Mathematical models can prevent parasite attack, says **Andy Fenton.**

WAR of the WORMS

Nematodes emerging from an infected insect.

Arnold Hara, University of Hawaii

Roundworm, hookworm and other parasites infect about a third of the world's population. Treatments for these conditions drain cash-strapped health services. Similarly, parasitic infections of domesticated animals cost the farming industry billions. Two issues concern researchers: some parasites quickly evolve resistance to drug treatments; and chemical treatments to prevent infection can damage the environment.

Mathematical models can help us to develop effective, targeted control programmes. These models show why existing efforts do or don't work, and allow us to explore alternative control approaches yet avoid expensive and potentially risky field trials. This is the story of how we used models to determine the best control methods involving two very different parasites, one beneficial to us, a nematode worm, and one harmful, a fish louse.

Garden centres sell the microscopic nematode worm *Steinernema feltiae* as a biological agent to control pests like black vine weevil and leatherjackets. Gardeners apply the worms to the soil much like a chemical pesticide. Unlike chemicals, this worm actively seeks out insects. When it finds one, the nematodes burrow into the insect, kill it, and gorge on its tissues. Once the worm has devoured its host we discover the second advantage over chemical pesticides – the insect splits apart and releases thousands of new insect-seeking nematodes back into the soil.

Gardeners use nematodes to ward against a range of insect pests, but we wanted to see if they could control tiny flies (sciarid flies) in mushroom houses. We combined field trial data with a mathematical model similar to the ones used to model infectious diseases in humans.

A farmer would normally apply nematodes in a single dose at the start of the mushroom growing cycle. Our model reckoned another approach may work better. It showed that splitting the nematodes into two doses and applying some at the start and some a week later could reduce fly populations. We found we could reduce the overall dose of nematodes by 75 percent of the current recommended dose and still achieve the same level of control, providing we carefully chose the timing of the doses. Importantly, because we had built the model on a sound understanding of the biology of the fly-nematode interaction, we could use the model to determine why we had achieved such high levels of control. The first application hits the initial wave of invading flies and the second application targets the peak in abundance of fly larvae in the compost. Without the model we wouldn't have known the reason for the success or appreciated the importance of targeting the larvae at a certain time.

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We applied a similar approach to develop control strategies for parasites found in fish farms in Finland. The fish louse *Argulus coregoni* often plagues these fish farms causing considerable economic losses. Large-scale chemical applications currently control these lice, with potentially harmful effects on the environment. Our mathematical model revealed that the infestation level relied on the number of parasite eggs that survive over winter. Using egg traps in winter to remove the parasite eggs would greatly reduce the parasite population. In addition, the model demonstrated that giving the fish a medicated feed to kill the infecting parasites could prove a highly effective short-term control method. However, the model brought bad tidings: these approaches may not last long. The parasites can go into a prolonged hibernation, protecting the population from our control methods. We want to find solutions but we think that similar hibernation strategies are a major factor reducing control success for other disease-causing species around the globe. Certainly the battle against fish lice goes on.

This last example shows that even in simple situations with just one host species (the fish) and one parasite species (the lice) living in a well-controlled environment (the fish farm), various factors reduce the efficacy of control. When we try to apply these models to human diseases, the picture becomes more complicated. People differ in their exposure and susceptibility to diseases, and other hosts often maintain the disease. Also, you can't rule out a variety of parasites and pathogens infecting a host at the same time.

We need to understand how all these factors combine to harm the host, and determine how the host and parasites will respond to an imposed control programme. Well-developed, well-tested models are effective tools in this process, and it may be that lessons learnt from modelling these less well-known species will give us confidence when we apply them to more devastating diseases in humans and livestock. It is only then that we can truly make progress in our war against the worms. ❖

*Dr Andy Fenton is a lecturer at the School of Biological Sciences, University of Liverpool.
Tel: 0151 795 4473, email: a.fenton@liv.ac.uk
www.liv.ac.uk/bio/people/academic/fenton_a/index.html*