R-10577: Part 1 of a two-part project

Pigs as Hosts of Bovine Tuberculosis in New Zealand – a review

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Landcare Research Contract Report: LC0203/098

PREPARED FOR:
Animal Health Board
PO Box 3412, Wellington

DATE: May 2003

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DOI: https://doi.org/10.7931/rd25-2860

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Summary

Project and Client

The role of feral pigs as hosts and vectors of bovine tuberculosis (Tb) in New Zealand and the consequent need for pig control was reviewed by Landcare Research, Lincoln, for the Animal Health Board (Phase 1 of the two-part project R-10577) during August 2002 – March 2003.

Objectives

Review the role of feral pigs and pig hunting in the maintenance and spread of bovine tuberculosis, by:

- updating 1990s reviews of pig ecology, Tb-host status and control methods;
- providing an initial assessment of whether and, if so, how pigs and pig hunters might be managed as part of vector control operations.

Main Findings

Feral pigs occupy 35% of New Zealand (c. 93 000 km^2). Most New Zealanders, and Māori in particular, view feral pigs more as resources than as pests. In 1988, an estimated 23 000 hunters hunted pigs on c. 300 000 days and killed about 100 000 pigs. Pigs have a high reproductive rate, and unhunted populations can potentially double within a year. They are widespread within Tb-infected areas in New Zealand, but are usually held at low numbers by recreational hunting with dogs.

The prevalence of Tb in pigs in some areas is high (>90%). Despite this, hunters currently have a limited knowledge of Tb. Hunters translocate pigs to boost hunting opportunities, and also transport potentially infected carcasses long distances. A few dispose of carcass parts in uninfected areas where they could be scavenged by other wildlife. The best routes for providing hunters with information are presentations at hunting competitions and club meetings, and via hunting magazines and newsletters.

Pigs occupy large home ranges. In good habitat, most range sizes are likely to be less than 10 km^2, at least for sows, and a 6-km radius around a pig kill site is likely to encompass most of its home range. However, shifts of up to 35 km have been recorded in New Zealand.

Pigs appear to be much more susceptible to becoming infected with Tb than cattle, deer, or possums in the same area. This underpins use of pigs as sentinels for detecting the presence of Tb.

Most recent data on prevalence, lesion distribution, and pathogenesis are consistent with pigs becoming infected through scavenging. Some field evidence suggests that possum control substantially reduces the force of infection in pigs.

There are no new data that contradict the long-standing inference that pigs are **not** maintenance hosts in New Zealand. The rate of intraspecific transmission in the wild appears insufficient to independently maintain Tb in pigs. However, we speculate scavenging of pigs by pigs could help maintain Tb for several generations when both pig density and their Tb prevalence are initially high.

Despite the weight of evidence pointing to spillover-end-host status, some circumstantial evidence suggests pigs may play a role in the maintenance and spread of Tb in New Zealand. Infected pig carcasses may transmit Tb to scavengers such as ferrets, cats, and possibly also possums, but there is no evidence indicating direct transmission from live pigs to possums, deer, or cattle. Grossly infected pigs sometimes have large suppurating lesions, so spread via environmental contamination is also possible, but the rarity of infection in susceptible and commonly sympatric species such as sheep and rabbits suggests such transmission is rare.

Overall, our assessment is that there is no strong new imperative for pig control within areas of established infection provided both possums and ferrets are reduced to low densities. Where pig and ferret densities are both high, it is possible that pig control could speed the reduction in reactor rates by at least removing some of the reservoir of infection in the area.

At the margins of infected areas, pig control might reduce the risk of Tb spread, but such control would be costly and be opposed by hunters. It is likely to be more cost-effective to detect totally new outbreaks as they occur rather than to undertake prophylactic vector control to prevent them.

Annual maintenance control is required to maintain a consistently low density of pigs. There is a wide range of affordable options available for pig control when (if) required. Aerial shooting and ground hunting with dogs (with or without Judas pigs and/or trapping) are likely to be the most socially acceptable options. If toxins are to be used, the toxin–bait combination needs to be tailored to the particular situation.

Recommendations

The AHB should not routinely include pig control as part of ongoing vector control operations within VRA’s, except perhaps where:

(a) Vector control is being initiated in areas with both high prevalences of Tb and high densities of pigs. The aim would be to rapidly remove the large reservoir of Tb in pigs, and pig control would need to be coupled with removal of all other long-lived Tb hosts such as deer (where possible infected carcasses should be removed). The AHB should assess whether this is already achieved by current-practice aerial 1080 operations, and if not consider developing bait–toxin combinations that might achieve simultaneous control of possum and pigs more effectively. This approach would likely be opposed by hunters, but could be made more acceptable to them by confirming that it resulted in larger numbers of pigs with less disease within just 2–3 years.

(b) There is a high prevalence of Tb in pigs and moderate or high densities of ferrets. Here the precautionary aim is to reduce the unconfirmed risk of a ferret–pig co-scavenging Tb cycle maintaining the disease independently of possums. However, even in this context pig control is probably not necessary if ferret numbers can be reduced to very low levels more cost effectively than pigs.

At the margins of VRAs and for up to 50 km radius from them, the AHB should not undertake pig control, but should implement a surveillance programme based on feral pigs in areas in which few livestock are available for testing. Ideally, this surveillance programme should aim to utilise pigs killed by recreational hunters (see Ramsey et al. 2001a), but when required complement this with contracted hunting and/or trapping of pigs (or other sentinels such as ferrets) in areas where surveillance coverage is light. This recommendation should be considered in light of a current proposal for a nationwide review of the need for wildlife surveillance. Where Tb is detected in a single pig outside the known infected area, intensive surveillance (and therefore control) of feral pigs within a 6-km radius of the kill site should be implemented. This surveillance could include REA typing of tuberculous pigs. If few pigs are available, either ferrets should be surveyed instead, or Tb-free pigs should be released into the area. Where this surveillance identifies further infection, vector control should be implemented over a 6-km radius around known infection sites, and the surveillance area extended to about 10 km around these sites.

The AHB should aim to reduce the risks posed by translocation of infected pigs or pig carcasses, by (a) educating hunters about these risks via clubs newsletters, magazines, and at pig hunting competitions, and (b) eliminating any new feral pig populations in areas not currently occupied by resident pigs, at least near VRAs.

Longer term, the role of pigs in the maintenance and spread of Tb should be more quantitatively assessed, both by monitoring outcomes of various combinations of vector control within VRAs and by determining the frequency of pig-to-possum transmission, and ferret-to-pig transmission. Some preliminary research on these topics has been initiated at one dryland site (Clarence Valley, Canterbury), but replication in other habitats and with other combinations of vectors and scavengers is needed.

If pig control is undertaken, and if aerial poisoning of pigs as part of initial possum control is not an option, aerial shooting (with Judas pigs) and ground hunting with dogs are the recommended pig control tools, based primarily on their acceptability to hunters. If demand for a poisoning tool grows, an encapsulated (and, ideally, fast-acting) toxin-and-bait combination suitable for aerial sowing, use in bait stations, and as buried ground-laid baits should be developed and tested.

1. Introduction

The role of feral pigs as hosts and vectors of bovine tuberculosis (Tb) in New Zealand was reviewed by Landcare Research, Lincoln, for the Animal Health Board (AHB) (Phase 1 of the two-part project R-10577) during August 2002 – March 2003. The review included an assessment of the need for pig control as part of the National Pest Management Strategy for Tb, a review of potential methods for communicating with the pig hunting fraternity, and a summary of the control tools and management options available.

2. Background

Feral pigs were introduced to New Zealand before 1800, and are now widely but patchily distributed in both indigenous and modified habitats. Their management is complicated by the conflict between them being both a pest and a valued resource. Like other large introduced animals, feral pigs are hunted for food, sport, and money (Fraser 2000, 2001), and historically have been harvested commercially for export. Feral pigs are also widely used by Māori in a way some see as a substitute for traditional foods. However, feral pigs are regarded as conservation pests due to perceived impacts on native species such as kiwi and invertebrates and on ecosystem health and functioning (Nugent et al. 1996; McIlroy 2001). Feral pigs also cause economic damage through lamb predation, damage to pasture and exotic plantations (McIlroy 1990), and the risks to livestock and human health posed by the diseases they sometimes carry. Pigs are potential carriers of exotic diseases (e.g., foot and mouth disease), outbreaks of which could result in significant economic damage to New Zealand.

High prevalences of Tb have been recorded in some feral pig populations in Vector Risk Areas (VRAs: areas in which Tb is regarded as established in wildlife) in New Zealand (Nugent et al. 1996). However, feral pigs are generally considered “spillover” hosts incapable of independently sustaining Tb. One of the main reasons for this is because Tb disappeared from feral pigs in the Northern Territory of Australia when infected cattle and buffalo (but not pigs) were removed (Corner et al. 1981; McInerney et al. 1995).

However, farmers and vector managers in some parts of New Zealand are faced with an extremely high prevalence of Tb in pigs but a comparatively low prevalence of Tb in possums, which are also often at low density. They therefore find it difficult to discount pigs as contributors to the ongoing maintenance of infection in wildlife.

As a consequence, the AHB is faced with ongoing and sometimes strident requests to fund pig control (P. Livingstone, pers. comm.). It therefore requested Landcare Research to undertake an assessment of the likely role of pigs and pig hunting in the local maintenance and spread of Tb. The role of pigs as a host of Tb was previously reviewed for the Board in the mid-1990s (Nugent et al. 1996), and McIlroy (2001) provides a recent update of what is known about the ecology of the species in New Zealand. However, there are some new and as yet unpublished data on the pathogenesis and epidemiology of Tb in pigs (e.g., Lugton 1997; Nugent et al. 2002), and new insights into the potential role of scavenging as a route of

Tb transmission from "end hosts" such as pigs and deer to maintenance hosts such as possums and ferrets (at high densities) (e.g., Ragg et al. 2000; Nugent et al. (in press)). Unfortunately, few quantitative data are available for objectively assessing the threat posed by infected feral pig populations as potential spreaders of Tb. Therefore, this review cannot conclusively resolve the role played by pigs. That will require new information. Instead, the review provides the AHB with the most up-to-date picture as a basis for rejecting (or not) the suite of current proposals for pig control. The primary aim is to determine whether the epidemiological data and insights gained since the mid-1990s reinforce previous conclusions about pig host status.

3. Objectives

Review the role of feral pigs and pig hunting in the maintenance and spread of bovine tuberculosis, by:

- updating 1990s reviews of pig ecology, Tb-host status and control methods;
- providing an initial assessment of whether and, if so, how pigs and pig hunters might be managed as part of vector control operations.

4. Sources of Information

This review updates that of Nugent et al. (1996) using information published in the scientific literature since then, but also drawing on unpublished data held by Landcare Research and (where known about and available) by vector managers and other researchers. It includes an update of Nugent et al.'s (1996) review of potential control tools for feral pigs.

We also assessed potential methods for communicating with the pig hunting fraternity and influencing their behaviour. This included:

(a) Surveying hunting clubs (Appendix 14.1). In September 2002, a two-page questionnaire (Appendix 14.2) was posted to 45 pig hunting clubs. Club officers were asked to provide information on the number of members, forms of communication between the club and its members, and how best they thought members of their club could be educated about Tb;

(b) Assessing the distribution and circulation of pig hunting magazines and newsletters;

(c) Assessing the frequency of (and attendance at weigh-ins for) pig hunting competitions. Most of the information on pig hunting competitions was provided by Bob Jeffares, head of the Ridgeline Judging Systems team (and editor of the New Zealand Pig Hunter magazine). The Ridgeline Judging Systems team comprises four experienced pig hunters who judge pig hunting competitions. During the 2002 season, which extended from Easter to Labour Weekend, they attended 19 competitions and were associated with another 18 in an advisory role, mostly in the North Island;

(d) Surveying individual pig hunters. In late 2002, 60 pig hunters (21 of whom were not members of a pig hunting club) were surveyed (Appendix 14.3) by phone. The main aim was to identify the best way information on Tb issues could be provided to hunters, especially those that did not belong to clubs. Hunters were asked to describe the land types they hunted on, the frequency with which they hunted, how they disposed of killed pigs and offal, and their knowledge of Tb symptoms and VRA locations.

5. Population Status and Resource Value of Feral Pigs

5.1 Distribution, population size, and densities

Feral pigs currently occupy 35% of New Zealand (93 000 km^2; Fraser et al. 2000; Fig. 1). The distribution of pigs has expanded since it was mapped in the 1970s (Challies 1976) and in 1983 (Johns & McGibbon 1986), with the main recent expansions being in Otago, Southland and on the West Coast of the South Island (Fraser et al. 2000). These expansions stem partly from natural spread, but are mainly a consequence of illegal liberations (Section 5.2). They also reflect the extensive conversion of pastoral land to plantation forests, which provide more suitable habitat for pigs.

Extremely high pig densities apparently prevailed in New Zealand earlier last century (123/km^2; Wodzicki 1950). More recently, densities of up to 8/km^2 in heavily hunted areas and 12–43/km^2 in unhunted areas have been reported for the Murchison area (McIlroy 1990). However, these are “preferred habitat” densities, and appear high when harvest data are related to the overall distribution of pigs.

There are no accurate estimates of the number of feral pigs in New Zealand. Extrapolating from the sole estimate of the total harvest (c. 100 000 pigs taken nationally in 1988; Nugent 1992), and assuming an exponential rate of increase of 0.6 (Section 5.3), a sustained annual harvest of this size suggests a population size of c. 110 000. This equates to roughly 1 pig/km^2 as an average across the entire established pig distribution.

5.2 Pig liberations

Hunters continually (and often illegally) liberate domestic and feral pigs to boost hunting opportunities, sometimes in areas previously free of pigs. Twenty-five new populations were identified during the 1990s, at least 22 of which had resulted from illegal liberation (Fraser et al. 2000). Discussion with “officials” from pig hunting clubs indicated that although they were aware of this translocation of pigs by hunters, few clubs were actively involved. A particular exception is the Tokoroa Pig Hunting Club, which manages a large-scale release programme involving some hundreds of pigs annually. In this instance, the liberations are legal, have the approval of the forestry company involved, and the pigs are tested for Tb before release.

The main reasons for the translocation of pigs are: (a) to conserve pigs locally; (b) to increase the quality and/or size of pigs locally; and (c) to establish hunting opportunities in new areas. Many liberations are small-scale and opportunistic translocations made by individual hunters (because they just happened to catch piglets suitable for translocation). Detection of illegal liberations is extremely difficult.

Fig. 1 Geographical distribution of the established range of feral pigs in New Zealand. New populations since approximately 1990 are indicated as points (▪) (from Fraser et al. 2000).

5.3 Population dynamics

For large mammals, pigs have a high intrinsic rate of increase. The gestation period is c. 113 days, and sows can breed from 5–8 months of age, producing up to 10 piglets per litter (Dzieciolowski et al. 1992). The main birth pulse is in late winter and spring (July to November, peaking in September), with a smaller peak in March (Dzieciolowski et al. 1992). Most piglets die before maturity (McIlroy 1990).

Dzieciolowski et al. (1992) estimated an exponential intrinsic rate of increase of 0.90/year for New Zealand pigs, based on reproductive rates and the age structure of harvests. In Australia maximum annual rates of increase of between 0.57 and 0.85 have been measured when food is plentiful (Hone & Pedersen 1980; Caley 1993; Choquenot & Ruscoe 2003). Such rates mean pig populations can double in size within a year. Populations can also collapse rapidly when food is short (e.g., Caley 1993).

Although some New Zealand populations appear unstable with booms and bust possibly related to cycles in the availability of fruit (Thomson & Challies 1988), populations in other areas such as tussock grassland, pine forest, or fern country appear more stable, perhaps because the food supply is more constant in such habitats.

In two New Zealand populations studied by Dzieciolowski & Clarke (1989) in the northern South Island, the mean age at harvest varied from 11.6 to 29.2 months. The factors causing these differences were thought to be pig density, length of time the pigs had been established, and local hunting pressure.

5.4 Resource value

Historically, thousands of pigs were commercially harvested annually for export (Nugent 1992), but commercial harvesting has decreased after a pesticide-residue scare in 2001. There is no nationwide agency responsible for the administration of pig hunting on all lands. The Department of Conservation (DOC) issues about 63 500 “big-game” hunting permits annually (Fraser 2000). These cover deer, goats, chamois, thar, and wallabies as well as pigs. In most commercial pine forests, pig hunting is also conducted under permit, or by allocation of hunting rights to a particular group or pig hunting club.

The recreational value of feral pigs is partly food value, partly the value placed on the hunting experience itself, partly the value associated with working with dogs, and partly the value of sharing experiences and competing with other hunters. In 1988, c. 23 000 hunters spent c. 300 000 days hunting pigs, and took about 100 000 pigs (0.33 pigs/hunted day) at an average cost of $77/pig (Nugent 1992). Targeting of pigs during Tb-vector control operations is therefore likely to be met by strong opposition from recreational pig hunters.

This opposition is likely to be strongest in poor rural areas, such as the central North Island. In these predominantly Māori communities, high unemployment levels results in reliance on feral pigs (and deer) as subsistence foods, with pig hunting and wild pork being an integral part of the way of life. For many Māori, pigs and pig hunting have effectively become part of their “traditional” culture.

6. Home Range Size and Movement Patterns of Feral Pigs

The scale and patterns of movements of pests provides insight into their potential to spread disease (Saunders & Kay 1996), and informs decisions on the scale and type of control required to manage them (Saunders & Kay 1991; Caley 1997).

6.1 Home range sizes

Home range size of feral pigs is correlated with resource abundance, population density, and body weight (Singer et al. 1981; Baber and Coblentz 1986; Saunders 1988; Caley 1993; Dexter 1999; Saunders & McLeod 1999; McIlroy 2001). Variability in these factors explains the wide variation in mean home range sizes in Australia (Table 1) where resource abundance is largely driven by stochastic environmental events (mainly rainfall) and population densities of feral pigs are highly variable (Choquenot et al. 1996). The few New Zealand data conform to this pattern: in pasture/beech forest habitat at Murchison, where food was apparently abundant, home range size varied from 0.3 to 2.1 km^2 (n = 7, McIlroy 1989), whereas home ranges varied from 5.4 to 157.2 km^2 in apparently poorer quality tussock grassland/scrub habitat in Central Otago (n = 14, Knowles 1994).

Including three studies using released pigs (some neutered) as sentinels for disease detection, the mean home range size estimated in five New Zealand studies ranged from 0.70 to 11.7 km^2 (Table 1). Most of the pigs in these five studies had estimated home range sizes of less than 10 km^2 (Fig. 2). However, mean home range size was not estimated for the study in Central Otago where individual ranges much larger than 10 km^2 were recorded, so the upper limit of mean home range size in New Zealand above is an underestimate.

The above estimates are likely to be biased low by the short duration of tracking and the low average number of re-locations per pig in some of the studies (Table 1). Another potential bias results from most New Zealand studies being conducted in areas with limited hunting pressure. In Australia, low-intensity pig hunting did not appear to affect home-range size, but pigs subjected to intense hunting pressure sometimes left their previously defined home range (Caley 1997). Saunders & Bryant (1988) suggested hunting pressure resulted in a sow moving 55 km.

Home ranges are generally larger for boars than sows (Giles 1980; Saunders 1988; McIlroy 1989; Saunders & Kay 1991, 1996; Knowles 1994; Caley 1997; McIlroy & Gifford 1997). However, this pattern is not evident in all studies (Singer et al. 1981; Boitani et al. 1994; Nugent et al. 2002; K. Barber unpubl. data).

6.2 Dispersal and maximum movement distances

Long-distance movements by pigs are of particular interest in the Tb context because they could potentially result in new outbreaks of disease outside VRAs.

In a piglet movement study at Mt. White, Canterbury, 24 piglets (2–15 kg; note piglets of this size may be infected with Tb (see Section 7.1)) were radio-tracked for 2–10 months. No large-distance dispersal occurred, and home range size ranged from 0.1 to 14.9 km^2. The maximum distance between two known locations of any juvenile was 5.8 km (K. Barber unpublished data; Table 1). Caley (1997) found that in Australia there was no significant effect of time since initial capture on recapture distance, suggesting there was no long-term trend for pigs to disperse with increasing age.

Adult feral pigs in New Zealand also appear relatively sedentary when food and cover are adequate (Martin 1975; McIlroy 1989; Landcare Research unpublished data), but are perhaps more nomadic in less forested areas (see Knowles 1994). Long distance movements do occur: one sow moved 35 km, apparently after being chased out of Hochstetter Forest, West Coast, by hunting dogs and shifts of up to 55 km have been recorded in Australia (Table 1). In a study of released pigs, Nugent et al. (2002) suggest that a 6-km radius around the location of a killed pig is likely to encompass 95% of all previous locations.

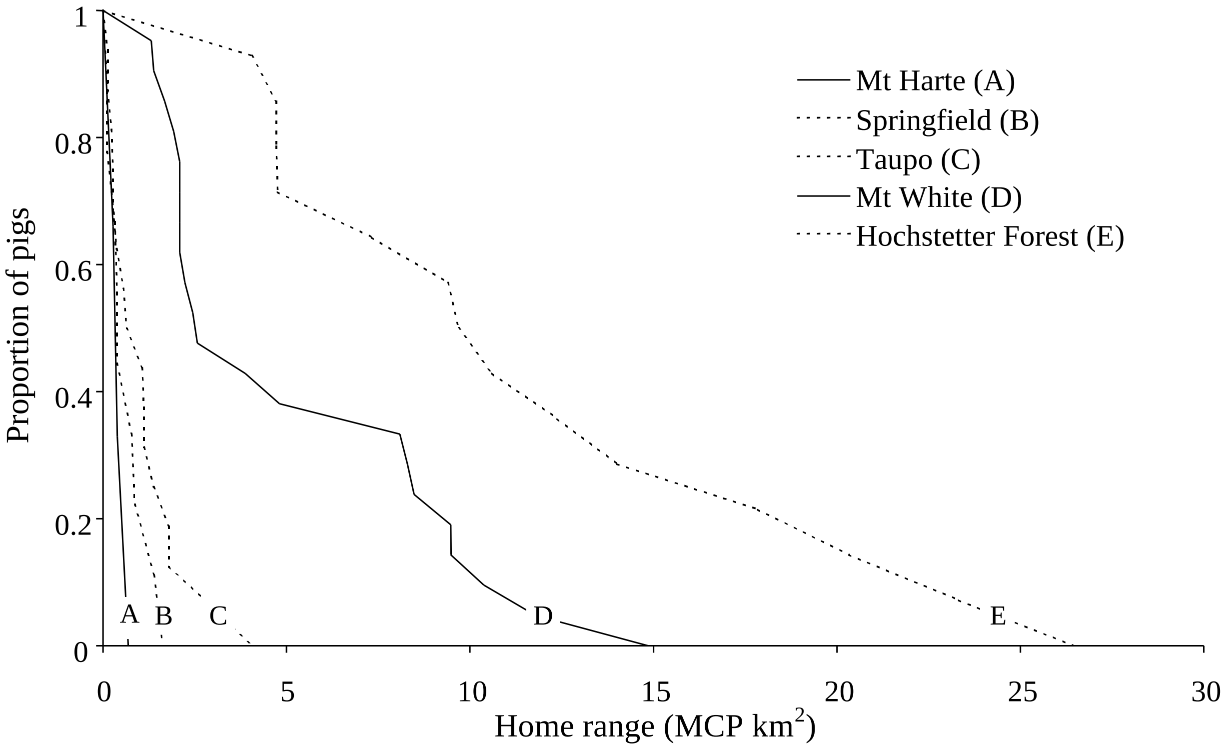

Fig. 2. Aggregate home range estimates (MCP; minimum convex polygon) for feral pigs in New Zealand. Pigs tracked for less than 4 months have been omitted. Sentinel pig studies are indicated by dashed lines (- - - -). See Table 1 for study descriptions.

Table 1 Home range estimates (minimum convex polygon) for feral pigs in New Zealand and Australia, including study duration, average number of locations and the maximum distance between known locations for any individual pig. Sentinel pig studies are indicated by *

Study region		Study duration (months)	Average number of re-locations per pig	Home range (km^2)				Maximum distance (km) ♂/♀	Source
				Male		Female			
				Mean (n)	Range	Mean (n)	Range		
Lees Valley, North Canterbury	NZ	1–25	–	– (10)	–	– (12)	–	13.0 ♂ 0.8 ♀	Martin 1975
Mount Harte, Murchison	NZ	0.5–6	71	0.89 (4)	0.38–2.09	0.70 (3)	0.28–1.17	>2.4 ♂	McIlroy 1989
Pisa Range, Central Otago[a]	NZ	<20	<12	– (6)	22.57–157.17	– (8)	5.43–23.41	29.8 ♂ 9.3 ♀	Knowles 1994
Springfield, Canterbury*	NZ	5–6	9	0.66[b] (9)	0.11–1.63	–	–	3.9 ♂	Landcare Research unpubl. data
Mokai, Western Taupo*	NZ	4–8	8	3.23[b] (8)	0.27–12.83	–	–	4.8 ♂	Landcare Research unpubl. data
Mokai, Western Taupo*[c]	NZ	4–6	8	0.79[b] (8)	0.23–2.33	–	–	2.5 ♂	Landcare Research unpubl. data
Mt White, Canterbury[d]	NZ	2–10	22	4.53 (12)	0.10–14.85	4.87 (12)	0.58—11.79	5.8 ♂ 4.9 ♀	K. Barber, unpubl. data
Hochstetter Forest, Central Westland*	NZ	2–10	10	11.35 (4) 7.36[b] (4)	4.76–20.34 3.57–12.39	11.74 (9)	3.38—26.44	35 ♀[e]	Nugent et al. 2002
Western NSW	AUS	–	–	43	–	6.2	–	23	Giles 1980
Namadgi National Park, ACT	AUS	1–5	35	4.94 (25)	1.0–22.6	4.23 (17)	0.7–8.5	>5	McIlroy et al. 1989
Sunny Corner, NSW	AUS	1–24	204	10.7 (7)	4.1–21.8	4.9 (5)	3.5–6.8	>10	Saunders & Kay 1991
Kosciusko National Park, NSW	AUS	4–27	28	34.6 (12)	13.2–70.1	10.21 (8)	3.7–19.9	18	Saunders & Kay 1996
Douglas-Daly area, NT	AUS	12	>150	33.5 (6)	–	24.1 (6)	–	23	Caley 1997
North-west NSW	AUS	<20	–	7.9–11.6[f]	–	4.2—8.0[f]	–	50 ♂	Dexter 1999

[a] home range assumed to be calculated as minimum convex polygon

[b] males castrated

[c] domestic pigs

[d] juvenile pigs (<15 kg at start of radio-tracking)

[e] individual recovered 15 months after release

[f] seasonal means

7. Feral Pigs and Bovine Tuberculosis

7.1 Pathogenesis

Of all the domestic species, the pig is considered to be the most susceptible to infection with Tb (Francis 1958). Lugton (1997) reviewed Tb infection in pigs and concluded that the overall contribution of transmission mechanisms, such as, respiratory excretion, draining abscesses, sexual contact, urine, and mammary lesions to infection in pigs was likely to be minor compared to the ingestion of tuberculous material. He considered oral ingestion and uptake via the tonsils to be the primary transmission mechanism and that the lymphatic drainage pathways of the soft palatine tonsil adequately explained the widespread involvement of the multiple head nodes. Overall, there is general agreement that the predominance of lesions in the head and gut-associated lymph nodes in feral pigs in New Zealand (see below) result from scavenging tuberculous carrion (Nuttal 1986; de Lisle 1994).

Young pigs appear highly susceptible to the disease and rapidly develop severe lesions in the tonsils, head lymph nodes, lungs and abdominal organs compared to older pigs, which are much more resistant (Griffith 1907 cited in Lugton 1997). Lymph node lesions initially show nodal enlargement with caseation and softening that later becomes calcified. With time, progressive fibrosis and calcification occurs and the lesion reduces in size (Lugton 1997). Lesion regression and resolution of the lesions into fibrous tissue can occur (Ray et al. 1972; Bollo et al. 2000).

Numbers of bacilli in lesions appear generally to be low. Lugton (1997) cultured Tb from 26 of 30 pigs from which tissue was cultured, but acid-fast bacilli (AFBs) were seen in only three of the 18 of these animals subjected to histopathology. Montgomery (1995) notes Tb infection generally appears more contained in pigs than deer, with cattle intermediate between the two, and implies that AFB numbers are comparatively low in pigs. Cooke et al. (1999) notes, in contrast, that AFBs are typically present in high numbers in possum lesions, and sometimes also in ferret lesions. Together, the evidence points to pigs being one of the hosts best able to cope with Tb infection.

Bovine Tb has been isolated from non-lesioned lymph nodes (Ray et al. 1972; Lugton 1997; Nugent et al. 2001), which possibly reflects recent infection. Conversely, some typical tuberculous lesions have failed to yield Tb on culture suggesting either that the mycobacteria were only present in extremely low numbers in the lesions (i.e., disease resolution had occurred) or that other bacteria may have caused the lesions (Nuttall 1986; Lugton 1997; Nugent et al. 2002). Pigs rarely show clinical signs of the disease – in the Hochstetter study described above, all 16 pigs became infected within 2 months of exposure (Nugent et al. 2002) but all were in good condition with no external visible signs of infection when shot up to 21 months after the probable time of first infection (Landcare Research unpubl. data). The implication is that Tb-induced mortality is usually low, at least within the first year of the animal becoming infected.

7.2 Patterns of prevalence and persistence

Overseas data

Bovine Tb has been found in feral pigs in several countries in areas where the disease occurs in other hosts. In Australia, Corner et al. (1981) documented high prevalence of Tb (48–85%) in feral pig populations that shared their habitat with infected cattle (*Bos taurus*) and water buffalo (*Bubalus bubalus*). Similarly, infected feral pigs have been linked to presence of infection in cattle and/or deer in Hawaii (USAHA 2000), Italy (Mignone et al. 1991; Serraino et al. 1999), Spain (Aranaz et al. 1996) and Central Europe (Pavlik et al. 2002). However, there are no reported cases of *Mycobacterium bovis* (bovine Tb) persisting in feral pig or wild boar populations in the absence of other infected species.

In the Northern Territory of Australia the prevalence of Tb in feral pigs declined after cattle and buffalo numbers were reduced to very low levels (Corner et al. 1981; McInerney et al. 1995). This decline, and the lack of infection in pigs in areas that had been restocked with Tb-free cattle, led to the conclusion that feral pigs are an end-host for *M. bovis* infection. The likelihood of horizontal transmission was thought to be small because of the low prevalence of generalised disease, the lack of excretory routes in the absence of pulmonary infection, and the scarcity of contact between pigs and other species (Corner et al. 1981).

On Molokai, Hawaii, a 20% prevalence of Tb was recorded in feral pigs in 1980, and Tb had previously been found in both cattle and wild axis deer (*Axis axis*) (Essey et al. 1981). The island was completely destocked between 1983 and 1987, but Tb was found in one cow, and then in two pigs some 10 years later in 1997 (USAHA 2000). This cow and the one pig from which Tb was isolated had the same strain of Tb, and the two infected pigs were shot on the same pasture indicating the infection was somehow linked. However, the prevalence in pigs has declined to very low levels (1%, n = 183), and no Tb has been detected in pigs from the part of the island where highest levels of infection had previously been recorded. The implication again is that removal of cattle as a reservoir of infection resulted in Tb virtually disappearing from pigs, although the question of how Tb persisted outside cattle over 10 years remains open. Long-lived sympatric deer may have provided an alternative reservoir.

In Italy, DNA typing of porcine and bovine isolates of Tb showed that the most common strain occurred in both cattle and wild boar, leading the authors to conclude that interspecific transmission had occurred (Serraino et al. 1999). They speculated that the most likely pathway was from the feral pigs feeding on pastures contaminated by infected cattle. In Spain, Aranaz et al. (1996) used DNA typing to show that transmission of infection occurred amongst cattle, deer and wild boar.

New Zealand domestic pigs

Historically, domestic pigs in New Zealand and elsewhere were commonly infected with Tb. Although some infection still occurs occasionally in areas where Tb is endemic in cattle and other hosts, changes to pig husbandry practices and the Tb control programme has led to such infection becoming rare (Nuttall 1986; de Lisle 1994).

Most infection in domestic pigs in New Zealand was in the head and gut-associated lymph nodes, suggesting that infection usually occurred by ingestion, probably by being fed unpasteurised milk from tuberculous cattle, or possibly by eating grain and/or meal contaminated by infected possums, or by grazing pasture contaminated by infected possums, cattle or deer (Nuttall 1986). Being fed infected possum carcasses has also caused infection in pigs (McLaughlin 1989).

New Zealand feral pigs

Bovine Tb was first identified in a New Zealand feral pig in 1962 (Allen 1991). Ekdahl et al. (1970) document 14 cases of *M. bovis*-infected feral pigs dating back to 1964 from the Wellington district, North Canterbury and North Westland. Subsequent cases have been reported from feral pigs living in most areas where the disease is endemic in livestock and other wild hosts, including Woodhill State forest, central North Island, Wairarapa, Otago and Southland (de Lisle 1994), but infection is rarely reported from non-endemic areas.

Central Otago: In a feral pig survey undertaken between 1989 and 1990 in Central Otago, Wakelin & Churchman (1991) found a prevalence of 31% (n = 251) based on histological diagnosis. Of these, 96% showed infection in one or more of the head lymph nodes and 33% had lesions in the lung or bronchial lymph nodes. Generalised infection, where lesions were present in four or more sites, was found in 27% (21) animals. Prevalence increased with age, with 24% of pigs less than 2 years old infected compared with 42% of pigs aged over 2 years.

A further survey conducted in this area between 1991 and 1993 reported a histological prevalence of 32% (Knowles 1994) and again, most lesions were found in the mandibular lymph nodes. No cases of generalised tuberculosis were found, and infected animals were restricted to some valleys. Tuberculosis was clustered in family groups (up to 100% prevalence) within these valleys, with some infected piglets less than 2 months of age, shot with infected sows, having tuberculosis lesions (Lugton 1997). The home range of the feral pigs overlapped with farmland (Wakelin & Churchman 1991), and both tuberculous ferrets and possums were also present in the area, albeit in low numbers (unpubl. data cited by Nugent et al. 1996).

Castlepoint and Hauhungaroa Ranges: Lugton (1997) reported a high prevalence of infection in pigs surveyed in the Castlepoint and Hauhungaroa areas where infection in other wildlife species was common. Tuberculosis was diagnosed in 96% (n=24) of the pigs from the Castlepoint area and 80% (n = 5) of pigs from the Hauhungaroa Range. The disease was generalised (thoracic and/or peripheral node lesions were present) in 63% of animals in which sufficient amounts of the carcass were available for examination (n = 24). The youngest infected pig was approximately 2 months of age. All of the diseased pigs had infection in sites associated with the alimentary tract, which include the head lymph nodes, oropharyngeal tonsils, and gastric, hepatic and mesenteric lymph nodes. Tuberculous thoracic lesions were present in 35% of the animals, with the most severe found in the younger pigs. Due to the age at which pigs were found infected and the severity of pulmonary infection found in younger pigs, Lugton (1997) did not preclude the possibility of pseudo-vertical transmission.

Hochstetter Forest and Hauhungaroa Ranges: Landcare Research (unpubl. data) has surveyed resident feral pigs in Hochstetter Forest and the western Hauhungaroa Range, both areas with moderate or high possum densities and known Tb infection in the possum and deer populations (Coleman & Cooke 2000; Coleman et al. 2000). Pooled across years, the prevalence of Tb was 63% (n = 38) and 88% (n = 8), respectively. Pooled data from both areas suggests that the prevalence in pigs aged ≤6 months (63%) was not much lower than in pigs aged >6 months (75%). Again, the most common sites of infection were in the head and mesenteric lymph nodes. Generalised infection was found in 28% of the animals, but in contrast to the Castlepoint survey few of the young pigs were severely infected (Lugton 1997).

The eastern flank of the Hauhungaroa Range was also surveyed. Possum densities there were reduced to near zero by aerial poisoning in 1994, but by 2000 had increased to almost 10% Residual Trap Catch (RTC; Coleman et al. 2000; Environment Waikato unpubl. monitoring data), about 40% of pre-control levels. In winter 2000 possum densities were again reduced to low numbers (0.16% RTC; Environment Waikato unpubl. monitoring data). Of 107 pigs shot between 1996 and 2001, 44% were infected with Tb. Prevalence declined from 60% in 1996 to 24% in 1999, rose to 77% in 2000 when possum numbers had climbed to almost half of pre-control levels, and then decreased to 32% in 2001 after the area had been repoisoned. Generalised infection was found in 30% of the infected pigs, and although animals <2 months of age were infected, the most severe infection was in older pigs.

Fewer pigs ≤6 months old (20%) were infected than pigs aged >6 months (60%). Only 5% of the pigs <3 months of age were infected compared with 50% of piglets of similar age in the pooled “high possum density” sample from Hochstetter Forest and the western Hauhungaroa Ranges.

In the eastern Hauhungaroa Range, the prevalence of Tb in pigs ≤6 months old decreased markedly with increasing distance away from an uncontrolled possum population, but no such infection gradient was evident in older pigs ($\chi^2_1 = 4.63$, $P = 0.03$; Fig. 3). The reason for the difference is not clear, but we speculate that older pigs are more likely to have spent at least some time near or in the area with an uncontrolled possum population. More importantly, the zero prevalence in young pigs shot furthest away from an uncontrolled possum population strongly suggests that infection levels in adults have little or no impact on the force of infection in young pigs and/or that intraspecific transmission is a slow process.

In summary, it appears that where infected possum populations are at moderate or high densities the prevalence of tuberculosis in feral pigs is high (i.e., approaches 100% in adult pigs). A high proportion of the young pigs are also infected. Where possums have been reduced to low densities, fewer young pigs become infected before they mature, suggesting that possum control substantially reduces the force of infection.

However, our unpublished data from the eastern Hauhungaroa Range is puzzling. By winter 2000, possum numbers over the whole range had been reduced by recent aerial poisoning. Despite that we still recorded moderate levels of infection in pigs in 2001 and 2002 (c. 30% prevalence based on unconfirmed field diagnoses; culture results pending). At least some of these infected pigs were <6 months old and were shot in the area where they are unlikely to have ranged widely enough to have encountered an uncontrolled possum population. The prevailing RTC in the local area at the time was < 3%, and only one Tb-infected possum has been recorded from more than 100 necropsied over the last 5 years, indicating a low prevalence of Tb in possums. Densities of deer and the prevalence of Tb in deer in the area were likewise low. It is therefore difficult to conceive that these piglets could have encountered and eaten enough possum and deer carcasses in their short lives for one-third of them to have become infected. We speculate that pigs may be becoming infected by scavenging on pig carcasses, as we believe that they are likely to be far more common than infected possum or deer carcasses. Regardless of the mechanism, however, these data show clearly that new infections continue to occur, and Tb can persist in feral pig populations near farmland for more than 8 years after the initiation of large-scale possum control.

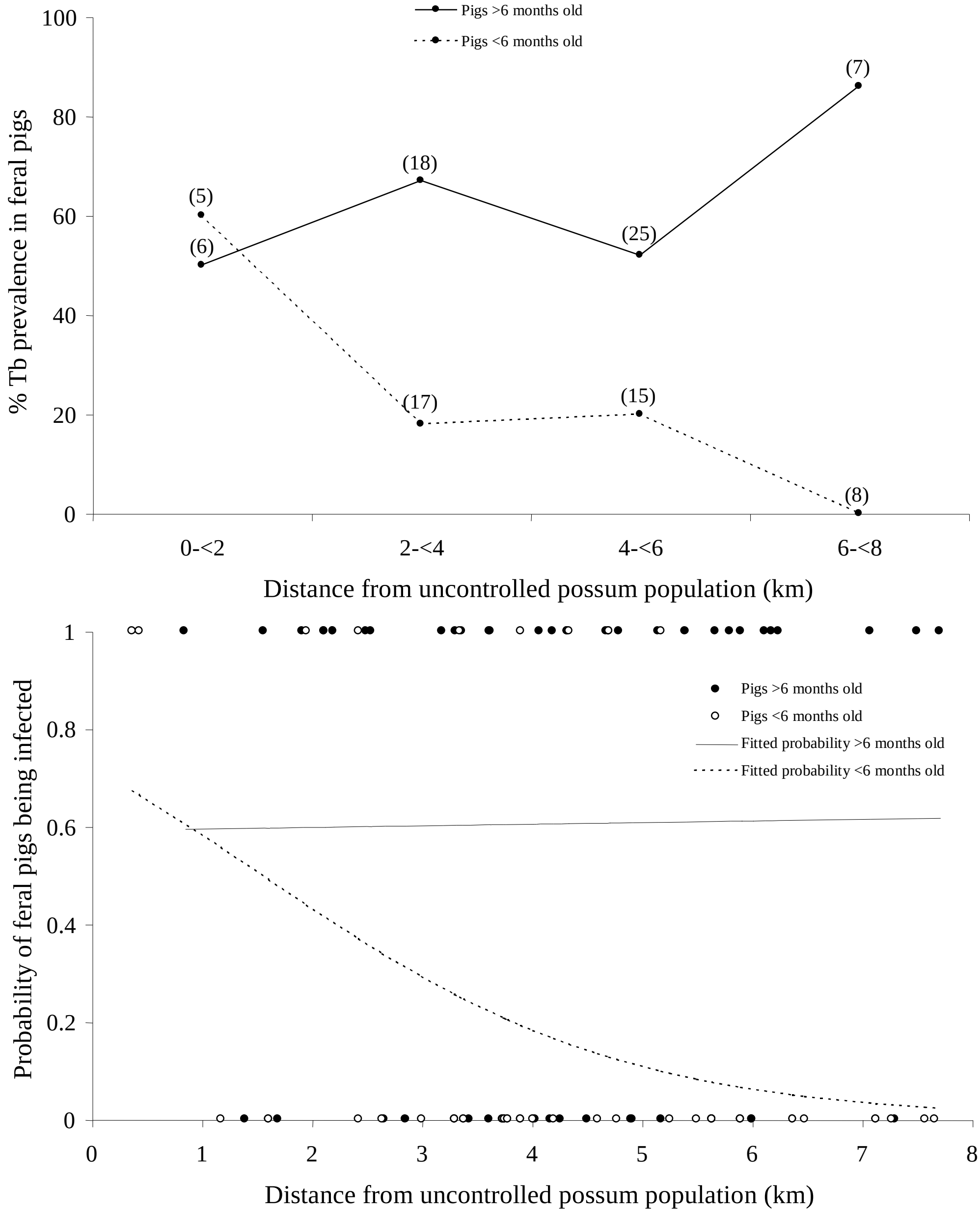

Fig. 3 Prevalence of bovine tuberculosis in necropsied pigs ≤6 months and >6 months of age versus distance from an uncontrolled possum population in the Hauhungaroa Range; (a) Prevalence in 2-km distance classes (sample sizes shown in parenthesis), and (b) Fitted probability of prevalence (logistic model; infection of individual animals in both age classes is represented by a probability of 0 or 1).

7.3 Geographic distribution of Tb in feral pigs in New Zealand

General patterns

At a national level, feral pigs are present in all of the larger VRAs, although scarce or absent in many parts of the more southern parts of the West Coast VRA. Arguably there is some linkage between presence of pigs and presence of Tb. Areas with few pigs, such as the Ruahine and central Tararua ranges, do not appear to have Tb. To date Tb does not appear to have spread eastward through the Kaimanawa and Kaweka ranges (where there are few pigs, but a universal presence of possum and moderate or high densities of deer) – it has however spread northward from Turangi through native and pine forest that does contain pigs and some of the earliest indications of that spread were hunter reports of diseased pigs (Nugent & Proffit 1994). In the North Canterbury high country, there is little evidence of Tb in livestock in the westernmost areas where there are apparently few pigs (e.g., St James Station), but much higher incidence in livestock in more eastern parts where pigs are more abundant.

Historically, infected pigs have occasionally found in areas where Tb was not known to be established in other wildlife. For example, a tuberculous feral pig was found at Kaeo in Northland in 1991, an area with very low incidence of Tb in domestic cattle. Surveys of wildlife populations found no evidence of disease in 30 pigs, c. 750 possums, and c. 700 semi-feral goats. It is possible that the infected pig was caught outside Northland and either was liberated or escaped at Kaeo, presumably bringing the disease with it (Nugent et al. 1996). Other examples are the discovery of an infected pig in the Richmond Range, Nelson, 35 km away from the nearest VRA boundary, and of an infected pig on Arapawa Island (M. Mitchell, pers. comm.).

Recent operational surveillance surveys

District disease control managers throughout New Zealand increasingly use feral pigs either to identify whether Tb exists in wildlife in specific areas where unexplained cattle or deer breakdowns have occurred, or to confirm (or not) the success of possum or ferret control operations. Table 2 lists those surveys in 2001–2002 for which we were able to obtain summary data.

In general, few infected pigs were found in these surveys, because they were mainly conducted at the margins or outside VRA's, or in areas where possum numbers have been controlled to low levels. Two key exceptions are high levels of infection at the site of a new Tb outbreak in the southern Urewera Range, and in the North Canterbury/Marlborough high country where Tb has long been established and where there is no vector control. The data are consistent with the belief that pigs are rarely infected in the absence of other infected hosts.

Table 2 Surveys undertaken by vector managers in New Zealand in 2001–2002 (unless otherwise stated) to identify prevalence of Tb in feral pig populations. Possum and ferret information is not presented for regional surveys.

Survey	Prevalence (%) (Sample size)	Possums (P) & Ferrets (F)		Infection in possums or ferrets	Source
		Populations controlled	Densities		
Ure/Medway, Marlborough	3.7 (82)	Yes	Low P & F	Yes	Marlborough Regional Council
Richmond/Rai, Marlborough	0 (186)	No	Moderate/high P	Unknown	Marlborough Regional Council
Upper Waihopai, Marlborough	14.3 (7)	No	Low P & F	No	Marlborough Regional Council
Acheron Catchment, Marlborough high country	85.2 (61)	No	Moderate P & F	Yes	Marlborough Regional Council
Golden Downs, Tasman	1.9 (315)	No	Moderate/high P Unknown F	No	Southern Pest Management
Hokonui Hills, Southland	0 (7)	Yes	Low P	Yes	Southland Regional Council
Taringatura, Southland	0 (21)	Yes	Low P	No	Southland Regional Council
Tomogalak, Southland	0 (59)	Yes	Low P	Yes	Southland Regional Council
Whirinaki-Waipunga, Southern Urewera Range	25 (8)	No	High P	No	Bay of Plenty Regional Council
Maungataniwha, Hawke’s Bay	0 (130)	No	High P	No	Hawke’s Bay Regional Council
Hawke’s Bay Region	0 (134)	–	–	No	Hawke’s Bay Regional Council
Weber, Manawatu/Wanganui	2.1 (47)	No	High P	No	Horizons, Manawatu/Wanganui
Taunoka (1998), Manawatu/Wanganui	4.8 (21)	No	High P	Unknown	AgriQuality , Wanganui
Taunoka, Manawatu/Wanganui	3.2 (31)	No	High P	Unknown	AgriQuality, Wanganui
Waitotara Headwaters, Manawatu/Wanganui	0 (42)	No	High P	No	AgriQuality, Wanganui
Mangaporau, Manawatu/Wanganui	0 (46)	Yes	Moderate P	Unknown	AgriQuality, Wanganui
Taranaki Region	0.3 (288)	–	–	No	Taranaki District Council

7.4 Susceptibility to Tb and use of pigs as sentinels

Although the livestock Tb-testing programme in New Zealand provides surveillance in most farmed areas, there are many areas with few or no livestock available as sentinels. For such areas pigs appear particularly well suited to a sentinel role (Nugent 2001) because:

(a) They are highly susceptible to Tb (Francis 1958), readily develop detectable lesions in the head, particularly the mandibular lymph nodes (Lugton 1997), and remain infected for extended periods (Nugent et al. 2002);

(b) They are widely distributed (Fig. 1), particularly in forested areas where ferret densities are likely to be low or zero;

(c) Mostly they have home range sizes that are as large or larger than those of ferrets and wild deer (Table 1; Nugent 2001);

(d) They are generally believed to be end-hosts that do not contribute to ongoing disease maintenance.

The use of released (rather than resident) pigs as sentinels provides more precise information on when and where any infected pig becomes infected. A feasibility trial at Hochstetter Forest, Westland, demonstrated that this approach was practical, and all of 17 released pigs successfully recovered were infected (Nugent et al. 2002). In a subsequent survey at Springfield, Canterbury, none of nine released pigs became infected with bovine Tb, although *Mycobacterium avium* was isolated from one pig. In an ongoing trial at Mokai, Taupo, none of 14 pigs released and recovered in 2002 had contracted bovine Tb, although again three had *M. avium*. In both the Springfield and Mokai surveys, reactor rates in sympatric livestock had fallen to zero, so the absence of Tb in the released pigs could well reflect Tb freedom in those two areas.

Evidence of the high susceptibility of feral pigs to infection with Tb (relative to the susceptibility of other common domestic and other wildlife hosts) is:

- Wakelin & Churchman (1991) report a prevalence of 31% (n = 251) in feral pigs from Central Otago at a time when the prevalence of Tb in domestic cattle (0.2%) and farmed deer (0.3%) in the area was low. On Muzzle Station, Clarence Valley, we have detected lesions in almost all adult pigs (see the results of the nearby Acheron survey in Table 2), yet less than 1% of c. 1400 cattle, and c. 100 deer Tb-tested annually are lesioned reactors (C. Nimmo, Station owner, pers. Comm.). This suggest pigs are more susceptible than farmed deer and cattle.
- In the central Hauhungaroa Range, where infected possums are common, all of five adult pigs inspected were infected (G. Nugent unpubl. data) compared with only 37% of 30 adult deer (Coleman et al. 2000). Likewise, 96% of 33 pigs (all ages) in the Castlepoint area, Wairarapa, were infected, compared with about 30% of 30 deer (all ages) (Lugton 1997). In Hochstetter Forest, West Coast, all of 16 released pigs appeared to have become infected within 2 months of release (Nugent et al. 2002), suggesting that there was, on average, one new infection per 30–60 pig days. Tb prevalence in a sample of 163 wild red deer shot between 1997 and 2000 in the same area was 11% (Landcare Research unpubl. data). The mean age of these deer was 2.6 years, suggesting one new infection per 8600 days. This suggests that pigs are more susceptible than wild deer.
- In 1999, a Tb prevalence of 5% was recorded in possums from the eastern part of the Hochstetter Forest area (Coleman & Cooke 2000). Conservatively assuming infected possums survive only 6 months (see Ramsey et al. 2001b), this suggests one new infection

per 3650 possum days. This suggests that pigs are more susceptible than possums. It also suggests possum susceptibility is intermediate between that of wild deer and pigs.

- The prevalence of Tb in ferrets is consistently much higher than that in sympatric possums (Lugton 1997; Caley et al. 2001). This suggests the ferrets are more susceptible than possums.
- In October 2002, 6.8 Tb reactors were identified per 10 000 cattle tested, compared to 14.6 reactors per 10 000 farmed deer tested (Animal Health Board website unpubl. data.) Although a range of factors will have contributed to this twofold difference, it strongly suggests that the difference in susceptibility of the two livestock species is not vastly different.

Taken together these quantitative and semi-quantitative observations suggest that scavengers such as ferrets and pigs are much more susceptible to becoming infected with Tb than the herbivore hosts (wild deer and farmed deer and cattle), with possums intermediate. The Hochstetter data, in particular, suggest that pigs are several hundred times more susceptible than wild deer.

The high susceptibility of pigs is likely to reflect their ability to detect and scavenge possum carcasses. In a recently completed study conducted during winter 2002 at Mt. White, Canterbury, 40 possum carcasses were randomly placed in a 400-ha area within the home range of at least 20 radio-collared pigs (K. Barber unpubl. data). Of these 32 (80%) were scavenged by pigs in the ensuing 4 months (Table 3). In a current study near Mokai, Taupo, 20 possum carcasses were placed in the vicinity of four groups each of four released pigs. Eight (40%) of these were scavenged by the pigs, but these were all within the area known to be used by the pigs (i.e.; the 12 carcasses not found and scavenged were outside the home ranges of the pigs; Table 3)

Table 3 Fate of possum carcasses at Mokai (Taupo) in autumn 2002, and at Mt White (Canterbury) in winter 2002.

Site	Number of possum carcasses	Pig scavenged	Hawk scavenged	Other scavengers	Decayed – not scavenged
Taupo	20	8	3	1	8
Mt White	40	32	1	3	4

Tables 2 and 3 in Ramsey et al. (2001b) suggest that about 80% of Tb-infected possums that die will be accessible to pigs, at least in forest. If 75% of those that fall within the home range of pigs are likely to be found and scavenged by pigs, the probability an infected possum carcass will be scavenged by sympatric pigs would be at least 60% in winter.

7.5 Transmission from feral pigs

There are four main possibilities for transmission from pigs: direct and indirect intraspecific transmission and direct and indirect interspecific transmission.

Intraspecific transmission

In New Zealand, pseudo-vertical (sow to dependent piglet) transmission has been suggested as an explanation for severe infection in very young pigs (Knowles 1994; Lugton 1997). However, piglets 1–2 months old in Hochstetter Forest, West Coast, had eaten carrion (Nugent et al. 2002), and DNA typing in that study showed six of these piglets were all infected with the same Tb strain (suggesting the same source of infection) but that their mother was infected with a different strain (Landcare Research unpubl. data). In the same study, no infection was found in seven piglets 1–2 months old shot with a sow that had large lesions in the head lymph nodes (Nugent et al. 2002). The clustering of Tb in family groups and widespread infection in young pigs, both of which have been cited as evidence for intraspecific transmission (Knowles 1994), could equally reflect group scavenging of infected carcasses rather than horizontal transmission by other mechanisms.

There can be little doubt that pig–pig transmission can and does occur, either directly or indirectly. However, the apparent failure anywhere in the world of Tb to persist in pigs in the absence of infection in other wildlife or livestock (despite innumerable opportunities to do so) is compelling evidence that pigs are not maintenance hosts. The most conclusive verification of that is the decline in Tb in feral pigs in Australia after cattle and buffalo numbers were reduced to very low levels (Corner et al. 1981; McInerney et al. 1995). We found no new data that substantially contradicts that conclusion, but, rather, much to support it. The strong implication is that intraspecific transmission rates by any mechanism in the wild must be low, in spite of the close association with family groups and in spite of the observations that pigs will occasionally scavenge carcasses of other pigs (Thomson & Challies (1988) report that pig carrion formed 1.8% of pig diet in the Urewera Ranges).

Interspecific transmission

Although there are observations of solitary pigs sometimes associating closely with cattle, there is little evidence or suggestion in the scientific literature that behavioural interaction between live pigs and other hosts is likely to be an important route of interspecific transmission (whereas this has been suggested as the main route of transmission between terminally ill tuberculous possums and cattle and deer; Morris & Pfeiffer 1995).

The typically very low numbers of bacilli and the relatively low level of purulent infection seen in most older pigs (Section 7.1; Francis 1958) suggest they are unlikely to cause significant environmental contamination. Lugton (1997) found no evidence of excretion of bacilli in urine, faeces or the nasal cavity in four pigs with widespread and especially florid lesions, but there are occasional reports of grossly infected pigs with draining abscesses under the jaw and elsewhere (e.g., Lugton 1997). Feral pigs may have contaminated wallows on a ranch in California and contributed to disease maintenance in cattle (Allison 1967 cited in Knowles 1994), but the much lower rates of infection in livestock of farms in the North Canterbury high country than in sympatric pigs indicate that pig–livestock transmission rates must be low.

A more important question in New Zealand, therefore, is whether pigs can transmit disease to possums or ferrets, both of which are maintenance hosts when their densities are moderate or high (Coleman & Caley 2000; Caley 2002). Transmission to ferrets via scavenging seems highly probable: In February 2003, video footage was obtained of a family of six ferrets feeding extensively on a single pig’s head, and on parts of the gut (Landcare Research unpubl. data). As yet, it is not clear whether pigs will feed on ferret carcasses (in the same ongoing study, pigs have walked past a ferret carcass but not eaten it). They do, however, eat rodents (Nugent et al. 2002) so consumption of ferrets is not inconceivable. If so, then a ferret–pig–ferret scavenging cycle becomes possible. Regardless of that, ferrets do transmit Tb to livestock (Caley et al. 1998) so pigs can indirectly contribute to livestock Tb as a source of ferret infection. The important question is whether that occurs often enough to add significantly to the burden of Tb in ferrets caused by possums or intraspecific transmission.

Thus far, there are no observations of possums feeding on pig's heads, but possums have been filmed feeding on deer heads and carcasses (Nugent et al. in press) – this scavenging behaviour of possums is far from universal, but was not difficult to film, suggesting that it is not an extremely rare event. In addition, pigs in forest frequently use hollow logs and tree trunks as resting places, and the same places are sometimes used by possums as dens (G. Nugent pers. obs.). Contamination of such sites by pigs with draining mandibular lesions is therefore a potential mechanism for transfer to possums.

8. Communicating with the pig hunters

8.1 Pig hunting clubs, competitions and magazines

Appendix 14.1 provides an updated list of known pig hunting clubs and their contact details. Eleven of the 28 clubs surveyed responded by post, and the remaining 17 were contacted by telephone. These 28 clubs had a total of c. 2600 pig hunters (approximately 11% of the estimated number of pig hunters in 1988; Nugent 1992). Club size ranged from 10 to 1050, with most (57%) clubs having fewer than 50 members and 89% of clubs fewer than 100 members. The size of the two largest clubs, Kinleith Forest Recreation Club (430 members) and Tokoroa Pig Hunting Club (1050 members), reflects a requirement by forest owners that hunters belong to a particular club.

Clubs communicate internally via meetings (96% of clubs, with an average of nine meetings per year), newsletters (69%) and club websites (11%). Most (85%) clubs were interested in having a web page on a collective website for pig hunting clubs in New Zealand. Most clubs (63%) organised pig hunting competitions.

Club officers considered pig hunters could be best informed about Tb issues,by:

- presentations at club meetings, huis on local maraes, or at pig hunting competitions;
- brochures that could be included in club newsletters, pig hunting competition entry forms, or attached to hunting permits from the Department of Conservation or forestry companies/managers;
- articles in pig hunting magazines.

There are two pig hunting magazines in New Zealand, *New Zealand Pig Hunter* and *Morepork.* They have a circulation of approximately 5000 per bimonthly issue, but accurate figures are not available. The readership factor (number of people that actually read an issue of a magazine) has not been assessed for either magazine. However 88% and 73% of the pig hunters surveyed (Section 8.2) read *New Zealand Pig Hunter* and *Morepork*, respectively.

The total number of annual pig hunting competitions has been estimated at approximately 100, but many of these also include deer and other game (B. Jeffares pers. comm.). During 2002, up to 200 pig hunters entered each competition, with estimated attendances ranging from 100 to 2000. Ridgeline Judging Systems has a database with over 680 names and addresses of pig hunters who enter competitions. Many competitions include only boars above a certain weight.

8.2 Individual hunters

The 21 hunters who were not members of pig hunting clubs recommended pig hunting magazines (86%), posters at competitions (71%) and videos (71%) as being the best way of providing them with information on Tb-related issues (Table 4). The 39 who were members of clubs also favoured hunting magazines (90%) and posters at competitions (87%), but also favoured club newsletters (98%). Websites were favoured by only 37% of all respondents.

Table 4 Percentage of individual hunters (n=60) favouring each potential form of communicating Tb information to them

	Non-club member	Club member
Pig hunting magazines	85.7	89.7
Posters at competitions	71.4	87.2
Videos	71.4	74.4
Newspapers	50.0	75.7
Television	47.6	76.9
Newsletters	28.6	97.4
Websites	23.8	43.6

Most (87%) surveyed club members participate in hunting competitions compared with 57% of non-club members.

Over 70% of respondents hunted not only on private farms, but also on forestry blocks and conservation land, suggesting that most pig hunters could be provided with information on Tb issues when obtaining permits to hunt on conservation land or forestry blocks (assuming that hunters obtained permits to do so).

Respondents hunted an average of 73.1 ± 7.2 (s.e.) days per year and killed 57.2 ± 7.1 (S.E.) pigs per year. In a postal survey of 161 pig hunters in the northern South Island, Clarke (1991) reported hunters averaging 49 hunts per year and killing 57 pigs per year. The hunting days and pigs killed in both of these surveys are considerably higher than those estimated for 1988 (15.86 and 10.26, respectively; Nugent 1992). The differences reflects the pig-hunter-specific nature of this and Clarke's (1991) survey, whereas the 1988 survey included hunters who killed pigs incidentally while hunting deer and other game.

All of the pig hunters surveyed gutted the animals in the field and left the entrails at or near the kill site. However, only 13% left the pig's head at the kill site. The majority later buried or placed the head, skin and other unwanted parts of the pig in offal pits (which are not necessarily scavenger-proof), but several hunters "dumped heads in paddocks", "threw the head in the bush" or "dumped the head and skin in forestry blocks". Some pig hunters either ate pig heads themselves (8%) or fed them to their dogs (38%).

Almost all pig hunters had heard of Tb (92%) and believed they knew where to look for Tb in a pig (77%). However, based on their descriptions of where they would look for Tb in a pig only 33% of hunters would correctly identify early symptoms of Tb (lymph nodes in head). Only 48% of pig hunters knew what part of their region (if any) was designated as a VRA.

A voluntary surveillance programme using recreational hunters is unlikely to be successful given the current lack of knowledge in identifying early symptoms of Tb. Hunters also raised concerns in phone surveys that identification of Tb in pigs may result in control operations in their hunting areas.

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9. Control of feral pigs

9.1 Current control

There is no national plan or pest management strategy for feral pigs in New Zealand. Official control of pigs as pests is infrequent and uncoordinated (see Nugent et al. 1996). However, DOC reports killing c. 400 pigs annually during its feral goat control operations, with most being killed in the East Coast, Wanganui, and Nelson/Marlborough Conservancies (Parkes 1996). In addition, DOC's Southland Conservancy is planning eradication of pigs from the Auckland Islands (Shaw 1993). The National Pest Management Strategy for Bovine Tuberculosis (Animal Health Board 2001) states that feral pigs "will be targeted on a limited scale through poisoning and shooting", partly because they are useful indicators of the presence of Tb.

9.2 Effect of recreational hunting on pig density

Recreational hunters with dogs provide the principal means of regulating feral pig numbers in New Zealand (Clarke & Dzieciolowski 1991). In the absence of any substantive effort by state agencies, the present low densities of pigs over much of their range (c. 1/km^2) must be attributed to the effectiveness of private hunters and their dogs, although there are little hard data to substantiate this. Pigs now persist in substantial numbers only in areas where they are protected by the landowner, where there is extensive cover, or where access is difficult.

9.3 Control methods

There are four ways managers can reduce pig numbers and their impacts – by excluding them, by modifying habitat to make it unsuitable for pigs, by reducing their reproductive rate, or by removing or killing animals. In general, only the latter is considered practical for regional or large-scale control of pigs in New Zealand (Nugent et al. 1996). Advances in pig control technology since 1996 have mainly focused on killing animals.

Poisons

Poisoning has widely been used to control pigs in Australia (Hone & Stone 1989), and to a lesser extent in New Zealand (Mackintosh 1950; Miller 1955; Eason 1989) using a variety of toxins (e.g., 1080, anticoagulants, phosphorus), bait types (e.g., cereal, fishmeal, meat, carcasses), and bait application methods (e.g., aerial sowing, ground-laying, bait stations). Poison baiting methods have achieved high kill rates in many instances, but alone have never achieved local eradication. Disadvantages are risks to non-target animals, which are exacerbated by the relatively high toxic loadings required for effective pig baits, and public and hunter opposition to poisoning.

Phosphorus: Phosphorus has been widely used in carcass baits in Queensland and New South Wales (Choquenot et al. 1996). However, phosphorus-based poisons are not recommended for pig control by Natural Resources and Mines, Queensland (2001) as they are considered unnecessarily inhumane, less effective than other poisons such as 1080, and can result in secondary poisoning of non-target species.

1080 (and zinc phosphide): The most widely used poison for feral pigs in Australia is 1080, and its use has resulted in reductions of pig numbers by 58–99% (Choquenot et al. 1996). The variability in percent kill may be a result of pigs vomiting soon after ingestion of 1080 bait (Hone & Kleba 1984; Eason & Henderson 1991; Choquenot et al. 1996), and the vomitus can also pose a significant hazard to non-target wildlife (O'Brien et al. 1986). Operations using 1080 to control possums in New Zealand are likely to reduce hunting pressure in that region as hunters do not want to potentially expose their dogs to 1080 poison. Such operations do kill pigs, but there are no estimates of percent kill, through either primary or secondary exposure, although the by-kill seems lower than for deer. Only one small pig carcass was found compared with 54 fallow deer carcasses after aerial 1080 poisoning of part of the Blue Mountains, Otago (Nugent & Yockney 2001). Typically, pigs appear to recover quickly after control, possibly because of some combination of reduced hunting pressure, an increased supply of carrion (poisoned possums), reduced competition for fruit and insects from possums, and reduced competition for pasture in areas where domestic stock are removed for control operations. In the eastern Hauhungaroa Range, only five pigs were shot incidentally during a deer survey conducted just before an aerial poisoning operation in winter 1994, but 19 were shot with approximately similar effort 2 years later (Coleman et al. 2000). In Pakistan, encapsulated zinc phosphide bait has been reported to result in 80–100% reductions in feral pig activity in rice fields (Kohokhar & Rizvi 1998).

Some research in New Zealand currently aims at encapsulating 1080 and zinc phosphide by developing enteric-coated, environmentally stable tablets that dissolve in animals' stomachs, where the consumption of one tablet will result in a lethal dose to the target animal (J. Kerr, Feral R&D Ltd., pers. comm.). Although this recent technology has not been tested on pigs, Parker & Allen (1991) previously found the strategy of encapsulating 1080 to be ineffective against pigs. If successful, however, this technology may reduce the incidence of vomiting ingested bait. Anti-emetics have also been investigated to prevent vomiting by pigs.

Warfarin: Warfarin has been successfully used to control pigs in New Zealand (in pen trials; Clarke 1993, Henderson et al. 1993: in field trials; Clarke 1992, 1993) and Australia (in field trials; McIlroy et al. 1989; Saunders et al. 1990; Choquenot et al. 1996). One major issue associated with the use of warfarin for poisoning pigs is the humaneness of the poison. Thomas & Young (1998) suggested that pigs poisoned with warfarin may suffer for days before dying. Bleeding into the leg joints as a result of anticoagulant poisoning may compromise the welfare of larger animals such as pigs, if it becomes too painful for them to move in search of food (P. Fisher, Landcare Research, pers. comm.). Poisoned pigs may also pose a threat to dogs through secondary poisoning. Warfarin is not registered for feral pig control in New Zealand.

Brodifacoum: Brodifacoum has not been evaluated for pig control in New Zealand, but it is possible that some pigs are killed through secondary poisoning in New Zealand (Eason et al. 1999). Brodifacoum residues (from possum control) have been detected in feral pigs, posing a risk to pig hunters and dogs that consume pig meat and offal (Eason et al. 1999). This risk probably precludes widespread ongoing use of brodifacoum for pig control in New Zealand, although brodifacoum may be suitable for one-off eradications of pigs from offshore islands.

Cyanide: In Australia, limited testing showed cyanide tablets (Feratox® tablets) incorporated in meat baits and cereal feed blocks were highly effective in killing penned pigs, but the efficacy in field trials was low (J. Kerr, Feral R&D Ltd., pers. comm.). Feratox® tablets of the size required to kill pigs cannot easily be encapsulated, so the poor field results may reflect a lack of stability in the environment, or low acceptance of baits by free-ranging pigs. Of the current and potential pig toxins, cyanide is likely to be the most humane. Also a lethal dose can be delivered in one feed, it poses little risk to non-target native species scavenging pig carcasses, is unlikely to persist in the environment, and may reduce the risk of bait-shyness developing in pigs. Feratox® has provisional registration for pig control in New Zealand.

Cholecalciferol: Cholecalciferol has not yet been evaluated for pig control in New Zealand. Connovation has investigated the use of cholecalciferol injected in carcasses for poisoning pigs in Australia. It is unlikely to persist in the environment or result in secondary poisoning (J. Kerr, Feral R&D Ltd., pers. comm.). Cholecalciferol is registered in New Zealand as Feracol®, but is not currently registered for use against feral pigs.

Baits

The success of poisoning, and also some other pig control methods depends on the attractiveness, acceptability, availability and durability of the baits, on the baiting strategy used, and on the timing of the operation (McIlroy et al. 1993). An extremely diverse range of baits has been used for pigs, reflecting their omnivorous feeding habits, but for large-scale operations by state agencies such as DOC and AHB, manufactured baits will generally be preferred for their convenience. The choice of toxin, and of the bait delivery system, will depend on the aims and on the social and ecological context of the operation. Weather-resistant polymer baits are, for example, perhaps most appropriate for high-rainfall remote areas such as the Auckland Islands, but their persistence becomes a problem in farming areas (Clarke 1993).

Hunting

Hunting is the method most widely used to control pigs in New Zealand. The main forms are ground- and/or helicopter-based (aerial) shooting, and ground-based hunting with dogs. Aerial hunting using the Judas technique, initially developed for feral sheep and goats (Taylor & Katahira 1988) has been successfully used to control feral pigs in the open grasslands of Central Otago, New Zealand (Knowles 1994) and in areas with limited cover in Australia (Hone 1990; McIlroy & Gifford 1997). McIlroy & Gifford (1997) reported a 75% reduction in low-density pig populations that had previously been controlled 2 years earlier using that technique. Radio-collared sentinel pigs have also been used opportunistically as Judas pigs in Westland (Nugent et al. 2002). The main limitations of this technique are that it is suitable only in relatively open habitats and can be expensive compared to poisoning or ground-based hunting.

Ground-based shooting without dogs accounts for very few of the pigs killed in New Zealand (Nugent 1992). Using dogs to help locate and hold pigs greatly increases the efficiency of ground-based hunting. From a national survey of big-game hunters, Nugent (1992) estimated over 100 000 pigs were killed in 1988, of which 87% were killed by hunters using dogs. In a postal survey of pig hunters in the northern South Island, Clarke (1991) reported 97% of hunters owned pig dogs. Although McIlroy & Saillard (1989) concluded dogging was not as efficient as poisoning for the large-scale reduction of pig densities, the method has been successfully used to eradicate pigs in Hawaii (Stone & Keith 1987), and from several New

Zealand islands (McIlroy 1990). It is also an effective way of removing residual pigs after densities have been reduced by other forms of control (Caley & Ottley 1995). There are few published data on the effectiveness of pig hunting using dogs in reducing densities of feral pigs in New Zealand.

10. Discussion

Pigs are widespread within Tb-infected areas in New Zealand, but in the main are held at low numbers by recreational hunting with dogs despite having a very high reproductive potential. The prevalence of Tb in pigs in some areas is extremely high. Hunters translocate pigs to boost hunting opportunities, so may sometimes move infected pigs outside VRAs. There are no data with which we can assess the likely frequency of such events. It seems likely to be far more cost-effective to reduce the number of such translocations than to continually detect and eliminate released pigs. Reducing the number of translocations will require both hunter education and active discouragement through penalties and/or rapid removal of any known new populations. A hunter-education programme would likely need to emphasise not only the threat to conservation and production values, but also the illegality of many liberations, and the threat to their sport if VRAs are expanded as a result. Experience with the eradication of new deer populations from Northland (Fraser et al. 2002) suggests that such a programme needs to be coupled with a commitment to eradicate new populations, to demonstrate to hunters that their efforts are futile.

Hunters currently have a limited knowledge of what Tb is, how to detect it, and which parts of the country contain infected wildlife. Some hunters transport potentially infected carcasses or part carcasses long distances from actual kill sites, and a few dispose of key parts (especially the head) in areas where they could be scavenged by other wildlife. As this practice is likely to be one of convenience, it is likely to be preventable through better education of hunters about the risk of spreading Tb. The best routes for providing hunters with information and advice are likely to be via attendance and presentations at hunting competitions and club meetings, and via articles in hunting magazines.

Pigs occupy large homes ranges that likely increase with decreasing habitat quality. In good habitat, range size is likely to be less than 10 km^2, at least for sows, and a 6-km radius around a pig kill site is likely to encompass most of its home range. However, some pigs (especially males) appear nomadic and/or shift long distances on occasion. Natural dispersal by infected pigs can also transfer Tb long distances, possibly as much as 50 km.

Pigs appear to be hundreds of times more susceptible to infection with Tb than sympatric cattle, deer, or possums. This largely reflects their skill in locating and feeding on most carrion available within their home range. This high susceptibility and large home range size relative to possums (and also their presumed end-host status) underpins a burgeoning use of feral pigs as sentinels for detecting the presence of Tb.

Lugton’s (1997) review and most recent unpublished data on prevalence, lesion distribution, and pathogenesis is consistent with pigs becoming infected through scavenging, but, particularly in older pigs, also being resistant to rapid progression of the disease, and perhaps even able to overcome infection and resolve lesions. In line with this, some field evidence suggests that possum control substantially reduces the force of infection in young pigs, apparently to near zero (Fig. 3).

There is no new data that contradict the long-standing inference that pigs are **not** maintenance hosts in New Zealand, despite their high susceptibility to Tb and the extremely high prevalences that sometimes result. Although intraspecific transmission occurs in captivity (Ray et al. 1972), there is little field evidence to suggest it occurs in the wild. No area exists where Tb prevalence is high in feral pigs but low or zero in all other species. The widespread belief that feral pigs, by themselves, are end-hosts for Tb is strongly supported by the available overseas data, but has not yet been rigorously tested in the field in New Zealand. However, we speculate that when both pig density and Tb prevalence are high scavenging of pigs by pigs could help Tb persist in feral pigs for several cycles or generations before eventually going extinct, especially if Tb persists in carcasses for extended periods during New Zealand's cool winters.

Despite the weight of evidence pointing to spillover-end-host status, some circumstantial evidence suggests pigs may play a role in the maintenance and spread of Tb in New Zealand. Infected pig carcasses may transmit Tb to scavengers such as ferrets, cats, and possibly also possums, but there is no evidence indicating direct transmission from live pigs to possums, deer, or cattle. Grossly infected live pigs do sometimes have large suppurating lesions, so spread via environmental contamination is possible, but the rarity of infection in susceptible and commonly sympatric species such as sheep and rabbits suggests such transmission is rare (Lugton 1997).

Other pointers to pigs possibly having a role in the maintenance and spread of Tb in New Zealand are:

(a) Most areas with persistent Tb also contain feral pigs. In contrast, largely pig-free areas such as the Ruahine, Kaweka, and central Tararua ranges remain effectively Tb free despite the common occurrence of Tb on nearby farms. In places, Tb appears to have spread more slowly through forested areas without pigs than through areas with pigs.

(b) There are some indications from the eastern Hauhungaroa Range that feral pigs are somehow maintaining moderate levels of infection despite over 8 years of possum control. The epidemiological mechanism for this is unknown, but clearly the continued presence of infection in pigs continues to pose a risk to permanent achievement of Tb freedom on adjacent farms.

(c) Evidence of scavenging by multiple ferrets on pigs heads suggests the possibility of a ferret–pig co-scavenging cycle of transmission that could potentially maintain Tb or at least slow its eradication (particularly if only possums are targeted). However, the extent of pigs scavenging on ferrets needs to be quantified.

(d) It seems certain that translocation by hunters and/or natural dispersal results in spread of infected pigs away from their home ranges. That in turn has the potential to establish new distant foci of infection, particularly in ferrets, but possibly also in possums. There are no data with which to quantitatively assess this risk.

Overall, our assessment is that there is no strong new imperative for pig control within areas of established infection provided both possums and ferrets are reduced to low densities. Where pig and ferret densities are both high, it is possible that pig control and where possible the removal of carcasses could speed the reduction in reactor rates by at least removing some of the reservoir of infection in the area. This would also require removal of other long-lived reservoirs such as infected deer. In the absence of information of rates of interspecific transmission, particularly from ferrets to pigs, and from pigs to possums, it is not possible to conclude that pig control is unnecessary. Obtaining the knowledge needed to make that conclusion requires either direct measurement of transmission rates or monitoring of management outcomes with and without control of pigs, in combination with control of various other hosts.

At the margins of infected areas, the apparently strong likelihood of natural or human-assisted spread of infected pigs suggests that pig control might be worthwhile as a precautionary measure. However, the potentially very long distances involved (particularly with the human-assisted spread of live pigs and transport of pig carcasses) suggest that almost regional-scale pig control would be required. This would be opposed strongly by hunters. This opposition, the expense of regional-scale control, and presumed rarity with which a translocated pig is likely to establish a new foci of infection, suggest that it may be more cost-effective to try to detect new outbreaks as they occur rather than to try to reduce the risk of such outbreaks through prophylactic control of possums and ferrets at the margins of VRAs. Pigs could play a major role in providing the surveillance needed to achieve this (Ramsey et al. 2001a).

We conclude that it is feasible to reduce the risk of Tb spread by pigs by better educating hunters about Tb, and that that can be done via presentations at competitions and clubs, and in magazines and newsletters. However, we believe it would also require decisive and consistent action to detect and eliminate new populations, at least in high-risk areas adjacent to current VRAs, to demonstrate to hunters that translocations are unlikely to succeed.

Depending on forest cover, accessibility to ground-based hunters, pig density, and the presence of non-target species, there are a wide range of affordable options available for pig control. Aerial shooting and ground hunting with dogs (with or without Judas pigs and/or trapping) are likely to be the most socially acceptable options. The high reproductive rate of pigs, and largely anecdotal reports of increases in pig numbers 2–3 years after aerial 1080 poisoning of possums, indicates that annual maintenance control would be required to maintain a consistently low density of pigs. If toxins are to be used, then the toxin–bait combination needs to be tailored to the particular situation. The long-term persistence of sublethal residues of brodifacoum in pigs largely precludes use of this toxin.

11. Recommendations

The AHB should not routinely include pig control as part of ongoing vector control operations within VRA's, except perhaps where:

(a) Vector control is being initiated in areas with both high prevalences of Tb and high densities of pigs. The aim would be to rapidly remove the large reservoir of Tb in pigs, and pig control would need to be coupled with removal of all other long-lived Tb hosts such as deer (where possible infected carcasses should be removed). The AHB should assess whether this is already achieved by current-practice aerial 1080 operations, and if not consider developing bait–toxin combinations that might achieve simultaneous control of possum and pigs more effectively. This approach would likely be opposed by hunters, but could be made more acceptable to them by confirming that it resulted in larger numbers of pigs with less disease within just 2–3 years.

(b) There is a high prevalence of Tb in pigs and moderate or high densities of ferrets. Here the precautionary aim is to reduce the unconfirmed risk of a ferret–pig co-scavenging Tb cycle maintaining the disease independently of possums. However, even in this context pig control is probably not necessary if ferret numbers can be reduced to very low levels more cost effectively than pigs.

At the margins of VRAs and for up to 50 km radius from them, the AHB should not undertake pig control, but should implement a surveillance programme based on feral pigs in areas in which few livestock are available for testing. Ideally, this surveillance programme should aim to utilise pigs killed by recreational hunters (see Ramsey et al. 2001a), but when required complement this with contracted hunting and/or trapping of pigs (or other sentinels such as ferrets) in areas where surveillance coverage is light. This recommendation should be considered in light of a current proposal for a nationwide review of the need for wildlife surveillance. Where Tb is detected in a single pig outside the known infected area, intensive surveillance (and therefore control) of feral pigs within a 6-km radius of the kill site should be implemented. This surveillance could include REA typing of tuberculous pigs. If few pigs are available, either ferrets should be surveyed instead, or Tb-free pigs should be released into the area. Where this surveillance identifies further infection, vector control should be implemented over a 6-km radius around known infection sites, and the surveillance area extended to about 10 km around these sites.

The AHB should aim to reduce the risks posed by translocation of infected pigs or pig carcasses, by (a) educating hunters about these risks via clubs newsletters, magazines, and at pig hunting competitions, and (b) eliminating any new feral pig populations in areas not currently occupied by resident pigs, at least near VRAs.

Longer term, the role of pigs in the maintenance and spread of Tb should be more quantitatively assessed, both by monitoring outcomes of various combinations of vector control within VRAs and by determining the frequency of pig-to-possum transmission, and ferret-to-pig transmission. Some preliminary research on these topics has been initiated at one dryland site (Clarence Valley, Canterbury), but replication in other habitats and with other combinations of vectors and scavengers is needed.

If pig control is undertaken, and if aerial poisoning of pigs as part of initial possum control is not an option, aerial shooting (with Judas pigs) and ground hunting with dogs are the recommended pig control tools, based primarily on their acceptability to hunters. If demand for a poisoning tool grows, an encapsulated (and, ideally, fast-acting) toxin-and-bait combination suitable for aerial sowing, use in bait stations, and as buried ground-laid baits should be developed and tested.

12. Acknowledgements

We thank the many pig hunters, magazine editors, researchers, and others who provided information useful in compiling this report. In addition, we thank Garry Knowles (National Disease Control Manager – Southern region) the external reviewer designated by the AHB, and Tony Arthur, for reviewing this report. Finally, we thank Christine Bezar for editorial assistance and Wendy Weller for word processing.

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14. Appendices

14.1 Partial list of pig hunting clubs in New Zealand (postal addresses as at November 2002)

Club	Postal Address
Bay of Plenty Pig Hunting Club	PO Box 4016, Western Heights, ROTORUA
Golden Bay Pig Hunting Club	c/- J&C Rose, Puramahoi, RD2, TAKAKA
Grand Tavern Hunting and Fishing Club	c/- W Robinson, 477 Piraunui Road, RD 1, TE AROHA
Hawke’s Bay Pig Hunting Club	PO Box 2377, Stortford Lodge, HASTINGS
Helensville Pig Hunting Club	500 Kaipara Coast Highway, RD 1, KAUKAPAKAPA
Kinleith Forest Recreation Club	4 Rimu Place, TOKOROA
Mangorewa Kaharoa Te Tahmata Hunting Club	c/- 3 Nihariki Street, ROTORUA
Marlborough Pig Hunting Club	PO Box 310, BLENHEIM
Matakana Island Pig Hunting Club	c/- Matakana Island Post Office, TAURANGA
Muriwhenua Incorporation	5399 Ngataki Road, RD 4, KAITAIA
Ngamanawa Hunting Club	278 Bethlehem Road, Bethlehem, TAURANGA
Reporoa Pig Hunting Club	PO Box 590, TAUPO
Rotoiti Hunting Club	33 Barnard Road, ROTORUA
Rotorua Hunting Club	13 Karaka Street, ROTORUA
Rusti Hooks Fish and Hunting Club	PO Box 140, Takanini, AUCKLAND
South Auckland Pig Hunting Club	PO Box 140, Takanini, AUCKLAND
Southern Pig Hunting Club	RD 2, Tapanui, SOUTH OTAGO
Taieri District Pig Hunting Club	PO Box 66, MOSGIEL
Te Kuiti Pig Hunting Club	PO Box 235, TE KUITI
Tokoroa Pig Hunting Club	PO Box 389, TOKOROA
Top of the South Pig Hunting Club	PO Box 2281, STOKE
Triple B Pig Hunting Club	c/- 11 Salisbury Road, ROTORUA
Turangi Boars Nest Hunting and Fishing Club	37 Raukura Street, TURANGI
Waikarimoana Pig Hunting Club	c/- Postal Centre, Tuai, WAIROA
Wairoa Pig Hunting Club	c/- Brian Wilcox, RD 3, WAIROA
Wanganui and District Hunters and Stalkers Club	100 Peat Street, WANGANUI
Whakawe Hunting and Fishing Club	358 State Highway 5, RD 2, NAPIER
Whitianga Pig Hunting Club	PO Box 4, WHITIANGA

14.2 Postal survey sent to pig hunting clubs in New Zealand

Pig Hunting Club Survey

Name: ________________________________ Phone number: _________________________

Club name: ____

Your role in the club (e.g., president, secretary): ____

Club mailing address: ____

____

____

Number of members in club: ________________

What forms of communication exist between the club and its members (please circle) ?

Newsletters Y / N

Meetings Y / N If yes, how many per year?__________________

Competitions Y / N If yes, how many per year?__________________

On average how many hunters enter each competition? _________________

Email Y / N

Do you have a club website (or page on website): Y / N

Other Y / N

If yes, please list the other forms of communication: __________________________

____

Would you be interested in having your own web page on a collective website for pig hunting clubs ? Y / N

How best do you think pig hunters in your club may be educated about bovine tuberculosis (Tb) ?
(e.g., educate hunters about how to recognise Tb, what the risks of eating Tb are etc.)

____

____

____

____

Do you have contact details of other pig hunting clubs in New Zealand?

Club Name:	Contact Person:	Phone Number:

Could you please provide details of 3-5 pig hunters (members or non-members of your club) whom we can contact to survey about pig hunting in New Zealand (each hunter we contact will go in the draw to win a handmade knife):

Contact details of pig hunters

Name:	Phone Number:

Thank you for completing this survey - please enclose this survey in the self-addressed pre-paid envelope.

14.3 Phone survey of pig hunters

Pig Hunter Survey

Interviewer: ______________________________ Date: / / 2002

Name: ____________________________________ Phone number: ________________________

Are you a member of:

Pig hunting club Y / N Name of club: _________________________________

Other shooting/hunting club Y / N

What region(s) of the country do you pig hunt: ____

____

Do you hunt pigs on:

Private farms Y / N DOC land Y / N

Forestry blocks Y / N

What season of the year do you mostly hunt pigs in: Summer Winter

Autumn Spring

How many days per year do you hunt pigs:

<10 10–30 31–50 Other (or estimate of number): ___________________________

How many pigs do you kill on average per year:

<10 10–30 31–50 Other (or estimate of number): ___________________________

When a pig is killed, what do you do with:

	Leave where killed?	If dispose elsewhere – where?
Stomach contents	Y / N	____
Head	Y / N	____
Hide	Y / N	____
Carcass	Y / N	____

Do you enter organised pig hunting competitions: Y / N

If an organisation wanted to provide you with information on pigs and pig hunting, what form of media would be suitable?

Magazines	Y / N	Video/CD	Y / N
Newspapers	Y / N	Web page	Y / N
Club newsletters/ brochures	Y / N	Television	Y / N
Posters at competitions	Y / N		

Do you read:

NZ Pighunter Magazine	Y / N
Morepork	Y / N
Other NZ hunting magazines	Y / N

Have you heard about tuberculosis? Y / N

Do you know where to look for tuberculosis in a pig, if so where: Y / N

Where: ______________________

Have you seen what you think is tuberculosis in a pig? Y / N

Are you aware what a Vector Risk Area (VRA) is? Y / N

Are you aware where VRA areas are? Y / N

Do you know what the role of the Animal Health Board is in relation to NZ wildlife? Y / N