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Vaccination of calves and weaners for Clostridial diseases

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Abstract

Vaccination against common clostridial diseases in cattle is recommended as being best practice husbandry and perceived by farmers and veterinarians to reduce disease and mortality. Even though its prevalence is thought to be relatively low, tetanus is likely to be the most important clostridial disease for young cattle in northern Australia, because of its high case fatality rate (~80%) when outbreaks are observed (Radostits, 2007). However, only 8% and 13% of stations within the Barkly and Katherine regions of NT, respectively, are estimated to administer either 5-in-1 or 7-in-1 vaccine to weaner cattle and means that significant proportions of young cattle are potentially at risk of infection, particularly when husbandry procedures are performed (Cowley et al. 2014). This study sought to investigate the mortality and economic benefits of application of administering a single-shot 5-in-1 vaccine under field conditions in the NT. Additionally, this study also documented mortality rates in recently weaned cattle managed under commercial conditions.

Executive summary

Except for botulism, the practice of vaccinating cattle for clostridial diseases is not undertaken by a significant proportion of the northern beef cattle industry in extensive management systems unlike many producers in southern and central Queensland who routinely use the vaccine when they process their calves. This producer demonstration study aimed to increase the awareness of management practices at and around the time of weaning and investigate the effectiveness of administering a single dose of 5-in-1 vaccine prior to or at the time of dehorning/castration on 'missingness', a proxy measure of suspected mortality.

The objectives of the project were:

1. Demonstrate best practice husbandry procedures routinely conducted on young cattle.
2. Generate mortality data on extensively managed calves and weaner cattle following dehorning and castration.
3. Measure mortality reduction from vaccinating young cattle for clostridial diseases under commercial conditions.
4. Assess cost benefits of vaccinating young cattle for clostridial diseases under commercial conditions.

The experiment utilised twelve study groups of animals extensively managed across 10 commercial breeding enterprises within the Victoria River District, Sturt Plateau and Barkly Tablelands regions of the Northern Territory. Study animals were individually identified using both NLIS ear tags and visual management tags during 2015-2017 to compare the likelihood of missingness for animals that received a single dose of 5-in-1 vaccine before or at the time of dehorning/castration to those that were not vaccinated. Individual animal measurements were recorded electronically crush-side, including vaccination, dehorning, castration and gender.

Data analysis did not show a statistically significant reduction in the occurrence of animals 'missing' at future musters when vaccinated at the time of either or both dehorning and castration. However, a statistically significant association between castration status and missingness (P=0.001) with a 4.9% (1.7-8.0% 95%CI) unit increase in the expected occurrence of missingness for castrated animals when compared to entire animals was observed.

The occurrence of dehorning and the frontal sinus being exposed if dehorned were recorded in this study. In this study, 92.3% (88.0-96.5 95% CI) of animals were dehorned at the time of processing and of those, the occurrence of at least one frontal sinus exposed was 40.6% (20.7-64.1% 95% CI).

Two workshops aiming to increase awareness and use of best practice husbandry procedures were completed during the course of the producer demonstration study. The location of these workshops were Katherine Research Station, Katherine and Brunchilly Station, Barkly Tableland. Monitoring and evaluation assessments indicated that this study was successful in increasing awareness of management practices at and around the time of weaning and dehorning/castration.

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1 Background

Clostridial diseases are caused by anaerobic bacteria that can be found in soil and manure, are widespread throughout northern Australian and can survive for long periods of time. With the exception of botulism, tetanus is likely to be the most important clostridial disease as even though low in prevalence, has a case fatality rate in the order of 80% when occasional outbreaks occur, usually in association with wounding management practices being conducted. Prevention for these diseases relies heavily on vaccination. There are few articles presenting field results relating to the efficacy of clostridial vaccines preventing disease and mortality in cattle. But despite this, vaccination against common clostridial diseases in cattle is perceived by farmers and veterinarians to reduce disease and mortality and is recommended as being best practice husbandry.

The practice of vaccinating cattle for clostridial diseases is not undertaken by a significant proportion of the northern beef cattle industry in extensive management systems, unlike many producers in southern and central Queensland who routinely use the vaccine when they process their calves. In the recently completed 2010 NT pastoral industry survey, the vast majority of respondents did not vaccinate with only 8% and 13% of respondents in the Barkly and Katherine regions, respectively, administering at least one vaccination of either 5-in-1 or 7-in-1 vaccine to weaner cattle (Cowley et al. 2014). Data describing why respondents did not vaccinate was not collected within this survey. However, it is speculated that low adoption is partly due to the logistical constraints of administering booster vaccinations 4-6 weeks after the first vaccination as per the manufacturer's recommendation and therefore, producers predominantly either only administer one vaccination at the time of conducting husbandry procedures or do not vaccinate at all due to the belief that the second vaccination is required to provide a protective level of immunity. The greatest challenge from diseases such as Tetanus and Gas Gangrene will be often encountered within two weeks of the procedure, while the development of immunity to most bacterial vaccines is 10–14 days. So, there is reasoning to suggest that an initial shot followed by a natural challenge could offer reasonable protection. The low use of preventative measures means that significant proportions of young cattle that have undergone standard husbandry procedures such as castration (both surgical and elastration) and dehorning are potentially at risk of infection by clostridial disease and production loss. With the cost of commercial vaccines being in the order of 40-60 cents per dose, the cost of vaccination is considered likely to be exceeded by the production benefits.

This study proposed to use a multi-disciplinary approach to increase knowledge and awareness around wounding management procedures, such as dehorning and castration, and management of clostridial diseases. Additionally, this study also documented mortality rates in recently weaned male and female cattle managed under commercial conditions.

2 Project objectives

By 30th June 2019, in young extensively managed cattle:

1. Demonstrate best practice husbandry procedures routinely conducted on young cattle.
2. Generate mortality data on extensively managed calves and weaner cattle following dehorning and castration.
3. Measure mortality reduction from vaccinating young cattle for clostridial diseases under commercial conditions.
4. Assess cost benefits of vaccinating young cattle for clostridial diseases under commercial conditions.

3 Phase 1: In-field assessment of vaccinating young cattle for clostridial diseases

3.1 Methodology

A cohort study involving approximately 5,500 calves/weaners was conducted during 2015-2017 to compare the percentage of animals missing at future musters after receiving a single dose of 5-in-1 vaccine before or at the time of dehorning/castration to those that were not vaccinated. This field study was conducted within the Northern Territory using extensively managed commercial breeding enterprises within the Victoria River District, Sturt Plateau and Barkly Tablelands regions.

3.1.1 Selection of study locations

A multi-stage enrolment process was used with seven stations enrolled in 2015 and another five during 2016 and is a convenience sample of representative beef breeding enterprises within the northern regions of the Northern Territory. Candidate collaborators were largely self-identified following a call for participants using some different regional communication channels such as regional newsletters, attendance of Northern Territory Cattlemen's Association and Regional Beef Research Committee meetings, and *ad hoc* one-to-one discussions.

After expressing an interest in participating in the study, station owners and/or managers were contacted to discuss the benefits of participation, project objectives and participation requirements of the project. Only those stations that: had an interest in weaner management, were willing to individually electronically identify study animals, were committed to managing and monitoring the study group for approximately 1 year, were confident in being able to provide a relatively secure paddock to graze study animals for approximately 1 year and were able to contribute a minimum of 400 calves/weaners were enrolled into the study. Presented in Figure 1 are the locations of collaborating stations and their corresponding region (Victoria River District, Sturt Plateau and Barkly Tablelands).

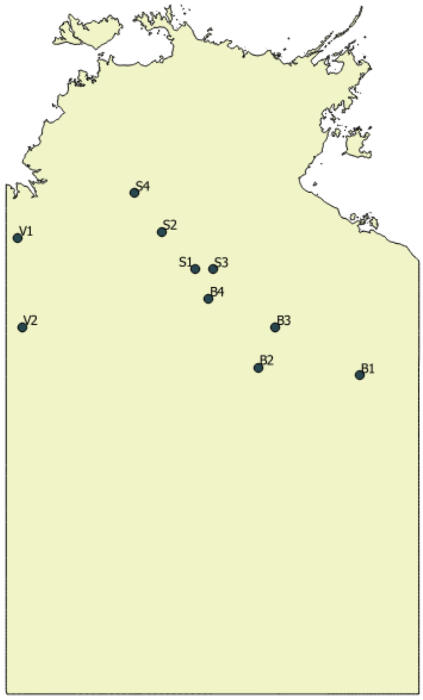

Figure 1. Map showing the location of the collaborating stations (S=Sturt Plateau, V=Victoria River District, B=Barkly Tablelands).

3.1.2 Animals and treatments

Most stations enrolled a single cohort of calves/weaners that varied in number in either 2015 or 2016. Calves were drafted from the main breeder group just before the husbandry procedures were conducted, which was at the time of enrolment. Calves were returned to the main breeder group shortly following the husbandry procedures being performed. Weaner animals were enrolled following a 'weaning' process at approximately 10-14 days after being separated from the breeder mob.

Study animals were enrolled at the time when husbandry procedures were conducted and were systematically (odd or even ear tag number) assigned to either 5-in1 vaccination (vaccinated) or control (not vaccinated) treatment groups. Animals were individually identified using both a visual management tag and an NLIS compliant RFID ear tag which was used to record basic animal data including: sex (Male / Female), age class (Calf / Weaner) and where practical, liveweight.

The vaccinated group (odd ear tag numbers) were injected subcutaneously with two mL of Ultravac® 5-in-1 vaccine at a single time point, while the not-vaccinated group (even ear tag numbers) were not vaccinated. A placebo product was not necessary and not used in the not-vaccinated group in this trial. All husbandry procedures were completed by station staff, including the administration of all vaccinations.

3.1.3 Assessment of 'missing' animals

Data were recorded at the individual animal level; capturing whether an animal was either present or absent at future mustering events as an indicator of mortality. Follow up musters occurred on average 3.7 months (range 1.5 to 6) from processing. Following husbandry procedures being performed, individual animals were ascribed as being 'missing' (recorded using a binary variable; 0=not missing, 1=missing) if they were absent from future mustering events. In situations where animals were assigned as missing but later reappeared, these animals were retrospectively updated as not missing.

Animals found dead by station staff were recorded as a 'confirmed death' and were identified using either the visual management tag or an electronic tag. The suspected cause of death was recorded if provided by station staff. However, due to the extensive nature of management and limited observation of animals under northern conditions, carcasses were often located well after death had occurred and a definitive cause of death unlikely. However, for animals that have been found to be clinically affected or have recently died, the presence of extensor rigidity (saw horse position) or protruding third eyelid membrane was considered diagnostic for tetanus.

Assessment of husbandry procedures

It is common under northern conditions for branding, castration and dehorning to all take place at the same time and for these procedures to be applied to animals ranging in size and age. Within cohorts of animals on a single station, it was expected that different methods and tools would be used and the choice of method is often reflecting personal preferences and size of the animal. Station personnel conducted all husbandry procedures, and the techniques used for castration and dehorning were assessed and recorded at the individual animal level.

Assessment of dehorning

Whether an animal was dehorned or not (recorded as a binary variable; 0=Not dehorned, 1=Dehorned) and technique used was recorded. For the animals dehorned, following an inspection of both sides of the head whether or not the frontal sinus on either side of the head had been exposed (recorded as a binary variable; 0=Frontal sinus not exposed, 1=Frontal sinus exposed) was recorded.

The dehorning methods observed in the present study included the use of a dehorning knife, scoop dehorners, parrot beak dehorners and cup dehorners and was recorded at the individual animal level. A dehorning knife is most effective for small horns and animals. The knife is curved in shape with a blunt end and is used to cut away the skin around and under the horn bud, removing the horn from the base. For dehorning larger animals, the choice of tool is varied, but the cup or scoop type dehorners are the most common. Cup dehorners are large and are used by placing cups either side of the horn and using a scissor-like action to remove the horn. Scoop dehorners are placed over the horn and as the operator spreads the leverage arms the horn is 'scooped' out.

Parrot beak dehorners are used to 'tip' the horn of older animals and do not remove the tissue surrounding the horn and therefore do not prevent regrowth.

Castration

Whether an animal was castrated or not (recorded as a binary variable; 0=Not castrated, 1=Castrated) and technique used was recorded. The most common castration method in northern systems is surgical castration or cutting. Banding using an elastrator is also sometimes used.

3.1.4 Statistical analyses

Analyses followed a standardised format, with descriptive analyses completed using summary statistics, including mean and 95% confidence intervals for continuous data and proportions expressed as percentages for nominal data.

For each outcome variable of interest (missingness, exposed frontal sinus), regression analyses were conducted to assess the strength of association between explanatory factors (dehorned, dehorning technique, castration, exposed frontal sinus) upon these outcome variables. Where it was possible to combine data from multiple properties into a single analysis, the mob was included as a random effect to adjust for clustering at the mob level.

To provide additional explanatory detail about associations, statistical models were used to estimate the differences in the expected occurrence of outcome variables (missingness, exposed frontal sinus) for the different levels of explanatory variables (vaccination, dehorned, dehorning technique, castration).

All analyses were conducted using Stata, version 13 (www.stata.com) with alpha=0.05.

3.1.5 Ethical clearance

The Animal Ethics Committee, Charles Darwin University, Darwin, approved Ethical clearance (A15008) for 9000 cattle to be involved in this study over two years.

3.2 Results

Data relating to husbandry practices were recorded for 5,995 individual animals and were representative of 10 different stations. Two stations, however, contributed data from two cohorts of animals, enrolling a new cohort in each of the year's 2015 and 2016 (Table 1). Each station enrolled on average 499 animals and ranged between 217 and 1,116. The number of animals enrolled, and liveweight if recorded, has been summarised by sex, age class, station and region and is presented in Table 1.

Table 1. Number and average liveweight (kg) of study animals enrolled by region, age class, sex and station.

Region and Station	Female			Male		
	No.	Average	Range	No.	Average	Range
Barkly Tableland						
- Alexandria Station				736	228.0	(164-285)
- Brunchilly Station – 2015	598	168.5	(90-227)	518	176.0	(104-243)
- Brunchilly Station – 2016	409	161.8	(111-223)	381	160.9	(103-242)
- Eva Downs Station				514	183.9	(122-290)
- Newcastle Waters Station	253	-	-	198	-	-
Sturt Plateau						
- Buchanan Downs Station	217	182.4	(130-258)	179	195.1	(136-293)
- Gilnockie Station				390	191.1	(144.5-230)
- Hayfield Station	124	-	-	151	-	-
- Mathison Station – 2015	128	149.3	(77-209)	127	152.7	(59-231)
- Mathison Station – 2016	154	156.0	(76.5-233)	129	165.8	(89.5-232)
Victoria River District						
- Newry Station	285	-	-	273	-	-
- Bunda Station	217				-	-
Total	2,083			3,352		

Apart from three collaborating stations, sufficient data were captured at follow-up mustering events to allow the outcome variable 'missingness' to be ascribed at the animal level (Table 2). Data were not captured on one station due to this station withdrawing from the study and resulted in 217 animals being lost to follow-up. Data were not captured on two other stations due to project staff not being advised that study animals were planned to be mustered and presence/absence data were not captured by station staff. Data were validated by cross-referencing RFIDs of study animals to the national database of livestock transactions as all male animals were relocated to an adjoining property after the muster and therefore identified male study animals that were present at the muster.

Table 2. Dates of enrolment and re-mustering for collaborating stations

Station	Method of castration	Mustering Dates		
		Enrolment	Re-muster 1	Re-muster 2
Enrolled 2015				
- Newcastle Waters Station	Surgical	11-May-15	09-Oct-15 (5m)	
- Brunchilly Station	Surgical	14-May-15	12-Nov-15 (6m)	
- Bunda Station	NIL	11-Jun-15	LTFU*	
- Gilnockie Station	Elastrator	12-Jun-15	09-Oct-15 (4m)	21-Apr-16 (10m)
- Newry Station	Surgical	15-Jun-15	11-Oct-15 (4m)	
- Hayfield Station	Surgical	10-Jul-15	20-Oct-15 (3.5m)	
- Mathison Station	NIL	14-Jul-15	26-Sep-15 (2.5m)	26-Oct-15 (3.5m)
Enrolled 2016				
- Brunchilly Station - Y2	Surgical	24-Apr-16	LTFU*	
- Buchanan Downs Station	NIL	18-May-16	28-Jun-16 (1.5m)	
- Eva Downs Station	Surgical	2-Jun-16	LTFU*	
- Alexandria Station	Surgical	4-Jun-16	12-Oct-16 (4m)	
- Matheson Station - Y2	NIL	11-Aug-16	19-Nov-16 (3m)	

*LTFU = Lost to follow up

3.2.1 'Missingness'

Data were recorded at the individual animal level; capturing whether an animal was either present or absent at future mustering events as an indicator of mortality. Sufficient data were captured allowing 'missing' to be ascribed to 4,189 cattle. However, it should be noted that animals that failed to present at a subsequent muster for reasons other than mortality such as loss of individual identification or were un-reportedly relocated within the station are also potentially represented within the 'missing' outcome. To minimise misclassification error, animals identified as 'missing' were cross-referenced with the national database of livestock transactions and their records updated if a transaction had been recorded.

On average, 4.4% (0.8-8.0% 95% CI) of all study mobs were identified as 'missing' and greatly varied between stations, ranging between 2.7 and 15.5%. The timing of mustering was thought to partly explain this variation with those stations that conducted re-mustering sooner, generally observed as having a lower prevalence of missingness. Regression analysis results confirmed this, determining a statistically significant positive association ($P<0.05$).

Two of the eight collaborating stations conducted more than one re-mustering event to identify missing animals. On further inspection of the data restricted to these stations, 65.9% (55.6-75.0% 95%CI) of the animals that were 'absent' at the first muster were likely to have been mismustered, as they reappeared at the second muster. These findings confirm that missingness is an overinflated estimate of mortality when based on only one follow-up muster. On stations that only completed a single follow-up muster, a large proportion of animals currently assigned as 'missing' are likely to be alive but were failed to be located and mustered. Had a second subsequent muster been completed on all stations, and assuming similar levels of miss-mustering across stations has occurred, one potential estimate of overall missingness is 3.8%.

As the incidence of mismustering was determined to be similar for each vaccination group (P=0.67) it was not considered a confounding variable, as it was not associated with both the risk factor (vaccination) and the outcome (missingness). Therefore, mismustering was not thought to alter the interpretation of results when assessing the impact of risk factors on missingness using data derived from stations that only conducted a single remustering event.

Except for mortality, the reasons for an animal to be missing are likely to occur at random and not to be associated with treatment. Therefore, observed differences in percent missingness for groups within a single station are likely to be largely reflective of differences in the prevalence of mortality. However, appropriate caution should be exercised when interpreting this measure as data to assign 'missing' was based on a minimal number of consecutive musters and the study period animals were observed is considered to be shorter than periods used under routine commercial conditions for classifying missing. Furthermore, weaners are more likely to escape from a paddock than most other classes of animals as they are smaller and can find gaps in the fencing and they generally take longer to settle and become accustomed to their new surroundings.

3.2.2 Vaccination

Vaccination status was recorded for each animal. Overall, animals that were vaccinated with a single dose of 5in1 had a 0.3% lower likelihood of missingness, compared to animals that were not vaccinated (VACC = 4.3% vs CONT = 4.0%). This association was not statistically significant, however (P=0.53).

There was also no significant effect of vaccination on missingness within both males (P=0.88) and females (P=0.63). However, the trend of slightly lower incidence of missingness for vaccinated animals was observed for both males (n=2701; VACC = 4.3% vs CONT = 4.4%) and females (n=1474; VACC = 4.8% vs CONT = 5.3%).

Similarly, there was no association between vaccination status and missingness when regression analyses were repeated for each of three subsets of data restricted to only those animals classified as castrated, dehorned or having exposed frontal sinus (P=0.97, P=0.46 and P=0.99, respectively).

These findings indicate that for the mobs involved in this study in years which they were observed, there was limited or no benefit in vaccinating for 5-in-1.

3.2.3 Dehorning

Dehorning status was recorded for 5,990 individual animals at the time of husbandry procedures being performed and represented 12 study mobs. Of these, missingness information was only available for 4184 animals that represented 9 study mobs. This dataset was subjected to a regression analysis and there was no association between dehorning status and occurrence of missingness (P=0.81).

On average 92.3% (88.0-96.5 95% CI) of animals within study mobs were dehorned when husbandry procedures were performed. The incidence of dehorning was higher for some stations than others and varied between 78.3% and 100% (P<0.001).

The percentage of animals dehorned was observed to be similar in males (92.5%; 85.7-96.3% 95%CI) to females (89.0%; 77.7-95.0% 95%CI) (Table 3; P=0.19). On one station, where both calves and weaners were enrolled into the study, the occurrence of dehorning was observed to be similar for calves (96.8%, 77.0-116.6% 95%CI) as it was for weaners (99.1%, 90.1-108.2% 95%CI) (P=0.84).

Table 3. Prevalence of dehorning for males and females

Station	Female		Male	
	N	Percentage dehorned	N	Percentage dehorned
Alexandria Station			736	96.1%
Brunchilly Station - 2015	598	83.8%	518	92.9%
Brunchilly Station - 2016	409	74.1%	381	82.7%
Buchanan Downs Station	217	93.5%	179	95.0%
Bunda Station	217	98.6%		
Eva Downs Station			514	82.3%
Gilnockie Station			390	99.7%
Hayfield Station	124	90.3%	151	90.7%
Matheson Station - 2015	128	92.2%	127	96.1%
Matheson Station - 2016	154	100.0%	129	100.0%
Newcastle Waters Station*	253	92.9%	198	94.4%
Newry Station*	285	99.3%	273	98.2%
Average	2,385	89.0%	3,596	92.5%

* includes calves that were returned to the breeder management group

There was no significant association between weaning weight and dehorning (P=0.78). However, using data from stations that used more than one dehorning technique, there was a statistically significant association between weaning weight and dehorning technique (P<0.001). This finding is consistent with current knowledge that choice of dehorning technique is based on horn and animal size, which are closely correlated with animal weight.

Animals dehorned using a dehorning knife had the lowest weaning weight and were significantly lighter than animals dehorned using other techniques. Animals dehorned using reverse scoops had the highest weaning weight and were significantly heavier than animals dehorned using either a dehorning knife or scoop dehorners (P<0.05).

These observations are also consistent with current understanding with dehorning knives being the instrument of choice for use on younger calves up to about 2-3 months of age (La Fontaine and De Witte, 2002), while instruments such as reverse scoops are generally chosen for tipping of older animals to retard horn growth rather than attempting to remove all of the horn material and adjacent tissue.

3.2.4 Exposed frontal sinus

Data were recorded against 3,809 dehorned animals classifying if at least one frontal sinus was exposed following an inspection of both sides of the head and represented nine stations. On average, at least one frontal sinus was exposed for 40.6% (20.7-64.1% 95% CI) of dehorned study animals. The incidence of exposed frontal sinus was found to be associated with study mob (P<0.001), with the occurrence of exposed frontal sinus ranging between 1% and 82.8% across study mobs.

Using a subset of data (n=1737) drawn from three stations, a highly significant association between dehorning technique and the observed occurrence of exposed frontal sinus (P<0.001) was determined, with the expected occurrence of exposed frontal sinus estimated as 10.5% (7.7-13.5% 95% CI) and 84.7% (77.2-92.1% 95%CI) percent for dehorning knife and scoop, respectively. It is acknowledged, however, that this association is likely to be confounded by the age of the animals. As reported above, the use of scoop dehorners correlated with animals of heavier weaning weights, which is likely to indicate an older age, and more likely that the horn bud is attached to the skull at the time of dehorning, increasing the risk of an exposed frontal sinus.

The occurrence of missingness was similar for dehorned animals regardless of exposure of frontal sinus or not (P=0.67). As liveweight was associated with both the prevalence of missingness and the incidence of exposure of the frontal sinus, regression analyses it was treated as a confounding variable in regression analyses.

3.2.5 Castration

Using only data from stations where both non-castrated and castrated animals were enrolled, the impact of castration status on missingness was investigated using regression analysis. The dataset included 2,117 animals which represented four stations.

There was a statistically significant association between castration status and missingness (P=0.001) with a 4.7% (1.7-7.5% 95%CI) unit increase in the expected occurrence of missingness for castrated animals when compared to entire animals. Despite there being limited scientific papers quantifying the effect of castration on the risk of mortality, these results are consistent with the current understanding that greater mortality risk is likely due to complications associated with castration such as poor hygiene, blood loss, and infection by clostridial diseases. Importantly, however, this finding was independent of vaccination status with no difference in missingness observed when subgroups of castrated animals of different vaccination status were compared (P=0.97). These results are not easily explained and possibly suggest that only providing a single shot of 5-in-1 vaccine does not provide a preventative level of immunity against infection by clostridial diseases resulting in elevated levels of mortality but, this may not be the case over a number of years and more numbers may be required to detect a prevalence of 0.1 to 0.2%.

3.2.6 Economic analyses

To explore the concept of calculating the required response from vaccinating to absorb the cost of incorporating the practice into a business a simplified break-even analysis was completed for a mob of 1000 weaners and comparing the cost of administering a single shot 5in1 vaccine at the branding cradle to the value of a mortality event.

The baseline assumptions to calculate the average cost of vaccination on a per animal basis were that 500 weaners could be processed per day and a single 2 mL dose of 5 in 1 vaccine was valued at $0.57 ($129 + GST per pouch, which delivered 250 doses). Even though it may not be required in some situations, it was assumed that an additional casual staff member needed to be employed to deliver the vaccine and their casual rate for employment was $375 per day.

The baseline assumptions to value the cost of loss of production were that a weaner averaged $180/kg and if sold at the point of weaning was valued at $3/kg. No production losses due to suppressed performance were accounted for in this analysis. Nor were any other associated losses to the business resulting such as opportunity cost or value of the animal at its typical point of sale i.e. a live export steer or a retained heifer for breeding. A single mortality event was valued at $540.

Under these assumptions, administering a single shot vaccination at the branding cradle would be cost neutral to a business if it prevented 5 mortality events per 2,000 animals (0.25%). If vaccination could be performed by existing staff, however, it was significantly reduced to 19 mortality events per 18,000 animals (0.11%).

4 Phase 2: Extension activities promoting the use of best practice husbandry procedures routinely conducted on young cattle

Two workshops aiming to increase awareness and use of best practice husbandry procedures were completed during the course of the project. The location of these workshops were Katherine Research Station, Katherine and Brunchilly Station, Barkly Tableland. The target audience was identified as on-station staff that have both experience and influence i.e. owners, managers and assistant managers, leading hands and head stockmen or stockwomen.

4.1.1 Workshop 1 – Katherine Research Station

On the 4th October 2016, a Weaner Management Workshop was held at the Katherine Research Station was attended by eight producers that were largely associated with stations from the Victoria River District.

The in-field study results were presented by Jodie Ward and discussed thoroughly. Dr Lee Taylor (Zoetis) assisted with the delivery of this workshop and delivered a presentation on the epidemiology of tetanus and other clostridial diseases relevant to northern Australia. Other topics covered including appropriate treatment and administration of vaccines. A facilitated discussion followed aiming to discuss the positive and negative aspects of vaccinate for clostridial diseases. The day was concluded with participants utilising best-practice castration and dehorning techniques in a practical session to foster skillset development.

4.1.2 Workshop 2 - Barkly animal husbandry workshop

In conjunction with the 2017 Barkly Herd Management Forum (BHMF) a second weaner management workshop was completed at Brunchilly Station, which is located in the Barkly Tableland region. The forum was attended by 17 station staff that held positions responsible overseeing the correct application of husbandry procedures, such as Leading hand, Head Stockperson or Assistant Manager. Collectively, these attendees represented over 450,000 cattle and a grazing area of 64,000km^2.

The workshop included both a theoretical and practical component. The theoretical component included a presentation summarising the results from the in-field study, which were presented in a class room setting by Jodie Ward with ample time allocated for discussion.

During the presentation, the concept of 'missingness' was explained, including its limitations and how the project was overcoming such barriers (monitoring of the NLIS database for appearance after the station's involvement with the project had concluded). It was noted during the presentation that there was a higher association of missingness with those castrated than those not castrated irrespective of treatment group. It was also mentioned that there was a correlation between station and frontal sinus exposure, which is likely to have been affected by age of animal being dehorned. Possible management strategies discussed between participants and presenters for overcoming post-husbandry procedure setbacks in weight gain and missingness included:

- leaving males entire and the implications this would have on required infrastructure,
- three rounds of weaning to ensure calves were dehorned at a younger age hence less exposure of frontal sinus, and
- separation of cows from weaners (as per standard practice) for a period of a number of weeks followed by husbandry procedures such as castration, vaccination and dehorning, allowing for two vaccinations against clostridial diseases, thereby increasing levels of immunity.

The practical component of the workshop included a demonstration of best practice dehorning and castration, which was presented by well-known and respected veterinarian, Ian Braithwaite. Topics such as appropriate handling and administration of vaccines were also discussed at length. The practical session concluded with attendees utilising best-practice castration and dehorning techniques under supervision.

Pre and post participating surveys were completed with some participants strongly indicating that the demonstration had increased their confidence in conducting dehorning and or castration and that there was a positive change in the survey participant's knowledge, attitude and or skills.

Key messages from the surveys are summarised below:

Frequently reported activities that participants said they would start doing:	*Frequently reported activities that participants said they would research/investigate further:*
- Start monitoring weaner weight in association with annual weaning rate - Improved castration technique - Improved livestock handling techniques - Administration of pain relief - Make more time for branding - Conduct husbandry procedures at younger ages - Improved dehorning technique - More frequently changing needles while vaccinating	- Thinking about new castration technique - Look into overall best practice manual - Wean then brand one month later - New castration technique experimenting - Using 5-in-1 vaccine - New castration technique - Calf mortality rate research

5 Monitoring and evaluation

To evaluate the management practices of collaborators before their involvement in the study, or after their attendance at a workshop, each collaborator, or workshop attendee, was asked to complete a survey (Appendix). The objective of survey questions was to examine any increases in awareness surrounding the risk of clostridial diseases and reasoning for their current management choices.

In total, six survey responses were received, with five collaborators and one workshop attendee responding to the survey. In total, survey respondents managed 82,000 head of cattle (3.7% of NT herd) and were responsible for the management of 15,487km2 of pastoral area.

All survey responses expressed a high level of confidence in their current management of clostridial diseases, with all participants scoring >7 using a 1 to 10 sliding scale (**Error! Reference source not found.**). Overall, responses to the survey indicated a slight increase in awareness of vaccination to control clostridial disease. While some respondents indicated that their awareness of clostridial diseases had increased significantly by involvement in this study, the overall limited improvement in awareness may be partly explained by the high level of confidence held by participants on their current management practices. Two respondents commented in free text sections that whilst, involvement in this study did not necessarily make them aware of new knowledge, their involvement in the study made them consider their future actions more than they would have normally.

Table 4. Summary of M&E survey responses

Question	Response category	Percentage of responses (n=6; each response = 16.7%)	
What is your current estimate of mortality associated with conducting husbandry procedures, including disease, to young cattle in		Male	Female
	<1%	33%	33%
	1-2%	17%	34%
	2-3%	17%	0%
	>3%	0%	0%
	Unsure	33%	33%
Before involvement in this study, was the use of either 5-in-1 or 7in1 vaccine a routine management practice	No	67%	
	Yes	33%	
What castration method of young male cattle on your station is routinely used	Entire	33%	
	Surgical	50%	
	Rings	17%	
If you currently do, or were to vaccinate for clostridial diseases which of these disease do you consider the most important to control on your station	Black leg	0%	
	Black disease	0%	
	Lepto	17%	
	Mal.Oedema	0%	
	Pulpy Kidney	0%	
	Tetanus	100%	
Are you aware of or suspect that significant mortalities (greater than 0.5%) due to clostridial diseases (such as tetanus) have occurred on your station either currently/or in the past?	Yes	17%	
	No	83%	
How confident are you that your vaccination program is effective? [Sliding scale 1 - Not Confident to 10 – Confident]	Average	7.8	
	Range	7 to 9	
Your involvement in this study/workshop has increased your awareness of vaccination to control clostridial diseases? [Sliding scale 1 - Disagree to 10 – Agree]	Average	6.5	
	Range	4 to 9	
Your involvement in this study/workshop has (or is likely to) result in changes to your management practice? [Sliding scale 1 - Disagree to 10 – Agree]	Average	6.3	
	Range	2 to 9	

6 Discussion

This producer demonstration study used a multi-disciplinary approach to increase knowledge and awareness around wounding management procedures, such as dehorning and castration, and management of clostridial diseases.

The importance of making management decisions that are based on evidence was highlighted through demonstrating the use of an 'odds and even' trial to generate evidence on for a topic of concern on their own properties. The trial sought to investigate the efficacy of only administering a single shot 5-in-1 vaccination at the time of husbandry procedures under commercial field conditions. A limited number of such research could be found during a brief literature review, highlighting how this producer demonstration study contributed to research as well as fostering skillset development and increased knowledge. Within cohort vaccination trials are a powerful method to determine the prevalence and effectiveness of vaccines for animal health issues. This approach has previously demonstrated to show significant impacts of vaccination for both vibriosis (Schatz 2006) and botulism (Smith, pers com) in MLA funded heifer research projects conducted in the Northern Territory and the Pilbara.

As well as assessing the effectiveness of a vaccine protocol, this study also provided the opportunity to document suspected mortality rates in male and female cattle that had been recently weaning in extensively managed herds of northern NT. In these commercial operations it is typical to define mortalities by the absence of an individual animal at consecutive mustering events. On average, 4.4% (0.8-8.0% 95% CI) of all study mobs were identified as 'missing' which was higher than expected. The MLA funded Liveweight Gain study involved 11 stations from across the Barkly and Katherine regions of the NT reported a 1.9% average missingness over a 12 month period (Streeter *et al.*, 2014). The increase rate of missingness observed in the current study is likely to be associated with an increased likelihood of misclassification error in the current study, as it was derived from a minimal number of consecutive musters with the period of observation concentrated to the few months after weaning. Therefore, is likely to represent an overinflated estimate of mortality. Even though some caution is recommended when interpreting the suspected mortality rate results in this study, the reasons for animal to be missing were considered to occur at random and independent of vaccination treatment and other explanatory factors, such as castration, dehorning, exposure of frontal sinus. Therefore, even though the actual rates of missingness reported in this study might be slightly elevated, when compared to actual, the mean differences between groups is likely to reflective of differences in the incidence of mortality.

While providing only a single shot 5-in-1 vaccination at the time of husbandry procedures is practical for most northern NT commercial conditions, the findings of this study appear to indicate that there was limited or no benefit in providing a single shot of 5-in-1 at the time of completing husbandry practices. A slightly lower percentage (0.3%) of vaccinated animals went missing animals relative to non-vaccinated animals, but this association was not statistically significant (P=0.53). When analyses were restricted by sex, similarly, was no association between vaccination status and missingness within both males (n=2701; P=0.88) and females (n=1474; P=0.62). However, interestingly, the effect of vaccination for missingness appeared to be greater for females versus males, with vaccinated females having a 0.5% lower missingness versus 0.1% in males, when compared to their counterparts. These results are difficult to explain as diseases like tetanus are typically a consequence of wound contamination, with parts of the body in contact with soil at greatest risk of infection and means that males are typically thought of as being at greater risk of infection due to castration. However, when analyses were repeated for each of three subsets of data restricted to only those animals classified as castrated, dehorned or having exposed frontal sinus, there was no association between vaccination status and missingness (P=0.97, P=0.49 and P=0.98, respectively).

There are potentially multiple factors contributing to these findings. The number of animals involved in this study were too small to detect statistically significant differences for interventions resulting in responses in the order of 0.1 to 0.2 percentage units. The prevalence of clostridial diseases for the herds, in the years involved in this study, was also likely to be low. Clostridial diseases are very sporadic in nature and treatment options are ineffective and difficult to apply in extensive management situations should an incident occur. The simple economic analyses completed as part of this study demonstrated that only a minimal response from vaccination (prevent 1 mortality per 1000) was needed to make the practice of administering a single shot vaccination at the branding cradle cost neutral to the business if the vaccinations could be performed by existing staff.

Even though *Clostridium tetani* is considered ubiquitous and found in all parts of the world with a reported higher presence in warmer climates (Popoff, 2016), no significant outbreaks of tetanus or gas gangrene found during the conduct of this study. Had tetanus outbreaks occurred in this study, a mortality rate exceeding the overall missingness measured during this trial would be expected, as tetanus has a case fatality rate in the order of 80% in young cattle.

The incubation period for tetanus is reported to range between 3 and 21 days, while a vaccine-induced immune response is thought be achieved by 10-14 days after vaccination, meaning that there was small risk that some vaccinated animals were not able to develop a preventative level of immunity for the disease. As the single dose of 5in1 was administered at the time of conducting castration and or dehorning for this study despite attempt to vaccinate earlier it is not known if administering the single vaccination of 5 in 1 prior to these procedures would have achieved a different outcome. Equally, it is also unclear if the vaccine had been administered as per the manufacturer's recommendations of 2 shots 4-6 weeks apart would have produced a different outcome had stations been able to follow these guidelines which are much more expensive and difficult to adopt as additional mustering and handling is required.

The lack of response to vaccination could also represent appropriate post-surgical management of cattle and adequate levels of hygiene being practiced by technicians. Employing good surgical technique by ensuring adequate drainage of the surgical site and by appropriate disinfection of the surgical site and instruments is likely to avoid many cases of tetanus. While appropriate management of cattle after wounding management practices are conducted, such as minimising their time spent in cattle yards, is also likely to reduce the risk of infection as *C. tetani* favours environments with high levels of manure and moisture, such as sprinkling to reduce dust while working cattle.

This procedure to dehorn cattle is typically conducted at the same time as branding and or castration for safety reasons of stock people, and potential welfare and production benefits. Horned cattle can cause bruising of other livestock during transport and while being worked in yards. In the current study, 92.3% (88.0-96.5 95% CI) of animals within study mobs were dehorned. This ranged between 78.3% and 100% (P<0.001) across properties. Despite Bunter et al. (2013) strongly suggesting a causative association between calf mortality and dehorning, no association between dehorning and missingness was observed in the current study (P=0.80) with only a 0.2% higher percentage of dehorned animals absent from subsequent mustering events, when compared to cattle that were not dehorned. Mortality rates from dehorning are not well described. However, Bunter et al. (2013) suggested that a 2.1% mortality rate observed in dehorned calves was due to the procedure. The lack of impact from dehorning in the current study potentially further supports that high-levels of hygiene and skill were practiced by technicians completing the procedures in this study.

The animal being polled (hornless) or scurred was typically the only reason why an animal was not dehorned, suggesting that a potential estimate for polled or scurred animals involved in the current study was 7.7% (3.5%-12% 95% CI). This estimate is broadly consistent with Prayaga's (2005) finding that 10% of Brahmans were naturally polled or scurred, as the majority of cattle involved in the current study were high-grade Brahman.

The practice of dehorning exposed the sinus on 40.6% (20.7-64.1% 95% CI) of dehorned study animals in the current study and was associated with dehorning technique (P<0.001). The technique used to dehorn an animal was largely determined by the size and age of the animal. Dehorning knives are typically used on smaller animals, with at least one frontal sinus exposed for 10.5% (7.7-13.5% 95% CI) of animals dehorned used this technique in the present study. The sinus was exposed on 82.8% of animals that were dehorned with scoop dehorners, which are typically used for bigger and older animals. Even though dehorning technique has been shown not to be associated with growth (Streeter et al, 2014), the previously reported pain and risk of infection associated with exposed sinuses (Fordyce et al, 2014) suggests that producers should be encouraged to minimise its occurrence.

Castration of male calves is a common management practice performed in Australian beef production systems. In the present study there was an estimated 4.7% (1.8-7.5% 95%CI) unit increase in the occurrence of missingness for castrated animals, when compared to entire animals. The mortality risk due to castration has not been well described for northern Australia. However, these results are consistent with the current understanding that greater mortality risk is likely due to complications associated with castration such as poor hygiene, blood loss, and infection by clostridial diseases and if this statistically association is true it is an unacceptable level of loss. In a survey of New Zealand farmers 1% mortality due to surgical castration has been attributed (Stafford et al, 2000). However, the age of calves at the time of the procedures average 4.3 months, which is much younger than when procedures are typically performed in northern Australia. Similarly, McCosker and Schatz, (2011) reported a potential mortality rate of 1.2% loss due to castration by comparing differences in missingness for males, compared to females, when processed at weaning for station located within the Barkly Tableland.

7 Conclusions and recommendations

This study completed an efficacy study of a vaccine protocol under commercial settings and two workshops within the Northern Territory to increase awareness around management of clostridial diseases around the time of branding/weaning. In doing so, this study generated and summarised suspected mortality data, as well as employing analytical techniques to explore possible associations between missingness and candidate risk factors, such as dehorning, castration and exposure of the frontal sinus.

While providing only a single shot 5-in-1 vaccination at the time of husbandry procedures is practical for most northern NT commercial conditions, the results from this study suggest that this may not have established a preventative level of immunity against clostridial disease. The analyses showed that there was no association between vaccination status and missingness within both males and females. Similarly, there was no association between vaccination status and missingness when regression analyses were repeated for each of three subsets of data restricted to only those animals classified as having been castrated, dehorned or having exposed frontal sinus.

The prevalence of clostridial diseases for the herds, in the years involved in this study, was likely to be low, with no reported cases of tetanus or gas gangrene throughout the entire study period. Clostridial diseases are very sporadic in nature and treatment options are ineffective and difficult to apply in extensive management situations should an incident occur. Therefore, where possible, producers should continue to be encouraged to continue implementing management practices that prevent clostridial disease following wounding husbandry procedures. This includes producers considering using clostridial vaccines as per the manufacturer recommendations of two shots four to six weeks apart.

The simple economic analyses completed as part of this study demonstrated that only a minimal response from vaccination was needed to make the practice of administering a single shot vaccination at the branding cradle cost neutral to the business, particularly if vaccination could be completed by existing staff.

Producers should also ensure staff maintain a high level of proficiency in conducting husbandry procedures. Diseases such as tetanus are usually a consequence of contamination and many cases are likely to be avoided by employing good surgical technique, ensuring adequate drainage of the surgical site and by appropriate disinfection of the surgical site and instruments.

This study has also provided the opportunity to capture some useful and interesting descriptive information with 4.4% (0.8-8.0% 95% CI) of study mobs identified as 'missing', a potential proxy indicator of mortality.

This study identified a statistical association for castration with an estimated 4.5% (1.9-7.1% 95%CI) higher occurrence of missingness for castrated animals when compared to animals that were not castrated ($P<0.001$). This equates to 45 head out of 1,000 and is totally unacceptable if true. This association warrants further investigation.

Dehorning and exposure of the frontal sinus were not found to be associated with missingness. However, the frontal sinus was exposed in approximately 40% of dehorned animals. As this is known to cause prolonged pain and increased risk of infection, producers should continue to dehorn calves as young as possible.

A potential population estimate for polled or scurred animals in commercial herds of the Northern Territory was 7.7% (3.5%-12% 95% CI).

Monitoring and evaluation outcomes indicate that this project was successful in increasing knowledge and awareness around wounding management procedures and management of clostridial diseases. Additionally, this project reinforced the importance of making management decisions that are based on evidence and the ability to capture informative data. Through their involvement in this study industry stakeholders were equipped with techniques, such as the odd and evens trial, that will allow them to generate evidence on a topic of concern in their own environment.

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9 Appendix

9.1 Monitoring and Evaluation survey

Does single shot vaccination of calves and weaners for clostridial diseases reduce the risk of mortality in northern NT beef herds?

Station: Click here to enter text. Name of manager: Click here to enter text.

No of retained cattle annually: Click here to enter text. Size of property: Click here to enter text. km^2

What is your current estimate of mortality associated with conducting husbandry procedures, including disease, to young cattle in **- Males:** and **- Females**

- Males	- Females
☐ less than 1%	☐ less than 1%
☐ 1-2%	☐ 1-2%
☐ 2-3%	☐ 2-3%
☐ greater than 3%	☐ greater than 3%
☐ not aware	☐ not aware

Before attending the workshop, was the use of either 5in1 or 7in1 vaccine a routine management practice?

☐ YES
☐ NO

IF YES: Please explain why Click here to enter text.

The timing of vaccination with 5in1/7in1 is best described by which of the following.

☐ At time of husbandry procedures
☐ At time of husbandry procedures + booster 14 days after
☐ Less than 7 days before husbandry procedures
☐ Greater than or approx. 7 days before husbandry procedures
☐ Greater than or approx. 7 days before husbandry procedures + booster at time of husbandry procedures

If a booster is not administered, please explain why Click here to enter text.

IF NO: The reason for not using either 5in1 or 7in1 vaccine is best described by which of the following

☐ cannot administer the booster as recommended so I believe that the vaccine won't be effective
☐ time constraints at time of conducting husbandry procedures
☐ don't believe clostridial diseases (ie tetanus) are a problem and don't result in many mortalities
☐ lack of cost benefit
☐ Other: Please specify Click here to enter text.

Young male cattle on your station are routinely?

☐ Surgically castrated
☐ Castrated with rings (ligature castration)
☐ Left entire

What method of dehorning is routinely used?
☐ Dehorning knives
☐ Scoop dehorners
☐ Cup dehorners
☐ Hot iron/heat cauterising

If you currently do, or were to vaccinate for clostridial diseases which of these disease do you consider the most important to control on your station?
☐ Black leg
☐ Black disease
☐ Leptospirosis
☐ Malignant oedema
☐ Pulpy kidney
☐ Tetanus

Are you aware of or suspect that significant mortalities (greater than 0.5%) due to clostridial diseases (such as tetanus) have occurred on your station either currently/or in the past?
☐ YES
☐ NO

How confident are you that your vaccination program is effective?

Not Confident									Very Confident
1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐

Your involvement in this study/workshop has increased your awareness of vaccination to control clostridial diseases?

Strongly disagree									Strongly agree
1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐

Your involvement in this study/workshop has (or is likely to) result in changes to your management practice?

Strongly disagree									Strongly agree
1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐

Thank you for completing this survey it is greatly appreciated.