Manaaki Whenua
Landcare Research

Toxoplasmosis in New Zealand: trying to fill the knowledge gaps around transmission to livestock and native wildlife

Chris N. Niebuhr

Toxoplasmosis

- *Toxoplasma gondii*
- Protozoan parasite
- Infects most warm-blooded animals
  - Humans
  - Domestic/agricultural animals
  - Wildlife
- Complex lifecycle

Toxoplasmosis in wildlife

Type X strains of *Toxoplasma gondii* are virulent for southern sea otters (*Enhydra lutris nereis*) and present in felids from nearby watersheds

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[3]School of Veterinary Medicine and Biomedical Sciences, and [4]School of Natural Resources, University of Nebraska, Lincoln, NE 68583, USA
[5]California Department of Fish and Wildlife, Marine Wildlife Veterinary Care and Research Center, Santa Cruz, CA 95060, USA

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An atypical genotype of *Toxoplasma gondii* as a cause of mortality in Hector's dolphins (*Cephalorhynchus hectori*)

W.D. Roe[a,*], L. Howe[b], E.J. Baker[c], L. Burrows[b], S.A. Hunter[d]

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[b] *Infectious Disease Group, Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11222, Palmerston North, PN4222, New Zealand*
[c] *University of Edinburgh, Royal (Dick) School of Veterinary Studies, Easter Bush Veterinary Centre, Roslin, Midlothian, Scotland, United Kingdom*
[d] *New Zealand Wildlife Health Centre, Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11222, Palmerston North, PN4222, New Zealand*

Toxoplasmosis on sheep farms

- Significant cause of abortion in sheep, goats, and pigs
- The timing of infection is critical in terms of impacts on lambs
  - Before pregnancy: transient fever (ewe)
  - Early pregnancy: likely death (lamb)
  - Late pregnancy: possible death or weak at birth (lamb)
- Following infection, ewes develop robust immunity
- Source of infection in sheep is contaminated pasture, food supplies and water
- Fields treated with manure or hay from farm buildings where cats live and defaecate pose a significant risk of disease transmission

- Hawke's Bay region estimates (Walker 2014)
  - Potential loss of lambs due to toxoplasmosis (up to $18 million)
  - The cost to vaccinate all replacements* in the region (~$1 million)
    - *The vaccine is administered to replacement ewes each year

Toxoplasma gondii lifecycle

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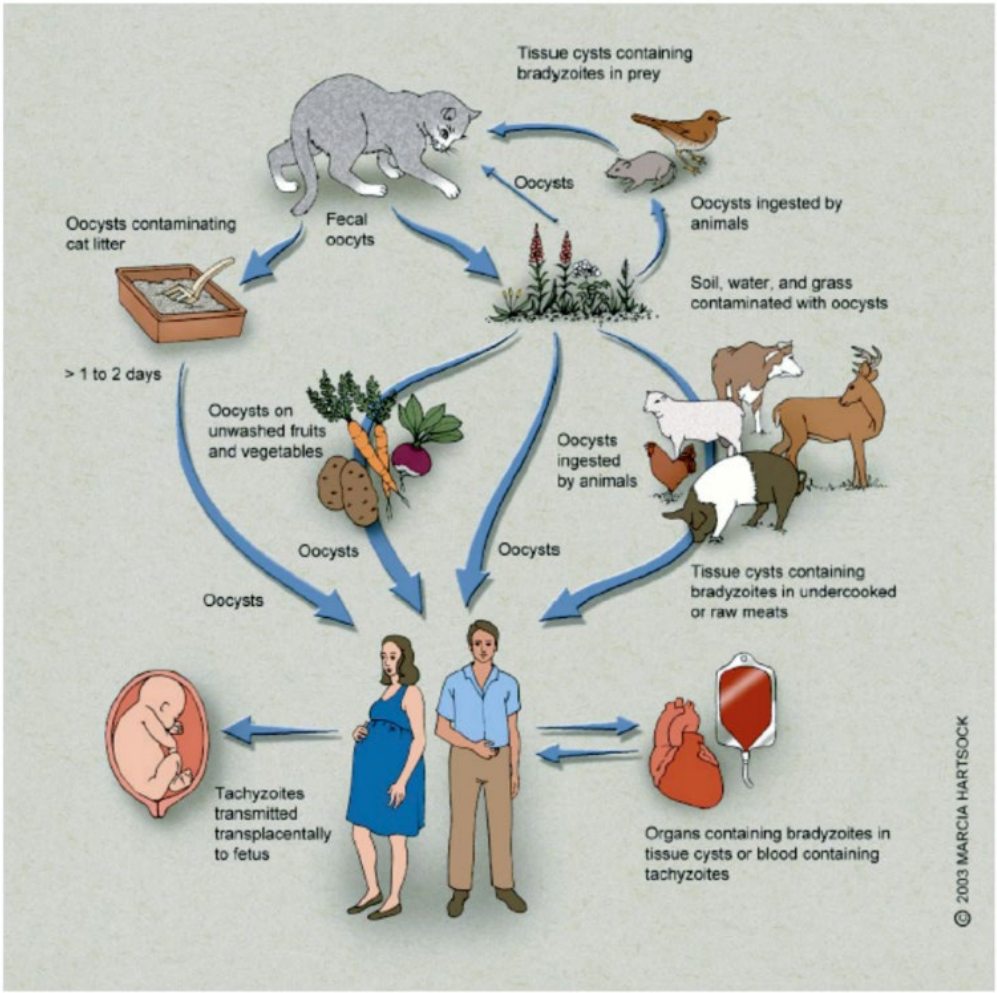
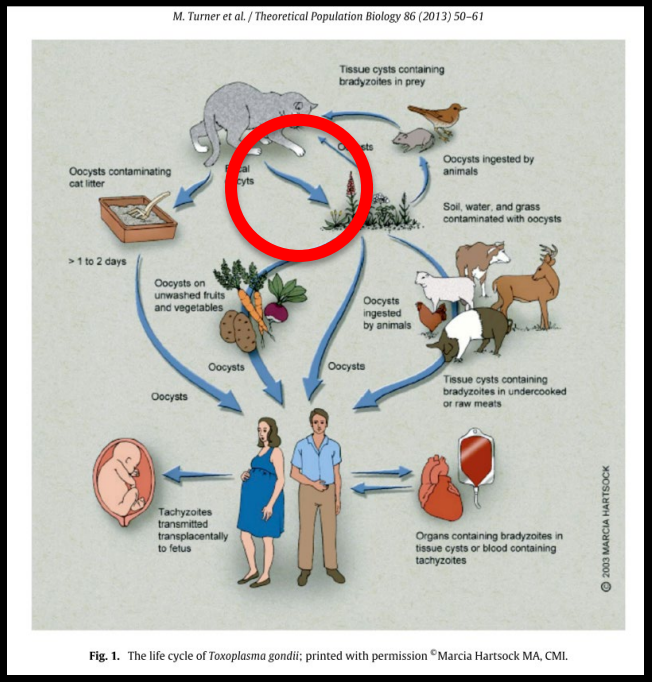


Fig. 1. The life cycle of *Toxoplasma gondii*; printed with permission ©Marcia Hartsock MA, CMI.

Transmission

- *T. gondii* infections in accidental hosts are primarily a result of transmission from the environment
- Therefore, to reduce oocyst loading in the environment, we should manage cat populations



Stopping transmission

- *T. gondii* infections in accidental hosts are primarily a result of transmission from the environment
- Therefore, to reduce oocyst loading in the environment, we should manage cat populations

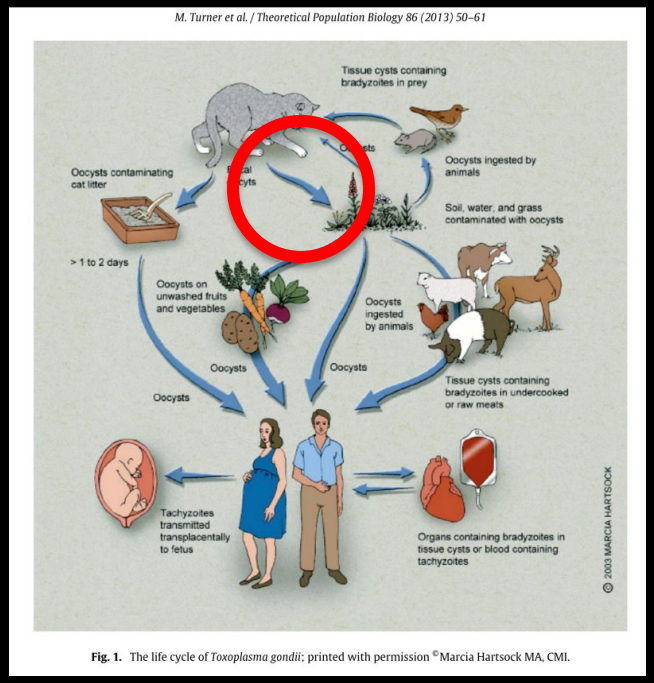


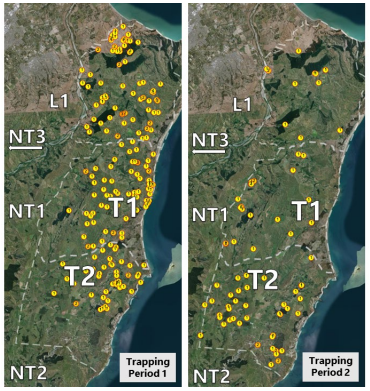
Fig. 1. The life cycle of *Toxoplasma gondii*; printed with permission ©Marcia Hartsock MA, CMI.

Is it that simple?

Preliminary evaluation of the effect of predator control on *T. gondii* seroprevalence in sheep

as part of the Cape to City Programme, Hawke's Bay Regional Council

- Seroprevalence of one-year-old ewes was compared prior to, and after commencement of, large-scale control of predators, including feral cats.
- Sheep seroprevalence was highly variable among sites and over time.
- A knockdown of feral cat abundance was observed, but did not last.
- Conclusions: Likely more targeted and/or long-term control needed



Niebuhr and Norbury (2020) report to HBRC

Environmental persistence

- A single cat may shed >20 million oocysts into the environment
- Oocysts can remain infective in soil and fresh water for at least 1 year, and in seawater up to 2 years

Cat definitive hosts

- Oocyst shedding typically occurring early in life
- Unowned cats (stray, feral)
  - have shorter life spans (a few years, compared with 15+ years for pet cats) (Gillies & Fitzgerald 2005)
  - breed more rapidly
  - Therefore, feral cats would be priority for control

Intermediate hosts

- Maintain infections for multiple generations (vertical transmission)
- Infection in cats occurs at a much higher rate from predation on infected intermediate hosts than from ingestion of oocysts from environment
- Varying predation rates (unowned vs owned cats)

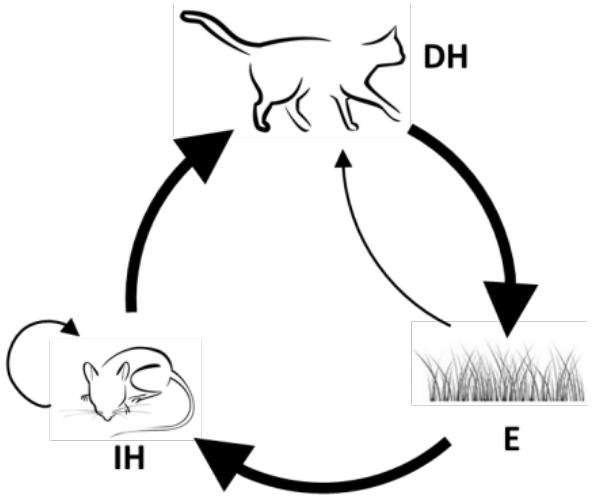


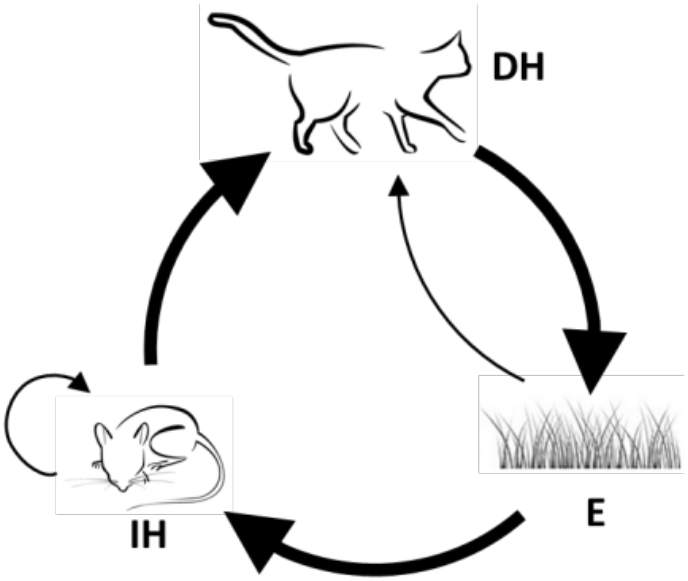
Figure: Emmanuelle Gilot-Fromont et al. (2012)

Disease Management

Is it that simple?

Image: Emmanuelle Gilot-Fromont et al. (2012)

Disease Management



Is it that simple?

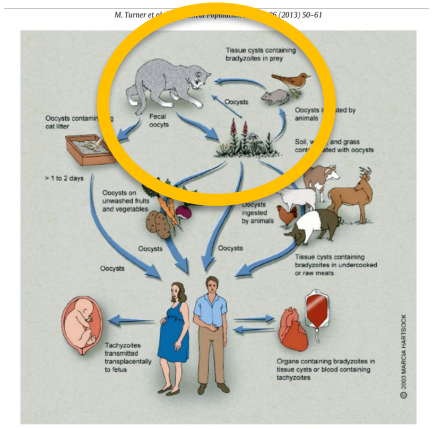
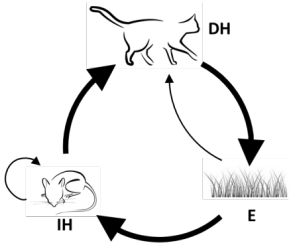


Fig. 1. The life cycle of *Toxoplasma gondii*; printed with permission ©Marcia Hartsock MA, CMI.

Epidemiological modelling



- Several modelling studies have investigated impact of different management practises on toxoplasmosis in farm systems.
- Turner at al. (2013)
  - differential equation model that explores
    - transmission pathways
    - potential control mechanisms

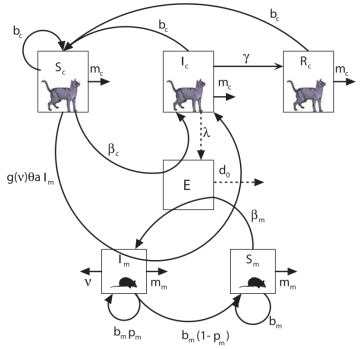


Fig. 2. A schematic representation of the transmission of *T. gondii* between the definitive host (cat), intermediate host (mouse), and the environment.

$$
\begin{cases}
\dot{S}_c = b_c N_c - \left(m_c + (b_c - m_c)\dfrac{N_c}{K_c}\right) S_c \\
\quad -\beta_c E S_c - g(v)\theta a S_c I_m - V S_c \\
\dot{I}_c = -\left(m_c + (b_c - m_c)\dfrac{N_c}{K_c}\right) I_c + \beta_c E S_c \\
\quad +g(v)\theta a S_c I_m - \gamma I_c \\
\dot{R}_c = -\left(m_c + (b_c - m_c)\dfrac{N_c}{K_c}\right) R_c + \gamma I_c + V S_c \\
\dot{E} = \lambda I_c - d_0 E \\
\dot{S}_m = b_m S_m + b_m (1 - p_m) I_m \\
\quad -\left(m_m + (b_m - m_m)\dfrac{N_m}{K_m}\right) S_m - \beta_m E S_m - a N_c S_m - H S_m \\
\dot{I}_m = b_m p_m I_m - \left(m_m + v m_m + (b_m - m_m)\dfrac{N_m}{K_m}\right) I_m \\
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$$
\begin{cases}
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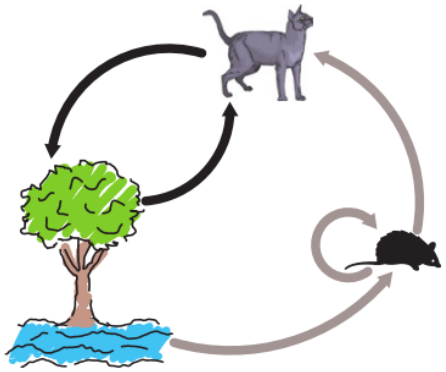
M. Turner et al. / Theoretical Population Biology 86 (2013)

Epidemiological modelling

- Carrying capacity of cats



Environmental infection in cats

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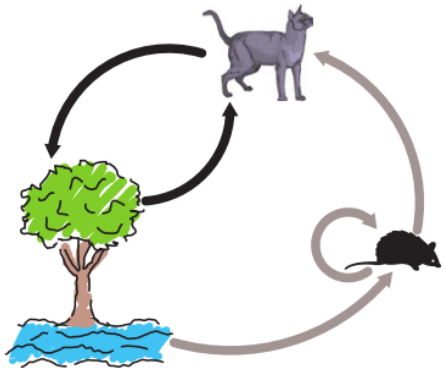
Epidemiological modelling

- Carrying capacity of cats
- Predation rates



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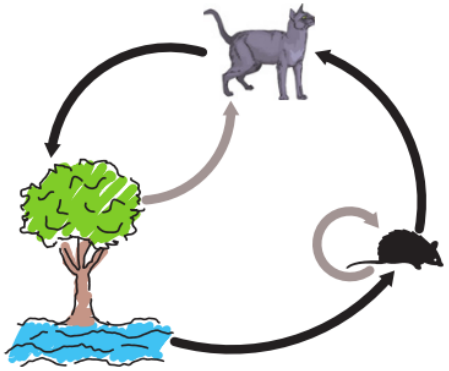

The predator-prey cycle

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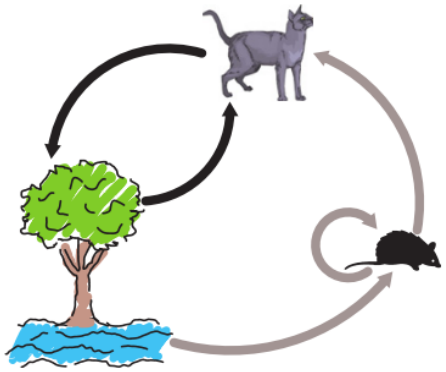
Epidemiological modelling

- Carrying capacity of cats
- Predation rates
- Vertical transmission in intermediate hosts



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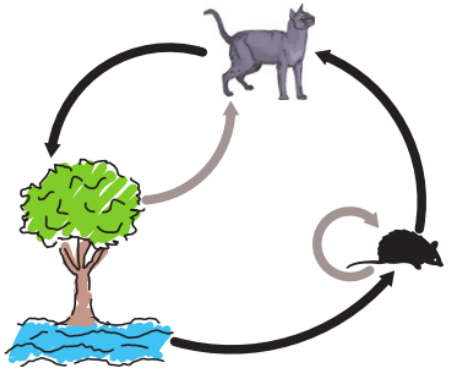

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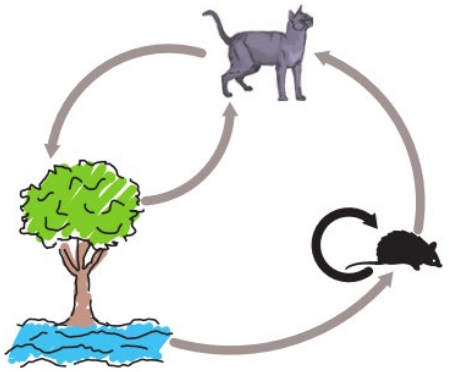

Vertical transmission in mice

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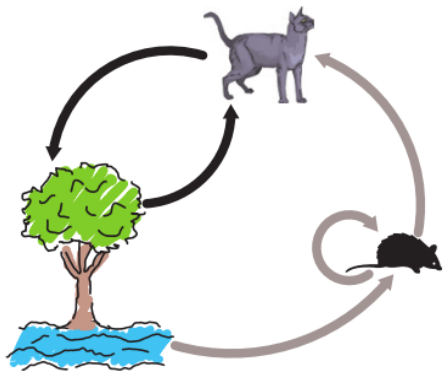
Epidemiological modelling

- Environmental risk to cats increases as the carrying capacity (K) of cats is increased
  - e.g. for densely populated regions, no other life cycle necessary for infection to persist



Environmental infection in cats

Epidemiological modelling

- Environmental risk to cats increases as the carrying capacity (K) of cats is increased
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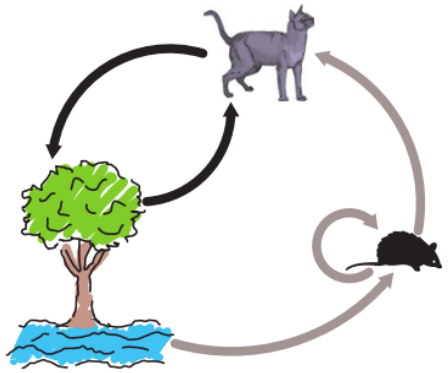
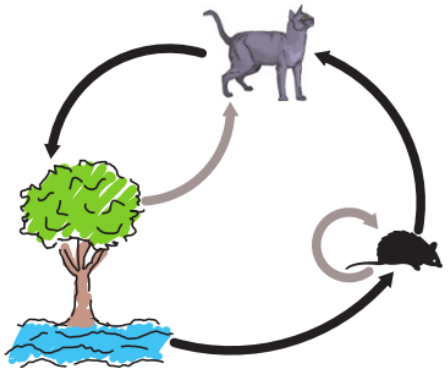
- For moderately high predation, the predator-prey cycle is all that is necessary to sustain infection



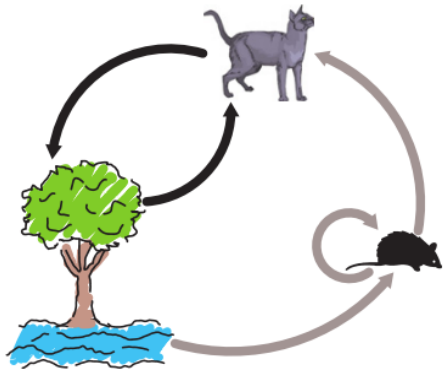
Environmental infection in cats



The predator-prey cycle

Epidemiological modelling

- Environmental risk to cats increases as the carrying capacity (K) of cats is increased
  - e.g. for densely populated regions, no other life cycle necessary for infection to persist
- For moderately high predation, the predator-prey cycle is all that is necessary to sustain infection
- For sparsely populated regions with low predator-prey life cycle (e.g. urban areas, following control), vertical transmission in IH is a deciding factor for disease persistence
  - "a parasite struggling for survival would benefit most by increasing vertical transmission in mice"



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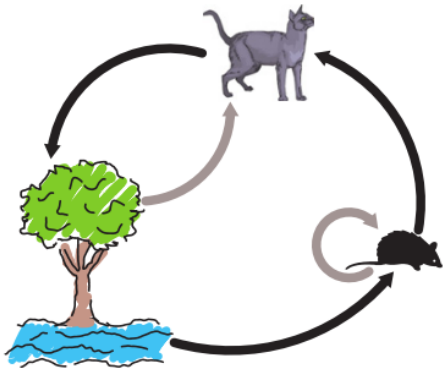
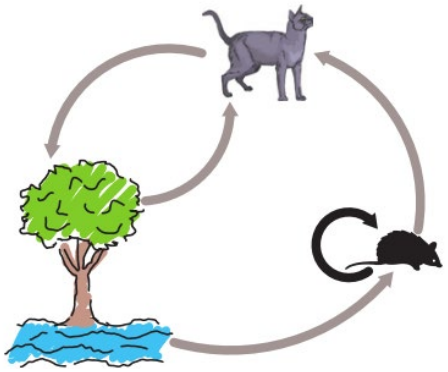


The predator-prey cycle



Vertical transmission in mice

Disease modelling

- Turner at al. (2013) modelling simulation example: (discussed in Tompkins 2014)
  - Controlling disease in 90% of the cat population each year is predicted to result in local disease eradication.

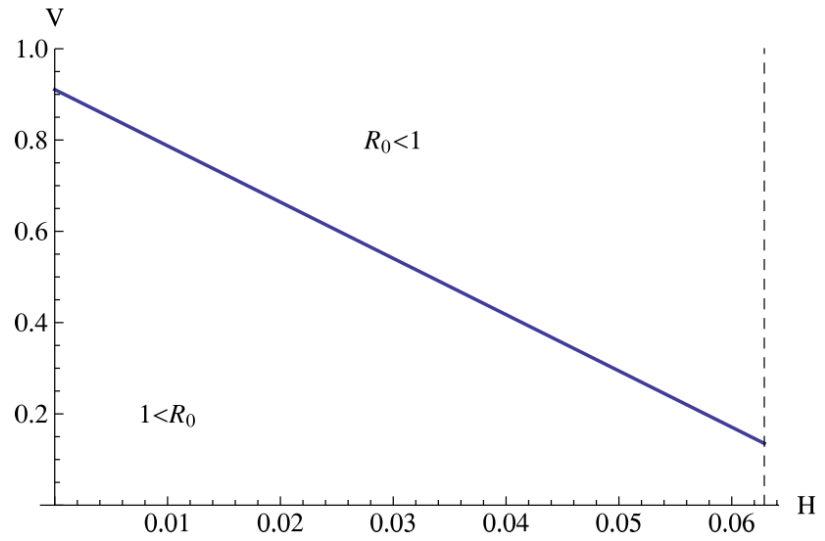


Fig. 7. Control program of constant rate cat vaccination and/or mouse harvesting. The dashed line represents the maximum allowable harvesting rate H_a. The virulence to mice is $\nu = 0.3$. All other parameters take the default values in Table 1.

Disease modelling

- Turner at al. (2013) modelling simulation example: (discussed in Tompkins 2014)
  - Controlling disease in 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 amount of yearly cat control needed to result in predicted disease eradication was reduced to 20%
  - In other words, the model suggests less-intensive cat control is necessary if mouse populations are reduced concurrently

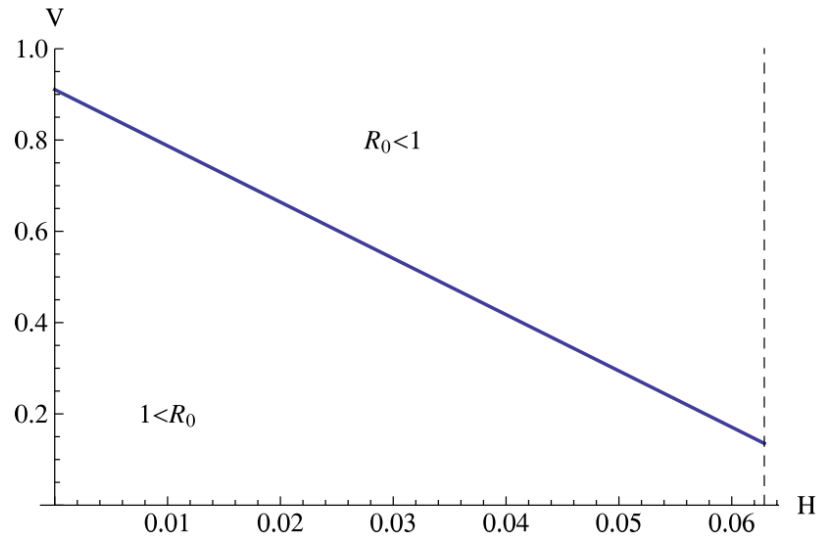


Fig. 7. Control program of constant rate cat vaccination and/or mouse harvesting. The dashed line represents the maximum allowable harvesting rate H_a. The virulence to mice is $\nu = 0.3$. All other parameters take the default values in Table 1.

Create a NZ specific model

- transmission pathways
- potential control mechanisms

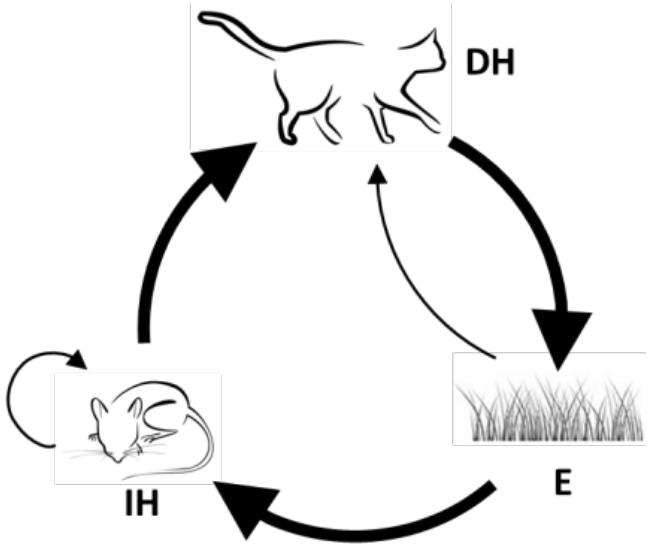
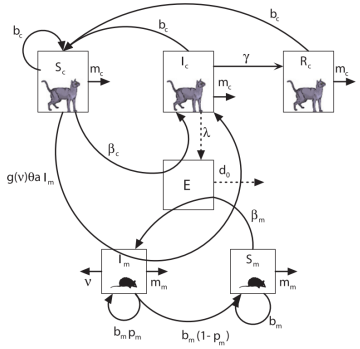


Figure: Emmanuelle Gilot-Fromont et al. (2012)



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\end{cases}
$$

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Future plans for Toxoplasmosis studies

- Role of intermediate hosts in transmission dynamics of *T. gondii*
  - Rodents (mice, multiple rat species)
  - Other (e.g. rabbits?)
- Geographic and host distribution of *T. gondii* genotypes in NZ
- Research investigating potential management regimes to reduce (or eliminate) toxoplasmosis impacts
  - Bioeconomics: cost/benefit of wildlife control on impact to livestock
- Infection status of other wildlife in NZ
  - Wild game animals; risk to humans?
  - Acting as sentinel species?

Manaaki Whenua
Landcare Research

Questions?

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