Manaaki Whenua
Landcare Research

Editorial: Developing better tools for managing pests


Possum with young

In November 2016, the International Union for Conservation of Nature (IUCN) launched the 'Honolulu Challenge on Invasive Species'. Coming out of the September 2016 IUCN World Congress, the Challenge recognises the losing battle being fought against invasive species globally, and calls for an international increase in efforts and initiatives to both stop new incursions (such as myrtle rust) and better manage legacy pests (such as weeds and invasive predators). New Zealand is helping spearhead this international challenge, with our Predator Free 2050 goals to eradicate rats, possums and stoats from the country being a lead initiative. Landcare Research and our collaborators are helping spearhead the research needed to achieve both these local pest management goals and the wider global vision.

And for just rats, possums and stoats, the research needs are broad. I've been pulling material together for an overview talk on 'Predator Free 2050' that I gave at the 17th Australasian Vertebrate Pest Conference in Canberra last April. This exercise brought home three key realisations. First, local pest managers and researchers have made amazing advances in their ability to manage invasive predators in the past 60+ years. They have gone from eradicating rats off islands of a few hectares in the Hauraki Gulf in the 1960s, to eradicating them off Campbell Island (112,700 ha) in the 2000s. Second, notwithstanding this progress, Predator Free 2050 is an audacious goal. It's audacious in a good sense – the global community find what is being achieved is inspirational, and is once again looking to New Zealand to lead the way. But pest managers now need to scale up their plans to the eradication of predators from the 27 million ha of New Zealand.

And this is where the third realisation comes in. Multiple research streams on traps, toxins, making old approaches better, identifying new approaches, detection devices, and understanding the ecology and behaviour of target pest species have enabled an increase in the areas eradicated from the 20th to the 21st century not in a linear fashion but in a logarithmic fashion. This means that the capability to get the job done has been accelerating, and it's been combinations of tools and approaches, each with their own strengths and weaknesses, that has allowed this. So, this is the challenge now. This broad range of research must be kept going to support the accelerating pace of pest management.

In this issue of Kararehe Kino, some of the latest advances are showcased. Many of Landcare Research staff are working with the New Zealand's Biological Heritage National Science Challenge. Patrick Garvey and colleagues discuss a new type of stoat lure being developed with the Challenge, based on higher-order predator rather than food or mating odours, which could enhance the detection and trapping of these devastating pests of native fauna. And the Biological Heritage Challenge is not just about invasive vertebrates. Bob Brown and Ronny Groenteman present work on using infectious mites and parasitoids to control invasive wasps, predators in their own right (of native invertebrates and honey bees).

Helping the Biological Heritage Challenge with its mission to "reverse the decline of New Zealand's biological heritage" is a wide range of other research projects. Advances are still being made in the optimisation of conventional approaches to pest management. Graham Nugent and colleagues show how aerial 1080 can be used not only for the eradication of bovine tuberculosis, but also how with modern application methodology it comes very close to also eradicating possums and rats. Further advancement could very well take this up to 100% control. Recognising that much of the cost of deploying traps and surveillance devices for pest management is people's time, Bruce Warburton and colleagues discuss the utility of wireless networks for reporting device triggering. Bruce and colleagues also discuss how advances in thermal imaging camera technology can be put to use for animal pest surveillance.

Large gains in pest management can also be achieved by empowering end-users and stakeholders actively involved in operations to make the decisions themselves, about the best approaches to take for their circumstances, and how to optimise management impact (and subsequent benefit) from the resources that they have available. Dean Anderson and colleagues present a user-friendly web-based tool for rapidly assessing the success of an eradication attempt. Andrew Gormley and Graham Nugent detail a similar tool for use by OSPRI (TBfree New Zealand) vector control managers in their planning of post-control surveillance to demonstrate TB freedom – JESS (Just Enough Surveillance Sensitivity).

Finally, ground-breaking advances in the understanding of genetics being made in other disciplines, most notably human medicine, offer potential for a new set of tools and approaches for pest management. Not all of these necessarily involve genetic modification (GM). For example, Brian Hopkins and colleagues discuss how an understanding of the genetic code of pests and approaches from the pharmaceutical industry, can be used to develop new host-specific toxins for target pests. Damian Dowling and colleagues demonstrate laboratory proof-of-concept for a novel approach that has been in development just since 2012 – the Trojan Female Technique – based on the selective breeding of naturally occurring mutations in mitochondrial DNA that reduce male fertility.

The role as pest management researchers in New Zealand is to present the public and policy makers, stakeholders and end-users, with the best range of approaches to achieve the country's pest management goals. Internationally, GM is offering large advances in pest management for both human health and conservation benefit. For example, the Gates Foundation is funding 'Target Malaria', a large program including genetic modification of mosquitoes to eradicate human malaria. Researchers in New Zealand are thus also starting to explore these options, to provide the necessary information based on which decisions regarding their use can be made. Brian Hopkins discusses how GM can be used in the laboratory setting, to rapidly accelerate the discovery of pest-selective toxins. To explore the use of GM to directly control animal pest populations in a safe and socially responsible manner, Landcare Research has joined a partnership of leading international agencies investigating all aspects of such approaches for rodent management – Genetic Biocontrol of Invasive Rodents (GBIRDd).

Through maintaining a broad research portfolio, and considering how different pest management approaches can best complement one another, New Zealand's environmental goals such as Predator Free 2050 are likely to be achieved in a responsible and socially acceptable manner.

Dan Tompkins, Portfolio Leader Managing Invasives, Landcare Research

tompkinsd@landcareresearch.co.nz

Rapid Eradication Assessment (REA): a user-friendly web-based tool

Eradications of invasive species have been successful on islands all over the world. Following any eradication attempt it is necessary to confirm the success of the operation. Terminating monitoring for survivors too soon risks a false declaration, but monitoring for too long can be an unnecessary waste of resources and time. The traditional approach is to wait 2 years, and if no survivors are found then, eradication is declared successful. The risk in this 'wait and see' tactic is that if survivors are present in a small localised area, their population could grow and become widespread in 2 years. The eradication effort would then either have to begin again from scratch or be abandoned. Early detection and removal of survivors would result in important cost savings and biodiversity benefits, especially for difficult-to-eradicate species such as mice.

Dean Anderson and Araceli Samaniego-Herrera previously reported in *Kararehe Kino* (issue 19; pp 10–11) on a statistical model to quantify the probability of eradication immediately following an eradication operation on islands. While this was a useful tool, it was not designed for easy use by eradication managers, who are in most need of such a tool. Dean and Araceli, in collaboration with researchers at the University of Auckland, have developed the confirmation tool into a user-friendly graphical user interface (i.e. point and click) that is accessible online (www.rea.is).

The user inputs survey data on the spatial locations of detection devices, or a proposed spacing of an island-wide grid of such devices, the number of days or nights of deployment, and the time between eradication and surveillance sessions (see Figure 1). Also input are parameter distributions related to detection probability, home-range kernel, dispersal kernel, probability of reinvasion, and population growth rate. The software calculates the probability that pests have been eradicated from the area given that none are detected.

The Rapid Eradication Assessment (REA) tool has now been used by the Grupo de Ecología y Conservación de Islas as an eradication confirmation tool on eight successful operations for mice and rats in the dry and wet tropics of Mexico (Samaniego-Herrera et al. 2017; doi: 10.1017/S0030605316001150.). The use of REA immediately following the eradication operation removed the need for repeated return trips to confirm eradication success and allowed restoration activities to begin sooner rather than later.

Araceli Samaniego-Herrera was funded with a CONACyT doctoral scholarship and a WWF EFN fellowship.

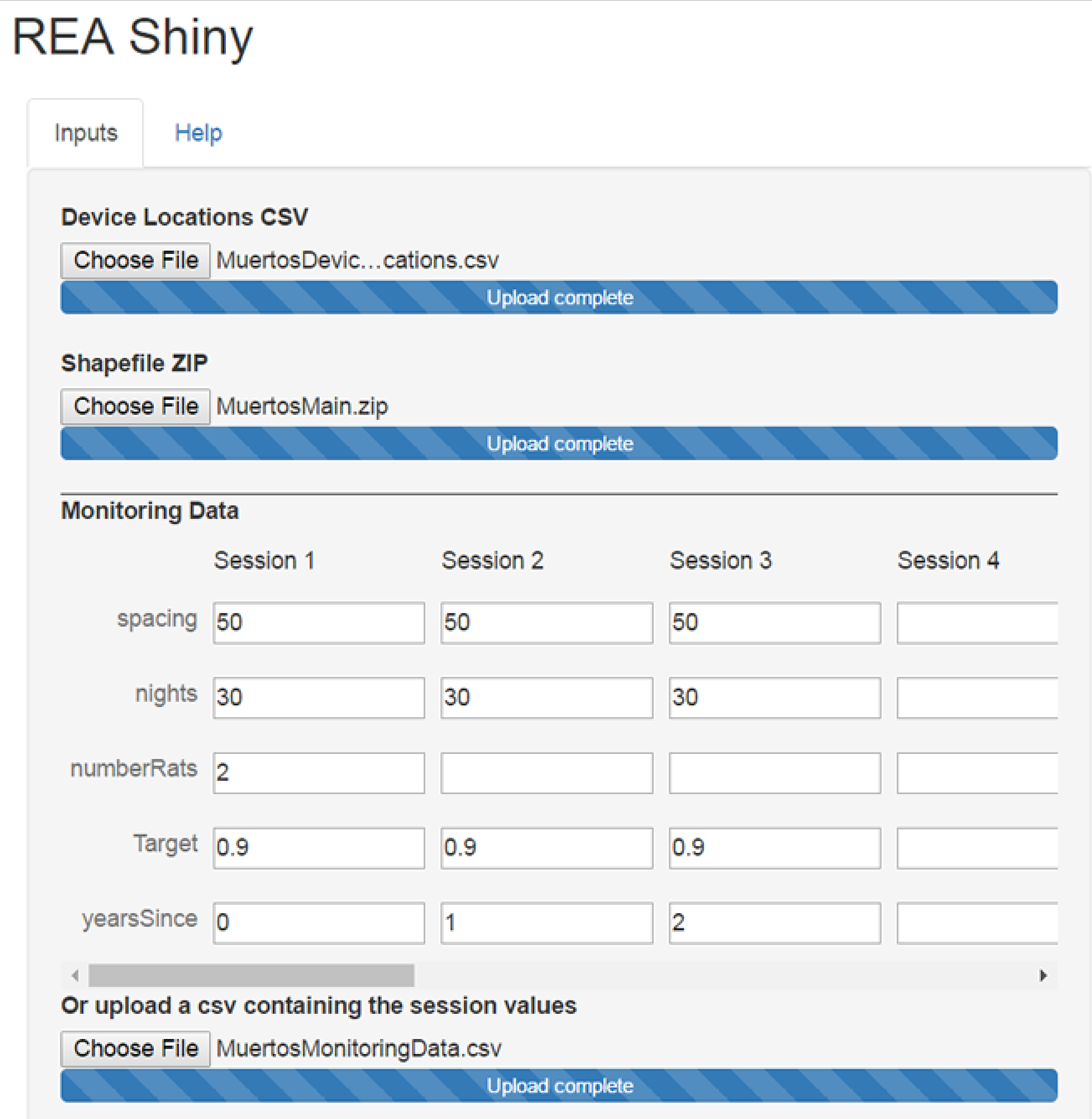


Figure 1. Graphical user interface of the REA model where the user inputs monitoring data, a shapefile to define the area of eradication, and details of the monitoring effort.

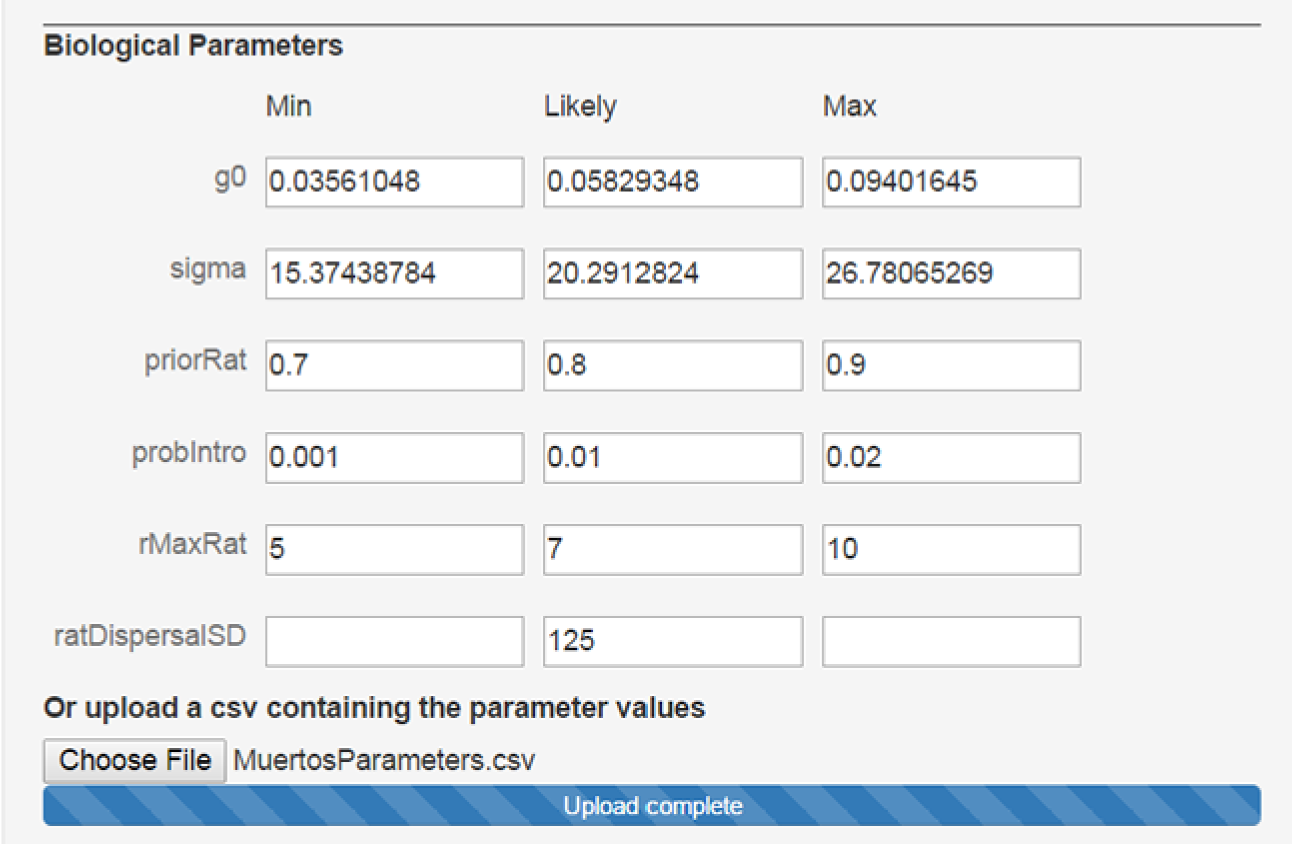


Figure 2. Graphical user interface of the REA model, where the user inputs model parameter values. (From Samaniego-Herrera et al. 2013, Journal of Applied Ecology 50).

Dean Anderson (Landcare Research) andersond@landcareresearch.co.nz

James Russell, Hannah Binnie, Jimmy Oh, Araceli Samaniego-Herrera (University of Auckland)

JESS (Just Enough Surveillance Sensitivity): a flexible decision support tool for TB surveillance

TB lesion in the armpit of a brushtail possum.

Bovine tuberculosis (TB) is a livestock disease that also infects humans. It is caused by a bacterium (*Mycobacterium bovis*) that evolved from the strain that causes human TB. Globally TB is still a major threat to human and animal health, with longstanding efforts to reduce or eradicate the disease ongoing in many countries.

In New Zealand eradication of TB is difficult because it became established in brushtail possum populations over about 40% of the country (10.4 million ha). Possums are the main wildlife host: they act as independent reservoirs of infection and readily transmit TB to farmed cattle and deer. To reduce the threat to human and animal health, OSPRI (formerly the Animal Health Board), operating under a National Pest Management Plan (NPMP), has made concerted efforts since 1994 to reduce and eliminate TB from wildlife. In July 2016 the NPMP goals were extended to include, for the first time, biological eradication of the disease from the whole country by 2055, and, as an intermediate milestone, to achieve TB freedom in possums by 2040.

OSPRI declares local management areas (called Vector Control Zones, or VCZs) free of TB when it is about 95% confident that the disease has been eradicated from possums. To achieve freedom from all wildlife, OSPRI first carry out possum control to reduce and maintain the population at levels too low for TB to persist. Surveillance is then carried out to confirm freedom of wildlife from TB. Surveillance can involve a range of activities, including capturing and testing possums and sentinel species (i.e. spillover hosts that do not maintain the disease) such as ferrets, pigs and deer. The more cumulative surveillance carried out that does not detect the disease, the more confident managers are that the disease has indeed been locally eradicated from a given VCZ.

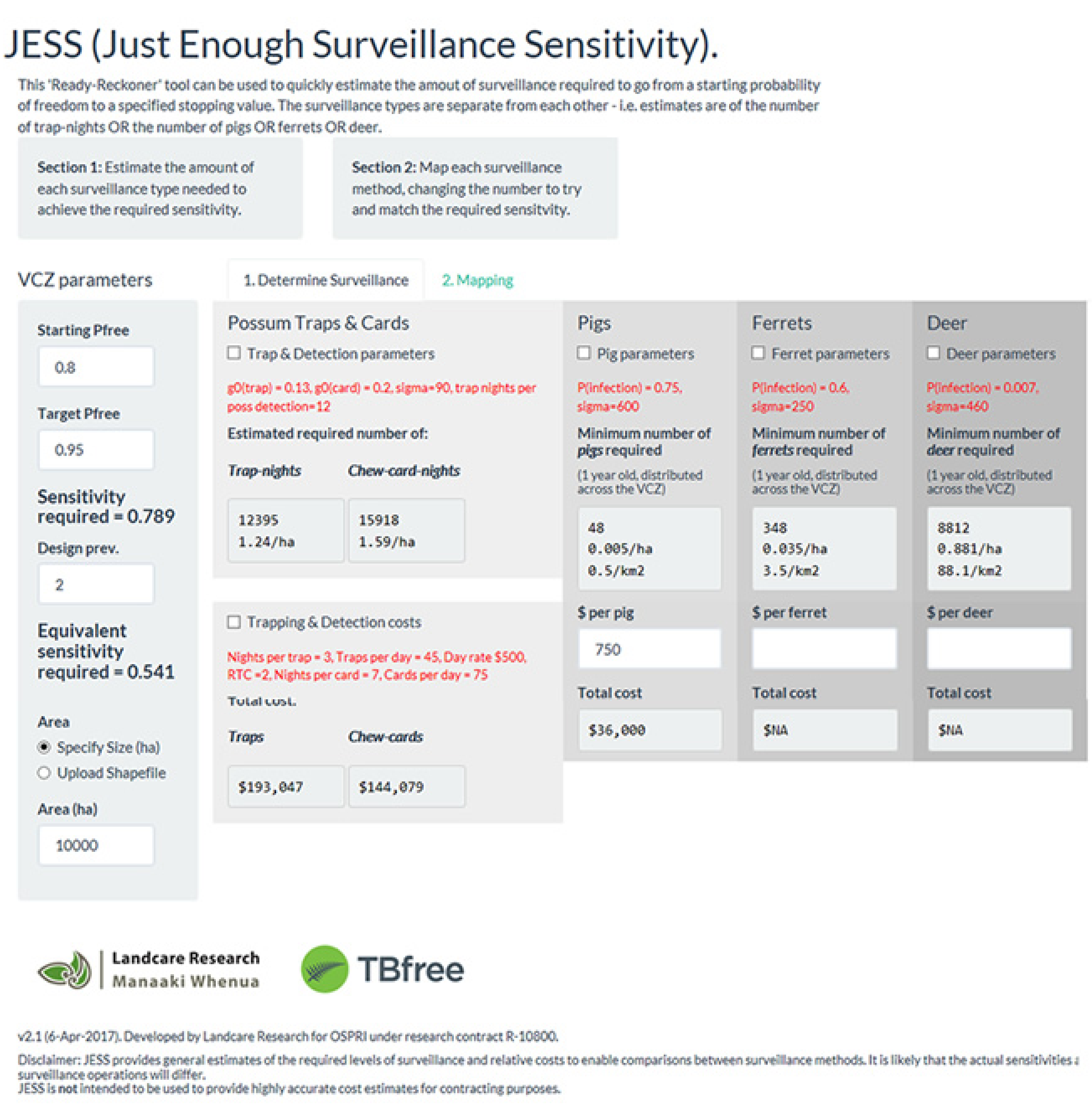
Given that surveillance can be extremely costly and that there are vast areas to be surveyed, it is desirable to carry out just enough surveillance to meet the desired level of confidence about TB freedom in a VCZ so that resources can then be directed to other areas. However, the amount of surveillance required varies widely between VCZs, depending on how confident managers are that TB has been eradicated, the size of the area, what TB hosts are present that can be used for surveillance, and what they might cost to survey. Until now there has been no easy way to assess the lowest-cost approach to surveillance.

Andrew Gormley and Graham Nugent of Landcare Research have developed an online decision support tool to predict the best mix of possum and/or sentinel surveillance for any given VCZ. This tool, JESS (Just Enough Surveillance Sensitivity), takes into account a range of factors, including the current probability of freedom from TB, the area of the VCZ, the home range and trappability of possums and sentinels, and the relative costs of surveying them.

JESS is designed to be easy to use and flexible: the user can enter VCZ-specific unit costs associated with possum and sentinel surveillance, as well as VCZ-specific estimates of their home range and trappability. The tool uses a simplified version of the sophisticated computer software package (called Proof of Freedom, PoF) that OSPRI uses to calculate probabilities of TB freedom *after* all of the surveillance data have been gathered. In contrast, JESS *predicts in advance* the area-wide surveillance sensitivities that would result from various mixtures of wildlife and an estimate of total surveillance costs. By using the same methodology as the PoF utility, the estimates of survey sensitivity are entirely consistent with those obtained by entering actual survey information.

The first stage of JESS has been developed in close collaboration with key OSPRI staff (such as area disease managers). This close working relationship has ensured that JESS was adopted by managers as soon as it became available in late 2016, and by early 2017 its predictions were being routinely incorporated into the operational planning of surveillance programmes.

By allowing managers to easily and quickly determine the minimum amount and type of surveillance required to achieve TB freedom in VCZs, the app is expected to result in significant savings of both cost and time. This will result in faster progress toward TB freedom, and ultimately the eradication of TB from possums nationally.

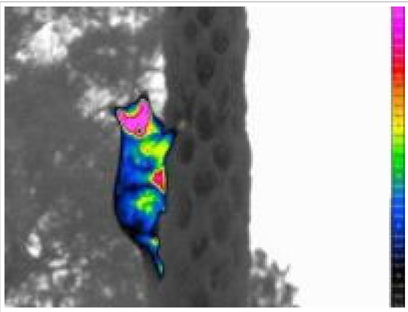


Screenshot of JESS showing the inputs and outputs for an illustrative VCZ.

This work was funded by OSPRI.

Andrew Gormley (Landcare Research) gormleya@landcaareresearch.co.nz

Thermal imaging cameras for animal detection



Possum clearly visible by its heat signature

As with many technologies, thermal imaging cameras have been advancing rapidly over the past 10 years, with hunters, pest biologists and ecologists looking at their potential for detecting animal targets, pests and threatened species. Low-resolution thermal cameras cost $5,000–$10,000, but high-resolution cameras can cost more than $100,000. So before purchasing a thermal camera it is important to understand the limitations of the technology, and to be aware of the camera's suitability for your target animal and the likely operating environment (e.g. in open or forested habitat, by day or by night, in a helicopter or drone, or travelling slowly or quickly).

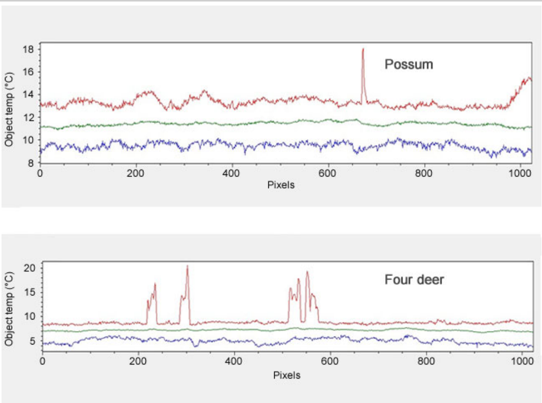
Bruce Warburton and Ivor Yockney of Landcare Research, and Grant Halverson of Airborne Technologies, have been assessing the potential of using thermal cameras for detecting possums, wallabies, pigs and other species. Bruce's team have been seeking a thermal camera that can be used in aerial surveys for detecting animals at very low densities, to determine whether a species has been eradicated from an area (i.e. not finding any animals, but being confident none have been missed). To be effective, aerial surveys need to achieve near total coverage, and the wider the aerial swath, the fewer the flight paths needed to cover an area. While the swath width can be increased by flying higher, the camera's resolution is fixed, so increasing the height of the aircraft results in the camera's pixel coverage of the ground growing proportionally larger, making it more difficult to detect and/or distinguish animals.

For example, using a camera with a 1024 × 768 pixel resolution and a fixed-focal-length lens of 30 mm, flying 300 m above the ground provides a swath of approximately 130 m. At this altitude an animal the size of a pig can be easily detected and identified, with approximately 13 pixels on the animal. However, using these same parameters would provide only 1–2 pixels coverage on an animal the size of a possum, rabbit or feral cat. To identify these smaller species with the same hardware requires flying at much lower altitudes, and this in turn results in a significantly narrower swath width and many more flight paths to cover the same area.

The technology is also limited by the frame rate of the camera (or Hertz rate) and the thermal response speed of each individual pixel. The aircraft speed, altitude and camera frame rate need to be optimised. Fast survey speeds at low altitudes create a blurring effect in the video, making it difficult to identify species, and a slow thermal pixel response also adds a smearing effect. Although more sophisticated research-grade thermal cameras with higher frame rates and faster pixel response speeds are available, they are prohibitively expensive for most uses (over $300,000).

An additional factor to consider is that thermal camera detectors operate at three different wavelengths – short, mid or long. Each wavelength has its advantages and disadvantages, depending on its application and the prevailing climate conditions. For applications in cooler environments, like New Zealand's, long-wave thermal cameras produce better results, giving higher contrast between animals and their background, and they are less affected by solar glint than mid-wavelength cameras.

Some thermal imaging cameras are radiometric (they also display and record the absolute temperature of each individual pixel). Such raw radiometric data can be processed using proprietary software at a later date, and specific animal temperatures can be obtained.



Radiometric data from a thermal imaging camera

Another critical issue associated with using thermal imaging to detect animals is obstruction by vegetation. Animals surrounded by vegetation and under forest canopy can sometimes be undetectable. However, there are often sufficient small gaps in the vegetation cover to allow an animal's emitted energy to be detected from above. Pilot trials have revealed that scanning even heavily forested areas from multiple angles enables detection of 'hot sites', which can then be investigated more carefully to identify the source.

Larger species such as deer, goats, pigs and thar can be detected with lower-cost, less-high-specification cameras, but detecting small species such as possums and rabbits requires higher resolution and more sophisticated thermal cameras, especially if used in aerially based surveys. Bruce and his team are further testing thermal cameras for detecting wallabies and pigs, and comparing the cost-effectiveness of this technology with conventional methods such as dogs and visual inspections.

This work was funded by OSPRI and Landcare Research.

Bruce Warburton (Landcare Research) warburtonb@landcareresearch.co.nz

Ivor Yockney

Grant Halverson (Airborne Technologies)

Biocontrol of wasps

Since 2014 Bob Brown and his colleagues at Landcare Research have been reinvestigating the potential for using natural enemies for the biological control of invasive social (common and German) *Vespula* wasps. The mite *Pneumolaelaps niutirani*, recently discovered infesting wasp nests in New Zealand, was the first potential agent investigated. To determine its range and prevalence throughout New Zealand the public were invited in the winters of 2014 and 2015 to send in any wasp queens they found overwintering. Inspecting these revealed that the mite is widely distributed from Northland to Southland.

In the summers of 2015 and 2016 wasp nests were excavated and examined for the mite. Photographs were also taken of the comb fragments of each nest to determine nest size by counting the number of cells. The results from the first season were very promising, with mite-infested nests being much smaller (average of c. 4,100 cells) than un-infested nests (average of c. 11,500 cells). However, in 2016 the small numbers of mites in the majority of nests appeared to have no correlation with nest size.

Bob's team also observed mites feeding from the mouths of wasp larvae as they regurgitated their nutrient rich 'soup' for the rest of the colony to feed on. It would thus appear that the mite doesn't directly feed on the wasps as a classic parasite would, but behaves more as a social parasite or commensal agent. This means the mite is unlikely to act as a classic biocontrol agent (a self-sustaining biocontrol solution that works in perpetuity). However, it may still end up being used as a control tool if it can act as a vector for wasp-specific pathogens, and this potential is being explored as part of the New Zealand's Biological Heritage National Science Challenge.

In 2016 the team directed its efforts away from the mite to pursue the introduction of new genetic stock of *Sphecophaga vesparum*, a parasitoid wasp that attacks social wasps in their nests. The female parasitoids lay their eggs on the *Vespula* larvae just as they begin to pupate. When the eggs hatch, the parasitoid larvae migrate to the bottom of the cell and begin feeding on the pre-pupal *Vespula*. This life history makes them prime candidates for biocontrol of *common* wasps, and many thousands of them were introduced from Switzerland into New Zealand for this purpose in the 1980s. However, they appear to have only established in a handful of sites in the South Island.

A key reason for the team's renewed interest in this parasitoid is recent research demonstrating that the common wasp was introduced into New Zealand from the United Kingdom and not from Switzerland. Preliminary work indicates that the United Kingdom is also the likely origin for New Zealand's population of German wasps. Thus, enriching the parasitoid gene pool and matching ecotypes via new introductions from the United Kingdom may increase the parasitoid wasp's effectiveness as a control agent of New Zealand's *Vespula* wasp populations. Also, most of the really hard work on the parasitoid biology was carried out in the 1980s by researcher Barry Donovan, who documented its life cycle and developed techniques for rearing it. Currently, the newly imported parasitoids are in containment to ensure they are disease free and can survive on New Zealand-sourced wasp brood. Once they are approved for release from containment they will be released at multiple locations in the South Island.

This work is funded by the Ministry for Primary Industries' Sustainable Farming Fund.

Sphecophaga vesparum larva (circled) feeding on a *Vespula vulgaris* pupae.

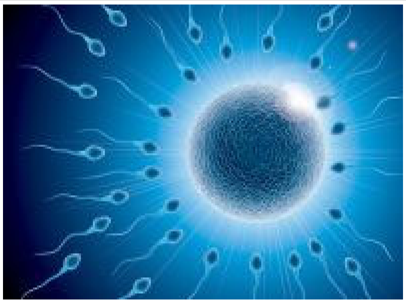
Sphecophaga vesparum female on wasp nest.

A newly emerged *Sphecophaga vesparum* male.

Bob Brown (Landcare Research) brownb@landcareresearch.co.nz

Ronny Groenteman

The Trojan Female Technique: a new approach to pest control


Spermatozoa and egg

Pest species pose serious threats to the ongoing survival of many of our native species, and incur massive economic costs on agricultural industries and the environment. While existing pest control strategies have undoubtedly made substantial headway in mitigating these costs, recent advances in the fields of genomics and ecology offer new opportunities for the development of innovative approaches to pest control, of a kind that might have been considered the stuff of science fiction just a decade or two ago.

One such innovation, which is now well on the way to development, has been dubbed the 'Trojan Female Technique', or TFT, a reference to the myth of the wooden horse used by the ancient Greeks to infiltrate and conquer the walled city of Troy. Instead of filling a wooden horse with warriors, this pest control technique seeks to load fertile females of a target pest species with a heritable genetic variant that knocks out the fertility of the sons but leaves the female 'Trojans' and their daughters unscathed.

Sound familiar? The idea of unleashing sterile males on a pest population is already an established paradigm for pest control and is commonly used to control insect pest populations. If released in large enough numbers into a pest population, the sterile males will mate with many of the females, leaving their eggs unfertilised and conferring a reduction in population numbers. This 'Sterile Male Technique' has proven highly effective, but it is laborious and costly. Males must be manually sterilised prior to release, and the population control is effected only in the generation of release. The TFT picks up the baton at this point, because the sterility-inducing agent will be genetically encoded and passed from mothers to offspring and then grand-offspring. This mutation will have no effect whatsoever on female fertility, and indeed might even confer a slight reproductive advantage to the females that carry it. But in males, these variants will lead to sub-fertility or even complete infertility, and in every generation a new army of sterile males will be produced from the fertile Trojan females.

The idea of releasing pests that carry genetic 'time-bombs' that lead to a population's decimation from within might evoke alarm as the first reaction. However, the intention of the TFT is to harness a set of naturally occurring genetic variants in the DNA of mitochondria, the energy-producing 'batteries' that occur in the cells of all animals and plants. These variants reduce the energy output of mitochondria just enough to cause male sterility through effects on high-energy-demanding sperm, but not enough to affect anything else, with reduced fertility leading to smaller populations.

Population genetic theory has long predicted that a set of genes in our energy-producing mitochondria were prone to accumulate male-sterilising variants. This is because these mitochondrial genes are maternally inherited. The evolutionary implication is profound: nature's quality control process, which Charles Darwin called 'natural selection', is only able to remove harmful variants from mitochondrial genes when they are also harmful to females. Mitochondrial variants that are male-specific in their sterilising effects may therefore slip under the radar of natural selection and accumulate within populations.

Recently, candidate TFT variants have been identified within the mitochondrial DNA sequences of fruit flies that depress the fertility of males. Similar variants have been identified in European hares and mice, confirming the promise that the TFT could be applied across the gamut of pest species – from mites to mammals. Indeed, such variation in the mitochondrial DNA sequence appears to be a common cause of male infertility in humans too.

A consortium comprising researchers from Landcare Research, the University of Otago and Monash University has made significant headway towards developing the TFT. The consortium uses a multi-pronged approach that incorporates (1) theoretical modelling, (2) experimental validation of the technique in an insect model (the fruit fly, *Drosophila melanogaster)*and in a mammalian model (the mouse *Mus musculus)*, and (3) research into the social acceptability of the TFT, via engagement with the general public and stake-holders through focus group sessions.

In fruit flies, the consortium has targeted a candidate TF variant in the cytochrome B gene, and has extensively tested its capacity to confer male sterility across a range of mating contexts, nuclear genomic backgrounds and thermal environments. In all cases its efficacy holds true, depressing the fertility of males. The consortium has now completed a large-scale multi-generation experiment in which hundreds of populations of flies were seeded with Trojan females carrying this TFT variant to determine its capacity to suppress populations. The results were striking: suppression occurred and persisted over the trial period of 10 generations. These experiments in fruit flies had strong theoretical underpinnings, with mathematical modelling guiding the design of the experiments in terms of the number of TFT females seeded into each population and the conditions in which populations were maintained.

Proof of utility has also been achieved in mice by screening the sperm parameters of numerous genetic strains of mice, each of which shares a common set of nuclear DNA but a different mitochondrial DNA sequence, consisting of a unique set of variants. This research has verified that variants within the mitochondrial genes of mice also affect male fertility.

The research consortium is now working with AgResearch to apply the TFT to the control of a real-world pest for the first time, the clover root weevil, which affects pasture quality and causes significant losses to the dairy industry.

This research was funded by the Ministry of Business, Innovation and Employment's Smart Ideas programme.

Damian Dowling (Monash University)

Dan Tompkins (Landcare Research) tompkinsd@landcareresearch.co.nz

Neil Gemmell (University of Otago)

Development of lures for stoats

Humans are a visual species and our eyes relay the majority of sensory information we receive about the world. This reliance on sight is typical for diurnal mammals, yet many animals live in complex habitats, are active at night or forage underground – all situations where vision is naturally impaired. For these species smell is often the most important and reliable source of information. All animals continually emit odour as they move through their environment, creating a vast network of invisible chemical cues. Interception of these odours by co-existing species leads to predictable changes in behaviour, and creates an opportunity for pest managers to exploit these responses to achieve conservation goals.


Stoat. Image - Grant Morriss.

The goal of 'Predator Free New Zealand by 2050' has given greater urgency to the search for new tools and techniques for managing invasive species. Stoats are one of three species targeted as priority pests due to the devastating toll they inflict on native wildlife. In common with other mustelids, stoats rely heavily on using odour for communication, which makes them an ideal target for olfactory lures. Predator management in New Zealand currently relies on food-based lures (e.g. rabbit meat) to attract stoats to traps or to monitoring devices such as tracking tunnels or cameras. However, food lures have limitations when deployed for managing predators. First, the effectiveness of food as an attractant is reduced when prey are plentiful. Second, after a management operation to control a pest species, the survivors become wary of food lures, while the reduction in competition increases the relative availability of prey. Third, food lures degrade quickly, reducing their appeal to any passing predator, and must be replenished frequently to remain attractive. Given the limitations of food lures it is not surprising that a concerted effort is being made to find new 'super lures' to improve the success of stoat monitoring and control.

This search took an unexpected turn when Patrick Garvey and his supervisors discovered that stoats are attracted to the odour of co-existing dominant predators. As part of a pen trial investigating interactions between invasive species, stoats were exposed to the body odour of ferrets and cats. The prediction was that stoats would avoid these odours because previous experiments showed they avoided the physical presence of these two competitively superior adversaries. So it was a surprise to find that stoats are strongly attracted to the odour of ferrets and cats. This response was intriguing, and its potential application for wildlife management was immediately apparent.

A field experiment using movement-activated cameras was devised to investigate whether ferret odour would provoke similar responses in free-ranging stoats. Over a 1-month trial, detections of stoats increased three-fold (Figure 1) when ferret odour was added to rabbit meat at monitoring sites. Estimates of site occupancy by stoats changed from rare to common with the addition of predator odour (Figure 2), whereas monitoring with a food lure alone would have considerably underestimated the distribution of stoats across the landscape. Attraction to the ferret odour was not limited to stoats, as detections of two other damaging invasive predators – hedgehogs and ship rats – also increased at the monitoring sites.

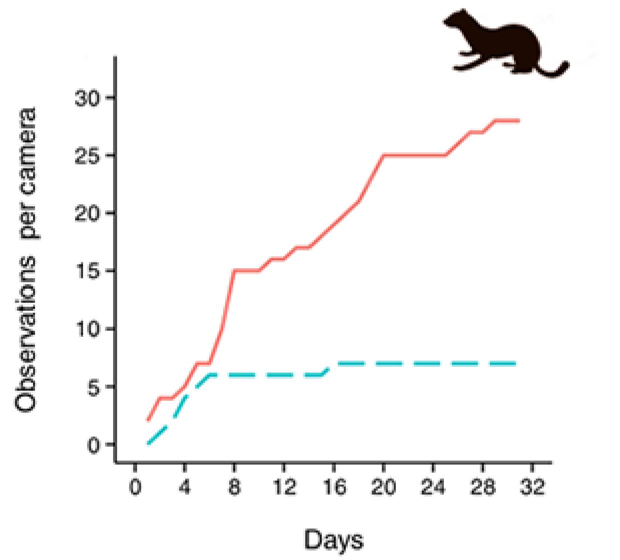


Figure 1. Number of stoat detections over a 32-day period

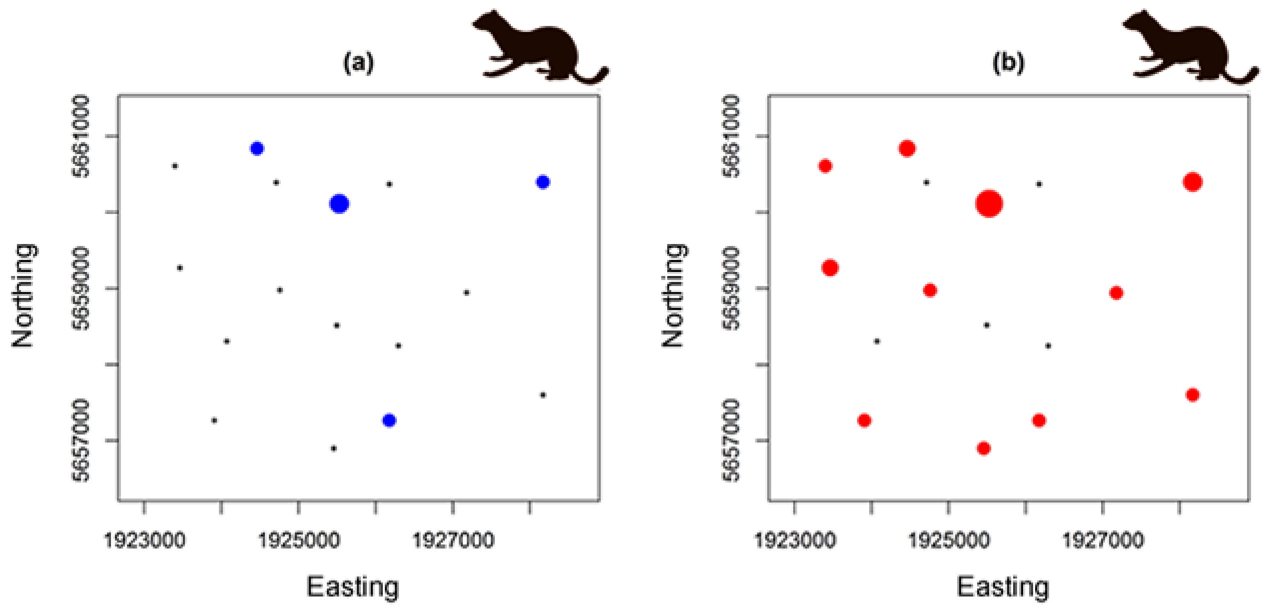


Figure 2. Number of stoat detections using alternative lures, indicated by blue points (rabbit meat) or red points (rabbit meat + ferret odour), across an area of 36 km2. The size of a red or blue point indicates the number of stoat detections at a particular monitoring site. Monitoring sites where cameras did not detect stoats are indicated with black dots.

Now that a candidate lure has been discovered, the next stage is to isolate the chemicals within ferret odour that provoke this attraction. Much as a perfumer strives to create an alluring fragrance, identifying and combining the compounds that stimulate such attraction should produce a powerful lure. By creating an artificial copy of the scent rather than using the primary biological material, the life and hence effectiveness of the lure could be extended and sufficient quantities produced to provide 'scent from a can' for stoat control projects across New Zealand.

The development of new super lures, where attraction is provoked by hard-wired competitive and predatory behaviour, could provide a step change for the management of stoats and other invasive predators. Deploying dominant predator odour is a novel approach that could contribute to population monitoring and invasive species management in New Zealand. The research will also provide insights into the ways that animals use chemical communications. Super lures derived from predator odour should also have applications for conservation in other parts of the world; for example, in situations requiring highly sensitive detection methods for rare or endangered species.

This project is jointly funded by the New Zealand's Biological Heritage National Science Challenge and Landcare Research.

Patrick Garvey (Landcare Research) garveyp@landcareresearch.co.nz

Bruce Warburton

Wayne Linklater – Project Leader (Victoria University)

Elaine Murphy (Lincoln University)

Craig Bunt (Lincoln University)

From fruit fly to vertebrate pest control

Fruit fly

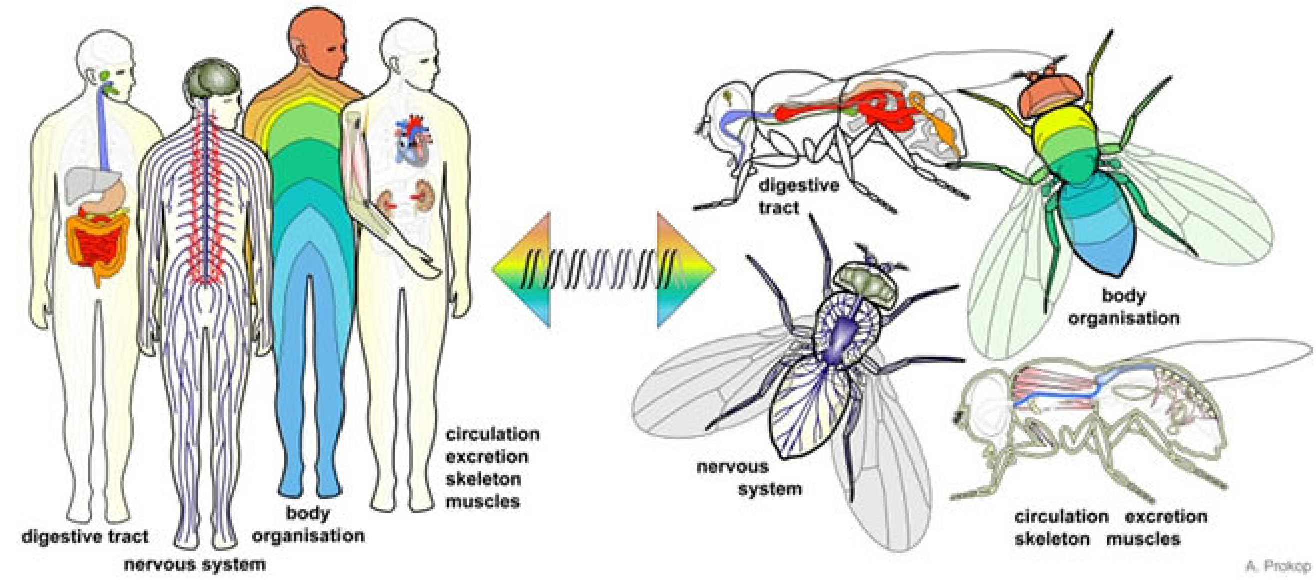
Toxins are essential tools for vertebrate pest control because trapping and other approaches become too costly at a large scale. However, concerns over their environmental persistence and non-target impacts – particularly on pets, livestock and native species – reduce the public's acceptance of the main toxins currently used in New Zealand.

As a consequence, new innovative technologies such as the genome mining approach highlighted in this issue of *Kararehe Kino* (see Hopkins et al) are being investigated as a means of developing species-selective toxins to support initiatives such as Predator Free NZ and Zero Invasive Pests. However, the normal development processes to produce registered efficacious products need to be significantly fast-tracked to get these new tools into the hands of pest managers as quickly as possible.

To achieve this, Brian Hopkins is investigating new ways of screening compounds that could accelerate product development. Traditional approaches generally consist of *in vitro* assays, *in vitro* cell culture, and enzymatic or receptor binding assays. In these assays, the chosen physiological target (an enzyme, receptor or other key protein) is presented in a way that allows high-throughput screening of compounds to identify candidates that can be developed (through extensive medicinal chemistry programmes) into useful toxins.

These assays can be extremely expensive and often don't predict *in vivo* outcomes: the majority of positive hits identified through such *in vitro* screens are found to be ineffective in subsequent validation experiments using whole-animal models. They are also unable to determine many of the essential characteristics required for commercialisation, such as oral availability and stability. These shortcomings often result in inappropriate compounds being selected, which are a waste of money and can cause significant delays in product development.

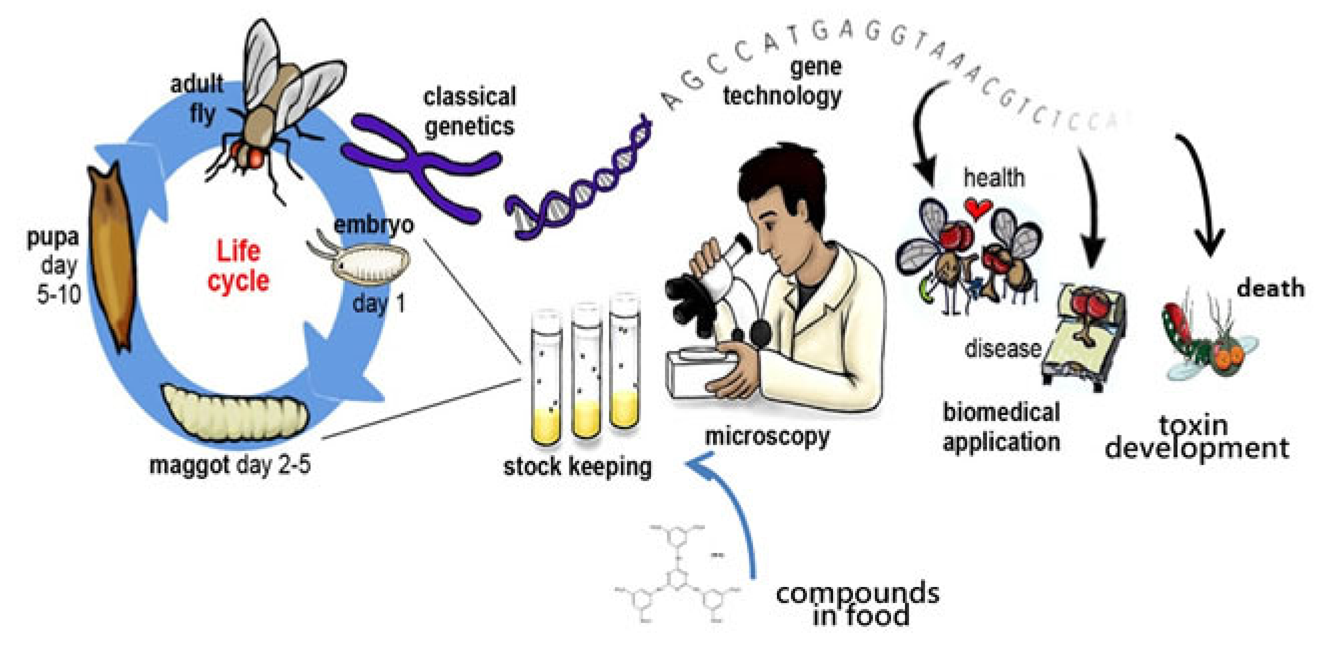
Brian has recently come up with an approach that could overcome these shortcomings. The approach involves adapting a sophisticated *in vivo* fruit-fly (*Drosophila melanogaster*) model that has often been used for screening human therapeutic drugs, in order to provide an alternative low-cost assay to decrease the time taken to discover and develop species-selective vertebrate pest toxins.



Fruit fly as a model genetic organism

The fruit fly is a versatile model organism, which has been used in biomedical research for over a century to study a broad range of drug-related phenomena. As such it is the most extensively used and one of the best understood of all the model organisms. What makes it so useful is the surprisingly close relationship between fruit flies and mammals, with many basic biological, physiological and neurological properties being preserved and many of the control genes being common to both species. For example, 75% of the genes known to be linked to human diseases are also found in the fruit fly and can be used as targets for human therapeutic drug development. As a consequence, species-specific targets identified in a vertebrate pest as being suitable for toxin design (their 'Achilles heel') can be inserted into the fly's genome with the knowledge that they will behave in a functionally similar way to those in the pest itself. Essentially, the fly will become a highly predictive *in vivo* surrogate pest model.

Further advantages of the fruit-fly model include its extremely low cost of maintenance, propagation and screening, and the rapidity of studies in the fly due to short generation times compared with traditional mammal-based models.



Fruit fly application in drug and toxin discovery

Compounds designed to target pests' Achilles heel will be screened by administration through the fruit flies' water supply or their food, and their lethal activity directly assessed on the assumption that compounds lethal to the fly could also be lethal to the pest species. Compounds identified this way will also have already-confirmed oral availability and metabolic stability, allowing them to be progressed significantly quicker down the developmental pathway to a usable product.

Once proven, this screening model will be readily adaptable, accelerating the discovery of selective toxins for a wide range of pest species.

Brian Hopkins (Landcare Research) hopkinsb@landcareresearch.co.nz

One-hit elimination of multiple pests and TB: does aerial 1080 baiting even come close

Camera trapping enables easy

In 2016 New Zealand committed to twin goals: eradicating bovine tuberculosis (TB) from possums (and other wildlife and livestock) by 2055, and eliminating three widespread predators (possums, rats and stoats) by 2050. For both goals a major hurdle will be achieving success in the vast areas of forest and steep mountain land beyond developed areas. At present the only safe, practical and affordable approach available is aerial 1080 baiting. It would therefore be useful to know how close this tool comes to achieving local elimination of the targeted pests: could such baiting be developed to deliver large-scale, one-hit elimination of multiple pest species?

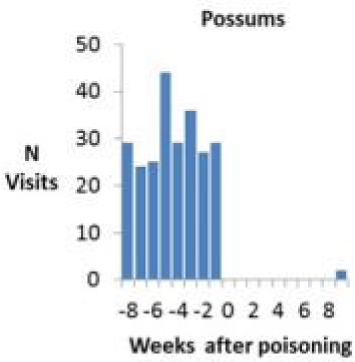
Currently aerial 1080 is used to control (rather than locally eliminate) possums and/or rats as the assessment of large animal abundance

primary targets, depending on whether the operation is TB- or conservation-focused, but it also kills some of the other pest species, including stoats. Assessments of the effectiveness of aerial 1080 have historically focused on just one or a few species, largely because different monitoring techniques are required for different species. However, the advent of trail cameras largely overcomes this problem, potentially enabling the monitoring of all terrestrial vertebrates present.

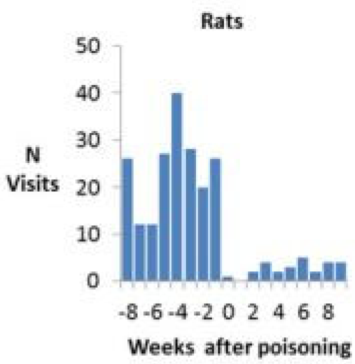
Graham Nugent, Peter Sweetapple, Grant Morriss and co-workers used a combination of chew-card monitoring, leg-hold trapping, radio-collaring, trail-camera monitoring and post-1080 carcass searches to assess the impact of an aerial 1080 operation on the abundance of large and small mammals in the Hauhungaroa Range in winter 2016. The operation was primarily targeted at achieving and confirming that the TB cycle in possums there was broken. If so, it is expected to be the last time 1080 is required there for that purpose. The operation used a moderately low sowing rate (1.5 kg of 1080 bait/ha) and most of the 80,000 ha was pre-fed twice with non-toxic bait.

The operation killed 240 of 241 radio-collared possums – a 99.6% kill. The number of possum visits recorded at 23 trail cameras likewise declined by 99.3% (see graph). No TB was found in 332 possums necropsied for TB just before or just after the operation, and none in over 230 pigs taken from the area and checked for TB since the last known TB-infected pig was recorded in the centre of the range in early 2015.

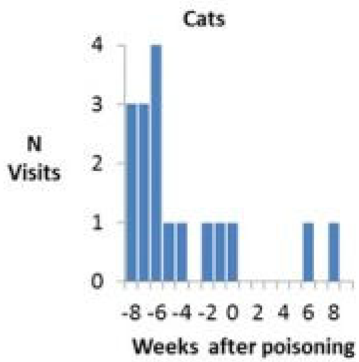
Using mark–recapture methods, the pre-control population was estimated at about 4,000 possums, and this was reduced to about 20 after control – just one possum per 4,000 ha. At these extremely low densities, epidemiological theory indicates an infinitesimal likelihood of TB persisting after baiting, because possums usually die within 4–6 months of becoming infected and would not come into contact with other possums often enough to pass on the disease. These results leave little doubt that TB has been eradicated from possums in the Hauhungaroa Range. However, possums themselves were not eradicated.



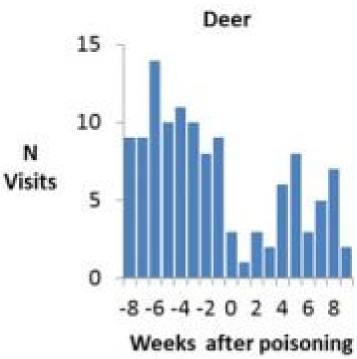
Number of visits by possums



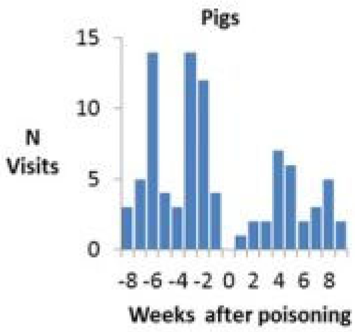
Number of visits by rats



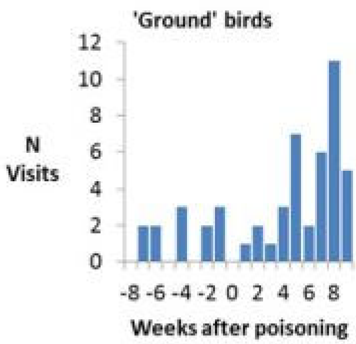
Number of visits by cats



Number of visits by deer



Number of visits by pigs



Number of visits by 'ground' birds

Number of visits by possums, rats, cats, deer, pigs and 'ground' birds recorded by 23 trail cameras over 8 weeks before aerial 1080 baiting and over 9 weeks after baiting. 1080 baiting occurred at the start of Week 0.

For common species other than possums, there were fewer visits recorded by trail cameras after control than before. For rats, there were no visits in the second week after baiting, but the number of visits increased soon after that to about 10% of pre-control levels (see graph). The pattern was similar for cats (and hedgehogs), but some of that increase might reflect seasonal activity patterns. Mice were recorded nine times before and eight times after 1080 baiting. Very few (four) stoat visits were recorded before control, and none in the 9 weeks after (but one has been recorded since).

The study also provided one of the first assessments of 1080 impacts across a wider suite of vertebrates than is usually monitored – red deer, goats and pigs, and common 'ground-feeding' birds (mostly blackbirds and thrushes). For deer, there were far fewer visits to trail cameras in the first month after poison baiting, but in the second month the visitation rate was only moderately lower (42%). The pattern was broadly similar for goats and pigs, the visitation rate for both being 46% lower in the second month after baiting compared to the month before baiting. These reductions are about the same as the annual population recruitment rate for deer and well below the recruitment rate for pigs and goats, so the medium-term impact on the density of these species will be low. In contrast to mammals, the number of visits by ground birds more than doubled.

In summary, twice-prefed aerial 1080 baiting in its current form is a highly effective tool for TB eradication, but in this study did not really come close to locally eliminating any mammal pest. Local elimination will therefore require either somehow increasing the effectiveness of 1080 baiting or finding an affordable way to locate and kill the few survivors. For the former, work is currently underway (by Landcare Research and the Zero Invasive Pest foundation) to determine whether 100% kills of possums and rats can be achieved in a single operation. For the latter, the possum example highlights the immensity of the problem: how does one find a single animal in 4,000 ha of forest? And then reliably repeat that across all such 4,000 ha areas?

The possum and TB surveys were funded by OSPRI, and the camera trapping by Landcare Research (core funding).

Graham Nugent (Landcare Research) nugentg@landcareresearch.co.nz

Peter Sweetapple

Grant Morriss

Aran Proud

Ivor Yockney

The economics of using wireless networks for monitoring traps

Networks of traps cover increasingly large areas (e.g. >26,000ha)

Vertebrate pest control in New Zealand has been evolving over the last decade, from a paradigm of control applied periodically with intervening periods of no control, to essentially continuous control to maintain pest numbers at low levels (presumably below some threshold at which desired values are protected). There has also been a trend towards increasing the scale of control programmes, with some now covering hundreds of thousands of hectares.

This evolution of control programmes has resulted in the increasing use of permanent networks of live- and kill-traps, employing a wide range of trap setting and checking regimes. Irrespective of the implementation details, a common outcome of such programmes is that pest numbers are held at low density, and when checking live-capture traps daily the majority of traps checked are empty. Once a trap network is established (i.e. the initial capital cost is committed), the main cost of running a network is staff or contractor time to check the traps.

Wireless systems have been developed recently to enable a wide range of environmental sensors to be monitored remotely, and, if required, in real- or close-to-real time. Hawke's Bay Regional Council (HBRC) has been assessing the value of wireless monitoring together with Encounter Solutions, who have developed a system for monitoring traps over larger areas. Bruce Warburton, Chris Jones and Jagath Ekanayake worked with HBRC staff to carry out an economic analysis of the ability of wireless solutions to reduce operational costs, and to identify which critical factors ('pinch points') might determine whether such technology is cost-effective.

Live- and kill-traps are set and checked in a wide range of scenarios, and remote monitoring using wireless systems generates few economic benefits for some scenarios and potentially large benefits for others. Rather than simply assume the adoption of wireless technology will provide significant savings to a pest control programme, managers of such programmes need to be aware of the range of scenarios in which wireless systems can be used and, if possible, carry out an economic analysis of any proposed system.

There are three main reasons for checking traps: (1) legal requirements – restraining traps must be checked daily; (2) trap saturation –

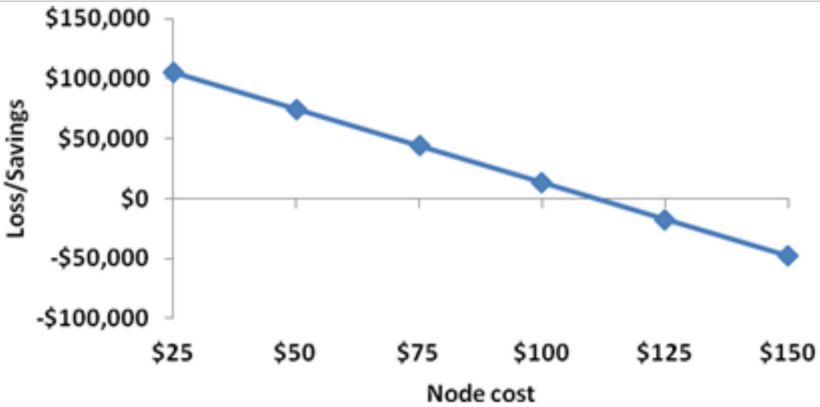
when more than about 20% of traps are sprung, the capture rate of the trap network declines; and (3) bait replacement – if bait does not have a long field life then all traps need to be visited frequently and rebaited. Bait replacement might also be necessary if bait is taken by non-target species.

One of the scenarios analysed by Bruce and his colleagues was using wireless sensor networks (WSNs) to monitor kill-traps, and they developed a simple spreadsheet economic model to determine which scenarios might have provide savings or losses. The model was based on a scenario that required the trapper to check only those traps that have been sprung when the overall percentage of sprung traps reaches an agreed trigger level. The inputs for the model (see table) were based on a kill-trap network established as part of the ongoing HBRC predator control programme.

*Kill-trap economic model input parameters and values based on HBRC's predator control programme. * A node is the sensor on each trap that signals whether the trap has been sprung or not.** A relay station or hub is a device that takes the signal from the nodes and communicates through the cellular or satellite network to the web, a cellphone or a computer.*

Parameter	**Example values**
Number of traps	700
Cost of trap node*	$25
Cost of relay station**	$1,000
Ratio of nodes to stations	700:1
Daily contractor rate	$400
Person days to check all traps	4
Months to get to 25% of traps sprung	3
Discount rate	0.06
Years for depreciation	5
Months between rebaiting of all traps	12

The model generated savings or losses for various kill-trapping options over a range of parameter values, but for this article only the savings or losses for the parameter values given in the table above are shown, but with node costs of $25, $50, $75, $100, $125 and $150. The model indicated that if nodes cost less than $100 (i.e. the cost of the sensor on each trap), then using a WSN (given the other parameter values in the table) would provide savings (see graph). This model enables each of the parameter values to be varied so each can be assessed for their impact on whether use of the system will provide savings or losses. Further analyses planned include comparing Net Present Values (NPV) of checking traps with and without wireless monitoring.



The 10-year cumulative loss or savings from using a WSN to monitor a kill-trapping programme with node costs ranging from $25 to $150.

This work was funded by MBIE and Hawke's Bay Regional Council.

Bruce Warburton (Landcare Research) warburtonb@landcareresearch.co.nz

Chris Jones

Jagath Ekanayake

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Email info@landcareresearch.co.nz | **Phone** +64 3 321 9999 | **Fax** +64 3 321 9997 | PO Box 69040, Lincoln, New Zealand