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Investigation of an outbreak of *Taenia saginata* cysts (cysticercus bovis) in dairy cattle from two farms

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ABSTRACT

The paper describes the epidemiological investigation carried out on two dairy farms with cattle infected with *Taenia saginata* cysts. On the first affected farm it was estimated using Bayesian techniques that approximately 65% of 1400 mixed-age cattle were infected with *Taenia saginata* cysts.

The investigation aimed to determine potential exposure pathways of cattle to *Taenia saginata* with a view to finding the human source of infection and to describe the epidemiology of the outbreak on the affected farms. In order to determine potential exposure pathways, investigation was centred on how feed or water could have been contaminated with eggs. The plausibility of pathways was determined by examining the spatial and temporal association between factors related to the pathway and the prevalence of infection in cattle strata. We describe the investigation carried out on affected farms.

1. Introduction

The lifecycle of the human tapeworm, *Taenia saginata* involves humans as the definitive host for the tapeworm and cattle as the intermediate host for the larval stage. Cattle become infected after eating *Taenia saginata* eggs (or proglottids) from infected humans. Once cattle are infected, cysticerci develop in the muscle and subsequently become infective to humans after approximately 10 weeks (Flisser et al., 2005). Generally, the cysticerci remain viable for only a few months (Flisser et al., 2005), although they have been reported to be viable 18 months post-infection (Dewhirst et al., 1963).

Human infection results from eating raw or partially cooked beef containing viable cysticerci. Three months after ingestion of cysticerci, the adult tapeworm becomes sexually mature (Flisser et al., 2005). Proglottids containing eggs are then shed and passed with faeces; however, they may also be shed by natural migration from the host's anus (Flisser et al., 2005). Eggs that are released before defecation usually become mixed with faces. Eggs may be distributed directly onto the ground, or indirectly from contaminated clothing and bedding. An infected human host is generally asymptomatic, although mild gastrointestinal signs may occur (White and Weller, 2008) and in some instances complications can develop (Pawlowksi and Schultz, 1972).

Once a human host is infected, the amount of eggs shed per day is highly variable but may reach many hundreds of thousands; though the average daily egg production is approximately 150,000 eggs per day (Froyd and Round, 1959). Cattle may be infected directly from hands contaminated with eggs, but are more likely to be infected when ingesting eggs carried in drinking water, or feed (Murrell, 2005). There are a variety of pathways for feed and water to be contaminated. These pathways include contaminated

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water sources flooding pasture, discharge of human effluent, and conveyance of eggs by fomites, arthropods and wildlife (Murrell, 2005). Egg viability is dependant on temperature and the availability of moisture, surviving for many months given ideal conditions (Murrell, 2005).

Routine meat inspection is generally the only diagnostic tool used for *Taenia saginata* cysts. In New Zealand meat inspection involves visual inspection of the oesophagus; inspection and palpation of the masseter, tongue, and diaphragm; and inspection, palpation and incision of the heart. There is some variability in predilection of *Taenia saginata* cysts between muscle groups and organs (Lopes et al., 2010; Maeda et al., 1996; Scandrett et al., 2009). The sensitivity of inspection will vary with the number of cysts in the muscles examined as well as the stage of cysts. The measure is also very subjective and will vary with operator. In some instances sensitivity of meat inspection may be as low as 10–20% (Blackmore, 1983; Abuseir et al., 2006; Geysen et al., 2007). Despite the low sensitivity of detection in individual animals the main value of meat inspection is as a herd level test to detect infected herds.

Only sporadic reports of infection in cattle with *Taenia saginata* cysts have occurred in New Zealand (McFadden, 2010). On affected farms the numbers of infected animals detected is generally low. There have only been 14 cases of taeniasis reported in New Zealand between 2000 and 2010 (Anonymous, 2010). All affected people had a history of overseas travel. *Taenia saginata* occurs worldwide with prevalences being particularly high in some African, Latin American, Asian and Mediterranean countries (Murrell, 2005).

The Investigation and Diagnostic Centre (Wallaceville, New Zealand) was notified of an outbreak of bovine cysticercosis in a dairy farm identified during routine meat inspection. Subsequently, a second farm neighbouring the first was identified. The following paper describes the epidemiological investigation carried out to determine potential exposure pathways of cattle with a view to finding the human source of infection and to describe the epidemiology of the outbreak on the affected farms.

2. Materials and methods

2.1. Investigation methodology

The period that infection of cattle occurred was estimated by aging *Taenia saginata* cysts histologically and also by determining the confidence that *Taenia saginata* cysts were not present at different periods based on non-detection in animals slaughtered at meat processing plants. Confidence values were determined using FreeCalc software (Cameron and Baldock, 1998a,b).

In order to determine the pathways that cattle may have been exposed to *Taenia saginata*, investigation was centred on how feed or water could have been contaminated with eggs. The plausibility of pathways was determined by examining the spatial and temporal association between factors related to the pathway and the prevalence of infection in different cattle management groups (strata).

We examined the temporal relationship between when cattle were infected and when factors occurred. Pathways were dismissed when factors occurred after the estimated infection date. The period elapsing between potential contamination and exposure was taken into account. Both farms were rotationally grazed, where cattle are moved to new paddocks with fresh pasture every 1–2 days. Hence it was necessary to take into account the rotation period for grazing all or that part of the farm used for grazing.

Prevalence of infection of cattle from different management groups was determined for both affected farms. The importance of determining infection by management group relates mainly to differences in land grazed. Other spatial factors such as the source location of any supplementary ration fed, exposure to pasture affected by stream flooding, and exposure to pasture contaminated with septic tank effluent were examined to see if they were associated with a difference in prevalence between strata.

We investigated the potential that drinking water provided to cattle was contaminated. No reliable methods were available to test environmental sources directly for *Taenia* eggs; however, various water quality variables were tested as a proxy for water being contaminated with human effluent. We hypothesised that if the coliform count was high it indicated that water could have been contaminated with faeces and therefore, drinking water could have acted as a potential pathway for exposure of cattle. The probability of water borne infection resulting from streams passing through the farm were examined by determining the history of slaughter and inspection of cattle sent to meat processing plants from down stream farms.

Meat processing data recording the identification of affected and unaffected cattle slaughtered was used to estimate the prevalences on the first detected farm (Farm A); however, data was insufficient to determine prevalences on the second farm (Farm B). Ancillary serological testing with an Ag-ELISA of cattle from different management groups was used to clarify prevalence on Farm B and to determine the infection rate of new cattle introduced onto Farm A. On Farm A, a change in management at the time of the outbreak meant that the original herd was sold and the farm restocked with a new cattle herd.

2.2. Antigen ELISA Taenia saginata cysts

On 7 October 2009, clotted blood was collected from cattle used to restock Farm A. There were approximately 30 sera collected from each of two management groups grazing separate parts of the farm. On the same day, approximately 60 sera were collected from cattle from each of three management groups from Farm B. The B158/B60 antigen ELISA was carried out using the methods described by Brandt et al. (1992) and modified by Dorny et al. (2004).

2.3. Collection and testing of stool samples

Farm staff and management associated with both affected farms and present on the farms over the period where exposure of cattle was likely to have occurred (between January and June 2009) were contacted by telephone during September 2009 and asked if they could assist the investigation by providing stool samples and completing a questionnaire (20 people). At this initial contact,

information was provided about the condition of taeniosis and the current outbreak of bovine cysticercosis. Appropriate sample collection material was couriered to those contacted as well as a fact sheet on taeniosis, specimen containers, an instruction sheet on the methods of sample collection, a questionnaire and a return addressed courier bag.

Faecal samples were submitted for a coprological examination for *Taenia* eggs. Three samples from separate bowel movements were requested from each subject. Faecal samples were frozen at −20 °C until testing was carried out.

The testing procedure consisted of initial inspection of faeces for *Taenia saginata* proglottids. Then a portion of faecal samples, of approximate size of a sultana grape, were mixed with 20 ml of water and shaken to fully disperse the material. The suspension was then filtered through a 300 μm sieve and 15 ml of the filtrate was centrifuged at 2000 rpm for 5 min. The supernatant was poured off, 12 ml of saturated sodium nitrate was added and the sediment was triturated with a disposable pipette. A meniscus was created by adding saturated sodium nitrate until the level reached the top of the tube and a coverslip (22 mm × 22 mm) was placed on top. The combination of meniscus and coverslip were allowed to stand for 10 min and then the coverslip was lifted vertically and placed in the centre of a labelled slide. The full area of the coverslip (approximately 10 traverses) was viewed at 100× magnification and inspected for *Taenia* eggs. The procedure was validated using varying concentrations of *Taenia* eggs seeded into faecal samples and the eggs counted. There was a linear reduction in the number of eggs observed with diminishing concentration of eggs seeded into faecal samples used as positive controls.

2.4. Questionnaire

Those that provided stool samples were asked to complete a questionnaire relating to their country of origin; foreign countries visited over the last ten years; whether they ate home-killed beef; whether they ate meat rare or partially cooked; whether they had been treated for tapeworm; whether they had observed evidence of tapeworm infection, such as fragments resembling cucumber seeds in their underwear; and whether defecation had occurred on farm land away from normal toilet facilities.

2.5. True prevalence of infection

The distribution of the likely true prevalence on Farm A was determined in WinBugs using Bayesian techniques described by Lunn et al. (2000). The beta distributions for sensitivity and specificity of meat inspection for *Taenia saginata* cysts were determined from indices provided by Blackmore (1983), Abuseir et al. (2006), Geysen et al. (2007), (specificity: minimum > 73%, mode = 97%; sensitivity: minimum = 10%, mode = 33%) and the prevalence determined from meat inspection data of slaughter consignments as: minimum = 6%, mode = 48%). The following expression (Rogan and Gladen, 1978) was solved to determine true prevalence:

$$\text{Apparent Prevalence} = \text{Sensitivity} \times \text{True Prevalence} + (1 - \text{Specificity}) \times (1 - \text{True Prevalence}).$$

2.6. Data analysis

Exploratory analysis and graphical presentations of data were carried out using the lattice package in R (Ihaka and Gentleman, 1996).

2.7. Histology

Cysts collected from infected cattle from several consignments sent to slaughter at several meat processing plants were fixed in 10% buffered formalin, then trimmed into cassettes for routine processing. Paraffin-embedded tissues were cut at 5 μm and stained with H&E. The cysts submitted for histological examination were not linked to any specific animal but were grouped according to the organ type the sample was collected from and the slaughter consignment the animal had originated from. Cysts were aged histologically using age related morphology of cysts described by Silverman and Hulland (1961) and Oryan et al. (1998).

2.8. Water quality testing

Water quality testing was carried out at the Institute of Environmental Science and Research Limited (ESR; Christchurch, NZ). Contamination of water with total coliform bacteria and *Eschericia coli* was determined using Colilert quanti-tray which allows determination of the most probable number count (MPN) of organisms present per 100 ml (Clescerl et al., 2005).

3. Results

3.1. Detection at meat processing plants

Taenia saginata cysts was detected in cattle during meat processing inspection from two contiguous dairy farms, Farm A on 11 May 2009 and approximately 2 months later on Farm B (6 July 2009). Farm B shares a contiguous northern and western boundary with Farm A. In addition, a road intersects the two farms on Farm A's eastern boundary (Fig. 1). Both Farm A and B are large farms, approximately 1400 and 1200 cows respectively, compared to the average New Zealand sized dairy farm of 351 cows (Anonymous, 2008).

Taenia saginata cysts were detected in 3/49 mixed-age cattle from Farm A on 11 May 2009. Lesions were subsequently detected in three other mixed-age cattle consignments sent to slaughter soon after the first (21 May 2009, 8/20; 29 May 2009, 20/20; 3 June 2009, 27/48), (Fig. 2). Affected cattle were detected in 2 of 3 meat processing plants where cattle had been slaughtered. The location of cysts and the number of cysts identified per affected animal was not collected.

Taenia saginata cysts were not detected in three cattle consignments sent from Farm A prior to the first positive consignment (19 December 2009, 0/4; 24 March 2009, 0/50; and 7 May 2009, 0/54). On Farm B, *Taenia saginata*

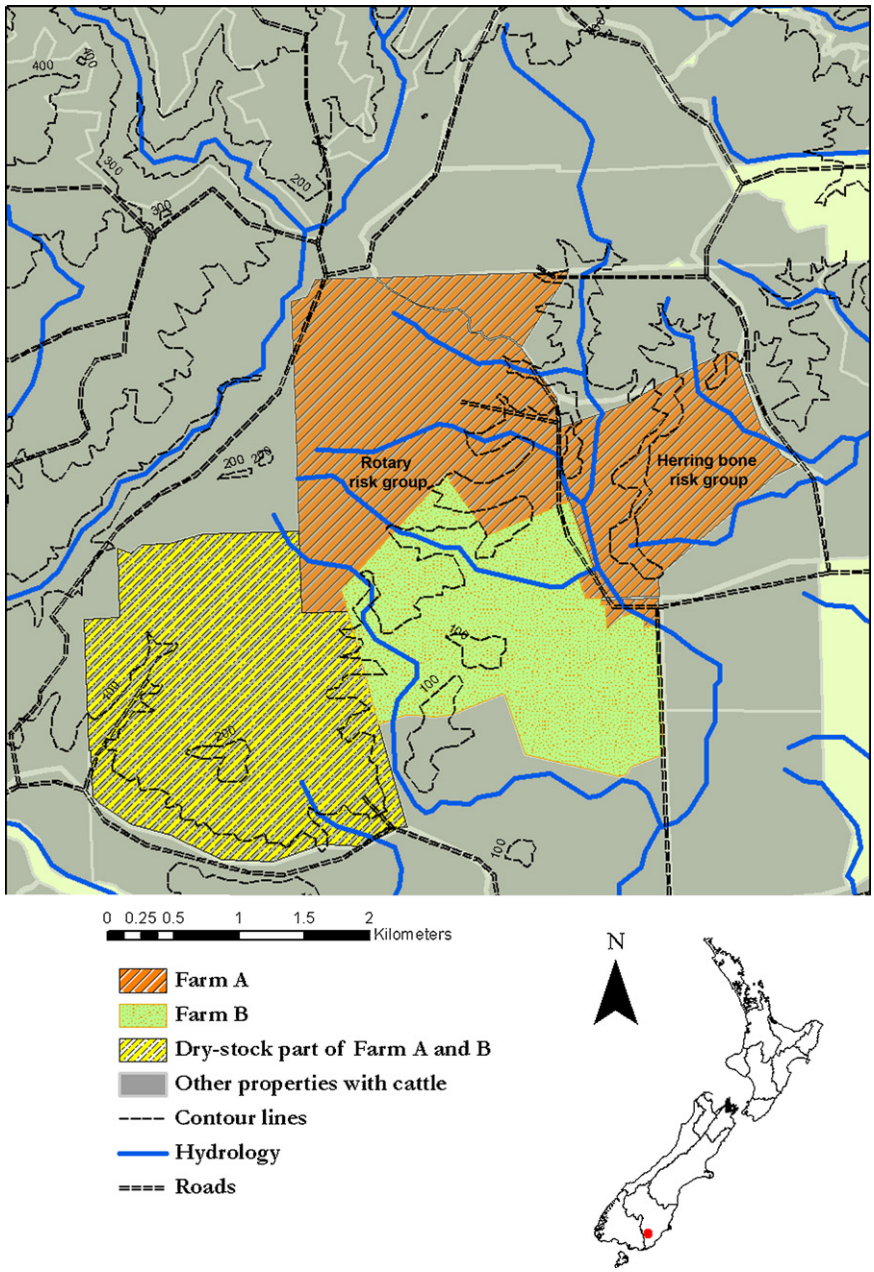

Fig. 1. The locations of properties (Farm A and B) with cattle infected with *Taenia saginata* cysts.

cysts was detected at a low prevalence (6 July 2009, 2/42) in one consignment only (Fig. 2).

3.2. Cow management groups

Farm A had two milking parlours, a rotary shed where approximately 1000 cows divided into two herds were milked (rotary risk group) and a herring bone shed (herring bone risk group) where one herd of approximately 400 cows were milked. The earliest calving cattle from both risk groups were initially milked out of the herring bone shed. From early October 2009 (subsequent to calving being completed and prior to mating beginning) cattle were drafted into their respective herring bone or rotary groups.

The total number of infected cattle detected from four kill lines from the rotary risk group was 39/91 (43%) and from three kill lines from the herring bone risk group was 11/34 (32%). All but 6 of the 104 cows culled from the negative consignments prior to *Taenia saginata* cysts being detected were from the rotary risk group.

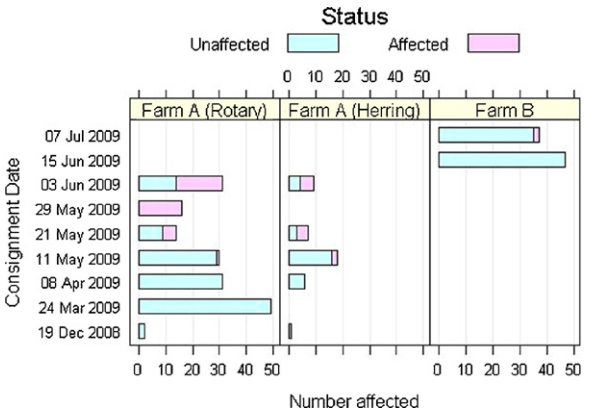

Fig. 2. The status of adult cattle for *Taenia saginata* cysts determined by meat inspection of cattle from Farm A for two risk groups (herring bone risk group and rotary risk group) and from Farm B for all risk groups (87 (214/245)% of cattle from consignments were able to be assigned to a risk group slaughtered at meat processing plants over time).

The apparent prevalence of *Taenia saginata* cysts infection in cattle from Farm A in 3/4 positive freezing works consignments was high (40–100%). The relatively low sensitivity of detection of *Taenia saginata* cysts through meat inspection is likely to significantly underestimate true prevalence. Results from simulations in WinBugs showed that the mean prevalence from simulations was 64 (SD = 21)%.

On Farm A, management of the farm changed in early June 2009 and all cattle were sold. The farm was completely restocked with new cattle on 1 July 2009. Several weeks after arrival of cattle on to the farm, cattle were broken up into the same management groups (rotary and herring bone) that had been used previously. The prevalence of infection in cattle, 100 days after arrival, based on serological testing was 0 (0/27)% and 0 (0/29)% for the rotary and herring risk groups, respectively.

On Farm B, cattle were divided into three management groups that grazed on separate spatial areas of the farm. Group one consisted mainly of cows on their first and second lactation; Group two of mixed age cows and Group three of yearling replacement cattle grazed on the dry-stock (non-milking herd) part of the farm. The history of the two affected cattle on Farm B was insufficient to determine whether exposure had occurred within a specific management group grazed on a specific part of the farm. Serological testing gave the prevalence of infection as 0 (0/61)%, 2 (1/62)% and 2 (1/51)% for Group one, two and three, respectively.

3.3. Replacement stock management

On Farm A, young stock incorporating rising one-year-old and two-year-old cattle were grazed on a 500 acre dry-stock property located on the south-western side of the rotary shed farm (Fig. 1). Cattle from the dry-stock part of the farm were unlikely to have been exposed to pasture from the dairy farm beyond 1 November 2008. On 19 August 2009 *Taenia saginata* cysts was detected in 50 (3/6)% of cattle from the young stock group sent to slaughter.

On farm B, young stock were managed on the same dry-stock property used by Farm A, but grazed separately from Farm A young stock. The only area common to both groups was a yarding area where cattle from both farms were brought in for animal health interventions such as drenching.

3.4. Infection dates

Cysts from the 3 June 2009 consignment from Farm A were aged as approximately two to four months old giving an infection date between February and April 2009. Cysts from young stock from the Farm A 19 August consignment were aged as over 4 months old giving an infection date of mid-April 2009. On farm B, cysts from the 7 July 2009 shipment were aged at over 4 months old giving an infection date of early February 2009.

3.5. Septic tanks

Six septic tanks on Farm A were inspected and one determined to be dysfunctional. The malfunctioning septic tank was leaking raw sewage onto nearby pasture and was identified as being a potential pathway for exposure of cattle to human effluent. The dysfunctional septic tank was associated with the house on the herring bone farm, inhabited by the farm manager and family.

Analysis of grazing management showed that only cattle from the herring bone risk group grazed in close proximity to the dysfunctional septic tank during the period that infection of cattle was likely to have occurred. Conveyers such as motorbikes or people walking through the effluent could potentially expose cattle from the rotary risk group. We were not able to identify any significant carriage of material that could explain similarly high prevalences between the Farm A management groups. The paddock where the septic tank was located was not a natural throughway of people or vehicles to the rotary shed farm; nor did it appear that natural drainage would contaminate other areas of grazing. On Farm B all septic tanks appeared to be functioning appropriately. No septic tanks from both farms had been emptied within a two-year period prior to the outbreak occurring. None of the effluent from septic tanks drained into animal effluent reservoirs.

3.6. Ration and water supply

The herring bone herd from Farm A was fed an all grass diet in contrast to the rotary shed herds where supplements included concentrated whey permeate and balage, a form of ensiled grass, sourced from the dry-stock part of the farm. Water for all herds was sourced from either the town supply water scheme (potable water) or from a bore located at a depth of approximately 30 m. The bore was not capped, nor set in concrete, providing a potential opportunity for contamination of the water supply to occur.

The bore water from Farm A was found to be high quality with a total coliform count of 2 MPN/100 ml and an *Escherichia coli* count of <1 MPN/100 ml. Hence there was no evidence for contamination of drinking water with human faeces.

3.7. Water conveyance

A large stream passed through Farm A but was located only on the herring bone part of the farm. Access to the stream by cattle was limited as most sections of the waterway were fenced off from general grazing areas. The sections of land that the stream passed through had not been subject to flooding. The water from the stream has previously been identified as being of poor quality (Brown, personal communication, 2009),[1] exceeding guidelines for total nitrogen (1.220 g/m^3), dissolved reactive phosphorous (0.13 g/m^3), total phosphorous (0.301 g/m^3), and *Escherichia coli* (660 MPN/100 ml).

The stream did not pass through Farm B but was in close proximity (<50 m) to a bore used to supply cattle from Farm B with water. The bore water was found to be high quality with a total coliform count of 1 MPN/100 ml and an *Escherichia coli* count of <1 MPN/100 ml.

Taenia saginata cysts were not detected in 71 cows sent for slaughter on 1 May 2009 from a dairy farm directly downstream from Farm A and contiguous to the eastern boundary of both Farm A and B.

3.8. Farm staff

Data was collected on staff present on both farms between January and June 2009. Over this period, Farm A and B were staffed with six and eight workers, respectively in addition to the managers and family. Of those staff present 7/14 (50%) were from overseas origin (3 South American, 3 European and 1 Asian). All farm management and staff had travelled overseas at least once over the previous 5 years. Three New Zealanders, two from Farm A and one from Farm B, had travelled to Asia but none had visited Latin America. There were no staff common to both Farm A and B; although there was close association between staff from both farms. There were a number of short term contractors used on both Farm A and B.

Four (20%, 4/20) of the questionnaire respondents indicated that they had defecated somewhere on the farm without the use of toilet facilities. The frequency of this behaviour was not provided. All four of these respondents indicated that they knew of other farm staff that had carried out the same behaviour. All respondents ate beef and 60 (12/20)% and 20 (4/20)% indicated that they preferred their beef rare and ate home killed beef, respectively. None of the respondents indicated that they had observed evidence of tapeworm infection. Faecal samples were provided from 90 (9/10)% of people from Farm A and 100 (10/10)% of people from Farm B. All of these samples were negative for *Taenia saginata* eggs and proglottids.

4. Discussion

The high prevalence of infection in cattle from Farm A indicated that there had been a significant source of contamination of cattle feed/water with *Taenia saginata* eggs. Failure to detect *Taenia saginata* cysts serologically in new cattle grazed on Farm A implied that there had been a point source exposure to the original herd on Farm A. In contrast to the high prevalence on Farm A, the prevalence of infection in the affected consignment of cattle from Farm B and those cattle tested serologically was low. The disparate infection rates and the timeline for detected infection implied that people strongly associated with Farm A and weakly associated with Farm B were probably the source for Farm B's infection rather than vice versa.

On Farm A, the rotary and herring bone risk groups were kept relatively separate. A high prevalence of infection in both risk groups inferred a common water or food borne source of infection or contamination over a wide area of the farm. No ration was common to both risk groups subsequent to stock being drafted into their respective risk groups from early October 2008. No evidence was found of contamination occurring in drinking water, or water contaminating pasture from the main stream passing through the farm.

Unhygienic toiletry practices of people associated with Farm A could explain the high prevalence of infection of cattle in Farm A and the presence of infection on Farm B. The eastern reaches of Farm A were approximately 2 km and 1.5 h from the rotary dairy shed. The distance and time from the cow shed, as well as privacy provided by topography and early morning milking of cattle could have meant that in some instances unhygienic toiletry behaviour, such as defecation on pasture may not have been inhibited by normal cultural practices. Four respondents indicated that at times they had defecated outside of normal toilet facilities. Given the sensitivity of providing this type of personal information it is likely that others carried out the same type of behaviour. Indirect spread through spontaneous release of proglottids from human hosts could lead to contamination of food or water with eggs (Hall et al., 1981; Flisser et al., 2005). However, whilst this mode of spread is possible it would seem doubtful that this would explain the high prevalence of infection in Farm A, but could explain the low prevalence on Farm B.

Staff from both Farm A and B were multicultural, originating from Asia, Europe and Latin America. Latin America is known to have high rates (0.1–0.8) of taeniosis in humans (Murrell, 2005). The rate is somewhat lower in Europe (0.02–0.03), (Murrell, 2005; Abuseir et al., 2006). The overseas origin of farm staff where prevalence of taeniosis is high has relevance as a potential pathway for future outbreaks of bovine cysticercosis in New Zealand cattle. New Zealanders who have travelled overseas and potentially been exposed to *Taenia saginata* cysts could also be a source. Data obtained from farm workers showed that overseas travel was very common amongst people associated with both affected farms; although Latin America and Africa, where taeniosis is high, did not appear to be a common destination. If farm workers were responsible for spreading infection through unhygienic toiletry practices, other farms are likely to be exposed if affected workers left current employment and maintained the same vocation.

No farm staff associated with affected farms was identified as being infected with *Taenia saginata*. Despite poor sensitivity of an individual faecal test, test sensitivity was increased by testing three stool samples from each per-

[1] E. Brown, Otago Regional Council, Dunedin, New Zealand.

son. In addition personal history provided some evidence that people were not infected. There remains the possibility of false negative tests or infection having been lost in the interval between infection of cattle and testing of people.

Faecal samples were examined using microscopy. Other test methods such as anal swabs or the Graham scotch tape method offer superior sensitivity (Pawlowksi and Schultz, 1972; Dorny et al., 2005); however, they require a medical intervention for sample collection. We chose faecal testing as we considered that people would be more likely to provide samples for testing. Three samples were provided from each subject as test sensitivity increases with repeated sampling (Hall et al., 1981). Other testing methods such as copro-antigen testing and copro-PCR are likely to have increased sensitivity; however, they were not readily available in New Zealand.

There were a number of farm contractors used by both farms. Only two of these were identified as being plausible as a potential source of cattle infection. The first contractor was a weed sprayer used in early February 2009. Only the dry-stock property, used by replacement cattle of both farms, was sprayed; although, grass harvested from this area was used to feed cattle from the rotary risk group of Farm A in the spring. Hence, exposure from this contractor would not explain high prevalences in both risk groups from Farm A. The second contractor was used to spray accumulated effluent over pasture grazed by the rotary risk group. If the contractor's tank/equipment had been contaminated with human effluent exposure would have occurred in this risk group only. Evidence for human contamination of effluent spraying equipment was not found and the contractor denied that collection of human effluent had ever occurred. In addition, if either these contractors or others had been the source of infection it would be expected that a number of other farms would have been exposed at similarly high prevalences. To date this presentation has not occurred.

The investigation identified a dysfunctional septic tank on Farm A where raw human effluent was draining directly onto pasture. The temporal and spatial relationship between exposure and prevalence in cattle strata did not support the septic tank as a source. In addition, none of the permanent occupants of the house were identified as being infected with *Taenia saginata*. Despite the lack of evidence, this pathway cannot be completely excluded. Septic tank sludge has been identified as a common source of high prevalence infection in cattle from previous reports in the literature (Ilsøe et al., 1990).

It is difficult to interpret the significance of the negative consignments in Farm A prior to *Taenia saginata* cysts being identified. Assuming the sensitivity and specificity of meat inspection to be 33% and 97%, respectively inspection of 50 cattle would be sufficient to detect a prevalence of infection of 10% and inspection of 100 cattle to detect a prevalence of 1%. Therefore negative consignments may indicate that infection was not present at the time that these negative consignments were inspected.

Exposure of cattle could have occurred in late April 2009 given a 2–3 week period for earliest development of cysts (Silverman and Hulland, 1961); however this does not fit with histological aging of cysts which suggested that first exposure may have occurred in early February 2009. The true date of exposure is likely to lie somewhere between February and April 2009, with the most likely period of exposure being late March/early April 2009.

Aging of cysts is problematic as there is a large amount of variation in morphology of cysts between animals and within tissues from the same animal (Silverman and Hulland, 1961). In addition, the experimental studies used to age cysts involved artificially infecting calves. It is likely that the host reaction to infection will vary with age; hence, these studies may not be reliable when aging cysts from adult cattle. Not identifying the animal that cysts were collected from in our investigation could also have affected the accuracy of aging.

Despite an intensive investigation, the source of infection of cattle was not found. Several risk factors for exposure of cattle were identified that may be applicable in future outbreaks. People were commonly employed from countries where the prevalence of taeniosis was high. Overseas travel was common amongst people associated with both farms, although travel to countries with high prevalences of taeniosis/cysticercosis was not common. Unhygienic toiletry behaviour did not appear to be uncommon on both farms, perhaps reflecting the availability of normal toilet facilities. A dysfunctional septic tank had gone unnoticed that was draining raw effluent onto pasture grazed by cattle. If these factors are common to other farms it is possible that more high prevalence outbreaks could occur in the future.

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