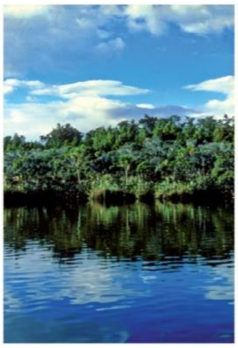

Potential of Feral Cat Control to Reduce the Incidence of Toxoplasmosis on Sheep Farms. Report Addendum.

Landcare Research
Manaaki Whenua

Potential of Feral Cat Control to Reduce the Incidence of Toxoplasmosis on Sheep Farms. Report Addendum.

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February 2014

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Contents

Summary

Project and Client

- In 2013, Hawkes Bay Regional Council (HBRC) contracted Landcare Research to provide a report on the ‘Potential of feral cat control to reduce the incidence of toxoplasmosis on sheep farms’. An addendum has been requested to include considerations from the recent epidemiological modelling literature.

Addendum Aim

- To consider the benefit of feral cat control to the Hawkes Bay farming community, through the mechanism of reduced sheep production losses due to toxoplasmosis and its management, in light of the recent epidemiological modelling literature.

Methods

- Several modelling studies have investigated toxoplasmosis in farm systems, and the impact of different management practises. These were interrogated to draw conclusions regarding the likely effect of feral cat control on toxoplasmosis on Hawkes Bay farms.

Results

- Controlling the disease in approximately 90% of the cat population each year is predicted to result in local disease eradication. With as little as 6% reductions in mouse populations each year, the requirement for yearly cat control to result in disease eradication is predicted to be reduced to 20%.

Addendum Conclusions

- If, as is suggested here, feral cat control (as part of a larger pest management programme) is able to locally eradicate toxoplasmosis from sheep farms in the Hawkes Bay region, the estimated cost to the Hawkes Bay farming community of sheep vaccination against this disease ($336,000 per annum) would no longer be necessary to prevent the estimated $1,032,180 per annum of lost lamb production.

1 Background

Toxoplasma gondii is an intracellular protozoan for which the definitive hosts (in which the sexual stage of the parasite lifecycle occurs) are felids (Tenter et al. 2000), often domestic cats *(Felis cattus)*. Susceptible cats become infected by preying on infected intermediate hosts, and excrete *T. gondii* oocysts (resistant transmission stages) into the environment. Intermediate hosts include most of all warm-blooded animals (Tenter et al. 2000), and become infected by ingesting oocysts from contaminated environments. Cats can also become infected by ingesting oocysts from the environment, but at a much lower rate than via predation of infected intermediate hosts (Dubey 2010). *Toxoplasma* in intermediate hosts such as rats and mice may also be transmitted congenitally (from mother to offspring through the placenta) via asexually produced transmission stages (tachyzoites and bradyzoites) (Wildfuhr 1954; Beverley 1959; Webster 1994).

Since the 1950s toxoplasmosis had been recognised as a significant cause of abortion in sheep, goats and pigs (Hartley et al. 1954; Hartley & Marshall 1957; Dubey 1986; Blewett & Watson 1983; Johnston 1988). Current management for toxoplasmosis on farms where it is an issue is through the prophylactic vaccination of stock with commercially available registered such as Toxovax®. In 2013, Hawkes Bay Regional Council (HBRC) contracted Landcare Research to provide a report on the 'Potential of feral cat control to reduce the incidence of toxoplasmosis on sheep farms' (Hopkins 2013). The Hawkes Bay farming community incurs significant cost vaccinating against toxoplasmosis to prevent he resultant high abortion rate in pregnant ewes on first infection; HBRC is thus considering cat control to assist farmers. The report concluded that the costs of cat control for management of toxoplasmosis appears to be prohibitively expensive compared with the systematic use of Toxovax®. HBRC have since requested that the cost/benefit analysis underpinning this conclusion be expanded to include considerations from the recent epidemiological modelling literature of the likely benefits, in terms of saving to farmers, of large-scale control being conducted for a wide pest species range and multiple purposes.

2 Addendum Aim

To consider the benefit of feral cat control to the Hawkes Bay farming community, through the mechanism of reduced sheep production losses due to toxoplasmosis and its management, in light of the recent epidemiological modelling literature. The cost of control is not considered here, under the assumption that such control will occur as part of a wider strategy.

3 Original Report Analysis

The original cost/benefit analysis is based on the critical assumption that feral cat control is unlikely to reduce *Toxoplasma* presence in the farm environment, due to (i) the resistance of *Toxoplasma* oocysts to environmental degradation (longevity of infectious stages ≥ 2 years), (ii) the maintenance of infection in rodent reservoirs in the absence of cats (long-term persistence irrespective of cat presence), and (iii) *Toxoplasma* oocysts originating from infected domestic cats (not controlled, with no available commercial cat vaccine).

Based on this assumption the conclusion of the original report holds – while an estimated current expenditure of $336,000 per annum on sheep vaccination with Toxovax® is preventing an estimated $1,032,180 per annum of lost lamb production in the Hawkes Bay region, feral cat control (at whatever cost) would likely not prevent this loss (Hopkins 2013). At most, such control would only partly reduce the exposure of sheep to infective oocysts (and hence vaccination would still be required), and the reduction in exposure would only be short-term.

4 Expanded Analysis

Exploring the assumption that feral cat control is unlikely to reduce *Toxoplasma* presence in the farm environment, and identifying the circumstances under which this assumption either likely or potentially will not hold, is thus critical to quantifying in greater depth the benefit of such control in terms of reduced sheep production losses.

Longevity of Toxoplasma oocysts in the environment

As noted by Hopkins (2013), multiple studies have demonstrated that *Toxoplasma* oocysts can remain infectious in the environment for long periods of time (Dubey & Beattie 1998). However, although the longest recorded period of longevity is over two years (when stored at 4^{o}C; Lindsay & Dubey 2009), it is generally accepted that outdoors in water or moist soil under normal conditions, up to approximately one year longevity is more usual (see Table 1 in Dumetre & Darde 2003).

Maintenance of infection in rodent reservoirs

As noted by Hopkins (2013), *Toxoplasma* in rodents can be congenically transmitted from mother to offspring via the placenta (Beverley 1959; Wildfuhr 1954), raising the possibility that *Toxoplasma* infection could be maintained by intermediate host populations in the absence of cats and oocysts (Owen & Trees 1998; Marshall et al. 2004). When such transmission pathways are included in models of toxoplasmosis in farm systems, simulations reveal that intermediate hosts (mice in this case) can indeed be more likely to become infected through congenital transmission than through exposure to oocysts (Jiang et al. 2012), and thus potentially allow persistence in the absence of cats.

Maintenance of infection by domestic cats

As noted by Hopkins (2013), domestic (as well as feral) cats are very likely to be infected with Toxoplasma. Overall prevalence in cats ranges between 10% and 80% (Kraus et al. 2003) however, as further noted by Hopkins (2013), less than 1% of cats are actively shedding oocysts at any one time. In addition, with infection related mainly to the availability and ingestion of infected intermediate hosts, infection is more common in stray, farm and feral cats than in pet cats (Wallace 1971; Dubey *et al.* 1977). There is thus potential for both feral cat control to reduce toxoplasmosis on farms *and* for domestic cats to facilitate its persistence in their absence.

5 Toxoplasma Epidemiology

The above expanded analysis indicates that the conclusion of Hopkins (2013), that feral cat control is unlikely to prevent sheep production losses due to toxoplasmosis in the Hawkes Bay region, could very well hold in many circumstances. However, it also indicates that there is also scope for feral cat control *to* impact toxoplasmosis levels on farms (in a context-dependent manner). For complex systems such as multi-host disease systems like *Toxoplasma*, an epidemiological modelling approach is required to determine the circumstances under which different potential outcomes are likely.

Several modelling studies have investigated toxoplasmosis in farm systems, and the impact of different management practises. Mateus-Pinilla *et al.* (2002) simulated *Toxoplasma* transmission on swine farms. While their model included an accurate representation of oocycte longevity, it only explicitly incorporated stock and cats; their justification for excluding other intermediate hosts (such as rodents) was that cats are the ultimate source of infection and hence set infection levels, citing epidemiological data in support (Smith et al. 1992; Weigel et al. 1995). They concluded that reducing cat numbers was the most effective of the management practises simulated (in comparison to different hypothetical cat vaccination strategies), with 80% reductions in farm cat populations predicted to locally eradicate the disease irrespective of variation in other factors (Fig. 1).

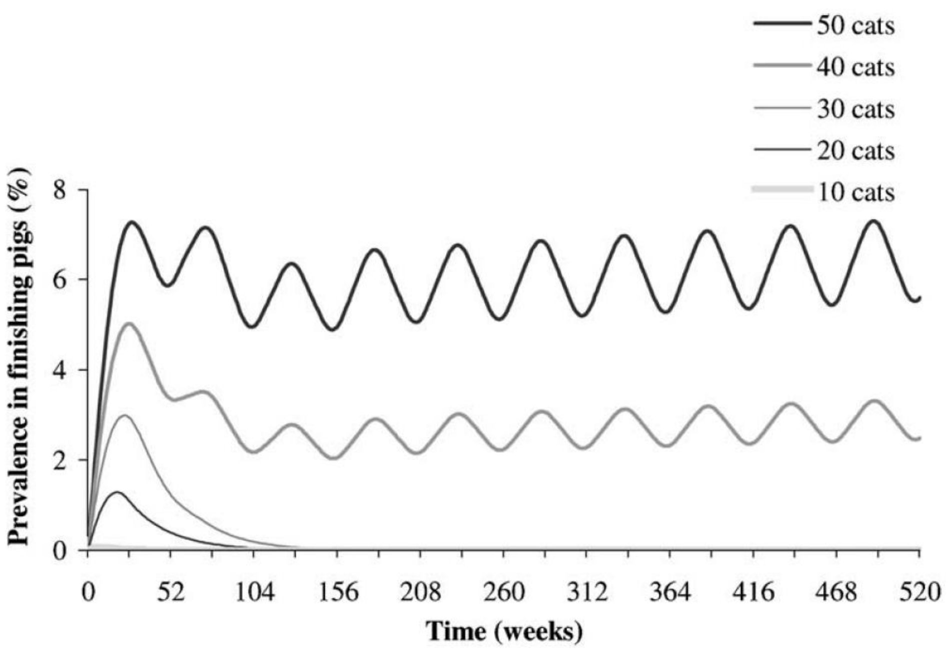

Figure 1. Example set of model simulations from Maeus-Pinilla et al. (2002), of toxoplasmosis control on swine farms. In this example, 50% of the cat population were being captured and vaccinated.

Jiang et al. (2012) expanded upon this work, investigating *Toxoplasma* transmission dynamics on generic farms, with disease in intermediate hosts explicitly incorporated. Their model included mice, the intermediate host in which congenital transmission occurs at rates an order of magnitude greater than in other species (Dubey & Frenkel 1998). While not simulating control strategies, they identified that under certain conditions intermediate host populations may indeed support the disease in the absence of cats and oocysts. They also speculate that (1) reduced cat populations may increase the risk of the disease spreading due to higher mouse numbers, and (2) controlling mice may successfully prevent the disease. In light of these speculations, they conclude that the overall effect of cat population control will likely depend on the trade-off between the role that cats play in disease transmission and the role that cats play in controlling the disease via mouse predation.

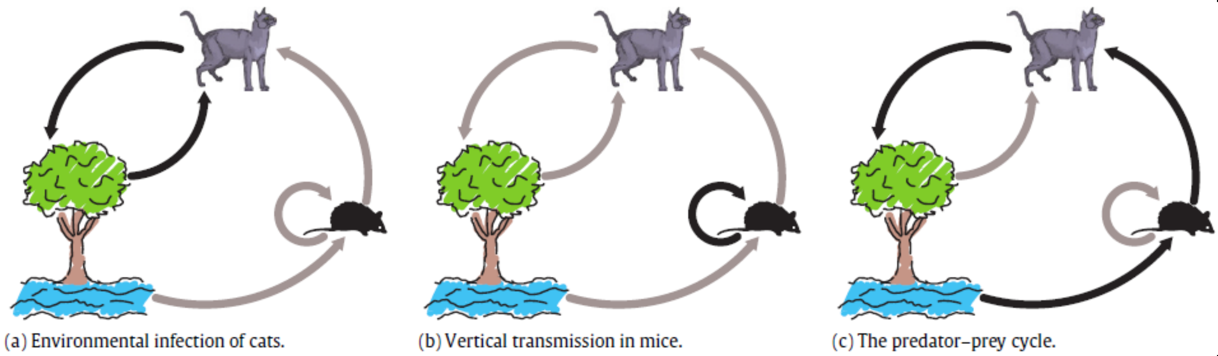

Figure 2. *Toxoplasma* transmission pathways included in the Turner et al. (2013) model.

In the most recent and comprehensive *Toxoplasma* modelling study to date, Turner et al. (2013) further expanded this approach to assess the effect of different potential control mechanisms while including transmission pathways within and between both cats and mice (including congenital transmission within the intermediate host, infection of both cats and mice by environmental contamination with oocysts shed from cats, and cats becoming infected by predating infected mice; Fig. 2). Their simulations predict that at realistic levels of congenital transmission within realistic intermediate host populations, controlling the disease in approximately 90% of the cat population each year (in this case by vaccination which, for the model formulated, has the same effect on *Toxoplasma* transmission dynamics as the equivalent percentage reduction in cat population size) results in local disease eradication. Furthermore, combining cat control with mouse population management was predicted to greatly reduce the requirement (in terms of the percentage of the cat population controlled) for *Toxoplasma* local eradication (Fig. 3). With as little as 6% reductions in mouse populations each year, the requirement for yearly cat control to result in predicted disease eradication was reduced to 20% (Turner et al. 2013).

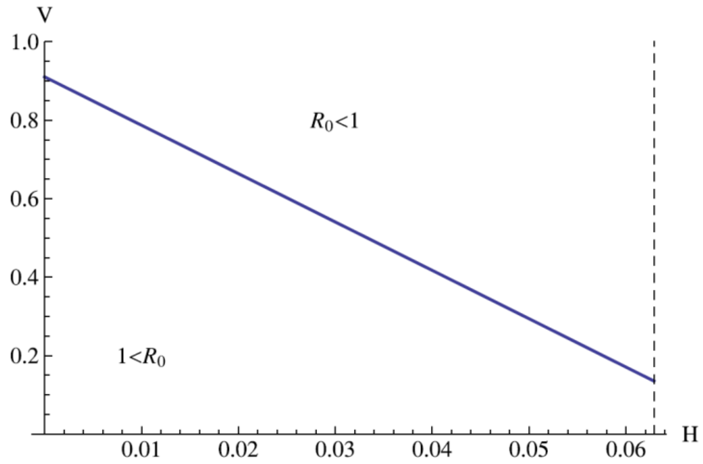

Figure 3. Local eradication of *Toxoplasma* under different combinations of yearly cat (V) and mouse (H) population control, as predicted by the Turner *et al.* (2013) model. Eradication is predicted to occur in the graph area where R_0 (the basic reproduction number for *Toxoplasma*) is less than 1.

6 Addendum Conclusions

In the Hawkes Bay region, feral cats are estimated as comprising 90% of the cat population in rural areas (with the remainder being domestic cats), while close to significant urban areas it is estimated as being closer to 60% (Campbell Leckie pers. com.). In light of the predictions of Turner *et al.* (2013), this implies that removing the feral cat population through control would (1) locally eradicate toxoplasmosis from most rural areas in the Hawkes Bay region with no other management necessary, and (2) with some mouse control, also be able to eradicate it from areas close to significant urban areas (i.e. those with greater domestic cat populations) as well. Since the feral cat control under discussion here is being proposed as part of a programme of large-scale control to be conducted for a wider species range and multiple purposes, simultaneous mouse control is likely.

If, as is suggested here, feral cat control (as part of a larger pest management programme) is able to locally eradicate toxoplasmosis from sheep farms in the Hawkes Bay region, the estimated cost to the Hawkes Bay farming community of sheep vaccination against this disease ($336,000 per annum; Hopkins 2013) would no longer be necessary to prevent the estimated $1,032,180 per annum of lost lamb production. However, three steps are recommended that could improve the robustness of this prediction. First, more accurate assessment of domestic versus feral cat numbers across the Hawkes Bay region would allow a more precise estimation of control potential effects, from the Turner *et al.* (2013) study, to be made. Second, simulation of mathematical models specific to Hawkes Bay region sheep farms would assess whether benefits of cat control similar to those predicted by Turner *et al.* (2013) are to be expected in this context. Finally, the effect of feral cat control on toxoplasmosis incidence in unvaccinated sheep flocks could be monitored (either in a pilot study, or attached to operational control efforts), to provide some hard evidence for this predicted benefit.

7 Acknowledgements

Funding was provided by Hawkes Bay Regional Council. Thanks to Andrea Byrom and Campbell Leckie for comments on an earlier version.

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