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Risk factors for bobby calf mortality across the New Zealand dairy supply chain

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ABSTRACT

The objective of this study was to identify risk factors for morbidity and mortality of bobby calves across the whole dairy supply chain in New Zealand. A case-control study was carried out in the 2016 spring calving season. A total of 194 bobby calves, comprising 38 cases (calves that died or were condemned for health or welfare reasons before the point of slaughter) and 156 controls (calves deemed acceptable and presented for slaughter) were included in the study. Case and control calves were selected by veterinarians located at 29 processing premises across New Zealand. Information regarding management of selected calves on-farm, during transport and at the processor was obtained retrospectively via questionnaires administered to supplying farmers, transport operators and processing premises personnel. Associations between management variables and calf mortality (death or condemnation) were examined using multivariable logistic regression models. Factors associated with an increased risk of calf mortality included time in the farm of origin's calving season, duration of travel from farm to the processor and processing slaughter schedule (same day or next day). Every additional week into the farm's calving season increased the odds of mortality by a factor of 1.2 (95%CI 1.06, 1.35). Similarly, each additional hour of travel time increased the odds of mortality by a factor of 1.45 (95% CI 1.18, 1.76). Risk of mortality was significantly greater for calves processed at premises with a next day slaughter schedule than those processed at premises with a same day slaughter schedule (OR 3.82, 95% CI 1.51, 9.67). However, when the data set was limited to those cases that died or were condemned in the yards (i.e. excluding calves that were dead or condemned on arrival) the effect of same day slaughter was not significant. In order to reduce bobby calf mortality and morbidity, transport duration should be kept as short as possible and a same day slaughter schedule applied. While these factors can be regulated, New Zealand's pastoral dairy system means that calves will inevitably be transported for slaughter across several months each spring. Although farm management factors did not apparently influence the risk of mortality in this study, the effect of time in farm's calving season suggests there may be farm-management related factors that change over the season. This requires further investigation.

1. Introduction

Surplus or unwanted dairy calves, referred to as bobby calves in New Zealand and Australia, are considered a by-product of the dairy industry. Bobby calves are defined as unweaned calves that are transported for slaughter at meat processing premises for human consumption or pet food, usually within the first week of life (Anonymous, 2015). In New Zealand, around 4 million dairy calves are born between July and September each year (Anonymous, 2017b). Approximately one quarter of these are kept as replacement dairy animals (Hickson et al., 2015), with the remainder sold as bobby calves or to be raised as beef cattle, or killed on farm (Wesselink, 1998; Stafford et al., 2001; Mellor, 2011). Thus, each year in New Zealand approximately 2.2 million bobby calves aged between four and approximately seven days are transported to slaughter.

Bobby calves are at particular risk of welfare compromise, morbidity and mortality due to the very young age at which they are removed from their dam, transported, mixed and held off feed prior to slaughter (Wesselink, 1998; Fisher et al., 2009). In the 2015 New Zealand dairy season, bobby calf mortality before the point of slaughter

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was 0.25 %, dropping to 0.12 % in 2017 (Anonymous, 2017a,b), equating to between 4800 and 5500 calves per year. While the current mortality rate is low, it may be important to further reduce this for animal welfare, economic and reputational reasons by understanding and addressing the underlying risk factors in each stage of the supply chain. Factors associated with the rearing, management, handling, transport and yarding of bobby calves at the processor before slaughter have the potential to impact on their health and welfare, which may in turn influence mortality rate.

Several studies have identified risk factors for on-farm morbidity and mortality in calves (e.g. Gulliksen et al., 2009; Khan et al., 2011; Al Mawly et al., 2015; de Passillé et al., 2016; Renaud et al., 2018), with fewer studies focussing on the effects of transport and processing. No studies were found that explored risk factors for mortality in surplus dairy calves across the entire supply chain. The aim of this research was to identify risk factors for calf condemnation and mortality across the New Zealand dairy supply chain.

2. Materials and methods

Because bobby calf mortality is a rare event, a case-control design was selected as the most appropriate way to explore risk factors for mortality associated with the farm, transport and processing stages of the supply chain. Cases were defined as calves that died or were condemned before the point of slaughter and controls were acceptable calves that were slaughtered as per standard procedure. Case and control calves were selected by Ministry for Primary Industries Verification Services (MPI VS) veterinarians at meat processing premises around New Zealand. Their management from the farm to the point of arrival at the processor was traced back using questionnaires completed by interviewing the supplier of the calf (farmer/farm manager) and transporter of the calf as soon after the event as possible and by recording features of management at the processing premises. At the time of the interview, neither the researchers nor the farmers/transporters knew whether the calf was a case or a control.

Calf selection and retrospective data collection occurred over an 18-week period in six regions of New Zealand between June and October 2016. In each region, data were collected over three non-consecutive weeks at the start, peak and end of the season (Table 1).

2.1. Selection of case and control calves

Researchers visited each region for one week in each stage of the calving season. In total, 29 meat processing premises were visited over the season, with each premises visited between one and three times. When more than one premises was to be visited during the researcher's week in that region (Table 1), calves were selected on alternating days. All calves that died or were condemned (cases) at a premises during the week of the visit were included in the study and a case calf details form, including identification, classification, condemnation and post mortem information (Supplementary Table1) was completed by the attendant veterinarian. Case calves were recorded as either dead on arrival (DOA), condemned on arrival (COA), dead in yard (DIY) or condemned in yard (CIY). The decision to condemn a calf was made by the yard operator or supervisor and/or animal welfare officer and/or MPI veterinarian, according to the premises standard operating procedure.

Up to 10 control calves per day were randomly selected from those classified as 'acceptable' by verification services veterinarians at the processing premises, in accordance with the MPI VS Animal Welfare Procedure for Bobby Calves document (Anonymous, 2015). To be deemed acceptable, calves were required to be at least 4 days old; have an umbilicus that was wrinkled, withered and shrivelled; and be in good health, mobile, active, bright in the eye and have upright ears (Anonymous, 2016). Only one control per transport consignment was selected on a given day. Thus, the numbers of control calves varied throughout the season depending on the number of consignments arriving at the processing premises. If no case calves were present on the allocated day then only control calves were selected. To ensure unbiased selection, control calves were chosen using random number tables.

Table 1
Schedule of visits to meat processing premises in different regions of New Zealand that supplied case or control calves for a study of risk factors for bobby calf mortality. Each region was visited on three occasions corresponding to the early, peak and late part of the calving season.

Rotation	Study week	Regions	Number of premises visited
1 (Early)	1	Bay of Plenty/Waikato	1
	2	Bay of Plenty/Waikato	2
	3	Manawatu/Wanganui/Hawkes Bay	2
	4	Otago/Canterbury	1
	5	Otago/Canterbury	2
	6	Taranaki	1
2 (Peak)	7	Bay of Plenty/Waikato	1
	8	Bay of Plenty/Waikato	3
	9	Manawatu/Wanganui/Hawkes Bay	2
	10	Southland	4
	11	Otago/Canterbury	2
	12	Taranaki	2
3 (Late)	13	Bay of Plenty/Waikato	2
	14	Waikato/Auckland/Northland	3
	15	Manawatu/Wanganui/Hawkes Bay	3
	16	Otago/Canterbury	4
	17	West Coast/Tasman/Marlborough	2
	18	Southland	4

In 2016, all calves that died or were condemned were subject to post mortem examination. Therefore, the case calf details form completed by the attendant veterinarian included a section that captured findings of the post-mortem examination. For the purposes of the research, guidelines were provided to the veterinarians to assist with completion of the case calf form and the post-mortem form to ensure consistency in reporting of the reason for condemnation and interpretation of results (Supplementary Table 1).

2.2. Questionnaires

A separate questionnaire was developed for each stage of the supply chain and these were approved by the Massey University Human Ethics Committee (MUHEC SOB # 16/18). The development of the questionnaires was informed by a systematic literature review in conjunction with input from members of a project steering committee who represented various industry stakeholders. Feedback was sought from the steering committee on multiple occasions during questionnaire development and modifications were made accordingly. Brief details of each of the questionnaires are provided below; complete versions are available in Supplementary Table 2. All interviews were written/conducted in English. Interviewing and completion of the questionnaires was undertaken by a single researcher to reduce variability.

2.2.1. Farm questionnaire

The questionnaire was based on a previously validated questionnaire used in a Canadian study conjointly undertaken by the Université Laval, Agriculture and Agri-Food Canada, Valacta and the Université de Montréal (Vasseur et al., 2010) which identified the most important factors affecting successful dairy heifer rearing. It comprised 99 questions (77 closed and 22 open) relating to on-farm calf management during the first week of life. Questions focussed on the topics of calving, neonatal care, feeding, housing, health and collection for transport as undertaken during the specific week the selected calf was sent to the processing premises (i.e. in the last 7 days). Information was collected on the management of both bobby calves and replacement heifer calves, with the latter excluded from the risk analysis. The researchers were provided with farm of origin details for selected calves by the processing premises veterinarian. Supplying farms were then contacted by telephone and asked to participate in the study. Where consent was received, a meeting was arranged on-farm between the researcher and farmer or farm manager to complete the questionnaire. The questionnaire took 20–30 minutes to complete during the face-to face meeting

2.2.2. Transport questionnaire

This comprised 35 questions (29 closed and 6 open) regarding transport factors specific to the week the selected calf was sent to the processing premises (i.e. in the last 7 days). Questions included variables related to staff and training, vehicle details, calf numbers and transhipping. The researchers were provided with transport company details for selected calves by the processing premises veterinarian. The questionnaire was completed by either the company dispatcher or the operator who transported the selected calf during a telephone interview with the researcher.

2.2.3. Processing premises questionnaire

This comprised 62 questions (53 closed and 9 open) pertaining to processing premises management as undertaken during the seven days prior to the interview. Questions related to features of the unloading & holding facilities, staff details and training programmes, and calf management. The questionnaire was administered only once during the 18-week study period. Therefore, only information that was relevant to all calves processed across the season could be used in the case control study. Any questions that related to a practice undertaken during the week the questionnaire was completed were excluded from analysis on the basis that they may not have reflected the practice undertaken during the specific week the case or control calf was processed. Completion of the questionnaires took place either in person at the processor or via telephone interview.

It should be noted that retrospective data collection meant that information on individual calf age or disease status could not be obtained. Therefore, associations between these variables and risk of bobby calf mortality were not explored in the present study.

2.3. Data management and analysis

Data from the written questionnaires were entered into Excel spreadsheets. For the purposes of subsequent analyses, open questions with more than 6 unique responses were collapsed into fewer categories based on the response distribution. For example, the question “How often is bedding added to the pen for replacements” elicited 30 unique responses, which were subsequently collapsed into five categories: weekly, fortnightly, monthly, once or twice per season and never.

2.4. Statistical analyses

Summary statistics were calculated for all variables in the farm, transport, processing premises and case calf details data sets. Categorical variable data were summarised using counts and percentages. The method used to summarise continuous variables varied depending on whether the data were normally distributed. Normally distributed data were summarised by means and standard deviation while non-normally distributed data were summarised by median, minimum, maximum and the 25th and 75th percentiles.

The risk factor analysis was conducted on two separate data sets. The first comprised all cases (n = 38) and controls (n = 156). The second included all controls (n = 156) and only those cases that were condemned or died in the yards at the processing premises (n = 18). The separate data sets were created to allow a better understanding of the significance of processor-related factors. Importantly, for calves that died or were condemned on arrival at the processing premises (DOA/COA), processor variables may not have influenced the risk of being a case.

A multivariable model was constructed in a six-step process. Firstly, a binary outcome variable was generated that coded for whether the calf was a case or control and exact logistic regression models were then used to determine the association between mortality and each explanatory variable. The second step involved checking correlations between all variables associated with the outcome at $P < 0.2$. Correlations between pairs of variables eligible for inclusion were determined. For the pairs of continuous variables correlation was assessed using the Pearson correlation coefficient, whereas the Kendall’s correlation was used for the pairs of categorical variables. In both cases one variable in the pair was included in the model if the correlation exceeded an absolute value of 0.7. Thirdly, a multivariable model was constructed that included all variables that were associated with the outcome at $P < 0.20$. In the fourth step, a preliminary multivariable model was created by stepwise removal of the least significant variable (assessed using the Deviance test statistic) until all remaining variables were statistically significant at $P < 0.05$. When a variable was dropped from the model, changes in co-efficient and standard error were examined. The fifth step was an assessment of whether the continuous variables modelled had a linear relationship with the logit through the inclusion of a quadratic term. The quadratic term was retained in the model, or the variable converted to a categorical variable, if it significantly improved the fit as determined by the likelihood ratio test statistic. In the final step, the model was applied to the restricted data set (excluding cases that died or were condemned in the yards). For both models, the fit was assessed using the Hosmer & Lemeshow Goodness of Fit test and by examining the Pearson’s residuals.

All analyses were conducted in SAS Version 9.4 (SAS Institute Inc., Cary NC, USA).

3. Results

3.1. Response rates

A total of 606 dairy farmers across New Zealand were contacted as suppliers of a selected case or control calf. Of these, 194 (32 %) agreed to participate and completed the questionnaire. Of the 194 participating farms, 38 had supplied case calves and 156 had supplied control calves. Fig. 1 shows the distribution of selected calves by region of origin.

Seventy different transport companies transported selected calves during the study period. Calf transport information was obtained from 38/70 (53 %) transport companies. The 38 respondents were responsible for transporting 99/194 (51 %) selected calves, including 7/38 (18 %) cases and 91/156 (58 %) controls. Where a transporter did not respond or declined to complete the questionnaire, transport duration information (from time of collection on farm to arrival at the processor) for most calves was instead obtained from the transport docket at the processing premises. Thus, transport duration data were available for 185/194 (95%) calves (n = 34 cases and n = 151 controls). No detailed transport data were available for nearly half of all selected calves, including more than 80 % of control calves, therefore the only transport-related variable that could be included in the risk factor analysis was duration of travel.

Processing premises data were obtained from all 29 premises that supplied case and control calves. Although each premises involved in the study processed multiple case and/or control calves during the season, data were only collected on a single occasion meaning that data could not be linked to the specific week in which a selected calf was processed. Therefore, only those processing variables that were stable across the season could be included in the risk analysis.

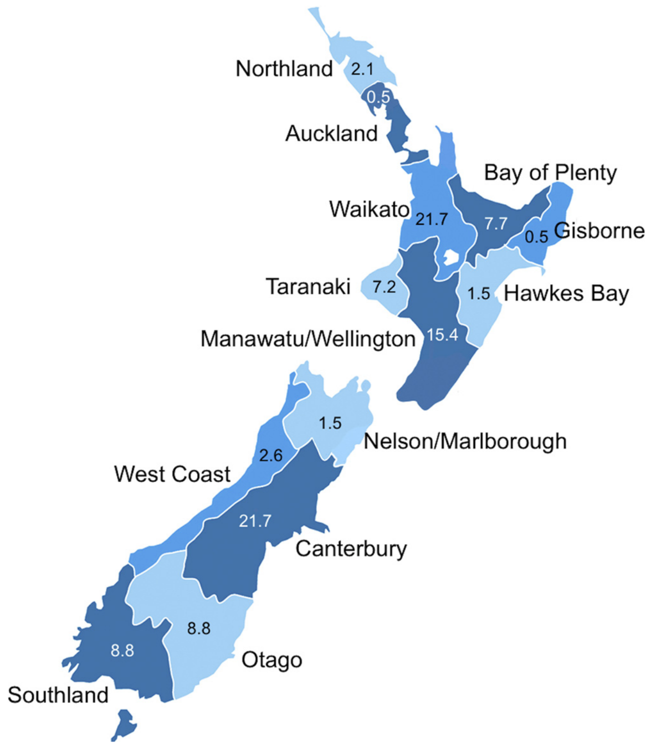

Fig. 1. Map of New Zealand showing the percentages of selected calves (all cases and controls) by region of origin.

In total, 73 unique variables were included in the risk analysis. These are presented in Table 2.

3.2. Case calf characteristics

Of the 38 case calves for which retrospective information could be obtained, 18 (47.4 %) were condemned on arrival at the processing premises and a further 10 (26.3 %) were condemned at some point in the yards. Thus, nearly three quarters of case calves were condemned, rather than dying before the point of slaughter. Half of those condemned on arrival (9/18) were unable to walk off the truck. Of the 10 calves that died, eight died in the yards while waiting to be slaughtered, whilst two were dead on arrival at the processing premises. The most frequently recorded reasons for calf condemnation were weakness, recumbency, thin body condition and dehydration (Table 3).

The most frequently recorded post-mortem findings were diarrhoea and/or enteritis (n = 11; 29 %), inflamed umbilicus/urachus (n = 6; 16 %), musculature bruising (n = 5; 13 %) and peritonitis (n = 4; 11 %). Approximately one third of post-mortem examinations of case calves recorded no significant findings (n = 13; 34.2 %). It should be noted that in some cases (n = 3; 8 %), no significant findings were recorded alongside other findings.

3.3. Risk factor analyses

The results of the univariate exact logistic regression analyses for those variables with p-values < 0.20 when using the full data set (all cases and controls) are provided in Table 4. Full results of the univariate screening of all variables are available in Supplementary Table 3. Of the continuous variables considered for inclusion in the model, a significant association was found between the two variables Time in farm's season (weeks since first calving on the farm of origin) and Time in processor's season (weeks since start of processing at the premises where the calf was processed). This was unsurprising, given that both were measures of time in season. The decision was made to include Time in farm's season in the model, as the association with calf mortality was strongest for this variable.

While there is some value to viewing the relationship between a single variable and risk of mortality (the unadjusted odds ratio); we refer to the odds ratio obtained from the multivariable model (the adjusted odds ratio), as this accounts for the effects of other variables in the model.

The results of the multivariable model for both data sets are shown in Table 5. Both data sets gave similar estimates for the effect of Weeks into farm's season and Travel time on the odds of mortality. After adjusting for travel time and premises slaughter schedule, the odds of mortality increased by a factor of 1.2 for every additional week into the farm's season. Similarly, for every additional hour travelled the odds of mortality increased approximately 1.5 times. When using data from all cases and adjusting for Time in farm's season and Travel time, the odds of mortality was 3.8 times higher when calves were processed at a premises with a next day slaughter schedule. However, when the data set was limited to those cases that died or were condemned in yards the effect was not significant. When the model was applied to the full data set, the Hosmer-Lemeshow goodness-of fit test indicated that the model was a good fit for the data (χ^2 (8, 194) = 14.2, P = 0.08). Examination of Pearson's residuals indicated that 2.06 % of values were greater than |3|. When applied to the restricted data set, the Hosmer-Lemeshow goodness-of fit test again indicated that the model was a good fit for the data (χ^2 (8, 174) = 3.5, P = 0.9) and examination of Pearson's residuals revealed 2.87 % of values greater than |3|.

3.4. Time in farm's season

On average, case calves (all cases) were collected and transported later in the farm's calving season (8.62 ± 3.04 weeks) than were control calves (5.98 ± 4.05 weeks). When cases were restricted to those that died or were condemned in yards, the case calf average was 8.93 ± 4.51 weeks into the season.

3.5. Transport duration

On average, case calves (all cases) travelled for longer (5.38 ± 2.45 h) than did control calves (3.11 ± 1.97 h). When cases were restricted to those that died or were condemned in yards, the average travel duration for case calves was 5.44 ± 2.43 h.

3.6. Slaughter schedule

Of the 38 case calves, 30 (79 %) died or were condemned at processing premises that were operating a next day slaughter schedule that week while 21 % of cases died or were condemned at premises operating a same day slaughter schedule. In comparison, 37 % of control calves were processed at premises operating a next-day slaughter schedule and 63 % at premises operating a same day schedule (Table 6). When cases were restricted to those that died or were condemned in yards, 67 % of case calves died or were condemned at premises operating a next day schedule.

4. Discussion

The New Zealand bobby calf supply chain consists of three main stages: on-farm rearing, transport from farm to processor and holding in yards for slaughter. Each of these has features that may influence the risk of calf morbidity and mortality. Despite existing guidelines governing pre-transport feeding, fitness for transport, transport duration and time off feed prior to slaughter (Anonymous, 2018b), some bobby calves do not survive the journey to the processor or their time in the yards prior to slaughter or are so seriously compromised that they are humanely killed. The objective of the present study was to investigate the integrated risk factors across farm, transport and processing

Table 2
Description of explanatory variables included in the analysis of risk factors for bobby calf mortality.

Data source	Variable name	Description	Response categories (binary/categorical data)
Case/control calf form	Sex	Sex of calf	male, female
	Breed	Predominant breed on farm	Friesian/Friesian cross; Jersey/Jersey cross; Kiwi cross; other
Farm questionnaire	Region	Region of NZ where the farm was located	Auckland; Bay of Plenty; Canterbury; Gisborne; Hawke's Bay; Marlborough; Manawatu/Wanganui; Northland; Otago; Southland; Taranaki; Tasman; Waikato; Wellington; West Coast
	Island	Whether the farm was in the North or South Island	North; South
	FarmType	Type of farm	dairy; mixed
	EntType	Enterprise type	organic, conventional
	OpStructure	Farm operating structure	contractor/manager; owner; share milker
	CalvPatt	Calving pattern	spring; split
	TotMilkCows	Total number of milking cows (including dry cows) at time of visit	
	NoReplace	Number of replacements (excluding unweaned calves) at time of visit	
	ReplaceRate	Annual replacement rate (%)	
	NoStaff	Number of staff involved in the day to day care of calves (FTE)	
	SepBobStf	Whether separate staff care for bobby calves	yes; no
	PrimaryFarm	Number of years the primary calf carer has spent in livestock farming	
	PrimaryBob	Number of years the primary calf carer has spent rearing bobby calves	
	PrimaryStatus	Status of primary calf rearer	family full-time; family part-time; paid full-time; paid part-time
	PrimaryTime	Hours/day spent on duties associated with calf rearing	
	MngChg	Whether there have been significant management/staff changes since the last calving season	yes; no
	Training	Type of calf-rearing training provided to staff	none-farming background; none-on the job training; workshops, short local vet courses; primary Ag ITO or Diploma Ag; University: Ag Sci, Vet Sci, Vet nurse
	ChgRoutine	Any staff issues in calving that have changed the routine in past 7 days	yes; no
	Vaccinate	Are pregnant heifers/cows vaccinated for rotavirus/coronavirus pre-calving?	yes; no
	CalvingLoc	Location of calving in the last 7 days	outside in rotational paddock; outside in specific paddock; calving pad or indoor
	CalfWeigh	Whether calves are weighed prior to transport	yes; no
	DiffBirth	Farm procedure for difficult birth	dam left outside; dam brought inside
	SepDam	How long after birth is the calf separated from the dam (hours)	
	CalfCollect	How often calves are collected from the calving area (per day)	
	Transport	How calves are transported from the calving area to the calf rearing facility	walk, trailer; both
	PredWeather	Predominant weather over last seven days	dry; wet
	Navel	Whether bobby calf navel is treated post-calving	yes; no
	NavelTime	How long after birth navel treatment was applied	none; ≤24 hours; > 24 hours
	ColostPool	Whether colostrum is pooled on the farm	yes; no
	FstColost	Type of colostrum provided for first meal	true; mixed
	ColostVol	The volume of the first feed of colostrum (litres)	≤2, > 2/to fill, unknown
	TempColost	Whether the colostrum was fed warm or cold	Warm; cold
	MethColost	The method of providing first colostrum feed	dam; teat bottle; teat feeder; tube
	QualColost	Whether the quality of colostrum was tested	yes; no
	Oesoph	Whether an oesophageal feeder was used if calves did not drink enough colostrum in first 24 hr	yes; no
	DiffFeedPro	If there is a different feeding programme for bobby and replacement calves	yes; no
	TypeMilkB	Type of milk fed to bobby calves	colostrum; transition; both
	MilkVolB	Volume of milk per feed (litres)	≤2; 2–4, > 4/ad lib; unknown
	MilkNoB	Number of milk feeds per day	1; 2; > 2/ad lib
	FeedSysB	Type of feed system	automatic; cafeteria; multi teat
	MilkTempB	Whether milk was fed warm or cold	warm; cold; both
	TempChk	Whether the milk temperature is checked	yes; no

(continued on next page)

Table 2 (*continued*)

Data source	Variable name	Description	Response categories (binary/categorical data)
	BHseNo	Whether calves were housed individually or in groups	individual; group
	BHseLoc	Whether calves were housed indoors or outdoors	indoor; outdoor
	BHseType	Type of housing	bars, solid walls; both
	BStockD	Stocking density in bobby calf pens	
	BAgeHse	Age entering the housing unit (days)	
	BDaysHse	Number of days spent in the housing unit	
	Bbed	Type of bedding used	river stones; wood substrate (shavings, sawdust, chips); straw; wooden slats
	BBedChg	How often the bedding is changed	weekly; monthly; once or twice per season; every second year; never
	BBedAdd	How often bedding is added to the pen	weekly; fortnightly; monthly; once or twice per season; never
	BBedCalf	Whether bedding is changed between groups of calve	yes; no
	Bdisinfect	How often the housing is cleaned or disinfected	never; daily; weekly; fortnightly or less often
	BHseAir	Whether the air flow is checked in the housing unit	yes; no
	BobSep	Age at which bobby calves were separated from replacement calves	birth; 1–3 days; > 3 days
	HseCollCode	Where the calves were housed on the day of collection	rearing pen; elevated pen/hutch; ground level pen/hutch; trailer
	CollVol	Volume of pre-collection feed (litres)	≤2; 2–4; > 4/ad lib; unknown
	FedCollType	Type of pre-collection feed	dam; colostrum; transition
	Loading	The type of loading facilities on the farm	walk on; manual lift
	StaffColl	Whether a member of staff is present when calves are collected for transport	yes; no
	WCalCol	Number of weeks from start of calving to date of collection	
Transport questionnaire or transport docket	TimeTravel	Duration (minutes) of travel from farm to processor	
Processor questionnaire	Slaught	Slaughter schedule	same day; next day
	RampAuto	Whether ramps are automated	yes;no
	RampCode	Angle that offloading ramp is set at	≤12 degrees; > 12 degrees
	TruckInsp	Whether truck in inspected on arrival	yes; no
	ArrCond	Who assesses calves on arrival	AsureQuality staff; MPI vet/Animal welfare officer (AWO); yard operator/supervisor; yard operator/supervisor + MPI vet/AWO
	CalfCond	When calf condition is assessed	unloading only; unloading + penning; unloading + ante mortem; unloading + penning + ante mortem
	HumSlgt	Number of staff trained in humane slaughter	
	MngChg	Whether there was significant management change since previous season	yes; no
	WColSla	Number of weeks from start of processing to date of calf arrival	

Table 3
Reasons cited for condemnation of case calves (n = 28) that were condemned on arrival (n = 18) or in yards (n = 10) at the processing premises.

Reason	Frequency	Percentage[1]
Weak	19	67.8
Recumbent	7	25.0
Thin Body Condition	4	14.3
Dehydration	3	10.7
Navel	3	10.7
Injured	2	7.1
Enteritis	1	3.6
Blind	1	3.6
Not recorded	3	10.7

[1] Calves could be condemned for more than one reason, therefore percentages do not add to 100.

premises for bobby calf mortality or condemnation prior to slaughter.

Three significant risk factors for calf morbidity/mortality were identified: time into the farm of origin's calving season, duration of travel from the farm to the processor and whether calves were processed at premises operating a same day or next day slaughter schedule.

4.1. Time in farm's calving season

Calves collected later in the calving season of the supplying farm were more likely to die or be condemned on arrival or in the holding yards. The persistence of this variable in the multivariate model suggests that the effect was due to some feature of the farms which changed over the duration of their season. Furthermore, the fact that this effect on mortality remained significant after accounting for travel time and slaughter schedule indicates that it was not due to seasonal changes in travel time.

It may be that seasonal changes in farm management, which altered the likelihood of gastrointestinal infection or of nutritional scouring contributed to the observed seasonal effect on mortality. Such changes might include alterations in staffing or staff behaviour, or in features of bobby calf management. An example of the latter might be management of bedding in the calf pens, such that pathogen load might increase as the farm's calving season progressed, increasing the risk of infection later in the season. The severity of infectious disease in calves has been shown to be influenced by management and hygiene practices (Castro-Hermida et al., 2002) as well as immune status (Meganck et al., 2014). Furthermore, disease transmission among infected calves may

Table 4
Results from univariate logistic regression analysis of explanatory variables for bobby calf mortality using all case calves (n = 38; dead on arrival, condemned on arrival, dead in yard, condemned in yard) and control calves (n = 156). Data are only provided for variables with *P* values < 0.2. Full results are provided in Supplementary Table 3.

Variable	Case calves (n = 38)	Control calves (n = 156)	Odds ratio (95% CI)	p-value
Farm location %				0.067
North Island	71	53	2.159 (1.001–4.655)	
South Island	29	47	REF	
Enterprise type				0.196
Conventional	97	100	NC	
Organic	3	0	REF	
Calving pattern %				0.049
Spring	84.2	94.2	REF	
Split	15.8	5.8	3.063 (1.018–9.214)	
Staff issues %				0.137
Yes	7.9	2.6	REF	
No	92.1	97.4	0.307 (0.066–1.434)	
Predominant weather %				0.164
Dry	60.5	73.0	0.565 (0.269–1.185)	
Wet	39.5	27.0	REF	
Type of first colostrum %				0.152
True	81.6	90.4	REF	
Mixed	18.4	9.6	2.123 (0.798–5.643)	
Colostrum quality tested %				0.076
Yes	0	8.3	REF	
No	100	91.7	NC[1]	
Mean number of days spent in housing unit (range)	6.5 (4–11)	6.1 (4–14)	1.183 (0.950–1.472)	0.142
Age at separation from replacements %				0.015
Birth	52.6	63.5	1.185 (0.522–6.808)	
1–3 days old	39.5	18.6	4.827 (1.259–18.51)	
> 3 days old	7.9	17.9	REF	
Location at time of collection %				0.013
Rearing pen/shed	60.5	48.1	0.307 (0.058–1.624)	
Elevated hutch	21.1	45.5	0.113 (0.019–0.655)	
Ground level hutch	10.5	4.5	0.571 (0.076–4.297)	
Trailer	7.9	1.9	REF	
Loading method %				0.031
Manually lifted	68.4	48.7	2.281 (1.075–4.841)	
Walk-on	31.6	51.3	REF	
Mean time in farm's season weeks (range)	8.6 (2.0–13.3)	6.0 (0.1–18.0)	1.187 (1.079–1.306)	0.0002
Travel duration hours (range)	5.4 (0.75–10)	3.1 (0.1–10.0)	1.008 (1.004–1.001)	< 0.001
Slaughter schedule %				< 0.001
Same day schedule	26.3	62.8	0.296 (0.105–0.831)	
Next day schedule	73.7	37.2	REF	
Truck inspection on arrival %				0.076
Yes	100	91	REF	
No	0	9	NC	
Who assesses calves on arrival %				0.026
AQ staff	3	12	0.345 (0.041–2.902)	
MPI vet/AWO	0	3	NC	
Yard operator/supervisor	74	47	2.48 (1.087–5.662)	
Yard op/sup & MPI vet	23	38	REF	
When calf condition is assessed %				0.078
Unloading	63	62	NC	
Unloading & penning	29	24	NC	
Unloading & ante mortem	8	3	NC	
Unloading, penning & ante mortem	0	11	REF	
Time in processor's season weeks (range)	9.8 (3.7–20.0)	6.2 (0–20)	1.184 (1.092–1.292)	< 0.001

REF = reference category; NC = Not Calculable due to there being no cases in one or more categories; AQ = AsureQuality; AWO = Animal Welfare Officer.
[1] Data available for n = 34 cases and n = 151 controls.

Table 5
Results from mixed effect multivariable models exploring risk factors for bobby calf mortality using all case and control calves (n = 194; 38 cases) and the subset of case calves that died or were condemned in yard (DIY/CIY) (n = 174; 18 cases).

	All cases		DIY/CIY cases only	
Variable	OR (95% CI)	P-value	OR (95% CI)	P-value
Time in farm's season (per week since first calving on farm)	1.20 (1.06–1.35)	0.0030	1.21 (1.03–1.42)	0.0216
Travel time (per hour)	1.45 (1.18–1.76)	0.0003	1.53 (1.17–2.02)	0.0022
Processor slaughter schedule (next day vs same day)	3.82 (1.51–9.67)	0.0046	2.80 (0.81–9.62)	0.1028

OR = adjusted odds ratio.

Table 6
Frequency and percentage of case and control calves that were selected at processing premises with same day and next day slaughter schedules.

Classification	Slaughter schedule		Total
	Same day	Next day	
All cases	8 (21.05%)	30 (78.95%)	38
DIY/CIY cases	6 (33.3%)	12 (66.7%)	18
Control	98 (62.8%)	58 (37.2%)	156
Total[1]	106 (54.6%)	88 (45.4%)	194 (100%)

DIY = died in yard; CIY = condemned in yard.
[1] DIY/CIY cases are a subset of all cases and are therefore excluded from the total.

also be affected by management factors such as housing, group size and hygiene (Trotz-Williams et al., 2007; Lorenz et al., 2011), which may change over a farm's season. Although no significant associations were found in the multivariable model between farm variables such as frequency of bedding change or housing cleaning/disinfection and calf mortality in the present study, it should be noted that the number of case calves was relatively small (n = 38 for the full data set and n = 18 in the restricted data set). In addition, given that considerable variation was observed among farms in factors such as frequency of cleaning/disinfection of housing and frequency of bedding change, the associations between time in the farm's season and such factors may warrant further investigation.

Furthermore, research into the prevalence failure of passive transfer (FPT) of maternal antibodies in New Zealand dairy calves found that FPT was more prevalent in the middle compared to the early calving period (Cuttance et al., 2017b). If this were also the case for calves in the present study, this may have contributed to the observed seasonal effect on risk of mortality.

4.2. Travel time

In the present study, the duration of calf transport from farm to processing premises ranged from 0.1–10 hours. Calves that travelled for a longer duration were more likely to die or be condemned on arrival or in the yards, regardless of the time in the farm's calving season. For every additional hour of travel time, the risk of death or condemnation was 1.45 times higher overall and calves were 1.53 times more likely to die or be condemned in the yards. The increase in risk with travel time was linear across the 0.1–10 -h range, meaning that there was no threshold below which travel time did not affect risk of mortality; rather, any increase in travel time increased the risk, and shorter travel times posed lower risk.

Although the effect of transport duration on calf mortality has not previously been investigated, others have looked at the effect of a related variable: transport distance. In a retrospective analysis of bobby calf mortality data from Northern Victoria, Australia between 1998 and 2000, Cave et al. (2005) identified an exponential increase in mortality with increasing transport distance (from farm to processor) over the range 100–800 km. Although travel duration was not known, the authors assumed that travel duration and travel distance were correlated and that distance was therefore a proxy for duration (Cave et al., 2005).

Interestingly, the reported effects of travel distance on mortality applied only to mortality on arrival at the processor (equivalent of DOA or COA in the present study), with no effect of travel distance found on mortality in yards (defined as 'dead overnight') (Cave et al., 2005). This contrasts with the present study, in which transport duration was significantly associated with mortality in yards as well as overall. This apparent difference may be due to the definitions applied to death/condemnation in yards. In the present study, death or condemnation in yard could occur at any point prior to presentation for slaughter, whereas the previous study defined this as 'dead overnight', implying death or condemnation after overnight holding only. According to the Victorian Code of Accepted Farming Practice for the Welfare of Cattle bobby calves held overnight must be fed as soon as practicable (Anonymous, 1996). Thus, the provision of feed may have offset any deleterious effects of transport in calves held overnight.

There are a number of possible reasons for the observed effect of travel time on calf mortality in the present study. Transportation of young animals from the farm to the processor imposes stressors that affect their biochemical, hormonal and metabolic status (Trunkfield and Broom, 1990). Longer journey distances (Cave et al., 2005; Večerek et al., 2006; Uetake et al., 2011) loading and unloading (Kent and Ewbank, 1986; Cave et al., 2005), novel human-animal contact (Lensink et al., 2001), and the inability to lie down (Uetake et al., 2011) have all been shown to negatively affect calf health and welfare and increase mortality.

In the current study, transport duration was the only transport-related factor that was included in the risk analysis, due to the unavailability of transport data for half of the selected calves. While it is possible that this was the only transport-related factor that influenced calf mortality, the effect of other variables cannot be ruled out without further study. Given that for the foreseeable future bobby calves will have to be transported some distance for processing, further research should focus on identification of transport factors that influence the risk of mortality and animal welfare status, to allow mitigation of these.

4.3. Slaughter schedule

Calves that were processed at premises operating a next-day slaughter schedule were more likely to be cases than those processed at premises operating a same-day schedule. The precise reason for this finding is not clear. Intuitively, it might be assumed that a next day slaughter schedule equates to more time spent in the yards prior to processing. However, it is conceivable that calves arriving at a premises late in the evening and being processed early the next day could spend less time in yards than calves arriving in the morning and being processed in the evening of the same day.

Given that there is no requirement in New Zealand to provide feed to calves in yards, provided they are slaughtered within 24 h of their last feed on-farm (Anonymous, 2016), longer yarding times may be associated with longer time off feed. Prolonged feed withdrawal may negatively impact on calf energy and hydration status. For example, young dairy calves deprived of feed for up to 30 h demonstrated progressive reductions in plasma glucose and increases in plasma beta hydroxy butyrate, indicating the development of hypoglycaemia and switch to lipid for energy metabolism (Todd et al., 2000). Additionally, although free water is provided in the yards, it is not known whether calves consume this. Therefore, it is possible that prolonged feed withdrawal may be accompanied by water loss, leading to dehydration.

While information was available on the length of time between arrival at the processing premises and death/condemnation of case calves, no information was available on time in yards prior to processing for control calves. Therefore, the relationship between slaughter schedule and time in yards could not be determined in this study. It is possible that other factors, such as staffing and frequency of monitoring of calves in yards may also vary according to processing schedule. Further research is required to determine what feature or features of a next-day processing schedule contribute to increased mortality risk.

Although processing premises slaughter schedule was significantly associated with calf mortality, the precise impact of a next day slaughter schedule on the odds of mortality was unclear. Analysis of data from all cases indicated a 4-fold greater risk of mortality when the processor had a next day slaughter schedule. When cases were limited to those calves that were condemned or died in the yards, there was no significant effect of slaughter schedule on mortality risk. This was unexpected, given that these latter calves were more likely to be impacted by a policy of next day slaughter.

There are two possible reasons for these findings. Firstly, calves that were classified as dead or condemned on arrival included animals that died/were condemned within two hours of arrival. It is plausible that assessors at premises reporting a next day schedule would be more likely to condemn a 'borderline' animal to minimise suffering and/or to have the death associated with transport rather than with the processor. Secondly, we may not have detected a true association in the restricted data set because of a lack of statistical power as there were only 18 cases in the CIY/DIY subset. A post hoc power analysis estimated that the power to detect an association in the limited data set was relatively low (0.43). It is not possible to postulate as to which reason is more likely. Given that day of slaughter is something that can be controlled, undertaking further research to determine the impact of slaughter schedule should be a priority.

It should be noted that since the time of data collection, new legally enforceable regulations have come into effect. These limit the travel duration for young calves to a maximum of 12 h and require that calves be slaughtered as soon as possible after arrival at the processing premises and within 24 h of their last feed (Anonymous, 2016). These new regulations are consistent with the findings of this study, namely that limiting travel duration and time to slaughter is associated with reduced mortality. Accordingly, the bobby calf mortality rate in New Zealand has declined since this research was undertaken, from 0.25 % in 2015 to 0.12 % in 2016, and 0.06 % in 2017 (Anonymous, 2017a, 2018a). This likely reflects both the introduction of new regulations, as well as recent education and extension efforts by various industry stakeholders.

It was somewhat surprising that variables reflecting on-farm management and implying calf health status were not associated with mortality in the current study. However, retrospective data collection meant that information on individual calf age, health and immune status or age at separation from the dam was not available. Therefore, the influence of these factors on calf mortality could not be assessed. Previous studies of dairy calf mortality on New Zealand farms have identified disease status and failure of passive transfer of immunity (FPT) as risk factors for mortality. For example, a prospective study of calf and replacement heifer mortality on 32 New Zealand dairy farms in 2015 found that risk of mortality on-farm in the first week of life was higher in herds with disease problems, such as scours, and among calves that were removed from the dam within 12 h of birth and hand-fed colostrum (Cuttance et al., 2017a). A related study investigating passive transfer of immunity and colostrum quality found that calves that remained with the dam for ~24 h had lower prevalence of FPT (Cuttance et al., 2017b). The authors postulated that feeding poor quality, pooled, stored colostrum (with low antibody and high bacterial concentrations) to calves less that 24 h old was responsible for the observed effects (Denholm et al., 2017). The present study collected information on colostrum feeding practices (e.g. true or mixed) and quality management (whether or not colostrum quality was checked) on-farm. Neither of these factors were found to significantly influence mortality risk in the final multivariable model. Given the relatively small sample size in the present study, along with the small number of farms that reported checking colostrum quality, further investigation of the effects of colostrum management on bobby calf mortality may be informative.

4.4. Limitations

A major limitation in this study was the relatively small sample size and the subsequent impact on study power. The requirement for data collection to take place over a single season, combined with the low response rate from supplying farmers, meant that we were unable to achieve the required sample size of 150. As a result, it may well be that variables other than those in the final model had a significant impact oncalf mortality risk.

As this was an exploratory analysis, there was limited *a priori* decision making regarding the inclusion/exclusion of variables. However, this study represents an important first step in developing a focus for further research and potential intervention strategies to improve calf welfare.

The study design ensured that recall bias was limited, as both the researchers delivering the questionnaire and those completing it were blinded as to whether a given calf was a case or control. However, the information obtained may have been influenced by participant memory, such that respondents may have answered according to what was the norm for them, as opposed to being able to recall specific details for the day in question. This may have biased the results toward the null.

5. Conclusions

The present study identified three significant risk factors for bobby calf mortality in New Zealand: time in farm of origin's calving season, duration of travel and processing premises slaughter schedule. Whilst the current mortality rate is low, it may be possible to further reduce this by addressing these risk factors, as evidenced by the decline in mortality since the introduction of new regulations consistent with these findings. Although travel time and slaughter schedule can be, and are now, subject to regulation, time in season is more difficult to regulate due to the wide calving spread in New Zealand's pastoral-based dairy system. However, the identification of this as a risk factor provides some insight into factors of potential importance on farm. It is possible that further education and extension within the industry could be effective in reducing animal welfare compromise and mortality associated with seasonal effects. As the present study design did not permit the collection of information on individual calf age or disease status, the influence of these factors on risk of mortality in bobby calves should also be investigated.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.prevetmed.2019.104836.

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