Management of internal nematode parasites on beef rearing farms in the North Island of New Zealand

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Introduction

The background to this study is set out in the companion cattle part of the report entitled “Prevalence of anthelmintic resistance on beef rearing farms in the North Island of New Zealand”. The objectives of this study were to provide information on current farmer opinions and farming practices thought to be related to drench resistance, and to test for associations between anthelmintic resistance and management practices.

Materials and methods

For the statistical modelling in this study, data were examined with descriptive statistics prior to testing for associations between the outcomes of interest with χ^2 tests for categorical variables and univariate logistic regression tests for continuous independent variables as a first screening process. As a general rule, variables significant at the $p < 0.20$ level were entered into the multivariate logistic regression models provided >90% of the farms exhibited that factor. All selected variables were entered and non-significant variables eliminated one at a time beginning with the variable having the highest *p*-value. NCSS® was used to construct the fixed effect models that best explained the data. In all other aspects, the materials and methods used in this study are reported in detail in the companion “Prevalence of anthelmintic resistance on beef rearing farms in the North Island of New Zealand” section of the report.

Results

The physical details and locations of the 59 participant farms for which there were completed questionnaires are described in the companion cattle section of the report.

Summer—autumn and autumn—winter grazing management

Farmers were asked to indicate the systems of grazing management mostly used for their bull beef calves in their first summer-autumn period after weaning from a list of 4 options. There was no response from 10 farmers, 39 used shifts every 2 to 10 days, 3 of the 4 who used daily shifts also used shifts every 2 to 10 days, 10 used shifts at intervals of >10 days (2 of these also set stocked and 1 shifted every 2 to 10 days), and 3 set stocked.

Farmers were asked to indicate the systems of grazing management mostly used for their bull beef calves in the late autumn-winter period when pasture length is shorter. There was no response from 10 farmers, of whom 9 did not respond to the question reported in the preceding paragraph. Of 12 who used daily shifts, 2 also shifted every 2 to 10 days. Shifts every 2 to 10 days was used by 39 farmers, shifts at intervals of >10days by 6 and set stocking by 2.

Farmers were asked to indicate the system of grazing management they mostly used for their traditional beef weaners in their first autumn-winter period after weaning. There was no response from 15 farmers. This non-response rate was acceptable since almost all of the non-responders did not farm traditional beef weaners and hence the question did not apply to their circumstances. Daily shifts were used by 6 farmers and two of these also shifted every 2 to 10 days. Shifts every 2 to 10 days was used by 29 of the 44 respondents and one also used shifts at intervals of >10 days. Four farmers set stocked.

Farmers were asked to nominate the type of programme they followed for integrating sheep or older cattle in their grazing management of their bull beef or traditional beef.
The responses are shown in Table 1.

Table 1. Distribution of numbers and proportions of farmers using planned, random or no integrated programme involving the use of sheep or older cattle in their management of their bull beef or traditional beef rearing enterprises

System of integration	N farmers	Frequency% (95% CIs)
Non respondents	5	8 (4, 18)
Planned integration that you try to follow	20	34 (23, 47)
Random integration – i.e. only if circumstances suit	26	44 (32, 57)
Don't integrate at all	8	14 (7, 25)
Total	**59**	

Farmers were asked how long on average they usually take before putting their bull beef calves onto a pasture that was last grazed by sheep or cattle older than 1 year.
The responses for each system but not combinations of systems (which were infrequent) are shown in Table 2.

Table 2. Distribution of times farmers took on average before putting their bull beef calves on pasture that was last grazed by >1 year-old sheep or cattle

System of rotation	N farmers
No response or did not apply to their circumstances	13
Between 0 to 1 month	18
Between 1 to 2 months	20
Between 2 to 3 months	3
More than 3 months or does not apply	6
Co-graze with sheep continuously during this period	2
Co-graze with sheep occasionally during this period	2
Co-graze with older cattle continuously during this period	4
Co-graze with older cattle occasionally during this period	0

Farmers were asked how long on average in the period from April to the end of September, they usually took before putting their yearling beef animals (either bull beef or traditional beef animals less than 15 months-old) onto a pasture that was last grazed by sheep or cattle older than 1 year. The responses are shown in Table 3.

Table 3. Distribution of times in the period from April to the end of September that farmers usually took before putting their yearling beef animals (either bull beef or traditional beef animals less than 15 months-old) onto pasture that was last grazed by >1 year-old sheep or cattle

System of rotation during April to September	N farmers
No response or does not apply	15
Between 0 to 1 month	0
About 1 to 2 months	21
About 2 to 3 months	10
More than 3 months or does not apply	12
Co-graze with sheep continuously during this period	1
Co-graze with sheep occasionally during this period	5
Co-graze with older cattle continuously during this period	0
Co-graze with older cattle occasionally during this period	0

Of the 48 farmers with >150 ewes, 19 (40%, 27, 54) grazed their weaner cattle in front of ewe mobs over winter.

Farmers were asked if sheep or deer, or cattle older than 18 months were grazed on pastures in between their use for grazing beef for finishing or stores between weaning and 12 months of age. The distribution of the responses is shown in Table 4.

Table 4. Distribution of frequency of use of sheep, deer or cattle older than 18 months for grazing pastures between their use for grazing beef for finishing or stores between weaning and 12 months of age

Grazing pastures with other classes of livestock	N farmers	Frequency% (95% CIs)
No response or does not apply	5	8 (4, 18)
Never	7	12 (6, 23)
Occasionally	30	51 (38, 63)
Often	12	20 (12, 32)
Always	5	8 (4, 18)
Total	**59**	

The distribution of the responses to the Question "what proportion of your farm was grazed or will be grazed by cattle under 12 months of age between 1st July 2003 and 30th June 2004" is shown in Table 5.

Table 5. Distribution of proportion of farm grazed by cattle from 1st July to 30th June in the following year among 57 farmers

Proportion grazed	N farmers	Frequency% (95% CIs)
No response or does not apply	2	3 (1, 12)
Less than ¼	15	25 (16, 38)
Between ¼ and ½	18	31 (20, 43)
Between ½ and ¾	8	14 (7, 25)
Greater than 3/4	16	27 (17, 40)
Total	**59**	

Drenching policies and procedures

In Question 9.1, farmers were asked what general treatment program they followed for control of internal parasites. All 59 respondents followed a set plan but also relied on various other criteria for decision making. Only 13 relied solely on a set plan. The sums of responses to each criterion listed in the questionnaire are shown in Table 10.

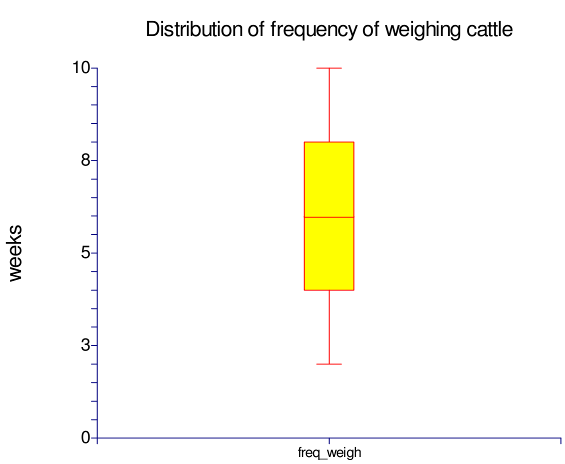
Table 6. General treatment programmes for deciding when to treat for internal parasites and number of farmers using those programmes

General treatment programme	Number
I have a planned programme which I follow	59
I treat them straight after I purchase them	34
Rely wholly or partially on faecal egg counts (FEC)	7
Poor growth rate, condition or condition score	23
Signs of parasites such as scouring or dirty hocks	30
Gut feeling	11

Use of scales

All participating farmers had cattle scales and 44 of 59 (75%, 62, 84) farmers routinely weighed cattle that they were rearing for finishing or stores. Three farmers who routinely weighed their cattle did not report how frequently they weighed them. The distribution of the average intervals between weighings for the 48 farmers who responded to the question about weighing intervals is shown in Figure 1.

Figure 1. Distribution of interval between weighings for 48 participating farmers



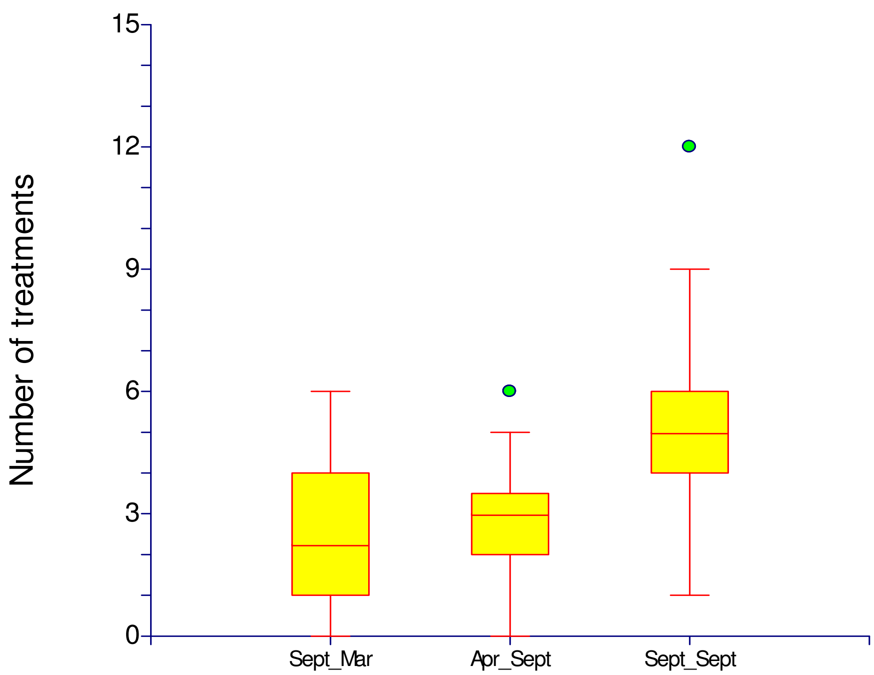
Faecal egg count testing

Faecal egg counts were routinely conducted on 19 farms (32%, 22, 45) and 3 of those were done by the farmer and 16 by veterinarians. The question did not specify genus for testing so the results should be treated with that caution in mind.

Frequency of anthelmintic treatments

In Questions 9.5 and 9.6 farmers were asked how often they treated their beef calves between September and March and their beef weaners between April and September. Medians for the respective periods were 2.3 and 3 occasions and the number of treatments ranged from 0 to 6 for both periods. The median number of occasions for September to September was 5 (range 1 to 12). The 75th percentile was 8, indicating that one in four farmers used anthelmintics on 8 to 12 occasions during that period. The distributions of the number of treatments in each period and overall are shown in Figure 2.

Figure 2. Box plot distributions of number of treatments given to beef calves between September and March and beef weaners between April and September and overall for September to September



Trading patterns

Two farmers did not complete the section of the questionnaire dealing with numbers of animals purchased or weaned. Of the 57 who provided data for that section, 38 reared traditional beef sourced animals either sourced from their own herd, or bought in, or a mixture of both, 46 reared dairy sourced animals, 27 reared both types, 11 reared traditional beef animals only and 19 dairy derived animals only. Several farmers had small numbers of beef breeders but gave no indication that the offspring were used for bull beef type rearing.

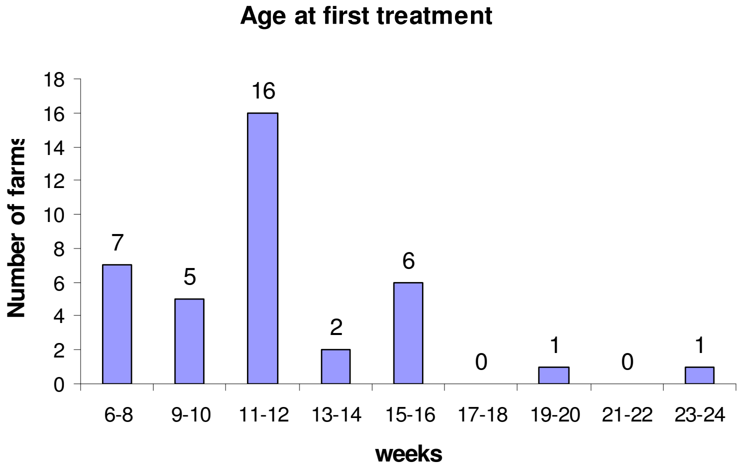
Treatment of beef calves at marking, in-calf heifers and cows in traditional beef cattle enterprises

Of the 42 farmers with beef breeders, 13 (31%, 19, 46) indicated that they routinely drenched their home reared beef calves at marking time, 9 (21%, 12, 36) routinely drenched their cows >2years, and 18 (43%, 29, 58) their rising 2 year-old in-calf heifers before calving.

Age of first treatment of dairy sourced calves

Data for the earliest age at which dairy sourced calves were treated was available for 38 farms. The mean earliest age was 12 weeks and ranged from 6 to 24 weeks. The distribution of ages of first treatment is shown in Figure 3.

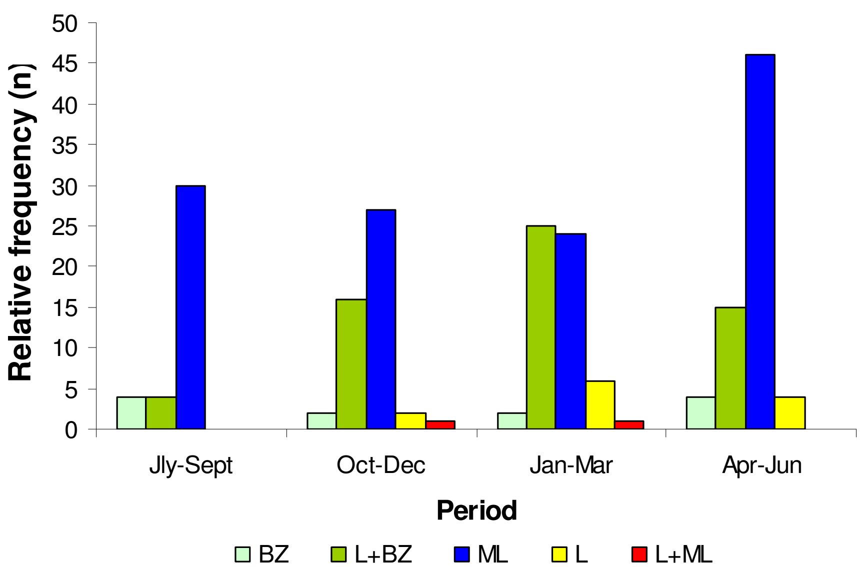
Figure 3. **Distribution of age of first treatment for dairy sourced calves on 38 farms**



Current and recent action family usage

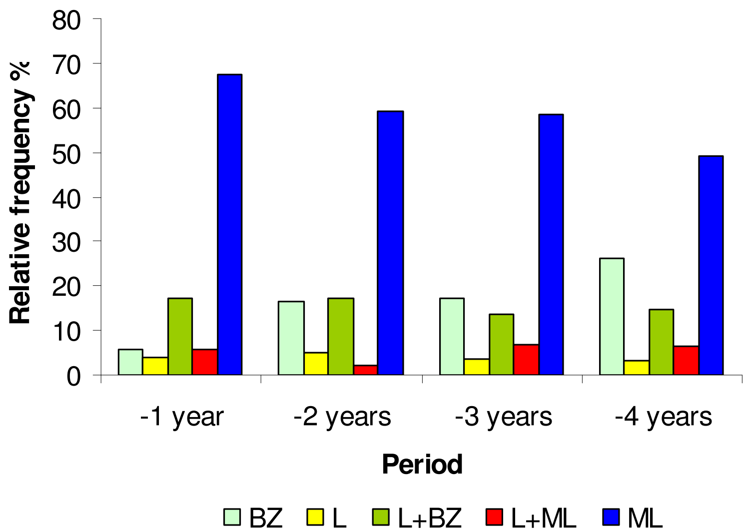
Farmers were asked to specify the names of the anthelmintics they had used or intended to use in each season of the current year on their beef animals born in the previous spring. The distribution of action families used or intended to be used over the 4 seasons of the year are shown in Figure 4.

Figure 4. **Relative frequency of past and intended usage of benzimidazoles (BZ), macrocyclic-lactones (ML), levamisole (L) and their combinations (L + BZ and L + ML) in the current year for animals born in the previous spring**



Data were collected on the frequency of use of action families of anthelmintic most used on cattle born in the late winter-spring over the past 4 years. The relative distributions shown as percentages are shown in Figure 5. There appears to have been little variation in the relative frequency of usage by action families over the past 4 years apart from a slightly higher usage of benzimadazoles 4 years previously.

Figure 5. Relative frequency (%) of usage of action families of anthelmintic used most on cattle born in late winter-spring over the past 4 years



In this section of the questionnaire, farmers were also asked to list the names of anthelmintics they used most over the past 4 seasons on their rising 1 year (R1) cattle. Understandably, some farmers were unable to recall that information. The list is therefore incomplete and the data should be interpreted cautiously. Nevertheless, while it was not possible to collect data on the number of times each anthelmintic action family was used, the totals of each family used most over the past 4 seasons can be expected to give a crude indication of usage of the families and their combinations. The totals and their relative percentages are shown in Table 7.

Table 7. Totals and percentages of action families of anthelmintics listed as used most on cattle <1year old over the past 4 seasons

Action family	N	%
Benzimidazole	66	16
Levamisole	16	4
Levamisole + benzimidazole	63	16
Levamisole + macrocyclic-lactone	21	5
Macrocyclic-lactone	234	59
Total	400	

One farm reported use of levamisole only, two levamisole and benzimidazole combination only, and one benzimidazole only. Otherwise all other farms reporting this section of the questionnaire indicated use of macrocyclic-lactones at some time in the past 5 years. Usage of action families and their combinations for the 57 farms that responded to that section of the questionnaire are shown in Table 8.

Table 8. Anthelmintic action families and usage over the past 4 seasons among 57 farms

Action family	Usage n	Frequency% (95% CIs)
Macrocyclic-lactone	18	32 (21, 44)
Macrocyclic-lactone + benzimidazole	6	11 (5, 21)
Macrocyclic-lactone + benzimidazole + Levamisole	23	40 (29, 53)
Macrocyclic-lactone + Levamisole	6	11 (5, 21)
Benzimidazole	1	2 (0, 9)
Levamisole + benzimidazole	2	4 (1, 12)
Levamisole	1	2 (0, 9)
Total	**57**	

There was no history of use of levamisole on 20 farms and benzimidazole on 21 farms. Sole usage of macrocyclic-lactones was reported for 18 farms, 23 farms used all action families at some time and 6 used macrocyclic-lactone and levamisole.

Of the 25 farmers who indicated they had changed treatments between the present and previous seasons, 6 were concerned that the treatments were not working. Three of these 6 farmers were influenced by veterinarians in this decision and one also by price. Recommendations for change came from veterinarians on 7 occasions and on 4 occasions from other persons. Four farmers were changing as part of a planned rotation of action families and four for cheaper options.

Post-treatment grazing management

In Question 9.18 farmers were asked if they returned young cattle to the same paddock after treatment. The distribution of responses is shown in Table 9.

Table 9. Placement of young cattle after treatment

Do you return the young cattle to the same paddock after treatment?	n responses	Frequency% (95% CIs)
Always	1	2 (0, 9)
Never	21	36 (25, 48)
Occasionally	34	58 (45, 69)
Often	3	5 (2, 14)
Total	**59**	

Multiple options for the question on types of pasture and their grazing history where young cattle were placed after treatment were recorded and the overall distribution of responses is shown in Table 10.

Table 10. Pasture type of locations for placement of young cattle after treatment

Placement of young cattle after treatment	n farms
Pasture re-growth from earlier grazing with calves	33
Pasture re-growth from another class of stock	38
New pasture	8
Crop	3
Other	1

The response to the Question 9.20 “How many times (on average) did you treat your 1 to 2 year-old cattle last season” is shown in Table 11.

Table 11. Numbers of farms and number of treatments given to 1 to 2 year-old cattle in the previous season

N treatments for 1 to 2 year-old cattle last season	n farms	**Frequency% (95% CIs)**
0	3	5 (2, 14)
1	13	22 (13, 34)
2	17	29 (19, 41)
3	7	12 (6, 23)
>3	17	29 (19, 41)
No answer	2	3 (1, 12)
Total	**59**	

Of those who treated their 1 to 2 year-old cattle in the previous season, 2 did so because of high faecal egg counts, 12 because of scouring, and 44 as part of a set program. Other reasons were for a quarantine drench (1), to control *Ostertagia* in the spring (1), to coincide with a feed change (1), cattle not doing well (4), and after a drench test (1).

The distribution of replies to the Question 9.22 “When treating your cattle for worms, how often do you check the volume of the drug delivered by the applicator or gun?” are shown in Table 16.

Table 12. Frequency of use of procedures used to check the accuracy of drench applicators when treating their cattle for worms

Checking gun for accuracy	n farms	**Frequency% (95% CIs)**
Before starting and again when finished	1	2 (0, 9)
Always before starting	10	17 (9, 28)
Before starting and again when finished	2	3 (1, 12)
Occasionally before you start treatments	27	46 (34, 58)
You rely on the applicator/gun being accurate	16	27 (17, 40)
No answer	3	5 (2, 14)
Total	**59**	

Three farmers checked their guns for accuracy (after approximately 6, 7 and 10 animals) when treating.

The integrity of drench gun seals was tested routinely by 43 of 59 farmers (73%, 60, 83).

In Question 9.25 farmers were asked to nominate how they estimated body weights of cattle <1year-old the last time they treated a mob of cattle. Basing the dose rate on the heaviest animal in the group was used by 47 farmers (80%, 68, 88), on the average live weight by 6 (10%, 5, 20) and on individual body weights by 6.

History of testing for drench resistance in cattle and sheep

Few farmers had tested for drench resistance in cattle. Three farmers had tested cattle, one in about 1993, one in 1995 and the other in 1999. Resistance to benzimidazole was found at two properties (specified as *Cooperia* resistance on one). Albendazole had a 96% efficacy on the farm where no resistance was found.

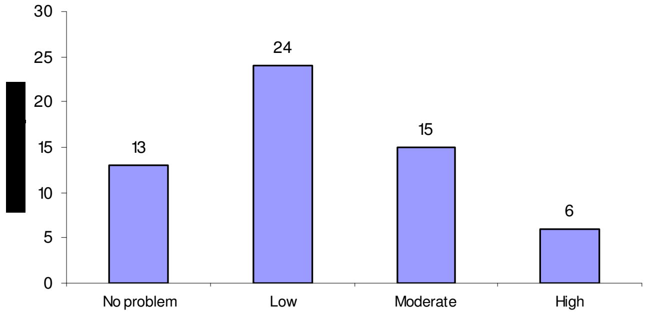
Resistance in sheep tests had been conducted on 16 farms (27%, 17, 40), and repeated twice in subsequent years on 5 (8%, 4, 18) and thrice on 3 farms (5%, 2, 14).

Farmer perceptions

In the Farmer Opinion section of the questionnaire, farmers were asked several questions regarding their perception of the seriousness of drench resistance, the length of time needed for infected pastures to become safe, the three most important disease or production limiting factors for cattle finishing operations, and how they rated 15 questions about management techniques for prevention of drench resistance.

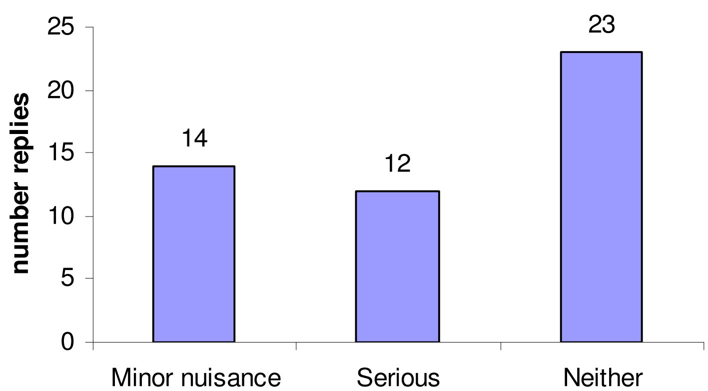
The distribution of 58 responses for how farmers rated drench resistance as a cattle animal health problem on their farms is shown in Figure 6. There was no statistical association between farm benzimidazole resistance status and how drench resistance as an animal health problem was categorised by farmers.

Figure 6. Distribution of 58 responses as to how farmers rated drench resistance categorised as no, low, moderate or high problem as a cattle animal health problem on their farms



The distribution of 49 responses for how farmers rated drench resistance as a sheep animal health problem on their farms is shown in Figure 7.

Figure 7. Distribution of 49 responses for how farmers rated drench resistance categorised as a minor nuisance, a serious problem, or neither a minor nuisance or a serious sheep animal health problem on their farms



The distribution of the responses to the Question 10.3 “Do you believe drench resistance is a problem for the cattle industry?” is shown in Table 13.

Table 13. Distribution of the responses to the Question “Do you believe drench resistance is a problem for the cattle industry?”

Answers	n	Frequency% (95% CIs)
Did not answer	4	7 (3, 16)
Don’t know	3	5 (2, 14)
No it is unlikely it will ever be a problem	2	3 (1, 12)
Not yet but will be in the next 10 years	3	5 (2, 14)
Not yet but will be in the next 5 years	7	12 (6, 23)
Yes it is a problem now but not a serious one	23	39 (28, 52)
Yes it is a serious problem now	17	29 (19, 41)
Total	**59**	

The distribution of the responses to the Question 10.4 “Do you believe drench resistance is a problem for the sheep industry?” is shown in Table 14. The distributions of the responses to the same questions for sheep and cattle are similar but there was a perception of drench resistance in sheep being a more serious problem at the present time.

Table 14. Distribution of the responses to the Question "Do you believe drench resistance is a problem for the sheep industry?"

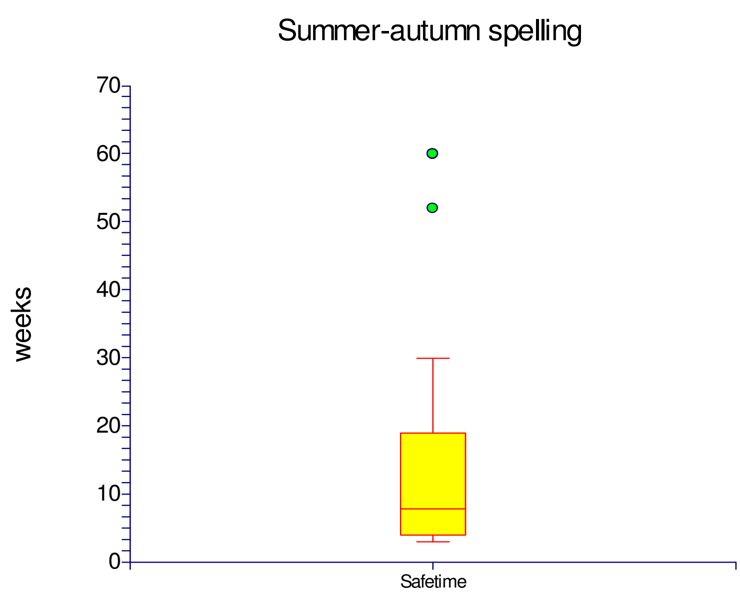
Answers	n	Frequency% (95% CIs)
Did not answer	6	10 (5, 20)
Don't know	1	2 (0, 9)
No it is unlikely it will ever be a problem	2	3 (1, 12)
Not yet but will be in the next 10 years	1	2 (0, 9)
Not yet but will be in the next 5 years	4	7 (3, 16)
Yes it is a problem now but not a serious one	14	24 (15, 36)
Yes it is a serious problem now	31	53 (40, 65)
Total	**59**	

The distribution of the number of weeks that farmers considered a grass pasture needs to be spelled over the summer-autumn period before it becomes "safe" is shown in Table 15 and displayed in a box plot in Figure 21. Of the 53 responses, 10 were "never" and for convenience of presentation these are shown as 60-week mild outliers ( ) in the Figure 8 box plot.

Table 15. Distribution of farmer responses for number of weeks a grass pasture needs to be spelled over the summer-autumn period before it becomes "safe"

Weeks to become safe	Number of responses	Frequency% (95% CIs)
3	4	8 (3, 18)
4	12	23 (13, 36)
5	1	2 (0, 10)
6_10	12	23 (13, 36)
>10	24	45 (33, 59)
Total	**53**	

Figure 8. Distribution of the number of weeks that farmers considered a grass pasture must be spelled in the summer-autumn period before it becomes "safe"



Farmers were asked to rank on a scale of 1 to 3, with 1 indicating the most important, the three most important disease or production limiting factors for cattle rearing and finishing operations. The results for this question plus an overall score for each item where Ranks 1, 2 and 3 were weighted 3, 2 and 1 points respectively are shown in Table 16. The table clearly demonstrates that farmers rated feed quality and quantity, and parasites as the most important diseases or production limiting factors affecting their enterprises with lower concerns shown for management factors and disease.

Table 16. Ranks and an overall score for disease or production limiting factors nominated by farmers as affecting their cattle rearing and finishing enterprises

Disease or production limiting factors	Rank 1	Rank 2	Rank 3	Score
Did not answer	7	10	17	58
Feed and water			Total	112
Feed quality and quantity	24	15	6	108
Feed and water	1			3
Water quality and supply			1	1
Parasites			Total	119
Worms	15	20	5	90
Worms and flukes	1			3
Ostertagia	3	1		11
Cooperia	1	1	1	6
Liver fluke	1		1	4
Internal and external parasites	1	1		5
External parasites		1	1	3
Management			Total	21
Behaviour problems		1	2	4
Stocking rates		1	1	3
Management			2	2
Import with purchased cattle	1			3
Breed/genetics of stock			3	3
Adequate colostrum	1			3
No effective drench program			1	1
Pugging winter damage		1		2
Disease			Total	36
Bvd	1		1	4
Facial eczema	1	1	5	10
Endophytes and fungal toxins			1	1
Bloat			1	1
Pink eye			1	1
Unexplained deaths			1	1
Woody tongue			1	1
Respiratory disease		1		2
Copper	1	1	2	7
Cobalt		1		2
Mineral deficiencies		2	4	8
Production limiting e.g. abortion		1		2
Total	**51**	**48**	**41**	

In Question 11 farmers were asked to nominate and rank from a table of listed methods the three management methods practised on their farm which they considered the most important for preventing or controlling drench resistance. They were also asked to indicate any of the listed methods that they considered were useless. The results are shown in Table 17 with an overall score calculated for each item by weighting Ranks 1, 2 and 3 with 3, 2 and 1 points respectively.

Table 17. Ranks and an overall score for methods used by individual farmers for prevention or control of drench resistance in cattle

Methods used by individual farmers for prevention or control of drench resistance in cattle (Question 11)	**Rank 1**	**Rank 2**	**Rank 3**	**Score**	**Useless**
Change drug action families frequently	12	2	1	41	14
Change drug action families regularly each year or every second year	12	2	1	41	11
Treat regularly every 4 to 6 weeks to keep worm populations suppressed	36	18	3	147	9
Treat only when faecal egg counts indicate a problem	3	0	0	9	6
Treat only when cattle are not doing well or are scouring	12	6	2	50	10
Use combination drugs	3	10	4	33	1
Use generous doses of drench	6	4	2	28	7
Use sheep in the grazing rotation to clean up pastures	18	20	5	99	2
Follow young cattle with older animals or sheep as part of the grazing strategy	9	4	11	46	2
Integrate crop or hay/silage making with grazing management	0	6	3	15	2
Operate an all-in all-out system for bull beef or traditional beef	0	0	2	2	5
Use quarantine treatment when buying in new batches of animals	24	8	5	93	0
Use feed budgeting to keep animals growing to their potential	3	14	4	41	2
Follow advice of veterinarians and advisors	6	8	2	36	0
Pasture renewal and/or cropping as part of the grazing feeding system	3	2	4	17	2

Score = (Rank 1*3)+(Rank 2*2)+(Rank 3*1)

Tests for associations between management practices and inefficacy

The data were first tested for associations between <90% inefficacy to ivermectin calculated with the Presidente formula. All independent variables identified with p values <0.2 were tested in a multivariable logistic regression model but no statistically robust and biologically plausible model could be constructed. This outcome was not surprising given the high prevalence of ivermectin inefficacy (50 of 61 farms exhibited inefficacy) and the relatively few farms in the 59 farm questionnaire dataset.

The analysis was repeated using <75% efficacy to ivermectin (about median efficacy) and the results of the univariate analyses are shown in Appendix 1. However, once again no credible model could be constructed.

The results of the univariate analyses for factors associated with inefficacy to albendazole at <90% level calculated with the Presidente formula are shown in Appendix II. Inefficacy to albendazole was found in 37 of 62 farms. Management data were available for 59 farms and the multivariable logistic regression analysis dealt with 33 case and 24 non-case farms due to missing data for 2 farms. The results of that analysis are shown in Table 18.

Table 18. **Estimates of β coefficients (Coeff), standard errors (se), standard deviations (sd), P-values and Odds Ratios (OR) with 95% confidence intervals in brackets for farm management and animal factors influencing occurrence of inefficacy to albendazole at <90% level**

Variables	Coeff	se	sd	P-value	OR (95% CIs)
CONSTANT	1.91315	1.03404		0.06	
B12	-1.77802	0.98149		0.07	0.17 (0.02, 1.16)
B23	-1.0804	1.16791		0.35	0.34 (0.03, 3.35)
G34	-1.80702	1.06045		0.09	0.16 (0.02, 1.31)
BCH	-0.01007	0.0041	138.39	0.01	0.25 (0.08, 0.75)
R1S	0.00769	0.00365	182.99	0.04	4.08 (1.1, 15.12)

Deviance = 58.48
P-value = 0.28
Df = 53

This model suggests that the risk of inefficacy to albendazole was reduced on farms where between ¼ and ½ (B12) or greater than 3/4 (G34) of the farm are grazed by cattle <12 months old compared to farms where less than ¼ of the farm is similarly grazed. The risk of inefficacy increases as the number of R1s (R1S) held at about June 30th in the current year increases and decreases as the number of breeding beef cows and heifers >2 years (BCH) on the farm at that time increases. The Odds Ratios shown for the continuous variables (BCH and R1s) in this table indicate the size of the effect for an increase in one standard deviation for those variables. However the dataset is small and the associations are best described in general terms rather than with absolute values.

If the 95% confidence intervals do not include 1, then that is analogous to saying there is less than a 1 in 20 chance (probability < = 0.05) that the effect is due to chance alone.

Farm enterprise type

Before undertaking this study it was hypothesised that intensive bull beef farming systems were more likely to be associated with the development of anthelmintic resistance than traditional beef rearing properties on which weaner steers or bulls were retained for rearing rather than being sold as weaners. However, the study farms did not fall neatly into two enterprise types since some farms reared both dairy and traditional beef farm sourced animals. A further complication was purchase of rising 2 year old (R2) animals by some farms. Data were available for 57 study farms and their distribution by type and purchase of R2 animals is shown in Table 19.

Table 19. **Breakdown of 57 study farms by enterprise type and R2 purchasing behaviour**

Enterprise type	Number of farms	R2 purchasing
Traditional beef only	11	0
Dairy source only	19	3
Mixture of traditional beef and dairy	27	9
Total	**57**	**12**

The distribution of FECRT efficacies according to enterprise type for ivermectin, albendazole and levamisole are shown in Figures 9 to 11. The Y axis scale of 60 to 100% for levamisole in Figure 11 should be noted when interpreting that figure. There was no statistically significant association found in logistic regression models between enterprise type, R2 purchase behaviour and efficacy to any of the anthelmintics, where <90% efficacy was the dependent variable.

Figure 9. Box plots of efficacy % for ivermectin on farms that only rear calves sourced from dairy farms (Dairy only), traditional beef farms (Beef only), and farms that rear calves from both sources (Mix dairy beef)

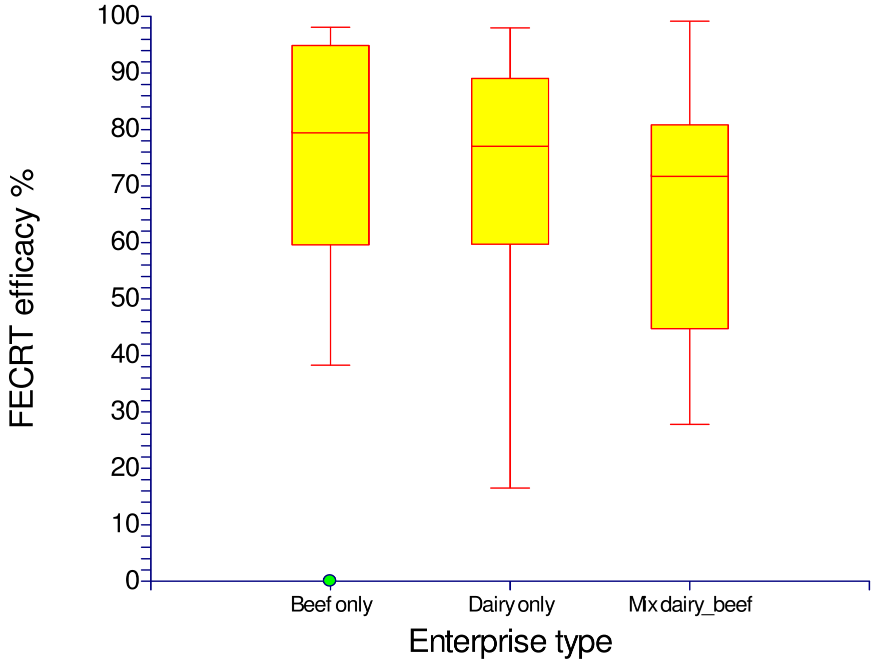


Figure 10. Box plots of efficacy % for albendazole on farms that only rear calves sourced from dairy farms (Dairy only), traditional beef farms (Beef only), and farms that rear calves from both sources (Mix dairy beef)

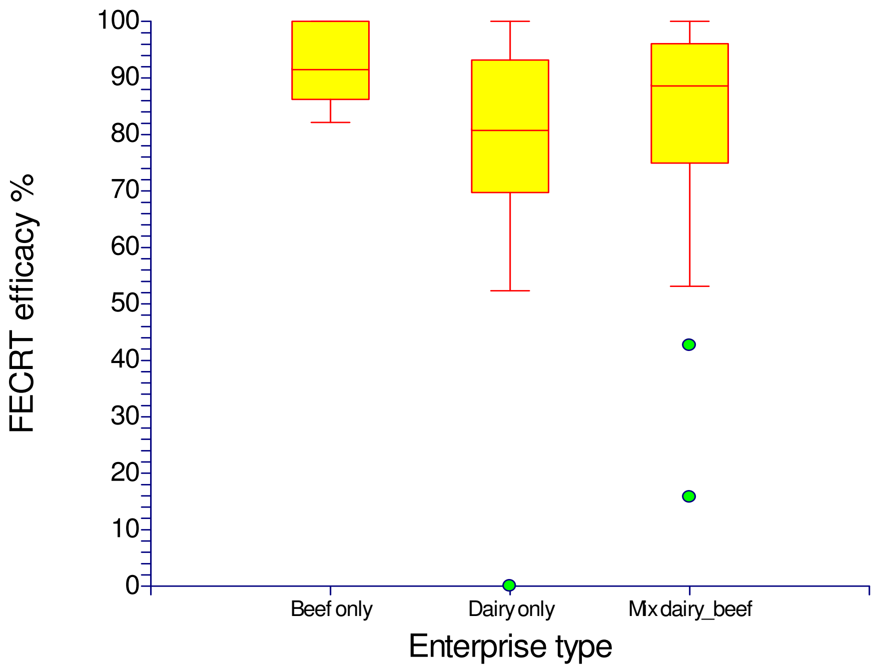
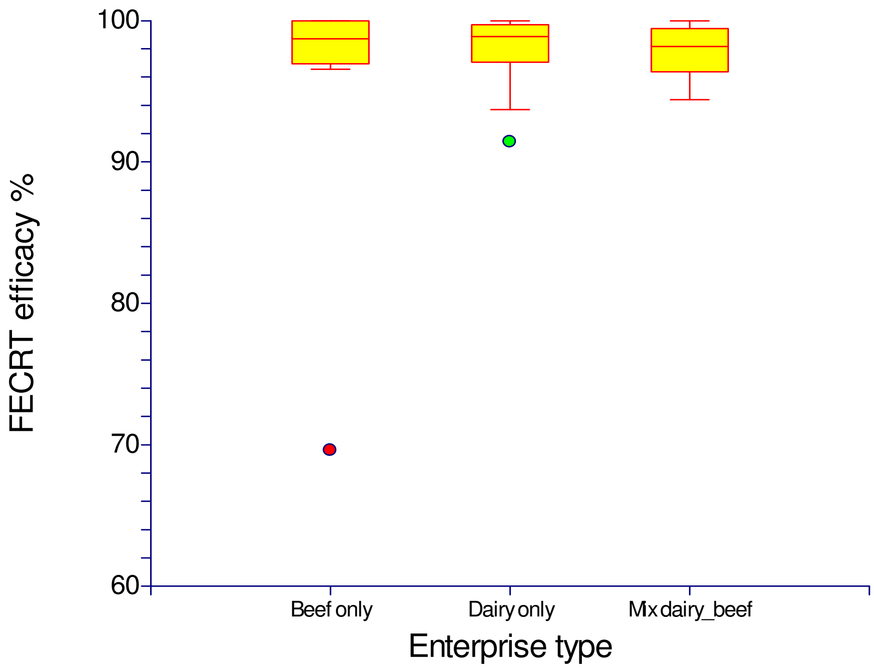


Figure 11. Box plots of efficacy % for levamisole on farms that only rear calves sourced from dairy farms (Dairy only), traditional beef farms (Beef only), and farms that rear calves from both sources (Mix dairy beef)



There were five farms where the FECRT showed >95% efficacy to ivermectin. Summary case details for these farms are presented here for interest.

Summary profiles of five farms with >95% efficacy to ivermectin

Farm I. Long established buying pattern of about 170 four-day-old dairy calves and sells when they are about 30 months of age. No other livestock. Has only used levamisole for the past 5 years and treats about nine times. Efficacy >95% for all anthelmintics tested. Cooperia and *Ostertagia* present at >25 epg in the control sample.

Farm II. Weans about 140 traditional six-month-old beef calves, buys in about 50 more in February-March and sells when they are about 23 months of age. Mates about 160 beef cows and 1400 ewes. Gives 3 drenches per year: this year doramectin injection and albendazole and levamisole combination, previous four years albendazole and levamisole combination, and ivermectin plus chlorsulon injection. Efficacy >95% for all anthelmintics tested. Cooperia and *Ostertagia* present at >25 epg in the control sample.

Farm III. Weans about 300 traditional six to seven-month-old beef calves, buys about 20 four-day-old dairy calves and sells when they are about 10 months of age. Mates about 350 beef cows and 4,500 ewes. Treats 3 times between weaning and selling with avermectin pour on. Efficacy >95% for all anthelmintics tested. Cooperia present at >25 epg in the control sample.

Farm IV. Weans about 60 traditional eight-month-old beef calves, buys about 20 four-day-old dairy calves and sells when they are about 24 to 30 months of age. Mates about 65 beef cows and 1,000 ewes. Treats once with a benzimidazole. Efficacy >95% for all anthelmintics tested. Cooperia, *Ostertagia* and *Trichostrongylus* present at >25 epg in the control sample.

Farm V. Weans about 400 traditional seven-month-old beef calves and sells when they are about 16 to 22 months of age. Mates about 400 beef cows and 1,200 ewes. Treats twice with doramectin injection and once with a benzimidazole. Efficacy >95% for all ivermectin and levamisole tested. Cooperia, *Ostertagia* and *Trichostrongylus* present at >25 epg in the control sample.

Discussion and Conclusions

This study provides an overview of current farmer opinions and farming practices thought to be related to development of drench resistance, and tested for statistical associations between anthelmintic resistance and management practices.

The companion paper "Prevalence of anthelmintic resistance on beef rearing farms in the North Island of New Zealand" reported a high prevalence of anthelmintic resistance on beef rearing enterprises with 57 of 62 study farms showing <95% efficacy to ivermectin, 47 to albendazole and 5 to levamisole. Larval tests indicated high failure rates for ivermectin and albendazole with respect to *Cooperia* spp. *Ostertagia* resistance to Ivermectin was diagnosed on 6 of 42 farms tested and to albendazole on 16 of 35. *Trichostrongylus* resistance to ivermectin was diagnosed on 2 of 19 farms tested and to albendazole on 3 of 15. The study focused on *Ostertagia, Cooperia* and *Trichostrongylus* since they are generally considered to be the most important nematode genera and *O. ostertagi, C. oncophora and T. axei* the most important species for New Zealand cattle (Brunsdon 1964).

It was intended that at either of the two visits to the farm the veterinarian would interview the farmer and complete the questionnaire examining parasite and farm management practices. Although the questionnaires were designed to be administered as interviews by contracted veterinarians, only 37 of the questionnaires appeared to be interview based and the remainder (22) were apparently filled in by farmers. This failure to follow the set protocols may have adversely influenced the quality of data, such as names of anthelmintics, which were often reported with no indication as to whether they were injectable, topical or oral preparations.

Most farmers ranked parasites highly, and at about the same level as feed quality and quantity, as important production limiting factors for their enterprises, although the high score for parasites may have been influenced by the strong focus on parasites in the questionnaire. This contrasts with drench resistance which was not perceived to be an animal health problem on 13 farms, and was rated low importance on 24, moderate on 15, and high on six. There was no association between farm benzimidazole resistance status and how drench resistance as an animal health problem was categorised by farmers but the data set was too small to allow any definite conclusions to be drawn on that point.

Important considerations for anthelmintic resistance studies involving FECRT's are how precise the test is, and how well it is associated with efficacy levels, parasite burdens, and effects on the host. The test only measures effects on egg production by mature worms and egg output does not correlate well with actual worm numbers in cattle.

Insights into the dynamics of intestinal nematode infections of young cattle were provided by studies in the late 1960's and early 1970's (Brunsdon 1968; Brunsdon 1969; Brunsdon 1971; Brunsdon 1972) which were reviewed by Bisset (Bisset 1994) and summarised by Charleston (Charleston 1994). These studies were conducted in the lower part of the North Island and while it is not known how closely they reflect patterns in other climatic and agro-pastoral regions of the country, they are considered generally useful for wider application and inference. In New Zealand most beef calves are born in spring and are infected with larvae that have over-wintered. Re-infection with second generation larvae result in higher levels of parasitism with major pasture infestations by late autumn. Egg production and counts, particularly for *Ostertagia*, tend to fall about this time even though worm burdens may be high and increasing. Numbers of mature *Ostertagia* and *Cooperia* peak in the first winter and by 12 to 14 months of age there is usually a high level of immunity developed to *Cooperia*. Numbers of *Ostertagia* fall around 12 to 15 months of age but inhibited larvae may persist in the yearlings. Numbers of *T. axei* are generally greatest at about 12 to 15 months of age at which time pasture contamination with this species from cattle is greatest. Cattle at 18 to 20 months of age should have well developed immunity to *Ostertagia, Cooperia* and *Trichostrongylus* but maintenance of low levels of susceptible populations in adults may be hindered by overzealous control with anthelmintics prior to this time. The capacity for adult cattle to tolerate low levels of parasitism means they can maintain an epidemiologically important *refugia* of susceptible parasites, and also reduce larval levels on pasture in mixed age grazing systems. Ostertagia is considered the most pathogenic of the three genera, but the effects of *Trichostrongylus* and *Cooperia* on young cattle are poorly understood. Debates about the effect of *Cooperia oncophora* in natural infections of cattle in the New Zealand environment are common, but are generally unproductive due to the limited amount of available information, which on balance appears to indicate some pathogenicity (Pomroy 1999) (Familton 2001). It would seem an area of high priority for investigation, given the high prevalence of *Cooperia* resistance to ivermectin and albendazole and the widespread and common occurrence of the parasite.

Interpretation of faecal egg counts in cattle is made very difficult due to mixed populations of adult and immature worms of the three main genera which vary naturally over time and in response to treatment. It is further complicated by varying rates of egg production over time. Efficacy cut-off points of 90% or 95% employed in FECRTs have no quantitative meaning with regard to numbers of worms or proportions of populations that survive treatment but can be useful for indicating a developing or established problem.

Some comfort may be taken from an absence of case reports of clinical parasitism in cattle in New Zealand where the effect of resistant nematodes has been quantified. Farmers in this study were generally aware of anthelmintic resistance in cattle but did not express high levels of concern or see it as a major problem. Only three farmers had tested for anthelmintic resistance in cattle. There was more concern and awareness about the importance of anthelmintic resistance in sheep flocks and 16 farmers had tested for this. The relative complacency about cattle may be due to use of long acting anthelmintics that may mask adverse effects in the face of developing or established resistance, or a more simple explanation might be that the well known link between a perceived effect and expectation of an effect after an intervention may be operating among farmers. An interesting observation was that despite all farmers having a planned programme, there was still heavy reliance on signs of parasitism such as scouring or dirty hocks, and poor growth rates or condition scores, and intuitive ‘gut feeling’ for deciding when to treat for internal parasites.

Scales were used routinely by about 75% of farmers but the survey did not enquire as to whether growth rates were routinely calculated and used as an indicator of when to treat. The median number of treatments given between September and March was two and between April and September was three, but the range of 0 to six for both periods indicated wide variation in the frequency of treatments. The proportion of the anthelmintics with extended action that were employed is not known but given the ease of application of pour-on and injectable products and their predominance in the anthelmintic market, their usage was probably substantial. Macrocyclic-lactones were the treatments of choice in July to September and April to June but there was comparable use of oral combination products during October to March when cattle are small and amenable to oral drenching. The median number of treatments administered to young cattle from September to September was five and ranged from one to 12. The wide range partly reflects the differences in age of entry on to the farm with some farms only rearing animals either purchased or weaned at about four to six months of age. However, regardless of the effect that age of entry to a farm might have on the overall number of treatments, the high frequency of treatments (eight to 12) on one in four farms would be expected to produce a correspondingly high pressure for selection of resistant parasites.

Reliable information about frequency of drenching of traditional beef cattle has not been available until now. The number of treatments generally recommended for beef calves in the 1970’s was two or three treatments at six to eight-week intervals starting at weaning with a further treatment in the spring recommended to account for development of *Ostertagia* about that time(McMullan 1973; Charleston 1994). Later usage was probably greatly influenced by studies in traditional beef cattle that showed economic advantages for four to six treatments starting at weaning and repeated at six-week intervals under grazing conditions that produced clinical parasitism in animals treated only once at weaning (McPherson, Cairns et al. 1989; McPherson, Bowie et al. 1997). The increasing uses of Friesian beef bulls sourced from the dairy industry and reared under intensive single species grazing systems has further increased anthelmintic usage.

This study revealed some interesting behaviour with regard to treatment of older animals with about one in three farmers with beef breeder cows routinely treating their calves at calf marking time (normally done at about six to eight weeks of age), one in five treating mixed age cows, and almost half treating rising two year-olds before calving. Calves were treated at least once by the time they were nine to ten weeks old on 12 of the 38 farms that reared dairy sourced calves. This early-life drenching policy suggests management practices that rely heavily on anthelmintic use for dairy sourced calves. It is also possible that it is more related to convenience at weaning time or quarantine management than an epidemiological need to reduce an established worm population. New Zealand (Charleston 1994) and overseas literature (Coles 2002; Coles 2003) does not support routine treatment of traditional beef calves at marking, or older animals except in cases of clinical ostertagiosis. It may be that use of 'endectocides' in older animals is part of routine annual endoparasite control but the study did not seek clarification on that point. Nevertheless, in cow-calf enterprises a large part of pasture contamination comes from adult cattle and it has been suggested worms in *refugia* in non-treated older animals play an important part in delaying the development of resistance (Stafford and Coles 1999; Coles 2003).

Macrocyclic-lactone anthelmintics or their combinations with other action families were currently and for the past five years used more than benzimidazoles and levamisole and benzimidazole-levamisole combinations. All but four farms had used macrocyclic-lactones at some time during the past five years. The study did not enquire as to reasons for use of particular action families but six of the 25 farmers who indicated they had changed families in year of the study did so because they were concerned that the drugs were not working. Only four farmers were changing action families as part of a deliberate drench rotation program, suggesting poor use of that strategy which has been sometimes promoted as a method for delaying onset of resistance. It was interesting that 24 farmers ranked annual or frequent action family changes as the most important strategies for prevention or control of drench resistance in cattle while 25 other farmers considered them to be useless for that purpose. Treating regularly every four to six weeks to keep worm populations suppressed was given the highest ranking as a strategy for prevention or control of resistance. Other practices that ranked high were quarantine drenching, incorporating sheep or older cattle in the grazing management and treating only when cattle were showing signs of parasitism. However, opinions were divided on the value of almost all methods, and markedly so for treating in response to onset of clinical signs or poor thrift, using generous doses of drench, regular treatments every four to six weeks, and changing action families. Speculation here about the reasons for the divided opinions on many issues is not likely to be productive. The important finding is simply that opinions were divided on many issues.

Most farmers checked the integrity of the seals in their drench applicators before use but about one in four placed complete reliance on the applicator being accurate, and about half checked its accuracy occasionally. On the other hand, the importance of giving the required dose was acknowledged by the 80 per cent of farmers who based the dose rate on the heaviest animal in the group, and the 75 per cent who routinely weighed their cattle.

There was no clear pattern of behaviour regarding placement of cattle after anthelmintic treatment. Only about one in three farmers never returned cattle to the same paddock after treatment. Most of the others did so occasionally, and there were strong indications that pastures previously grazed by another class of stock, or by calves, were preferred. New pasture and crop were seldom used for placement after treatment but opportunities to use them were probably limited by the relatively small areas of crop and new pasture available. The response to how long a grass pasture needs to be spelled over the summer-autumn period before it becomes "safe" elicited a wide range of periods varying from three weeks to never, and indicated a poor understanding of survival of parasites on pasture.

Most farmers shifted their beef calves in their first summer-autumn period after weaning every two to ten days and most followed the same routing during the first autumn-winter period. Daily shifts were uncommon and set-stocking was rare. About two thirds of farmers integrated their young cattle's grazing with sheep or older cattle. Of that two thirds, about one half endeavoured to follow a definite program all the time, while the other half used integrated grazing only when circumstances permitted.

The responses to questions about the time between grazing with cattle and previous grazing by sheep or cattle older than one year are difficult to interpret because decisions on when to graze a paddock are more likely to have been influenced by pasture growth and quality and circumstances at the time rather than parasite control. However, co-grazing with other species was clearly shown to be an uncommon practice, while follow-on grazing within three months after older cattle or sheep was common. The study showed that for most farms, cattle grazing was restricted to part of the farm. This finding has implications for parasite control and persistence of larvae in *refugia*, particularly if the same part of the farm is used for cattle production year after year. Under those conditions, pasture larval challenge would be expected to be higher and generation turnover more rapid than under more extensive conditions where larval challenge would be generally lower due to the diluting effect of a larger area and the potentially advantageous effect of grazing other stock species and classes.

A stated objective for this cross-sectional study was to test for associations between farm anthelmintic resistance status and management practices. This objective was expected to develop hypotheses for future testing, and it was not intended to identify causal links between management practices and development of resistance. Longitudinal epidemiological studies of at least three to five years' duration would be required for identification of risk factors for development of anthelmintic resistance, although surprisingly, none have as yet been undertaken. Inference from cross-sectional studies can be hindered by recollection bias but more importantly here by an absence of any indication of the time that resistance first developed on individual farms. For the study farms, resistance may have developed recently or it may have been long-standing.

Univariate and multivariate analyses were conducted as part of the stated objectives and for the convenience of readers, some explanation of the results is given in the materials and methods section of the paper. No credible multivariate models could be constructed where the outcomes were less than 90 per cent or less than 75 per cent efficacy for ivermectin. The model for resistance to albendazole indicated that the risk of inefficacy to albendazole was reduced on farms where between one quarter and one half or greater than three quarters of the farm was grazed by cattle less than 12 months-old compared to farms where less than one quarter of the farm was similarly grazed. The risk of inefficacy increased as the number of rising one year-old cattle held at about June 30th in the current year increased and decreased as the number of breeding beef cows and heifers over two years-old on the farm at that time increased.

In general terms, this indicates that the risk of resistance was greatest for farms where only one quarter of the farm was grazed by cattle and implies that the risk is greater when cattle grazing is restricted to a relatively small part of a farm. Restricted grazing would be expected to lead to a higher concentration of infective larvae and more severe challenge than would occur with more expansive grazing and dilution of pasture contamination.

A crowding effect and a higher risk with increased population-at-risk size are predictable effects for infectious diseases. A decrease in risk as the number of adult cattle increases is compatible with theoretical concepts of the importance of adult animals for their value for reducing the infectivity of pastures and maintaining low levels of parasitism with susceptible parasites in *refugia*.

The questionnaire did not enquire about quarantine treatment of purchased animals. This was unfortunate since purchase behaviour is a serious consideration for entry of any infectious disease and resistant parasites are likely to be transmitted among farms with purchased animals. More information about the risk associated with buying is needed, not only to identify risky practices, but also to identify sources of animals that do not carry infective burdens of resistant parasites. In this regard, four day-old dairy calves have negligible risk whereas weaned dairy calves reared under intensive conditions might constitute a high risk. The situation for traditional beef weaner calves should be given priority for investigation. The theoretical risk for resistance is low on cow-calf enterprises but a better appreciation of the level of risk would assist beef rearing enterprises in deciding safer sources of weaners. It could also give useful information for restocking if spelling of beef rearing farms was introduced to combat resistance which cannot be controlled by other means.

Spelling is an important control mechanism for infectious diseases where environmental sources of infection can be reduced to negligible levels through depopulation for a short time. Its uptake for anthelmintic resistance would depend on the duration of survival of resistant larvae, the importance of cross infection from sheep, and demonstration of economic and disease control benefits.

It was suggested long ago (Michel 1968),, albeit for UK conditions, that a single change of pasture accompanied by one effective anthelmintic treatment would adequately control parasitic gastro-enteritis and permit the achievement of linear liveweight gains throughout the season. Systems for dairy cattle based on grazing calves ahead of adult cattle (Ruakura system), or placing a few calves in each of the paddocks used in rotation for adults and moving the calves around, are claimed to give good parasite control. However, information about the efficacy of these and other programs for controlling parasitism and the development of resistance is lacking. The five farms where the FECRT showed >95% efficacy to ivermectin have interesting features but are too few to draw any conclusions about the reasons for their anthelmintic resistance status.

The authors of a review of anthelmintic resistance in New Zealand (Leathwick, Pomroy et al. 2001) listed several key points that are highly relevant to any discussion of development of resistance in cattle. Widespread resistance to all existing broad-spectrum anthelmintic chemical classes is an inevitable consequence of current drenching practices. Anthelmintic treatments applied to animals with a high level of immunity, or which become immune while the anthelmintic is active, are likely to select for resistance faster than treatments applied to non-immune stock. However, it seems clear that in practice, resistance is a secondary consideration behind achieving productivity advantages from the use of anthelmintics. Good management decisions are based on good data and it is unfortunate that there is very little quantitative information available on the economic impact of resistance and its effects on productivity to help guide decision making. It seems that the incidence and severity of resistance in cattle will continue to rise. The challenge for intensive beef rearing enterprises with regard to control of nematodes was summed up by the statement “it is difficult to see how dairy beef farming can be a sustainable farming system in the medium to long term unless new nematode control systems are developed” (Pomroy 1999).

The overall outlook for anthelmintic resistance in cattle is bleak unless the need for integrated and long-term research activities is acted upon soon.

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The farmers who were initially contacted by phone and who agreed to participate in the survey must be acknowledged for their willingness to support an initiative that has established important benchmarks for the whole industry. These farmers worked through the inconvenience of screening sampling as well as the management inconvenience of testing through what were, at times, challenging climatic conditions.

AgriQuality provided a random selection of farms for initial contact from AgriBase.

The staff at AgResearch, Palmerston North, planned and undertook the tasks of creating, managing and receiving all the kits and samples. They undertook all the faecal egg counting, and in conjunction with staff from Massey University carried out all the larval counts. In addition, AgResearch completed all sample and initial data analysis.

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Appendix I Univariate analysis – outcome of interest <75% efficacy for ivermectin

Independent variables	n	n=1	n=0	O R (95% CIs)	P
Beef cows & heifers (breeding) 2yrs & over4.1	58			0.8 (0.46, 1.39)	0.02
Beef cows & heifers (breeding) 1-2yrs old	58			0.83 (0.46, 1.5)	0.02
Beef cows & heifers (not for breeding) 2yrs & over	58			1.83 (0.73, 4.61)	0.03
Beef cows & heifers (not for breeding) 1-2yrs old	58			0.48 (0.2, 1.16)	0.04
Beef heifers (rising 1 year old) and calves	58			0.77 (0.44, 1.35)	0.02
Steers 2 yrs old and over	58			0.92 (0.54, 1.57)	0.02
Steers 1-2 yrs old	58			0.73 (0.38, 1.43)	0.02
Steers (under 1 year)	58			0.64 (0.3, 1.38)	0.03
Beef non-breeding bulls 2yrs & over (R3)	58			1.11 (0.65, 1.89)	0.02
Beef non-breeding bulls 1-2yrs old (R2)	58			1.1 (0.65, 1.84)	0.02
Beef non-breeding bulls (under 1 year) (R1)	58			1.28 (0.72, 2.26)	0.02
Beef breeding bulls (all ages)	58			1.05 (0.63, 1.77)	0.02
Dairy heifers (rising 1 year) and heifer calves 4.13	58			1.16 (0.67, 1.98)	0.02
Dairy cows & heifers (over 1 year) in milk or in calf	58			0.92 (0.53, 1.58)	0.02
Dairy cows & heifers (over 1 year) not in milk or in calf	58			0.91 (0.52, 1.58)	0.02
Ewes (2 th and over) put to Ram (Dec-May 2004) 4.18	58			0.87 (0.5, 1.51)	0.02
Ewe Hoggets	58			0.81 (0.46, 1.42)	0.02
Ram and wether hoggets	58			0.75 (0.41, 1.38)	0.02
Rams (2 tooth and over)	58			1.01 (0.6, 1.68)	0.03
Wethers (2 tooth and over)	58			2.34 (0.39, 14.14)	0.02
Deer over 1 year (Q 4.23)	58			0.93 (0.55, 1.58)	0.03
Deer under 1 year	58			0.67 (0.32, 1.43)	0.02
Beef area ha (Q 1.2)	53			1.14 (0.66, 1.95)	0.02
Total area ha (Q 1)	56			0.9 (0.53, 1.54)	0.02
Sheep and beef area ha (Q 1)	55			0.89 (0.51, 1.55)	0.02
Traditional beef animals +	41	20	21		1.0
Traditional beef animals -	15	6	9		
Traditional beef animals 0	2	0	2		
Dairy animals +	13	5	8		1.0
Dairy animals -	43	21	22		
Dairy animals 0	2	0	2		
Feed budget (Yes/No) (Q 3.1)	58	9	49		1.0
Mainly flat to rolling downlands (Q 2.1)	19	11	8		0.02
Mainly moderate to steep hill country	22	9	13		
More a mixture of both flat and hill country (reference)	17	6	11		
Bbatch (#batches) (Q 6.1)	56			0.87 (0.51, 1.48)	0.02
Dbatch (#batches) (Q 5.2)	56			1.27 (0.75, 2.17)	0.02
Bbuy (#beef animals reared) (Q 6.1)	56			0.53 (0.25, 1.12)	0.04

Independent variables	n	n=1	n=0	O R (95% CIs)	P
Dbuy (#dairy animals reared) (Q 5.2)	56			1.73 (0.86, 3.46)	0.03
Bobage (bought as bobby calves) (Q 5.1) +	16	7	9		
Bobage (bought as bobby calves) (Q 5.1) -	42	19	23		
Weanage (introduced as weaned calves) (Q 5.1) +	29	14	15		
Weanage (introduced as weaned calves) (Q 5.1) -	29	12	17		
Months (#months animals were sold over) (Q 7.3)	43			0.82 (0.44, 1.54)	0.05
Sellage (age most commonly sold at) (Q 7.1)	57			0.82 (0.48, 1.39)	0.02
1. Friesian (Q 7.5) +	34	16	18		0.97
1. Friesian (Q 7.5) -	24	10	14		
2. Dairy cross (e.g. Friesian Hereford cross) +	14	7	7		0.85
2. Dairy cross (e.g. Friesian Hereford cross) -	44	19	24		
3. Traditional straight bred beef (e.g. Angus, Hereford) +	9	4	5		1
3. Traditional straight bred beef (e.g. Angus, Hereford) -	49	22	27		
4. Traditional cross (e.g. Angus Hereford cross) +	13	3	10		0.65
4. Traditional cross (e.g. Angus Hereford cross) -	45	23	22		
5. Exotic cross (e.g. Hereford Charolais cross) +	17	5	12		0.73
5. Exotic cross (e.g. Hereford Charolais cross) -	41	21	20		
6. Exotic (e.g. Charolais, Simmental, Main Anjou) +	6	2	4		0.72
6. Exotic (e.g. Charolais, Simmental, Main Anjou) -	52	24	28		
Integrated (Q 8.4)	20	8	12		0.02
Non Integrated	8	5	3		
Random Integration (reference)	25	10	15		
CFRONT (Q 8.9) +	18	9	9		0.89
CFRONT (Q 8.9) -	40	17	23		
Never - grazing with other species between (Q 8.10)	7	3	4		0.01
Occasionally	30	12	18		
Always	5	2	3		
Often (reference)	12	7	5		
No response	4	2	2		
Between ¼ and ½ (Q 8.15) B12	17	7	10		0.02
Between ½ and ¾ B23	8	3	5		
>3/4 G34	16	6	10		
Less ¼ L1 (reference)	15	8	7		
No response	2	0	2		
Hay (Q 8.11) +	30	14	16		0.94
Hay (Q 8.11) -	28	12	16		
Renew (Q 8.13) +	28	15	13		0.02
Renew (Q 8.13) -	30	11	19		
Number of drenches from Sept to Marc (Q 9.5)	58			1.38 (0.81, 2.34)	0.02
Number of drenches from April to September (Q 9.6)	58			0.8 (0.47, 1.36)	0.02
Always (treated as Missing value) (Q 9.18)	1	0	1		0.05
Never	20	13	7		
Often	3	1	2		
Occasionally (reference)	34	11	23		
Number treatments to 1 to 2 year-old cattle (Q 9.20)	56			1.44 (0.84, 2.47)	0.03

P value = likelihood ratio p-value for continuous variables

The Odds Ratios shown for continuous variables in this table indicate the size of the effect for one standard deviation of the data for that variable.

Odds Ratios are a way of representing probability and are applied here to compare the odds of resistance between two groups, one group with, and the other group without the exposure factor. If the Odds Ratio is <1 then there is a sparing effect, if = 1 there is no effect and if >1 then there is a positive statistical association between the exposure factor and resistance.

	Resistance +	Resistance -
Exposure +	a	b
Exposure -	c	d

$$Odds\ Ratio = \frac{a/b}{c/d} = \frac{a \times d}{b \times c}$$

Appendix II Univariate analysis – outcome of interest <90% efficacy for Albendazole

Independent variables ALB	n	n = 1	n = 0	O R (95% CIs)	P
Beef cows & heifers (breeding) 2yrs & over (Q 4.1)	59			0.38 (0.18, 0.82)	0.09
Beef cows & heifers (breeding) 1-2yrs old	59			0.35 (0.13, 0.94)	0.06
Beef cows & heifers (not for breeding) 2yrs & over	59			1.82 (0.63, 5.22)	0.03
Beef cows & heifers (not for breeding) 1-2yrs old	59			0.71 (0.4, 1.28)	0.03
Beef heifers (rising 1 year old) and calves	59			0.47 (0.24, 0.91)	0.06
Steers 2 yrs old and over	59			1.01 (0.6, 1.7)	0.02
Steers 1-2 yrs old	59			0.2 (0.05, 0.8)	0.1
Steers (under 1 year)	59			0.41 (0.16, 1.07)	0.05
Beef non-breeding bulls 2yrs & over (R3)	59			2.55 (0.38, 17.3)	0.03
Beef non-breeding bulls 1-2yrs old (R2)	59			1.93 (0.96, 3.86)	0.05
Beef non-breeding bulls (under 1 year) (R1)	59			5.62 (1.63, 19.36)	0.14
Beef breeding bulls (all ages)	59			0.74 (0.4, 1.36)	0.03
Dairy heifers (rising 1 year) and heifer calves 4.13	59			2.09 (0.59, 7.34)	0.04
Dairy cows & heifers (over 1 year) in milk or in calf	59			5.32 (0, 8696.96)	0.03
Ewes (2 th and over) put to Ram (Dec-May 2004) 4.18	59			0.48 (0.21, 1.08)	0.05
Ewe Hoggets	59			0.58 (0.3, 1.12)	0.04
Rams (2 tooth and over)	59			0.48 (0.22, 1.04)	0.05
Wethers (2 tooth and over)	59			1.08 (0.62, 1.87)	0.02
Deer over 1 year (Q 4.23)	59			1.03 (0.61, 1.75)	0.02
Deer under 1 year	59			1.38 (0.68, 2.84)	0.03
Beef area ha (Q 1.2)	54			1.13 (0.65, 1.97)	0.04
Total area ha (Q 1)	57			0.6 (0.32, 1.13)	0.03
Sheep and beef area ha (Q 1)	56			0.5 (0.22, 1.15)	0.05
Traditional beef animals +	42	21	21	1 (1, 1)	1
Traditional beef animals -	15	12	3		
Traditional beef animals 0	2	1	1		
Dairy animals +	44	28	16	1 (1, 1)	0.8
Dairy animals -	13	5	8		
Dairy animals 0	2	1	1		
Feed budget (Yes/No) (Q 3.1) +	10	5	5	1 (1, 1)	1
Feed budget (Yes/No) (Q 3.1) -	49	29	20		
Mainly flat to rolling downlands (Q 2.1)	19	4	5		0.07
Mainly moderate to steep hill country	23	8	15		
More a mixture of both flat and hill country (reference)	17	12	5		

Independent variables ALB	n	n = 1	n = 0	O R (95% CIs)	P
Bbatch (#batches) (Q 6.1)	57			0.49 (0.26, 0.91)	0.07
Dbatch (#batches) (Q 5.2)	57			1.57 (0.87, 2.83)	0.04
Bbuy (#beef animals reared) (Q 6.1)	57			0.33 (0.13, 0.84)	0.1
Dbuy (#dairy animals reared) (Q 5.2.)	57			4.32 (1.58, 11.77)	0.15
Bobage (bought as bobby calves) (Q 5.1) +	17	9	8	1 (1, 1)	0.86
Bobage (bought as bobby calves) (Q 5.1) -	42	25	17		
Weanage (introduced as weaned calves) (Q 5.1) +	30	23	7	1 (1, 1)	1
Weanage (introduced as weaned calves) (Q 5.1) -	29	11	18		
Months (#months animals were sold over) (Q 7.3)	44			0.88 (0.48, 1.61)	0.03
Sellage (age most commonly sold at) (Q 7.1)	58			0.82 (0.48, 1.39)	0.02
1. Friesian (Q 7.5) +	35	25	10	1 (1, 1)	1
1. Friesian (Q 7.5) -	24	9	15		
2. Dairy cross (e.g. Friesian Hereford cross) +	15	9	6	1 (1, 1)	0.89
2. Dairy cross (e.g. Friesian Hereford cross) -	44	25	19		
3. Traditional straight bred beef (e.g. Angus, Hereford) +	10	4	6	1 (1, 1)	0.73
3. Traditional straight bred beef (e.g. Angus, Hereford) -	49	30	19		
4. Traditional cross (e.g. Angus Hereford cross) +	14	3	11	1 (1, 1)	0.6
4. Traditional cross (e.g. Angus Hereford cross) -	45	31	14		
5. Exotic cross (e.g. Hereford Charolais cross) +	18	9	9	1 (1, 1)	0.86
5. Exotic cross (e.g. Hereford Charolais cross) -	41	25	16		
6. Exotic (e.g. Charolais, Simmental, Main Anjou) +	7	4	3	1 (1, 1)	0.86
6. Exotic (e.g. Charolais, Simmental, Main Anjou) -	52	30	22		
Integrated (Q 8.4)	20	11	9		0.04
Non Integrated	8	5	3		
Random Integration (reference)	26	14	12		
CFRONT 8.9 +	19	11	8		0.91
CFRONT 8.9 -	40	23	17		
Never - grazing with other species in between (Q 8.10)	7	6	1		0.02
Occasionally	30	15	15		
Always	5	2	3		
Often (reference)	12	7	5		
No response	5	1	4		
Between ¼ and ½ B12 (Q 8.15)	18	10	8		0.06
Between ½ and ¾ B23	8	4	4		
>3/4 G34	16	9	7		
Less ¼ (reference) L1	15	9	6		
No response	2	0	2		

Independent variables ALB	n	n = 1	n = 0	O R (95% CIs)	P
Hay (Q 8.11) +	30	21	9		0.96
Hay (Q 8.11) -	29	13	16		
Renew (Q 8.13) +	28	20	8		1.0
Renew (Q 8.13) -	31	14	17		
Number of drenches from Sept to Marc 9.5h	59			1.59 (0.91, 2.76)	0.04
Number of drenches from April to September 9.6	59			0.95 (0.57, 1.6)	0.02
Always (treated as Missing value) 9.18	1	1	0		0.02
Never	21	13	8		
Often (treated as Missing value)	3	1	2		
Occasionally (reference)	34	19	15		
Number treatments to 1 to 2 year-old cattle 9.20	57			1.34 (0.78, 2.28)	0.03

P = Likelihood ratio P-value for continuous variables