ELSEVIER

Preventive Veterinary Medicine 20 (1994) 33-46

PREVENTIVE VETERINARY MEDICINE

Effect of management and host factors on seroprevalence of bovine anaplasmosis and babesiosis in Costa Rica

Enrique Perez[a,*], Marco V. Herrero[b], Carlos Jimenez[b], David Hird[c], Gerald B. Buening[d]

[a]*Herd Health Section, Dutch Interuniversity Cooperation Program, School of Veterinary Medicine, Universidad Nacional, PO Box 86-3000, Heredia, Costa Rica*

[b]*Programa de Investigacion en Enfermedades Tropicales, School of Veterinary Medicine, Universidad Nacional, PO Box 304-3000, Heredia, Costa Rica*

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

[d]*Department of Veterinary Microbiology. College of Veterinary Medicine. University of Missouri, Columbia, MO 65211, USA*

(Accepted 16 November 1993)

Abstract

The relationships between the seroprevalences of *Anaplasma marginale*, *Babesia bigemina*, *Babesia bovis* and some selected factors were assessed. Factors studied were age, breed, herd size, farm size, rotational grazing schedule, grass variety and acaricide usage. These relationships were analyzed in 39 herds belonging to a Livestock Information System developed by the School of Veterinary Medicine: 23 dairy farms (1352 animals), eight cow-calf and eight dual purpose farms (2204 animals) from different ecological areas in Costa Rica. Using random-effect logistic regression as analytical method, the following risk factors were found: season (rainy), age (over 1 year) and dipping interval (30 days) for the seroprevalence of *A. marginale*, *B. bigemina* and *B. bovis* in the dairy farms. On the other hand, in beef and dual purpose cattle, breed (*Bos taurus*), age (over 1 year) and season (rainy) were detected as risk factors for the seroprevalence of *A. marginale* and season (dry), age (less than 1 year) and breed (*Bos taurus*) for seroprevalence of babesiosis.

*Corresponding author.

SSDI 0167-5877(93)00348-9

1. Introduction

Bovine anaplasmosis and babesiosis cause major economic losses in animal production in Costa Rica (McCauley and Perez, 1980). Anaplasmosis is transmitted by several tick species of the genera *Boophilus* sp., *Rhipicephalus* sp., *Ixodes* sp., *Hyalomma* sp. and *Dermacentor* sp. (Harwood and James, 1979). *Babesia bigemina* and *Babesia bovis* are transmitted biologically by *Boophilus* sp. ticks. *Boophilus microplus* is the most prevalent tick species encountered in Costa Rica and is widely distributed in areas below 2000 m above sea level (Leroy, 1979).

A. marginale, *B. bigemina* and *B. bovis* are widespread in Costa Rica (Perez et al., 1994). Apart from studies executed in 1980 (Perez et al., 1980), the epidemiology of anaplasmosis and babesiosis in Costa Rica has not been thoroughly investigated. Successful management of anaplasmosis and babesiosis in cattle will depend on increased knowledge of the interactions between the parasites, the vectors and the ruminant host. The objective of the study was to investigate the relationships among management and host factors and the seroprevalence of hemoparasites in Costa Rican cattle.

2. Materials and methods

2.1. Study population and sampling methodology

The farms selected were typical of a specialized dairy production system practiced in the highlands and the dual purpose and cow–calf enterprises of Costa Rica (Cappella et al., 1991). The herds were selected from a large number of farms participating in the Livestock Monitoring System initiated by the School of Veterinary Medicine, on the basis of cooperation.

To select individual animals, a sample size was calculated. An estimated seroprevalence of 50% for both diseases, a confidence of 95% and an error of 5% using the EPISCOPE package were used (K. Frankema and J.O. Goelema, 1991. Agricultural University, Dept. of Animal Husbandry, PO Box 338-6700 A H Wageningen, The Netherlands). Stratified random sampling (using a random number table) was employed. The strata were the age divided into the following three groups: (1) less than 1 year old, (2) between 1 and 2 years old, and (3) older than 2 years. A proportional allocation of the sample size calculated for each herd at each sampling period was performed according to the number of animals present in each of the three age categories, allowing larger sample sizes from strata containing larger numbers of animals.

2.2. Study design

This was a prospective cohort study executed between April and October 1991. Blood samples were obtained from animals in the three age strata during four sampling periods in 1991: dry season (April), transition from dry to rainy season

(July), rainy season (August) and peak of the rainy season (October). Simultaneously, a pre-tested questionnaire was administered to the farmers or managers on each farm. The following information was obtained and categorized using quartiles: farm size (size of grazing area), herd size and number of paddocks. Moreover acaricide usage practices, grass variety and cattle breeds were dichotomized.

2.3. Collection of samples

Blood samples were collected from the coccygeal vein using disposable needles and vacuum tubes and transported on ice to the laboratory the same day. In the laboratory the samples were centrifuged to obtain serum, and stored at −20°C for less than 1 month until testing.

2.4. Serological assays

Sera were tested for *A. marginale* using the rapid-card agglutination test as prescribed by the manufacturer (Brewer Diagnostic Kit, Wescott and Dunning, Inc.); results were reported as positive when an agglutination reaction occurred.

The indirect fluorescent antibody test (IFAT) as described by Payne and Scott (1982) was used to detect antibodies to *B. bigemina* and *B. bovis*. The antigen slides for each parasite were prepared from monospecific in vitro colonies maintained at the University of Missouri. Positive control sera for each parasite were supplied by the US Dept. of Agriculture Animal Research Laboratory, Ames, Iowa,

Table 1
Seroprevalence (%) for *A. marginale*, *B. bigemina* and *B. bovis* in dairy cattle by age and season of the year, Costa Rica 1991

Age (years)	April		July		August		October	
	No. sampled	(%)	No. sampled	(%)	No. sampled	(%)	No. sampled	(%)
A. marginale								
<1	116	4.31	53	7.54	51	17.67	48	8.33
1–2	86	5.81	42	4.76	35	34.28	46	8.69
>2	287	15.67	239	14.64	173	45.08	176	14.7
B. bigemina								
<1	116	38.7	53	33.9	51	68.6	48	18.7
1–2	86	59.3	42	45.3	35	56.8	46	32.6
>2	287	56.7	239	41.4	173	77.4	176	36.3
B. bovis								
<1	116	24.1	53	43.4	51	80.4	48	54.8
1–2	86	36.0	42	54.8	35	88.6	46	26.0
>2	287	33.8	239	57.3	173	95.4	176	35.2

Table 2
Logistic binomial multiple regression for seroprevalence of *A. marginale* in dairy cattle, Coasta Rica, 1991

Term	β	SE (β)	*P* value	OR	95% CI (OR)
Intercept	−1.10	0.76			
Month of sampling					
July[a]	0.31	0.28	0.28	1.35	0.77–2.35
August	2.22	0.25	0.01	9.15	5.59–15.0
October	0.71	0.28	0.01	2.03	1.17–3.52
Age					
1–2 years[b]	0.31	0.36	0.40	1.36	0.66–2.78
≥2 years	0.93	0.27	0.01	2.52	1.49–4.29
Breed					
Holstein[c]	−1.61	0.45	0.01	0.20	0.08–0.48
Farm size					
41–80 ha[d]	−1.39	0.51	0.01	0.25	0.09–0.68
81–150 ha	−3.10	1.09	0.01	0.04	0.005–0.38
151–300 ha	0.17	0.48	0.72	1.19	0.46–3.06
Herd size					
41–118 head[e]	1.25	0.66	0.06	3.50	0.95–12.82
119–195 head	2.28	0.82	0.01	9.76	1.95–48.72
196–265 head	3.53	1.01	0.01	34.1	4.67–249.0
Dipping interval					
22 days[f]	−0.40	0.65	0.54	0.68	0.18–2.40
30 days	1.03	0.46	0.03	2.80	1.12–7.03
60 days	−1.56	1.16	0.17	0.21	0.02–2.02
Product					
Pyrethrines and	−2.12	0.99	0.03	0.12	0.01–0.84
pyrethroids[g]	−0.63	0.52	0.22	0.53	0.19–1.47
Formamidines					
Type of dipping					
Spray[h]	−0.83	0.28	0.01	0.43	0.24–0.76
Random term	0	0.09			

[a]Sampling on April used as reference level.
[b]Age category: less than 1 year used as reference level.
[c]Breed: Jersey used as reference category.
[d]Farm size: 1–40 ha used as reference level.
[e]Herd size: 1–40 head used as reference level.
[f]Dipping interval: 15 days used as reference level.
[g]Product: organophosphate used as reference level.
[h]Type of dipping: sponge used as reference level.

Table 3
Logistic binomial multiple regression for seroprevalence of *B. bigemina* in dairy cattle, Costa Rica, 1991

Term	β	SE (β)	*P* value	OR	95% CI (OR)
Intercept	−0.32	0.32			
Month of sampling					
July[a]	−0.47	0.16	0.01	0.62	0.45–0.85
August	0.84	0.18	0.01	2.30	1.62–3.25
October	−0.80	0.17	0.01	0.45	0.31–0.62
Age					
1–2 years[b]	0.64	0.21	0.01	1.90	1.27–2.85
≥2 years	0.66	0.16	0.01	1.94	1.42–2.65
Breed					
Holstein[c]	−0.18	0.17	0.28	0.83	0.59–1.16
Farm size					
41–80 ha[d]	−0.59	0.29	0.04	0.56	0.31–0.98
81–150 ha	−0.14	0.37	0.71	0.87	0.42–1.81
151–300 ha	0.23	0.22	0.29	1.26	0.81–1.93
Herd size					
41–118 head[e]	−0.19	0.24	0.42	0.82	0.52–1.32
119–195 head	0.27	0.23	0.24	1.31	0.83–2.08
196–265 head	0.51	0.23	0.03	1.66	1.05–2.62
Dipping interval					
22 days[f]	0.10	0.23	0.67	1.10	0.69–1.76
30 days	0.64	0.31	0.04	1.90	1.02–3.51
60 days	0.14	0.32	0.64	1.16	0.62–2.15
Random term	0	0.10			

[a]Sampling on April used as reference level.
[b]Age category: less than 1 year used as reference level.
[c]Breed: Jersey used as reference category.
[d]Farm size: 1–40 ha used as reference level.
[e]Herd size: 1–40 head used as reference level.
[f]Dipping interval: 15 days used as reference level.

USA. The conjugate, an anti-bovine IgG, was purchased from Sigma Chemical Company.

The IFAT was performed at a 1:80 dilution for all sera (controls and unknowns) and at a 1:200 dilution for the conjugate. These dilutions were considered optimal because they gave high specific intraerythrocytic fluorescence and few unspecific reactions in the background. Only those reactions were accepted as positive when specific intraerythrocytic fluorescence was present in association with the parasite. Negative controls showed no intraerythrocytic fluorescence.

Table 4
Logistic binomial multiple regression for seroprevalence of *B. bovis* in dairy cattle, Costa Rica, 1991

Term	β	SE (β)	*P* value	OR	95% CI (OR)
Intercept	−1.55	0.66			
Month of sampling					
July[a]	0.81	0.18	0.01	2.26	1.60–3.18
August	3.21	0.26	0.01	24.8	14.7–41.4
October	−0.18	0.19	0.34	0.83	0.57–1.20
Age					
1–2 years[b]	0.44	0.24	0.06	1.56	0.97–2.48
≥2 years	0.58	0.19	0.01	1.79	1.24–2.60
Breed					
Holstein[c]	−0.23	0.41	0.56	0.78	0.35–1.76
Farm size					
41–80 ha[d]	−0.02	0.39	0.97	0.98	0.45–2.13
81–150 ha	0.71	0.40	0.08	2.03	0.92–4.48
151–300 ha	1.11	0.42	0.01	3.05	1.31–7.08
Herd size					
41–118 head[e]	0.13	0.42	0.76	1.13	0.49–2.58
119–195 head	1.02	0.39	0.01	2.77	1.27–6.03
196–265 head	0.38	0.32	0.24	1.46	0.76–2.78
Random term	0.72	0.15			

[a]Sampling on April used as reference level.
[b]Age category: less than 1 year used as reference level.
[c]Breed: Jersey used as reference category.
[d]Farm size: 1–40 ha used as reference level.
[e]Herd size: 1–40 head used as reference level.

2.5. Statistical analysis

The unit of analysis was the individual animal. Response variables were serological results (positive, negative) for *A. marginale*, *B. bigemina*, *B. bovis*. Exposure variables were cattle breed, season of the year, and age stratum (host variables), size of pasture area, herd size, acaricide usage and grass variety (farm variables). Data were analyzed by production system (dairy and dual purpose, cow–calf) independently. All continuous variables were categorized using quartiles. A primary screening using $2\times K$ contingency table of the exposure variables with the outcomes was performed (PROC FREQ; Statistical Analysis Systems Institute Inc., 1989). All covariates associated with the outcome variables with $P \leq 0.25$ were considered in the secondary steps of the screening procedure. A stratified analysis of the host variables by the farm level variables was performed with EGRET (Statistics and Epidemiology Research Corporation (SERC),

Table 5
Seroprevalence (%) for *A. marginale*, *B. bigemina* and *B. bovis* in dual/beef cattle by age and season of the year, Costa Rica 1991

Age (years)	April		July		August		October	
	No. sampled	(%)	No. sampled	(%)	No. sampled	(%)	No. sampled	(%)
A. marginale								
<1	181	14.3	211	39.8	164	57.0	189	33.8
1–2	115	32.11	89	44.9	80	52.5	129	58.1
>2	279	32.25	248	66.5	205	51.7	314	58.9
B. bigemina								
<1	181	47.5	211	56.8	164	53.0	189	29.0
1–2	115	44.3	89	57.3	80	46.2	129	24.0
>2	279	51.2	248	62.9	205	31.14	314	25.7
B. bovis								
<1	181	64.0	211	81.9	164	69.5	189	34.9
1–2	115	54.7	89	66.2	80	62.5	129	53.4
>2	279	54.1	248	77.0	205	59.5	314	44.2

1990). Common odds ratios across strata were calculated; if the null hypothesis of homogeneity was rejected ($P < 0.05$) an interaction term for the multivariate analysis was created. All main effects and interaction terms selected in the screening procedures were used in the multivariate analysis performed using EGRET (SERC, 1990). A backward elimination process was employed; an examination of the Wald statistic for each variable and assessment of the odds ratios estimate were done at each step. All non-significant terms were eliminated and a new model fitted. A proportionate change of 5% in the estimates was used as a criterion to force the covariate to remain in the model as a potential confounder. Models were compared using the likelihood ratio test. To control for possible herd effects, a logistic-binomial regression model for distinguishable data was used (Mauritsen, 1984). This model was selected because the data had variables measured both at herd level (herd effects) and animal level (host effects) associated rather with the individual responses than just with the herds.

3. Results

3.1. Dairy

The data set contained information from 23 dairy farms; all the farmers decided to participate. No one withdrew during the study period. Eighty-five percent of the farms had Holstein cows and 15% Jersey. All farms raised their own replacements and only 23% occasionally bought heifers or cows elsewhere.

The nutrition was mainly pasture based, with some grain supplementation. All

Table 6
Logistic binomial multiple regression for seroprevalence of *A. marginale*, in beef and dual-purpose cattle, Costa Rica, 1991

Term	β	SE (β)	*P* value	OR	95% CI (OR)
Intercept	−1.06	0.26			
Month of sampling					
July[a]	1.27	0.13	0.01	3.57	2.77–4.62
August	0.90	0.13	0.01	2.48	1.92–3.19
October	1.21	0.13	0.01	3.37	2.62–4.30
Age					
1–2 years[b]	0.47	0.13	0.01	1.60	1.24–2.04
≥2 years	0.70	0.10	0.01	2.01	1.65–2.45
Breed					
Bos indicus[c]	0.18	0.23	0.42	1.20	0.76–1.87
Cross breed	−0.23	0.16	0.06	0.74	0.54–1.01
Farm size					
106–126 ha[d]	0.45	0.19	0.01	1.57	1.09–2.26
127–230 ha	0.59	0.18	0.01	1.81	1.27–2.60
231–1200 ha	0.63	0.23	0.01	1.88	1.18–2.98
Number of paddocks					
11–18[e]	−0.04	0.20	0.81	0.96	0.64–1.40
19–22 paddocks	−0.44	0.19	0.02	0.65	0.44–0.93
23–40 paddocks	−0.44	0.20	0.03	0.65	0.43–0.96
Type of grass					
Natural grass[f]	−0.88	0.22	0.01	0.41	0.27–0.63
Random term	0	0.08			

[a]Sampling on April used as reference level.
[b]Age category: less than 1 year used as reference level.
[c]Breed: *Bos taurus* used as reference category.
[d]Farm size: 9–105 ha used as reference level.
[e]Number of paddocks: 3–10 used as reference level.
[f]Grass type: African Star grass used as reference level.

farms used Kikuyu grass (*Penisetum clandestimun*), 68% as the only type of grass and 32% combined with some varieties of clovers (*Tripholium* sp.), Star grass (*Cynodon plectostachyus*) or Rye grass (*Lolium perenne*).

Median farm size was 80 ha, with a median number of paddocks of 60, and median herd size of 117. For the control of ticks and other ectoparasites, 83% of farms used a back-pack sprayer and 17% used sponges or a cotton cloth. Intervals between treatments varied from 15 days (44%), 22 days (26%), 30 days (19%) to 60 days (11%). The chemical pesticide employed on 67% of the farms was

Table 7
Logistic binomial multiple regression for seroprevalence of *B. bigemina* in beef and dual-purpose cattle, Costa Rica, 1991

Term	β	SE (β)	*P* value	OR	95% CI (OR)
Intercept	−0.39	0.23			
Month of sampling					
July[a]	0.41	0.12	0.01	1.51	1.19–1.91
August	−0.19	0.11	0.10	0.83	0.65–1.03
October	−0.95	0.12	0.01	0.39	0.30–0.49
Age					
1–2 years[b]	−0.18	0.12	0.14	0.83	0.65–1.06
≥2 years	−0.13	0.09	0.19	0.87	0.72–1.06
Breed					
Bos indicus[c]	−0.44	0.20	0.03	0.65	0.43–0.95
Cross-breed	−0.42	0.13	0.01	0.66	0.50–0.85
Farm size					
106–126 ha[4]	0.29	0.17	0.08	1.33	0.96–1.85
127–230 ha	0.28	0.16	0.06	1.32	0.97–1.80
231–1200 ha	−0.61	0.21	0.01	0.54	0.36–0.82
Number of paddocks					
11–18[e]	0.40	0.18	0.03	1.49	1.04–2.10
19–22	0.60	0.17	0.01	1.81	1.28–2.55
23–40	0.59	0.18	0.01	1.80	1.25–2.58
Type of grass					
Natural grass[f]	0.76	0.19	0.01	2.14	1.46–3.13
Random term	0	0.05			

[a]Sampling on April used as reference level.
[b]Age category: less than 1 year used as reference level.
[c]Breed: *Bos taurus* used as reference category.
[d]Farm size: 9–105 ha used as reference level.
[e]Number of paddocks: 3–10 used as reference level.
[f]Grass type: African Star grass used as reference level.

formamidines, 28% organophosphates, and 5% pyrethrins and pyrethroids. Vaccination against hemoparasites on the farms was not carried out.

Of the 1352 animals from 23 dairy farms sampled during the study, 20% were aged less than 1 year, 16% were between 1 and 2 years and 64% were over 2 years (Table 1). The crude seroprevalence of *A. marginale* was 83%, *B. bigemina* 50%, and *B. bovis* 50%.

The highest odds of infection were detected during the rainy season (August) (Tables 2–4); for all three infections Holsteins had lower odds of seropositivity than Jerseys (only statistically significant for *A. marginale*). The odds of sero-

Table 8
Logistic binomial multiple regression for seroprevalence of *B. bovis*, in beef and dual-purpose cattle, Costa Rica, 1991

Term	β	SE (β)	*P* value	OR	95% CI (OR)
Intercept	0.62	0.22			
Month of sampling					
July[a]	0.95	0.13	0.01	2.57	1.98–3.34
August	0.14	0.12	0.23	1.15	0.91–1.45
October	−0.58	0.11	0.01	0.55	0.44–0.70
Age					
1–2 years[b]	−0.06	0.12	0.60	0.93	0.73–1.20
≥2 years	−0.23	0.09	0.02	0.80	0.65–0.97
Breed					
Bos indicus[c]	−0.53	0.24	0.03	0.58	0.36–0.94
Cross-breed	−0.39	0.21	0.06	0.67	0.44–1.01
Herd size					
116–184 head[d]	0.51	0.19	0.01	1.66	1.13–2.43
185–207 head	0.06	0.20	0.98	1.00	0.67–1.49
208–834 head	0.16	0.19	0.40	1.17	0.81–1.71
Random term	0	0.06			

[a]Sampling on April used as reference level. [b]Age category: less than 1 year used as reference level. [c]Breed: *Bos taurus* used as reference category. [d]Herd size: 11–115 heads used as reference level.

positivity tended to increase with farm size. None of the tick control management practices were associated with *B. bovis* seropositivity.

3.2. Beef and dual purpose

The median farm size for cow–calf herds was 120 ha, and for dual purpose farms 126 ha. The median number of paddocks per farm were 20 and 15 for cow–calf and dual purpose farms, respectively. The median number of cattle per farm was 115 in cow–calf farms, and 196 in dual purpose farms.

Nutrition was exclusively pasture based. Star grass was the only pasture used on 37% of the farms while 63% of farms combined this grass with natural grass and jaragua (*Hyparrhenia rufa*). Supplementation with molasses and mineral salt often occurred during the dry period (May to December).

The most frequently used pesticide against ticks was pyrethrins and pyrethroids (67%) followed by organophosphates (34%). All farms used back-pack sprayer for applications. As with the dairy farms, no vaccination against hemoparasites was practiced.

During the study period 2204 animals from eight cow–calf and eight dual purpose farms were sampled. The crude seroprevalence rates were 57% for *A. mar-*

ginale, 59% for *B. bovis*, and 44% for *B. bigemina* (Table 5). Rates stratified by type of farm showed no statistical difference ($P > 0.05$).

The dry season (April), was the season of lower odds of seropositivity for *A. marginale* (Table 6). On the other hand, *B. bigemina* and *B. bovis* serological results presented a lower odds of seropositivity during the peak of the rainy season in October (Tables 7 and 8). Tables 6, 7, and 8 show a trend for seropositivity for *A. marginale* to increase with age, no association with age for *B. bigemina*, and a diminished likelihood of seropositivity for *B. bovis* as age increased. *Bos taurus* cattle exhibited an increased odds of seropositivity for *Babesia* spp. when compared with cross-bred or *Bos indicus* animals. Larger sized farms had an increased odds for seropositivity against *A. marginale*, but decreased odds for *B. bigemina*. Finally, as the number of paddocks increased or as farms used Star grass more frequently, the odds of seropositivity increased for *B. bigemina* and decreased for *A. marginale*.

4. Discussion

4.1. General

In this study there was a potential lack of within-herd independence due to lateral transmission, clustering of cases within herds and repeated measures on the same animal. This extra variation introduced between groups is extra-binomial variation (Mauritsen, 1984). The random effects logistic regression models can be used to model outcomes where an observation can be either group-level data, an individual within a group or a repeated observation on the same animal (Kristula et al., 1992). For that purpose random effects models add a scale parameter which models the excess of variation. Thus, the estimated probability of infection becomes not only a function of the fixed parameters but also the herd random-effect term. Furthermore, the data are non-experimental, with the attendant difficulties of establishing causal relationships.

Only two of the cow–calf and dual purpose farms reported clinical cases of tick-borne disease during the year of study reflecting endemic stability (Callow, 1984). Conversely, all the dairy farmers reported clinical cases during the year, reflecting an epidemiological unstable condition (Callow, 1984). Possibly at the dairy farms, ecological factors or the nature of tick control measures, caused tick populations to be low and insufficient to maintain parasite transmission necessary for premunition of young animals.

4.2. Month of sampling

In both areas there was a clear pattern of increased seropositivity during the rainy period (months of August and October), perhaps associated with increased tick activity in the preceding months (dry season). The only bio-ecological study of *Boophilus microplus* in Costa Rica indicated a peak of larvae in the pastures during the dry season (months of January through April) (Perez et al., 1980). Similar seasonal patterns in seropositivity have been reported in other studies in Louisiana (Hugh-Jones et al., 1988) and Argentina (Guglielmone et al., 1992). Furthermore, in Paraguay, low seropositivity levels were associated with study sites where ticks were either absent or low in number (Payne and Osorio, 1990).

An alternative explanation of the pattern for anaplasmosis seroprevalence might be that the annual massive vaccination against anthrax and pasteurellosis was performed at the end of the dry season (April–May) facilitating iatrogenic transmission (Reeves and Swift, 1977).

4.3. Age

The dairy data showed a trend of increased seropositivity for anaplasmosis and babesiosis with age, consistent with previous reports (Hugh-Jones et al. 1988); younger animals are more resistant to primary infections (Trueman and Blight, 1978). The beef/dual purpose data were equivocal in demonstrating a diminished likelihood of seropositivity for *B. bovis* in older animals. The increased likelihood of *Babesia* transmission in young animals could be explained by a decreased resistance to ticks under nutritional stress (Gladney et al., 1973; Sutherst et al., 1983) combined with a the peak in activity of infective larvae, since *B. bovis* is mainly transmitted by larvae (Riek, 1966). The region experiences a long dry season of 6 months (December to May) when grass is sparse and the nutrition is deficient.

4.4. Breed

The beef/dual purpose data showed an association between *Bos taurus* and seropositivity. Several researchers have suggested that certain breeds may be more susceptible to *Babesia* infection than others (Mahoney and Ross, 1972; Johnston et al., 1978). Recently, Mount et al., 1991 showed a difference of tick (*Boophilus microplus*) survival rate on the host depending on breed. Haile et al. (1992) demonstrated different inoculation thresholds for *Babesia* species depending on the breed.

4.5. Farm size and herd size

Hugh-Jones et al. (1988) found no association between herd size and positive serology to anaplasmosis. On the other hand, in the dairy data in this study a clear trend of increased seropositivity in larger herds was detected.

4.6. Tick control management practices

The results did not demonstrate clear associations of acaricide usage and seroprevalence in the beef/dual purpose data. In the dairy data inconsistencies in the results such as an increased odds of seropositivity at dipping intervals of 30 days but a decreased odds at intervals of 22 and 60 days are difficult to explain. Morley and Hugh-Jones (1989) reported lack of associations between the use of external parasite control and anaplasmosis seropositivity.

4.7. Number of paddocks and type of grass

In the beef/dual purpose data, these variables were associated with seropositivity of *A. marginale* and *B. bigemina*, but with different patterns, which corroborates that these infections behave in different manners. Different types of vegetation could be associated with different vectors (Morley and Hugh-Jones, 1989). Moreover, levels of rickettsemia vary markedly in persistently infected animals, reflecting a cyclical multiplication of *A. marginale* (Kieser et al., 1990); this can vary the probabilities of the potential vectors being infected and thus maintaining transmission. On the other hand, parasitemia levels of *Babesia* fluctuate less which is attributed to superinfection by ticks infected with different strains of *Babesia* rather than to cyclical relapses.

5. Conclusion

The results demonstrated that the pattern of seropositivity of *Babesia* parasites behaved very differently from that of the rickettsia *Anaplasma*. The differences in epidemiological patterns between the parasites should give rise to different control strategies for the dairy farms and the beef/dual purpose farms as well as within farms to control *Anaplasma* and *Babesia* as suggested by other authors (Lawrence and de Vos, 1990). Prospective interventional studies are indicated as well as experimental studies to clarify some association of the potential vectors and the parasitemia.

References

Callow L.L., 1984. Animal Health in Australia, Vol 5. Protozoal and Rickettsial Diseases. Australian Bureau of Animal Health, Australian Government Publishing Service, Canberra, pp. 181–199.

Cappella E., Buurman, J., Perez E., Baayen M. and Muller E., 1991. Development of a livestock information system in Costa Rica. Part 2: Uptake and validation of Vampp software in Costa Rican dairy farms. XXIV World Veterinary Congress, 18–23 August 1991, Rio de Janeiro, Brazil. Figueroa, D.F., 38 pp.

Gladney, W.J., Graham, O.H., Trevino, J.L. and Ernst, S.E., 1973. *Boophilus annulatus*: effect of host nutrition on development of female tick. J. Med. Entomol., 10: 123–130.

Guglielmone, A.A., Aguirre, D.H., Späth, E.J.A., Gaido, A.B., Mangold, A.J. and de Rios, L.G., 1992. Long-term study of incidence and financial loss due to cattle babesiosis in an Argentinian dairy farm. Prev. Vet. Med., 12: 307–312.

Haile, D.G., Mount, G.A. and Cooksey, L.M., 1992. Computer simulation of *Babesia bovis* and *Babesia bigemina* transmission by *Boophilus* cattle ticks. J. Med. Entomol., 29: 246–258.

Harwood and James, 1979. Entomology in Human and Animal Health. Washington State University, Pullman, 410 pp.

Hugh-Jones, M.E., Busch, D., Raby, C. and Jones, F., 1988. Seroprevalence survey for *Anaplasma* card-test reactors in Louisiana, USA, cattle. Prev. Vet. Med., 6: 143–153.

Johnston, L.A., Leatch, G. and Jones, P.N., 1978. The duration of the latent infection and functional immunity in Droughmaster and Hereford cattle following natural infection with *Babesia argentina, Babesia bigemina*. Aust. Vet. J., 54: 14–18.

Kieser S.T., Ericks, I.S. and Palmer, G.H., 1990. Cyclic rickettsemia during persistent *Anaplasma marginale* infection of cattle. Infect. Immun., 58: 1117–1119.

Kristula, M.A., Curtis, C.R., Galligan, D.T. and Bartholomew, R.W., 1992. Use of a repeated-measures logistic regression model to predict chronic mastitis in dairy cows. Prev. Vet. Med., 14: 57–68.

Lawrence, J.A. and de Vos, A.J., 1990. Methods currently used for the control of Anaplasmosis and Babesiosis: their validity and proposals for future control strategies. Parasitologia, 32: 63–71.

Leroy, E., 1979. Informe Final Proyecto M.A.G. 184. Ministerio de Agricultura y Ganaderia, San Jose Costa Rica, 25 pp.

Mahoney, D.F. and Ross, D.R., 1972. Epizootiological factors in the control of bovine babesiosis. Aust. Vet. J., 48: 292–298.

Mauritsen, R.H., 1984. Logistic regression with random effects. Ph.D Dissertation, Dept. of Biostatistics, University of Washington, Seattle, pp. 1–88.

McCauley, E.H. and Perez, E., 1980. Investigaciones sobre el control de garrapatas y de las enfermedades por ellas transmitidas en Costa Rica: evaluacion economica. Cienc. Vet., 2: 219–223.

Morley, R.S. and Hugh-Jones, M.E., 1989. The effect of management and ecological factors on the epidemiology of anaplasmosis in the red river plains and south-east areas of Louisiana. Vet. Res. Commun., 13: 359–369.

Mount, G.A., Haile, D.G., Davey, R.B. and Cooksey, L.M., 1991. Computer simulation of *Boophilus* cattle (Acari:ixodidae) population dynamics. J. Med. Entomol., 28: 223–240.

Payne, R.C. and Osorio, O., 1990. Tick-borne diseases of cattle in Paraguay. I. Seroepidemiological studies on anaplasmosis and babesiosis. Trop. Anim. Health Prod., 22: 53–60.

Payne, R.C. and Scott, J.M., 1982. Anaplasmosis and Babesiosis in El Salvador. Trop. Anim. Health Prod., 14: 75–82.

Perez, E., Leroy, E. and Carrillo, J.M., 1980. Anaplasmosis y piroplasmosis: Estudio epidemiologico en la estacion experimental Los Diamantes. Cienc. Vet., 2: 2–20.

Perez, E., Herrero, M.V., Jimenez, C., Carpenter, T.E. and Buening, G.B., 1994. Epidemiology of bovine anaplasmosis and babesiosis in Costa Rica. Prev. Vet. Med., 20: 23–31.

Reeves, J.D. and Swift B.L., 1977. Iatrogenic transmission of *Anaplasma marginale* in beef cattle. Vet. Med. Small Anim. Clin., 72: 911–912.

Riek, R.F., 1966. The life cycle of *Babesia argentina* in the tick vector *Boophilus microplus*. Aust. J. Agric. Res., 17: 247–254.

Statistical Analysis Systems Institute Inc., 1989. SAS User's Guide: Statistics, Version 6 Edition. SAS Institute Inc., Cary, NC, 1028 pp.

Statistics and Epidemiology Research Corporation (SERC), 1990. EGRET Statistical Package Users Manual. SERC, Software Division, Seattle, WA.

Sutherst, R.W., Kerr, J.D., Maywald, G.F. and Stegeman, D.A., 1983. The effect of season and nutrition on the resistance of cattle to the tick *Boophilus microplus*. Aust. Vet. Agric. Res., 34: 329–339.

Trueman, K.F. and Blight, G.W., 1978. The effects of age on the resistance of cattle to *Babesia bovis*. Aust. Vet. J., 54: 301–305.