Factors Influencing Direct Deposition of Cattle Faecal Material in Riparian Zones

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Executive Summary

Goal: To establish beef cattle defecation frequency and distribution on hill country in New Zealand and quantify the effects of a number of environmental factors. This information is likely to be used in a model to predict the effect of factors influencing stream water quality.

Context of the project: Livestock farming has been suggested to be one of the major causes of deterioration of riparian areas and water quality. Microbes and nutrients from manure enter streams by several potential pathways. One direct deposition from the animals as they drink, graze, or otherwise spend time in and along the stream. It has been suggested that the impact of defecation on aquatic ecosystems may be resolved by excluding stock from streams by fences. However, fencing would be economically prohibitive in the United States (Platts & Wagstaff, 1984) and in New Zealand (Bettjeman, 1997). There have been few studies on the effect of cattle defecation in streams under New Zealand farming conditions. The aims of this project were to establish beef cattle defecation frequency and distribution on hill country in New Zealand and quantify the effects of season; an alternative water source to the stream; other resources near the stream (shade); size of the field; and pasture availability.

Approach: In a study examining factors influencing the use of streams by cattle (Bagshaw, 2001),three experiments were carried out. During the course of these experiments the location and timing of defecation for each animal was recorded. The defecation data from the three experiments were amalgamated.

Outcomes:

- Beef cattle on hill country in New Zealand defecate in the riparian zone at a rate of 0.2 faeces per cow per day. Half of the faeces were deposited in the water and the other half were deposited within the 2m stream bank (demarcated as the riparian zone in this study).
- There was an indication that the number of faeces deposited by a cow in the riparian zone is related to the amount of time the individual spends in that area.
- Beef cattle in this study spent on average 4 percent of the day in the riparian zone and cows voided about 4 percent of the expected number of faeces in this time. Despite the relatively low number of faeces deposited in the riparian area, the impact may be high on water quality.
- The numbers of defecations in the riparian zone were not affected by season, the presence of a trough, other resources next to the stream, field size, or pasture availability.
- If management rather than exclusion techniques are to be used to prevent cattle from defecating in streams then we need to understand how to control animals by manipulating resources in the environment.
- Previous study by Bagshaw (2001) investigated the relative importance of resources in the riparian zone. The stream was found to be used daily and all the resources investigated were used (water to drink, water to cool, shade, and forage specific to the riparian area). The relative importance of these resources to cattle is still unclear.
- Amelioration methods to reduce the amount of faeces deposited in riparian zones could include: 1) the manipulation of the availability of the factors near the stream (such as water to drink, water for cooling, shade or forage specific to the riparian area); 2) reducing the availability of resting sites; 3) presenting combinations of attractive resources distant from the stream.
- Further studies are required to determine behavioural techniques to reduce the amount of faecal material deposited directly in riparian zones.

Publications:

Bagshaw, C.S. (2001) Factors influencing cattle (*Bos Taurus*) use of streams, *PhD. Thesis* (Psychology Department, University of Auckland).

Contents

1. Introduction

Livestock farming has been suggested to be one of the major causes of deterioration of riparian areas and water quality. Hafez and Bouissou (1975) found that grazing cattle defecate between 12 to 18 times in 24 hours. Most bacterial water quality criteria are based on the concentrations of faecal coliforms and faecal streptococci. The ratio of faecal coliforms to faecal streptococci can be used to identify particular animal sources of faecal contamination (Geldreich, 1976 in Baxter-Potter & Gilliland, 1988). Cow faeces have been found to be a reservoir for *Escherichia coli (E. coli)* (Hussein, 2000) and other pathogens.

Thelin & Gifford (1983) found that 100 ml of bovine faeces contained 10^7 coliforms. Not surprisingly, perhaps, with figures like these, bacterial densities in run-off from agricultural lands often exceed water quality standards (Baxter-Potter & Gilliland, 1988). Microbes and nutrients from manure enter streams by several potential pathways. One is direct deposition from the animals as they drink, graze, or otherwise spend time in and along the stream (Tiedemann *et al.*, 1988).

The second pathway is via runoff or overland flow, where deposits of manure along with organisms and nutrients in the manure are transported to the stream (Gary *et al.*, 1983; Larsen *et al.*, 1994). Other pathways include subsurface transport and filtration, and artificial drainage. The extent or severity of elevated bacterial indicator organisms in grazed streams in the US is proportional to the increase in cattle numbers, and inversely related to size of pasture (Darling & Coltharp, 1973; Gary *et al.*, 1983; Larsen *et al.*, 1994). In addition, bacterial concentrations in stream water from grazed pastures are directly related to the availability of meadows near the water (Tiedemann *et al.*, 1988).

It has been suggested that the impact of defecation on aquatic ecosystems, may be resolved by excluding stock from streams by fences, and by providing alternative water in troughs. However, fencing would be economically prohibitive in the United States (Platts & Wagstaff, 1984) and in New Zealand (Bettjeman, 1997). There have been few studies on the effect of cattle defecation in streams under New Zealand farming conditions.

In a study examining factors influencing the use of streams by cattle (Bagshaw, 2001), three experiments were carried out. During the course of these experiments the location and timing of defecation for each animal was recorded.

The aims of this study were to establish; (1) both the distribution and frequency of cattle defecation in the riparian zone and remainder of the grazing area; (2) the seasonal pattern of cattle defecation in the riparian zone and the remainder of the grazing area; (3) the effectiveness of locating a water trough distant from a stream on discouraging defecation in the riparian area; (4) the effectiveness of other resources (e.g. shade) on discouraging defecation in the riparian area. All experiments in this study were carried out under normal farm management practices on hill country in New Zealand.

2. General Method

LOCATION

The study site was located on a hill country farm at the Whatawhata research station, near Hamilton, New Zealand.

BEHAVIOURAL OBSERVATIONS

Observations were undertaken in the same way for each experiment. Observations were recorded by a team of trained observers assigned to each field, one observer per field. Each observer was located in a hide on a field opposite to the study field. In the Experiment 1, cattle were observed between 8 am to 5.30 pm every second day. In Experiment 2 and 3, the cattle were observed from dawn (approximately 5.30 am) until dusk (approximately 8 pm). Two different behavioural recording schedules were used. The behaviour and location in the field of each individual was recorded every 10 minutes (10 minute scan sampling data) (due to the requirements of a separate experiment) using the behavioural categories and definitions shown in (Bagshaw, 2001). In addition, for all cattle within 2 m of the riparian zone, the behaviour of the individuals (location and defecations) was recorded every minute. A cow was recorded as defecating when the base of the tail was raised and arched away from the body, the hind legs were placed slightly forward and apart, and the back was arched (Hafez & Bouissou, 1975) and faeces expelled.

FIELDS

The dimensions of the fields, and zones within the fields, were calculated using laser-range finder binoculars with azimuth and inclinometer (Leica Vector GIS, Leica, Heerburg, Switzerland). Each field was divided into four zones from top to stream (top, middle, bottom, and riparian zones). The top, middle and bottom zones were each approximately one third of the field, and were indicated by 50-cm high white stakes placed across the field. The riparian zone was defined as the area within one cow's body length (2 metres) of the stream. A stream flowed along the valley floor of each field. The channels of the stream were approximately 2 m wide, the water width was approximately 1 m, and the depth of the water was approximately 9 cm.

PASTURE COVER

In Experiments 1 and 2 a trained observer measured pasture availability, immediately before (pre-trial) and after (post-trial) the trial. Pasture was recorded as kilograms of dry matter per hectare (kg DM/ha). In Experiment 3 a trained observer measured pasture cover in each zone, before grazing of each replicate, at mid-replicate (on Day 7), and after each replicate.

WEATHER

Weather data were collected throughout the trial using a nearby weather station. Hourly measures included: maximum and minimum air temperature; rainfall; and relative humidity.

EXPERIMENTAL PROCEDURE

Experiment 1 examined the behaviour of beef cattle in the fields in each of the four seasons. Experiment 2 examined the behaviour of cattle when there was high pasture availability in the summer. In addition, both Experiments 1 and 2 examined the effect on provision of an additional water source on cattle behaviour. Experiment 3 examined the effect of specific factors in the stream environment on cattle use of the stream area (and the rest of the field). In all experiments, individuals were identified with large numbered ear tags and large numerals painted on both sides of their bodies with pink stock paint. A description of the method for each experiment will be given below.

EXPERIMENT 1

Animals

In the Autumn and Winter replicates, 30 pregnant Angus cows of mixed age were allocated at random to two groups (15 cows in each group). These animals had been together as part of a larger group of cows since calving. In the Summer and Spring replicates, 20 or 40 Angus cows of mixed age, with calves at foot, were allocated at random to either two or four groups (10 cows and 10 calves in each group), respectively.

Field Description

Four fields were used in the study, with the same aspect, and of similar size (on average 1.1 ha). The fields were paired according to size; field 1 and 2, and field 3 and 4. The slopes within each of the fields varied from 7^o to 35^o. The average height of the fields from the stream to the top of the hill was 150 m. The pairs of study fields were separated from each other by a field and a gully to minimise social interaction between groups. The field characteristics are summarized in Table 1.

Table 1. Size of each zone in each field

Zone	Field 1 Size	Field 2 Size	Field 3 Size	Field 3 Size
Top	1428 m^2	2620 m^2	6667 m^2	2562 m^2
Middle	2679 m^2	1815 m^2	5384 m^2	4291 m^2
Bottom	3889 m^2	2753 m^2	4896 m^2	3428 m^2
Riparian	1012 m^2	217.6 m^2	1142 m^2	1126 m^2
Total	**8 844 m^2**	**7 406 m^2**	**18 089 m^2**	**11 407 m^2**

Trial Design

Replicates were conducted in each season over two consecutive years, except for Spring where one trial only was conducted (Table 2). Fields 1 and 2 were used for all replicates. In addition, during one Summer replicate, and the Spring replicate, fields 3 and 4 were used. In each pair of fields, a 50 l water trough was located at the top of one field, and not in the other. Water for the troughs was pumped from a stream in the catchment supplying the stream water. The experimental design was a cross-over design. For each pair of fields, the trough was placed in one field for a particular season, and in the opposite field in the same season the following year (Table 2). Cattle resided in the fields for 6 days. On the first day of the trial, cattle were moved into the fields in the late afternoon. Observations were recorded on the 2^{nd}, 4^{th} and 6^{th} day of each trial (referred to as Day 1, 2 and 3 in the results). However, in the second Autumn trial, the animals were kept in the fields for three days only, as there was not enough pasture to feed the animals for 6 days. Therefore, observations in this trial were recorded on 1^{st}, 2^{nd} and 3^{rd} days of the trial.

Table 2. Experimental Design

Season	Field 1	Field 2	Field 3	Field 4
Autumn 1	Trough	No Trough	Not Measured	
Winter 1	No Trough	Trough	Not Measured	
Spring 1	Not measured			
Summer 1	No Trough	Trough	Not Measured	
Autumn 2	No Trough	Trough	Not Measured	
Winter 2	Trough	No Trough	Not Measured	
Spring 2	Trough	No Trough	Trough	No Trough
Summer 2	Trough	No Trough	Trough	No Trough

1 indicates the first year of the trial, and 2 indicates the second year of the trial. Trough indicates that a trough was located in the top zone.

EXPERIMENT 2

Animals

In both trials, 60 lactating Angus cows of mixed age, each with a suckling calf, were allocated at random to four groups (15 cows with calves in each group). Stocking density was maintained at a similar level as Experiment 1 (average 9.1 cow-calf pairs per ha). These animals had been together as part of a larger group of cows since calving.

Field Description

It was important that the fields had a stream at the bottom and a ridge at the top. In order to achieve this, there was some variation in field size (1.1 to 2.2 ha) (Table 3).

Table 3. Size of each zone in each field

Zone	Field 1 Size	Field 2 Size	Field 3 Size	Field 4 Size
Top	3611 m^2	1391 m^2	2947 m^2	1629 m^2
Middle	6264 m^2	1979 m^2	3162 m^2	2254 m^2
Bottom	7602 m^2	4746 m^2	5981 m^2	7303 m^2
Riparian	189 m^2	148 m^2	176 m^2	250 m^2
Total	**1 7666 m^2**	**8264 m^2**	**1 3402 m^2**	**1 1436 m^2**

Trial Design

The experiment was conducted in early summer (December) and late summer (March), with each period including two replicates. Each replicate comprised a pair of fields. A trough was positioned at the top of one of the fields. Cows and calves grazed the fields for six days, and observations were conducted every second day. The procedure was similar for both the early and later summer periods, except that the troughs were alternated between the pairs of fields (change over design) (Table 4).

Table 4. Experimental Design

Trough indicates that a trough was located in the top zone.

	Field 1	Field 2	Field 3	Field 4
Early summer				
Replicate 1	Trough	No Trough	-	-
Replicate 2	-	-	No trough	Trough
Late Summer				
Replicate 1	-	-	Trough	No trough
Replicate 2	No Trough	Trough	-	-

EXPERIMENT 3

Animals

Seventy-nine Angus cows of mixed age with calves were used in the experiment. These animals had been running together as part of a large group of cows since calving. There was also a separate group of 30 first-calvers (2 year old cows who had produced their first calves) with calves who were joined to the mixed age group during the experiment. All calves were 5 months old at the beginning of the study.

Animals were allocated randomly to four fields. One group of four fields constituted one replicate. There were four replicates, conducted consecutively over the summer period January to March. The allocation of the 109 cow-calf pairs for each replicate is shown below.

Replicates 1 and 2

Four groups of 10 cows with calves were drawn at random from two groups of cattle, mixed age cows and first-calvers. The 40 animals consisted of 35 mixed age cows and 5 first-calvers with calves. Each group was placed in a separate field. One cow died in the first replicate in Field 1, and a naïve mixed-age cow with calf was added to this group.

Replicate 3

Four groups of 10 naïve cows with calves were drawn at random from the remaining group of mixed-age cows with calves. The first-calvers group was not available as the cows and calves in this group had been weaned and removed from the experiment.

Replicate 4

Four groups of 10 cows with calves were drawn at random from the five naïve cows with calves remaining in the mixed age group, and 35 mixed age cows with calves were drawn from those used in Replicate 1 and 2.

Fields

Four different fields were allocated to each replicate. An unused field and a gully separated each field from another to minimise social interactions between groups. The field characteristics are summarised in Table 5. Field size varied from 0.4 ha to 1.6 ha and the average height from the bottom to top of the field was 133 m. A single 50 l trough was located within 2 m of the stream. The animals entered the fields via gates at the top of the hills.

Table 5. Size of each zone and slope of each field in each replicate

The size and inclination of the three areas of the field used in fields 1 to 16. B + R = bottom plus riparian zones

Rep. 1	**Field 1**		**Field 3**		**Field 5**		**Field 7**	
	Size m²	**Slope (°)**	**Size m²**	**Slope (°)**	**Size m²**	**Slope (°)**	**Size m²**	**Slope (°)**
Top	4092	21	3906	24	2313	25	3310	19
Middle	3039	33	4003	34	2525	36	1099	31
B + R	2128	33	2980	23	2009	24	1606	37
Total	9259	28	10889	27	6847	26	6015	27
Rep. 2	Field 2		Field 4		Field 6		Field 8	
Top	1536	23	1317	25	1823	20	2955	21
Middle	3609	33	1894	29	2423	32	2707	23
B + R	3734	26	4638	19	2145	38	2244	32
Total	8879	28	7849	23	6391	29	7906	25
Rep 3	Field 9		Field 11		Field 12		Field 13	
Top	6101	21	2873	25	895	16	2670	25
Middle	4987	19	2346	19	2011	22	2136	19
B + R	4310	25	3205	19	5426	28	4130	23
Total	15398	23	8424	25	8332	23	8332	23
Rep. 4	Field 10		Field 14		Field 15		Field 16	
Top	5280	19	2433	22	849	25	3600	15
Middle	5818	20	3456	28	1094	33	2676	31
B + R	5007	24	3009	26	2060	30	2188	36
Total	16105	22	8898	25	4003	28	8404	26

Treatments

Four factors were identified from the literature that may attract cattle to the riparian zone. They were: water to drink; water for cooling; shade; and forage that grows in the riparian zone. In order that Treatments could be given in a systematic manner, the following arrangements were devised.

Shade

Shade structures were erected in each field. Each structure was assembled using 6 poles (10 cm diameter) placed near the stream bank, in a rectangular shape, 6 m long by 3.6 m wide by 2.5 m high. The structures were orientated with the longest length parallel to the stream, and positioned on the flattest ground available as close as possible to the stream bank. They were situated 2 m from the stream bank edge (i.e., outside the riparian zone). Black shade cloth (80 percent shade cover) was placed on the top of the structure when shade was made available to the cows, and otherwise rolled back.

Water to Drink

In this treatment, electric fences along the stream bank prevented cattle having direct access to most of the stream. Cows were given two easy access points to the stream, up stream and down stream, where drinking areas were created using the electric fence. In these specified areas, cattle could stand on the stream bank and drink from the stream. There was enough room for a cow to place her head and front two feet in the water.

Complete Access to the Stream

When cattle were provided complete stream access, they had the opportunity to enter the stream along its length. Cows were not able to cross the stream to the opposite bank as an electric fence on the opposite bank prevented this.

Forage

Particular species of plants near the water may attract cattle to the riparian zone. Forage in and near the stream was available to be grazed during the first 4 days of a replicate. On Day 5 of each replicate forage was removed within a 2 m radius of the stream. This was achieved by intense grazing of the designated stream area. Electric fences were used to hold the experimental cattle from each field within the specified area for approximately 2 hours. This will later be referred to as forage treatment.

Design for Allocating Treatments

Each replicate was carried out over 12 days. The 12 days were divided into 2-day periods (i.e., there were 6 periods during each replicate). The Treatments were changed between 8.00 am and 10.00 am on the first day of each period. It was thought that this would give cattle time to adjust to the change prior to being observed on the second day of each period.

Stream Treatments

There were four possible Treatments in the stream area:

1. A control condition, where cattle had access to the shade structure and the stream. The remaining three Treatments each had at least one factor removed.
2. No shade, removal of the shade, where the shade cover was rolled back. The animals still had complete access to the stream.
3. No paddle, removal of access to walking in the stream (paddling), where the animals were able only to drink from the stream, and shade in the shade structure was available.
4. No stream, removal of access to the stream so animals did not have access to walking in the stream (paddling) or to drinking in the stream. Shade in the shade structure was available.

In all Treatments, a Trough was always available near the stream.

Latin Square Design

There were two phases to the design of each replicate, Phase I and Phase II. There was forage available at the stream in Phase I but not during Phase II (forage treatment).

Phase I was the first four days of the replicate (2.2-day periods). During these days forage was available in the riparian zone. The order in which the Treatments were allocated to the fields in Phase I was based on the last 2 rows of the four field by four Treatment, Latin square design (Phase II). This allowed an assessment of the effect of forage in the riparian zone on each Treatment. Phase II was carried out over the following 8 days (4 x 2-day periods). On the first day of Phase II (Day 5 of the replicate), forage was removed from the riparian zone. This allowed a test of each Treatment, without forage at the stream, in Phase II. The order in which the Treatments were allocated to the fields in Phase II was based on a 4 x 4 Latin square design. Each Treatment is donated by either A, B, C, or D (Table 6).

Table 6. Experimental design for each replicate

Phase II treatments were based on a Latin square design. Phase I treatments were the same as the last 2 rows of the Latin square of Phase II. The same procedure was followed for each replicate, although the four Treatments (A, B, C and D) were allocated in a different order across periods.

	Period	Field i	Field ii	Field iii	Field iv
Phase I	1	C	D	A	B
	2	D	A	B	C
	Forage was removed in the riparian zone				
Phase II	3	A	B	C	D
	4	B	C	D	A
	5	C	D	A	B
	6	D	A	B	C

3. Statistics

The defecation data in the three experiments were amalgamated for analysis. The data was available as mob-day totals, summarised as the numbers of defecations in the stream, the riparian zone (bank plus stream) and the whole of the field. There were too few defecation data to split into the nominal areas of the field (top, middle and bottom).

Data were initially examined as potentially Poisson-distributed counts using the GLMM procedure in the Genstat statistical package to determine the error structure required to model the correlation's inherent to repeated measures data.

The presence of error strata for mob, day and field clustering were tested for, allowing for fixed effects arising from a general difference between the three experimental sets of data. The fixed effects were season (with and without distinction between the two summer periods), day of grazing within grazing-period (as a reflection of changing pasture availability), absence of a drinking trough in fields, presence of a shade structure in the riparian zone, and forage treatment in the riparian zone. The latter two effects arose only in Experiment 3 and the trough effect only arose in Experiments 1 and 2. The fixed effects were tested both in models that restricted their effect to the relevant experimental data sets and as overall comparisons, as the fixed effects model was reduced by omitting the negligible effects. Terms were nominally rejected at the $p > 0.05$ level, but in fact p-values were generally much higher for most fixed effect tests.

Both "in water" and total defecations in the riparian area led to the conclusion that variation arose solely from random mob-to-mob differences with residual Poisson variation. Whole field numbers on the other hand showed an overall average difference between summer-autumn and winter-spring periods with no error structure, but a residual greatly in excess of that expected from Poisson variation. Analysis of data was therefore completed by confirming fixed effects in Gamma error regression models to the mob per cow per day averages for "in water", total data for the riparian zone and per cow per day individual observations for the whole field data respectively. Gamma variation was confirmed by testing the fit of various alternatives for error distribution.

The percentage of whole field defecations observed "in the water" or in the riparian zone were also analysed. This led to a model comprising between mob average variation with a binomially distributed day-to-day residual. Mob averages were very well fitted by Beta distributions.

4. Results

NUMBERS OF DEFECATIONS IN THE RIPARIAN ZONE

Random Effects

There were no random sources of variation. Daily defecations per cow supported a common Gamma distributed variation for each of the following (1) in the water, (2) on the bank and (3) in the riparian zone (in the water plus on the bank). Each Gamma distribution had a coefficient of variation close to 100 percent, which was compatible with an exponential distribution. The total numbers of defecations for each mob each day in the riparian zone (in the water plus on the bank) can be modelled (within short grazings) as a Poisson variate. In this case the average is based on a number per cow per day arising independently for each mob from the same exponential distribution.

Fixed Effects

The numbers of defecations deposited in the water, on the bank or in the riparian zone (in stream plus on bank) per cow per day were not significantly effected by Season, Trough, Shade, or Field.
The average number of defecations per cow per day in the water, on the bank and in the riparian zone are shown in Table 7.

Table 7. Average number of defecations per cow per day

	Average per cow per day
Defecations in the water	0.11
Defecations on the bank	0.09
Defecations in the riparian zone	0.2

Since the number of hours cattle were observed each day varied between experiments (from 9 to 16 hours) the average number of defecations was analysed per hour. Within this measure, the average number of defecations per cow per hour in the water, on the bank and in the riparian zone were also not significantly effected by Season, Trough, or Shade.
The average number of defecations per cow per hour in the water, on the bank and in the riparian zone are shown in Table 8.

Table 8. Average number of defecations per cow per hour

	Average per cow per hour
Defecations in the water	0.009
Defecations on the bank	0.007
Defecations in the riparian zone	0.016

Pasture Availability

There was no effect of pasture in the riparian zone on the numbers of defecations in the riparian zone.

Time Spent in the Riparian Zone

Cattle spent on average 4 percent of their day in the riparian zone Table 9. The amount of time spent in the riparian zone varied across experiments from 1.5 to 6.7 percent.

Table 9. The average proportion of time spent in the riparian zone across three Experiments

	Average number of minutes in the riparian zone (mins/cow/day)	Average number of minutes observed (min)	Percent of time spent in the riparian zone (% per cow per day)
Experiment 1	8.3	540	1.5
Experiment 2	25.3	600	4.2
Experiment 3	57	840	6.7
Average time across studies spent in the riparian zone			**4.1**

Percent of total defecations in the riparian zone

Random Effects

There were no random sources of variation.

Fixed Effects

The percent of total defecations in the water, on the bank or in the riparian zone (in water plus on bank) were not significantly effected by Season, Trough, or Shade (Table 10).

Table 10. The average percentage of cattle defecation in the water, on the bank, and in the riparian zone (in water plus on the bank)

	Average percentage
Defecations in the water	8.3
Defecations on the bank	6.3
Defecations in the riparian zone	14.6

Numbers of defecations in the whole field

Random Effects

There were no random sources of variation. The observed daily defecations per cow supported a Gamma distribution.

Fixed Effects

The total numbers of defecations in the field was not significantly effected by Trough, or Shade.

Season

There were significantly more total defecations in the field during the Summer and Autumn compared to Winter and Spring, which arose independently each day for each group of cows in a particular field (mob).

There was variations in the length of time animals were observed each day between seasons, therefore the numbers of defecations in the whole field were analysed per hour. However, the length of time animals were observed did not account for the significant difference in the numbers of defecations between seasons.

The average total number of defecations per cow per day was 1.2 and the average total number of defecations per cow per hour was 0.1.

5. Discussion

On average beef cattle, on hill country defecated at a rate of 0.2 faeces per cow per day, in the riparian zone. In this study, the numbers of defecations in the riparian zone, the total numbers of defecations in the field and the percent of defecation in the riparian zone were unaffected by factors such as the presence or absence of a trough, the availability of a shade structure, the size of the field, or pasture availability in the riparian zone.

Hafez & Bouissou (1975) reported that cattle at pasture defecate 12 to 18 times in a 24-hour period, and Wagnon (1963) observed grazing cattle defecating between 9 to 12 times over 24 hours. In a more recent study Sahara et al. (1990) found that Holestein cows indoors, average defecation frequencies were about half (9 +/- 2.5) that observed by Hafez & Bouissou (1975). Over these studies, the average rate of defecation for cattle was 11.5, therefore, it is reasonable to expect approximately half the number of excreta in a 12 hour period (5.75).

Cattle in this study spent on average 4 percent of the day (12 hours) in the riparian zone. If cows defecate at an average rate of 5.75 faeces per 12 hours, then in 4 percent of the day cows would deposit on average 0.23 faeces, which is similar to the average number of faeces deposited in the riparian zone in this study (0.2 faeces). Consequently, it may be suggested that the number of faeces deposited by a cow in the riparian zone may be related to the amount of time the individual spends in that area.

In a recent study, Davies-Colley et al. (in prep.) observed cows travelling down a 200m raceway and across a 20m river. Despite the difficulty in estimating the numbers of defecations in the water (e.g. due to cattle bunching together) they suggested that cows were about 50 times more likely to defecate in the river (on the ford) than elsewhere on the raceway. This might have been due to the longer periods of time the cows spent in the river, rather than the presence of water per se. Unfortunately, this study does not indicate the length of time cows spent on the raceway, however, Davies-Colley et al. (in prep.) report that cows tended to linger in the water much longer than elsewhere on the raceway. Thus, it appears that Davies-Colley et al. (in prep.) data may support the notion that defecation in an area is in proportion to the time spent in that area.

Individual cows in this study were observed defecating on average 1.2 times in the non-riparian parts of the field in (approximately) a 12-hour period, which is much lower than would be expected from information in the literature. A possible reason for the low numbers of defecations observed in the field was as a result of the particular recording protocol used (as required in another associated study); the behaviour and location of cattle in the field were recorded every 10-minutes. Excretion behaviour is relatively infrequent and short duration behaviour, therefore, it is perhaps not surprising that relatively few instances of defecation were recorded in the 10 minute scan sampling. However, when the cows were in the riparian zone, the behaviour of individual animals was recorded every minute. Therefore, there is confidence that the numbers of defecations recorded in this area would be close to the actual numbers of defecations deposited in this area (during daylight hours).

Despite the low numbers of defecations recorded at pasture, cows were found to defecate more (in the entire field) during the summer and autumn compared with the spring and winter. The most likely explanation for this is higher feed availability during the summer and autumn compared with the spring and winter.

In the three experiments of this study, it appears that cows spent relatively little time in the riparian zone, with a small number of faeces per cow deposited each day in this area. Despite this, the impact of even small amounts of faecal material on water pathogen levels may be quite high (Davies-Colley et al., in prep.). Further studies are required to quantify the precise risks to New Zealand waterways from the proximity of cattle to streams.

Reducing the time cows spend in the riparian zone may be one method of minimising the bacterial contamination of streams by faecal material. To assess the possibility of decreasing cattle stream use, firstly, it is essential to understand where cattle spend their day, and, secondly, it is important to establish what attracts cattle to the riparian area. Both aspects are likely to influence the use of streams and the surrounding area.

Bagshaw (2001) described the diurnal behaviour pattern of beef cattle on hill country in New Zealand. Bagshaw (2001) found that cattle on hill country in New Zealand have strong diurnal behaviour patterns. They graze mostly in early morning and evening, and rest mostly in the middle of the day (Martin, 1978; Sneva, 1970; Hafez & Bouissou, 1975; Bagshaw, 2001). Typically, at 8 am (Experiment 1), cows graze on the flattest land near the top of the field. Cows would weave their way back and forth across the field grazing for about 3 hours. Cows grazed longer on the upper slopes of the field in the Morning and Midday time intervals as the days of the trial progressed. Occasionally, animals would drink from the trough when they were at the top of the field, during the Morning and Midday time intervals. Often, the animals would rest between 11 am and midday. They would stand or lie down, ruminating, for approximately 2 to 3 hours on flat areas either at the top or middle of the field. In field 3, there was a large flat area at the top of the field next to a trough, cattle would spend the majority of their resting time in this area, and there was an increase in trough use. This resting bout appeared to be reduced if there was low pasture availability, which was also found by Hafez & Bouissou (1975).

The behaviour of cattle near the stream also showed a diurnal pattern. Bagshaw (2001) and Duncan (1996) observed cattle drinking from the stream mostly in the afternoon. Bagshaw (2001) typically observed that at approximately 2 pm, one or two individuals would move towards the stream. Within half an hour of this the rest of the group was often observed running down the slope to the stream. Dominant animals would push others out of the way, and there was often much bunting, as animals tried to get first access to the water through one of the two common stream access points. Some individuals would move into the stream while others would queue on the stream bank.

Cattle may defecate on the stream bank while waiting to get into the stream or in the stream itself. Once an animal was next to the water it would drink, then stand for several minutes before either walking into the stream, or on to the stream bank where they would graze or rest. By late afternoon, most animals had drunk from the stream. Cows would then drift away from the stream, grazing up the slope to their night-time resting sites near the top of the hill. The cows, in this present study behaved in a manner similar to cattle grazing a variety of pasture types in other studies (Sneva et al., 1973; Hafez & Bouissou, 1975). The diurnal behaviour of cattle appears to be robust in nature. Consequently, it may be difficult to change.

Researchers have suggested that cattle congregate in riparian habitats to gain access to numerous factors such as shade (Garrett et al., 1960), particularly succulent vegetation, proximity to water and gentle terrain (Platts, 1978; Armour et al., 1991; Kie & Boroski, 1996; Bryant, 1982; Roath & Krueger, 1982; Smith et al., 1992). External factors in the stream environment which may influence the time cattle spend in an area have been discussed in detail by Bagshaw (2001). In Experiment 3, (Bagshaw, 2001) the importance of water for drinking, water for cooling, shade and forage specific to the riparian area on use of the riparian habitat was investigated. In relation to the frequency and distribution of defecation, the resources available in an area may be important if they alter the amount of time cattle spend in an area. Bagshaw (2001) suggested that the stream area (riparian zone) was relatively attractive to cattle. It was found that pasture availability was one factor which may influence the time cattle spend near streams.

When there was an abundance of good-quality pasture elsewhere in the field, cattle spent less time drinking from the stream compared to later in the trial (when there was less forage available). Thus, when pasture availability is low, there is a potential for a greater impact on streams. In addition, the opportunity to cool was possibly an important feature of the stream. When cattle were unable to paddle in the water they spent more time under the shade structure compared to when they had complete stream access.

The role of the other factors investigated remains unclear, but because all of the resources that were made available were used, it would appear that factors such as shade, food and access to water are important. As yet, it is not possible to ascertain the relative importance of the various streamside factors to cattle. If important features could be identified, then such factors might be able to be manipulated to reduce the use of riparian areas by cattle and defecation in these areas (Bagshaw, 2001).

Further studies are required to ascertain the influence of different combinations of resources to alter the time cattle spend in an area.

Management Implications

There is an indication from this study that the length of time cattle spend in a particular area may influence the number of faeces deposited in that area. Obviously, if this were true, it should be possible to reduce the numbers of defecations in the riparian zone by reducing stream use. Cattle have a particularly strong diurnal pattern of behaviour, which is likely to be quite difficult to change. In addition, they are highly likely to be attracted the riparian area, which is rich in resources. Bagshaw (2001) suggested a number of ways which might reduce the amount of time cattle spend in the riparian zone:

1. the manipulation of the availability of the factors near the stream (such as shade, water for cooling, water to drink or forage specific to the riparian area);
2. reducing the availability of resting sites;
3. presenting combinations of attractive resources distant from the stream to reduce the time spent in the riparian area;
4. perhaps also block access into the stream, as in hill country there are usually few convenient and easy access points to the stream;
5. further studies are required to test amelioration methods to reduce defecation by cattle in sensitive ecological areas.

6. Conclusion

- Beef cattle on hill country in New Zealand defecate in the riparian zone at a rate of 0.2 faeces per cow per day. Half of the faeces were deposited in the water and the other half were deposited within the 2m stream bank (demarcated as the riparian zone in this study).
- There was an indication that the number of faeces deposited by a cow in the riparian zone is related to the amount of time the individual spends in that area.
- Beef cattle in this study spent on average 4 percent of the day in the riparian zone and cows voided about 4 percent of the expected number of faeces in this time. Despite the relatively low number of faeces deposited in the riparian area, the impact may be high on water quality.
- The numbers of defecations in the riparian zone were not affected by season, the presence of a trough, other resources next to the stream, field size, or pasture availability.
- If management rather than exclusion techniques are to be used to prevent cattle from defecating in streams then we need to understand how to control animals by manipulating resources in the environment.
- Previous study by Bagshaw (2001) investigated the relative importance of resources in the riparian zone. The stream was found to be used daily and all the resources investigated were used (water to drink, water to cool, shade, and forage specific to the riparian area). The relative importance of these resources to cattle is still unclear.
- Amelioration methods to reduce the amount of faeces deposited in riparian zones could include: 1) the manipulation of the availability of the factors near the stream (such as shade, water for cooling, water to drink or forage specific to the riparian area); 2) reducing the availability of resting sites; 3) presenting combinations of attractive resources distant from the stream.
- Further studies are required to determine behavioural techniques to reduce the amount of faecal material deposited directly in riparian zones.

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