Kararehe Kino

Vertebrate Pest Research

Issue 15 / Dec 2009

Orongorongo Valley
Edition

Landcare Research
Manaaki Whenua

ISSN 1175-9844 (Print) ISSN 1170-3016 (Online)

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Also available electronically: http://www.landcareresearch.co.nz/publications/newsletters/index.asp

Issue 15 / **Dec 2009**

In this issue...


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Orongorongo Valley: an important long-term research area

In 1965, the Ecology Division of the then Department of Scientific and Industrial Research (DSIR) selected an area of about 1200 ha of mixed beech–podocarp–broadleaved forest in the Orongorongo Valley, near Wellington, as a site to 'conduct research on the interactions between introduced and native flora and fauna'. The emphasis was on long-term research on a variety of ecosystem components, supplemented with shorter term and more intensive studies. Even then, the area had a history of research activity, being used during the 1950s by the Department of Internal Affairs and the Forest Service for research on possum population dynamics and diet, and for some of the early trials of aerial poisoning of possums.

Those early studies helped clarify the impacts of possums on native vegetation, particularly their role in the death of native trees, and the relationships between periodic heavy 'mast' seeding of beech trees and associated outbreaks of rodents and stoats (see Brockie 1992, p. 20). Forty-four years on, the baseline information provided by the 'Orongorongo Valley' data sets is hugely valuable, and of great interest internationally for understanding long-term trends in forest tree seed production.

The Orongorongo Valley Research Area is now part of the Rimutaka Forest Park. Geologically, even by New Zealand standards this area is quite 'young' with several major earthquakes and floods shaping the valley in the last several thousand years. The Rimutaka Forest Park is managed by the Department of Conservation (DOC), which works closely with the Rimutaka Forest Park Trust to promote the conservation of native flora and fauna.

In recent years, Landcare Research has made frequent use of the research area around the existing field station. Our use of the research area is covered by an MOU with DOC; in which DOC and Landcare Research agree to work together on issues such as access to the valley, liaison with other groups such as the Rimutaka Forest Park Trust, collection and use of meteorological data, and dissemination of research results. The field station provides an excellent base for research conducted in a number of current Landcare Research programmes and projects. Visitors are welcome too – the station is used occasionally by DOC staff for retreats, or by visiting international researchers conducting research projects on site.

Sustaining funding for long-term research is difficult, and with a decline in research funding for Orongorongo-Valley-based projects over the last few years, some data such as long-term measurements of possum abundance are collected less frequently or are collected for specific research purposes differently to the historical data. However, other data collections such as seedfall measurements and measurements of possum and rodent abundance (see later article in this issue by Phil Cowan) are more spatially extensive than they were in the past. The challenge of funding perhaps explains why, despite a number of long-term ecological research sites in New Zealand like the Orongorongo Valley, New Zealand is not a formal participant in ILTER (International Long Term Ecological Research; www.ilternet.edu), a global network of research sites located in a wide array of ecosystems worldwide focused on understanding environmental change across the globe.

We hope you enjoy this special issue of *Kararehe Kino*, in which we profile the most recent research conducted in the valley and point you to some of the more commonly cited recent publications. Below we highlight a joint initiative by DOC and the Rimutaka Forest Park Trust, and our final article in this issue covers in more detail the long-term data sets collected in the Orongorongo Valley over the last 44 years.

Reference

Brockie B 1992. A living New Zealand forest. Auckland, David Bateman. 172 p.

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Rimutaka Forest Park Trust: **Kiwi update**

The North Island brown kiwi population in the Rimutaka Forest Park is going from strength to strength, thanks to the efforts of the Rimutaka Forest Park Trust working with the BNZ Operation Nest Egg™ programme. Twenty kiwi were transferred from Little Barrier Island in May 2009, and all are in good health. There are also three chicks at Bushy Park native bird sanctuary in Wanganui awaiting release. There are now 33 kiwi in the park, with 27 of them being breeding adults. The trust is one step closer to its goal of having a self-sustaining population of kiwi in the park, with the only future management intervention likely to be pest control.

The first known wild-born kiwi in 100 years was hatched in the park in September this year. Since 2007, the Trust has been removing fertile eggs from burrows as part of the BNZ Operation Nest Egg™ programme. These eggs are then incubated and hatched at specialist facilities, with the chicks being released and raised in a predator-free environment such as Little Barrier Island or Mt Bruce until they reach a body weight of 1200 g, sufficient to fight off a stoat, before being re-released back into the Park.

Four of the kiwi – Mattie, PC, Elvis and Colin – have been named by various sponsors that supported the transfer from Little Barrier Island. Success of this transfer was seen in October, with a pairing of two of these birds producing fertile eggs that were removed and hatched at the Pukaha Mt Bruce Wildlife Centre, near Masterton. With five more adult male kiwi currently incubating eggs in the park (females typically lay a clutch of two eggs, and males incubate them), it looks like the recent breeding success will continue provided ongoing predator control is maintained.

The importance of pest and dog control near kiwi areas in the park was highlighted in August when a kiwi was killed by a dog. As part of its commitment to kiwi in the park, the trust runs kiwi aversion training courses for pet and hunting dogs twice each year, which teaches them to avoid chasing or attacking kiwi in the wild, as well as encouraging dog owners to keep their pets on a lead. The trust also runs an extensive predator trapping programme, using 500 DOC and 200 kill traps covering over 2500 ha of forest and set following DOC best practice.

The trust was also busy during Conservation Week this year, visiting local schools in Wainuiomata and the Hutt Valley to talk about kiwi and predator control, and asking the pupils to bring in a hen's egg to use as bait for stoats. The idea is that the trust gets a good supply of eggs for stoat traps and the children get to be involved in, and learn about, the project. It was a great success and there are plans to repeat it again next year.

For more information about future kiwi avoidance training plans or to volunteer to work on the kiwi programme, contact trust spokesperson Melody McLaughlin on 04 564 6213 or 027 452 4982.

DOC *happenings in the Orongorongo Valley*

One hundred and fifty seven responses to a questionnaire on the future management of the Rimutaka Forest Park were outlined by DOC Poneke Area staff at a meeting of neighbours and park users in March 2009. Attendees also discussed proposals to accommodate mountain bikers and horse-riders in the logged areas of Catchpool Valley and suggested ways of maximising the use of the education centre. The considerable work of the Rimutaka Forest Park Trust was acknowledged.

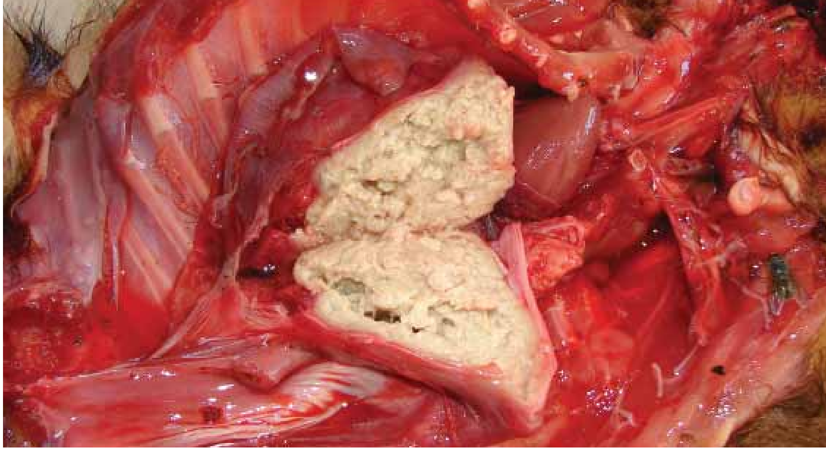
The replacement of the Shamrock and Haurangi huts was confirmed, with work expected to be completed by next summer. DOC is considering options for people accessing the valley after 6 p.m. in winter, and for horse riding and mountain bike access throughout the day. Other DOC huts are available for exclusive hire. Equipped with mattresses, cooking facilities and utensils, and crockery, and in some cases hot showers and flush toilets, they can be booked online on the DOC website.

New park information signs are being installed at Sunny Grove, and DOC and Landcare Research are working on signs to be erected in the Catchpool car park highlighting current research activities and road/track details.

For more information on DOC happenings, contact Kerry Swadling on 04 472 5821 or email kswadling@doc.govt.nz

How do *possums catch TB?*

G. Nugent



Widespread infection in one lung of a possum.

TB is present in the Orongorongo valley with the first case verified in 1985, and has persisted in possums in some areas of the valley since then.

We all know possums catch TB but, amazingly, not how. There is a widely held assumption that, by default, most possums become infected by inhaling infectious aerosols (i.e. air-borne particles), as is usual in humans. If this is the case in possums, we would expect to see infection firstly in the lungs. However, when Michelle Cooke (Massey University) and Jim Coleman examined naturally infected possums in detail, the most common sites of what appeared to be early-stage infection was not in the lungs but rather in the lymph nodes in the axilla (armpit) and/or groin.

When people have tried to experimentally mimic natural infection in possums by spraying aerosols containing *Mycobacterium bovis* bacilli into the lungs or placing an inoculum of the bacilli in the trachea (windpipe), the resulting tuberculosis has been far more aggressive than is natural, resulting in a massive and quickly lethal build-up of necrotic material (pus) in the lungs before the disease has spread very far throughout the body. For example, Dave Ramsey and his colleagues tested the effectiveness of a TB vaccine in the Orongorongo Valley in 2005, by putting a tiny dose of just 15 units or so of the bacilli into possum windpipes. All of the possums challenged died within 4 months whether they had been vaccinated against TB or not, and most had almost no healthy lung tissue left (*see photos*). By comparison, Dave Ramsey and Phil Cowan found in another study that even when possums naturally infected with TB had reached the stage where the disease could be detected clinically from external symptoms, they survived on average for only another 4 months.

Ivor Yockney

Graham Nugent and Jackie Whitford injecting M. bovis bacilli into the paw of a possum.

Michelle Cooke and Graham Nugent therefore believe that possums must somehow become infected via their paws. To test this, Graham and Jackie Whitford have just begun a three-part trial to see if they can reliably produce TB infection in possums by injecting or rubbing *M. bovis* into the skin between their toes or at the base of pads on their feet. The aim is to try to find a method of experimentally challenging (inoculating) possums that produces a slower more natural pattern of TB progression.

The first part of the trial was undertaken on Muzzle Station in North Canterbury, in early September 2009. Twelve possum were injected or inoculated in each of their paws (see photos) with either 50, 500, or 5000 clumps of M. bovis bacilli, and were then checked for disease spread 12 days later. In all four cases where 500 or 5000 bacilli were injected between the possum's toes, there were positive culture results for tissue taken from the nearest lymph nodes. Based on this trial, Jackie Whitford, Mike Perry and two Dutch veterinary students started a 3-month field study in the Orongorongo Valley in October 2009 to determine whether injection of 500 bacilli between the toes produces a natural pattern of progression of the disease in 24 free-ranging possums. A parallel study is to be undertaken early in 2010 by Bryce Buddle (AgResearch) with 22 captive possums at the Hopkins Institute in Palmerston North.

Despite being at a very early stage, preliminary results suggest that at least some free-ranging possums may indeed catch TB by handling or standing on infectious material rather than by inhaling it.

This work is being funded by the Foundation for Research, Science and Technology.

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Jackie Whitford

Spillback of residual TB *infection* in deer and pigs to possums – might it be important?

Where uniformly low possum densities are achieved through control, cattle testing data and modelling indicate that bovine TB (*Mycobacterium bovis*) will be lost within 5 years from formerly infected possum populations. However, other species such as pigs and deer also carry TB, and can either bring the infection back from some distant source into an area cleared of the disease or carry it through time long after TB has been eliminated from the possums.

Female deer pose the greatest risk of maintaining TB in wildlife over time. Work, contracted by the Animal Health Board to Landcare Research and carried out by Graham Nugent and Jackie Whitford showed that (like humans) many deer become infected at a young age, but do not initially develop progressive tuberculosis. Instead, they can remain latently infected for years until the disease activates as their immune system starts to fail in old age. Female deer can occasionally live for up to 20 years, so the risk is that if possum control is stopped after 5 years, possum numbers will quickly recover to near former levels and TB may spill back into their population and re-establish from old infected deer. To avoid this risk completely, possum numbers would have to be kept low for at least 10–15 years (by which time nearly all infected deer would have died), at a cost 2–3 times that of stopping possum control after approximately 5 years. But is the risk important? That depends on how likely it is for TB to pass from deer or pigs to possums.

To determine how often such transfers are likely to occur, Jackie and Graham injected a slurry of Rhodamine B dye into the lymph nodes in portions of pig and deer carcasses that nominally represented the carcass remnants left at kill sites by hunters. The marked carcass remnants were then left at sites accessible to possums. The team assumed that if some of the possums that fed on the remnants became marked by the dye, they could just as easily have become infected if the dye had instead been the contents of lesions in the lymph nodes of a TB-infected animal. The study was conducted in the Orongorongo Valley and at two other South Island sites in winter 2007.

Bite marks on 'chew cards' placed alongside each carcass remnant showed that possums visited almost all of them in all three areas. Most of the remnants were fed on by a variety of scavengers in the first week after placement, and after 6 weeks had usually been completely eaten, particularly those discovered by harriers and/or weka. At the two South Island sites (but seldom in the Orongorongo Valley), scavenging by harriers or weka often resulted in the dye slurry being spread from the lymph nodes over much of the remaining tissue and onto the ground nearby. This increased the likelihood that any possum subsequently visiting the site would come into contact with the dye.

Possums were directly confirmed as scavengers of the carcass remnants by the presence of dye-stained pieces of flesh in the stomach of one possum, deer hairs in the stomachs of three possums, probable dye around or in the mouth or on the stomach wall of four possums, and by one occurrence of dye-stained possum faeces independent of the other observations. Thus, it appears that few possums fed on the carcass remnants, and none appeared to have eaten large quantities of meat.

However, of 89 possums trapped 6–7 weeks after the carcass remnants were deployed, 2 of 29 from the Orongorongo Valley and 2 of 30 from Esk Head (North Canterbury) showed clear evidence of the dye in their whiskers (but none from the West Coast site were stained). Assuming the rate of possums marked with dye indicates the rate at which possums interact with infected carcasses, there is a small but significant probability (5%) they would ingest (or otherwise come into contact with) infectious material from TB lesions within such carrion. Hunters discarding heads and offal of TB-infected pigs and deer therefore create a risk of spillback transmission of TB to possums.

Graham and Jackie believe that the major implication from this work is that, because spillback infection can occur, possum numbers should not be left to recover to levels capable of maintaining TB in areas where the prevalence of TB in deer and/or the density of deer was initially high. Based on the typical age structure of a female deer population, the risk of possums picking up infection falls to infinitesimal levels after about 10 years unless the initial prevalence in deer was very high (>30%). That unfortunately indicates that complete avoidance of the risk of spillback infection into possums will require intensive possum control to continue for at least a decade. The alternative is to take a chance, stop possum control as soon as they are free of TB, and hope that in the few areas in which TB does re-emerge, the new outbreak can be detected and eliminated quickly and cheaply.

This work was done under contract to the Animal Health Board.

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How many RATS are out there?

Ship rats are invasive semi-arboreal pests. They are widespread and common in New Zealand lowland podocarp–broadleaved forests, where they prey on invertebrates and birds. Improved methods of determining rat abundance will help us to understand their ecology and how to control them.

The density of rats is usually estimated with capture-mark-recapture (CMR) live-trapping. This method requires multiple days of trapping, in which rats are caught, marked and released, and some later recaptured. The population size is then estimated with mathematical algorithms. These can be complex, but are generally based on the number of marked and unmarked animals captured daily. This estimate is then divided by the area trapped to provide an estimate of density. Estimating the area trapped is itself a challenge, because it depends on rat home ranges and movements. For example, traps arranged in a 1-ha square may catch rats with home ranges mostly within the square, and also rats with home ranges mostly outside the square.

Estimating density of rats with CMR is time-consuming and expensive, and an 'index' of rat abundance is often used instead. Examples of such indices are percentages of ink tunnels with rat tracks, chew cards or wax-tags marked by rats, or kill-traps catching animals after one or several nights. Such indices are, however, likely to be affected by weather, season, and food availability, and it is unclear how strongly they relate to rat density.

Deb Wilson and her team used CMR to estimate rat density in the Orongorongo Valley where rats were plentiful. A common problem encountered when using CMR is that too few animals are captured or recaptured for robust population estimates. To catch as many rats as possible, the team determined which of two commonly used 'live' traps (Elliott box traps and mesh cages) was most successful, and obtained highest rates of capture with mesh cages. They ran trials in April 2003, May 2003, and April 2004, using three arrays of mesh traps, spread over nearly 10 ha. Each array contained 48 traps, 15 m apart, in an open square, and was checked daily for five consecutive days (for methods see Wilson et al 2007).

The data were analysed using the computer program DENSITY (Efford 2004), available at http://www.otago.ac.nz/density/. The three trials provided estimates of the probability of catching a rat, depending on a trap's location relative to the rat's home range. These data were then used in DENSITY to simulate captures using alternative trap layouts. From these analyses, the team concluded that three arrays of 64 traps arranged in a grid with 20-m spacings or in two concentric squares (15-m spacing) would yield more precise density estimates than the layout they had used. Further, a team of two people could check these DENSITY-derived arrays of traps daily, if the terrain and distance between the arrays were similar to those of the trials.

DENSITY was also used to provide spatial information about the area the animals occupied, based on the locations of the traps that captured rats on different days (see article in this edition by Mike Perry).

So how many rats are there in the Orongorongo Valley? Deb and her team estimated that there were about five rats per hectare in autumn 2003, and nine per hectare in autumn 2004 at the locations they sampled. These estimates seem reasonable, since studies elsewhere in New Zealand forests have given similar values, and rat density can fluctuate considerably from year to year.

More recently, Landcare Research teams have been using CMR with the same mesh traps to estimate rat density at other North Island locations, together with DNA from hairs left behind on sticky material inside tracking tunnels to identify individual rats. These studies will provide better data on the density of rats and how it changes within and between years in New Zealand forests.

This project was funded by the Foundation for Research, Science and Technology.

Reference:

Efford MG 2004. Density estimation in live-trapping studies. *Oikos 106*: 598–610.

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Sam Brown, John Williamson

Home ranges and movements of **ship rats**

Ship rat populations in New Zealand forests are increasingly controlled using poison baits in bait stations, or by trapping. However, more cost effective ground-based control requires detailed knowledge of their home range and spatial detection parameters (i.e. probability of encountering and interacting with killing devices), but internationally there are relatively few estimates of any of these measures.

To generate these statistics, Mike Perry and colleagues radio-collared adult rats in the Orongorongo Valley and tracked them each month from January to May 2008 over a total of 31 days. Using data from mark-recapture studies (see following article), the researchers estimated the probability of capturing a rat at the centre of its home range, and the size of its home range.

Eleven male and 13 female rats were radio-tracked, with the number of fixes for each rat ranging from 6 to 46. Rats were tracked during daylight (301 fixes) to obtain den site locations, and during darkness (219 fixes) to determine where they were foraging. A sensitivity analysis of this data determined that robust estimates of home range require at least 15 fixes for female rats and 17 fixes for male rats. Based on this, the researchers calculated that home ranges of females varied from 0.6 to 3.2 ha and averaged 1.84 ha, while for males home ranges varied from 5.6 to 18.9 ha and averaged 10.24 ha (*Fig. 2*).

The median distance moved between radio-telemetry fixes by male rats ranged from 64.6 m over 1 day to 94.1 m over 28 days compared with 27.5 m over 1 day to 48.5 m over 28 days for female rats. For males, 95% of inter-fix distances over 28-day intervals varied from 5.0 to 341.0 m, and for females from 2.2 to 170.0 m. Overall, the majority of movements by rats were less than 341 m for males and 213 m for females (*Fig. 1*).

For the 412 radio-telemetry fixes for which information on the type of habitat use was recorded, 87% of fixes were in the subcanopy or canopy and only 13% on the ground.

Using the data from the mark-recapture study, Mike and his colleagues determined that depending on habitat and season, the probability of capturing a rat in a trap at the centre of its home range varied from 2% to 11% on any given night, while home range radii varied from 44 m to about 120 m. Thus, maximum daily movements of rats estimated from live-trapping data were lower than those obtained from radio-tracking.

Nevertheless, the radio-tracking data and the live-trapping data tell similar

A.Byrom

Ship rat with newly fitted radio collar and ear tag.

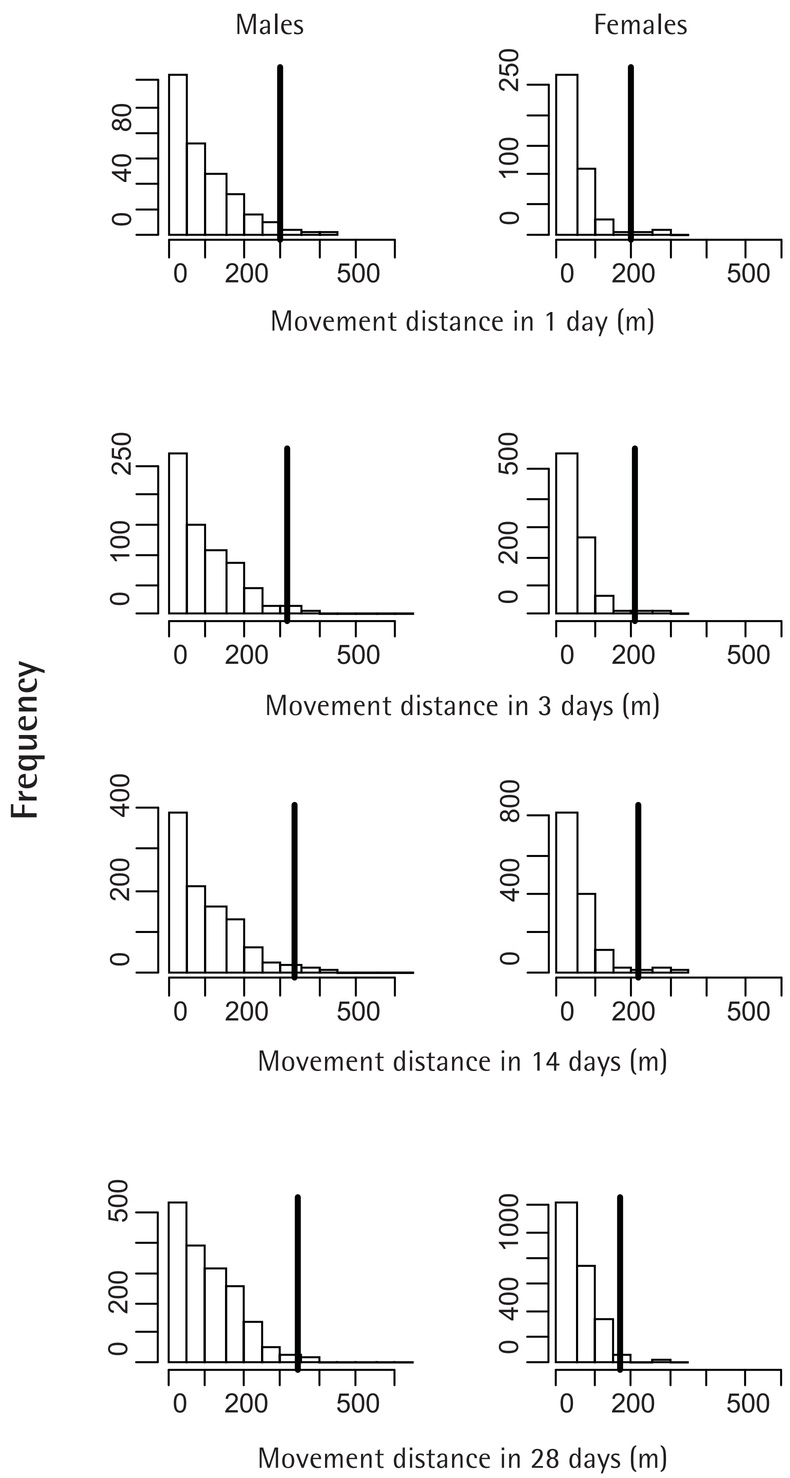

Fig.1. *Distance between radio-telemetry fixes of ship rats in the Orongorongo Valley at 1-day, 3-day, 14-day and 28-day intervals. The vertical bold line represents the 97.5% percentile, i.e. 2.5% of inter-fix distances were greater than the value where the line meets the x axis.*

stories. Based on rat captures in traps, the researchers modelled the proportion of a hypothetical population of rats in the Orongorongo Valley that would be captured if kill-traps were set for 7 nights and checked only at the end of the 7-night session. Using a simulated density of 5 rats/ha, an 80-ha grid of kill-traps spaced at 20-m intervals 'captured' 77% of the rats present. Increasing rat density to almost the maximum value observed during trapping resulted in 92% of the rats captured after 7 nights. Similarly, the radio-tracking data indicate that kill-traps or bait stations should be conservatively spaced no more than about 30 m apart in order to capture females (as they have smaller home ranges than males). But even that spacing would still not guarantee coverage of all home ranges.

Mike and his colleagues emphasise that the longer a kill-trap or bait station is left in the field, the greater the probability that a rat in the vicinity will encounter it and die. The team is now trying other combinations of simulated trap spacings, to refine ground-based control operations for rats, and ensure maximum coverage with limited pest control dollars. Such modelling must allow for the possibility that as rat populations decrease and competition for space with their conspecifics declines, rats may increase their home range size and foraging distances.

This project was funded by the Foundation for Research, Science and Technology.

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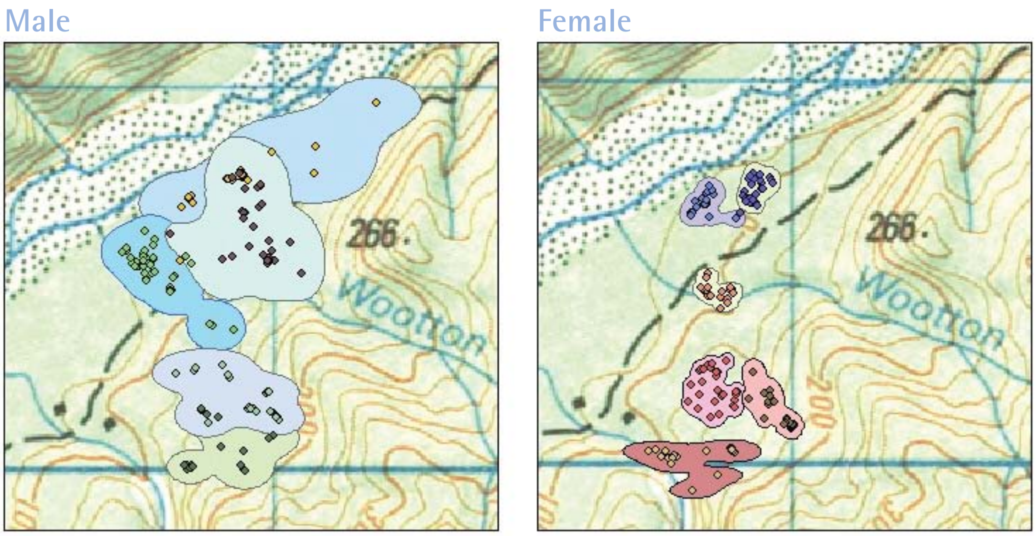

Fig2. *Home ranges (95% kernel estimate) of five male and six female ship rats in mixed beech–podocarp–broadleaved forest in the Orongorongo Valley, January–May 2008.*

A. Byrom

Rats are trapped, anaesthetized and have a small pit tag inserted under the skin for identification. This tag is then scanned when rats are recaptured.

Habitat use by ship rats in **New Zealand** forests

Understanding which parts of natural ecosystems are occupied by invasive mammals is vital to reducing their impacts on native species, improving the effectiveness of their control, and minimising reinvasion of controlled areas. In New Zealand forests, relatively little is known about how ship rats use microhabitat features (e.g. trees, ground-level vegetation, logs, and vines) or how patterns of use change over time (although these topics are under investigation; see articles in this issue by Deb Wilson, Mike Perry, and Rebecca Lawrence).

Dean Anderson and his colleagues have developed a model that uses forest attributes ('environmental covariates' including slope, aspect, and microhabitats) to predict where and when 'hot spots' of rats occur, and plan to use this information to help pest managers refine ground-based control.

The distribution and abundance of rats are likely to depend on:

- Microhabitats and topography
- Habitat attributes of adjacent areas
- Variability in food resources between seasons and years, and
- Population densities of directly interacting species (e.g. possums and stoats).

Initially, the researchers focused on habitat covariates likely to affect rat distributions. They developed two competing general hypotheses:

Hypothesis 1 (null hypothesis) – Rats have unpredictable, patchy distributions, with no identifiable environmental attributes characterising locations of high and low abundance, and with locations of high abundance changing through time.

Hypothesis 2 – Rats have distributions determined by microhabitat and topography, where the local abundance of their populations reflects the presence of habitat features that are permanent (e.g. aspect) or change only slowly over time (e.g. ground-level vegetation).

The data for the model came from a series of 5-night trapping sessions (see article in this issue by Mike Perry) at three locations in mixed beech–podocarp–broadleaved forest in the North Island (*Fig.*) on small (6.5 ha; traps at 20-m spacing) and large (1000 ha; traps at 100-m spacing) grids. Environmental covariates were recorded at each trap location.

The researchers found strong support for Hypothesis 2. High vegetation ground cover, a canopy of podocarps, and a northerly slope were all important in predicting where rats were most likely to be trapped (*Table*). Key findings were that some rats always occupied preferred microhabitat, but other fine-scale habitat patches were occupied ephemerally only after seasonal breeding.

One unexpected finding was that aggregation of rats could not be explained by environmental covariates alone. Ship rats can persist in unfavourable microhabitats if there are other rats nearby.

Although environmental predictors of rat abundance and distribution in these forests were identifiable (and consistent) in space and time, Dean and his colleagues think that there are important unanswered questions about the dynamics of rats in 'hotspots'. For example, can hotspots persist as source populations that provide rats to recolonise controlled areas or temporarily occupy surrounding poor-quality areas? Are there situations in forests where high-density populations occur in high-quality patches with fixed locations and only dispersing rats persist in the poor-quality, inter-patch forest?

Table. *Positive and negative habitat preferences of ship rats in podocarp– broadleaved forest.*

Habitat variable	Influence on rat abundance
Podocarp canopy cover	+
Tree canopy cover	+
Slope angle	+
Northerly aspect	+
Vegetation ground cover	+
Moss ground cover	–
Rock ground cover	–
Litter ground cover	–

Food supply, refuge from predation, and competition with possums are probably all factors that influence changes in the distribution and abundance of rats in New Zealand forests. In the first stage of this study the researchers focused only on environmental (habitat) covariates. However, such covariates interact with other important resources or trophic processes. For example, the presence of food trees is a strong predictor of rat abundance, but this observation may be modified if rats occur only in patches where there is minimal competition from possums. Likewise, predation 'refuges' such as rock crevices, thick vegetation, or logs that are either permanent or change relatively slowly are critical for safe foraging (see article by Rebecca Lawrence and colleagues in this issue) so rats are most likely to persist where these microhabitat features are present.

What do these results mean for rat control? Pest control managers on limited budgets already target areas such as thick vegetation where they think rats are most abundant. These results strongly support that approach. They also indicate that the efficiency of trap or bait lines or trapping grids could be improved by placing bait stations or traps in microhabitats where they are most likely to be encountered by rats.

This work was funded by the Foundation for Research, Science and Technology.

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Fig. *Location of three large (>1 km²) trapping grids (Kaimai, Urewera, and Orongorongo Valley), and two small (210 m x 210 m) trapping grids (Orongorongo Valley).*

C Thomson

Road into the Orongorongo Valley through beech podocarp–broadleaved forest.

Ship rat foraging behaviour – dining indoors or alfresco?

Many large- and small-scale control programmes for ship rats are undertaken each year throughout New Zealand using poison baits. Better knowledge of rats' foraging behaviour could lead to more cost effective and successful control.

At present there are few methods to measure rodent foraging behaviour. Radio tracking and the 'spool and line' technique can be used to measure the movements of rodents. However, radio tracking at night in dense forest is difficult, and does not directly monitor foraging behaviour. The 'spool and line' technique has worked overseas, but in dense vegetation the line is often difficult to follow and does not monitor how long an individual stays in a particular microhabitat.

A new method to measure where animals prefer to forage is 'Giving-Up-Densities' (GUDs). GUDs are measured using artificial patches of food, i.e. trays filled with food items in a non-food matrix. At first, food items are easily found by a foraging rat, but as the number of food items decreases they become harder to find and more search time is required. Eventually, the search effort does not compensate for the risk that the rat will be discovered by a predator. Therefore, the number of food items left after one night is a measure of a rat's perceived safety at the tray: the lower the GUD (the fewer food items remaining), the safer the microhabitat. Trials showed that GUDs for rats could be measured with 20 pumpkin seeds per tray, mixed through a litre of sand. A wire cage was used to prevent interference by possums, a clear plastic cover excluded rain, and paper and ink recorded the tracks of visiting rodents.

Rebecca and her collaborators used GUDs in North Island mixed podocarp–broadleaved forests to determine where ship rats prefer to forage and how predation risk from stoats affects this preference. GUD trays were placed in three microhabitats – tree trunk, open forest floor, and forest floor under kiekie (*Freycinetia banksii*; see photos) – in a stoat removal area (low predation risk) in the Kaimai Range and in a non-treatment area (no stoat removal: high predation risk) in the Orongorongo Valley in 2008 and in the Kaimai Range in 2009.

In 2008, rat foraging behaviour differed between the stoat removal and non-treatment areas. With low stoat predation risk, rats spent equal amounts of time foraging in all three microhabitats, and with high stoat predation risk rats spent more time foraging under kiekie (*Fig*.). However, in 2009 the opposite results were found. With low stoat predation risk, rats spent more time foraging under kiekie, and with high stoat predation risk rats spent equal amounts of time foraging in covered and open microhabitats (tree trunks weren't tested in 2009) (*Fig*.).

The 2008 results indicate that rats in the non-treatment area perceived they were most at risk from predators on open ground, but tree trunks were safer, and under kiekie was safer still. However, the 2009 results indicate that other factors also influence rat foraging behaviour. Rebecca and her team believe there are three main factors likely to be causing the difference in results: initial stoat and rat densities, differences in background food availability, and predation risk from feral cats. If rat densities were high enough within the 2009 non-treatment area, competition for food with conspecifics may have been more important to the rats than fear of predation, thus leading to foraging in open microhabitats in spite of high predation risk. If there was a shortage of food, competition may have encouraged rats to forage in covered microhabitats, away from conspecifics, even where predation risk was relatively low, as in the stoat-removal area in 2009. Some data are available on stoat and rat densities, and on food availability for rats, but these data are yet to be examined. Feral cats were not controlled

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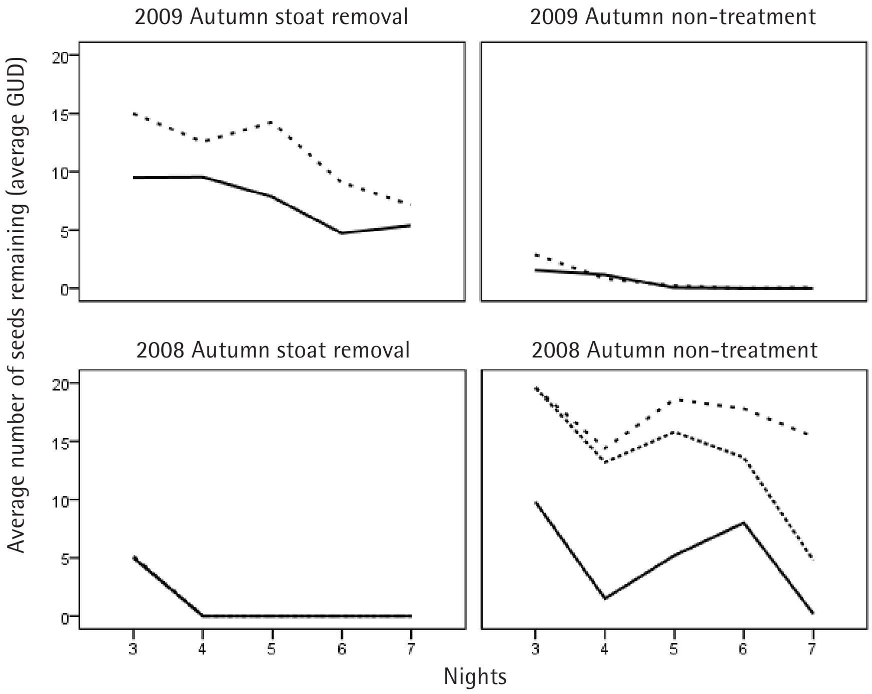

Fig. *Average number of seeds remaining in food trays in each microhabitat within the stoat removal and non-treatment areas in 2008 and 2009. Microhabitats: under kiekie (—), open forest floor (- -), tree trunk (· · ·). One line represents all three microhabitats for '2008 Autumn stoat removal'.*

The three microhabitats: tree trunk, open forest floor and under kiekie.

or counted at any of the study areas and their influence remains unknown.

Once the analyses are complete, the team will make recommendations for the placement of bait stations or traps to increase the efficiency of rat control programmes. Also, they should be able to predict whether the abundance of stoats could influence the efficiency of aerial baiting, when many baits land on open forest floor.

This work was funded by Landcare Research (FRST project C09X0506). Rebecca was supported by a Blair Postgraduate Scholarship, a Brenda Shore award, and the Department of Botany (University of Otago), and thanks those at INTECOL 2009 for discussion of these preliminary results.

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Impacts of **invasive** *mammals* on biodiversity

Several articles in *Kararehe Kino* in recent years have documented some of the results from Andrea Byrom's 'Spatial Ecology and Modelling' programme based in the Orongorongo Valley and Wendy Ruscoe's 'Multi-Pest Dynamics' programme located in several areas of podocarp–broadleaved forest in the North Island. Key results range from information on the features of the micro-habitats that determine the patchy distribution of ship rats in forests, to predictive models for changes in the abundance of mice, rats, possums and stoats following the control of one or more of these species. The two programmes have now been merged into a new 6-year programme of research on 'Invasive Mammal Impacts on Biodiversity'.

The aim of the new programme is to help land managers decide where and when to control vertebrate pests based on knowledge of their ecology and dynamics and their impacts on native species. Andrea and Roger Pech envisage the research will help manage pest mammals within conservation sites, as well as provide information likely to extend biodiversity benefits beyond areas where pests are controlled and ultimately link such sites across New Zealand. In this way the conservation value of each site will be increased by its contribution to national 'conservation networks'. This requires an understanding of the correct timing of pest control and of spatially targeted control, within and sometimes between sites. Recognising that agencies have limited pest control budgets, the Department of Conservation (DOC), regional councils, and community conservation groups need to have access to such ecological knowledge when coordinating their efforts at this landscape scale.

The new programme will continue to work on rats, mice, ferrets, stoats, feral cats, possums, rabbits, and hedgehogs. Much of the research effort will be directed towards better understanding the impacts of these mammals on native species and on how to increase the biodiversity benefits arising from pest control. Study areas will include North Island podocarp–broadleaved forests, such as Orongorongo Valley, and South Island drylands, as well as expansion to alpine, braided river, and beech forest ecosystems.

The new programme will include:

- Understanding of the dynamics and trophic interactions among multiple pest species and native fauna in high-priority ecosystems
- Responses of mesopredators (e.g. rats and mice) to the control of top predators (e.g. stoats and feral cats) or competitors (e.g. possums)
- Outcomes of single-species management including 'perverse' outcomes such as increases in the numbers of mice when rats are controlled
- Movements of animals, particularly incursions and reinvasions into control areas with or without perimeter control
- Impacts of invasive mammals on native flora and fauna, and 'thresholds' for pest control
- Spillover benefits of site-based pest mammal control, including increased dispersal of birds between protected sites
- The effect of invasive mammal removal on vegetation succession, and vice versa. For example, does increasing shrub density in drylands exacerbate problems caused by pests? Alternatively, does controlling pests also reduce the dispersal of weed species?
- Computer simulation models of pest animal behaviour and pest-pest interactions that enable researchers to put together all the data available on pest population dynamics and to predict the outcomes of standard and novel control strategies (e.g. different timing, frequency and intensity of control). Models will be designed for use by managers at local, regional and national scales (*Fig.*)

DOC is an important player in the new programme, providing scientific expertise and access to areas with, and without, pest control. Other collaborators include the Animal Health Board, regional councils, and scientists from several universities. The design and implementation of the programme will benefit from advice from an external steering group and a panel of high-profile, national and international ecologists.

Research in the Orongorongo Valley has provided critical long-term ecological data and insights into how ecosystems function. In this new programme, Andrea and Roger aim to continue to use the 'Valley' as a non-treatment site.

This programme is funded by the Foundation for Research, Science and Technology.

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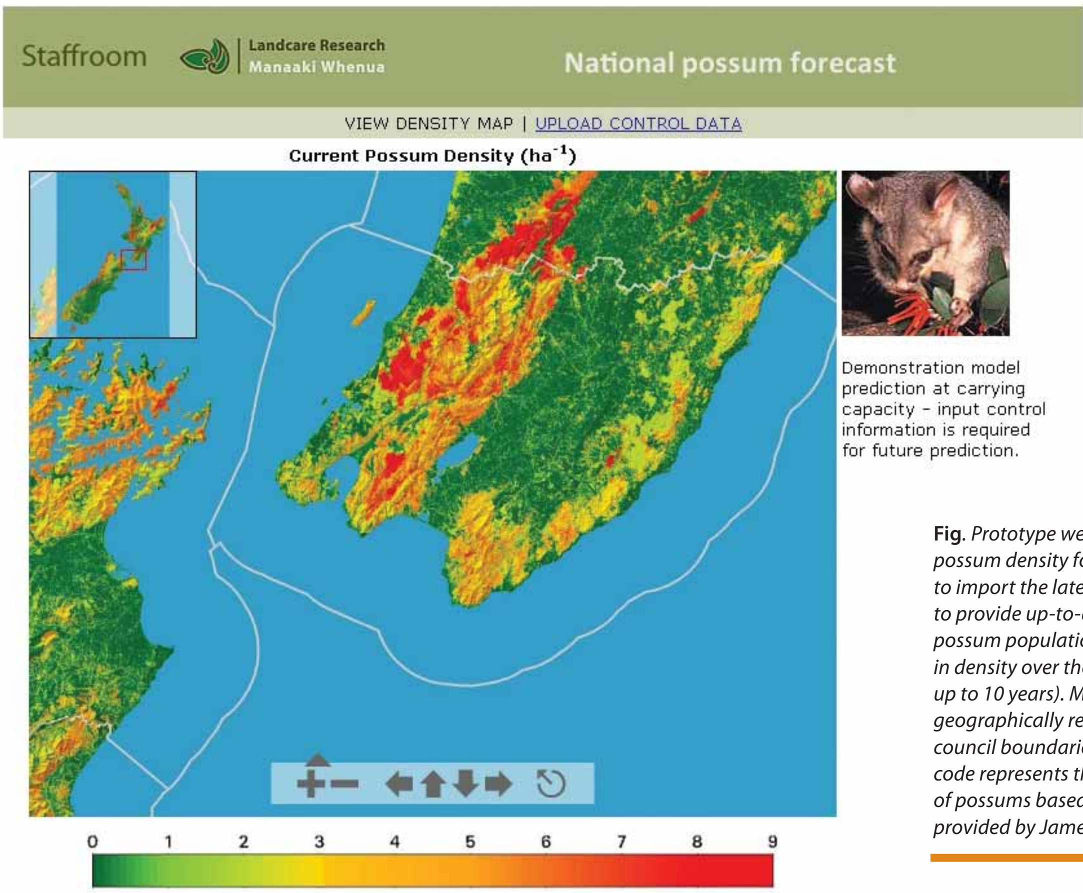

Fig. *Prototype web-based, interactive map of possum density for New Zealand. The concept is to import the latest data from control operations to provide up-to-date maps, and to use models of possum population dynamics to forecast changes in density over the short to medium term (e.g. up to 10 years). Maps can be merged with other geographically referenced data such as regional council boundaries (white lines). The colour code represents the estimated maximum density of possums based on type of habitat. Figure provided by James Shepherd.*

Did you know?

The Orongorongo Valley Research Area is one of New Zealand's key sites for monitoring long-term trends in abundance of many species in the ecosystem such as possums and rodents, and seed production by tree species. It is particularly important because it is an 'unmanaged' system: no pest control occurs in the Research Area apart from occasional culling of deer, goats and pigs by the Department of Conservation (DOC). Data from the Orongorongo Valley therefore give research staff 'baseline' information on how forest ecosystems containing invasive mammals such as possums, ungulates, and rodents function on mainland New Zealand.

Looking up the Orongorongo river valley.

Weather data have been collected at the Orongorongo Valley field station since the 1960s. In the last 12 months, the station was upgraded to store local weather information on a continuous basis and researchers are working towards being able to remotely download it in the near future. Watch this space! From June 2008 through to May 2009 there was a total of 2080 mm of rainfall in the Orongorongo Valley, with 6 September 2008 being the wettest day (120 mm in 24 hours). The hottest temperature recorded was 39.5°C on 15 March 2009, and the coldest was -1.4°C on 21 August 2008. Such data are used to give an accurate local picture of climate in the valley, and to identify the relationships between climate and seed fall.

The Research Area is an important site for monitoring long-term trends in seed and fruit production by hard beech (*Nothofagus truncata*) and hīnau (*Elaeocarpus dentatus*) trees. Twenty-one seed traps are located in the Research Area under hard beech trees near the field station (*Photo p. 4*), and 19 seed traps are located under hīnau trees. The measurements were begun to index food supply for possums and rodents, but the seed fall data from these two tree species have now been collected for more than 40 years, making the site important internationally for understanding continuous long-term trends in seed production and factors influencing them, and how forest ecosystems function. For example, native species such as birds and lizards eat seeds and fruits, as do invasive mammals such as rats, mice and possums, and invertebrates eat flowers prior to the formation of fruits and seeds later in the season. Quantifying seed-fall production also helps us understand population dynamics of tree species.

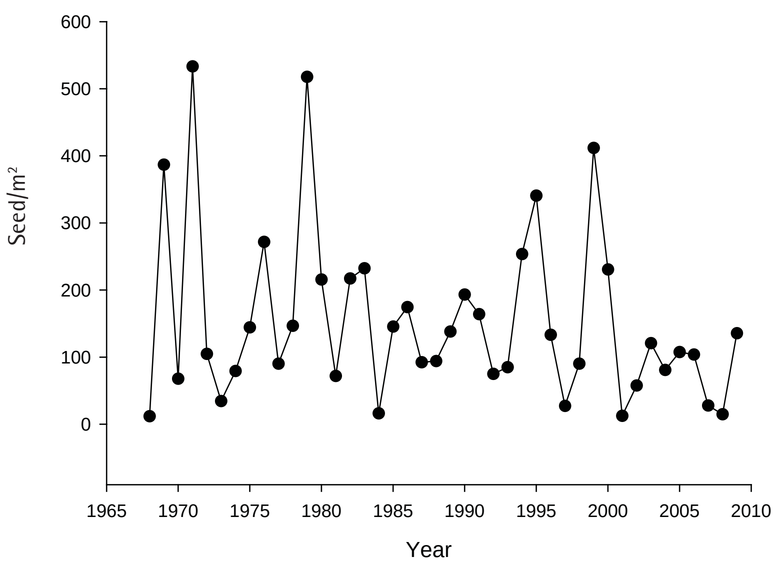

Fig.1. *Hīnau seed production in the Orongorongo Valley, 1968-2009.*

Interest has turned recently to better understanding how climate change affects ecosystem processes. For example, heavy seed fall events ('masting') in beech species are driven by warm January temperatures in the previous summer. There is evidence from around New Zealand that warmer temperatures may be contributing to more frequent masting events: the Orongorongo Valley data suggest this might be the case for hard beech too (*Fig.* 1). This year was a 'medium' mast year for beech, with a total of 15,222 seeds falling into our 21 seed traps. That equates to more than 2,700 seeds per square metre of forest floor. Flowering and fruiting of hīnau is also influenced by climate but seemingly in more complex ways than for beech. Landcare Research works closely with DOC to maintain collection of the seed fall data, and makes the information available to researchers at New Zealand universities.

Long-term studies on the population dynamics of invasive mammals have focused on possums and rodents. Possums in mixed podocarp–hardwood forest were live-trapped, ear-tagged and released on an area of about 15 ha adjacent to the field station every 1–3 months between 1966 and 2006. Mice and rats were snap-trapped every 3 months between 1969 and 1996 on a transect that ran from the field station for about 6 km through mixed podocarp–hardwood and hard beech forest.

Over the 40 years the possum population remained relatively stable at about nine possum per hectare, although short-term increases and decreases were evident in the trapping record (*Fig. 2*). Some of that variation was related to annual changes in hīnau fruit production – in years of heavy fruit fall, possums weighed more and had greater success in raising young to independence. But fruit fall was also related to possum density, declining when possum numbers increased. Such interactions were much more extreme between rodents (especially mice) and beech seeding, with highest mouse numbers closely associated with years of heavy beech masting (*Fig. 3*). Mouse breeding and survival is enhanced by the additional food provided both by the beech seed itself and by the increase in invertebrate numbers responding to the huge influx of beech flowers and seeds to forest floor litter.

The value of these long-term animal population studies is evident in the information they provide about natural fluctuations in abundance, against which trends, such as climate change impacts, and periodic events such as masting-induced ecosystem impacts can be assessed.

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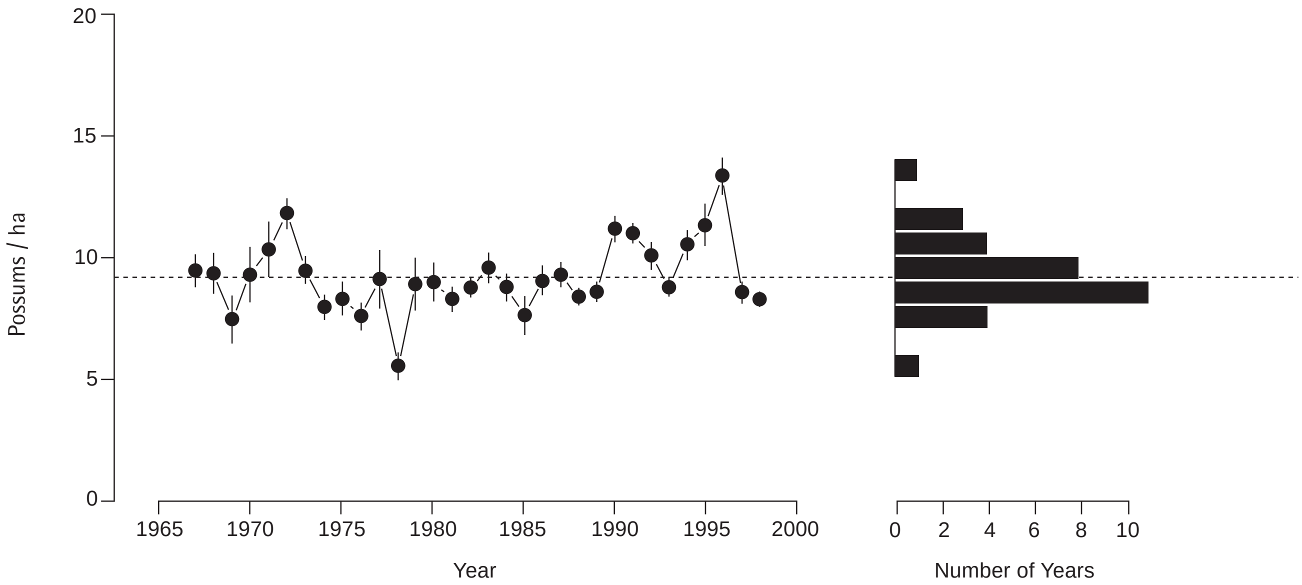

Fig. 2. *Long-term fluctuations in possum abundance in the Orongorongo Valley (from Efford 2000). The histogram shows the frequency distribution of annual density (class width 1 possum/hectare).*

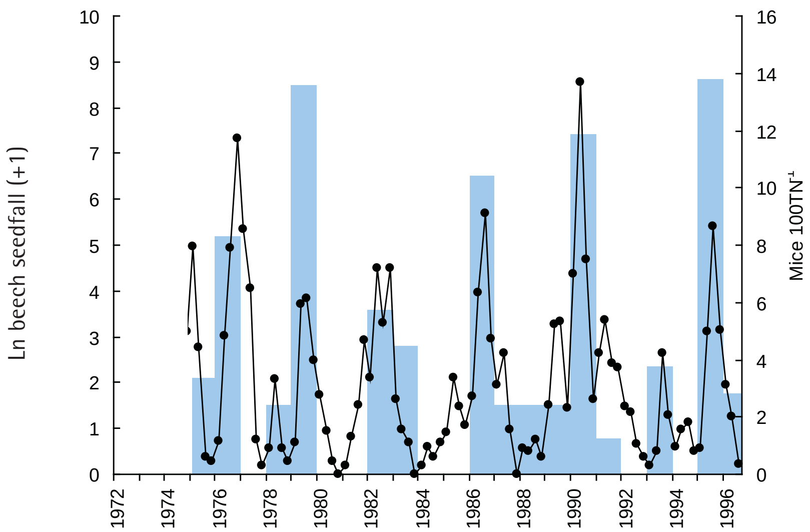

Fig. 3. *Long-term rodent abundance in the Orongorongo Valley in response to beech masting (from Choquenot & Ruscoe 2000).*

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