

## Editorial: Emerging and neglected pests

Across the history of colonisation, humankind brought 32 terrestrial mammal species to Aotearoa, alien to this land, that managed to establish self-sustaining populations. In addition, many birds, amphibians and reptiles have similarly been introduced and established, as well as countless invertebrate pests and weeds. We are all aware of how devastating these introductions have been for our native biodiversity, through depredation, herbivory, resource competition and disease impacts. What is astounding, however, is that the breadth and depth of these impacts are such that we are still discovering new ones today.



Red-eared slider turtle.

In this issue of Kararehe Kino we highlight ongoing studies into what are generally considered some of the more 'minor' pest species and impacts that we are contending with in New Zealand. While major new initiatives such as Predator Free 2050 are rightly focussing on the biggest threats, and driving the goals and timescales essential for building the national and international momentum needed to address them, we cannot lose sight of the other pest issues that are not 'minor' by any definition of the word. Some are neglected. Perhaps of greater concern is that some are emerging to become bigger threats in the future.

Continuing to inform on the impacts of invasive species, Grant Norbury and Chris Jones present data showing that the seemingly innocuous hedgehog sometimes poses the greatest predation risk to some native species, with up to 51% of native shorebird nests in the Mackenzie Basin being lost to them. Dave Latham and Graham Nugent highlight how many of the more 'minor' ungulate species in New Zealand can very likely cause large amounts of damage to native vegetation. And Peter Sweetapple and Mandy Barron show the complexities of achieving biodiversity outcomes through pest management, illustrating how the competitive release of rats caused by possum control can deleteriously impact arboreal invertebrates.

Furthering the insight into complexity, John Innes argues that not all rats are equal, and that there are likely to be benefits for tree-nesting birds from the control of ship rats alone. Mandy Barron and colleagues present work investigating why some islands in the Hauraki Gulf that have undergone mammal eradication programmes had subsequently become free of German and common wasps, wondering whether there is a mechanism at play that can be turned to their management.

In terms of emerging vertebrate pests in New Zealand, perhaps of greatest concern are wallabies. And we're not talking rugby. Bruce Warburton and colleagues present model predictions that indicate, if not managed, populations of Bennett's and dama wallabies could eventually occupy most of the South and North Islands respectively. But it's not as though we can't eradicate invasive vertebrates if we put our mind to it. James Reardon illustrates the exceptional progress being made in the eradication of the alpine newt, likely introduced to the Central North Island around the turn of the current century. In other cases, eradication may not be essential or even desirable for controlling impacts. For example, Grant Morriss advises that for the management of feral pigeons in New Zealand, the use of non-lethal methods that leave some resident pigeons to satisfy the demands of individuals who value them may be the best compromise in current New Zealand society.

Finally, Pablo Garcia-Dias suggests that we may be facing more and different pest problems in the future due to the ongoing threat of new emergent exotic species in New Zealand posed by the pet trade. While not arguing for a blanket ban, he contends that we need a more nuanced and up-to-date knowledge of the biosecurity risk currently posed by this trade.

Agencies such as the Department of Conservation and Regional Councils, and the many sanctuaries and community groups around the country, do exceptional jobs of protecting our native biodiversity against invasive species. It is the job of the New Zealand science system to support them to the best of our ability through the provision of new and increasingly improved management tools and strategies, and the necessary prioritisation of resources to do this well.

## Explaining *Vespula* wasp population structure in the Hauraki Gulf

Invasive *Vespula* (common and German) wasps have a negative impact on the environment throughout New Zealand, preying on native invertebrates and competing with native nectar-feeding birds and invertebrates for the honeydew produced by native scale insects in beech forests. Both wasp species also inflict large economic costs on the farming, beekeeping, horticulture and forestry industries, and are a major nuisance to recreational users of wildlands. There has been renewed interest in managing these painful pests, with a New Zealand's Biological Heritage National Science Challenge research programme to develop novel wasp suppression and eradication tools. The development of such tools requires an understanding of what factors limit or regulate wasp populations, a topic that PhD student Julia Schmack (University of Auckland) is investigating.



*Vespula germanica* collected on Great Mercury Island, New Zealand

Julia's supervisor, Jacqueline Beggs (University of Auckland), was intrigued by anecdotal reports that some islands in the Hauraki Gulf that had undergone mammal eradication programmes had subsequently become *Vespula* wasp-free. This was not thought to be due to non-target poisoning, since the toxin used to kill the mammals was applied in winter when wasps are inactive. Jacqueline realised that finding an ecological mechanism that limits or regulates wasp numbers could potentially be 'leveraged' for wasp control. Biologists have good understanding of the drivers of wasp population dynamics in beech forests, where *Vespula* wasps are hyper-abundant, but very little is known about what drives their presence and abundance in other habitats. Enter Julia, who is embarking on an intensive wasp survey of islands in the Hauraki Gulf.

Julia's first objective is surveying as many islands as she can to determine wasp presence and abundance, assessing ecological characteristics such as island size, distance to the mainland or nearest neighbouring island, proportional cover of different vegetation types and presence of other fauna. By analysing this information, Julia hopes to identify which factors best explain wasp presence and abundance on offshore islands. Any relationship with mammal eradication will lead onto further work to identify a potential mechanism. Wasp presence or absence on particular islands might also be an outcome of meta-population processes. For example, wasps might go extinct on some islands but recolonise them the next year via queens from the mainland or nearby islands. Assigning wasps to their population of origin is therefore important for understanding reinvasion paths, and essential for the biosecurity management of offshore islands.

With this in mind, Julia is collecting samples of worker wasps from each island to take back to the laboratory for DNA extraction and genetic variability estimation. With the help of Phil Lester's team (Victoria University), Julia aims to differentiate populations on different offshore islands and within mainland New Zealand, providing a biogeographical overview of the distribution and relatedness of *Vespula* wasp populations. If relatedness can be discriminated at the nest level there is also the potential to estimate wasp nest density; being able to do this without the time-consuming and often painful and dangerous effort of locating nests would be a huge advantage.

With spring underway, queen wasps are now emerging from their winter hibernation and Julia is gearing up for a big summer of fieldwork. She hopes to survey at least 10 islands this year. Unlike most people she is also hoping this summer will be a good year for wasps (summer 2016/17 was a low wasp year). Julia hopes her research into the drivers of wasp abundance on offshore islands will help identify a vulnerability that will lead to the development of better tools for large-scale wasp control, and thus contribute to the conservation of New Zealand's unique ecosystems.

This work is funded by [New Zealand's Biological Heritage National Science Challenge](#)

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## Flying beneath the radar: New Zealand's 'minor' wild ungulates

For a country that prehistorically had no native land mammals other than bats, New Zealand is now home to a surprising variety of ungulates. If moose are not yet extinct, and with wapiti now classed as separate from red deer, there are 15 species of ungulate (including local feral populations of 'domestic' sheep, cattle and horses) that still have one or more viable wild population.

Most New Zealanders are aware that there are widespread populations of feral goats, pigs and red deer, which provide a substantial hunting resource. These often have significant unwanted impacts on agriculture and the native environment, and there have long been efforts to reduce their numbers (as in the deer culling era of the 1930–1950s). Other species, such as Himalayan tahr, are less widespread and less well known but are intensively controlled in some places, particularly to prevent them spreading to new areas. These thus feature prominently on the radar screens of wildlife management agencies.



Fiordland Wapiti

In contrast, tucked away in the backblocks of the Bay of Plenty and Manawatū are comparatively small populations of sambar deer. Nestled at the head of Lake Wakatipu in Otago is a small herd of white-tailed deer, with a second herd on Stewart Island. However, having small geographic ranges does not mean these animals cause negligible damage to the environment. The damage can be significant, even if localised. Yet these minor species often go unmanaged. This may be a deliberate management decision because their impacts fall below a priority threshold when budgets are limited, or because there is inadequate information about their numbers, distribution and damage. In either case, they often tend to drop off the wildlife management radar, notwithstanding the advocacy of the newly formed NZ Game Animal Council (GAC).

Here we examine some of these 'minor' ungulate species in the light of three topical issues. First, there is evidence that some have expanded their ranges and become more abundant. This could increase their impacts on native biodiversity. Second, some are important game animals and their populations may qualify as 'herds-of-special-interest' (HoSI) as proposed by the GAC. Third, some geographically isolated herds may provide excellent case studies for eradication, with potentially important lessons for initiatives such as Predator Free NZ, despite their being herbivores.

With regards to native biodiversity, the impact of minor browsing species on vegetation is certain to differ to some degree from that of the more common species. They obviously also have far greater potential to spread to new areas, adding to the overall conservation threat. A good example of this is fallow deer. In the late 1990s, Wayne Fraser and colleagues identified 42 new populations of fallow deer in New Zealand, equating to 16% of all new populations of wild ungulates.

Observations suggest that many of these have since established and expanded. Further new populations have also emerged, almost exclusively due to farm escapes and illegal liberations (a pattern that holds for nearly all wild ungulates). While those responsible for such liberations, and some affected landowners and hunters, may be delighted with additional herds and the hunting opportunities they provide, other landowners, conservation groups, the Department of Conservation and regional councils may not be so happy.



Fallow Deer

Eradication of the new populations of fallow deer is probably achievable because they currently occur at low numbers and have low annual rates of dispersal. However, once neighbouring herds begin to expand into adjacent suitable habitat and merge with one another, it is probable that future attempts at eradication will be more difficult, because it will be difficult to find and kill them all. This will lead to recolonisation of controlled areas by adjacent uncontrolled herds. It is also likely to result in an inability to kill deer in the population faster than their rate of increase. These factors will increase both the cost of any eradication attempt and its social complexity (i.e. getting buy-in from a larger number of affected landowners).

Chamois are another 'minor' species that warrant further attention. Their impacts on native vegetation remain poorly documented, but also likely to be large at high numbers and different from those of other ungulates. Tahr often outcompete chamois, so their management may have unintended consequences for biodiversity via chamois population dynamics and ecology. Quantitative data are needed to ascertain if

the damage caused by these and other minor ungulate species is sufficiently high to warrant management intervention.

Although the minor ungulates are usually not front-and-centre on the conservation radar, they have long been a priority when it comes to management for hunting; they are perceived as 'special' simply because they are less common. However some, such as fallow deer, sika deer and white-tailed deer, have tended to occur at higher densities than red deer since the 1970s due to their being smaller and therefore less important for commercial hunters. Such species thus have high representation among the original 10 Recreational Hunting Areas formally established in the early 1980s. Wapiti, sika deer, white-tailed deer and fallow deer are under active consideration by the GAC for the same reasons, as it looks to establish and manage more HoSI.

A working example of the complexities in managing HoSI is the Fiordland wapiti herd, which is actively managed for hunting benefits under an agreement with DOC. The organisation that manages the herd, the Fiordland Wapiti Foundation, is funded by donations from recreational hunters, and uses that money to subsidise commercial deer culling aimed at reducing the proportion of red deer, red deer-wapiti hybrids, and female wapiti in the area. This keeps overall deer numbers and their impacts on the native vegetation at acceptable levels. Such management increases hunters' chances of getting a highly sought-after trophy wapiti, without worsening overall conservation outcomes. The fundamental goal of delivering benefits within overriding environmental considerations will apply to all HoSI.

Although simple in principle, achieving game management within acceptable environmental limits will require far more information about the biology, ecology and conservation impacts of these minor herds than is currently available. It is likely that some of these minor herds will become key 'laboratories' in helping unravel the complexities of the hunter-animal-impact relationships.

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## Hedgehogs: recent evidence of their impacts on native fauna

It seems the more we look, the more we find when it comes to the impacts of invasive pests. European hedgehogs are no exception. Once thought to provide a service by preying on garden pests such as slugs and snails, hedgehogs are now known to also prey on a wide variety of native species, including invertebrates, lizards, and the eggs and chicks of a range of native birds. We have learnt this by sorting through the remains of prey in their droppings and stomachs.

For example, 21% of hedgehog guts (each reflecting a single night's feeding) from Macraes Flat, north Otago, contained native skink remains; a single hedgehog dropping from near Alexandra contained 10 McCann's skink feet; and two separate studies have shown that female hedgehogs are three times more likely than males to have eaten native lizards. Rare native invertebrates are also eaten widely, and a single hedgehog gut from the central South Island was found to contain 283 wētā legs!

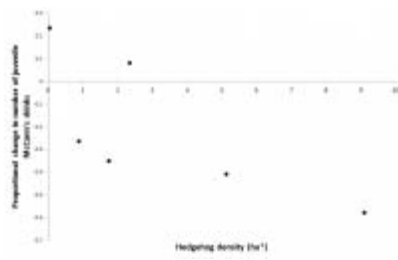
Diet composition is one thing, but the real impacts on native species are often more difficult to measure. Research over the past 15 years has begun to clarify the picture.

### Impacts on invertebrates and lizards

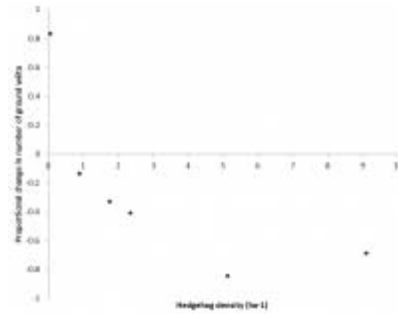
A field experiment undertaken by Chris Jones and colleagues in 2005/2006 in Otago enclosed various numbers of hedgehogs in six 0.5-hectare fenced areas containing naturally occurring populations of native ground wētā and McCann's skinks. The team found increasing rates of decline of the populations of both wētā and juvenile McCann's skinks as the density of hedgehogs rose from just under one per hectare to nine per hectare (see *Figure*).



A European hedgehog out hunting during the day



Proportional changes in the number of juvenile McCann's skinks before and after exposure to a range of hedgehog densities.



Proportional changes in the number of ground wētā before and after exposure to a range of hedgehog densities.

*Proportional changes in the number of ground wētā (left) and juvenile McCann's skinks before and after exposure to a range of hedgehog densities.*

## Impacts on birds breeding in braided riverbeds

Video surveillance by Mark Sanders and Richard Maloney of the Department of Conservation (DOC) of 164 clutches of native shorebirds (mainly nationally vulnerable banded dotterel, but also nationally endangered black-fronted tern and nationally critical black stilt), located largely on one riverbed in the Mackenzie Basin, showed that 9% of all clutches were preyed on by hedgehogs. These losses were similar to those caused by more frequently considered predators (9% by ferrets, 15% by cats and 2% by stoats).

Research by Grant Norbury and colleagues found far greater rates of hedgehog predation of clutches in the upper and lower Tekapō riverbeds in the Mackenzie Basin. Video surveillance of 198 nests of mostly banded dotterels (but also of nationally vulnerable wrybills and declining South Island pied oystercatchers) across four riverbed sites revealed predation rates by hedgehogs as high as 51%, higher than those of all other vertebrate predators combined (see *Table*). These rates are a big blow to the recruitment of shorebird populations from this area.

River	No. nests monitored	Percentage of nests preyed on by predators at each site			
		Hedgehogs	Ferrets	Cats	Stoats
Lower Tekapō	47	51%	9%	0%	0%
Upper Tekapō	46	35%	4%	2%	0%
Cass delta	54	6%	9%	0%	0%
Lower Macaulay	51	4%	18%	2%	0%

Trapping programmes by professional and community pest managers across New Zealand generally regard hedgehogs as annoying 'by-catch' that clog up traps set to catch other predator species. However, our increasing awareness of their impacts on a wide range of native wildlife means they are now targeted in many pest control programmes as one of the core suite of pests. Despite this, we still have no robust estimates of hedgehog densities in any New Zealand habitats. Trapping data suggest they are remarkably abundant. For example, of 3,636 introduced predators trapped by DOC at Macraes Flat over 3 years, an astounding 63% were hedgehogs. This pattern is repeated in trapping data from across the country.

Hedgehogs may not only be a significant threat to native wildlife; they may also play a part in transmitting Johne's disease, an inflammatory gut infection in farmed stock. Research by Graham Nugent and colleagues detected the bacterium responsible for the disease in 36% of hedgehogs from three South Island farms. It was also found in their droppings, suggesting that hedgehogs may act as wildlife vectors of the disease.

When hedgehogs were introduced to New Zealand they encountered an environment with plentiful food, few competitors and still fewer predators. The only constraints on population growth were and remain climatic: cold winters drive them to hibernate, restricting the length of their breeding season and leading to losses of their young (who fail to make it through to the next spring). In the milder more benign environments of the country these constraints may not operate. It is also possible that they produce two litters each year in warmer northern areas, as they do in some parts of their native Europe.

Although more research is required, there is a risk that hedgehogs may be having a far greater impact on our native biodiversity than has been realised, given their likely abundance and their potential to eat large numbers of small native animals in a short time. What we do know is that managers need to re-think what they regard as by-catch, and target hedgehogs where they are suspected of preying on the eggs or nestlings of endangered shorebirds or on other native animals. Removing hedgehogs potentially has significant biodiversity benefits.

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A South Island pied oystercatcher on the lower Tekapō riverbed attacking a hedgehog enjoying an early morning meal of oystercatcher eggs.

## Are large arboreal invertebrates threatened by possum control?

A common phenomenon in vertebrate pest control is an increase in the number of one pest species when another competing pest species is controlled. A good example of this in New Zealand is the increase in the abundance of rats following the poisoning of possums: in some forests, rat populations recover quickly over several months following poisoning, while possum populations are much slower and take several years to recover. With less competition from possums for seeds and fruit, rats attain densities far in excess of their pre-poisoning levels. What is not well understood is the consequence of this for native biodiversity. Do more rats undo some of the benefits of fewer possums in these forests?

Peter Sweetapple reported negative consequences of this effect for some ground-dwelling invertebrates and robins in [issue 11 of \*Kararehe Kino\*](#). Here, Peter and Mandy Barron look at the impacts of increased rat numbers following possum control on selected large-bodied invertebrate species that live in or on forest trees in the Tararua Range. Aerial poisoning of possums was undertaken there for the first time in spring 2010, when the team started monitoring arboreal invertebrate populations by extracting tree wētā, stick insect and slug faecal material (frass), and cockroach egg cases, from litter trays (*Photos a–d*). Samples were taken both inside and outside the poisoned areas at two widely separated sites (Tōtara Flat and Waitewaewae) over the November–February period for 5 years starting November 2010. These collections spanned a second poison operation in December 2013. Rats were monitored using tracking tunnels over the same 5-year period.

## Trends in rat and invertebrate abundance

When first measured after the first poison operation, the abundance of rats (revealed from their faeces) was low throughout both sites and near zero in poisoned areas (*Figure a*). Tracking tunnel indices showed that rat numbers rose to high levels in the poisoned areas (relative to unpoisoned areas) over the first 2 years, and that this was more pronounced at Tōtara Flat. Rat numbers were high again, particularly

within the poisoned areas, 1 year after the second possum control operation.

Throughout much of the study, cockroaches, stick insects and tree wētā at Tōtara Flat all exhibited abundance trends that were the opposite of those for rats. Their abundances were initially similar inside and outside the poisoned area, but then they increased outside to peak about three times higher than inside the poisoned area (Figure b, c, d). However, the initial trends in tree wētā frass fall at Tōtara Flat did not persist beyond 2013, for unknown reasons. Abundances of all three invertebrates was generally much lower at Waitewaewae than at Tōtara Flat (stick insects were very scarce at Waitewaewae), and there were virtually no differences in abundance trends with and without the 1080 poisoning of possums.

Slugs, on the other hand, did not respond to pest control at Tōtara Flat but showed complex abundance trends at Waitewaewae, which may have been unrelated to pest abundance and control (Figure e).

Overall, there were marked differences between the two sites in terms of the responses of rats and arboreal invertebrates to poisoning. Rats and invertebrates were generally less abundant at Waitewaewae, which probably reflects the wetter climate and less diverse, beech-dominated vegetation there. They were generally more abundant at Tōtara Flat, where beech was a minor part of the forest but fruit- and seed-producing species (including hīnau, rimu, supplejack and pigeonwood) were common. As seen elsewhere, the 'release' of rat populations after the removal of possums appears largely restricted to food-rich mixed podocarp-hardwood forests (the Tōtara Flat site in this study) that have high rat- and possum-carrying capacities. In these forests, sustained possum-only control does appear to have negative consequences for tree-dwelling invertebrates.

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Photo b: Faecal pellets from stick insects

Photo a: Faecal pellets from tree wētā

Photo c: Faecal pellets slugs





Photo d: Cockroach egg cases

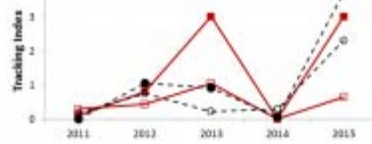


Figure (a): Trends in rat abundance

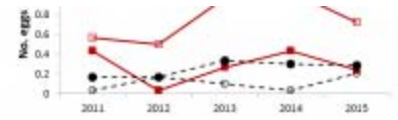


Figure (b): Trends in cockroach abundance

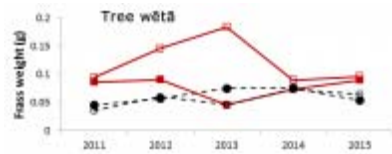


Figure (c): Trends in tree wētā abundance

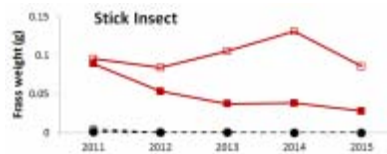


Figure (d): Trends in stick insect abundance

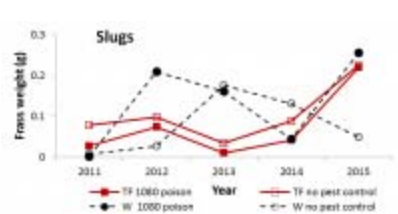


Figure (e): trends in slug abundance

## Norway rats in rural and urban New Zealand

The vision of a predator-free New Zealand by 2050 is usually about possums, stoats and rats. While possums and stoats are single species, there are three species of rat in New Zealand. In order of arrival – and of increasing distribution around New Zealand – they are the kiore or Polynesian rat (*Rattus exulans*), the Norway or brown rat (*Rattus norvegicus*), and the ship, black or roof rat (*Rattus rattus*). Kiore are believed to be extinct on the North Island mainland, but persist on some islands and in parts of Fiordland, Southland and South Westland, while Norway and ship rats are both widespread. However, while ship rats are the common rat in New Zealand forests and shrublands, and therefore are virtually ubiquitous, Norway rats are distributed much more patchily, usually living near water (including the sea), and are common in urban areas and on farms.

### Telling rats apart

Kiore average 100 g and are much smaller than ship rats, and have a small area of dark fur on their outer, rear ‘ankles’.





Ship rat (top) and kiore



The three coat colours or 'morphs' of the ship rat, from top to bottom: alexandrinus, frugivorus, and rattus.

Ship rats come in three coat colours, or morphs, which confuses people (see *photograph*). Most ship rats in the North Island are the *frugivorus* morph, whereas in the South Island they tend to be the *rattus* morph, but any of the three morphs may occur anywhere. Ship rats have slender tails longer than their body length (unless shortened by injury), and have big ears which when bent forward cover their eyes.



Norway or brown rat

Norway rats are always brownish (hence their other common name, brown rat); their tail is shorter than their body length and stout at the base, and their ears are small compared to those of ship rats (when bent forward they do not cover their eyes).

## Size, behaviour and abundance

Besides appearance, there are other important differences between Norway and ship rats, especially in their size and behaviour. Norway rats are much bigger (average 210 g, maximum 420 g) than ship rats (average 145 g, maximum 295 g), which should be considered when trapping them. Norway rats can climb trees but rarely do, unlike ship rats which are truly amazing climbers and thus threaten tree-nesting birds. However, Norway rats are better swimmers than ship rats and so are much more likely to invade nearby islands, where they are key pests of ground-nesting birds and other fauna. Being near water is a major feature in the distribution of Norway rats on the New Zealand mainland, probably because they can dive readily to find food and to escape predation. They are known predators of crabs on rocky coasts, and dive to prey on freshwater mussels in North Island lakes. They also prey on the eggs and nestlings of New Zealand dotterels and shore plover, and probably numerous other wetland, braided river and coastal birds.

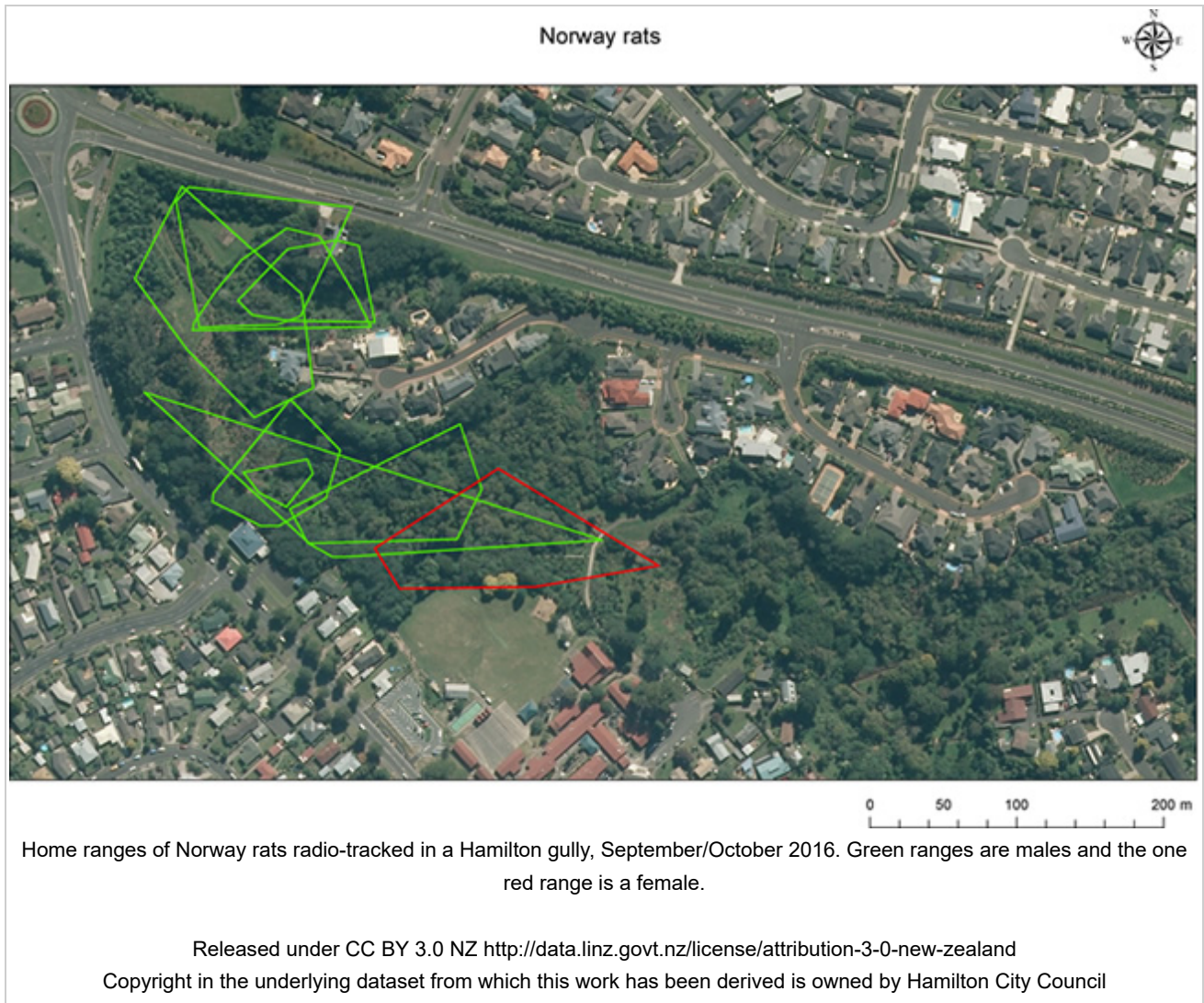
From studies so far, the proportion of trapped rats that are Norways varies from 2% in Waikato forest fragments to 100% in Waitaki Basin braided rivers. Outside forests, especially in urban and rural sites, there always seem to be a few Norway rats present. In urban and farmland sites, current data indicate that Norway rats comprise 5–50% of all trapped rats, mainly depending on whether the traps are placed near water. Norway rats are therefore typically very patchy across the landscape, and probably have long, thin distributions along waterways.

It is no surprise that Norway rats are found throughout New Zealand towns, cities and farms, because they (and not the ship rat) are the usual species in these habitats around the world. Contrary to some recent assertions, there is no city in the world that has actually been made rat-free, and so this remains a challenging milestone for New Zealanders taking on the vision of making New Zealand predator-free.

Neil Fitzgerald, John Innes and a student placement, Nicolas Sandoval (Waikato Institute of Technology), radio-tracked Norway and ship rats in September/October 2016 in a vegetated gully in urban Hamilton to see how far apart control devices could be placed and still be effective. In this study, Norway rats had a mean home range length of 269 m (see *Figure*) and moved further than ship rats, which had a mean home range length of 196 m (*not shown*). Both species stayed largely confined to the gullies and did not venture into nearby

backyards.

This research also suggested that Norway rats are more likely than ship rats to be seen in the daytime, and some literature suggests that Norway rats are more likely to travel on defined trails than ship rats.



## So what?

John and his colleagues' results indicate that there are likely to be benefits from controlling only the more widespread rat species, rather than just lumping them all as 'rats'.

Kiore are rare in all mainland habitats occupied by them and are not targeted in any control operations, other than on islands such as Aotea (Great Barrier Island). The two common rat species – ship and Norway – coexist all over New Zealand but have different habits and impacts. For example, to protect tree-nesting birds or freshwater mussels you would target ship rats or Norway rats respectively. Choosing what outcomes to measure to determine operation success should also be determined by the rat species targeted. Ship rats will be the only species killed if devices are set up trees, but both species will be killed by devices set on the ground. Traps that may catch Norway rats should perhaps be bigger and stronger, because Norway rats are much larger than ship rats. Humaneness approvals of control devices should be sought separately for the two species, again because Norway rats are much bigger than ship rats.

The researchers do not yet know if behavioural differences between ship and Norway rats mean that one will be harder than the other to eradicate in urban or rural settings.

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## When pets go rogue: the link between the wildlife trade and exotic species

New Zealand puts considerable effort into managing the impacts of invasive species. And with good reason: invasive species wreak havoc on the environment and pose significant threats to animal health. The commitment to managing such pests and reducing their impacts is well exemplified by the Department of Conservation's 'Battle for our Birds' campaigns to achieve environmentally driven goals. A second example is the control of possums by TBfree NZ, with the aim of eradicating bovine tuberculosis, an animal health-driven goal. More recently the launch of initiatives to eradicate some predators from the mainland by 2050 has put New Zealand at the global forefront of the battle against invasive species.

These management initiatives concentrate on exotic species that have established self-sustaining populations and spread throughout New Zealand. The presence of these invasive species is mainly a legacy of 'acclimatisation societies', which made it their goal to establish exotic species for human delight and use. Luckily such acclimatisation societies are no longer active in New Zealand, though that does not necessarily imply that releases of potentially invasive species have ceased: the purposeful release of animals is being replaced by more subtle pathways of transport and the introduction of new and emergent exotic species. This shift has occurred in recent times in countries around the world and has been driven by concomitant changes in the relationships between humans and animals.

In this new context most species are transported into countries either intentionally (e.g. trading to satisfy the demand for animal products) or unintentionally (e.g. species hitching a ride in containers shipped from one country to another). Unlike the goals of acclimatisation societies, these new pathways rarely if ever have the explicit objective of establishing exotic species. Rather, some species escape or are released into new environments where they may be capable of forming self-sustaining populations.

Mounting evidence reveals the key role played by the pet trade in shaping the new national pool of exotic species. Globally a large variety of species are traded to supply and meet the demand for pets. This demand is causing significant environmental problems. In their native range the exploitation of populations is leading to over-harvesting and population declines; in the recipient regions some of the imported and traded species may pose an untenable risk of becoming invasive species.

The rise in the relevance of the pet trade has also changed the type of exotic species transported worldwide. Where in the past there was an emphasis on mammals and some birds, nowadays the pool of potential exotic species is dominated by ornamental fish, amphibians, reptiles, and cage birds. New and emergent exotic species pose new threats to native biota. For example, exotic amphibians may carry emergent diseases such as the chytrid fungus and ranaviruses, which can imperil native frog species. Earlier this year a snake was intercepted on an incoming flight at Auckland airport. The introduction of snakes to New Zealand environments, where native communities are naïve due to their natural absence, could lead to an ecosystem-scale disaster akin to that caused by introduced brown tree snakes in Guam.

Preventing the introduction and establishment of exotic species is the best way to avoid potential detrimental impacts, but to be effective, preventive strategies need to be based on good evidence.

So, what is known about the risks of the pet trade in New Zealand? Trading in ornamental and aquarium fish has been highlighted as increasingly contributing to new introductions of exotic fish across the world. In New Zealand almost a quarter of the exotic fish present in 2012 were ornamental species (23.8%, or 5 out of 21). This proportion may further increase in the near future due to the growing numbers and diversity of exotic fish imported into the country.



Bearded dragons, native to Australia, are a popular pet in New Zealand



Koi carp are a prominent example of ornamental fish becoming invasive

Reptiles have also gained prominence as emerging exotic species. There is good information about exotic reptiles in the New Zealand pet trade thanks to the research of Heidy Kikillus in 2010, although an update would be welcome. Heidy reported 12 species of exotic reptiles found in the pet trade, with individuals of four species found at large (although none have established populations). It is not surprising that the most common pet reptile was the red-eared slider turtle, a species that has been traded in massive numbers globally. As in countless other countries, slider turtles are often found in the wild in New Zealand waterways, particularly around Wellington and Auckland. Rapid responses by governmental agencies to remove such animals have prevented their establishment in the wild, but these incursions represent a warning of the potential risks of pets.

Pablo García-Díaz has researched the role of the pet trade here as a source of new and emergent exotic species. Existing biosecurity arrangements, coupled with risk assessment tools for exotic imports (e.g. NIWA's fish risk assessment model), should help protect New Zealand from emergent exotic species. Pablo does not, however, argue for a blanket ban on the pet trade in New Zealand. Instead, he contends that we need a more nuanced and up-to-date knowledge of the biosecurity risk currently posed by this trade. The need to comprehend the nature of such novel biosecurity risks to manage the new generation of potentially exotic species effectively is clear-cut. Otherwise New Zealand may need to deploy 'Predator Free 2050-like' initiatives in perpetuity to deal with an ever-increasing number of newly established exotic species.

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## Emerging invasive threats: the alpine newt

There is a growing appreciation globally of the occurrence and ecological impacts of herpetological invasive species. New Zealand has historically suffered relatively few such incursions or establishments due to its relative isolation, yet as cross-border freight volume grows so too have the rates of interception of reptiles and amphibians. The Biosecurity Act 1993 provides effective justification for border management and controls on importation, yet incursions have still occurred. One such incursion is the alpine newt.



Male alpine newt in breeding condition

The alpine newt ranges from the French Atlantic coastline north to Denmark and eastwards to the Ukrainian Carpathians, Romania, and Bulgaria. It is widely distributed in the Balkans. Isolated populations are also present in southern Italy and northern Spain. It has established as an invasive species in the United Kingdom, where it was intentionally introduced, and in the Sierra de Guadarrama, central Spain. The species occurs from sea level to around 2,500 m a.s.l. in the Swiss and French Alps. One population naturally occurs in isolation in the Carpathian Mountains of NW Spain. Across this range the newts are described as consisting of six phenotypically and geographically distinct subspecies.

Alpine newts annually migrate to and breed in freshwater, and exhibit a high fidelity to natal waterbodies which may be permanent or ephemeral. They become sexually mature at 2 to 4 years of age. Like many Urodela (newts and salamanders), alpine newts engage in complex aquatic courtship dances that culminate in spermatophore transfer from male to female for internal fertilisation. Males develop flexible cutaneous crests on the tail and dorsal surface during the breeding/aquatic phase (see picture below). Females can produce up to 200 eggs per breeding season, which are laid individually or in small numbers on vegetation low in the water column. These eggs hatch in 10 to 30 days and can develop to metamorphosis in 75 days. Development may also be delayed, and neoteny (sexual maturity with aquatic larval characteristics retained) has been observed in high-altitude populations of some sub-species. Alpine newts grow to a maximum total length of 11 cm, can live beyond 20 years in the wild, and feed on invertebrates. It is an adaptable species able to occur in modified environments as well as those that are ecologically intact.

The invasion history of this species in New Zealand is limited to a single known event associated with aquaculture and the pet trade. This event was investigated by the Ministry for Primary Industries (MPI) and is the focus of an eradication effort being led by MPI and the Department of Conservation (DOC). The location of the release in the central North Island is in close proximity to native *Leiopelma* spp. frogs, and as such the newts are regarded as a serious threat for transmitting the chytrid fungus and other pathogens they are known to vector in their native range. First detected by a member of the public in May 2013 and reported to MPI, the specimen was identified as a sub-species that originates in the Tuscany region of Italy. An intensive survey of the immediate area quickly identified many high-density

populations consisting of all life-history stages and confirmed that a population had established within an approximate 300 m radius. Investigations suggest that the initial release probably occurred somewhere around the turn of the 21st century.

A commitment to contain and eradicate the newt was made by MPI, and towards the end of 2013 a workshop was held to develop an operational strategy. This strategy has gone through a number of iterations. It is currently dominated by an investment in fencing to delimit the incursion and function of newts that includes the deployment of pitfall traps to intercept them and divide the operational area into multiple discrete cells. Waterbodies are intensively trapped with fyke nets and Ortmann traps. Where possible, breeding waterbodies have been drained and capped, while vegetation known to be occupied by newts has been cleared and disposed of on-site through burying. Waterbodies have, in some instances, been replaced by sentinel ponds. These are designed to serve as an attractant for newts searching for their natal ponds, and to ensure that the newts are exposed to capture in pitfall traps or detection through a simplification of refuges available to them. Supporting these core tools is regular searching by detector dogs.

All efforts sit within an operation plan overseen by a technical advisory group (TAG) and supported by a proactive communication plan for all landowners affected by the eradication programme. Capture efforts have seen a marked increase between 2015 and 2017, and newt captures have declined dramatically over the course of the eradication effort (*Figure 1*).

The eradication effort is a world first for Urodela and as such has been highly adaptive in its approach. This has involved research into the development of several tools and techniques. James Reardon has tested the efficacy of a number of aquatic lures in an attempt to optimise aquatic trap captures. Trials suggested that female newts provide a modest level of attraction to male newts but none of the lure treatments had a significant impact on the proportion of newts captured. Time to capture corroborated the pattern of female newt attractiveness to males, but again the effects were not significant (*Figure 2*). *We also tested the lure effect of glowsticks and meat (spam) on newts as both are reportedly used in the capture of newts but no literature was available that tested their efficacy. Our tests suggest they have no positive effect as a lure for alpine newts.* More recently, research is underway to measure trap retention rates and to test alternative pitfall trap designs that improve capture and retention rates. Skeletochronology has also been investigated by Morgan Coleman (Manaaki Whenua - Landcare Research), as ageing of newts captured will be a critical variable in determining the progress of the eradication.

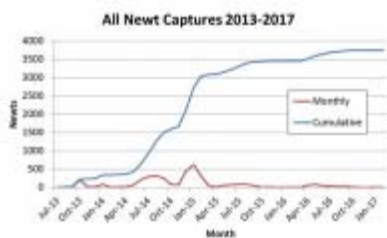


Figure 1: Alpine newt captures during the eradication effort

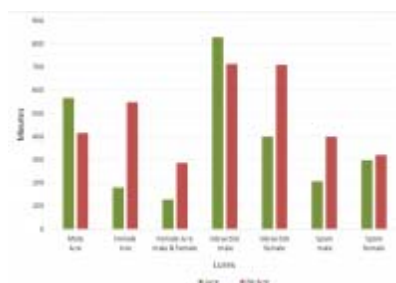


Figure 2: Aquatic lures for improving efficiency of traps

As with all eradications, the operational and TAG teams acknowledge that the greatest test lies ahead as the eradication progresses into the mop-up phase targeting the last individuals, and finally the confirmation of absence. Considering the cryptic nature of the species and its relative longevity, these final stages of the eradication will require considerable commitment from all stakeholders. However, as this eradication effort is a global first, it will hopefully stand as a notable contribution to global biosecurity practice.

This work was funded by the Ministry of Primary Industries and the Department of Conservation.

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## Feral pigeons – the problem and its management

The feral or rock pigeon is well-established throughout New Zealand and is a common sight in cropping regions, cities and large towns. Some people enjoy seeing and feeding pigeons, particularly in urban areas, whereas others view them as vermin equivalent to rats.

But are they really a problem? As with most pest species a few have little impact but flocks of several hundred or more have the potential to cause both economic and environmental damage. Pigeons can damage buildings and decorative structures with their excrement in urban areas, and cause crop losses in rural areas. They are also known carriers of zoonotic diseases such as salmonella, but evidence of pigeon-to-human transmission is scarce.



Figure a: Flocks of pigeons over crops.

Pigeon populations are limited in their distribution and abundance by the availability of roosting and nesting sites and by year-round availability of food. They will take advantage of seasonal foods such as sprouting cereals and legume crops, and can cause significant crop losses when in large numbers (*Figure a*). Farmers may need to re-sow crops if losses are high. Urban-based pigeons may congregate at grain-handling and storage facilities, and at sites where people intentionally or unintentionally feed them, such as parks and town squares.

In rural areas pigeon damage is most commonly mitigated using lethal control, either by shooting with shotguns (*Figure b*), or poisoning using the stupefying agent alphachloralose. Unwanted pigeons roosting and nesting in rural buildings can be eliminated at night using a torch in combination with an air rifle. Site-specific control measures in both rural and urban areas include multi-capture live traps, and exclusion from nesting and roosting sites using angled plates, plastic and metal spikes, tensioned line or wire, netting, electrified wire, barrier coil, and repellent gels. Predators can be used to manage specific pigeon populations. For example, a trained New Zealand falcon has been used to scare off pigeons at Canterbury University.

Sometimes the solution to reducing pigeon impacts is to remove food sources. In urban areas, better disposal of food refuse may be all that is required.

A fertility control agent (OvoControl® P) has been developed in the United States, and its manufacturers claim that it reduces pigeon populations by 90–95%. The agent contains nicarbazin and is fed daily to pigeons to reduce their fertility. While the product may be useful in certain urban situations in New Zealand, it is not currently registered for use here.



Figure b: Pigeon control by shooting

Pigeons are very successful opportunists, and changes in farming practices may create more opportunities for them and therefore more problems. New Zealand currently has a strong dairy-based economy, and dairy farms create reliable food sources for pigeons. Silage made from maize, triticale, oats and any other grain-based stock feed can sustain large populations of pigeons throughout the winter when cereal and legume crops are scarce. In the future, more changes to farming practices are likely as economics dictate what is profitable. Recently developed technology to produce synthetic protein may result in fewer animals farmed but greater pea production to produce the raw materials for this product – more pea paddocks also means more food for pigeons and more problems.

Urban pest managers need to determine the extent of their pigeon problem and decide whether the cost of remedial action is less than the cost of maintaining the status quo through repairing buildings and cleaning them. A control programme should not start unless its outcome is first clearly and measurably defined, there is some certainty that the planned control will achieve the desired outcome, and there is a commitment for ongoing funding until management is achieved. There will always be some people who value pigeons, and this difference of opinion will create difficulties when trying to manage their populations. Using non-lethal methods that leave some resident pigeons to satisfy the demands of individuals who value them may be the best compromise in current New Zealand society.

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# Expanding wallaby populations

Six species of wallabies were introduced into New Zealand during the late 1800s, either for recreational hunting or as part of the then desire to acclimatise exotic species. Four of these species are found on Kawau Island, with dama wallaby also found around Rotorua, and Bennett's wallaby found in South Canterbury / North Otago. Populations of both these species continue to spread on the mainland and have negative impacts on primary production and indigenous biodiversity.

Because of an increasing number of sightings outside these species' containment areas (as designated by regional councils), there is growing concern over the increasing cost of their impacts and the increasing challenge of containing them. This concern has led to the Ministry of Primary Industries (MPI) contracting Dave and Cecilia Latham and Bruce Warburton to review the current distribution of these two species, and to predict their possible distributions in 5, 10, 20, and 50 years if allowed to spread at historical rates.

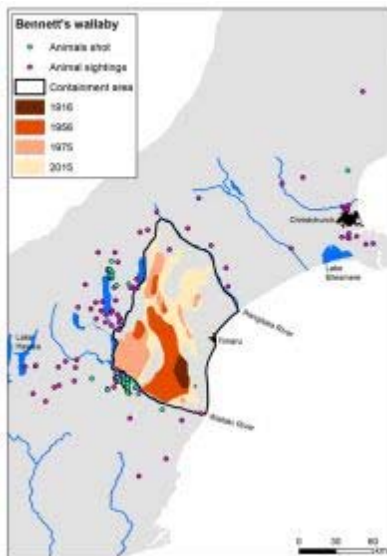


Bennett's wallaby

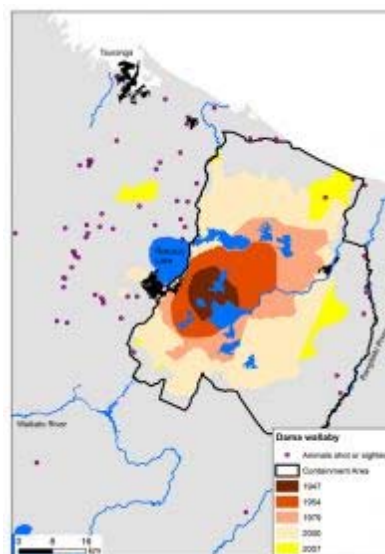
Maps of confirmed distributions along with additional data on recent sightings (live sightings and animals shot) were used to determine best- and worst-case distributions (Figures a and b). The historical distribution maps and recent GIS data on the distribution of these species at various stages since their establishment were used to generate rates of spread and to predict future distributions. It was assumed rates of spread would stay constant (i.e. containment would not become more effective nor rates of illegal liberations increase).

At present, Bennett's wallaby occupy an estimated c. 5,322 km<sup>2</sup> in the South Island centred on the Hunters Hills, South Canterbury. However, the large number of confirmed sightings and animals shot outside of this area suggest that they may occupy as much as 14,135 km<sup>2</sup> (Figure a). Based on current estimated rates of spread, the distribution of Bennett's wallaby in 50 years' time is likely to be between 9,621 km<sup>2</sup> and 20,631 km<sup>2</sup>, but possibly as large as 44,226 km<sup>2</sup>. The last value includes known illegal liberations and represents almost one-third of the South Island, or a 700% increase of the current known distribution.

At present, dama wallaby occupy an estimated c. 2,050 km<sup>2</sup> in the North Island centred around the Rotorua lakes in Bay of Plenty. However, the large number of confirmed sightings and animals shot outside of this area suggest that they may occupy as much as 4,126 km<sup>2</sup> (Figure b). Based on current estimated rates of spread, the distribution of dama wallaby in 50 years is likely to be between 3,265 km<sup>2</sup> and 11,070 km<sup>2</sup>, but possibly as large as 40,579 km<sup>2</sup>. This last value represents more than one-third of the North Island, or a 1,700% increase of the current known distribution.



Historical distributions and current containment areas of Bennett's wallabies with sightings and animals shot outside



Historical distributions and current containment areas of dama wallabies with

their designated containment areas.

sightings and animals shot outside their  
designated containment areas.

Based on habitat suitability models Bennett's and dama wallabies could, if not managed, eventually occupy most of the South and North Islands respectively. The models predict that the only areas from which they may eventually be absent are those associated with high-production exotic grassland (e.g. dairy lands), urban areas, and high elevations.

The current total annual costs of the impacts of Bennett's wallaby in the South Island were estimated to be c. \$23,700,000 (which includes c. \$22,200,000 in revenue lost to agriculture and c. \$1,500,000 to ecosystem services and biodiversity values). If Bennett's wallaby were allowed to spread without any active management, it was estimated that the total annual costs of their impacts in 10 years would increase to c. \$67,000,000. If widespread remedial control was applied to reduce their densities within their predicted distribution in 10 years, the costs incurred would be c. \$27,700,000. This suggests there is a large net benefit (c. \$39,300,000) to managing them to control their unwanted impacts as opposed to not managing them.

The net benefit of containing Bennett's wallaby would be even greater. That is, intensive control and surveillance within the present containment buffer would cost c. \$6,200,000. This represents one-third of the expenditure that would be incurred if wallaby populations were allowed to expand for 10 years and then controlled (\$18,000,000), or one-seventh the expenditure incurred if the populations were allowed to expand in the absence of management (\$43,400,000).

Because wallabies are not a nationally important pest, very little research has been carried out on control strategies, tools, detection, impacts, and the economics of various management options. However MPI, through the Sustainable Farming Fund, has funded Manaaki Whenua – Landcare Research to determine the detection probabilities of using both aerial-based thermal imaging and dogs to better manage wallabies that have 'escaped' their containment areas. Determining such probabilities will enable farmers and managers to quantify the likelihood that they have eradicated wallabies when none are detected, and provide more effective methods for detecting them when at low numbers and close to eradication or when they have recently invaded an area.

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**Dave Latham**

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