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SMALL ANIMALS

Echinococcus granulosus and other intestinal helminths: current status of prevalence and management in rural dogs of eastern Australia

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Objectives Ascertain the prevalence of intestinal helminths in rural dogs from eastern Australia and Tasmania. Identify farm management practices contributing to the perpetuation and transmission of *Echinococcus granulosus*.

Methods Helminth infection in dogs was determined microscopically through faecal flotation. Infection with *E. granulosus* was determined via faecal antigen-capture ELISA and coproPCR. Taeniid eggs were identified using molecular methods. Data on dog management and owner understanding of hydatid disease were collected via questionnaire.

Results Faeces were collected from 1425 Australian rural dogs (1119 mainland; 306 Tasmania). Eggs of hookworms were most prevalent, up to 40.2%, followed by whipworms (*Trichuris vulpis*), up to 21.2%. Roundworms (*Toxocara canis* and *Toxascaris leonine*) were least common, up to 6.1%. Taeniid eggs were found in 11 dogs (5 *Taenia pisiformis*; 2 *T. serialis*; 4 *T. hydatigena*); 2 of the *T. hydatigena*-infected dogs were also *E. granulosus* coproantigen-positive. Of the 45 dogs found to be *E. granulosus* coproantigen-positive, 24 were in Tasmania, 16 in NSW, 3 in Victoria and 2 in Queensland. Three Tasmanian coproantigen ELISA-positive dogs were also coproPCR-positive. The most common dog ration was commercial dry food, but half the owners fed raw meat to their dogs and some fed offal of lambs (8.9%) or mutton (7.8%). More than half (69%) of owners weighed their dogs before deworming. Few dewormed their dogs often enough to ensure they remained cestode-free and owners hunting wildlife usually left carcases where they were shot.

Conclusions *E. granulosus* is still present in Australian rural dogs, including Tasmania, but at low levels. Owner behaviour perpetuates transmission of cestodes.

Keywords cestodes; coproantigens; dogs; *Echinococcus granulosus*; hydatid disease; intestinal helminths

Abbreviations ACT, Australian Capital Territory; bp, base pair; NSW, New South Wales; OD, optical density

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Previous studies on the intestinal helminths of rural domestic dogs are few, dated and almost exclusively directed towards detecting the cestodes that have sheep as their intermediate host, namely *Taenia hydatigena, T. ovis* and *Echinococcus granulosus*.[1–3] Detection methods have been faecal flotation with microscopy for detecting taeniid eggs or arecoline purgation to obtain adult tapeworms. However, a more recent study in which sera were screened from Victorian farm dogs found that four of the dogs (10.2%) had detectable antibodies against *E. granulosus*.[4]

The *E. granulosus* coproantigen ELISA has been used worldwide to monitor dog infection in control campaigns.[5] The first and only report of a field study of *E. granulosus* in Australian dogs using this test collected faeces from rural dogs in two relatively small geographical areas: around Yass in New South Wales (NSW) and the other around Mansfield and Whitfield in Victoria.[6] The authors reported 'an unexpectedly large proportion' of *E. granulosus* coproantigen-positive dogs (NSW 99/344 (29%), Victoria 37/217 (17.5%)).

The prevalence trend of intestinal helminth infection in Australian dogs since the 1970s has been progressively downward,[7] the likely result of the production and ready availability of efficient deworming products that are actively promoted by veterinary pharmaceutical companies, as well as the development of highly palatable dry dog food.

Nevertheless, since its inception in 2006, the National Sheep Health Monitoring Program[8] has consistently reported high prevalences of cysticerci of *T. ovis* and *T. hydatigena* in slaughtered sheep from all sheep-rearing areas of Australia. Sheep infected with hydatid cysts of *E. granulosus* are also regularly reported, mainly from the eastern states, but at a lower prevalence compared with the cysticerci of *Taenia* species. These data suggest that the perceived drop in intestinal helminth infection in urban dogs[7] may not be as marked in rural dogs.

Although the prevalence of *E. granulosus* in Australian domestic dogs is less than it was 20 years ago, this is not the case in the wild dog population (dingoes and dingo–domestic dog hybrids). A number of studies conducted in eastern Australia have demonstrated high prevalence in most of the wild dog populations, commonly with worm burdens far higher than those seen in domestic dogs.[8–12] In areas where wild dogs and sheep interact, wild dogs may transmit *E. granulosus* infection (hydatid disease) to sheep, providing a potential conduit for transmission of infection to rural dogs, as has been demonstrated in Victoria.[11]

The present study was directed specifically towards intestinal helminth infection in rural and peri-rural dogs residing in eastern Australia, which commonly receive less veterinary supervision than their urban counterparts. During the study we also collected data, through

an owner questionnaire, on the feeding and deworming of rural dogs, other activities undertaken by owners, such as hunting and home slaughter, and also dog owners' knowledge regarding the transmission of hydatid disease. This survey of *E. granulosus* and other intestinal helminth infections in Australian rural domestic dogs was undertaken from Tasmania to south-eastern Queensland.

Materials and methods

Recruitment of dogs to the study

Farmers and people living in rural areas in NSW were contacted by Livestock Health and Pest Authority veterinarians or rangers. Farmers and rural dwellers in Tasmania, resident in the vicinity of traced-back hydatid-infected cattle, were contacted by their state hydatid control officer (Department of Primary Industries Parks Water and Environment) and requested to provide a faecal sample from their dogs. Therefore, the collection of faecal samples in Tasmania was more targeted than on the Australian mainland, because only rural dog owners located in the northern 25% of Tasmania were contacted, as this was the area from which hydatid-infected cattle have been identified during the past 12 years (Figure 1). Dr Jenkins contacted farmers in the Australian Capital Territory (ACT) via the ACT Leasees Association. Through articles in the rural press and interviews on rural regional radio programs, Dr Jenkins invited rural dog owners in Victoria and NSW to contact him if they wished to be included in the study. Dog pounds in the ACT, NSW, Queensland and Victoria, whose catchment covered at least some rural or peri-rural areas were contacted and invited to be part of the study. Faecal samples from 1608 dogs were examined during the study.

Dog owner questionnaire

Questionnaires were sent to all dog owners participating in the study. It was made clear to each owner that completing the questionnaire was completely voluntary. The questionnaires were not anonymous because it was important to be able to communicate findings back to owners. Apart from owner contact details, the questionnaire requested information on a range of topics, including property type,[13] presence of feral animals, source of water for livestock, whether owners hunted wildlife and the fate of hunted carcases, number and type of resident dogs (working, hunting, pet), home slaughter and fate of offal/meat, deworming frequency, what the dogs were fed and whether they were confined when not working. We also sought information about the level of understanding dog owners had on the transmission pathway of hydatid disease.

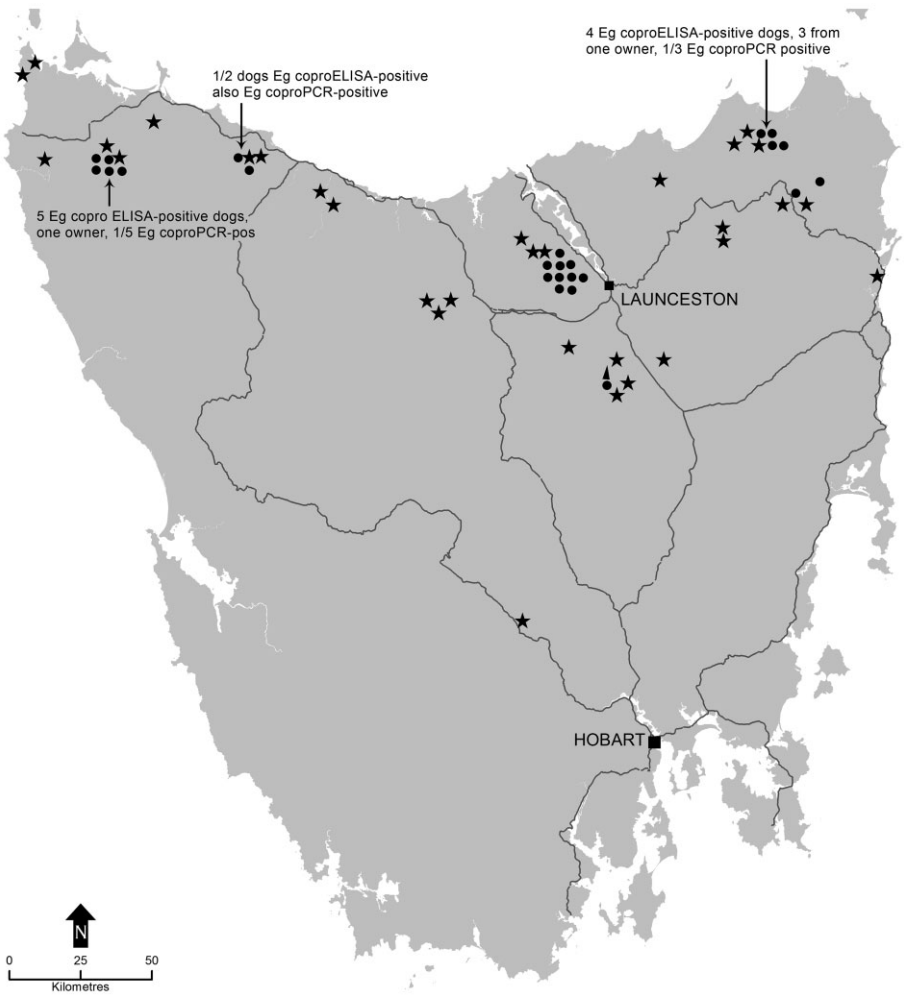

Figure 1. Locations of *Echinococcus granulosus*-infected cattle (stars) and sheep (triangles), *E. granulosus* coproantigen-positive ELISA and coproPCR-positive dogs (dots).

Faecal flotation

Samples of faeces were subjected to a faecal flotation test using standard methodology with saturated sodium nitrate as the flotation medium. Eggs were visualised microscopically and where possible identified to species level through their morphology. Approximately 2 g subsamples of faeces containing taeniid eggs were placed in 80% ethanol and sent to the Institute for Parasitology, University of Zürich, for identification by molecular methods.

Taeniid egg identification

Taeniid egg isolation was performed using a flotation and sieving method.[14] Briefly, 8 mL of zinc chloride solution (1.45 g/mL) were added to 2 g of each faecal sample. The samples were homogenised by vortex and centrifuged at 1000*g* for 30 min. The supernatant was passed through 41- and 21-µm mesh sieves. The taeniid eggs were collected from the 21-µm mesh and resuspended in water in a 10-mL flat tube. Egg identification was carried out using an inverted microscope. DNA extraction was performed using a multiplex PCR kit (Qiagen, Hilden, Germany).[15] A multipex-PCR[16] targeting two mitochondrial genes, NADH dehydrogenase subunit 1 (*nad1*) for *E. multilocularis* and small subunit of ribosomal RNA (*rrnS*) for both *E. granulosus* and *Taenia* spp., was used for species identification of the taeniid egg-positive samples. For samples that were positive for *Taenia* spp., species level was achieved by direct sequencing of the amplicons. Sequencing was performed by Synergene Biotech GmbH, Biotech Center Zurich, Switzerland (http://www.synergene-biotech.com) with the primer Cest5seq.[16] The sequences obtained were compared with those available in the GenBank nucleotide database by BLAST search (http://www.blast.ncbi.nlm.nih.gov).

Echinococcus granulosus *coproantigen ELISA*

A genus-specific sandwich ELISA (the Salford (UK) in-house *E. granulosus* coproantigen test) was used to test supernatants of dog faecal samples for the presence of *Echinococcus* coproantigen.[17,18] Controls including pooled supernatants of naturally infected Australian dogs and antigen spiked faecal samples (1 : 50 and 1 : 100 with *E. granulosus* whole worm extracts) were used throughout the procedure. Negative controls from the Falkland Islands were also included.

Echinococcus granulosus *copro-PCR*

Primers (Eg2691 5′-ACACCACGCATGAGGATTAC-3′ and Eg2692 5′-ACCGAGCATTTGAAATGTTGC-3′) amplifying an *E. granulosus* 133 base pair (bp) fragment of the tandem repeat and larger bands corresponding to size increments of 269 bp (the size of the unit repeat) were used,[19] implementing reagent modifications described by Boufana et al.[20] The PCR was performed in a final volume of 25 µL containing 10 mmol/L Tris-HCl, pH 9.2, 25 mmol/L KCl, 1.5 mmol/L $MgCl_2$, 200 µmol/L (each) dNTPs (Promega, UK), 0.4 µmol/L of each of the amplification primers, 2.5 units of *Taq* DNA polymerase (GoTaq, Promega, UK) and target DNA. The Mastermix fluid was covered with a layer of mineral oil to prevent evaporation. Thermal cycling of the amplification mixture was performed in a Strategene® Robocycler 96 (La Jolla, CA, USA) and involved 5 min at 95°C, followed by 35 cycles, each of 1 min at 95°C, 1 min at 55°C and 1 min at 72°C, with a final elongation step for 10 min at 72°C for 40 cycles.

Figure 2. Tasmanian hunting dog secured next to a dead cow for use as a food source.

Approvals

Collection of the dog faecal samples and the use of the questionnaire were approved by the Charles Sturt University Animal Experimentation Ethics Committee and the Human Experimentation Ethics Committees, respectively. Participating dog owners also signed a consent form agreeing to have the faeces from their dogs tested.

Results

Questionnaire

A total of 179 owners returned completed questionnaires; a synopsis of their responses is presented in Table 1. Not everyone provided answers for all questions.

Backgrounds of dogs in the study

The dogs included in the study came from a variety of farm types,[13] but 67% were from properties where sheep were raised as the sole enterprise or part of a mixed enterprise. The average number of dogs per property was four, comprising three working dogs and one house dog. The mean numbers reported per property were 2.81 (range 0–50) working dogs, 0.19 (range 0–13) hunting dogs and 1.03 (range 0–13) pet dogs. A total of 93 respondents (52%) allowed their dogs to travel in the vehicle cabin, and 85 (47.5%) allowed access to the house.

Dog diets

Almost all dogs (88.3%) were fed dry dog food exclusively or as part of their daily diet (Table 1). Of those fed a mixed diet, 29.6% were fed fresh raw meat, of which 5.6% of owners fed sheep meat. Home slaughter was undertaken by almost half the owners (49.2%) and between 7.8% and 8.9% of owners feed offal of lambs or mutton sheep to their dogs (Table 2). The most commonly identified offal component fed was hearts. In addition, 74.3% of owners thought their dogs could have access to carcases of dead animals and 20.1% of owners also fed whole rabbits to their dogs.

Deworming

Two main dog deworming programs were identified, every 2 months (22.4%) or every 4 months (32.9%), and 5.3% of owners reported they

Table 1. Synopsis of dog management and human activity data collected from 179 questionnaires returned by rural dog owners in eastern Australia between 2008 and 2011

Question (number responding to the question)	Number of positive responses (% of respondents to question)
Type of enterprise (165)	
Grain/sheep/beef cattle	28 (17.0)
Sheep/beef cattle	48 (29.1)
Sheep	35 (21.2)
Beef cattle	17 (10.3)
Dairy cattle	1 (0.6)
Other	36 (21.8)
Deworming interval (170)	
Never deworm	9 (5.3)
1 month	16 (8.9)
2 months	38 (22.4)
3 months	15 (8.8)
4 months	56 (32.9)
5 months	2 (1.2)
6 months	0
7 months	16 (9.4)
8 months	0
9 months	17 (10.0)
10 months	0
11 months	0
12 months	10 (5.9)
Dog food (179)	
Dry dog food only	75 (42)
Dry + raw sheep meat	10 (5.6)
Dry + frozen sheep meat	2 (1.1)
Dry + raw meat (unspecified species)	17 (9.5)
Dry + cooked meat (unspecified species)	9 (5.0)
Dry + wildlife (feral deer/pig/goat/rabbit)	11 (6.1)
Dry + kangaroo	15 (8.4)
Dry + offal (unspecified species)	2 (1.1)
Dry + chicken	7 (3.9)
Dry + bones (unspecified species)	5 (2.8)
Dry + canned food	5 (2.8)
Feed canned food only	3 (1.7)
Feed offal	
Lamb	16 (8.9)
Mutton	14 (7.8)
Sheep hearts	14 (7.8)
Beef	13 (7.3)
Wildlife	5 (2.8)
Whole rabbits	36 (20.1)
Dog access to carcases (wildlife or livestock) (179)	133 (74.3)
Home slaughter performed (179)	88 (49.2)
Hunting involvement (179)	75 (41.9)
Rabbits	63 (35.2)
Foxes	60 (33.5)
Kangaroos	44 (24.6)
Feral pigs	24 (13.4)
Feral goats	15 (8.4)
Wild dogs	10 (5.6)
Wallabies	2 (1.1)
Skinning wild dogs/foxes (86)	6 (3.4%)
Involvement in lethal kangaroo/wallaby control (179)	152 (84.9)
Fate of cull kangaroo/wallaby carcasses (152)	
Left in paddock/bush	18 (11.8)
Fed to dogs	3 (2.0)
Human consumption	1 (0.6)
Burnt	1 (0.6)
Buried	1 (0.6)
Fate of animals hunted for recreation (144)	
Left in paddock/scrub	24(16.6)
Buried	5 (3.4)
Burnt	4 (2.7)
Dog food	2 (1.4)
Human consumption	1 (0.7)

never dewormed their dogs. The mean deworming interval was 17.4 weeks. More than half of the owners (69.3%) weighed their dogs to ensure the correct dosage of anthelmintic was given, but the remaining 30% guessed the dose. Of those that responded, 49.7% used an all-wormer.

Faecal samples

A total of 1608 faecal samples was collected during the study. However, following collection it was found that 183 samples had been collected from pound dogs dewormed with an 'all-wormer' on arrival at the pound. All samples from these dogs were tested by flotation, found to be negative and not included in the study. Therefore, the study sample consists of faeces from 1425 dogs (1119 from the mainland and 306 from Tasmania: Table 2).

Taeniid egg identification

The faeces of 11 dogs were found to contain eggs of taeniid tapeworms. None was found to be *E. granulosus*. Six were identified as *Taenia pisiformis*, one as *T. serialis* and four as *T. hydatigena*. *Taenia ovis* was not found (Table 3).

Coproantigen ELISA detection

A total of 306 faecal samples from Tasmania and 1119 samples from the mainland were tested. A positive *E. granulosus* coproantigen result was obtained for 21 (1.9%) of the mainland samples and 24 (7.8%) of the Tasmanian samples.

CoproPCR

Fifteen faecal extracts from Tasmania, positive in the coproantigen ELISA (with optical density (OD) readings ranging from high to low) were also subjected to an *E. granulosus* coproPCR. Three of the samples returned a positive result for *E. granulosus*, one a high coproantigen ELISA OD, the other two with medium to low ODs.

On-farm hydatid control

The strategy regarded as most important by farmers for controlling hydatid disease on-farm was deworming dogs frequently (78/161 respondents; 48.2%). Not feeding offal to dogs (41/159; 25.9%) and washing hands frequently (38/160; 23.7%) were regarded as less important. Keeping dogs confined when not working was regarded as least important (2/158; 1.3%) although another 2 respondents considered that no strategy needed to be used, because they considered that there is only a small risk of infection.

Discussion

Approximately half of the rural dog owners nominated deworming dogs as the most important on-farm hydatid control strategy and many appeared to rely on this exclusively. Not feeding offal to dogs and attention to good personal hygiene following contact with dogs were regarded as less important for the control of hydatid transmission to humans. Keeping dogs confined when not working appeared to be regarded as unimportant. This is of concern, particularly as most owners did not deworm their dogs frequently enough to ensure they could never have a patent infection of *E. granulosus* and

Table 2. Intestinal worm prevalence data from farm and pound dogs in eastern Australia

No. of infected dogs (%)	NSW farm dogs (n = 312)	TAS farm dogs (n = 306)	NSW rural dogs (n = 234)	VIC rural dogs (n = 78)	ACT rural dogs (n = 25)	Mainland pound dogs (n = 470)
Total helminth-infected dogs	107 (34.3)	123 (40.2)	36 (15.4)	6 (7.7)	2 (8.2)	137 (29.1)
Species						
Trichuris vulpis	49 (15.7)	65 (21.2)	13 (5.5)	1 (1.3)	1 (4.0)	61 (13.0)
Hookworm*	55 (17.6)	123 (40.2)	24 (10.2)	4 (5.1)	1 (4.0)	82 (17.4)
Roundworm**	19 (6.1)	5 (1.6)	6 (2.6)	0	0	13 (2.8)
Taenia pisiformis	1 (0.3)	1 (0.3)	0	2 (2.6)	1 (4.0)	0
T. serialis	0	1 (0.3)	0	0	0	1 (0.2)
T. ovis	0	0	0	0	0	0
T. hydatigena	3 (1.0)	1 (0.3)	0	0	0	0
Spirometra erinacei	3 (1.0)	0	2 (0.8)	0	1 (4.0)	3 (0.6)
Dipylidium caninum	2 (0.6)	1 (0.3)	0	0	0	9 (0.2)

*Species not identified; **roundworm eggs were identified as *Toxocara canis* (73.3%) and *Toxascaris leonina* (26.6%).
ACT, Australia Capital Territory; NSW New South Wales; TAS, Tasmania; VIC, Victoria.

Table 3. Distribution of the 11 *Taenia* spp. egg-positive dogs and the 45 *Echinococcus granulosus* coproantigen-positive dogs identified during the study

Taeniid tapeworm species	ACT	NSW	QLD	VIC	TAS	Total positive dogs
E. granulosus	0	16	2	3	24	45
T. ovis	0	0	0	0	0	0
T. hydatigena	0	2 + 1*	0	0	1*	4
T. serialis	0	1	0	0	1	1
T. pisiformis	1	2	0	2	1	6

**Echinococcus granulosus* coproantigen-positive also.
ACT, Australia Capital Territory; NSW New South Wales; QLD, Queensland; TAS, Tasmania; VIC, Victoria.

many dog owners fed raw meat and offal and/or admitted their dogs had opportunities to access carcases of wildlife or livestock.

In view of many owners feeding offal and/or fresh meat to their dogs, the presence of eggs of taeniid cestodes in their faeces was expected. Because approximately one-third of owners fed whole rabbits to their dogs, the discovery of eggs of *T. serialis* and *T. pisiformis* in the faeces of some dogs was unsurprising. However, what was surprising, considering the number of respondents who reported feeding rabbits to their dogs, was how few dogs were found to be infected with *T. pisiformis* or *T. serialis*. In view of the number of owners who fed sheep offal (hearts) and/or fresh sheep meat to their dogs, few dogs had eggs of the *Taenia* species using sheep as the intermediate host in their faeces. Four dogs were infected with *T. hydatigena* (Table 3), indicating consumption of sheep offal in the recent past, but despite many owners admitting to feeding raw sheep meat and hearts to their dogs, none of the dogs was found to be infected with *T. ovis*. This absence of *T. ovis* is intriguing when considering the high prevalence of *T. ovis* metacestodes reported in slaughtered Australian sheep.[7]

The low number of dogs with taeniid eggs in their faeces could be related to (1) the dogs being uninfected or (2) if infected, the tapeworms were immature. However, some data recently presented at a parasitology meeting in the USA highlighted possible shortcomings of faecal flotation tests, particularly if centrifugation was not included. Adolph et al.[21] examined 97 dogs postmortem for intestinal helminths and also undertook faecal flotation using saturated sodium nitrate without centrifugation and saturated sucrose with centrifugation on faeces from the same dogs. Saturated sucrose plus centrifugation was found to detect most dogs with helminth eggs in their faeces; however, taeniid eggs were seen only in 4/7 (57.1%) of dogs with confirmed taeniid cestode infection, indicating infections in 42.9% of infected dogs would have been missed. Those authors did not clarify if the taeniid worms in the undetected infections were immature or gravid; nevertheless, these data suggest that, as we did not incorporate centrifugation with our flotation method, a number of *Taenia*-infected dogs in our study may not have been detected.

The high prevalence of hookworm and whipworm infections is unsurprising when considering the deworming intervals reported by dog owners and the conditions under which many of the dogs were observed being kept, chained to a kennel surrounded by faecal material or in a run containing abundant old faeces. The short (14–21 days)

prepatent period of hookworms[22] is likely to account for them being the most prevalent of the nematodes recovered. Despite the long (70–84 days) prepatent period of whipworms (*T. vulpis*),[22] any deworming interval longer than 2 months will increase the chance of infections persisting and reaching patency. Also, particularly with heavy infections, not all whipworms may be removed with a single application of anthelmintic, even at the recommended dose (Jenkins, unpubl. data).

Almost none of the respondents dewormed their dogs frequently enough to preclude taeniid cestodes ever reaching patency. However, despite the fact that owners were, apparently, not deworming frequently enough, maybe what they do is sufficient to keep their dogs free of taeniid cestodes, given that the exposure of dogs to the intermediate stages of these cestodes in sheep and rabbits they are fed is likely to be irregular.

A potential additional means of *E. granulosus* transmission to rural domestic dogs on mainland Australia, apart from being fed sheep offal, is through scavenging the carcases of culled and hunted macropod marsupials and feral pigs left in the bush. Macropod marsupials and feral pigs in many parts of eastern Australia are commonly infected with cysts of *E. granulosus*[9] and our questionnaire data showed that most culled and hunted animals are left where they were killed in paddocks or in the bush, which provides a potential, easily accessible source of *E. granulosus* for unconfined rural dogs.

None of the *E. granulosus* coproantigen-positive dogs had detectable eggs, segments or *E. granulosus* tapeworms in their faeces, a similar situation as previously described.[6] Absence of this unequivocal indication of infection should not be interpreted as the dogs being uninfected and the test results as false positives. Worm burdens of *E. granulosus* in Australian domestic dogs are usually low, a few hundred to less than 100 worms.[23] Compared with *Taenia* species, egg output of *E. granulosus* is small and irregular, with no release of eggs on some days.[24] The most likely explanation for the absence of eggs or segments of *E. granulosus* in these dogs was that the few eggs produced were unevenly distributed in the faeces and absent in the sample examined or that no eggs/segments had been released on the day of collection. Importantly, two of the *E. granulosus* coproantigen-positive/*E. granulosus* egg-negative dogs were also infected with *T. hydatigena*, confirming these animals had indeed been feeding on sheep offal, sometime in the recent past. None of the other *Taenia* species-infected dogs, including two others infected with *T. hydatigena* only, were *E. granulosus* coproantigen-positive, strong evidence that cross-reactions with *Taenia* species in the *E. granulosus* coproantigen test were not occurring.

DNA of *E. granulosus* was detected in only 3 of the 15 Tasmanian *E. granulosus* coproantigen ELISA-positive dogs. This may have been because of the small amount of faecal sample sent for testing (<1 g) or that during the extraction process some DNA was lost and if the amount of starting material is small the PCR may appear negative. Historically, it is well known that some coproantigen ELISA-positives are PCR-negative because faeces contains substances that inhibit the Taq polymerase in the PCR reaction.[19] However, in the absence of eggs or segments of *E. granulosus* in the faeces of the Tasmanian dogs, false-positive reactions in either the coproantigen or coproPCR test cannot be excluded unequivocally.

The prevalence of *E. granulosus* coproantigen-positive dogs on the mainland was low, 21 of 1119 (1.9%). From the questionnaire data, a potentially important source of infection may be through scavenging hunted wildlife carcases left in the bush or paddocks and sheep carcases not removed from paddocks or placed in dead animal pits that were not dog-proof.

Of major interest was that more than half of the *E. granulosus* coproantigen-positive dogs originated from Tasmania. The faeces from 306 dogs from the northern quarter of the island, the same area from which hydatid-infected cattle also periodically originated, were tested and 24 (7.8%) were *E. granulosus* coproantigen-positive (Figure 1). In 2006, following the discovery of a Tasmanian-born hydatid-infected cow, faeces from dogs on the same farm and a number of adjacent properties were *E. granulosus* coproantigen-tested. A coproantigen-positive dog was identified, treated with praziquantel and a subsequent coproantigen test from this dog returned a negative result (Jenkins unpubl. data). The incident was described in an article in the local press at the time.[25] Since 2000, more than 100 hydatid-infected cattle have been reported from Tasmania; however, most of these animals were 'imports' from the mainland. Nevertheless, a number of infected young Tasmanian cattle that had never left the island have been identified (Jessup, unpubl. data). These infected animals have mainly come from farms in the northern end of Tasmania, but the source of their infection has never been determined (Figure 1). DNA studies of cyst material from four of the cattle identified infection as the G1 sheep strain (Jenkins, unpubl. data).

The periodic reports of Tasmanian-born infected cattle and our current canine coproantigen data suggest that *E. granulosus* is still being transmitted in Tasmania, but at a low level. What is particularly curious is that infected sheep identified at slaughter have only been discovered once (Figure 1). Those sheep were slaughtered in a Victorian abattoir and no further reports have arisen. This absence of infected sheep is especially curious because sheep were kept on a number of the same farms or farms adjacent to where hydatid-infected cattle originated and/or *E. granulosus* coproantigen-positive dogs have been identified.

A transmission scenario currently on-going could be revolving around the packs of wallaby-hunting dogs found commonly in Tasmania. Our data have identified 8 (33.3%) of the 24 *E. granulosus* coproantigen-positive Tasmanian dogs as members of hunting dog packs. Wallaby hunters commonly own numerous dogs, sometimes up to 20 animals; feeding that many dogs is expensive and their owners are constantly on the look-out for potential sources of food. These may be hunted or road-killed animals (various macropodid species and possums) or dead livestock (sheep and cattle), fed in pieces or whole including the offal. Regarding the use of whole dead cows as dog food, one or more dogs may be secured within reach of the carcase and allowed to scavenge until it has been consumed (Figure 2). Only 4–5% of Australian bovine hydatid cysts are fertile (i.e. contain protoscoleces)[26] and therefore infective to dogs; nevertheless, whenever dogs are fed hydatid-infected bovine offal there is always a risk of infection. While this study was being conducted, a Tasmanian hunting dog was found to be infected with *T. hydatigena*, identifying this dog as having eaten sheep offal in the recent past.

Curiously, despite *E. granulosus* occurring commonly in sheep and domestic dogs prior to the commencement of the Tasmanian hydatid control campaign in 1965,[27] hydatid infection has never been described in Tasmanian wildlife.[28] The reason for this is unclear, but a suggestion has been that the wildlife top-order predator, the thylacine (*Thylacine cynocephalus*), was refractory to infection. Thus, the conduit between livestock and wildlife, present on the mainland via dingoes, has never existed in Tasmania.[29]

'Provisional eradication' of *E. granulosus* from Tasmania was declared in 1996[27] and a recent study of hospital records[30] has ascertained that transmission of hydatid disease to humans in Tasmania is not occurring. However, *E. granulosus* is still present in Tasmania and being transmitted at low levels between dogs and cattle. This situation needs to be closely monitored to ensure the parasite does not 'break out' into Tasmanian sheep and importantly, humans. Steps need to be taken to eliminate the parasite in Tasmania through an intense eradication program focused on hunting dogs and a re-education program targeted particularly towards hunters and farmers.

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