larger than the selection target (2 to 3 times the selection target) were selected in this process from each of the project regions and these then formed the list of ***initial selected properties***. Separately developed selection criteria were then applied to these lists starting with the first selected property (Selection Number=1) in each region and working down. Properties deemed to not meet the selection criteria were excluded from further involvement leaving a list of properties that had been randomly selected and that met selection criteria (***eligible selected properties***). The number of eligible selected properties was purposefully set higher than the target number for each region in the expectation that some properties may either refuse to participate or may participate but either be unable to provide the required information because of incomplete records or be forced to drop out due to the circumstances outside of the control of the study (sale of property or some natural event such as flood or fire etc.).

A project team member then contacted each of the ***eligible selected properties*** and performed a brief check to ensure that the property met the selection criteria and also to ask if the property owners/managers were prepared to co-operate with the study. Those properties that either did not meet criteria or that did not wish to be involved, were removed from further involvement and additional properties were contacted until the target number of properties was enrolled for each region. It was suggested that the number of properties enrolled for each project region (***enrolled properties***) be 2-3 more than the selection target number for that region as discussed above.

- ***Initial selected properties***: 20 randomly selected properties from each region
- ***Eligible selected properties***: Each of the above properties was assessed in order of selection against the selection criteria until 10 properties were identified that meet the criteria.
- ***Enrolled properties***: In order of selection number, eligible selected properties were contacted by a project team member to ensure they met the selection criteria and that they were willing to co-operate. About 7 properties were enrolled from each region.

If the starting numbers did not result in sufficient enrolled and eligible properties in each region then additional ***initial selected properties*** were drawn from the sampling frame and subjected to the same assessment and enrolment process until the target number was achieved. To minimise the risk of not achieving regional target numbers, additional properties were randomly selected and contacted to cooperate. Even with this approach, a number of properties were not able to be visited for a variety of reasons, including wet weather, wildfires and property managers changing plans during visits to the various regions.

8.2.3 Criteria for selection

The following criteria were applied to ***initial selected properties*** by a review team. The review team included suitably qualified and experienced individuals (producers or consultants or Departmental advisors) familiar with each of the regions. The review team assessed the list of ***initial selected properties*** for each region starting in order of selection (Selection Number=1) and worked down until sufficient eligible properties were identified. The following criteria were used in this selection process:

1. minimum number of breeders, i.e. 1,000 breeders,
2. breeder herd which is largely, self-replacing and relatively stable in total number,
3. willing to co-operate through a property visit in 2011 and follow up communications,
4. commercially viable enterprise that may be considered typical or representative of properties in the region,
5. maintain adequate cattle records for at least five (5) consecutive years, i.e. sales, brandings, breeder number - likely to mean they can contribute meaningful data and information to the project.

8.2.3.1 Summary of representativeness

The final list of properties that were enrolled in the main data collection part of the study were comprised of six properties that were selected in a non-random process during the pilot phase of the study and a further 39 properties that were selected in a modified random process. Modifications to a simple random selection process were employed to ensure that selected properties met various eligibility criteria and were likely to have sufficient records to be able to participate fully in the study. The purpose of employing some form of random selection was to ensure that properties that were selected in the study could be considered to be representative of the broader population of interest.

The approach of contacting more eligible properties than the target number in each region was adopted as a cost effective mechanism to ensure that target numbers in each region were achieved, in the expectation that some properties would either refuse to participate or would enrol and then be forced to withdraw or be unable to participate fully due to factors outside of the control of the study team or the management of the property. In one case (NT Alice Springs) this resulted in fewer participating properties than was stipulated in the target list (3 instead of 4) and in other regions there were more participating properties than were targeted.

Overall, the participating properties were broadly representative of the population of interest. It is important to note that the population of interest is likely to be not reflective of all beef properties in the northern part of Australia because of the selection criteria applied in this study. It may be more appropriate to describe the population of interest as the those commercial beef breeding properties that are likely to be committed to understanding factors that influence animal health, productivity and welfare and to ongoing improvement in management to optimise their performance.

8.3 Female mortality results

8.3.1 Descriptive statistics

Summary statistics for average annual female sales is shown in Table 22.

Table 22: Summary statistics for average of annual female sales

	Count of female sales				
	n	**Average**	**se**	**Minimum**	**Maximum**
QLD SthGulf	6	3,373	865	569	6,617
QLD NthGulf	2	2,298	1,837	461	4,135
NT Barkly	6	7,671	1,790	1,655	14,127
NT GKSt	3	1,376	746	357	2,829
Alice Springs	4	576	244	133	1,212
NT VRD	4	3,204	895	1,066	5,289
Kimberley east	3	3,534	1,378	920	5,601
Kimberley west	5	2,086	226	1,422	2,590
Pilbara	3	1,134	398	535	1,886
Total	36	3,182	512	133	14,127

Summary statistics for average annual female purchases is shown in Table 23.

Table 23: Summary statistics for average of annual female purchases

	Count of female purchases				
	n	**Average**	**se**	**Minimum**	**Maximum**
QLD SthGulf	6	1,096	869	0	5,426
QLD NthGulf	2	0	0	0	0
NT Barkly	6	3,986	1,641	0	8,587
NT GKSt	3	206	106	0	350
Alice Springs	4	64	64	0	256
NT VRD	4	773	328	144	1,560
Kimberley east	3	606	606	0	1,819
Kimberley west	5	9	6	0	34
Pilbara	3	10	10	0	31
Total	36	1,010	374	0	8,587

Summary statistics for average of annual branding percentage are shown in Table 24.

Table 24: Summary statistics for average of annual branding percentage (number branded as a percentage of opening breeders)

	Branding percentage (percentage of opening breeders)				
	n	**Average**	**se**	**Minimum**	**Maximum**
QLD SthGulf	6	61.5	2.9	53.0	70.0
QLD NthGulf	2	64.7	1.9	62.8	66.6
NT Barkly	6	60.4	2.2	54.2	69.6
NT GKSt	3	53.4	7.2	44.2	67.5
Alice Springs	4	56.7	6.4	41.8	73.1
NT VRD	4	59.2	1.8	53.9	61.7
Kimberley east	3	62.1	2.8	56.5	65.1
Kimberley west	5	67.6	3.8	60.6	80.8
Pilbara	3	72.9	4.5	67.6	82.0
Total	36	61.9	1.4	41.8	82.0

Summary statistics for number of animals branded per year for each region are shown in Table 25.

Table 25: Summary statistics for number of animals branded per year for each region. Derived from those 36 properties with non-negative female deaths. Includes all animals branded (steers and heifers).

	Count of number of animals branded per year				
	n	**Average**	**se**	**Minimum**	**Maximum**
QLD SG	6	6,798	2,053	560	15,363
QLD NG	2	5,744	4,760	984	10,503
NT Barkly	6	13,220	3,741	4,402	30,349
NT GKS	3	2,626	1,173	1,443	4,972
NT ASpr	4	1,578	346	761	2,453
NT VRD	4	7,472	1,515	3,720	9,940
WA EKimb	3	8,388	3,202	1,987	11,797
WA WKimb	5	5,699	704	3,143	7,313
WA Pilb	3	2,447	967	1,099	4,321
Total	36	6,574	971	560	30,349

Summary statistics for count of total females at risk of mortality are shown in Table 26.

Table 26: Summary statistics for count of total females at risk of mortality (opening females + 0.5*branding + 0.5*female purchases). Used as the denominator in estimating female mortality rate and referred to as count of adjusted females at risk of mortality.

		Average count of at-risk females used in estimation of mortality rates			
	n	**Average**	**se**	**Minimum**	**Maximum**
QLD SG	6	15,896	5,158	1,531	36,787
QLD NG	2	16,034	13,183	2,851	29,218
NT Barkly	6	32,896	7,753	8,849	61,091
NT GKS	3	9,064	4,285	4,579	17,630
NT ASpr	4	3,982	656	2,166	5,299
NT VRD	4	22,182	4,620	10,301	30,314
WA EKimb	3	24,142	9,204	5,737	33,622
WA WKimb	5	12,855	1,800	7,060	16,616
WA Pilb	3	5,585	1,683	2,507	8,305
Total	36	16,948	2,364	1,531	61,091

The plot shown in Figure 11 shows the average annual rainfall for the period of interest to the study (average of records collected from participating properties in each region. The plot also displays the 95% confidence intervals for the average rainfall over the period of interest for the study. In addition the plot displays the long term average rainfall for the region (derived from all available property records), which in some cases was derived from up to 100 years of records.

Figure 12 shows the annual pattern of rainfall based on mean monthly rainfall (mm) for each region, for the period of analysed cattle records.

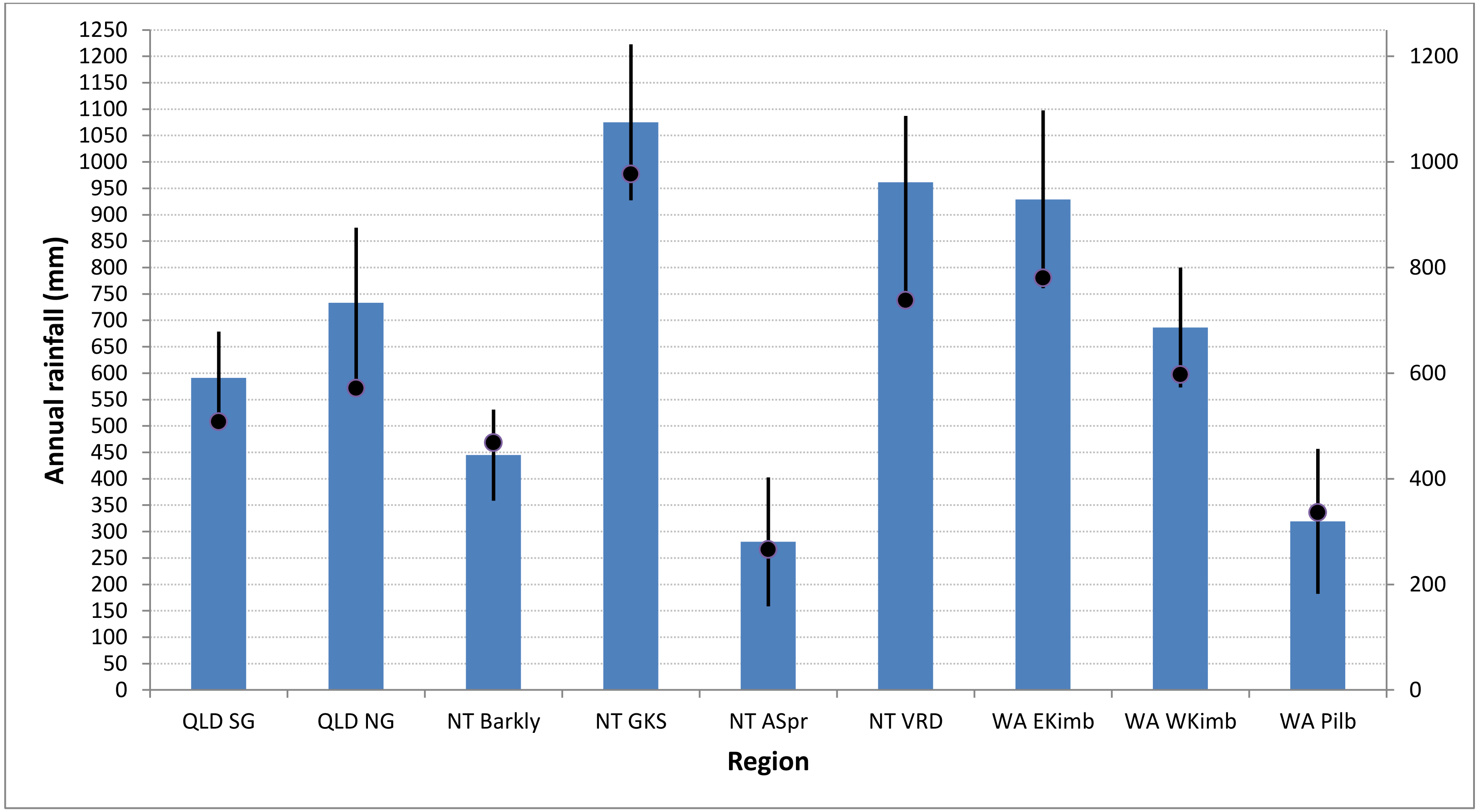

Figure 11: Summary of annual rainfall measurements by region. Blue columns represent mean annual rainfall derived from property records for the period coinciding with cattle records provided for the project. Bars represent 95% confidence intervals for the mean annual rainfall for the study period and the black circles represent the long term average (derived from property records or BOM records).

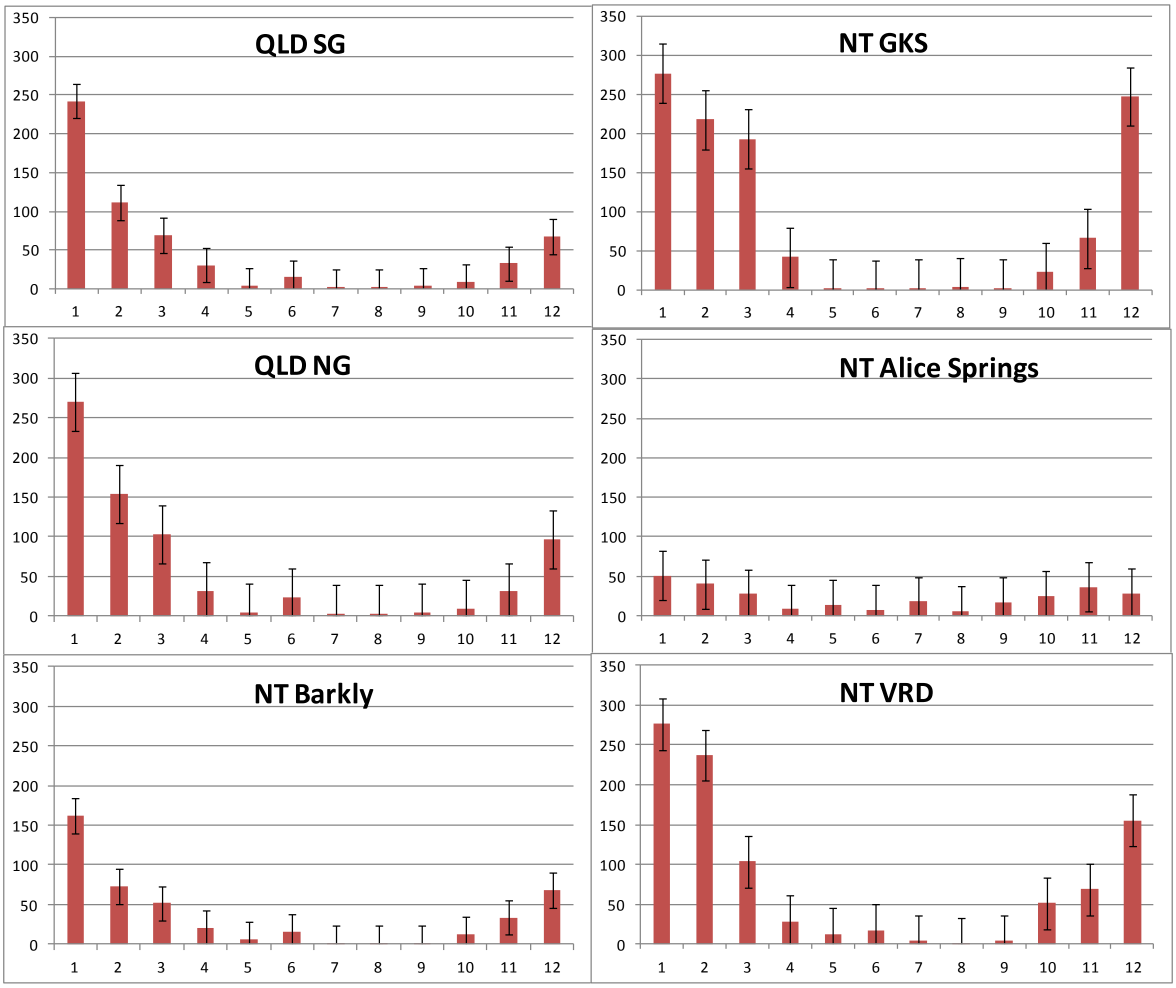

Figure 12: Mean monthly rainfall (mm) for each region, based on rainfall records provided by each property for the period coinciding with the period when cattle records were provided to the project team. Bars represent 95% confidence intervals.

The maximum and minimum annual rainfall measures were estimated at the property level and restricted just to the period of interest (the years covering the period of livestock data provided to the study). The range was calculated for each property as the difference between the largest maximum annual rainfalls for the period of interest minus the smallest minimum annual rainfall for the period of interest (Table 27).

Table 27: Annual rainfall estimates for each region covering the period coinciding with cattle records provided for this study.

		Annual rainfall		Minimum annual		Maximum annual			
Region	n	Mean	se	Min	se	Max	se	Range	se
QLD SG	6	603	54	239	29	1003	104	764	87
QLD NG	2	1033	121	546	160	1505	156	959	5
NT Barkly	6	459	70	244	89	757	79	513	83
NT GKS	3	1080	72	729	59	1365	106	636	162
NT ASpr	4	288	28	101	10	590	93	489	99
NT VRD	4	953	70	725	119	1161	63	436	124
WA EKimb	3	877	132	738	107	1132	217	394	110
WA WKimb	5	686	104	528	89	933	135	405	77
WA Pilb	3	290	27	181	49	423	7	241	44

8.3.2 Results of univariable screening of risk factors

A series of regression models (negative binomial models) were run using total female deaths as the outcome and the adjusted number of females as a measure of animal years at risk. Each candidate risk factor was then added to the model one at a time in a screening process. All models included region as a fixed effect and were performed using robust standard errors.

8.3.2.1 Rainfall

There was no statistical association between mortality rate and measures of annual rainfall (average, range, minimum annual, maximum annual or the ratio of range to average annual rainfall).

Monthly rainfall records for each property for the years of interest (years covering the period when livestock schedule data were provided to the project team) were used to estimate the length of the dry period in months. The dry period was deemed to have started in the month when total rainfall for that month fell below 50 mm, and to have ended in the first month after August when monthly rainfall exceeded 50 mm. In some cases the start and end month was adjusted if for example there was little rainfall in February or March and then heavy rainfall the following month. This process generated a crude annual measure of length of the dry period for each property. These measures were then used to derive overall measures of the dry period covering the years when each property provided livestock schedule data including average length of the dry (average of all the annual dry periods for each property), maximum dry period length, minimum dry period length, variance in annual dry period length, count of years when dry period length was longer than 8 months, and count of years when dry period length was longer than 9 months. The length estimates used in the threshold variables were based on the overall average dry period length (8 months) and the overall median dry period length (9 months).

The length of the dry period is acknowledged as a recognised factor likely to contribute to elevated mortalities in extensive beef production areas. There was no statistical association between mortality rate and measures of average length of dry, maximum length of dry, minimum length of dry, number of years when dry was longer than 8 months or the number of years when the dry was longer than 9 months.

An inspection of Figure 13 suggests that the regions with the highest female mortality rate appeared to have a range (difference between the highest and lowest rainfall during the study period) that greatly exceeded the average annual rainfall. This suggests that these regions experienced wide variability in rainfall during the study years, perhaps due to flooding.

It is not clear why this report has not identified any association between dry period length and mortality rate. It may be that the process of averaging several years of data into one measure as has been used in this report, may have obscured an association between annual rainfall and mortality in a specific year. There may also have been wider fluctuations during the study period with mortality due to both dry periods and flooding which may have interfered with statistical associations looking at effects of dry period length.

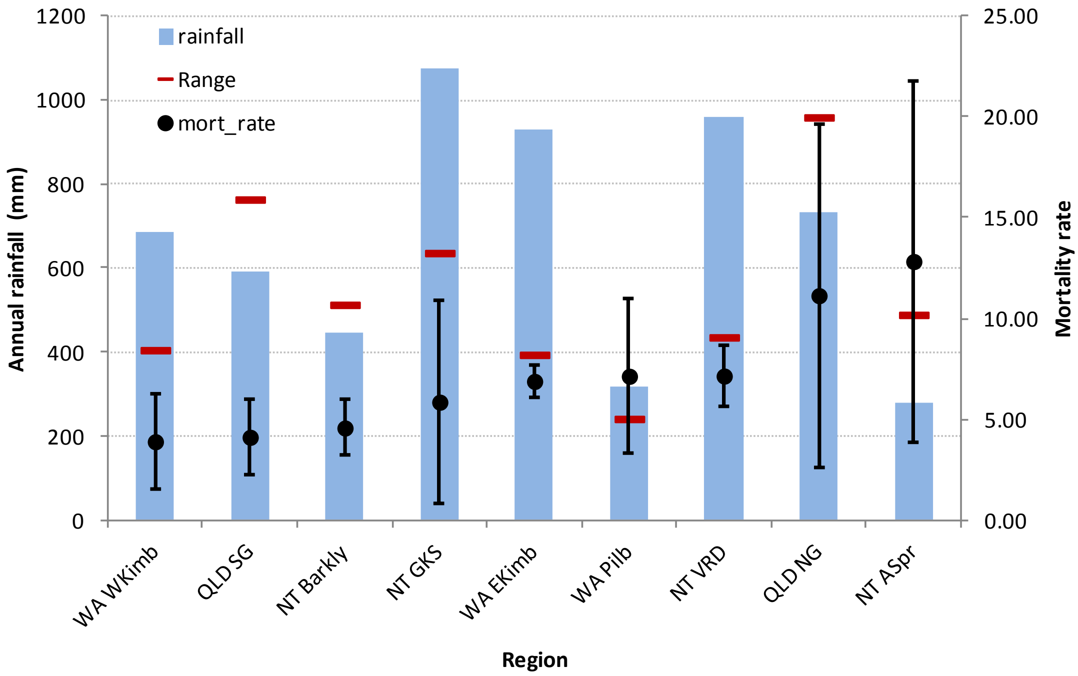

Figure 13: Combination plot showing average annual rainfall (blue columns), rainfall range expressed as the absolute difference between the highest and lowest annual rainfall during the period of interest (red bar), and the average annual female mortality rate (black circles with bars representing 95% confidence interval)

8.3.2.2 Record score

A score was recorded for the level of accuracy in records for each property. The scores were made by the project team members responsible for visiting and collecting data from each property and reflected a subjective level of confidence in the records from each property. Scores were recorded on a 3-point scale (1=accurate, 2=approximate, 3=best guess). Scores were assigned to each item of data (opening number of females, female purchases, closing number of females, and so on). An average score was then calculated for each property and then this score was used to produce region averages (Table 28).

Table 28: Summary statistics for record score (confidence in records) for each region

				95% CI			
Region	Count	Mean	se	Lower	Upper	Min	Max
QLD SG	6	1.5	0.36	0.79	2.21	1	3
QLD NG	2	1.2	0.14	0.90	1.43	1	1.33
NT Barkly	5	1.0				1	1
NT GKS	3	1.0				1	1
NT ASpr	4	1.7	0.25	1.25	2.22	1	2
NT VRD	4	1.1	0.03	0.99	1.11	1	1.1
WA EKimb	3	1.1	0.06	0.94	1.19	1	1.2
WA WKimb	5	1.4	0.25	0.90	1.90	1	2
WA Pilb	3	1.9	0.10	1.69	2.09	1.67	2
Total	35	1.3	0.09	1.16	1.49	1	3

There were differences between regions with respect to record score. The mean score for the Pilbara was significantly higher (lower level of accuracy) than for QLD NG, NT Barkly, NT GKS, NT VRD, and WA EKimb.

The mean score for NT ASpr was significantly higher (lower level of accuracy) than NT Barkly, NT GKS, NT VRD, and WA EKimb.

Other comparisons were not significantly different. There was no evidence for any statistical association between record score and estimates of female mortality rate, however this does not preclude either under or over estimation of mortality on individual properties.

8.3.2.3 Age at first joining

Properties were asked to indicate whether they first joined heifers under 24 months of age or over 24 months of age (Table 29).

Table 29: Count of properties in each region classified by management of age at first joining

	Count of properties			
Region	<24 mnths	>24 mnths	total	% <24 mnths
QLD SG	0	6	6	0
QLD NG	0	2	2	0
NT Barkly	2	4	6	33
NT GKS	0	3	3	0
NT ASpr	4	0	4	100
NT VRD	0	4	4	0
WA EKimb	1	2	3	33
WA WKimb	3	2	5	60
WA Pilb	0	3	3	0
Total	10	26	36	28

The regions with the highest percentage of heifers joined under 24 months were the NT Barkly, NT Alice Springs, WA East Kimberley and WA West Kimberley. This result may be partly explained by a relatively higher level of *Bos taurus* content in their heifers. There was no association between age at first joining and female mortality rate (p=0.5)

8.3.2.4 Month of peak calving

The count of the number of properties by region arranged by month of peak calving is shown in Table 30. For statistical purposes, the first two categories (Sept & Oct) were combined and the last three categories (Dec, Jan and Feb) were combined because of small sample sizes in each category.

Table 30: Count of the number of properties by region arranged by month of peak calving

Region	Sept	Oct	Nov	Dec	Jan	Feb	Total
QLD SG			5		1		6
QLD NG				1	1		2
NT Barkly		2	1	1		1	5
NT GKS		2	1				3
NT ASpr	3	1					4
NT VRD		1	2				3
WA EKimb	1		2				3
WA WKimb			3		2		5
WA Pilb		1	1	1			3
Total	4	7	12	3	4	1	34

There was no statistical association between month of peak calving and female mortality rate ($p=0.1$). If the sample sizes were greater, the analysis may have produced significant differences between peak calving months.

8.3.2.5 Use of spaying

The number of properties which spay in each region is shown in Table 31.

Table 31: Count of properties by region based on whether or not they spay female cattle at any time

	Count of properties			
Region	Yes	No	Total	% Yes
QLD SG	3	3	6	50
QLD NG	1	1	2	50
NT Barkly	1	5	6	17
NT GKS	2	1	3	67
NT ASpr	0	4	4	0
NT VRD	4	0	4	100
WA EKimb	3	0	3	100
WA WKimb	5	0	5	100
WA Pilb	3	0	3	100
Total	22	14	36	61

Properties that indicated that they did spay (spay=Yes) were then asked specific questions about application of spaying (Table 32).

Table 32: Count of properties by region that indicated particular applications for spaying: cull heifers, dry empty females, animals culled for age and animals to be culled for conformation.

region	Spay Yes	Cull heifers	Dry empties	Cull for age	conform
QLD SG	3	3	2	1	3
QLD NG	1	1	0	1	0
NT Barkly	1	1	1	1	1
NT GKS	2	1	1	2	2
NT VRD	4	4	4	4	4
WA EKimb	3	2	1	2	1
WA WKimb	5	3	2	3	3
WA Pilb	3	1	1	1	2
Total	22	16	12	15	16

The first column is the total count of properties in each region that used any form of spaying. The next columns provide counts of properties by region that use specific applications of spaying.

There was no statistical association between properties that did or did not spay and female mortality rate (p=0.2).

8.3.2.6 Age at which most steers are sold

The age class of when most steers are sold is shown in Table 33.

Table 33: Count of properties arranged by age class when most steers are sold

	Age at which steers are sold					
Region	<1 yr.	1-2 yrs.	2-3 yrs.	3-4 yrs.	4-5 yrs.	Total
QLD SG	3	1	1	1		6
QLD NG	1	1				2
NT Barkly	3	2	1			6
NT GKS	2	1				3
NT ASpr	2		1		1	4
NT VRD	4					4
WA EKimb		2	1			3
WA WKimb	1	2	2			5
WA Pilb			3			3
Total	16	9	9	1	1	36

For the purposes of statistical analyses, the upper three categories (2-3, 3-4, 4-5) were collapsed into one category because of small sample sizes. There was no statistical association between age class when steers are sold and female mortality rate (p=0.8).

8.3.2.7 Mustering efficiency score

Properties were asked to indicate their average mustering efficiency (Table 34)

Table 34: Count of properties by region according to estimated mustering efficiency

	Mustering efficiency		
Region	up to 80%	>80%	Total
QLD SG		6	6
QLD NG		2	2
NT Barkly		6	6
NT GKS	1	2	3
NT ASpr		4	4
NT VRD		4	3
WA EKimb	1	2	3
WA WKimb		5	5
WA Pilb	2	1	3
Total	4	32	36

There was no statistical association between mustering efficiency and female mortality rate (p=0.9).

8.3.2.8 Frequency of bang tail count

Information on the frequency of a bang tail count was collected and is shown in Table 35.

Table 35: Count of properties by region according to how often they perform a bang tail count

Region	5 yrs.	3 yrs.	2 yrs.	1 yr.	Never	Total
QLD SG		2			1	3
QLD NG	1	1				2
NT Barkly		2			2	4
NT GKS			1	1	1	3
NT ASpr	1			1	2	4
NT VRD		1	2			3
WA EKimb			1	1	1	3
WA WKimb		1			4	5
WA Pilb			1	2		3
Total	2	7	5	5	11	30

Categories were aggregated for statistical analyses into two categories: every 1 or 2 years, intervals of 3 yrs. or more (including those properties that indicated they never performed bangtail counts). There was a statistical association between categories of bang tail counts and female mortality rate (p=0.03), but the effect was counter-intuitive in that properties where bangtail counts were performed more frequently (every 1-2 years) appeared to have a higher female mortality rate compared to those properties where bangtail counts happened less frequently or not at all. It is possible that other reasons may be explaining this apparent effect such as those properties with higher mortality rates may be deciding to perform more frequent bangtail counts to get better information on mortalities.

8.3.2.9 Number of weaning rounds per year

Information on the number of weaning rounds per year was collected (Table 36).

Table 36: Count of properties by region classified by number of weaning rounds per year

	Number of weaning rounds per year			
Region	1	2	3	Total
QLD SG	1	5		6
QLD NG		1	1	2
NT Barkly		6		6
NT GKS	1	2		3
NT ASpr	1	2	1	4
NT VRD		4		4
WA EKimb		3		3
WA WKimb	2	3		5
WA Pilb	3			3
Total	8	26	2	36

The upper two categories were collapsed into category 2 for analysis because of the small sample size in the category of 3 weaning rounds. There was no statistical association between categories of weaning round and female mortality rate (p=0.5).

8.3.2.10 Joining maiden females separately to other breeders

Information on the whether maiden heifers were joined separately to other breeders was collected (Table 37).

Table 37: Count of properties by classification based on whether they joined maiden heifers separately to breeders.

	Separate joining - maidens		
Region	Yes	No	Total
QLD SG	6		6
QLD NG	2		2
NT Barkly	5	1	6
NT GKS	2	1	3
NT ASpr	2	2	4
NT VRD	4		4
WA EKimb	3		3
WA WKimb	5		5
WA Pilb	3		3
Total	32	4	36

There was no statistical association between this variable and female mortality (p=0.39).

8.3.2.11 Joining first calf heifers separately to breeders

The incidence of joining first calf heifers separately to other breeders is shown in Table 38.

Table 38: Count of properties classified by whether they joined first calf heifers separately to other breeders

	Separate joining - 1st calvers		
Region	Yes	No	Total
QLD SG		3	3
QLD NG		2	2
NT Barkly		4	4
NT GKS		3	3
NT ASpr	1	3	4
NT VRD		3	3
WA EKimb		3	3
WA WKimb	3	2	5
WA Pilb		3	3
Total	4	26	30

There was no statistical association between female mortality rate and the binary variable classifying whether or not properties joined first calf heifers separately to breeders (p=0.45).

8.3.2.12 Effect of fire, flood and drought

Properties were asked to indicate if they believed natural disasters (fire, flood, drought) had potentially impacted upon livestock and specifically breeder mortalities during the years representing the data they had provided to the project team for analysis (See Table 39).

In discussions during property visits, some managers reported instances in which heavy floods had resulted in significant deaths in breeders based on yard counts. Whilst fires and droughts impacted adversely on property operations, managers reported that implementation of appropriate strategies enabled them to reduce mortality risk in the breeder herd.

Table 39: Count of properties by region indicating that fire, flood or drought may have influenced livestock mortality rates during the period of interest

region	Total	Fire	Flood	Drought
QLD SG	6		1	4
QLD NG	2		1	
NT Barkly	6	1		4
NT GKS	3	1		2
NT ASpr	4	1		4
NT VRD	4	1		4
WA EKimb	3		1	
WA WKimb	5	1	2	2
WA Pilb	3			3
Total	36	4	5	23

Each of these variables was assessed as a binary variable (no, yes) in a screening regression with female mortality rate as the outcome. There was no statistical association between fire ($p=0.1$), flood ($p=0.4$) or drought ($p=0.8$) and female mortality rate.

The authors had expected to see some level of association between extreme climatic events and livestock mortality. There are a couple of possible explanations for why an association was not apparent. One is that analyses were conducted on aggregated data for each property. Although data were collected for each year, these data were aggregated into a single record for each property and used to produce average counts. The impact of a single year event may then be countered by adjacent years when losses might have been reduced. This approach was taken because in any one year cattle might be inadvertently missed and aggregating over several years would reduce this impact. Aggregated data were felt likely to better represent longer term trends and be less susceptible to single year unusual events. Another possible explanation is that northern beef producers exist in an environment where extreme climatic variation is the norm (wet vs. dry, droughts and floods and fire), and property managers are expected to manage their livestock to handle these events.

8.3.2.13 Age of females at last joining

Properties were asked about their policy on age of breeders at last joining (Table 40). Ages were determined by the age brand or ear tag applied at branding.

Table 40: Count of properties by region based on policy concerning age of breeders at last joining

	Age of cow at last joining (yrs)									No	
region	**7-8**	**8-9**	**9-10**	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**	**15-16**	**policy**	**Total**
QLD SG			2	2	2						6
QLD NG			2								2
NT Barkly			4		2						6
NT GKS		1	1		1						3
NT ASpr	2			1				1			4
NT VRD			4								4
WA EKimb		1	1					1			3
WA WKimb		1	1	1		1			1		5
WA Pilb				1		1				1	3
Total	2	3	15	5	5	2		2	1	1	36

There were so few properties in the older age categories that aggregation was necessary for analysis. Preliminary analyses were used to test assumptions before combining categories.

The lower two categories were combined to create one age class from 7 to 9 years. There was no statistical difference in mortality rate between cows joined at 7-9 yrs. and those joined at 9-10 yrs. (p=0.3). Based on this finding, a single age category was then developed as the baseline or reference category that included all age groups from 7 to 10 years.

Categories from 12-13 yrs. and older were then combined into a single category and compared to the 11-12 yrs. age category. There was no difference in female mortality rate between these two groups (p=0.2). These categories were then combined into a single category representing cows aged 11yrs or greater, and this category was compared to the 10-11 yrs. group. Again there was no difference (p=0.35) and the categories were combined into a single category representing cows aged 10 years or greater.

This process had collapsed the data into two age groups: up to 10 yrs., and greater than 10 yrs. These two groups were then compared and there was a statistically significant difference in female mortality rate (p=0.003). See Table 41.

Table 41: Female mortality rate (deaths per 100 females per year) by category of cow age at last joining. Derived from a model with region and age at last joining fitted as fixed effects. se=standard error, CI= confidence interval, RR=relative risk.

			95% CI		
Age at last joining	**Mort rate**	**se**	**Lower**	**Upper**	
Up to 10 yrs	4.29	0.50	3.31	5.28	
>10 yrs	8.03	1.49	5.10	10.95	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
>10 **vs** up to 10	1.87	0.40	1.23	2.83	0.003

The above table provides estimates of the female mortality rate for the two categories of age of cow at last joining. The bottom line of the table provides a relative risk that compares the two mortality rates. Properties where cows are last joined at ages >10 yrs. have a 1.87-fold higher female mortality rate compared to those properties where cows are last joined at ages up to 10 years. The inverse of this relative risk (1/1.87 = 0.53) provides an indication of the potential impact that reducing age at last joining may have (47% reduction in female mortality rate).

8.3.2.14 Age of females at last weaning

Data on the age of cows at last weaning is shown in Table 42. Ages were determined by the age brand or ear tag applied at branding.

Table 42: Count of properties arranged by region and category of age of cows at last weaning

	Age of cow at last weaning (yrs)									No	
region	**7-8**	**8-9**	**9-10**	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**	**15-16**	**policy**	**Total**
QLD SG				4	1	1					6
QLD NG				2							2
NT Barkly			1	3		2					6
NT GKS			1	1		1					3
NT ASpr		2			1			1			4
NT VRD				4							4
WA EKimb			1	1				1			3
WA WKimb		1		1	1		1		1		5
WA Pilb					1		1			1	3
Total		3	3	16	4	4	2	2	1	1	36

The same process for aggregation was used as described for age of cows at last joining with the only change being that every step was shifted one age group to the right.

Categories 8-9 and 9-10 yrs. were aggregated and compared to the 10-11 yrs. category. There was no difference in mortality rate (p=0.42) so these categories were collapsed into a single baseline group representing ages up to 11 years.

Categories 13-14 yrs. and older were collapsed into a single category and compared to 12-13 yrs. There was no difference in mortality rate (p=0.34) so these categories were collapsed into a single category aged 12 yrs. and older.

The 11-12 yrs. category was then compared to the 12+ category. There was no difference in female mortality rate between these categories (p=0.19) so they were combined into a single category representing cows aged 11yrs or greater at last weaning.

This produced a binary variable with age categories: up to 11 yrs., and >11 yrs. There was a tendency for a difference in female mortality rate between these two categories (p=0.08). See Table 43.

Table 43: Female mortality rate (deaths per 100 females per year) by category of cow age at last weaning. Derived from a model with region and age at last weaning fitted as fixed effects. se=standard error, CI= confidence interval, RR=relative risk.

			95% CI		
Age at last weaning	**Mort rate**	**se**	**Lower**	**Upper**	
Up to 11 yrs	4.67	0.62	3.46	5.88	
>11 yrs	7.36	1.57	4.28	10.43	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
>11 **vs** up to 11	1.57	0.41	0.94	2.63	0.080

The female mortality rate in those properties that completed their last weaning in cows aged up to 11 yrs. was 4.67 deaths per 100 females per year. The female mortality rate in those properties that completed their last weaning in cows >11 yrs. of age was 7.36 deaths per 100 females per year.

Those properties where cows at last weaning were aged >11 yrs., had a 1.57 fold higher female death rate compared to those properties where cows at last weaning were aged up to 11 yrs.

8.3.2.15 Age of cows at culling for age

Properties were asked to indicate the age at which most of their cull for age cows were sold (Table 44). Ages were determined by the age brand or ear tag applied at branding.

Table 44: Count of properties by region according to age of cows when most cull for age cows were sold

	Age of cow at cull-for-age (yrs.)									No	
Region	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	policy	Total
QLD SG				2	2		2				6
QLD NG				2							2
NT Barkly				3	1	1	1				6
NT GKS			1	1			1				3
NT ASpr		2			1			1			4
NT VRD				1	3						4
WA EKimb				1	1				1		3
WA WKimb		1			2			1	1		5
WA Pilb						1		1		1	3
Total		3	1	10	10	2	4	3	2	1	36

Data were aggregated into three categories that were broadly consistent with age groups used in other analyses:

- cows aged up to 11 yrs.
- cows aged 11-12 yrs.
- cows aged >12 yrs.

The explanatory factor representing age at which cull cows were sold has three levels. A separate statistical test was conducted to see if the overall explanatory factor was significantly associated with female mortality. There was a significant association between female mortality and age of cows at culling (cows cull for age), with p=0.01. In addition, comparisons were conducted between the three levels (pairwise comparisons). These also generate p-values which are presented in Table 45.

Table 45: Female mortality rate (deaths per 100 females per year) by category of cow age at culling. Derived from a model with region and age at culling fitted as fixed effects. se=standard error, CI= confidence interval, RR=relative risk.

Age culls sold	Mort rate	se	95% CI Lower	95% CI Upper	
Up to 11 yrs	3.98	0.52	2.97	4.99	
11 to 12 yrs	6.07	1.71	2.72	9.42	
>12 yrs	7.82	1.52	4.84	10.79	
	RR	**se**	**95% CI Lower**	**95% CI Upper**	**p-value**
11-12 **vs** up to 11	1.53	0.46	0.85	2.74	0.160
>12 **vs** up to 11	1.97	0.47	1.23	3.13	0.004
>12 **vs** 11-12	1.29	0.46	0.64	2.58	0.48

There was a progressive increase in female mortality rate as the age when most cows were culled for age increased. Comparisons of the mortality rates between age categories indicated that there was a significant increase in the female mortality rate for those properties where cull for age cows were mostly culled at ages greater than 12 yrs. compared to those properties that culled most cows at ages up to 11 yrs. (RR=1.97, p=0.004). Other comparisons were not significant.

8.3.2.16 Phosphorus supplementation

Properties were asked to indicate if they supplemented with phosphorus during the wet season. A binary variable was created indicating whether or not P-supplementation was provided (yes, no). If properties answered yes, they were asked to indicate whether supplementation was provided for the whole herd or only part of the herd (Table 46).

Table 46: Count of properties by region and whether or not they used supplementary phosphorus.

	P supplementation			
region	**No**	**Part herd**	**Whole herd**	**Total**
QLD SG	2	1	3	6
QLD NG	1		1	2
NT Barkly	1	2	3	6
NT GKS	1	1	1	3
NT ASpr	2	2		4
NT VRD	0	3	1	4
WA EKimb	1	2		3
WA WKimb	1	4		5
WA Pilb	3			3
Total	12	15	9	36

P-supplementation was not statistically associated with female mortality rate (p=0.5). See Table 47.

Table 47: Female mortality rate (deaths per 100 females per year) by category of phosphorus supplementation during the wet (no, yes). Derived from a model with region and P-supp. fitted as fixed effects.

P suppl during wet	Mort rate	se	95% CI Lower	Upper	
No	7.05	1.88	3.36	10.74	
Whole herd	5.26	1.21	2.88	7.64	
Part of herd	4.69	0.96	2.82	6.57	
	RR	**se**	**95% CI Lower**	**Upper**	**p-value**
No **vs** whole herd	1.34	0.45	0.70	2.57	0.40
No **vs** part herd	1.5	0.58	0.71	3.19	0.3
Whole herd **vs** part herd	1.12	0.39	0.57	2.2	0.7

Properties that did not supplement with P reported a 1.5 fold higher female mortality rate compared to those properties where P-supplementation was provided to part of the herd. The results indicate that P-supplementation has the potential to reduce the female mortality rate by up to 34%.

Insufficient information was collected during the study to accurately characterise differences in how properties might manage whole-herd supplementation from part-herd supplementation. Those properties that indicated that they supplemented only part of the herd may have a different approach to supplementation including using different forms of P-supplement, providing supplement at different rates or times of the year, different approaches to assessing whether not particular areas or cattle may be at risk of P deficiency and so on. Conversely properties that indicated they supplemented the entire herd may be putting out insufficient supplement even though it may be placed in all paddocks. In some instances, management had identified the most deficient phosphorous country on the property and supplemented only cattle running in these areas. The balance of the property may be only marginally less deficient in phosphorous or not deficient at all.

8.3.2.17 Nitrogen supplementation

Properties were asked whether nitrogen supplementation was carried out during the dry periods of the year (Table 48).

Table 48: Count of properties by region classified by whether or not they use nitrogen supplementation during the dry period. Properties that replied yes, were asked to indicate if they supplemented in a strategic sense (prior to a problem) or only in the face of a perceived problem.

		N supplementation		
region	**No**	**Strategic**	**Crisis only**	**Total**
QLD SG	2	4	0	6
QLD NG	0	2	0	2
NT Barkly	1	5	0	6
NT GKS	1	2	0	3
NT ASpr	0	1	3	4
NT VRD	0	4	0	4
WA EKimb	0	2	1	3
WA WKimb	0	5	0	5
WA Pilb	1	1	1	3
Total	5	26	5	36

A statistical model analysing the effect of nitrogen supplementation indicated there was no difference in female mortality rate for those properties that did not supplement nitrogen compared to those that did supplement (p=0.09).

Table 49: Female mortality rate (deaths per 100 females per year) by category of nitrogen supplementation during the dry (no, strategic, crisis). Derived from a model with region and N-suppl fitted as fixed effects.

			95% CI		
N suppl during dry	**Mort rate**	**se**	**Lower**	**Upper**	
No	11.87	5.61	0.88	22.86	
Strategic	6.19	2.59	1.12	11.26	
Crisis	3.67	1.89	0.00	7.27	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
No **vs** strategic	1.92	0.64	0.99	3.69	0.052
No **vs** crisis	3.33	2.96	0.58	18.98	0.2
Strategic **vs** crisis	1.74	1.54	0.3	9.9	0.54

There was also a tendency for strategic supplementation to be different to no supplementation but the p-value was not significant (p=0.052). Other comparisons were not significant. The small sample size in two of the levels may have interfered with the statistical power for these comparisons.

8.3.2.18 Botulism vaccination

The status of vaccination against botulism is shown in Table 50.

Table 50: Count of properties by region according to botulism vaccination status

	Botulism vaccination			
region	**No**	**Whole herd**	**Part herd**	**Total**
QLD SG		4	2	6
QLD NG			2	2
NT Barkly		2	4	6
NT GKS			3	3
NT ASpr	2	1	1	4
NT VRD		1	3	4
WA EKimb		2	1	3
WA WKimb		5		5
WA Pilb		3		3
Total	2	18	16	36

The overall effect of botulism vaccination on female mortality rate was associated with a p-value=0.06 (non-significant); however there were some interesting findings in the pairwise comparisons. The analysis and hence results were hampered by the fact that only two properties were not using botulism vaccination, meaning that there was a small sample size in this group for statistical comparisons. Refer to Table 51.

Table 51: Female mortality rate (deaths per 100 females per year) by category of botulism vaccination (no, yes). Derived from a model with region and Botulism vaccination fitted as fixed effects.

			95% CI		
Botulism vaccination	**Mort rate**	**se**	**Lower**	**Upper**	
No	10.58	6.81	0.00	23.94	
Whole herd	4.14	0.59	2.99	5.29	
Part of herd	6.39	1.30	3.84	8.84	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
No **vs** whole herd	2.56	1.72	0.69	9.54	0.16
No **vs** part herd	1.66	1.24	0.38	7.2	0.5
Whole herd **vs** part herd	0.65	0.16	0.39	1.07	0.09

The large confidence interval around the estimate for the Botulism=no category is because there were only two properties in this category (all others vaccinated). There was a large reduction in female mortality when botulism vaccination was undertaken regardless of whether part of the herd or the whole herd were vaccinated.

There was a reduced female mortality rate for those properties using botulism vaccination on the whole herd compared to those using it on part of the herd but the difference was not significant (p=0.09).

The study did not collect information on whether or not properties were using a two dose vaccine administered two initial vaccinations 4-6 weeks apart followed by an annual booster as per manufacturer recommendations. Producers that do not follow manufacturer recommendations run a high risk of deaths due to botulism if, for example, only an initial priming dose is given. The immunity given by this priming dose falls below protective level at around two month after injection, and the cost is almost certain to be much higher than the benefit to a small portion of the herd for which the dose might be effective because of recent prior experience.

8.3.2.19 Continuous mating vs. controlled mating

Properties were asked to indicate if they used continuous mating systems (bulls running with breeders all year) for breeding cows (yes, no). See Table 52.

Table 52: Count of properties by region and continuous mating status

	Continuous mating		
region	**Yes**	**No**	**Total**
QLD SG	2	1	3
QLD NG	2		2
NT Barkly	4		4
NT GKS	2	1	3
NT ASpr	4		4
NT VRD	3		3
WA EKimb	3		3
WA WKimb	4	1	5
WA Pilb	3		3
Total	27	3	30

This data is analysed against female mortality rates as shown in Table 53.

Table 53: Female mortality rate (deaths per 100 females per year) by category of continuous mating (no, yes). Derived from a model with region and mating system fitted as fixed effects.

			95% CI		
Continuous mating	**Mort rate**	**se**	**Lower**	**Upper**	
No	2.34	1.06	0.26	4.43	
Yes	6.56	0.84	4.91	8.21	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
Yes **vs** No	2.80	1.29	1.14	6.89	0.025

Those properties that practised continuous mating for cows reported a 2.8 fold higher female death rate compared to properties that did not practise continuous mating for cows. This result is likely to be related to general management factors rather than to some factor specifically related to continuous mating.

8.3.2.20 Dry season segregation for breeders

Data on the status of dry season segregation of breeders is shown in Table 54. Dry season segregation refers to the separation of breeders based on body condition or stage of pregnancy so they receive preferential pastures and/or supplementation.

Table 54: Count of properties by region and status of dry season segregation for breeders

	Continuous mating		
region	**Yes**	**No**	**Total**
QLD SG	3	2	5
QLD NG	1	1	2
NT Barkly	2	3	5
NT GKS	1	2	3
NT ASpr		4	4
NT VRD	3		3
WA EKimb	1	2	3
WA WKimb	1	4	5
WA Pilb		3	3
Total	12	21	33

There was a significant association between dry season segregation for breeders and female mortality rate (p=0.009). See Table 55.

Table 55: Female mortality rate (deaths per 100 females per year) by category of whether or not the property segregates breeders during the dry season (no, yes). Derived from a model with region and segregation system fitted as fixed effects.

Dry season segregation of breeders	Mort rate	se	95% CI Lower	Upper	
No	8.77	1.20	6.43	11.12	
Yes	2.56	0.39	1.81	3.32	
	RR	**se**	**95% CI Lower**	**Upper**	**p-value**
No **vs** Yes	3.42	0.78	2.19	5.34	<0.001

The relative risk of 3.42 between no dry season segregation of breeders and segregation of breeders indicates the female mortality benefits. Segregation of dry cows at the first round was reported to be the best strategy in the range of discussions with property owners and managers.

8.3.3 Multivariable model for female mortality rate

The following Table 56 presents the output from the final multivariable model, presented as relative risk estimates.

Table 56: Output from a final negative binomial statistical model using female mortality rate as the outcome of interest. Output expressed as relative risks (RR) and 95% confidence intervals.

						95% CI	
Variable	**Level**	**RR**	**se**	**z**	**p**	**Lower**	**Upper**
Region	QLD S Gulf	reference					
	Qld N Gulf	3.16	1.01	3.61	<0.001	1.69	5.90
	NT Barkly	1.13	0.31	0.44	0.659	0.66	1.92
	NT GKSt	0.66	0.26	-1.07	0.285	0.31	1.42
	NT Alice Spr	1.48	0.52	1.11	0.266	0.74	2.93
	NT VRD	4.20	1.06	5.69	<0.001	2.56	6.88
	Kimberley E	1.28	0.35	0.91	0.364	0.75	2.18
	Kimberley W	0.50	0.16	-2.12	0.034	0.27	0.95
	Pilbara	0.50	0.23	-1.48	0.139	0.20	1.25
Age at last weaning							
	<11 yrs	reference					
	11+ yrs	3.60	1.14	4.03	<0.001	1.93	6.71
Supplementary P							
	No	reference					
	Whole herd	1.73	0.54	1.75	0.079	0.94	3.21
	Part herd	1.28	0.24	1.32	0.188	0.89	1.84
Segregation of dry breeders							
	Yes	reference					
	No	3.02	0.48	6.95	<0.001	2.21	4.12
Age at last weaning # Supplementary P							
Age wean	Suppl P						
11+ yrs	Whole herd	0.21	0.12	-2.72	0.007	0.07	0.65
11+ yrs	Part herd	0.34	0.18	-2.04	0.041	0.12	0.96
Intercept		0.01	0.00	-15.63	<0.001	0.01	0.02

8.4 Breeder mortality results

8.4.1 Descriptive statistics

A summary of the adjusted opening non-breeder females and adjusted breeders are shown in Table 57 and Table 58 respectively. Adjusted counts represent the mathematically non-biased estimate of animals that are eligible to die in the period of interest. These animals form the denominator for mortality rate estimates and may be described as the at-risk animals (animals that are at risk of dying or eligible to die).

Table 57: Summary statistics by region for the count of at-risk non-breeder females (opening females – opening breeders + 0.5*(estimated branded females)

		Count of adjusted non-breeder females				adj	% of adj
	n	Average	se	Min	Max	females	females
QLD SthGulf	5	4,454	1,682	421	9,029	16,501	27.0
QLD NthGulf	2	7,360	6,077	1,283	13,438	16,034	45.9
NT Barkly	6	8,584	1,798	2,526	13,504	32,896	26.1
NT GKSt	2	4,395	2,813	1,582	7,208	11,306	38.9
Alice Springs	4	1,273	324	347	1,815	3,982	32.0
NT VRD	4	8,977	1,860	4,160	13,235	22,182	40.5
Kimberley east	3	10,768	4,283	2,218	15,482	24,142	44.6
Kimberley west	4	3,981	1,305	1,518	6,298	11,915	33.4
Pilbara	3	2,346	714	918	3,087	5,585	42.0
Total	33	5,865	831	347	15,482	17,456	33.6

Table 58: Summary statistics for at-risk count of breeders. Calculated as the at-risk count of females minus the at-risk count of non-breeders.

		Count of adjusted breeder females				adj	% of adj
	n	Average	se	Min	Max	females	females
QLD SG	5	12,047	4,643	1,110	27,758	16,501	73.0
QLD NG	2	8,674	7,106	1,568	15,780	16,034	54.1
NT Barkly	6	24,312	6,250	6,323	49,687	32,896	73.9
NT GKS	2	6,911	3,511	3,400	10,422	11,306	61.1
NT ASpr	4	2,709	343	1,820	3,483	3,982	68.0
NT VRD	4	13,205	3,014	6,141	19,216	22,182	59.5
WA EKimb	3	13,374	4,945	3,519	19,017	24,142	55.4
WA WKimb	4	7,934	1,193	5,126	10,263	11,915	66.6
WA Pilb	3	3,239	1,080	1,589	5,272	5,585	58.0
Total	33	11,591	1,857	1,110	49,687	17,456	66.4

Notice that the sum of the adjusted non-breeders and the adjusted breeder count is equal to the adjusted count of all females. The estimated average annual count of deaths in the adjusted non-breeding females is shown in Table 59.

Table 59: Summary statistics by region for average annual count of deaths in non-breeders. Estimated as 3% of the count of adjusted non-breeder females

	Count of deaths in non-breeders				
	n	**Average**	**se**	**Min**	**Max**
QLD SG	5	134	50	13	271
QLD NG	2	221	182	38	403
NT Barkly	6	258	54	76	405
NT GKS	2	132	84	47	216
NT ASpr	4	38	10	10	54
NT VRD	4	269	56	125	397
WA EKimb	3	323	128	67	464
WA WKimb	4	119	39	46	189
WA Pilb	3	70	21	28	93
Total	33	176	25	10	464

The estimated total female deaths are shown in Table 60.

Table 60: Summary statistics by region for the estimated total female deaths. Derived from properties as the difference between expected counts of females (book values) and actual counts

		Count of total female deaths			
	n	Average	se	Min	Max
QLD SG	5	457	153	24	889
QLD NG	2	992	501	490	1,493
NT Barkly	6	1,042	165	546	1,505
NT GKS	2	774	208	567	982
NT ASpr	4	498	244	117	1,161
NT VRD	4	1,383	470	473	2,606
WA EKimb	3	1,666	787	96	2,525
WA WKimb	4	442	119	172	680
WA Pilb	3	468	209	61	757
Total	33	841	120	24	2,606

A summary of breeder deaths by region is shown in Table 61.

Table 61: Summary statistics by region for count of total breeder deaths

	Count of total breeder deaths				
	n	**Average**	**se**	**Min**	**Max**
QLD SG	5	323	124	11	618
QLD NG	2	771	319	452	1,090
NT Barkly	6	785	123	390	1,139
NT GKS	2	642	123	519	765
NT ASpr	4	460	241	95	1,121
NT VRD	4	1,113	420	348	2,209
WA EKimb	3	1,343	658	29	2,061
WA WKimb	4	323	125	114	635
WA Pilb	3	398	189	34	666
Total	33	665	100	11	2,209

Note that the sum of the non-breeder deaths (**Error! Reference source not found.**) and the breeder eaths (Table 61) is equal to the total female deaths shown in Table 60.

8.4.2 Results of univariable screening of risk factors for breeder mortality

The same approach was implemented for breeder mortality data as has been described above for female mortality data.

All analyses used property specific data in a dataset with one row per property and a total of 34 properties. The outcome was a measure of breeder mortality based on a numerator representing a count of breeder deaths and a denominator representing an adjusted count of the number of breeders at risk (eligible to die) on each property as a measure of the animal years at risk. Each candidate risk factor was then added to the model one at a time in a screening process.

Tables of summary statistics were not produced for non-significant explanatory factors in this section. The reason is that the datasets were identical to those in the previous section which analysed total female deaths with the sole exception that two additional properties were excluded from analyses.

8.4.2.1 Rainfall

There was no statistical association between breeder mortality rate and measures of annual rainfall (average, range, minimum annual, maximum annual or the ratio of range to average annual rainfall).

There was no statistical association between mortality rate and measures of average length of dry, maximum length of dry, minimum length of dry, number of years when dry was longer than 8 months or the number of years when the dry was longer than 9 months.

There was a statistical association between the female mortality rate and the variance in the dry period length, with increasing variability in dry period length being associated with an increased risk of breeder mortality (p=0.03). The association was influenced strongly by very high variation in rainfall at one property in the Alice Springs area, which was due in turn to very heavy rainfall in 2010. When the data for this one property were removed from the dataset and the analysis re-run there was no significant association between variation in the dry period and female mortality rate. Caution is therefore urged to avoid over-interpreting this finding.

These findings are very similar to those reported and discussed in the previous section for female mortality.

8.4.2.2 Record score

A score was recorded for the level of accuracy in records for each property.

There was no evidence for any statistical association between record score and estimates of breeder mortality rate (p=0.2).

8.4.2.3 Age at first joining

Properties were asked to indicate whether they first joined heifers at less than 24 months of age or greater than 24 months of age.

There was no association between joining age and breeder mortality rate (p=0.9).

8.4.2.4 Month of peak calving

The month of peak calving was coded into three categories: Sept-Oct, Nov, Dec-Feb. There was no statistical association between month of peak calving and breeder mortality rate (p=0.82). This is not to say that breeders which dropped calves outside these peak calving months were not at greater risk of death, however the collected data does not provide evidence to support or refute this speculation.

8.4.2.5 Use of spaying

There was no statistical association between properties that did or did not spay and breeder mortality rate (p=0.7).

8.4.2.6 Age at which most steers are sold

Age at which most steers are sold was categorised into three levels: <1yr, 1-2yrs, and >2yrs. There was no statistical association between age when steers are sold and breeder mortality rate (p=0.8).

8.4.2.7 Mustering efficiency score

Properties were asked to indicate their average mustering efficiency. There was no statistical association between mustering efficiency and breeder mortality rate (p=0.8).

8.4.2.8 Frequency of bang tail counts

Frequency of bang tail counts was classified into three categories: never, every 1 or 2 years, intervals of 3 yrs. or more. There was no statistical association between categories of bang tail counts and breeder mortality rate (p=0.15).

8.4.2.9 Number of weaning rounds per year

The number of weaning rounds per year was categorised into two levels (one per year or more than one per year) for analysis.

There was no statistical association between categories of weaning rounds and breeder mortality rate (p=0.6). If reliable data on the age of calves at weaning was obtainable, there may have been some interesting interactions between the number of weaning rounds, age of calf at weaning and breeder mortality.

8.4.2.10 Joining maiden females separately to other breeders

There was no statistical association between this variable and breeder mortality (p=0.6).

8.4.2.11 Joining first calf heifers separately to breeders

There was no statistical association between breeder mortality rate and the binary variable classifying whether or not properties joined first calf heifers separately to breeders =0.8).

8.4.2.12 Effect of fire, flood and drought

Properties were asked to indicate if they felt that natural disasters (fire, flood, and drought) had potentially impacted livestock and specifically breeder mortalities during the years representing the period of interest for the study.

Each of these variables was assessed as a binary variable (no, yes) in a screening regression with breeder mortality rate as the outcome. There was no statistical association between fire (p=0.15), flood (p=0.14) or drought (p=0.14) and breeder mortality rate. These findings were similar to those noted for the total female mortality rate analyses.

8.4.2.13 Age of cows at last joining

Age at last joining was coded in two levels: up to 10 yrs., and greater than 10 yrs. Ages were determined by the age brand or ear tag applied at branding. These two groups were then compared and there was a statistically significant difference in breeder mortality rate (p=0.003). See Table 62.

Table 62: Breeder mortality rate (deaths per 100 breeders per year) by category of cow age at last joining. Derived from a model with region and age at last joining fitted as fixed effects. se=standard error, CI= confidence interval, RR=relative risk.

	Breeder		95% CI		
Age at last joining	**mort rate**	**se**	**Lower**	**Upper**	
Up to 10 yrs	6.06	0.82	4.46	7.66	
>10 yrs	11.60	2.42	6.85	16.35	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
>10 **vs** up to 10	1.92	0.42	1.25	2.94	0.003

The above table provides estimates of the breeder mortality rate for the two categories of age of cow at last joining. The bottom line of the table provides a relative risk that compares the two mortality rates. Properties where cows were last joined at ages >10 yrs. showed a 1.92-fold higher breeder mortality rate compared to those properties where cows are last joined at ages up to 10 years.

8.4.2.14 Age of cows at last weaning

The same process for aggregation was used as was described for age of cows at last joining with the only change being that every step was shifted one age group to the right. A binary variable was created with two age categories: up to 11 yrs., and >11 yrs. There was a tendency for a difference in breeder mortality rate between these two categories (p=0.053). See Table 63.

Table 63: Breeder mortality rate (deaths per 100 breeders per year) by category of cow age at last weaning. Derived from a model with region and age at last weaning fitted as fixed effects. se=standard error, CI= confidence interval, RR=relative risk.

			95% CI		
Age at last weaning	**Mort rate**	**se**	**Lower**	**Upper**	
Up to 11 yrs	6.56	0.94	4.71	8.40	
>11 yrs	10.62	2.35	6.02	15.23	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
>11 **vs** up to 11	1.62	0.40	0.99	2.64	0.053

The breeder mortality rate in those properties that completed their last weaning in cows aged up to 11 yrs. was 6.56 deaths per 100 breeders per year. The breeder mortality rate in those properties that completed their last weaning in cows >11 yrs. of age, was 10.62 deaths per 100 breeders per year.

Those properties where cows at last weaning were aged >11 yrs., had a 1.62 fold higher breeder death rate compared to those properties where cows at last weaning were aged up to 11 yrs., although just outside being statistically significant.

8.4.2.15 Age of cows at culling for age

Properties were asked to indicate the age at which most of their cull for age cows were sold.

Data were aggregated into three categories that were broadly consistent with age groups used in other analyses:

- cows aged up to 11 yrs.
- cows aged 11-12 yrs.
- cows aged >12 yrs.

The overall effect of the explanatory factor (age of cows at culling for age) was significant in the univariable model (p=0.004) (Table 64).

Table 64: Breeder mortality rate (deaths per 100 breeders per year) by category of cow age at culling. Derived from a model with region and age at culling fitted as fixed effects. se=standard error, CI= confidence interval, RR=relative risk.

			95% CI		
Age culls sold	**Mort rate**	**se**	**Lower**	**Upper**	
Up to 11 yrs	5.09	0.84	3.44	6.73	
11 to 12 yrs	10.01	3.46	3.23	16.80	
>12 yrs	11.63	2.38	6.97	16.29	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
11-12 **vs** up to 11	1.97	0.75	0.93	4.16	0.076
>12 **vs** up to 11	2.29	0.58	1.39	3.76	0.001
>12 **vs** 11-12	1.16	0.43	0.56	2.41	0.70

There was a progressive increase in breeder mortality rate as the age when most cows were culled for age increased. A similar association was described for female mortality.

8.4.2.16 Phosphorus supplementation

Properties were asked to indicate if they supplemented with phosphorus during the wet season. A binary variable was created indicating whether or not P-supplementation was provided (yes, no). If properties answered yes, they were asked to indicate whether supplementation was provided for the whole herd or only part of the herd.

There was no significant overall association between P-supplementation policy and breeder mortality rate (p=0.9).

Table 65 provides mortality rate estimates for each level of the explanatory variable (P-supplementation) and pairwise comparisons with relative risk estimates involving comparisons between the 3 levels.

Table 65: Breeder mortality rate (deaths per 100 breeders per year) by category of phosphorus supplementation during the wet (no, yes). Derived from a model with region and P-suppl fitted as fixed effects.

			95% CI		
P suppl during wet	**Mort rate**	**se**	**Lower**	**Upper**	
No	8.82	2.69	3.56	14.09	
Whole herd	7.46	2.12	3.31	11.61	
Part of herd	7.51	1.94	3.72	11.32	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
No **vs** whole herd	1.18	0.46	0.55	2.52	0.70
No **vs** part herd	1.17	0.54	0.47	2.91	0.7
Whole herd **vs** part herd	0.99	0.42	0.43	2.29	0.9

8.4.2.17 Nitrogen supplementation

There was no overall association between nitrogen supplementation and breeder mortality rate (p=0.16). Table 66 provides mortality rate estimates for each level of the explanatory variable representing N-supplementation and relative risks associated with pairwise comparisons between the three levels.

Table 66: Breeder mortality rate (deaths per 100 breeders per year) by category of nitrogen supplementation during the dry (no, strategic, crisis). Derived from a model with region and N-suppl fitted as fixed effects.

			95% CI	
N suppl during dry	**Mort rate**	**se**	**Lower**	**Upper**
No	19.69	15.85	0.00	50.75
Strategic	12.6	10.37	0	32.93
Crisis	3.47	1.83	0.00	7.05

			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
No **vs** strategic	1.56	0.54	0.80	3.06	0.19
No **vs** crisis	5.68	6.85	0.53	60.45	0.15
Strategic **vs** crisis	3.64	4.54	0.31	42.05	0.3

8.4.2.18 Botulism vaccination

The overall effect of botulism vaccination on breeder mortality rate was associated with a p-value=0.09 but there were some interesting findings in the pairwise comparisons (Table 67). The results were hampered by the fact that only two properties were not using botulism vaccination, meaning that there was a small sample size in this group for statistical comparisons.

Table 67: Breeder mortality rate (deaths per 100 breeders per year) by category of Botulism vaccination (no, yes). Derived from a model with region and Botulism vacc fitted as fixed effects.

			95% CI		
Botulism vaccination	**Mort rate**	**se**	**Lower**	**Upper**	
No	14.90	10.76	0.00	36.00	
Whole herd	5.62	1	3.66	7.58	
Part of herd	9.27	2.27	4.83	13.72	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
No **vs** whole herd	2.65	1.98	0.61	11.46	0.19
No **vs** part herd	1.61	1.38	0.3	8.65	0.6
Whole herd **vs** part herd	0.61	0.19	0.33	1.12	0.1

The large confidence interval around the estimate for the Botulism=no category is because there were only two properties in this category (all others vaccinated).

There was no difference in breeder mortality rate between those properties using botulism vaccination on the whole herd and those using it only on part of the herd. There was an apparent beneficial effect (reduction in breeder mortality rate) between those herds using any form of vaccination and those not vaccinating, but these comparisons were limited by the small sample size in the no-vaccination group.

8.4.2.19 Continuous mating vs. controlled mating

Properties were asked to indicate if they used continuous mating systems for breeding cows (yes, no). See Table 68.

Table 68: Breeder mortality rate (deaths per 100 breeders per year) by category of continuous mating (no, yes). Derived from a model with region and mating system fitted as fixed effects.

			95% CI		
Continuous mating	**Mort rate**	**se**	**Lower**	**Upper**	
No	3.32	1.20	0.98	5.67	
Yes	9.18	1.35	6.53	11.83	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
Yes **vs** No	2.76	0.98	1.38	5.54	0.004

Those properties that practised continuous mating for cows, reported a 2.76 fold higher breeder death rate compared to properties that did not practise continuous mating for cows. This result is likely to be related to the overall level of control of the breeder herd and therefore other management inputs to achieve this high relative risk. There were only two properties included in the dataset that indicated they practised controlled mating for cows.

8.4.2.20 Dry season segregation for breeders

There was a significant association between dry season segregation for breeders and breeder mortality rate ($p<0.001$). Refer to Table 69.

Table 69: Breeder mortality rate (deaths per 100 breeders per year) by category of whether or not the property segregates breeders during the dry season (no, yes). Derived from a model with region and segregation system fitted as fixed effects.

Dry season segregation of breeders	Mort rate	se	95% CI Lower	95% CI Upper	
No	12.32	2.11	8.19	16.46	
Yes	3.61	0.73	2.18	5.03	
	RR	**se**	**95% CI Lower**	**95% CI Upper**	**p-value**
No **vs** Yes	3.42	1.04	1.88	6.22	<0.001

Properties that did not practice dry season segregation of breeders had a 3.42 fold higher breeder mortality than those properties that did segregate breeders in the dry season.

8.4.3 Multivariable modelling

The following Table 70 presents the output from the final multivariable model.

Table 70: Output from a final negative binomial statistical model using breeder mortality rate as the outcome of interest. Output expressed as relative risks (RR) and 95% confidence intervals.

						95% CI	
Variable	**Level**	**RR**	**se**	**z**	**p**	**Lower**	**Upper**
Region	QLD S Gulf	reference					
	Qld N Gulf	5.91	2.29	4.57	<0.001	2.76	12.65
	NT Barkly	0.92	0.28	-0.27	0.787	0.51	1.67
	NT GKSt	1.11	0.49	0.23	0.819	0.47	2.63
	NT Alice Spr	1.58	0.71	1.02	0.309	0.65	3.82
	NT VRD	5.67	1.99	4.95	<0.001	2.85	11.26
	Kimberley E	1.20	0.53	0.41	0.679	0.51	2.84
	Kimberley W	0.39	0.20	-1.82	0.068	0.14	1.07
	Pilbara	0.66	0.38	-0.72	0.47	0.21	2.06
Age at last weaning							
	<11 yrs	reference					
	11+ yrs	4.07	1.25	4.56	<0.001	2.23	7.44
Supplementary P							
	No	reference					
	Whole herd	1.44	0.39	1.35	0.177	0.85	2.43
	Part herd	1.82	0.43	2.53	0.011	1.15	2.89
Segregation of dry breeders							
	Yes	reference					
	No	3.95	0.91	5.94	<0.001	2.51	6.22
Age at last weaning # Supplementary P							
Age wean	Suppl P						
11+ yrs	Whole herd	0.38	0.20	-1.8	0.072	0.13	1.09
11+ yrs	Part herd	0.29	0.16	-2.18	0.029	0.09	0.88
Intercept		0.01	0.00	-12.43	<0.001	0.00	0.02

8.5 Steer mortality results

8.5.1 Descriptive results for steer mortality

Summary statistics for opening number of steers per year for each region are shown in Table 71.

Table 71: Summary statistics for opening number of steers per year for each region. Derived from those 36 properties with non-negative female deaths.

	Count of opening steer number (annual average)				
	n	**Average**	**se**	**Minimum**	**Maximum**
QLD SG	6	2,663	1,419	361	8,825
QLD NG	2	3,703	3,340	363	7,042
NT Barkly	6	5,093	1,459	923	8,707
NT GKS	3	969	216	693	1,394
NT ASpr	4	1,263	703	306	3,350
NT VRD	4	828	185	444	1,258
WA EKimb	3	7,738	3,420	1,175	12,688
WA WKimb	5	3,953	1,270	87	6,647
WA Pilb	3	1,127	384	359	1,527
Total	36	3,099	570	87	12,688

Summary statistics for steer sales per year for each region are shown in Table 72.

Table 72: Summary statistics for steer sales per year for each region. Derived from those 36 properties with non-negative female deaths.

	Count of steer sales (annual average)				
	n	**Average**	**se**	**Minimum**	**Maximum**
QLD SG	6	3,277	1,021	434	7,780
QLD NG	2	3,368	3,005	363	6,373
NT Barkly	6	7,571	1,854	1,965	14,164
NT GKS	3	1,296	601	591	2,491
NT ASpr	4	891	248	279	1,398
NT VRD	4	3,807	808	1,799	5,508
WA EKimb	3	6,035	3,080	1,031	11,649
WA WKimb	5	2,963	371	1,824	3,873
WA Pilb	3	1,225	386	679	1,971
Total	36	3,642	564	279	14,164

Summary statistics for steer purchases per year for each region are shown in Table 73.

Table 73: Summary statistics for steer purchases per year for each region. Derived from those 36 properties with non-negative female deaths.

	Count of steer purchases (annual average)				
	n	**Average**	**se**	**Minimum**	**Maximum**
QLD SG	6	235	128	0	800
QLD NG	2	267	267	0	533
NT Barkly	6	1,629	769	0	4,384
NT GKS	3	0	0	0	0
NT ASpr	4	22	22	0	89
NT VRD	4	244	153	0	639
WA EKimb	3	2,193	2,193	0	6,578
WA WKimb	5	180	180	0	898
WA Pilb	3	0	0	0	0
Total	36	563	232	0	6,578

There were six properties where estimates of steer deaths were negative. These six properties were excluded from analyses. The count of adjusted steer numbers is shown in Table 74.

Table 74: Summary statistics by region for the count of at-risk steers (opening steers + 0.5*est. branded steers + 0.5*steer purchases)

	Count of At-risk steers				
	n	**Average**	**se**	**Min**	**Max**
QLD SthGulf	5	4,972	1,756	792	10,308
QLD NthGulf	2	5,272	4,663	609	9,935
NT Barkly	7	8,215	2,119	2,653	15,033
NT GKSt	3	1,625	507	1,054	2,637
Alice Springs	4	1,730	767	685	4,008
NT VRD	3	3,300	255	3,001	3,808
Kimberley east	2	15,560	3,366	12,195	18,926
Kimberley west	4	6,139	1,615	1,605	8,714
Pilbara	2	2,312	263	2,050	2,575
Total	32	5,466	870	609	18,926

The regional average annual count of steer deaths is shown in Table 75.

Table 75: Summary statistics by region for average annual count of deaths in steers.

	Count of steer deaths				
	n	**Average**	**se**	**Min**	**Max**
QLD SG	5	328	216	12	1,181
QLD NG	2	434	168	267	602
NT Barkly	7	395	107	68	778
NT GKS	3	189	97	13	347
NT ASpr	4	151	117	3	500
NT VRD	3	244	65	116	331
WA EKimb	2	1,227	511	715	1,738
WA WKimb	4	303	129	34	564
WA Pilb	2	411	5	406	416
Total	32	365	66	3	1,738

A summary of steer mortality rates is shown in Table 76.

Table 76: Summary statistics for steer mortality rate (deaths per 100 steers per year). Based on adjusted counts of steers at risk

		Mortality rate		95% Confidence interval	
	n	%	se	Lower	Upper
QLD SG	5	6.71	2.64	1.54	11.89
QLD NG	2	24.89	13.57	0.00	51.48
NT Barkly	7	6.25	2.27	1.80	10.70
NT GKS	3	13.93	8.04	0.00	29.69
NT ASpr	4	5.48	2.26	1.05	9.91
NT VRD	3	7.75	1.97	3.89	11.61
WA EKimb	2	7.52	1.19	5.19	9.86
WA WKimb	4	4.17	1.03	2.16	6.18
WA Pilb	2	17.97	1.31	15.41	20.53
Total	32	8.80	1.68	5.51	12.09

These findings were not expected in that the overall steer mortality rate (8.8 deaths per 100 steers per year) was higher than the overall mortality rate reported for total females (5.64 deaths per 100 females per year) and for breeders (8.03 deaths per 100 breeders per year).

It is particularly worth noting the following comments about selected results.

The mean steer mortality rate for the QLD Northern Gulf was 24.89%. There were only two properties contributing data to this region estimate and the property specific mortality estimates were quite far apart. One property included data on a small number of steers (~1800) steers and reported a very high mortality rate for these animals (over 43 deaths per 100 steers per year). Even a small error in numbers of animals recorded in the numerator could have increased the mortality rate estimate because of the relatively small denominator in this particular property.

There were also only two properties providing records for the Pilbara region of Western Australia but both of these properties reported similar and elevated mortality estimates (reflected in the much tighter confidence interval for this estimated compared to that for the QLD Northern Gulf).

There were three properties providing records for the Gulf-Katherine-Sturt region of the NT and there was also a wide range of mortality estimates at the property level in this region (ranging from 1% to 33%).

It is possible that there may be a range of factors operating at an individual property level that could contribute to an elevated risk of mortality amongst steers including even the risk of poaching that may be elevated for properties in some locations near to highways or town centres. However, it remains possible also that the data records for steer mortality are less accurate than those for females.

It is also possible that relatively large numbers of movements (purchases and sales) meant that denominator counts were less accurate for steers. In general there were relatively few purchases and most of the large movements were sales (movements off the property). However, sales were not used to adjust denominators in these analyses and the impact of not adjusting for sales is expected to result in an under-estimation of true mortality rates and not an over-estimation.

It seems possible that steers may be managed differently to females on many properties. It is normal practice for steers to be placed on the better country to ensure that they achieve optimal growth since steers may be considered to form the bulk of the cash flow for many properties. Some of these paddocks may be closer to hazards such as flooding rivers or other hazards that may be contributing to a higher mortality risk. It is possible (but unlikely) that some properties may be placing steers in worse country compared to heifers and breeders (trying to optimise fertility in the breeding herd); if so, this could also contribute to an increased risk of mortality in steers. It is also possible that management practices such as castration and dehorning may be associated with an elevated mortality risk in steers compared with heifers where these procedures either do not occur (castration) or may be less common (dehorning).

The confidence intervals for the steer mortality rate estimates are considerably wider for several regions and for the overall estimate than they are for total female mortality rates and for the breeder mortality rates. This suggests more variability in the property level estimates and less confidence in the actual levels of steer mortality.

It was unclear if there were differences in property level recording for steers. Some properties may consider steers to require less care and attention and muster them less frequently and devote less attention to maintaining accurate counts. This effect could also explain why steers may be associated with a more variable and often higher mortality rate.

8.5.2 Results of univariable screening of risk factors for steer mortality

The same approach was implemented for steer mortality data as has been described previously for total female and breeder mortality data.

All analyses used property specific data in a dataset with one row per property and a total of 33 properties. The outcome was a measure of steer mortality based on a numerator representing a count of steer deaths and a denominator representing an adjusted count of the number of steers at risk (eligible to die) on each property. Each candidate risk factor was then added to the model one at a time in a screening process. All models included region as a fixed effect and were analysed in Stata (www.stata.com version 12), using robust standard errors.

Tables of summary statistics were not produced for non-significant explanatory factors in this section. The reason is that the same dataset was used with the only change being that some different properties were excluded because they had negative steer death estimates.

8.5.2.1 Rainfall

There were significant associations between steer mortality rate and average annual rainfall and minimum annual rainfall, in models with rainfall measures fitted as continuous linear explanatory factors and steer deaths as the outcome. No other rainfall measures were associated with steer mortality. The associations that were observed appeared to be influenced mainly by two properties. The two properties were in the QLD NGulf and NT Gulf, and both properties provided data over a three period ranging from 2009-2011. The 2010 year was a year of extreme rainfall in these areas. Both properties had very wet years in 2010 in particular with single month totals exceeding 500 mm.

There was no statistical association between mortality rate and measures of average length of dry, maximum length of dry, minimum length of dry, or the number of years when the dry was longer than 9 months.

There was also a significant association between the number of years when dry was longer than 8 months and steer mortality (p=0.006) – increasing numbers of years with a longer dry was associated with reduced steer mortality. This association was also driven by two properties with the highest mortality rate for steers. When the analysis was re-run with these two properties omitted the effect was not significant.

The inability to identify any consistent association between measures of dry season impact and animal mortality was unexpected. Explanations may include the fact that data from multiple years were aggregated into a single summary value for analyses and this may have obscured underlying variability. Different properties may have contributed data from different years and during the period when data were provided from most properties (2002-2011) there were extreme dry years and extreme wet years such that an adverse effect of dry periods may have been offset in statistical models by an adverse effect of wet years.

8.5.2.2 Record score

A score was recorded for the level of accuracy in records for each property. There was no evidence of any statistical association between record score and estimates of steer mortality rate (p=0.17).

8.5.2.3 Age at first joining

Properties were asked to indicate whether they first joined heifers at less than 24 months of age or greater than 24 months of age. There was a tendency for an association between age at first joining and steer mortality rate (p=0.08). See Table 77.

Table 77: Steer mortality rates by age at first joining and relative risk (RR) comparing mortality rate in each class of age at first joining

			95% CI		
Age at first joining	**Mort rate**	**se**	**Lower**	**Upper**	
Up to 24 mnths	4.52	0.92	2.7	6.33	
>24 mnths	10.37	1.75	6.94	13.81	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
>24 **vs** up to 24 mnths	2.29	0.57	1.41	3.73	0.001

Those properties where breeders are first joined at more than 24 months of age have a higher steer mortality rate.

8.5.2.4 Month of peak calving

Month of peak calving was coded into three categories: Sept-Oct, Nov, Dec-Feb. There was no statistical association between month of peak calving and steer mortality rate (p=0.9).

8.5.2.5 Age at which most steers are sold

Age at which most steers are sold was categorised into three levels: <1yr, 1-2yrs, and >2yrs. There was a statistically significant overall association between the explanatory factor representing age when steers are sold and steer mortality rate (p=0.002).

Table 78 provides estimates of the mortality rate for each of the three levels of the explanatory factor and relative risks derived from pairwise comparisons between the three levels.

Table 78: Steer mortality rates by age at which most steers are sold and relative risk (RR) comparing mortality rate in each class of age at which steers are sold

			95% CI		
Age steers sold	**Mort rate**	**se**	**Lower**	**Upper**	
up to 1yr	5.42	1.18	3.12	7.73	
1 - 2 yrs	9.71	4.41	1.07	18.35	
>2 yrs	17.97	5.45	7.29	28.66	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
1-2 **vs** up to 1	1.79	0.96	0.63	5.10	0.3
>2 **vs** up to 1	3.31	1.15	1.68	6.55	0.001
>2 **vs** 1-2	1.85	0.93	0.69	4.96	0.2

There are relatively wide confidence intervals in some mortality rate estimates, reflecting variability in the data.

Properties that transfer/sell older steers generally have higher steer mortality rates.

This finding was unexpected. It is important to note that the mortality results being modelled do not represent mortalities in particular age groups of animals. The outcome is based on an estimate of overall steer mortality regardless of age. However, given that our expectation was that mortality rates might be lower in older steers compared to young animals, it seems reasonable to expect overall mortality rates in steers in general to be lower on those properties that retain steers for longer. It is not clear why our results suggest otherwise. More information is required to shed light on this issue.

8.5.2.6 Mustering efficiency score

Properties were asked to indicate their average mustering efficiency. There was no statistical association between mustering efficiency and steer mortality rate (p=0.8).

8.5.2.7 Number of weaning rounds per year

The number of weaning rounds per year was categorised into two levels (one per year or more than one per year) for analysis. There was a tendency towards a significant overall association between categories of number of weaning rounds and steer mortality rate (p=0.054). See Table 79.

Table 79: Steer mortality rate (deaths per 100 steers per year) by number of weaning rounds per year. se=standard error, CI= confidence interval, RR=relative risk.

No. of weaning rounds	Steer mort rate	se	95% CI Lower	95% CI Upper	
1 per year	14.98	4.31	6.54	23.42	
2+ per year	7.37	1.69	4.07	10.67	
	RR	**se**	**95% CI Lower**	**95% CI Upper**	**p-value**
1 per yr **vs** 2+ per yr	2.03	0.75	0.99	4.17	0.054

Properties that had only one weaning round per year had a 2.03 fold higher steer mortality rate compared to those properties that had two or more weaning rounds per year. A possible explanation for a statistical association between the number of weaning rounds per year and steer mortality rate may be because the number of weaning rounds per year may be a proxy for other factors such as the type of country or the level of management generally on the property.

8.5.2.8 Effect of fire, flood and drought

Properties were asked to indicate if they felt that natural disasters (fire, flood, and drought) had potentially impacted livestock and particularly breeder mortalities during the years representing the period of interest for the study.

Each of these variables was assessed as a binary variable (no, yes) in a screening regression with steer mortality rate as the outcome. There was no statistical association between fire (p=0.8), flood (p=0.6) or drought (p=0.5) and steer mortality rate. The lack of association between these factors and mortality rate is consistent with the findings from female and breeder mortality rates.

8.5.2.9 Age of cows at culling for age

Properties were asked to indicate the age at which most of their cull for age cows were sold. Data were aggregated into three categories that were broadly consistent with age groups used in other analyses:

- cows aged up to 11 yrs.
- cows aged 11-12 yrs.
- cows aged >12 yrs.

Preliminary analysis indicated there was no difference in steer mortality rate between the older two categories so they were combined to produce a binary category variable:

- cows aged up to 11 yrs.
- cows aged >11 yrs.

There was a significant increase in steer mortality rate as the age when the age when most cows were culled for age increased from up to 11yrs to >11yrs (p=0.007). This is considered more likely to be representing a proxy for unmeasured management factors rather than any plausible biological link between cow age when cows are culled for age and steer mortality (see Table 80).

Table 80: Steer mortality rate (deaths per 100 steers per year) by category of cow age at culling. Derived from a model with region and age at culling fitted as fixed effects. se=standard error, CI= confidence interval, RR=relative risk.

			95% CI		
Age culls sold	**Mort rate**	**se**	**Lower**	**Upper**	
Up to 11 yrs	5.29	1.18	2.97	7.61	
>11 yrs	13.07	3.59	6.04	20.10	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
>11 **vs** up to 11	2.47	0.82	1.29	4.75	0.01

8.5.3 Phosphorus supplementation

Properties were asked to indicate if they supplemented with phosphorus during the wet season. A binary variable was created indicating whether or not P-supplementation was provided (yes, no). If properties answered yes, they were asked to indicate whether supplementation was provided for the whole herd or only part of the herd.

As shown in Table 81, there was no significant overall association between the 3-level variable representing P-supplementation policy and steer mortality rate (p=0.5).

Table 81: Steer mortality rate (deaths per 100 steers per year) by category of phosphorus supplementation during the wet (no, yes). Derived from a model with region and P-suppl fitted as fixed effects.

			95% CI		
P suppl during wet	**Mort rate**	**se**	**Lower**	**Upper**	
No	12.60	5.01	2.79	22.41	
Whole herd	7.56	2.61	4.45	12.67	
Part of herd	6.87	2.21	2.55	11.20	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
No **vs** whole herd	1.67	0.95	0.55	5.09	0.40
No **vs** part herd	1.83	0.99	0.63	5.3	0.3
Whole herd **vs** part herd	1.1	0.58	0.39	3.1	0.9

Properties that did not supplement with P reported a higher steer mortality rate compared to those properties where P-supplementation was provided to part or the entire herd, however the effect was not statistically significant.

There was little difference between effects of whole and part herd supplementation.

8.5.3.1 Nitrogen supplementation

Nitrogen supplementation was coded as a three level variable (no supplementation, supplementation in a strategic sense, and crisis supplementation). Preliminary analyses indicated that there were only three properties with data in the crisis supplementation category and standard errors for mortality rate estimates were very large. A decision was made to re-code the variable into a binary form for analysis (no vs. yes).

There was a significant association between nitrogen supplementation and steer mortality rate (p=0.035). Refer to Table 82.

Table 82: Steer mortality rate (deaths per 100 steers per year) by category of nitrogen supplementation during the dry (no, strategic, crisis). Derived from a model with region and N-suppl fitted as fixed effects.

			95% CI		
N suppl during dry	**Mort rate**	**se**	**Lower**	**Upper**	
No	22.30	11.57	0.00	44.98	
Yes	7.14	1.18	4.82	9.45	
			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
No **vs** Yes	3.12	1.69	1.08	9.03	0.04

The result indicates that N supplementation is beneficial but the large standard errors indicate caution in interpreting the measure of effect.

8.5.3.2 Botulism vaccination

The overall effect of the three-level explanatory variable representing botulism vaccination on steer mortality rate was associated with a significant p-value of 0.006. The results (Table 83) were hampered by the fact that only two properties were not using botulism vaccination, meaning that there was a small sample size in this group for statistical comparisons.

Table 83: Steer mortality rate (deaths per 100 steers per year) by category of Botulism vaccination (no, yes). Derived from a model with region and Botulism vacc fitted as fixed effects.

			95% CI	
Botulism vaccination	**Mort rate**	**se**	**Lower**	**Upper**
No	3.63	2.56	0.00	8.65
Whole herd	5.06	0.77	3.54	6.57
Part of herd	14.79	4.57	5.83	23.75

			95% CI		
	RR	**se**	**Lower**	**Upper**	**p-value**
No **vs** whole herd	0.72	0.52	0.17	2.96	0.60
No **vs** part herd	0.25	0.24	0.04	1.6	0.14
Whole herd **vs** part herd	0.34	0.12	0.17	0.7	0.003

The large confidence interval around the estimate for the Botulism=no category is because there were only two properties in this category (all others vaccinated). This is an important issue in that the lack of apparent benefit for vaccination vs no vaccination as shown in Table 83, may be due characteristics of the two properties that are unrelated to the fact that they did not vaccinate.

It is not clear why part-herd vaccination might be associated with elevated steer mortality results. Inspection of the data indicated that the two properties with the highest steer mortality rates were contained within the part-herd vaccine group. However, when the analysis was repeated with these two properties removed the effect remained and the mortality rate estimate for the part-herd group only shifted slightly downwards.

Botulism is noted as an important disease of cattle in the Northern Territory and is capable of causing both outbreak losses and contributing to regular background cattle losses. Prevention is based on vaccination in combination with strategies such as P-supplementation and removal of carcasses.

8.5.3.3 Dry season segregation for breeders

There was a significant association between dry season segregation for breeders and steer mortality rate (p=0.003). See Table 84.

Table 84: Steer mortality rate (deaths per 100 steers per year) by category of whether or not the property segregates breeders during the dry season (no, yes). Derived from a model with region and segregation system fitted as fixed effects.

Dry season segregation of breeders	Mort rate	se	95% CI Lower	95% CI Upper	
No	13.06	2.46	8.24	17.89	
Yes	3.74	1.08	1.62	5.86	
	RR	**se**	**95% CI Lower**	**95% CI Upper**	**p-value**
No **vs** Yes	3.49	1.49	1.51	8.06	0.003

The reasons for this significant relationship are not clear. It is likely that dry season segregation of breeders is a proxy variable representing management factors. Those properties that do segregate breeders in some way in the dry season may be more likely to provide additional supplementary feed or in some other way manage their animals slightly differently when compared to properties that do not utilise some form of segregation of breeders.

8.5.4 Multivariable modelling

Explanatory variables that were significant in the screening process were then considered for inclusion in a multivariable model using steer mortality as the outcome. The model building process was as described for earlier models.

The model output for the final multivariable model is presented in Table 85.

Table 85: Output from a final negative binomial statistical model using steer mortality rate as the outcome of interest. Output expressed as relative risks (RR) and 95% confidence intervals. se=standard error, CI=confidence interval.

						95% CI	
Variable	**Level**	**RR**	**se**	**z**	**p**	**Lower**	**Upper**
Region	QLD S Gulf	reference					
	Qld N Gulf	16.51	4.91	9.43	<0.001	9.22	29.58
	NT Barkly	1.98	0.60	2.26	0.02	1.09	3.59
	NT GKSt	6.12	3.56	3.11	<0.001	1.95	19.15
	NT Alice Spr	1.23	0.56	0.46	0.65	0.51	2.98
	NT VRD	8.43	2.91	6.17	<0.001	4.28	16.59
	Kimberley E	0.72	0.18	-1.31	0.19	0.44	1.18
	Kimberley W	0.63	0.21	-1.41	0.16	0.33	1.20
	Pilbara	1.18	0.28	0.73	0.47	0.75	1.87
Age steers sold							
	up to 1yrs	reference					
	1-2 yrs	2.14	0.58	2.77	0.01	1.25	3.65
	>2 yrs	4.65	1.43	5	<0.001	2.55	8.50
Segregation of dry breeders							
	Yes	reference					
	No	2.72	0.69	3.93	<0.001	1.65	4.49
Age when most cull for age cows are culled							
	Up to 11 yrs	reference					
	>11 yrs	2.91	0.72	4.34	<0.001	1.80	4.73
Intercept		0.00	0.00	-17.04	<0.001	0.00	0.01

8.6 Mortality tool version 2

Table 86 shows the data entry for the mortality tool, version 2.

Table 86: Data entry sheet for version 2 of the mortality tool

CHECK STARTING ASSUMPTIONS HERE	***please change or enter values into the green cells***	
1. How many years of data are you going to enter?	5	
2. Enter 1 if you want to use calendar year and 2 if you want to use financial year	1	
3. For branding data, can you provide separate counts for branded steers and branded heifers or will you just provide a combined count?		
3.a. Enter 1 if you will provide separate counts for steers & heifers, OR 2 if you will provide a combined count.	1	
3.b. Not applicable	0.5	
4. Expected proportion of deaths per year in non-breeding females	0.03	
5. ENTER ANIMAL COUNTS BELOW FOR EACH YEAR		
Livestock schedule	**Year 1**	**Year 2**
Opening females	25,505	29,311
Opening breeders	18,293	16,331
Female sales	Enter sales and purchases by month in separate worksheets	
Female purchases		
Closing females (adjusted count)	29,311	32,799
Rations from females	0	0
Branded count during year	Enter branded count by month of the year in separate worksheet	
Opening steers	6,686	11,101

Sales of steers	Enter sales and purchases by month in separate worksheets	
Purchase of steers		
Closing steers (adjusted count)	11,101	16,264
Rations that are steers	35	34

The data entry sheet for version 2 of the mortality tool has a similar lay out to version 1 but users are asked to go to separate sheets to enter month by month counts for sales, purchases and brandings.

Table 87 shows the first two years of the data entry sheet for sales.

The first section asks users to consider four questions and check the default answers in the adjacent green cells. Users can alter these values if appropriate. The responses are used in various formulae embedded in the worksheets so users do need to check that the responses are correct and reflect how they will enter data into the worksheets.

1. How many years of data are you going to provide?

    The tool is capable of handling up to five years of data. It currently cannot handle more than five years of data. The tool can be modified to handle additional years of data but this will require extensive re-coding of the underlying calculations.

2. Enter 1 if you want to use calendar year or 2 for financial year.

    The default is calendar year (Jan to Dec). If users want to use a financial year (July to June), then they can enter 2 into the adjacent green cell and this will automatically result in changing the labels on the months in the three worksheets (Sales, Purchases and Brandings).

3. For branding data, you can provide separate counts for branded steers and branded heifers or will you just provide a combined count.

    a. Enter 1 if you will provide separate counts for steers and heifers, or 2 if you will provide a combined count.

        It is anticipated that some properties will have accurate records of brandings by heifer & steer and other properties will only have records of total brandings. If accurate data by sex are available then they should be entered separately under heifers and steers. If not, then the combined column is used.

    b. If you entered 2 to the above question, then do you wish to use a default of 50% males and 50% females (entered as 0.5) or do you wish to assign an unequal proportion.

If the only available data are combined counts of branded heifers & steers, then we need to use a proportion to assign branded counts to either females or males. The default here is 0.5. This should only be altered if you have a reasonably accurate indication of the value for your property. In most cases the most appropriate value is 0.5 which should reflect the long term pattern.

4. Expected proportion deaths in non-breeding females.

   This figure is used to calculate an expected count of deaths in non-breeding females. The residual deaths are then assumed to be from the breeding females. This figure can be altered if users have confidence in an alternative value. Values in the range from about 2% to 7% may be reasonable. Values outside this range may occur from time to time but would be expected to be unusual events.

The user is then asked to enter separate counts for sales of breeding females, non-breeding females (branded calves, heifers too young to be mated and spayed females), and steers. The green shading is used to indicate those cells where users may enter data and the grey or blue shading indicates cells where formulae will automatically update values.

The closing females (adjusted count) and closing males (adjusted count) represent the user’s most accurate estimate of the number of live animals on the property at the end of the year (these numbers then form the opening count for the following year).

Users can enter counts of the number of animals killed for rations over the course of each year – from females and males. Rations should not contribute to the mortality estimate for the year but they need to be recorded so that figures can be adjusted appropriately.

Table 87: The data entry sheet for sales

Enter 1 if you want to use calendar year and 2 if you want to use financial year	1	Use the same 12 month period as your other estimates of cattle numbers				
	Year=1			**Year=2**		
	Sales by month for each class					
Month	**Breeders (eligible to be bred that year)**	**Female non-Breeders (only if branded)**	**Steers (only if branded)**	**Breeders**	**Female non-breeders**	**Steers**
January						
February						
March	800			600		
April			864			1500
May	898			648		
June						
July						
August						1834
September						
October						
November						
December						
TOTALS	1698	0	864	1248	0	3334

A separate sheet is then used for entry of purchase data for breeding females, non-breeding females and steers. The layout is identical to the sheet used for sales.

A further sheet is then used to enter branding data by month. Refer to Table 88.

Table 88: First two years of data entry for count of brandings by month for each year. Entered data to include both steer and heifer brandings i.e. all animals branded.

BRANDED	**Enter counts of branded animals by month and year into the respective green cells.**		
	Year=1		
	Branded by month for heifers & steers		
Month	**Branded heifers**	**Branded steers**	**Not applicable**
January			
February			
March	550	548	
April	870	879	
May	1,145	1,152	
June	1,190	1,206	
July	732	748	
August	526	516	
September	695	710	
October			
November			
December			
TOTAL by year & sex	**5,708**	**5,759**	**Not applicable**

Note that in the example above, the user has entered data separately for branded heifers and branded steers.

If the user was entering a single combined count of branded heifers & steers together, then no data would be entered in the sex-specific columns and the single combined count would be entered in the last column. Once the user had altered the set up value (answer to Q.3. on the Data Entry sheet), the headings for the columns would automatically change and the third column above would display the heading "*Combined heifers + steers*".

The reason that month by month data collection of sales, purchases and brandings is important is that an animal is not considered eligible to die once it has left the property (sales) and similarly should not be considered eligible to die until it has entered the property (purchases or brandings). The month by month breakdown is then used to adjust the count of animals at risk (denominator in a mortality rate estimate) to accurately reflect the number of animal years at risk of mortality for that property.

The final output worksheets (Table 89 and Table 90) provide summary counts and mortality estimates.

Table 89: Summary counts of animals from data entry worksheets

Summary from entered data	
Number of years of records	**5**
Opening females	132,959
Opening breeders	90,300
Total female sales	20,674
Total breeder sales	20,674
Total female non-breeder sales	0
Total female purchases	0
Total breeder purchases	0
Total female non-breeder purchases	0
Total branded heifers	26,181
Closing females (adjusted + rations)	131,078
Opening steers	35,212
Total steer sales	31,906
Total Purchase of steers	2,666
Total branded steers	26,276
Closing steers (adjusted + rations)	29,433

Table 90: Estimates of mortalities and animals at risk derived using data from month-by-month breakdowns of relevant input counts.

Calculations using entered data to derive additional estimates	
138,466	Closing females - book (opening count - sales + purchase + branded heifers)
133,259	At-risk female animal-years
78,028	At-risk breeder animal-years
55,230	At-risk non-breeder female-years (Opening females-opening breeders+0.5*branded heifers)
7,388	Deaths in all females
1,657	Deaths in non-breeding females
5,731	Deaths in breeding females
32,248	Closing steers - book (opening count - sales + purchase + branded steers)
32,220	At-risk steer animal-years (Opening steers+male purchases+brandings*0.5-male sales)
2,815	Estimated steer deaths
Mortality rate estimates	
5.54	female deaths per 100 females per year
7.34	breeder deaths per 100 breeders per year
8.74	steer deaths per 100 steers per year

Where producers have month-by-month breakdowns of data for animals by class (steer, breeder and non-breeding females), this approach is expected to produce the most valid and unbiased estimates of annual mortality rates. However this assumes that the monthly mortality rates are all the same and this is unlikely to be the case e.g. most breeders probably die at the end of the dry season and coming into the wet season. Cobiac (2006) in a study at Kidman Springs research property reported that nearly 70% of deaths occurred in the late dry season or during the wet season. These periods coincided with peak calving, peak lactation and peak nutritional stress in the period immediately following opening rains.

8.7 Mortality tool user manual

8.7.1 Introduction

This user manual is intended to accompany an Excel® spreadsheet tool which can be downloaded and used by beef producers to estimate mortality in male and female cattle. The tool was developed as part of a research project funded by Meat and Livestock Australia.

Users should download the tool from the MLA website and then open it in Microsoft Excel®

Two forms of the tool have been produced: Version 1 and Version 2.

8.7.2 Mortality Tool Version 1

Version 1 of the *Mortality Tool* is based on annual livestock schedule counts. It is a simpler than Version 2. Version 1 is based on annual counts for various classes of livestock.

The tool has two worksheets. The first worksheet is labelled ***Data Entry*** and is where users enter data relating to livestock counts and also answer some initial set-up questions. The second worksheet is labelled **Output** and is where the outputs of the calculations are displayed.

8.7.2.1 Data Entry worksheet

The upper part of the data entry sheet asks for input for four set-up questions.

1. How many years of data are you going to enter?
   Enter a number between 1 and 10. The tool will automatically fill in the year numbers (Year 1, Year 2, …) up to the number you enter.
2. Enter the proportion of branded animals that are expected to be female. The default for this is 0.5 (50%) but the user may enter a different value if they wish.
3. Enter the expected proportion of deaths per year in young females (non-breeding females). The default value is 0.03 or 3% per year.

The lower part of the data entry sheet for Version 1 is where the user can enter counts of animals. The table below (Table 91) shows the first two years of data from an example file but the tool has the capacity to allow users to enter up to 10 years of data.

For the purposes of this tool, a year is a calendar year (January to December). The opening count at the start of the year (January) is assumed to be equal to the closing count from the last muster of the previous year. Closing counts are assumed to be based on the musters that have been conducted during that year, with appropriate adjustments to reflect animals that may have been missed from one or both musters but are likely to be alive. The closing count should reflect the best estimate of the live animals in that class on the property at the end of the year.

Table 91: Layout of the data entry worksheet from the mortality tool

Enter data and assumptions here	***please enter your data below***	
1. How many years of data are you going to enter?	5	
2. Proportion of branded animals that are expected to be female?	0.5	
3. Expected proportion of deaths per year in non-breeding females	0.03	
5. ENTER ANIMAL COUNTS BELOW FOR EACH YEAR		
Livestock schedule	**Year 1**	**Year 2**
Opening females	25,505	29,311
Opening breeders	18,293	16,331
Female sales	1,698	1,248
Female purchases	0	0
Closing females (adjusted count)	29,311	32,799
Rations - females	0	0
Closing females (adjusted count) + rations (female)	29,311	32,799
Branded count during year	11,527	10,183
Opening steers	6,686	11,101
Sales of steers	864	3,324
Purchase of steers	0	2,666
Closing steers (adjusted count)	11,101	16,264
Rations - males	20	18
Closing steers (adjusted count) + Rations (male)	11,121	16,282
Enter data by typing numbers into the green shaded areas		

- **Opening female:** Estimate of the closing number of females on the property from the end of the previous year – serves as the opening number for the next year. Represents all females that have been branded prior to opening estimates (includes weaners, unjoined heifers, joined heifers and cows).
    - Note that this figure should not include calves that will be branded during the course of the year – this is entered further down.
- **Opening breeder**: all animals that were mated in the current year
    - Includes heifers and cows.
- **Female sales:** this figure includes any female (any animal that is branded) that was sold during that year. There is no way of determining accurately the number of animals in any component class that were sold from these data (weaners, branded calves, heifers or cows), or of knowing whether any older females that were sold were bred, pregnant/empty or had calves at foot or not.
- **Females purchases**: Similarly this is simply an overall estimate of anything that was branded and female and that was purchased in the current year.
    - Females that were purchased as calves at foot (unbranded) are not counted in this total. They should be counted in the number of animals branded in that year.
- **Closing females (adjusted count):** Estimate of the closing number of females on the property at the end of the last muster of the year.
    - Should be derived from muster counts during the year with adjustments to reflect animals that may have been missed during mustering but are likely to still be alive and on the property.
    - Includes all branded females on the property by the end of the year so it does include females that were branded during the year.
- **Branded:** count of all animals (male + female) that were branded in the current year.
    - Includes animals that were branded and weaned and animals that might be branded and left on the cows
    - Enter the total number here (males + females). The proportion entered as an answer for question 2 in the upper part of the data entry sheet will be used in combination with the total number branded to estimate the number of branded females and males.
    - If users have actual counts of branded animals by sex (branded heifers and branded steers), then they can estimate the proportion female (count of females divided by total count of animals branded) and then enter the total number of branded and the proportion females.

- **Opening steers**: Count of all branded steers on the property based on the closing count from the end of the previous year.
    - Does not include any animals that were branded in the current year.
- **Sales of steers**: Count of all steers sold through the year.
    - Only includes branded animals.
- **Purchase of steers**: Count of all steers purchased that were branded at the time of purchase.
- **Closing steers (adjusted count):** Count of all branded steers on the property at the end of the year.
    - Includes all branded males on the property by the end of the year so it does include males that were branded during the year.
    - Should be derived from muster counts with adjustment to reflect animals that were missed and considered likely to be alive.

8.7.2.2 Output worksheet

Once you have completed data entry in the *Date Entry* worksheet, move to the *Output* worksheet. The *Output* worksheet is a display sheet only – it will display a summary of the data entry sheet (Section 1), interim calculations (Section 2) and mortality estimates (Section 3).

Output is presented in three sections, explained in order below.

Section 1: Summary of entered data

Section 1 displays an aggregate (sum) of the years of data entered in the *Data Entry* worksheet and also presents the entered responses for the four initial questions (See Table 92).

Table 92: Summary statistics derived from entered data for five consecutive years an reported in Section 1 of the Output sheet.

Summary from entered data	
Number of years of records	**5**
Opening females	132,959
Opening breeders	90,300
Female sales	20,674
Female purchases	0
Closing females (adjusted + rations)	131,078
Branded during year	52,517
Opening steers	35,145
Sales of steers	31,867
Purchase of steers	2,666
Closing steers (adjusted + rations)	29,349

In order to adjust appropriately for rations and exclude them from mortality estimation, they are added to the closing count just for the purposes of estimation of mortality.

Section 2 displays a series of interim calculations that use the entered data as inputs. These outputs are explained below and an example shown in Table 93.

Table 94: Section 2 output table from the mortality tool

Calculations using entered data to derive additional estimates	
26,259	Count of branded heifers
138,544	Closing females - book (opening count - sales + purchases + branded heifers)
146,088	At-risk females #1 (op_fem+0.5*brd_heif+0.5*purchase)
55,788	At-risk non-breeding females
7,466	Deaths in all females
1,674	Deaths in non-breeding females
5,792	Deaths in breeding females
26,259	Count of branded steers
32,203	Closing steers - book (opening count - sales + purchases + branded steers)
49,607	At-risk steers #1 (op_str + 0.5*brd_str + 0.5*purchase)
2,854	Estimated steer deaths
135,751	At-risk females #2 (op_fem+0.5*brd_heif+0.5*purchase-0.5*sales)
33,674	At-risk steers #2 (op_str+0.5*brd_str+0.5*purchase-0.5*sales)

- **Count of branded heifers**
  - = Count of total animals branded during the year * proportion of branded animals that are female.
- **Closing females - book (opening count – sales + purchases + branded heifers)**
  - = Opening females – female sales + female purchases + count of branded heifers.
  - This estimate assumes no mortalities
- **At-risk females #1**
  - = opening females + 0.5*branded heifers + 0.5*female purchases.
  - Not adjusted for sales.
  - Provides an estimate of the number of females at risk of mortality which serves as a denominator for estimating mortality rate in females.

- **At-risk count of non-breeding females**
  - = opening females – opening breeders + 0.5*branded heifers.
  - Assumes all purchased females are breeding animals.
  - Not adjusted for sales of females.
  - Provides an estimate of the number of non-breeding females at risk of mortality which serves as a denominator for estimating mortality in non-breeding females.
  - The difference between these two estimates provides an estimate of the at-risk count for breeding females.
- **Deaths in all females**
  - Calculated as the difference between the two different estimates of closing females.
  - Closing females (estimated from schedule records) - Closing females (actual).
  - Is actually an estimate of difference and may include missing animals, rations and deaths.
- **Deaths in non-breeding females**
  - Estimated by applying the expected proportion of deaths in non-breeding females to the estimated count of non-breeding females at risk of mortality.
- **Deaths in breeding females**
  - Estimated by subtracting the deaths in non-breeding females from the estimated total female deaths.
- **Count of branded steers**
  - = Count of total animals branded during the year * (1-proportion of branded animals that are female).
- **Closing steers - book (opening count – sales + purchases + branded steers)**
  - = Opening males – male sales + male purchases + count of branded steers in that year.
  - This estimate assumes no mortalities
- **At-risk steers #1**
  - = (opening steers + 0.5*branded steers + 0.5*purchased steers)
  - Not adjusted for sales.
  - Provides an estimate of the number of males at risk of mortality which serves as a denominator for estimating mortality rate in males.

- **Estimated steer deaths**
  - Calculated as the difference between the two different estimates of closing males.
  - Closing males (estimated from schedule records) - Closing males (actual).
  - Is actually an estimate of difference and may include missing animals, rations and deaths.
- **At-risk females #2**
  - = opening females + 0.5*branded heifers + 0.5*female purchases – 0.5*female sales.
  - Adjusted for sales.
  - Provides an estimate of the number of females at risk of mortality which serves as a denominator for estimating mortality rate in females.
- **At-risk steers #2**
  - = opening males + 0.5*branded steers + 0.5*male purchases – 0.5*male sales.
  - Adjusted for sales.
  - Provides an estimate of the number of males at risk of mortality which serves as a denominator for estimating mortality rate in males that is adjusted for sales.

The last section (Section 3) of the *Output* worksheet shows two alternative methods for estimating mortality rate in females and steers.

Estimating a mortality rate requires a numerator and a denominator. The numerator is a count of the number of new deaths that have occurred within a defined time period (one year). The denominator is an estimate of the number of animals that were at risk of mortality during that year.

Both methods use the same numerator (estimated count of deaths).

The two methods differ only in how they estimate a denominator with one method not incorporating adjustment for sales (adjusted count #1 from above), and the other method including adjustment for sales (adjusted count #2 from above). See Table 95.

Table 95: Section 3 output table from the mortality tool

Mortality rate estimates	
5.11	female deaths per 100 females per year, using adjusted count #1 (not adjusted for sales)
6.41	breeder deaths per 100 breeders per year
5.75	steer deaths per 100 steers per year, using adjusted count #1 (not adjusted for sales)
Mortality rate estimates using adjusted denominators that incorporate adjustment for sales (#2)	
5.50	female deaths per 100 females per year, using adjusted count #1 (adjusted for sales)
8.47	steer deaths per 100 steers per year, using adjusted count #1 (adjusted for sales)

Section 3 of the *Output* worksheet provides estimates of mortality rate, expressed as a percentage or as deaths per 100 animals per year.

8.7.3 Mortality Tool version 2

Version 2 of the *Mortality Tool* has the same starting layout to Version 1 but then incorporates a month by month breakdown of animal movements onto and off the property (sales, purchases and brandings) to allow more accurate adjustment of the denominators for mortality estimates.

Where users have month by month data for animal movements, Version 2 will produce more accurate estimates of mortality rates than Version 1.

Individuals who are interested in Version 2 should read the initial part of this manual describing Version 1 to gain an understanding of the more basic version prior to reading this part of the manual.

The following pages (Tables 95-99) provide images of the five worksheets for Version 2 of the mortality tool.

The colour coding is intended to provide guidance in that users should only enter or delete values in the green cells. All other cells either display static information or contain values generated by built-in formulas and should not be altered.

Users are encouraged to make a copy of the original file so that it changes are made to cells that result in calculations being interrupted, the user can revert to an original file again by creating another copy.

Table 96: Data Entry sheet for Version 2 of the Mortality Tool

CHECK STARTING ASSUMPTIONS HERE	please change or enter values into the green cells	
1. How many years of data are you going to enter?	5	The tool can handle up to 5 years of data
2. Enter 1 if you want to use calendar year and 2 if you want to use financial year	1	Calendar year runs from Jan to Dec. Financial year runs from July to June.
3. For branding data, can you provide separate counts for branded steers and branded heifers or will you just provide a combined count?		See the worksheet labelled "Brandings by Mont
3.a. Enter 1 if you will provide separate counts for steers & heifers, OR 2 if you will provide a combined count.	1	
3.b. Not applicable	0.5	You answered 1 for Q3.a. Q3.b. is not relevant and can be ignored
4. Expected proportion of deaths per year in non-breeding females	0.03	Starting assumption is 3% deaths per yr, enterec

5. ENTER ANIMAL COUNTS BELOW FOR EACH YEAR

Livestock schedule	Year 1	Year 2	Year 3	Year 4	Year 5
Opening females	25,505	29,311	32,799	22,836	22,508
Opening breeders	18,293	16,331	17,896	18,860	18,920
Female sales	Enter sales and purchases by month in separate worksheets				
Female purchases					
Closing females (adjusted count)	29,311	32,799	22,836	22,508	23,624
Rations from females	0	0	0	0	0
Branded count during year	Enter branded count by month of the year in separate worksheet				
Opening steers	6,686	11,101	16,264	576	585
Sales of steers	Enter sales and purchases by month in separate worksheets				
Purchase of steers					
Closing steers (adjusted count)	11,101	16,264	576	585	735
Rations that are steers	35	34	35	33	35

Table 97: Sales by Month sheet for Version 2 of the Mortality tool

SALES

	Year=1			Year=2			year=3			year=4			year=5		
	sales by month for each class														
Month	Breeders (eligible to be bred that year)	Female non-Breeders (only if branded)	Steers (only if branded)	Breeders	Female non-breeders	Steers	Breeders	Female non-breeders	Steers	Breeders	Female non-breeders	Steers	Breeders	Female non-breeders	Steers
January															
February															
March	800			600			3500		5000						1500
April			864			1500			5000	1500		2500	2500		
May	898			648			2500			1500					2000
June										1200					
July							2173			1829			1026		
August						1834			5000			2272			2164
September									2272						
October															
November															
December															
TOTALS by year	**1698**	**0**	**864**	**1248**	**0**	**3334**	**8173**	**0**	**17272**	**6029**	**0**	**4772**	**3526**	**0**	**5664**

Overall totals by class	
Female non-breeders	0
Female breeders	20,674
Total females	20,674
Steers	31,906

Total animal-years at-risk by class	
Female non-breeders	0
Female breeders	12,272
Total females	12,272
Steers	16,942

Table 98: Purchases by Month sheet for Version 2 of the Mortality tool

PURCHASES

	Year=1			Year=2			year=3			year=4			year=5		
	purchases by month for each class														
Month	Breeders (eligible to be bred that year)	Female non-Breeders (only if branded)	Steers (only if branded)	Breeders	Female non-breeders	Steers	Breeders	Female non-breeders	Steers	Breeders	Female non-breeders	Steers	Breeders	Female non-breeders	Steers
January															
February															
March															
April															
May															
June						2666									
July															
August															
September															
October															
November															
December															
TOTAL	0	0	0	0	0	2666	0	0	0	0	0	0	0	0	0

Overall totals by class	
Female non-breeders	0
Female breeders	0
Total females	0
Steers	2666

Total animal-years at-risk by class	
Female non-breeders	0
Female breeders	0
Total females	0
Steers	1333

Table 99: <u>Brandings by Month</u> sheet for Version 2 of the Mortality tool

BRANDED	Enter counts of branded animals by month and year into the respective green cells.			You answered 1 to Q.3.a. on the Data Entry sheet	This means you need to enter separate counts for heifers & steers										
	Year=1			Year=2			year=3			year=4			year=5		
	branded by month for heifers & steers														
Month	Branded heifers	Branded steers	Not applicable	Branded heifers	Branded steers	Not applicable	Branded heifers	Branded steers	Not applicable	Branded heifers	Branded steers	Not applicable	Branded heifers	Branded steers	Not applicable
January															
February															
March	550	548		490	508		248	256		446	435		317	338	
April	870	879		765	754		761	773		705	698		935	928	
May	1,145	1,152		1,061	1,051		910	905		839	875		99	102	
June	1,190	1,206		987	973		869	874		932	921		1,186	1,173	
July	732	748		770	759		655	648		602	611		921	916	
August	526	516		389	399		461	468		449	455		736	744	
September	695	710		261	254		395	401		318	326		1,164	1,158	
October				370	385		289	295		307	307		836	827	
November															
December															
TOTAL by year & sex	5,708	5,759		5,093	5,083		4,588	4,620		4,598	4,628		6,194	6,186	

Total by year	Year=1	Year=2	Year=3	Year=4	Year=5
	11,467	10,176	9,208	9,226	12,380

Totals by sex	Animals
branded heifers	26,181
branded steers	26,276
Totals if entered as combined data	Not applicable

Total Animal-years at-risk	
branded heifers	12,571
branded steers	12,618

Table 100: Output sheet for Version 2 of the Mortality tool

Summary from entered data	
Number of years of records	**5**
Opening females	132,959
Opening breeders	90,300
Total female sales	20,674
Total breeder sales	20,674
Total female non-breeder sales	0
Total female purchases	0
Total breeder purchases	0
Total female non-breeder purchases	0
Total branded heifers	26,181
Closing females (adjusted + rations)	131,078
Opening steers	35,212
Total steer sales	31,906
Total Purchase of steers	2,666
Total branded steers	26,276
Closing steers (adjusted + rations)	29,433

Calculations using entered data to derive additional estimates	
138,466	Closing females - book (opening count - sales + purchase + branded heifers)
133,259	At-risk female animal-years
78,028	At-risk breeder animal-years
55,230	At-risk non-breeder female-years
7,388	Deaths in all females
1,657	Deaths in non-breeding females
5,731	Deaths in breeding females
32,248	Closing steers - book (opening count - sales + purchase + branded steers)
32,220	At-risk steer animal-years
2,815	Estimated steer deaths
Mortality rate estimates	
5.54	female deaths per 100 females per year
7.34	breeder deaths per 100 breeders per year
8.74	steer deaths per 100 steers per year

8.7.3.1 Data Entry sheet

The data entry sheet for version 2 of the mortality tool has a similar lay out to Version 1 but users are asked to go to separate sheets to enter month by month counts for sales, purchases and brandings.

Table 96 shows the data entry sheet.

The first section asks users to consider four questions and check the default answers in the adjacent green cells. Users can alter these values if appropriate. The responses are used in various formulae embedded in the worksheets so users do need to check that the responses are correct and reflect how they will enter data into the worksheets.

1. How many years of data are you going to provide?

   The tool is capable of handling up to five years of data. It currently cannot handle more than five years of data. The tool can be modified to handle additional years of data but this will require extensive re-coding of the underlying calculations.

2. Enter 1 if you want to use calendar year and 2 for financial year.

   The default is calendar year (Jan to Dec). If users want to use a financial year (July to June), then they can enter 2 into the adjacent green cell and this will automatically result in changing the labels on the months in the three worksheets (Sales, Purchases and Brandings).

3. For branding data, can you provide separate counts for branded steers and branded heifers or will you just provide a combined count.

   a. Enter 1 if you will provide separate counts for steers and heifers, OR 2 if you will provide a combined count.

      It is anticipated that some properties will have accurate records of brandings by heifer & steer and other properties will only have records of total brandings. If accurate data by sex are available then they should be entered separately under heifers and steers. If not, then the combined column is used.

   b. If you entered 2 to the above question, then do you wish to use a default of 50% males and 50% females (entered as 0.5) or do you wish to assign an unequal proportion.

      If the only available data are combined counts of branded heifers & steers, then we need to use a proportion to assign branded counts to either females or males. The default here is 0.5. This should only be altered if you have a reasonably accurate indication of the value for your property. In most cases the most appropriate value is 0.5 which should reflect the long term pattern.

4. Expected proportion deaths in non-breeding females.

   This figure is used to calculate an expected count of deaths in non-breeding females. The residual deaths are then assumed to be from the breeding females. This figure can be altered if users have confidence in an alternative value. Values in the range from about 2% to 7% may be reasonable. Values outside this range may occur from time to time but would be expected to be unusual events.

The user is then asked to enter separate counts for sales of breeding females, non-breeding females (branded calves, heifers too young to be mated and spayed females), and steers. The green shading is used to indicate those cells where users may enter data and the grey or blue shading indicates cells where formulae will automatically update values.

The closing females (adjusted count) and closing males (adjusted count) represent the user's most accurate estimate of the number of live animals on the property at the end of the year (these numbers then form the opening count for the following year).

Users can enter counts of the number of animals killed for rations over the course of each year – from females and males. Rations should not contribute to the mortality estimate for the year but they need to be recorded so that figures can be adjusted appropriately.

8.7.3.2 Sales by Month sheet

Table 97 shows the Sales by Month sheet. The user is asked to enter separate counts for sales of breeding females, non-breeding females (branded calves, heifers too young to be mated and spayed females), and steers. There is an option of using calendar year or financial year but caution is urged that users need to use the same approach for all data entry. It is expected that most users will use a 12 month calendar year (January to December). The green shading is used to indicate those cells where users may enter data and the grey or blue shading indicates cells where formulae will automatically update values.

The reason that month by month data collection of sales, purchases and brandings is important is that an animal is not considered eligible to die once it has left the property (sales) and similarly should not be considered eligible to die until it has entered the property (purchases or brandings). The month by month breakdown is then used to adjust the count of animals at risk (denominator in a mortality rate estimate) to accurately reflect the number of animal years at risk of mortality for that property.

8.7.3.3 Purchases by Month sheet

A separate sheet is then used for entry of purchase data for breeding females, non-breeding females and steers. The layout is identical to the sheet used for sales.

A further sheet is then used to enter branding data by month. Refer to **Error! Reference source not ound.**.

8.7.3.4 Brandings by Month sheet

Note that in Table 99, the example shows data entered separately for branded heifers and branded steers.

If the user was entering a single combined count of branded heifers & steers together, then no data would be entered in the sex-specific columns and the single combined count would be entered in the last column. Once the user had altered the set up value (answer to Q.3. on the Data Entry sheet), the headings for the columns would automatically change and the third column above would display the heading "*Combined heifers + steers*".

8.7.3.5 Output sheet

The final output worksheet (Table 100) provides summary counts and mortality estimates. The output is presented in three sections using the same layout as in Version 1. Where producers have month-by-month breakdowns of data for animals by class (steer, breeder and non-breeding females), this approach is expected to produce the most valid and unbiased estimates of annual mortality rates. Mortality rate estimates expressed as percentage death per year are shown in **Error! eference source not found.**.

Users are referred to the FAQ section for additional information on approaches, interpretation of results and issues associated with estimation of annual mortality rates.

8.7.4 FAQs

1. Why can't we just directly count the dead animals to produce an estimate of mortalities?

   In smaller, more intensively managed beef properties (in the south-east of Australia), it may be possible to maintain close supervision of cattle and to know whenever an animal dies because animals can be directly observed every day. Under these circumstances it would be possible to produce accurate and direct counts of deaths.

   In extensive beef properties, cattle may only be mustered once or twice and occasionally more often in any one year. Cattle are not under close observation and deaths may be unobserved. In addition, it may be very difficult to achieve a complete muster every time that cattle are yarded and cattle may be missed on any given muster but still be alive. This has led to difficulties in estimating mortality rates on extensive beef properties.

   The approach outlined in this mortality tool is an attempt to use data that are available (mustering counts) coupled with some relatively simple assumptions, to produce estimates of mortality that will be reasonable given the limitations.

2. How good is the tool at estimating a count of the number of deaths in animals?

   The numerator or count of deaths is based on the difference between two estimates of closing counts of animals: one derived from a prediction based on opening counts minus sales plus purchases and plus new additions (branded animals), and the other based on counts derived from mustering rounds conducted through the year, with appropriate adjustments to reflect animals that were missed at musters but likely to be alive, and adjustments to exclude rations from mortality estimates.

This difference is an indirect estimate of mortality with the accuracy dependent in part on how well missing animals that are still alive may be accounted for. If mustering efficiency is reasonably good and if the property uses several years of data and not just one year, then the potential bias from poor mustering efficiency at any one muster should be minimised and the estimates of deaths will be most reasonable. However, it is important to accept that this tool produces an estimate of deaths that will be reasonably close to the true value but may be a little bit above or below the true value depending on possible explanations for missing animals on any given property.

3. Why do we need to enter multiple years of data?

   The Mortality Tool is designed to use multiple years of data (up to 10 years of data for Version 1 and 5 years of data for Version 2). Data are entered using an annual cycle and using opening and closing counts of animals derived from mustering periods through the year.

   The data are aggregated in calculations. This means that if several years of data are entered, the resulting mortality rates may be considered to represent an average over all years of data. The reason that this approach has been used is that in any one year there may be good or bad musters (fewer or more missing animals) and there may be individual years with either very low mortalities or very high mortalities. The Mortality Tool is considered to offer the best value when multiple years of data are entered and the results interpreted as a long-term or average estimate of mortality. Users can then assess their performance to see if there if there may be value in investing in strategies to either understand mortalities in more detail or to implement strategies designed to reduce mortalities.

   It is possible to enter just one year of data and determine an estimated mortality rate for one year. The accuracy of this sort of limited estimate will depend on the quality of the data and a single year estimate is probably likely to be most valid when it is estimated using the more detailed Version 2 of the *Mortality Tool.*

   It is also possible to add additional data each year to the existing *Mortality Tool* that already has data entered from previous years.

4. Why does the *Mortality Tool* need to produce an at-risk count of animals to produce an estimate of mortality rate?

   A mortality rate is based on two figures – the numerator or count of deaths, and the denominator or total number of animals at risk of dying.

   There are a number of difficulties in estimating mortality rates and it is important to get both counts as accurate as possible or the mortality rate estimates may be misleading. The above section explains some of the issues relating to the numerator. This section explains some of the issues relating to the denominator and their effects on mortality rate estimates.

The best way to explain these is through examples.

Example 1

Imagine a closed herd that starts the year with 1000 females. No female cattle are purchased, none are sold and no calves are weaned and branded to add to the herd. This sort of example is called a *closed herd* because there are no movements into or out of the herd. If we follow the herd for 12 months and 70 females die during that time then the mortality rate can be estimated as the numerator (number of deaths = 70) divided by the denominator (number of animals at risk of dying at the start of the period = 1000), which produces an estimate of 0.07. We can express this number as a percentage by multiplying it by 100 = 7%. We can then say that the mortality rate is 7% per year or 7 deaths per 100 animals per year. This sort of calculation of mortality rate is called a cumulative incidence rate. This is because it has a denominator that is based on the number of animals at risk of dying at the start of the period and a numerator based on the number of new deaths that occurred during the time period (one year).

Example 2

Imagine the same property starts the year with 1000 females. After 6 months, 600 of the females are sold and trucked off the property to the buyer's property. They are lost to follow up – all we know is that they were all alive at the time they left the original property and arrived at the buyer's property. The remaining 400 females stayed at the original property and were followed for the rest of the year.

There were 35 animals that died in the first 6 months of the year and 14 animals died in the second 6 months, producing a total of 49 animals that died over the whole year.
If we used the same cumulative incidence approach as described in *Example 1*, we could divide 49 by 1000 to produce an estimate of 4.9% mortality rate. The fact is that this estimate is wrong and represents an under-estimate of the true mortality rate, because of the 600 animals that were trucked off the property after 6 months. We should not count these animals as contributing time at risk to the denominator after they have left the property.

A better way to estimate the denominator is to think in terms of animal time at risk. There were 400 animals that were followed on the property all year (either died on the property or survived to the end of the year). Each animal contributed one year and so these animals altogether contributed 400 animal-years to the denominator. The other 600 animals were only present on the property for half of the year so they each contributed 0.5 animal-years to the denominator. Multiplying 0.5 by 600 produces 300. Having 600 animals on the property for half a year is the same as saying that these animals contributed 300 animal-years to the total time at risk. Adding the two component contributions, we get a total of 700 animal years at risk which were accumulated on the property during the 12 month period.

Then we can divide the total deaths (n=49) by the new denominator (700 animal years) and we get a mortality rate of 0.07 or 7%.

The fact is that the mortality rate is identical to the first example. The reason we have fewer total deaths is because 600 animals left the property after 6 months and were no longer available to die on the property. If we did not adjust the denominator appropriately we could produce a mortality rate estimate that is completely wrong and misleading.

Example 3
Imagine the same starting property that starts the 12 month period with 1000 females. After 6 months, an additional 3000 animals are bought onto the property.

In the first 6 months of the year, a total of 35 animals died. In the second half of the year a total of 105 animals died, producing a total count of deaths through the year of 140.

If we used the same cumulative incidence approach as described in *Example 1*, we could divide 140 by 1000 to produce an estimate of 14% mortality rate. This estimate is wrong and represents an over-estimate of the true mortality rate, because of the 3000 animals that were trucked onto the property after 6 months. We need to add additional animals to the denominator to account for the fact that there were 4000 animals on the property and available to die in the second half of the year.

Again, the best approach to this is to think in terms of animal time at risk. There were 1000 animals that were followed on the property all year (either died on the place or survived to the end of the year). Each animal contributed one year and so these animals altogether contributed 1000 animal-years to the denominator.

The other 3000 animals were only present on the property for half of the year so they each contributed 0.5 animal-years to the denominator. Multiplying 0.5 by 3000 produces 1500. Having 3000 animals on the property for half a year is the same as saying that these animals contributed 1500 animal-years to the total time at risk.

Adding the two component contributions, we get a total of 2500 animal years at risk that were accumulated on the property over the one year period.

Then we divide the total deaths (140) by the correct denominator of animal time at risk (2500 animal years) and we get a mortality rate of 0.056 or 5.6% mortality per year.

The point of these three examples is that in situations where the population can be described as dynamic (where animals can either leave or enter the population at risk at any time through the study period), using the starting count of animals as a denominator for estimating mortality rate can be wrong and can produce estimates that may be higher or lower than they should be. The most appropriate way to deal with this is to adjust the denominator by estimating contributions of different groups to the total animal time at risk. Each animal can only be counted in the denominator if it is actually on the property of interest and it should not be counted either before it arrives or after it leaves.

5. How do we adjust a denominator if we don't know when animals may have arrived or departed?

   Often we know that animals may have left or arrived during the year but we don't know exactly when.

   If we can assume that animals were able to arrive (or depart) at any time and that the likelihood of animals either departing or arriving was likely to be equally distributed across the period of interest, then the most appropriate way to adjust for this is to assume that the animals arrived (or departed) at the half way point.

   This is why we use the 0.5 adjustment for sales and purchases and branded animals – because we assume that they can all happen in either half of the year and therefore on average the animals that arrive or depart during the year will be contributing for only half of the year.

6. How good is this adjustment process?

   The examples described above clearly indicate that in an open herd situation (where animals may arrive or depart through the period of interest), estimation of rates is likely to be wrong unless some form of adjustment of the denominator takes place.

   If we can assume that animal movements do take place through the year or even just that they are equally likely to occur in the first half of the year as in the second half, then the simple assumption that all movements occur at the half-way point is a great way of producing a reasonably accurate estimate.

   However, if animal movements may occur mostly in one half of the year then even this simple adjustment process will be less accurate.

   Adjusting for sales involves making the denominator smaller to account for the fact that the sold animals are no longer contributing to the animal-time at risk once they have gone. If we assume sales occurred at the half-way point and in fact most of the sales occurred near the end of the year, then we will be making the denominator smaller than it should be and the resulting mortality estimate will be larger than it should be. If in fact nearly all of the sales occurred at the start of the year then we will be making the denominator larger than it should be and the resulting mortality estimate will be smaller than it should be.

   The effect for purchases will be in the opposite directions. If we assume all purchases occurred at the half-way point and in fact they nearly all occurred near the end of the year, then the denominator will be larger than it should be and the mortality estimate smaller. Conversely if nearly all the purchases occurred near the start of the year and we adjust assuming they occurred at the half-way point, then the denominator will be smaller than it should be and the mortality estimate higher.

   The point of this is that an adjustment of the denominator based on assuming movements occurred at the half-way point, is dependent on movements occurring roughly equally in the first half of the year and in the second half of the year. If this is not true then the estimates may be wrong and the error can be in either direction.

7. Why does the tool provide two estimates – one with an estimate of the animal-time at risk (denominator) that is not adjusted for sales and one where the denominator Is adjusted for sales.

   When we began using the livestock scheduling approach with adjusted denominators to account for animal movements during the year, we took interim figures back to producers to validate the findings. Adjustment of the denominators for purchases and incoming branded animals (animals that were branded during any one year) appeared to be producing output that was consistent with what producers were experiencing on their own properties. However, when movement of animals off the property (sales) were incorporated into the adjustment calculations, estimates of mortality occasionally became unrealistic, typically by being much higher than producers thought was possible. A possible explanation for this is if the movements were not evenly distributed across the entire year. This effect was explained in the previous FAQ.

   Our response to this was to produce an estimate of adjusted animal-time at risk (denominator) that was adjusted for purchases and incoming branded animals but was not adjusted for sales.

   The resulting mortality estimate will be most valid when any sales that did occur actually took place in the second half of the year.
   If sales resulted in movement of relatively large numbers of animals off the property in the first half of the year then this approach will produce mortality estimates that are too low.

   Discussion of interim results suggests that removing sales movements from the denominator adjustments resulted in output that was considered consistent with producers' own records of cattle numbers and mortalities.

   The *Mortality Tool* does produce a second set of estimates that are adjusted for sales. It is useful for users to compare these two estimates. If a user knows that sales have occurred in both halves of the year, then this estimate is likely to be the most valid estimate for that user.

   If most sales occurred in the first half of the year, then the estimate that does incorporate adjustment for sales will still be better than the estimate that is not adjusted for sales but both will be under-estimating true mortality rate.

   If the two estimates are very different, then this may suggest that animal sales resulted in large scale changes to animal-time at risk on the property and more detailed information to better estimate animal-time at risk may be needed. See the following FAQ for more information.

8. Is there a way of adjusting for the actual time when movements occurred?

   If producers are able to provide information on the month when movements occurred and the associated count of animals moving on or off (sales, purchases and brandings), then this detailed knowledge can be used to adjust the denominator more precisely for each movement. This is the approach taken in Version 2 of the *Mortality Tool* and where such information is available, using Version 2 will produce the most accurate estimate of mortality rates.