PEER REVIEWED

Herd-level Management and Biosecurity Factors associated with Measures of Reproductive Success in California Beef Cow-calf Herds

Bruce R. Hoar[1*], *DVM, PhD, DACVPM;* **Tremon C. Bell**[1], *DVM, MPVM;* **Veronica Villanueva**[1], *BS;* **Josh Davy**[2], *MS, PAS;* **Larry Forero**[2], *PhD;* **John Maas**[3], *DVM, MS, DACVN, DACVIM*

[1]*Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California, Davis, Davis, CA 95616*

[2]*University of California Cooperative Extension, Department of Agriculture and Natural Resources, University of California, Davis, Davis, CA 95616*

[3]*Veterinary Medicine Extension, School of Veterinary Medicine, University of California, Davis, Davis, CA 95616*

**Corresponding author: Dr. Bruce Hoar, Email: brhoar@ucdavis.edu, Phone: 530-754-5342*

Abstract

A cross-sectional study was performed to evaluate the relationship between herd-level management and biosecurity practices in a sample of California's beef cow-calf operations, and the estimated within-herd prevalence of antibodies to *Neospora caninum*, *Anaplasma marginale,* and the persistent carrier state of bovine viral diarrhea virus (BVDV PI). Serum samples were collected from 917 adult beef cows from 29 herds. Multivariable linear and logistic regression models were created to predict calving season length and the probability of a cow weaning a calf using selected herd-level management and biosecurity factors and the seroprevalence data.

The overall seroprevalence of *A. marginale, N. caninum* and BVDV PI was 47.4% (435/917), 8.9% (82/917) and 0.1% (1/917), respectively. The multiple linear regression analysis revealed no significant associations between management variables and calving season length. A logistic regression model found that the probability that a cow weaned a calf was associated with the number of first-calf heifers in the herd, whether the bulls were semen tested, whether the herd had a history of epizootic bovine abortion, and if the cow herd was vaccinated against *Clostridium* spp. Based on these findings, we conclude that herd-level management and biosecurity factors may be associated with reproductive success in beef cow-calf farms in California through their effect on the probability that a cow weans a calf.

Keywords: bovine, beef, *Anaplasma*, *Neospora*, BVDV, PI, reproduction

Résumé

Une étude transversale a été faite pour évaluer la relation qui existe entre les méthodes de gestion au niveau du troupeau et les mesures de biosécurité dans un sous-ensemble d'élevages vaches-veaux (bovins allaitants) en Californie et d'autre part la prévalence intra-troupeau d'anticorps contre Neospora caninum, Anaplasma marginale et le statut d'immunotolérance au virus de la diarrhée virale bovine (BVDV PI). Des échantillons de sérum ont été recueillis à partir de 917 vaches de boucherie adultes provenant de 29 troupeaux. Des modèles de régression multiple linéaire et logistique ont été utilisés afin de prédire la longueur de la saison de vêlage et la probabilité qu'une vache sèvre un veau en fonction du type de régie de troupeau, des mesures de biosécurité et des données de séroprévalence.

La prévalence sérique d'anticorps était de 47.4% (435/917) contre A. marginale, de 8.9% (82/917) contre N. caninum et de 0.1% (1/917) contre le BVDV PI. Le modèle de régression linéaire multiple n'a pas permis d'identifier une association entre les variables de régie et la longueur de la saison de vêlage. Le modèle de régression logistique indiquait que la probabilité qu'une vache sèvre un veau était associée au nombre de taures à leur premier vêlage dans le troupeau, au fait de tester la semence des taureaux, aux antécédents dans le troupeau d'avortements d'origine épizootique et au fait de vacciner contre Clostridium spp dans le troupeau. En se basant sur ces résultats, nous concluons que les facteurs de gestion au niveau du troupeau et les mesures de biosécurité peuvent être associés au succès reproducteur dans les élevages vaches-veaux

en Californie par l'intermédiaire de leurs effets sur la probabilité qu'une vache sèvre un veau.

Introduction

It is generally agreed that any beef production system that requires animals to be grouped for managerial purposes benefits from some form of restricted calving season.[2] Despite this, according to the most recent National Animal Health Monitoring System study of beef cattle production, more than 46% of cow-calf operations have calving seasons lasting four or more months.[13] Possible causes of prolonged calving season include inadequate nutrition, bull infertility/insufficient bull stocking density, infertility disease and conscious management decisions (e.g. taking advantage of alternative marketing opportunities).

Achieving optimal reproduction is of utmost importance in sustaining the economic viability of beef producers. Reproductive merit has been calculated as being 10 times more important than carcass quality, and five times more important than growth performance in terms of economic return.[20] Substandard management practices, such as inadequate biosecurity, can foster inefficient reproduction, facilitate disease agent introduction that may also affect reproduction, predispose cattle to diseases, and has the potential to adversely impact food safety.[1,6,10]

Management practices that may improve reproductive efficiency include all components of production such as breeding soundness examinations for all cattle, a balanced nutritional program, a vaccination protocol to protect against endemic disease agents, a fixed breeding season, an adequate replacement selection system and calf management programs. Good management practices also include a well-defined biosecurity plan that increases herd immunity, limits exposure to other livestock and reduces (as much as possible) exposure to wildlife. As responsibility for food safety is increasingly directed towards the producer, well-defined and documented biosecurity plans will be important in ensuring that animal products are safe, wholesome and acceptable.[1,6,10]

Given the importance of reproductive efficiency to profitability of beef cattle production, this study's primary objective was to evaluate herd-level management and biosecurity practices of California's beef cow-calf operations and determine their effect on reproductive efficiency, as measured by percent calf crop weaned and length of calving season. A secondary goal was to estimate within-herd prevalence of antibodies to *Neospora caninum, Anaplasma marginale* and of persistent infection with bovine viral diarrhea virus (BVDV PI) to assess the potential impacts these agents have on reproduction. We hypothesized that factors associated with management practices and biosecurity, including prevalence of antibodies against infectious disease agents, may be related to calving season length and probability of weaning a calf in beef cow-calf herds.

Materials and Methods

The study population consisted of 29 beef cow-calf herds from throughout California, with a combined total of 7,173 mature cows. Herds were selected for participation in this study based on convenience sampling after a solicitation for volunteers was announced, with the aid of the University of California Cooperative Extension livestock advisors and the California Cattlemen's Association. While the investigators were able to include a wide variety of herd locations, the possibility of selection bias cannot be ruled out, especially in terms of management practices. A herd was selected on its perceived representation of the population of beef cow-calf herds in California. Factors considered included location (very few beef cattle in the Central Valley and in Southern California), herd size (more than 80% of beef cow herds in California consist of less than 50 cows) and predominant breed (most herds are Angus or Angus cross). From each herd, whole-blood samples were collected from a random sample of approximately 30 cows; if there was an insufficient number, all available adult cows were sampled. This sample size allows detection of antibodies or antigen, if present at 5% prevalence or greater, with 80% confidence. Cows included in the study were chosen by the producer either by selecting every second or more cow through a chute (depending on herd size), or by gathering approximately 30 cows at random into the working facilities. Approximately 10 mL of whole blood were collected from the tail vein of each cow and sera were separated and stored at -112°F (-80°C) for future analysis. A standardized questionnaire, composed of 32 questions regarding herd demographics, herd management characteristics, disease occurrence and herd biosecurity protocols, was administered to each producer at the time of sampling.

Sera were tested by the California Animal Health and Food Safety (CAHFS) laboratory for presence of *N. caninum* antibodies, using a commercially available enzyme linked immunosorbent assay (ELISA)[a] with a reported sensitivity of 88.6% and specificity of 96.5%.[15] A serum-to-positive (S/P) V_{max} ratio of less than 0.45 was interpreted as absence of infection, as previously described.[15] Sera were tested for antibodies against *A. marginale* using a commercially available test kit[b] following manufacturer's directions. A sample was considered seropositive for *A. marginale* if ≥30% inhibition was detected, as previously described.[21] The manufacturer claims a sensitivity of 95% and specificity of 98% when used according to directions. Serum

samples were tested for BVDV PI using a commercially available antigen capture ELISA test kit.[c] Any BVDV PI-positive animals were retested one month later to ensure that they were persistently infected. The sensitivity and specificity of this test used on serum has not yet been validated, but the specificity may be as high as 99% and the sensitivity could be between 90-95% (Dr. Sharon K. Hietala, California Animal Health & Food Safety Laboratory System, personal communication).

Descriptive statistics of herd-level disease prevalence, management and biosecurity factors gathered from the questionnaires were generated. Selected factors from the questionnaires were used as potential predictors to test the hypothesis that prevalence of antibodies against infectious disease agents such as *N. caninum, A. marginale* and the persistent infection form of BVDV, coupled with management factors, may affect calving season length or percentage of weaned calf crop. A surrogate indicator for calving season length, the total number of days for 75% of the calf crop to be delivered, was used to prevent outliers exerting undue influence on the average. The percentage of weaned calf crop was calculated by dividing the number of calves weaned by the number of cows exposed to the bull at breeding and multiplying by 100.

A stepwise process was used to select a linear regression model[12] to predict the length of calving season. Mallow's cp and the coefficient of determination were used to choose the best model. A P-value of <0.05 was used to evaluate each predictor for significance.

Logistic regression was used to generate a model that would allow for the prediction of the odds of a cow weaning a calf given predictor variables. The initial model used cow as the unit of analysis. This model was determined by a backward elimination procedure using a software program.[d] An alpha of 0.05 was used to determine whether or not a predictor should be removed from the model. To adjust for potential clustering by farm, a random effect term was added to the model.

Results

Descriptive statistics (mean, median, confidence interval [CI], and range) of herd characteristics from the standardized questionnaire are presented in Table 1, while herd-level biosecurity parameters are summarized in Table 2. Geographic distribution of the herds included is shown in Figures 1 and 2. All herds sampled consisted solely of *Bos taurus* breeds. Median length of breeding and calving seasons (defined as the number of days until approximately 75% of the calves were born) was 106.5 (95% CI 90.6-133.0) and 57 (95% CI 46.7-73.50) days, respectively. There were 6,244 calves weaned on participating farms, for a mean weaning percentage of 89% (95% CI = 86% – 93%). Two distinct calving seasons were apparent: the majority of calves were born in January (19.7%), February (10.6%) and March (9.3%) or in August (12.4%), September (32.3%) and October (11.7%). While there were exceptions, herds in the far north of the state tended to calve from January to March, while herds further south and close to the coast tended to calve from August to October.

Blood samples were obtained from 917 adult animals (previously had at least one calf). The overall prevalence of antibodies against *A. marginale* and *N. caninum* were 47.4 and 8.9%, respectively (Figures 1 and 2). One cow (0.1%) tested positive for persistent infection with BVDV. The median within-herd seroprevalence of *A. marginale* and *N. caninum* were 36.7% and 9.1%, respectively. Of the 29 farms, 10.3% routinely vaccinate for *A. marginale.*

Results of linear regression modeling revealed that none of the management variables assessed were significantly associated with length of calving season.

Results of the logistic regression modeling procedures predicting the probability that a cow weans a calf are shown in Table 3. Given that animals within a herd are likely to be similar and therefore tend to exhibit similar outcomes, a random effect term was added to

Table 1. Descriptive statistics of herd-level management characteristics gathered by standardized questionnaire from 29 California cow-calf herds, 2006-2007.

Farm characteristic	Mean (95% CI)	Median (95% CI)	Range
No. mature cows that calved/year	185.3 (128.1-242.5)	150.0 (66.0-252.5)	20.0-550.0
No. bulls used during breeding season	10.7 (7.4-14.0)	10.0 (4-14.2)	1.0-37.0
No. of cows per bull	21.0 (18.9-23.0)	20.0 (18.0-25.0)	10.0-34.0
No. of heifers per bull	20.3 (17.6-22.9)	22.8 (18.0-22.8)	1.0-30.0
No. females exposed to bull	247.3 (169.2-325.5)	185.0 (93.8-350.0)	21.0-813.0
No. dams that weaned a calf	215.3 (148.9-281.8)	181.0 (77.8-302.3)	21.0-722.0
Weaning age (months)	7.8 (7.4-8.1)	8.0 (7.0-8.0)	6.5-10.0

the model. There was significant (<0.001) extra-binomial variation, indicating that a random effect term improved the fit of the model.

Discussion

Good management practices are essential to maintaining the viability and efficiency of any beef cow-calf operation.[23] This cross-sectional study identified several herd-level management factors associated with the probability that a cow weaned a calf on beef cow-calf farms in California.

One management factor that has been associated with suboptimal reproductive performance in beef cattle is breeding season length.[23] In our study, median breeding season length was 106.5 days and median calving season length was 57 days. Calving season length was determined as the date by which 75% of calves were born, so that late-born calves would not have strong influence on the data. It has been suggested that a 90-day breeding season is optimal in order to reduce late calving and increase the chance that a female will cycle early the following breeding season.[23] Feuz and Umberger[7] reported that one quarter of beef cow-calf operations in the United States have both a breeding season and calving season extending for five months or more. Nationally, only 69.8% of operations complete their calving season in 90 days.[13] While we found no significant relationships between variables in our study and calving season length, we suggest that further studies with larger sample sizes are warranted to further investigate any possible relationship that may exist.

Weather is an important factor that influences the beginning of the breeding season in many parts of the US.[7] This is especially true for beef herds in California, where the typical calving season depends on the climate and region.[1] While national studies indicate that most calves are born between February and April, with the largest proportion born in March (27.2%),[4] calves on farms in our study were born during late winter (January, February and March) and in early fall (September and October), with the peak during September (32.3%). These differences are likely attributable to the region and climate variation throughout the US. In our models predicting calving season length and odds of weaning a calf, season was not found to be a significant predictor variable.

Infectious diseases may lead to inefficient reproduction. The infectious disease agents that were of concern in this study were *A. marginale, N. caninum* and BVDV PI, each of which can affect different stages of reproduction. *A. marginale* causes abortion in cattle in several areas of the world, including California. The overall seroprevalence of the cattle sampled in our study was 47.4%, with a herd-level range of 0 to 100% seropositive cattle. Given the primarily tick-borne mode of transmission of this agent, prevalence varies widely depending on whether competent tick vectors are present or not. For example, a survey of Montana feeder cattle[21]

Table 2. Responses to survey of herd-level biosecurity parameters from 29 beef cow-calf farms in California, 2006-2007.

Herd Biosecurity	Yes	No	%
Replacement females home-raised (≥80%)	25	4	86.2
Bulls home-raised (≥80%)	3	26	10.3
Any bulls purchased from a market	11	18	37.9
Any bulls purchased privately	22	7	75.9
All bulls semen tested	18	11	62.1
Bulls tested for *Tritrichomonas foetus*			
All bulls tested	17 of 29		58.6
Only purchased/leased bulls tested	6 of 29		20.1
No bulls tested	6 of 29		20.1
Cattle exposed to dogs	27	2	93.1
Cattle exposed to coyotes	29	0	100.0
Cattle exposed to wild boars	15	14	51.7
Same-pasture exposure to other cattle	8	21	27.6
Fence-line exposure to other cattle	25	4	86.2
Vaccinate against *Clostridium* spp	28	1	96.6
Vaccinate against IBR, PI3, BVDV, BRSV	25	4	86.2
Vaccinate against *Leptospira* spp	25	4	86.2
Vaccinate against *Anaplasma marginale*	3	26	10.3
Vaccinate against *Neospora caninum*	1	28	3.4

found the prevalence of antibodies to *A. marginale* to be 1.82% and 1.35% in two consecutive years, while a study conducted in northern Veracruz State, Mexico reported an overall *A. marginale* seroprevalence of 69.2% using PCR and 54.6% with complement-fixation.[3] Of note in our study, however, is the apparently bimodal distribution of seropositive animals (Figure 1). It appears that the distribution is related to geographic location, with highest seroprevalence in foothill regions of the state (presence of competent vectors), and lowest seroprevalence within the Central Valley (few to no vectors present). We found that several herds had a very high proportion of positive cattle (>60%, 45% of herds), several herds had no positive animals (10% of herds), while another group (41% of herds) had seroprevalence between 1% and 40%. This last group could be considered to be susceptible to new infections from within the herd and also at increased risk should a carrier animal be introduced to the herd (transmission via fomites such as needles, dehorning equipment, etc.) or should the cattle be moved to areas with higher concentrations of competent tick vectors. Biosecurity programs to limit exposure of naïve, susceptible cattle would be especially important for these herds.

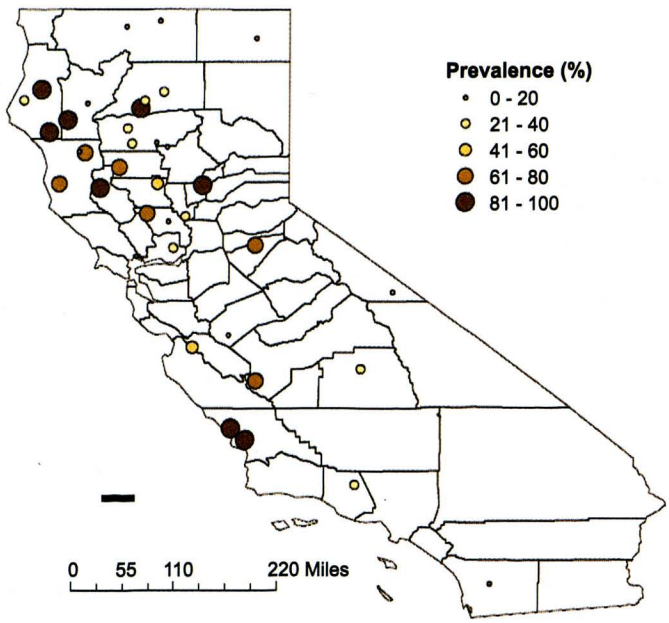

Figure 1. Herd-level prevalence and geographic distribution of antibodies to *Anaplasma marginale* from adult beef cattle in 29 herds in California.

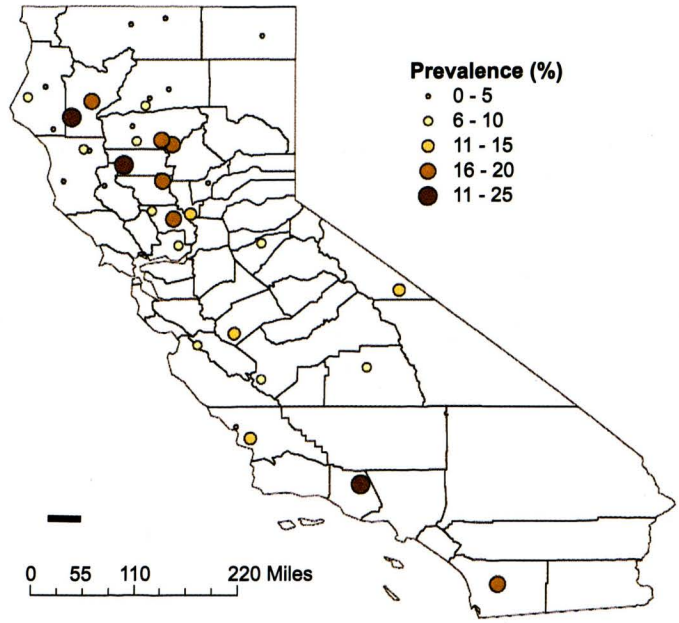

Figure 2. Herd-level prevalence and geographic distribution of antibodies to *Neospora caninum* from adult beef cattle in 29 herds in California.

Table 3. Final multivariable random-effects logistic regression model for estimating odds of a cow weaning a calf, given herd-level management variables from a standardized questionnaire of 29 beef cow-calf farms in California, 2006-2007.

Predictor	Odds Ratio	95% CI (OR)	*P*-value
Number first-calf heifers	0.99	0.99-1.00	0.001
Epizootic bovine abortion (EBA) status			
No previous cases diagnosed		Referent	
EBA cases previously diagnosed	0.47	0.39-0.56	0.001
Unknown EBA status	0.39	0.30-0.51	0.004
Breeding soundness evaluation of bulls			
No bulls evaluated		Referent	
All bulls evaluated	2.02	1.54-2.66	0.01
Only purchased bulls evaluated	1.77	1.32-2.37	0.03
Vaccinate against *Clostridium* spp	2.24	1.31-3.84	0.03

N. caninum, a protozoan parasite that causes significant losses due to abortions in many countries, can significantly impact beef cow-calf operations.[5] Large herd size and poor management practices can be risk factors for *N. caninum*.[14] Several studies have shown that animals seropositive for *N. caninum* are more likely to experience infertility and abortion.[22] The overall seroprevalence to *N. caninum* in our study was 8.9% (82/917), with a median within-herd seroprevalence of 9.1%. Prevalence within herds ranged from 0 to 23.3% (Figure 2). This was less than that found by Sanderson *et al*, who described an overall seroprevalence of 24% and a median within-herd seroprevalence of 19% in beef cattle in five northwestern states in the US.[17] The authors suggested that herds grazing rangeland during the summer had a lower seroprevalence compared to those that did not.[17] All herds in our sample grazed primarily native rangeland during summer months, which may be associated with lower seroprevalence. A Canadian study of serological status of *N. caninum*, BVDV and infectious bovine rhinotracheitis virus in beef cattle reported median *N. caninum* herd seroprevalence of 3.9%.[22] A review article lists results of several studies: dairy herds had mean cow-level prevalence values ranging from 5.6 to 25.5%, while values for beef herds ranged from 6.5 to 9.0%.[8]

BVDV can have devastating effects on beef cow-calf operations. In our study, only one animal of 917 tested positive for persistent infection with BVDV. In Europe, it has been suggested that half of dairy herds have a PI animal and the overall prevalence of PI animals is 1-2%.[9] This same study indicated that 4% of 76 beef herds randomly sampled had a PI animal.[9] Given that only cattle that had calved were sampled in our study, we likely underestimated the true prevalence of BVDV PI, as many infected animals die or are culled before reaching adulthood.

Herd-level biosecurity is important for farm sustainability, as well as for assuring food safety. A first step producers can take to reduce disease agents is to avoid purchase of animals with unknown health status that could serve as a source of disease for a naïve herd.[18] In our study, 86.2% of beef cow-calf producers raised more than 80% of their own heifers as replacements. This is in general agreement with national data that indicates that 88.3% of replacement heifers are home-raised.[13] In contrast, only 10.3% raise more than 80% of their own bulls. Bulls are purchased either from a market (37.9% of producers) or through private treaty sales (75.9% of producers). Of producers in the US, 26.8% reported that new bulls were introduced for the last breeding season.[13] Although our study did not investigate whether producers who imported animals to their herd had vaccination, testing, or quarantine protocols in place, it has been suggested that each of these procedures can minimize disease introduction.[16] As noted in Table 2, we found that a large proportion of beef cattle in California are exposed to other cattle by either fence-line contact or same pasture exposure. This exposure could result in the spread of many contagious diseases, including *Campylobacter* and BVDV. Also, in areas that practice shared grazing, animals are at increased risk of becoming infected with *Tritrichomonas foetus*.[18] Not only do domestic animals pose risk of disease threat, but wildlife exposure could result in transmission of diseases such as leptospirosis and *N. caninum*.[16] These findings suggest that California beef cow-calf herds could benefit from improved biosecurity protocols, as they currently maintain significant exposure to other herds.

A commonly used measure of a beef herd's performance is the percent calf crop weaned. In our logistic regression model, we found that increased number of first-calf heifers in a herd was associated with a reduced probability of weaning a calf. This is likely associated with the fact that first-calf heifers generally experience higher rates of calf mortality prior to weaning, associated with increased dystocia[13] and reduced quantity/quality of colostrum leading to increased susceptibility to disease. The relationship was statistically significant but numerically small, indicating that the relative importance of this finding may be minor. Also, having had previous cases of epizootic bovine abortion (EBA) was negatively associated with the probability of a cow weaning a calf. Epizootic bovine abortion is known to cause abortion in susceptible beef cattle in California, Oregon and Nevada,[19] therefore, finding that an agent of abortion is associated with reduced probability of weaning a calf is not surprising. We cannot rule out the possibility that this association is at least partially a result of reporting bias: managers with low weaning percentages may attribute their problems to infection with EBA without necessarily having a confirmed diagnosis.

If the producer reported that all bulls were subjected to a breeding soundness evaluation prior to breeding season, there was a 1.98 times greater probability that a cow would wean a calf, than if no bulls were evaluated. In this study, 62.1% of producers indicated that all bulls were evaluated for breeding soundness prior to being turned with females. This compares favorably with a national study that found only 17.3% of operations reported using breeding soundness evaluation of bulls (excluding purchased, leased, and borrowed bulls) while 57.3% of operations had newly introduced bulls evaluated for breeding soundness prior to the last breeding season.[13] The ability of a complete breeding soundness evaluation to aid in predicting reproductive performance is well established;[11] our findings confirm this.

We found that if a producer reported using *Clostridium* spp vaccinations in their cow herd, then there was a 2.24-fold increase in the probability that a cow would wean a calf. Given that only one herd did not vaccinate against this organism, we feel that this particular result should not be afforded a great deal of consideration.

While the investigators made every attempt to include herds that represented what would be considered "typical" of herds within California, the possibility of selection bias cannot be ruled out, especially in terms of management practices. This is apparent in the variable "Vaccinate for *Clostridium* spp", where only one herd reported that they did not perform this management procedure.

Conclusions

From this cross-sectional study, we conclude that herd-level management factors such as number of first-calf heifers, vaccination protocol and breeding soundness examinations are associated with reproductive success in beef cow-calf farms in California by affecting the probability of weaning a calf.

Endnotes

[a]HerdChek Neospora, IDEXX Laboratories, Westbrook, ME

[b]Anaplasma Antibody Test Kit cELISA, VMRD, Pullman, WA

[c]Bovine Virus Diarrhea Antigen Test Kit, IDEXX HerdChek, IDEXX Laboratories, Westbrook, ME

[d]Egret for Windows 2.0.1, Cytel Software Corporation, Cambridge, MA

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