Encroachment of *Echinococcus granulosus* into urban areas in eastern Queensland, Australia

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Objective To investigate the prevalence of *Echinococcus granulosus* in wild dogs (dingos and dingo–domestic dog hybrids) living in and around human habitation on Fraser Island and in townships of the Maroochy Shire, on Queensland's Sunshine Coast, Australia.

Design Wild dogs were humanely killed on Fraser Island and in the Maroochy Shire because they were deemed a potential danger to the public. Their intestines were collected and the contents examined for intestinal parasites.

Procedure Intestines were removed as soon after death as possible, packed in plastic bags and kept frozen until examination. The intestinal contents were washed, sieved and examined microscopically for the presence of helminths, which were identified and counted.

Results Intestines from 108 wild dogs, 7 foxes and 18 Fraser Island dingoes were examined. *Echinococcus granulosus* was only present in the wild dogs from Maroochy Shire (46.3%) with worm burdens of between 30 and 104,000. Other helminths included *Spirometra erinacei*, *Dipylidium caninum*, *Taenia* spp., *Ancylostoma caninum* and *Toxocara canis*. Two specimens of a trematode (*Haplorchinae* sp.) usually found infecting fish and seabirds were recovered from a Fraser Island dingo.

Conclusion Dingoes on Fraser Island are not infected with *E. granulosus* and do not pose a hydatid disease public health risk to residents or visitors. However, wild dogs examined from the Maroochy Shire do present a potential hydatid disease public health risk.

Key words: dingoes, *Echinococcus*, hydatid disease, public health, wild dogs
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Infection with the intermediate stage (hydatid cysts) of the canid intestinal cestode *Echinococcus granulosus* causes hydatid disease in humans and other animals. This zoonosis is of considerable public health importance in many parts of the world, including Australia.[1] Hydatid cysts develop in the internal organs of the intermediate host as large fluid-filled sacs, mainly in the liver and/or lungs and more rarely in other sites such as the brain and bone marrow. New cases of human hydatid disease continue to occur annually in Australia.[2,3] Infection in humans may lead to major illness and incapacity, with fatal consequences in rare cases. Treatment is commonly major surgery, sometimes accompanied by chemotherapy and a prolonged convalescence.

Echinococcus granulosus is thought to have been introduced into Australia with domestic animals during settlement,[4] possibly originating from north Africa and/or Spain.[5] The traditional transmission pattern of this strain of *E. granulosus* (G1 common sheep strain[1]) is between domestic dogs and sheep. However, the presence of a naïve suite of susceptible native marsupial wildlife intermediate hosts (macropodids), and a large eutherian canid top-order predator, the dingo (*Canis lupus dingo*), capable of killing and eating sheep, allowed the parasite to widely infiltrate Australian wildlife. Today, wildlife is an important reservoir for the perpetuation of *E. granulosus* in Australia,[6,7] while at the same time providing a conduit for the transmission of hydatid disease to domestic animals[8–10] and humans.[11,12]

Echinococcus granulosus occurs widely in wild dogs (dingoes and dingo–domestic dog hybrids) in eastern Australia, particularly in coastal areas and areas associated with the Great Dividing Range[13] where annual rates of precipitation are higher than in many other parts of Australia.[14] Wild dogs commonly have large worm burdens[6,15] and are currently the most important definitive host for the transmission of *E. granulosus* in Australia.

On the Australian mainland, wild dogs occupy top-order predator and scavenger status, ingesting mainly macropodid marsupials (commonly wallaby species), but also a range of other native and introduced species. Dingoes living on Fraser Island supplement this diet with reptiles, fish frames from anglers and birds washed up on beaches.[16]

The human population of Queensland is increasing, with associated urban sprawl, particularly in coastal towns. This urban sprawl commonly extends new suburbs into bushland that is occupied by wild dogs as part of their home range. Reports of wild dogs infected with *E. granulosus* in the vicinity of outer suburbs of some major Queensland urban centres, such as in Townsville, have already been reported,[17] but the extent of this problem in Queensland and the other eastern States has not been fully investigated.

Wild dogs in mainland urban environments cause a public nuisance by defecating in unfenced front gardens and urban public parks, spreading rubbish while scavenging in domestic rubbish bins,

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preying on domestic pets and threatening and occasionally attacking people. On Fraser Island, some dingoes have become habituated to humans through being fed by local residents and tourists, and their uninhibited behaviour is perceived to be a public safety issue. However, the public health implications concerning transmission of *E. granulosus* on the island have not previously been investigated. Maroochy Shire and Fraser Island are important tourist destinations for Queensland, and infiltration of canids infected with *E. granulosus* into urban areas poses an important potential public health risk. In Townsville, 6 of 27 wild dogs examined from areas adjacent to residential development were found to be infected with *E. granulosus*.[17]

Wild dog incursions into urban areas along the Sunshine Coast of Queensland have become such a nuisance that some local authorities, including the Maroochy Shire, now employ registered vertebrate pest controllers to remove them. On Fraser Island, several dingoes deemed aggressive and a potential risk to public safety have been destroyed. We took advantage of these situations to survey the status of *E. granulosus* infection in wild dogs euthanased in and around urban areas of the Maroochy Shire and dingoes euthanased on Fraser Island.

Materials and methods

Trapping locations

Maroochy Shire is located on the coast of Queensland, south of Fraser Island and north of Brisbane (Figure 1), and its main urban centre is Maroochydore (population approximately 17,500). Maroochy Shire is a popular holiday destination, hosting approximately 700,000 visitors annually. Wild dogs were trapped in various locations in and adjacent to urban areas in the Maroochy Shire. These urbanised areas ranged from dispersed development (residences on 5–10 hectare blocks) up to the small-to-medium sized urban communities of Eumundi, Yandina, Nambour, Woombye and Palmwoods, with populations ranging between approximately 500 (Eumundi) to 13,000 (Nambour) (Figure 2).[18] The Maroochy Shire population is most concentrated along the coast, becoming less concentrated in the more inland areas to the north and west of Maroochydore. The areas of human settlement are surrounded by cattle, sugar cane or pineapple farms and/or adjacent to State or national parks. Farms and parks are also interspersed with areas of privately owned scrub and/or woodland.

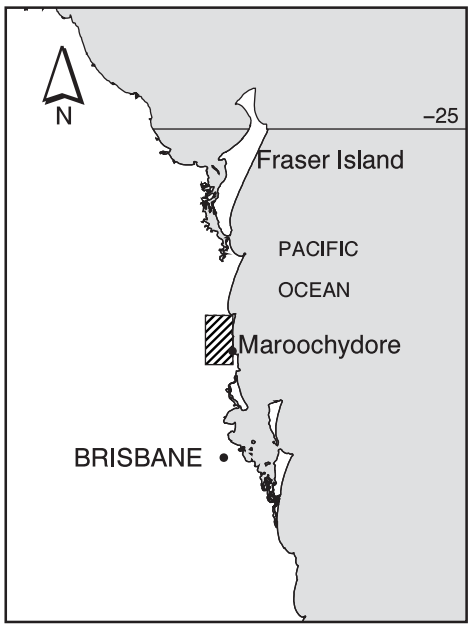

Figure 1. Sunshine Coast, Queensland, Australia, indicating the location of Fraser Island and the Maroochy Shire study area (shaded box, detailed in Figure 2).

Fraser Island is the world's largest sand island (123 km long and up to 25 km wide), situated 1.5 km off the coast of Queensland at its nearest point (Figure 1). A large proportion of the island is taken up by the Fraser Island National Park. Fraser Island has a small population of permanent residents (approximately 675, according to Maryborough City Council and Hervey Bay Council records) and a larger fluctuating population of tourists (approximately 350,000 per year) using camping grounds adjacent to beaches. The southern two-thirds of the island is covered with wet sclerophyll forest, while the northern one-third consists of coastal heath. Dingoes from Fraser Island were trapped around urbanised areas and camping sites on the island.

Duration of specimen collection

Intestines from the Maroochy Shire wild dogs were collected between June 2003 and August 2006, and from the Fraser Island dingoes between December 2003 and April 2005.

Licences and permissions

Trapping and destruction of wild dogs in the Maroochy Shire was undertaken by a licensed pest animal control contractor during the normal course of his duties; on Fraser Island, the dingoes were destroyed by officers of the Queensland Parks and Wildlife Service. All animals were trapped and destroyed in accordance with the relevant Queensland regulations and laws.

Age determination of the wild dogs

Age estimates were based on dentition (wear) and body development.

Collection and treatment of intestines

The intestines were removed as soon after death as possible (usually 15–20 min), packed individually in labelled plastic bags, kept refrigerated for 2 to 3 h while in the field and placed in a freezer on return to base. The intestines were stored frozen for several weeks at approximately –10°C until examination. Intestines (packed with ice in an insulated box) were sent to Canberra by overnight courier and arrived there for examination still frozen.

Prior to examination, each set of intestines was thawed, removed from its plastic bag, placed in a dish of cold water and slit

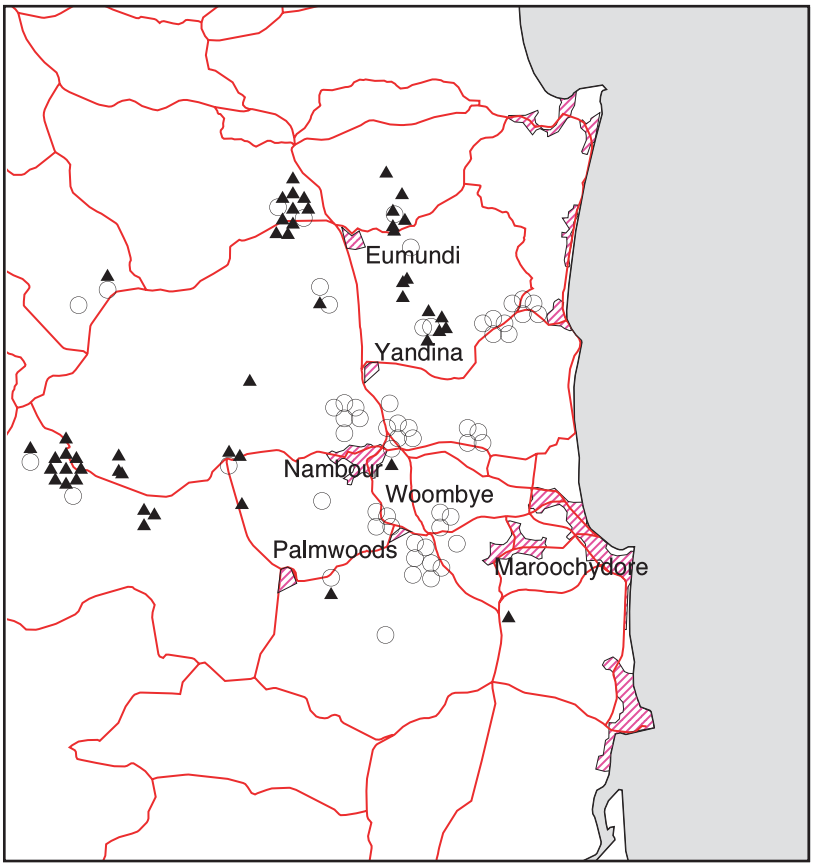

Figure 2. Location of *Echinococcus granulosus*-infected and uninfected wild dogs trapped in the Maroochy Shire study area between June 2003 and August 2006. O, Uninfected wild dogs; ▲, infected wild dogs; pink shaded areas, areas of habitation; lines, main roads.

longitudinally. The contents of the intestines, with any helminths, were dislodged by gentle rubbing and rinsing in the dish of water. The intestines was removed and placed in a 'contaminated waste' bag for later incineration.

Parasite cleaning and counting

The intestinal contents were transferred into a beaker and washed through a fine sieve (mesh 150 µm) with running water into a second beaker. The intestinal contents and any accompanying helminths trapped on the mesh of the sieve were back-washed into a beaker and the volume adjusted to 1 L. The contents of this beaker were stirred well, and two 50-mL subsamples (i.e. 100 mL, one-tenth portion of the intestinal contents) were removed separately into individual beakers. The contents of each 50-mL sample were examined in small amounts in a Petri dish using a stereomicroscope. All *E. granulosus* present in each Petri dish were counted, with the base of the Petri dish marked off in 1 cm squares to facilitate more accurate counting. The sum of *E. granulosus* recorded in each 50-mL subsample was multiplied by 10 to determine the approximate parasite burden of the dog. The number and identity of all other species of helminths present were also recorded.

Results

Examination of intestines

Small intestines from 108 wild dogs (102 estimated to be more than 1 year old and 6 estimated as less than 1 year old) and 7 foxes from the Maroochy Shire, and from 18 Fraser Island dingoes were examined. Of these, 50 wild dogs (46.3%) from the Maroochy Shire were found to be infected with *E. granulosus*, but none of the Maroochy Shire foxes or Fraser Island dingoes was infected.

Location and parasite infestations of wild dogs

Hydatid tapeworm. The *E. granulosus* burdens recovered from the Maroochy Shire wild dogs are recorded in Table 1, with burdens ranging from 30 to 104,000 worms. A proportion of the tapeworms in all infections (number/percentage not determined) were gravid (i.e. terminal segment full of shelled eggs). The sum total *E. granulosus* burden carried by the infected dogs amounted to approximately 599,000 worms. The hydatid tapeworm infections could be bracketed into four 'worm burden' groups based on the number of worms present in individual animals (Table 1).

Locations of infected wild dogs. Wild dogs were caught throughout the Maroochy Shire study area, including in and around each of

Table 1. Distribution of worm burdens in Maroochy Shire wild dogs

Group no.	Worm burden	Group size (% of infected animals)	No. of worms carried by each group (% worms recovered[a])
1	1–999	17 (33.3)	6930 (1.1)
2	1000–9999	20 (39.2)	84,480 (14.1)
3	10,000–21,000	8 (16)	110,120 (18.4)
4	49,000–104,000	5 (9.8)	397,470 (66.4)

[a]Total number of *E. granulosus* recovered from all dingos = 599,000.

the centres of human habitation (Figure 2). The majority of the animals infected with *E. granulosus* were recovered from the less densely settled areas (5–10 hectare blocks) of the study area to the west and north-west of Maroochydore. However, concentrations of wild dogs infected with *E. granulosus* were also caught around the townships of Eumundi (population approximately 500) and Yandina (population approximately 1024), with occasional infected wild dogs being caught in the vicinity of Nambour, Palmwoods and Maroochydore.

Wild dog morphology. Most of the wild dogs examined had ginger-coloured coats, but other dogs with coat colours such as brindle, white with brown or black or brindle patches were caught, and some animals also had tails that were shorter than normal (Figure 3).

Other helminths. Other species of worms recovered from the dingoes and foxes are shown in Table 2. One specimen of a species of *Taenia* and a specimen of *Dipylidium caninum* were recovered from Maroochy Shire wild dogs, but the *Taenia* sp. was in such a poor state of preservation that it could not be fully identified. Common dog round worms, *Toxocara canis*, were recovered from five Maroochy Shire wild dogs. *Spirometra erinacei* and the hookworm, *Ancylostoma caninum*, were commonly found in animals from both locations and were also present in some of the Maroochy Shire foxes.

Figure 3a,b. Wild dog in an urban street, defecating on the front lawn of a private house in Burpengary, Maroochydore Shire, Queensland (note naturally occurring stumpy tail, a feature seen regularly in dingo–domestic dog hybrids throughout eastern Australia) (photograph by M. Goullet).

Two specimens of a trematode (fluke) species were recovered, in good condition, from one of the Fraser Island dingoes. The specimens were clearly adult Heterophyidae; however, distortion of the genital complex of the mounted specimens precluded a definite identification of the species, but these specimens were thought to be *Haplorchinae sensu.*[19]

Table 2. Species of intestinal helminths recovered from the intestines of wild dogs and foxes collected in the Maroochy Shire and from dingos from Fraser Island

	E. granulosus	*Spirometra erinacei*	*Ancylostoma caninum*	Other (no. of animals infected)
Fraser Island				
Dingoes (n = 18)	0	4 (22.2%)	15 (83.3%)	Trematode: *Haplorchiinae* sp. (1)
Sunshine Coast				
Wild dogs (n = 108)	50 (46.3%)	42 (38.8%)	40 (37.0%)	*Taenia* spp. (1)
	0	1	3	*Diplydium caninum* (1)
Foxes (n = 7)				*Toxocara canis* (5)

Discussion

The findings of this study confirm for the first time that wild dogs infected with *E. granulosus* are infiltrating urban areas in the Maroochy Shire of Queensland. These animals cause public nuisance, scavenging in rubbish bins for food, preying on domestic pets and livestock, and defecating in residential gardens and public recreation areas. More importantly, they also represent a potential public health risk to humans through hydatid disease transmission. In the only other study of Queensland wild dogs entering urban areas,[17] it was suggested the local human health risk was low because of the hot dry climate of the area (Townsville) combined with the low worm burdens (all infections < 1000 worms). In the present study, 66% of the infected dogs had more than 1000 worms per dog and the climate is less dry than Townsville, creating conditions for eggs of *E. granulosus* to survive for prolonged periods in the environment. Eggs of *E. granulosus* contained in the faeces of wild or domestic dogs are immediately infective to humans or animals if accidentally ingested, requiring no maturation period in the environment prior to ingestion. Infected wild dogs have been identified as a potential source of infection for humans,[13] and it has been suggested that an important conduit for human hydatid infection could be via coprophagous flies distributing *E. granulosus* eggs by feeding on wild dog faeces and then moving directly on to human food.[17,20]

Studies of taeniid egg distribution via arthropods and other agents demonstrate that 10 days after deposition, a proportion of the eggs had dispersed up to 80 m from the point of origin.[21] It was found that the spread of eggs was equal in all directions in summer, irrespective of grass height, but in winter the spread was asymmetrical (downwind), suggesting that the symmetrical spread of eggs in summer was greatly influenced by the presence of coprophagous flies. Studies of the ingestion of taeniid eggs by coprophagous flies revealed that up to 860 eggs could be ingested by a single fly, and that 82.4% of ingested taeniid eggs were excreted within 24 h. At 24 h after release, flies were found to still be within 1.6 km of their release point. It has also been found that eggs of *Taeniia hydatigena* (a taeniid tapeworm species with a life-cycle similar to that of *Echinococcus* and with eggs morphologically almost identical to *E. granulosus*) were still infective for sheep after passage through the intestine of a fly.[21]

There have been several studies to determine the longevity of eggs of *E. granulosus* in a range of conditions.[21] Hot desiccating conditions are the most lethal, with eggs remaining infective for only a few hours.[22] However, in milder, more humid conditions, such as those found in coastal areas and areas associated with the Great Dividing Range of eastern Australia, some eggs of *E. granulosus* are thought to remain viable for up to a year.[21] This may be an underestimate because it has been demonstrated that eggs of *E. granulosus* may have a higher tolerance of desiccating conditions than previously realised;[23] for example, eggs of *E. granulosus* collected from faeces left in the arid environment of Patagonia (Argentina) for 41 months were used to successfully infect four of four sheep.

Many of the wild dogs examined in the present Maroochy Shire study did not have typical dingo coat colouration, but were brindle or white with brown or black or brindle patches, and a number of them had abnormally short tails. All the animals from Fraser Island were ginger with white feet and tail tip and had a normal length tail. Pure-bred dingo coat colours can be variable, but most commonly are ginger with white paws and tail tip, as well as black and tan or black with white paws and a white tail tip, or with white bodies and pale tan ears.[24] Variable coat colours and short tails are also morphological features commonly seen in wild dog populations in Victoria, New South Wales and the Australian Capital Territory (unpublished data), and indicate that these animals may be hybrids with domestic dogs.[24] Determining the heredity of members of wild dog populations using only morphological features or combined with skull measurements and/or DNA analysis is a highly contentious issue that has yet to be resolved.[25] However, no differences were noted in the *E. granulosus* worm burdens between the Maroochy Shire wild dogs that were apparently hybrids (broken colour and/or short tails) and those that were morphologically what would be regarded as a dingo. This is a similar situation to that seen in NSW, Victoria and the ACT (unpublished data).

Recent studies by Allen of the home range of urban wild dogs in the Maroochy Shire study area, using global positioning system (GPS) tracking collars, demonstrated that in urban areas the dogs have small home ranges, averaging 2.17 km^2.[26] These data contrast sharply with published data for bush-dwelling wild dogs, for which average home ranges were recorded as 21.9 km^2 and 27 km^2.[27,28] The home ranges of the animals tracked by Allen encompassed developed urban areas, town parks, school playgrounds and unfenced gardens of private houses, as well as adjacent pockets of bushland.[26] The absence of *E. granulosus* in most of the animals caught in the south-eastern part of the study area is in stark contrast to the abundance of animals infected with *E. granulosus* caught in trapping sites in the west and north of the study area.

This difference in the prevalence of *E. granulosus* could be related to one or a combination of reasons. Most likely, there is a high turnover of wild dogs in and around the urban areas because of collisions with vehicles and the activities of the local vertebrate pest control officers. This constant loss of animals may itself be reducing the rate of *E. granulosus* transmission between urban wild dogs and macropod marsupials living in the same urban areas, but differences in the social organisation and stability of urban wild dog packs, compared with sylvatic wild dogs, may be most important. As a result of the high turnover of wild dogs in and around urban areas, these areas may become a dispersal sink for itinerant lone animals moving from outside the study area into uncontested territory created by removal of resident wild dogs. This social disorganisation most likely causes urban wild dogs to occur in smaller social groups (singly or in pairs) than sylvatic animals, which consequently reduces their ability to prey on large macropods. As a result, they are likely to prey on the smaller animal species available in urban environments that do

not contribute to the transmission of *E. granulosus*, namely bandicoots (*Permales nasuta* and *Isoondon macrourus*), rats (*Ratus ratus, R. norvegicus* and *R. sordidus*) and possums (*Pseudocheirus peregrinus* and *Trichosurus vulpecula*) and also to scavenge on the ready supply of human food waste.

In the present study there was a wide range of *E. granulosus* burdens in the wild dogs examined, as shown in Table 1. Of the 50 worm populations counted, the majority of the worm burdens were less than 10,000 worms per dog, but 12% of the wild dogs had burdens greater than 10,000 worms per dog, and this small group of animals carried 84.8% of all the worms recovered. Of these animals, five individuals (9.8% of the animals examined) with the heaviest worm burdens accounted for 66.4% of the total worms recovered. Small numbers of unusually heavily infected wild dogs have also been identified in recent surveys in Victoria[9,29] and NSW.[6,15] This phenomenon, of parasite aggregation where most infected hosts have few parasites and a few hosts have many parasites, is seen in various wildlife populations with a range of parasite species, and has been reviewed in detail.[30] The sex and age of the host may also be contributory factors in parasite aggregation, but with *E. granulosus* in dingoes and wild dogs sex does not seem to play an important role (unpublished data). However, the number of previous exposures to *E. granulosus* has been identified as a factor influencing worm burdens in some domestic dogs,[31] and may also play a role in wild canid populations. Gemmell and Lawson referred to the unusually heavily infected members of canid populations as 'super spreaders' and identified their importance in transmission of infection to potential intermediate hosts, based on their high mobility, high egg output and ability to disperse large numbers of eggs over a wide area.[21]

The reason for the apparently recent phenomenon of dingoes infiltrating urban areas of Queensland is unclear. It is likely to be associated with abundant sources of easily accessible food in rubbish bins and the high population of 'domestic prey' (i.e. cats, dogs and livestock) in urbanised areas. An associated reason may also be that prior to urbanisation, these areas were part of the traditional home ranges of local wild dog packs. The urban areas infiltrated by dingoes in this study and that of Brown and Copeman[17] were commonly the more recently developed outer suburbs. During the disturbance associated with construction of new suburbs, resident wild dogs may vacate the area, only to return once building activities have ceased and revegetation has occurred.

The other species of intestinal helminths found, *S. erinacei*, *A. caninum* and *T. canis*, also cause zoonoses, but the most important from a human health perspective is *T. canis*.[32] The eggs of this helminth are highly resistant to environmental conditions and may remain viable in the environment for several years. If embryonated eggs of *T. canis* are accidentally ingested by a human, the larvae that are released migrate throughout the body.[32] Should a *T. canis* larva penetrate the retina of an infected person, partial or total unilateral blindness usually results.

The generally good condition of the trematode specimens recovered from one of the Fraser Island dingoes suggest they were from a genuine infection rather than a spurious infection resulting from accidental ingestion of adult trematodes when consuming a heterophyid-infected seabird. Infections of adult heterophyids are transmitted as metacercariae in the flesh of marine and freshwater fish. Because Fraser Island dingoes have regular access to fish frames discarded by anglers, there is a high probability that this dingo had accidentally ingested a metacestode of a heterophyid. Infections of heterophyids in domestic dogs are surprisingly common. The on-line Host-Parasite (helminth) Catalogue of the Natural History Museum (London) incorporates records of almost 50 species of heterophyids reported in dogs.[33] Probably none of these species is restricted to or even mainly a parasite of dogs, but the long list of species recovered from dogs is a likely reflection of the worldwide distribution of dogs and the relatively low host-specificity of heterophyids.

The *E. granulosus* reservoir in wildlife in eastern Australia is large and widespread,[7,13] but knowledge of the extent of *E. granulosus* infection in wildlife in Australia is incomplete, mainly because of the lack of comprehensive survey data of infection in wildlife, domestic animals or humans. This situation is exacerbated by a lack of political will associated with the relatively small number of humans diagnosed with hydatidosis each year[2] and the lack of data regarding financial losses to the meat industry resulting from hydatid disease. Annual losses to the Queensland meat industry because of hydatid infection in bovine livers alone has been variously estimated from $2.7 million[1] to $6 million.[34]

Until now, people living in urban centres were generally regarded as being insulated from exposure to hydatid infection by virtue of their urban lifestyle, away from offal-eating domestic and wild canids. This is clearly not the case in Maroochy Shire, and the situation is likely to be similar in adjacent shires along the Queensland coast where wild dogs are infiltrating urban areas.

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