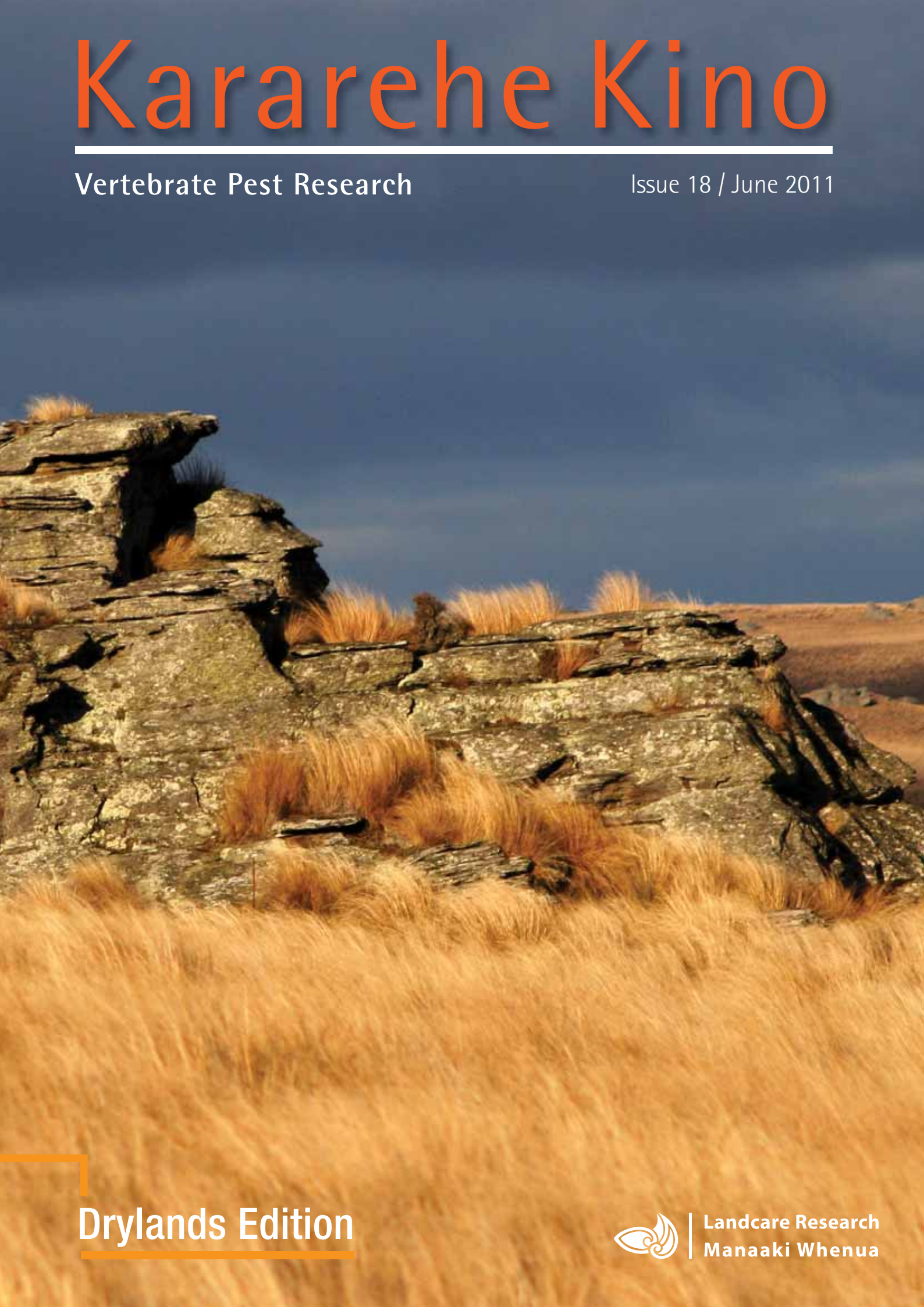
Kararehe Kino

Vertebrate Pest Research

Issue 18 / June 2011



Drylands Edition

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Front cover - photo by James Reardon. Macraes Flat rock tor – typical grand and Otago skink habitat.

Pages 2 & 3 photos - Grant Norbury holding endangered Otago skinks, Carlos Rouco holding a GPS collared possum.

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In this issue...

Issue 18 / **June 2011**

Introduction – New Zealand's dryland environments

Dryland tussock country, Mesopotamia Station.

New Zealand's dryland zone is located in the rain shadow east of the main mountain ranges and includes parts of the East Coast, Hawke's Bay, Wellington, Nelson-Marlborough, Canterbury, Otago, and Southland (*Fig.*). Drylands cover 19% of New Zealand's land area and contain some of the least protected and most threatened native ecosystems and species. They have undergone tremendous modification and change in land use in the past century with a historical emphasis on pastoralism, but more recently on cropping, viticulture, horticulture, dairying, forestry, and lifestyle blocks. Dryland environments contain about half of New Zealand's most threatened plant species, with more than 70% of such habitat lost and only 3% legally protected.

However, significant barriers exist to achieving conservation gains in many dryland areas due to low public awareness and appreciation of the indigenous fauna and flora there, the threats they face, their generally poor ecological condition, and their potential for recovery. New Zealanders are more familiar with conservation issues centred on large birds in forest ecosystems than those in dry non-forest ecosystems.

Hence, there are relatively few community-led conservation initiatives in drylands where the focus is on less 'charismatic' species (e.g. lizards and invertebrates) and communities (e.g. mixed indigenous–exotic shrublands commonly regarded as a nuisance by pastoralists). As a consequence, little indigenous biodiversity remains, restoration examples are few, and advocacy and protection activities have instead been focused on more intact, usually wetter and higher elevation ecosystems.

In recent years, public and agency awareness of the values of drylands has been raised by Crown Land reform, and resulted in the return of some leasehold high-country land to public ownership and management by the Department of Conservation. These values include those of amenity, biodiversity, and potential for carbon sequestration and soil and water conservation. With this growing awareness has come a raft of opinions about how DOC should manage this newly acquired land. Now more than ever, evidence-based science has a role to play in informing policy and management in dryland environments.

Landcare Research, together with a number of agencies, has been investigating how dryland ecosystems function and how they can be restored. This issue of *Kararehe Kino* highlights some of the recent vertebrate pest research in drylands, from gaining a greater understanding of exotic grazers on recently retired Crown land, modelling interactions among invasive mammal species, understanding the processes of germination and survival of threatened native plants, quantifying invasive mammal impacts on native biota, and predicting the outcomes of shrub succession for both native and introduced species. The common theme is a systems-based approach to the management of one of New Zealand's most precious ecosystems.

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Andrea Byrom and Susan Walker

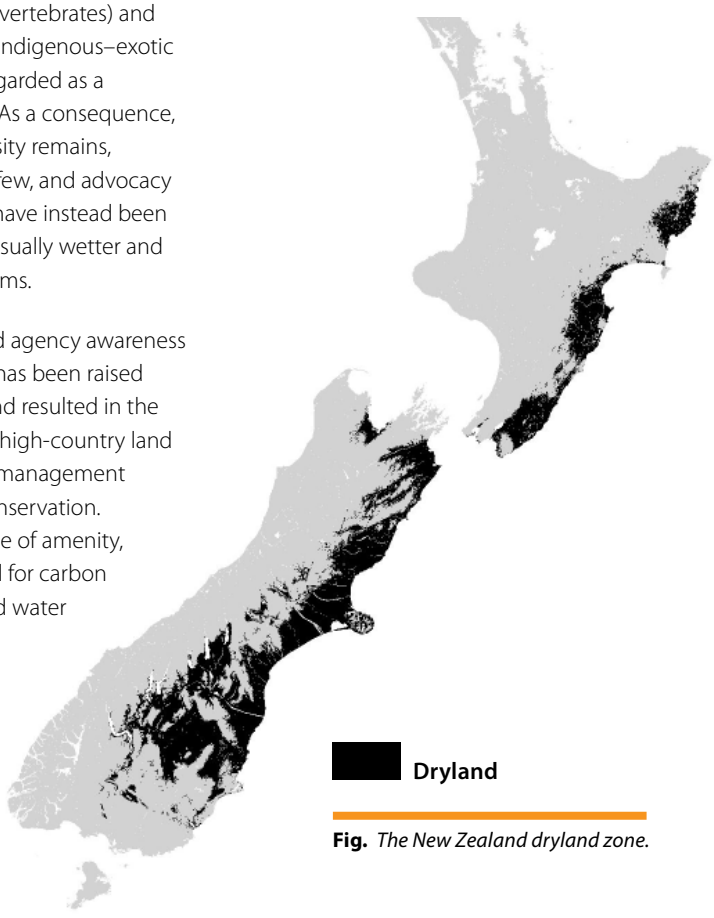

Fig. *The New Zealand dryland zone.*

Protecting biodiversity *in Central Otago*

Most of New Zealand's threatened indigenous dryland biodiversity is on land that is privately or commercially owned and faces multiple threats, including agricultural land clearance, pests and weeds. Public awareness of the need to conserve this biodiversity is extremely low, and only a small fraction of such lands is protected. There is therefore a need to raise public awareness and motivate and incentivise private landowners and regulatory authorities to increase protection of drylands. Grant Norbury and Susan Walker see three complementary ways of doing this. Firstly, by improving biodiversity knowledge and awareness to motivate communities and individuals to protect drylands. Secondly, by regulation to safeguard against activities that damage drylands. Thirdly, by providing individual private landowners with financial incentives to encourage and assist them to protect biodiversity on their properties. All three approaches are used, but they are often weak or ineffectual, and indigenous biodiversity continues to decline on private land. With notable exceptions, district councils tasked with maintaining biodiversity under the Resource Management Act are usually unskilled and poorly resourced in this area. More importantly, they are unmotivated because of perceived or actual conflicts with their economic development role. Furthermore, there is no national biodiversity policy to guide agencies on biodiversity targets and provide much-needed bottom-line standards for inactive councils (although a draft National Policy Statement is currently out for consultation).

Part of the solution is to train and motivate territorial authorities and others in biodiversity recovery and management. Over the last five years, Landcare Research has been helping in this process by undertaking three biodiversity initiatives in partnership with other agencies in Central Otago. This district is critical for dryland conservation and supports the greatest diversity of dryland habitat types. Nearly 90% of Otago's threatened plants occur in dryland habitats, as well as many threatened invertebrate and lizard species, but formally protected dryland areas are scarce (only 3% of Otago).

The initiatives undertaken include:

- **A biodiversity forum**

Landcare Research, Central Otago District Council, and DOC jointly organised a public biodiversity forum, as part of the Alexandra Thyme Festival in 2010. The irony of holding a forum on indigenous biodiversity during a festival that celebrates one of the district's most noxious weeds did not go unnoticed! A number of experts gave talks on Central Otago's pre-human ecology, remnant plant communities, pests and weeds, ecological restoration, and the role of government in balancing interests between conservation and economic development. A lively open-forum discussion followed. The talks will be packaged into a CD with accompanying material on dryland ecology and distributed to all territorial authorities in the dryland zone.

- **The Central Otago Ecological Trust**

In 2005, the local community in the Alexandra Basin formed the Central Otago Ecological Trust to restore dryland habitat and indigenous lizard communities. In doing so, they created a flagship to promote awareness about indigenous biodiversity in the district. The Trust has reintroduced critically endangered Otago skinks, which have been locally extinct for 40 years, into a new mammal-proof sanctuary, where baby skinks are now being recruited into the population. Its work with the local museum has led to three skinks being on public display and their feeding times becoming a great draw-card for the museum. Lizard conservation now appears regularly in local newspapers, radio, television, and school curricula. Even a skink float was entered into the Alexandra Blossom Festival last year! These activities have raised the profile of dryland conservation in central Otago.

- **Building relationships with the Central Otago District Council**

Staff from Landcare Research arranged a field day at Waikerikeri Station where a QEII National Trust covenant has recently been established. Also present were the council's CEO, five councillors, two high-country farmers, and the manager of DOC's Biodiversity Condition and Advice Fund. Maps of the extent of National Priority One Environments in the district were displayed. Councillors were surprised at the large extent of this critically threatened environment in Central Otago, and the maps highlighted the importance of protecting lowland native communities in the area. The attendees inspected the covenanted land, talked about its biodiversity values, and discussed options and external funding opportunities for the council to establish a biodiversity protection programme.

This work was funded by the Department of Conservation, Central Otago District Council, Central Lakes Trust, Otago Community Trust, and the World Wide Fund for Nature.

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Susan Walker

Otago skink (Oligosoma otagense).

What drives the dynamics of indigenous and invasive fauna in *grassland ecosystems?*

At Macraes Flat in eastern Otago, DOC staff are controlling cats, mustelids and hedgehogs over 4,600 ha of degraded herbfield, intact tussock, and mixed shrubland (*photos above*) to protect critically endangered skinks. Grant Norbury and colleagues are concurrently studying the population responses of other species in these same sites – common lizards, invertebrates (including weta), mice and rabbits – to test the following hypotheses:

- Invasive predators are the primary drivers of indigenous fauna and invasive herbivores
- Impacts of predators are greatest towards the edge of a control zone (where invasive immigrants abound)
- Structurally complex habitats support more abundant fauna
- Mice negatively affect indigenous fauna

The three habitat types studied at Macraes Flat: degraded herbfield (left), intact tussock (middle), and mixed shrubland (right).

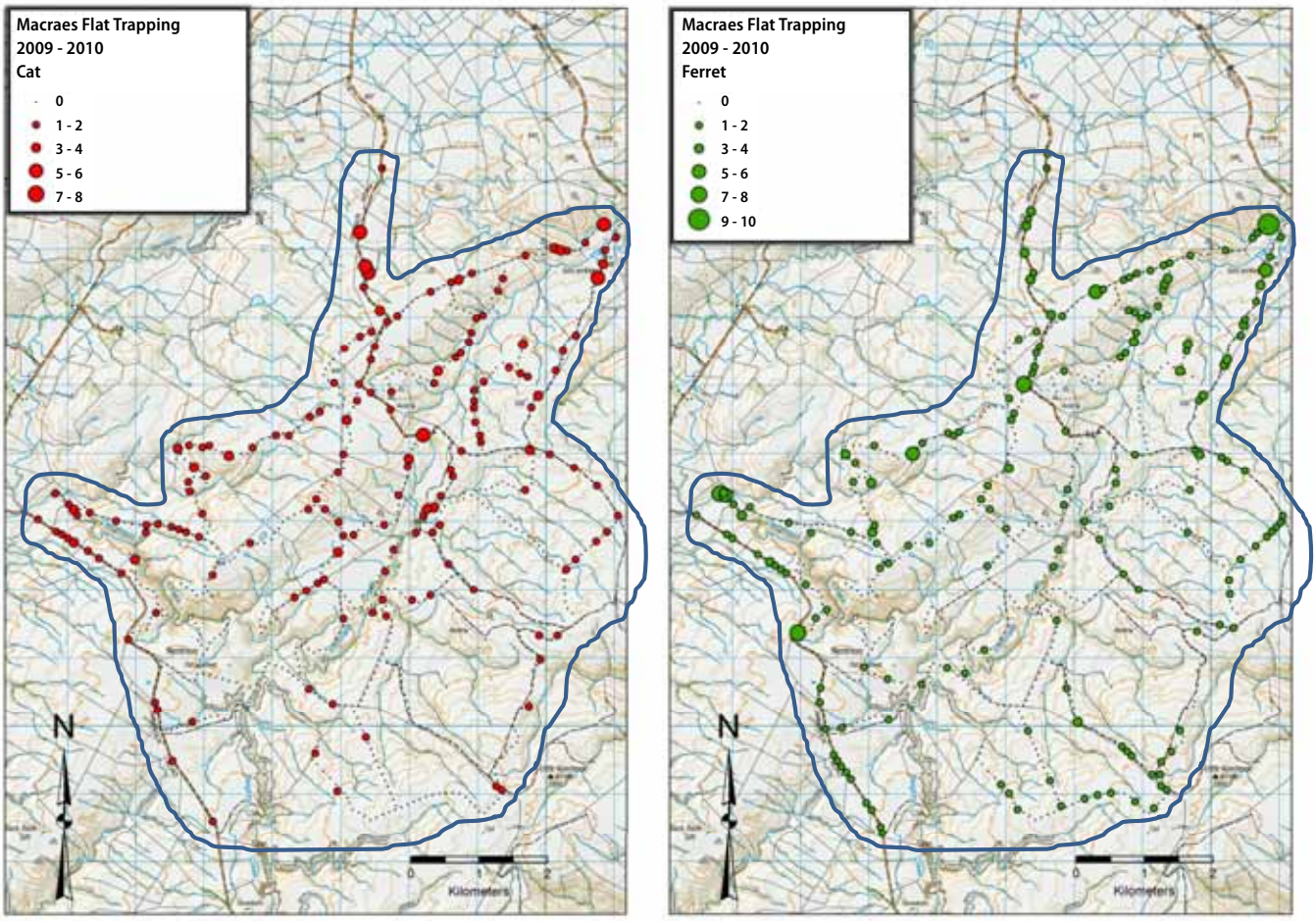

Fig 1. *Kill sites of predators at Macraes Flat during 2009–2010. More cats were killed (left) in the northern half of the trap area, and a similar pattern pertained for ferrets, although they were more concentrated around the edge (right).*

The work began with a pilot study in December 2010. Grant and his team randomly selected 48 grids, 45 x 45 m, stratified by the three habitat types. Tracking tunnels, artificial refuges, and rabbit faecal pellet plots were set on each grid. DOC's records of the numbers and locations of predators kill-trapped since 2006 were used to show where predators were distributed across the landscape – the team assumed that high captures of predators reflected their high abundances.

Ferrets and weasels were caught mostly towards the edge of the control area, while cats were caught mostly in the northern half (*Fig. 1*). The grids were therefore classified into five zones: northern half, southern half, outer edge, inner core, and in between the edge and inner zones. The north was surrounded by developed pasture and this benefited rabbits, which are the primary food source for predators in this system.

Indigenous fauna are often secondary prey for predators in dryland ecosystems and this can make them particularly vulnerable to population depletion and even localised extinction. The tendency for more predators to be captured towards the outer edge and the north would therefore suggest that indigenous fauna will be less abundant there. However, this was not the case. Lizard captures (in artificial refuges), for example, were similar in each zone (*Fig. 2)* as were captures of weta and other invertebrates.

Habitat type appeared to strongly affect some fauna – mice were only ever detected in shrub habitat (but only in a small proportion of sites), and geckos were often more abundant there (provided mice were absent) (*Fig. 3*). Rabbits showed the opposite pattern – they were least abundant in shrubland and most abundant in degraded herbfield (although not significantly so). This isn't surprising as rabbits are known to prefer more open and simplified habitat (see article by Whitehead et al., p.9 in this issue).

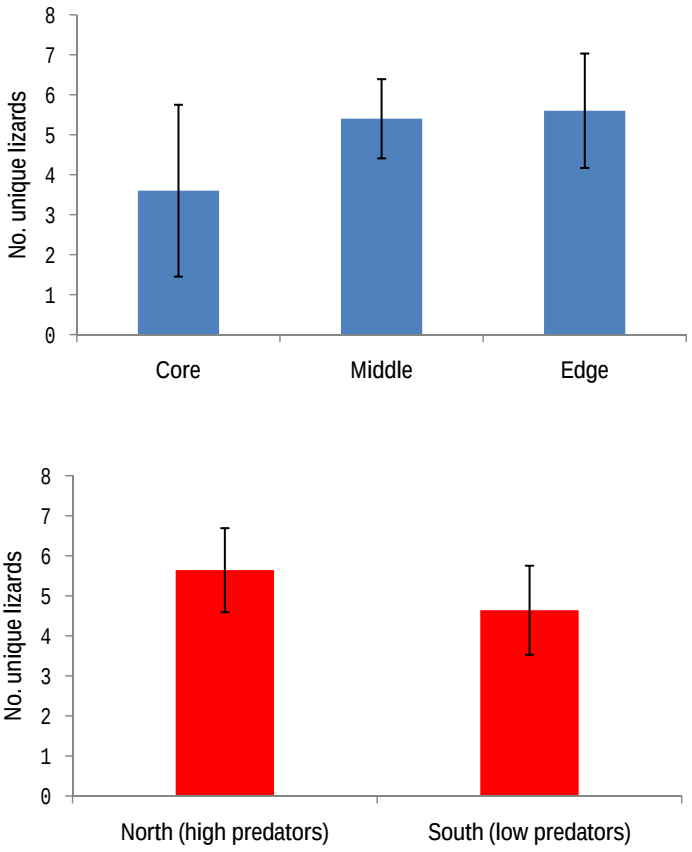

Fig 2. *Numbers (mean ± 95% CL) of common lizards captured per grid in the core versus the edge (top), and in the north versus the south (bottom), of the predator control area.*

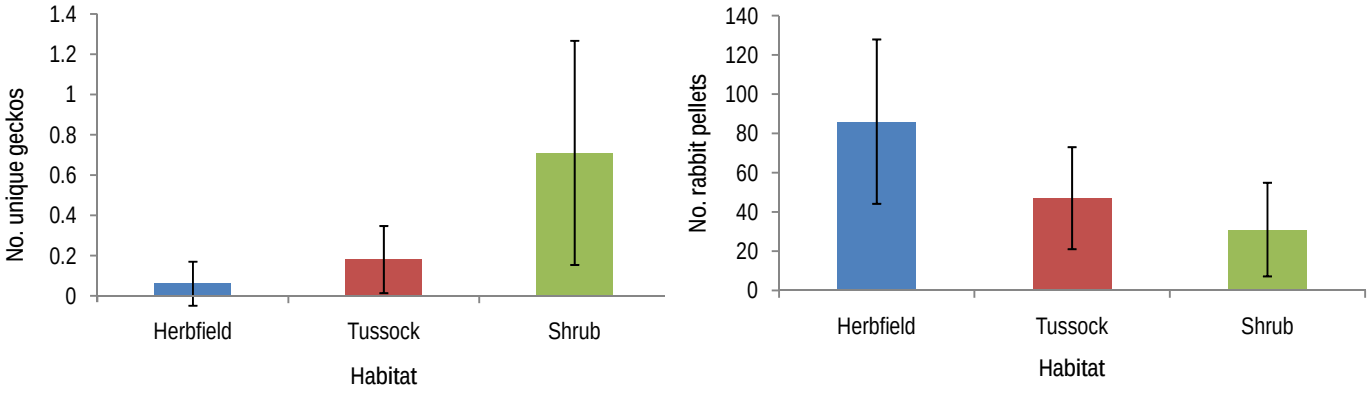

Fig 3. *Numbers (mean ± 95% C.L.) of geckos (left) and rabbit faecal pellets (right) per grid in each habitat.*

A controversial issue at Macraes Flat is whether predator control has led to an increased abundance of rabbits. The team's data do not support this. Significantly more rabbit faecal pellets were found in the northern zone (89 per plot), where predators are generally more abundant, than in the southern zone (21 per plot). Rather than predators driving the rabbits 'top-down', it appears that the rabbits are driving the predators 'bottom-up'. Rabbits are in turn driven 'bottom-up' by the development of their preferred pasture habitat in the north. Experiments elsewhere also show that removing rabbits leads to declines in predator numbers.

Mice are also predators (and potential competitors) of lizards and invertebrates but little is known of their impacts in grasslands. Grant's team were unable to measure mice impacts directly, but there was some evidence of predation or competition by mice from the negative relationships between mice and lizards, and between mice and invertebrates (*Fig. 4*). Lizard and invertebrate abundances varied greatly where mice were not detected, but they were always uncommon where mice were detected, indicating that mice may be detrimental to populations of some indigenous species.

These results suggest that for relatively common fauna at Macraes Flat, bottom-up effects associated with habitat type may be stronger than top-down effects of top predators. Succession of grasslands to mixed woody shrublands may be the key driver of remnant fauna in this system. Given that mice are expected to benefit from succession, understanding their functional role in these ecosystems is critically important.

This work is funded by the Ministry of Science and Innovation (Programmes C09X0909 and C09X0505), and in-kind funding from the Department of Conservation.

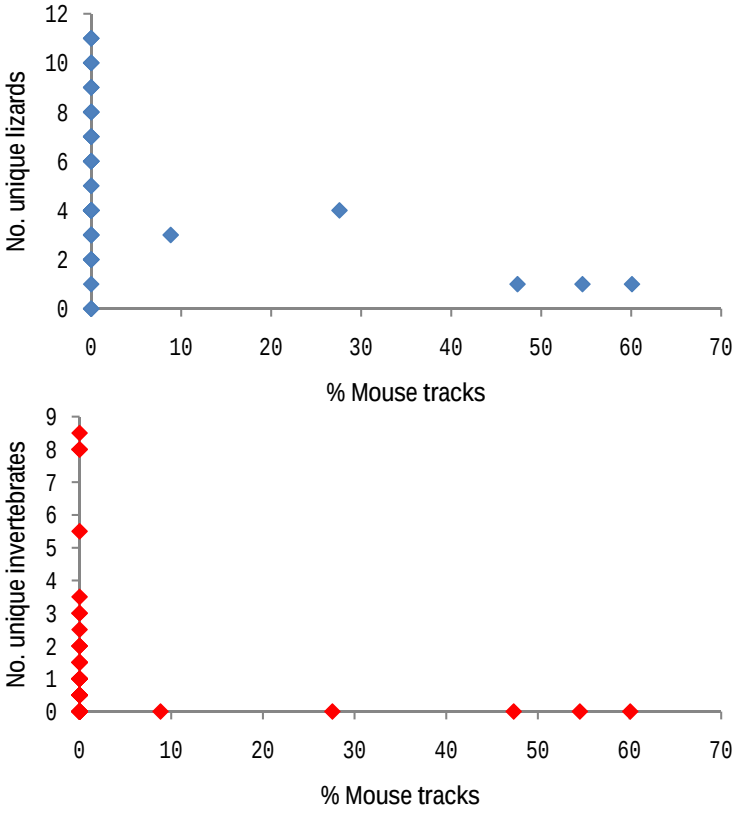

Fig 4. *Mouse tracking rates and numbers of lizards (top) and invertebrates (bottom).*

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Community responses *to livestock removal from drylands*

Sheep and cattle are known to affect native vegetation in drylands by browsing or trampling, reducing seedling recruitment and increasing the abundance of exotic plants. Managers often assume that removing livestock will reverse such processes, leading to the recovery of native biodiversity. However, plant communities are complex and the removal of grazing pressures may result in unexpected changes to community diversity and structure. For instance, a dense sward of exotic grasses may form after the removal of livestock if such grasses are more competitive than native shrubs. Sites retired from grazing may also be more attractive to invasive mammals, requiring more active management to attain positive conservation outcomes.

The variable nature of community responses to livestock removal make it difficult for conservation managers and policymakers to plan for the long-term impacts of a change from pastoral to conservation land. To manage former pastoral lease land for conservation, it is important therefore to clearly identify the potential responses of native communities to livestock removal, and the mechanisms that drive these changes.

Amy Whitehead and colleagues set out to investigate the impacts of livestock removal on mid-altitude dryland communities, by comparing the presence and abundance of plant and invasive mammal species on currently grazed sites with that on conservation sites where pastoralism ceased 10–40 years ago. Areas were chosen on four properties in the eastern South Island where paired pastoral and conservation sites were separated by fences.

Removal of livestock had little impact on the number of plant species present on either side of the fence. However, the composition and structure of these plant communities differed significantly (*Fig.*). Sites on conservation land had higher native biodiversity, with small native herbs, grasses and shrubs more abundant than on the adjacent pastoral sites. Sites on pastoral land were dominated by exotic plants, particularly herbs and grasses. Exotic grasses had a negative impact on native biodiversity on both sides of the fence but the effect was stronger on pastoral land. The exotic weed *Hieracium* was equally abundant on both pastoral and conservation land, while native shrubs were more abundant than exotic shrubs on conservation land. Amy believes these changes indicate that the study sites are undergoing successional changes towards a native-shrub-dominated ecosystem after the removal of livestock.

The change in tenure from pastoral to conservation land also had an impact on the invasive mammal communities present. Rabbits and hedgehogs were more abundant on pastoral sites, while possums, hares and mice were more abundant on conservation sites. Rabbits have a preference for short-grass habitats, while hedgehogs may be attracted to areas with animal dung containing abundant invertebrates such as fly larvae and earthworms. By comparison, invasive mammals found on conservation land were generalist species, attracted to structurally complex and diverse habitats. It is not clear whether these patterns are driven 'bottom-up' (i.e. by invasive mammals responding to available resources) or 'top-down' (i.e. by invasive mammals effectively engineering suitable habitat for themselves), or a combination of both.

Overall, removal of livestock led to the development of native-dominated plant communities, with a high abundance of shrubs. This has positive implications for conservation, as the low abundance of exotic weeds means there may be little need for active weed management. However, this outcome may be compromised by increases in the relative abundance of some invasive mammal species (see article by Norbury et al., pp. 12–13 in this issue).

This work has been funded by the Ministry of Science and Innovation (Programme C09X0909) and Landcare Research's Capability funding.

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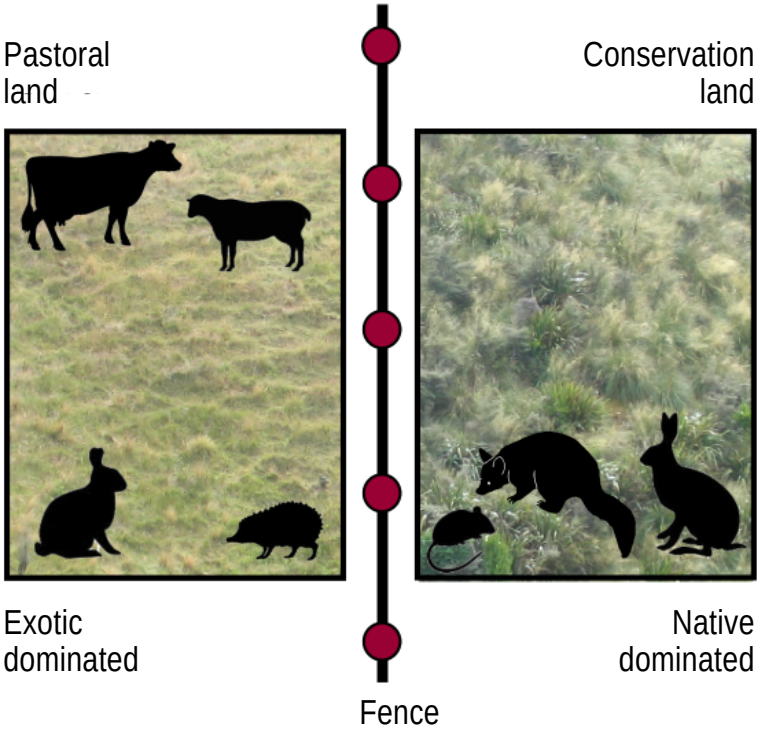

Fig. *Dryland ecosystems showed a significant response to the removal of livestock. Land grazed by sheep or cattle was dominated by exotic grasses, and carried many rabbits and hedgehogs. In comparison, land retired from grazing for conservation purposes was dominated by native herbs and shrubs, and had higher numbers of possums, hares and mice.*

Growth rates and recruitment of native shrubs on retired Crown land

Contrast between retired Crown land (Matata Reserve, right) and pastoral land (Mt Nimrod Station, left) in South Canterbury.

The effect of the removal of livestock on the diversity of native plant communities in the South Island's subalpine drylands (~1000m altitude) is discussed elsewhere in this newsletter (see Whitehead et al. p. 9). Here, Andrea Byrom and colleagues explore another important aspect of the effect of removing livestock: the recruitment and growth of shrubs.

A characteristic of these grasslands is their tendency to revert to woody vegetation. But how exactly do shrubs respond when exotic grazers are removed? Quantifying shrub recruitment and growth is an important first step in determining the role that woody vegetation plays in the conservation of biodiversity of retired pastoral land and how this may change with time through shrub succession. Shrubs potentially provide food and shelter for native fauna such as lizards and invertebrates. However, they also harbour invasive mammals such as mice and possums – species that prey on native fauna, and impact on native vegetation. The carbon sequestration potential of this land through reversion to a woody flora is also increasingly relevant, as New Zealand has committed to reducing greenhouse gas emissions.

Andrea and colleagues worked on the same properties mentioned in Whitehead et al.; each of the four areas contained grazed sites paired across fence lines with ungrazed sites where pastoralism had ceased 10–40 years ago. They concentrated on two native shrub species: matagouri and mānuka, and hypothesised that both species would have greater recruitment and growth rates in destocked areas.

Samples of up to 30 randomly located individuals of both mānuka and matagouri were cut from all eight sites and shrub age estimated by counting growth rings of stem sections. The team also measured stem diameter, and plant height, volume and biomass. On some sites, fewer shrubs were sampled, but the researchers were able to back-calculate the ages of all individuals by developing allometric relationships between age (growth rings) and stem diameter of the shrubs that were 'sacrificed'.

Surprisingly, Andrea's team found no evidence that removal of livestock had any long-term effect on the recruitment of either mānuka or matagouri (*Fig. 1*). If their hypothesis was correct, they would have recorded pulses of recruitment on sites with no livestock, but this was not so – individuals of both these species recruited onto grazed and ungrazed sites at the same rate, at least over the 40-year time frame of the project.

Age was very strongly correlated with stem diameter, height, volume and biomass for both mānuka and matagouri. Regardless of which of these growth variables was measured, the effect of grazing by livestock was counter-intuitive: growth rates were actually higher on grazed sites (*Fig. 2*). In

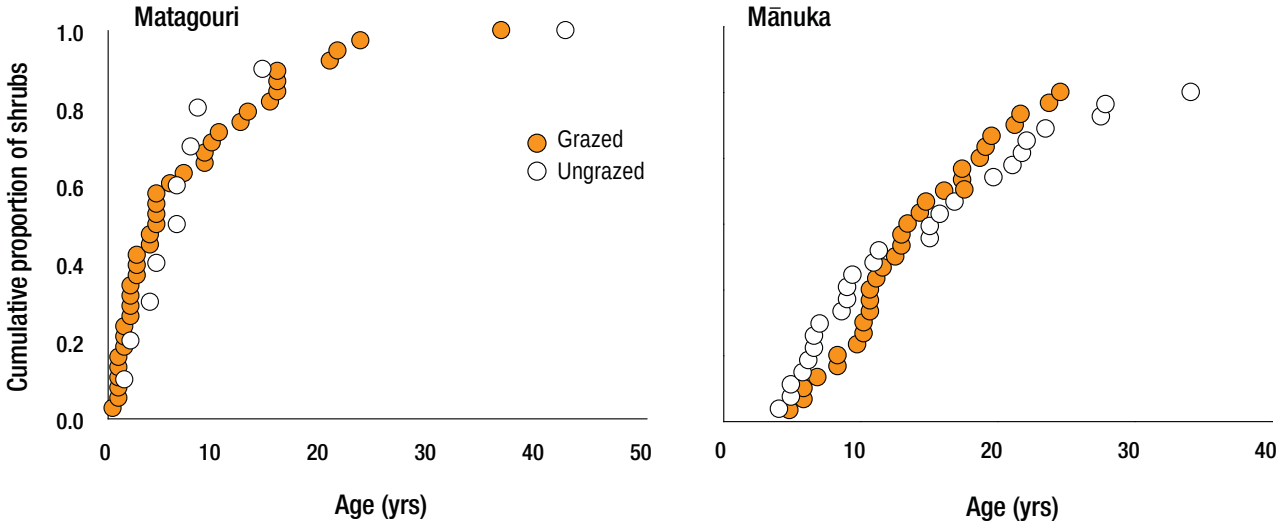

Fig. 1 *Recruitment of matagouri and mānuka on grazed and ungrazed sites. The plots show the cumulative proportion of shrubs recruited at a given age, and revealed there was no difference between pastoral and conservation sites for either species.*

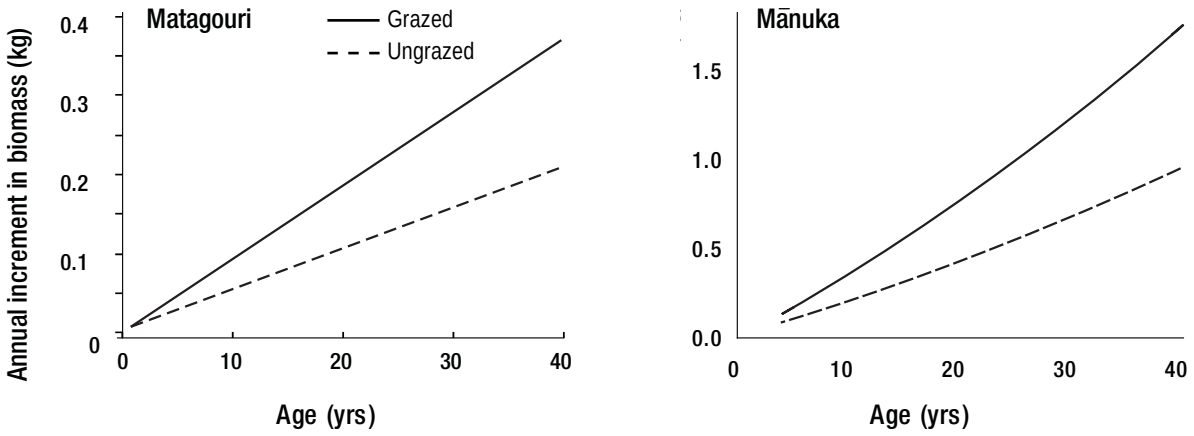

Fig. 2 *Growth of matagouri and mānuka on grazed and ungrazed sites. Both species showed faster growth rates on grazed sites compared with sites where livestock had been removed for 10–40 years.*

other words, plants on grazed sites were larger for their age than those on the ungrazed sites.

The findings of Andrea and her colleagues suggest that in mānuka- and matagouri-dominated seral plant communities in drylands, moderate grazing pressure from livestock may have very little effect on recruitment of shrubs. Also, while removal of grazing slows shrub growth in a 10–40-year time frame, previously grazed populations of adult shrubs can provide new recruits during reversion to shrubland. One possible explanation for the lack of difference in shrub recruitment on grazed and ungrazed sites is that grazing by livestock reduces competition from exotic grasses, thereby allowing small shrubs to establish, effectively 'cancelling out' any direct effect of grazing on the shrubs themselves.

These findings have important implications for the management of seral shrubland communities. In many parts of the drylands, plant communities are subject to occasional grazing, e.g. during short-term grazing leases, and to other forms of moderate to low-level grazing. While these findings apply to just two species of plants, both of which are relatively unpalatable to livestock, managers can be cautiously optimistic that grazing by livestock is not necessarily all bad for shrub retention and recruitment. Of course, over longer time frames or with longer periods of intensive grazing, and for different native shrub species, the effects of grazing may be more severe and potentially irreversible.

This work was funded by the Ministry of Science and Innovation (Programme C09X0909) and Landcare Research Capability funding.

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Why do indigenous fauna often *fail to respond to predator control*?

Predicting the outcomes of managing various parts of dryland ecosystems (*Fig. 1*) can be difficult. However, understanding how these ecosystems are structured, and the strengths of the component interactions, is needed in order to maintain and restore indigenous biodiversity. Grant Norbury and colleagues conducted a large-scale field experiment in Otago to examine the impacts of introduced predatory mammals on local indigenous fauna.

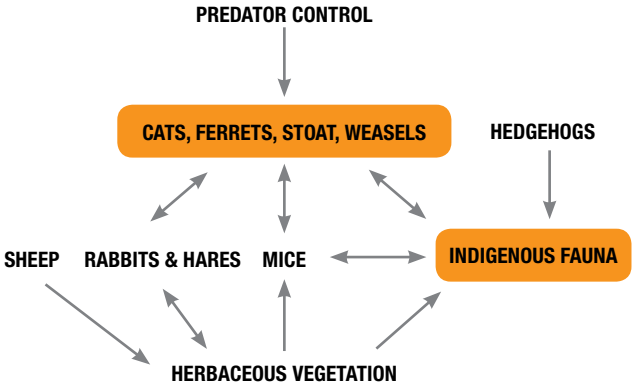

Fig 1. *A simplified food web in a typical dryland ecosystem.*

Grant's team controlled cats, mustelids, and hedgehogs over 400 ha near Alexandra, and over 650 ha near Macraes Flat, by deploying kill-traps continuously at high densities (26 per km^2) for more than 3 years. They measured the responses of indigenous lizards and invertebrates (and mice, rabbits and hares) in the area trapped for predators, and compared them to the responses in replicate non-trapped areas. They looked at changes in abundance over time, and compared the way rates of population change depended on their initial density. Intriguingly, the researchers found little evidence of an effect of predator removal on indigenous fauna (e.g. lizards, see *Fig. 2*).

To explain the lack of responses of indigenous fauna, Grant and his colleagues proposed four alternative hypotheses:

Hypothesis 1: Removal of cats and mustelids leads to more mice, and therefore increased predation or competition with indigenous fauna. The data did not support this hypothesis: rates of change for mice over the critical winter period were no different between the treated and untreated areas (*Fig. 3*).

Hypothesis 2: Predator removal leads to increased herbivore populations and therefore depleted habitat for indigenous fauna. There was no evidence that populations of rabbits and hares increased in response to predator removal, or that vegetation biomass was depleted. For example, pasture growth rates did not differ between predator removal and non-removal sites (*Fig. 4*).

Hypothesis 3: Indigenous fauna are not limited by predation but are driven primarily by food resources. There was some support for this hypothesis because fruit abundance was a key predictor of lizard population growth rates in summer, and seed abundance was an even stronger predictor of mouse dynamics (*Fig. 5*). As areas of grassland are destocked, increases in shrub fruits, grasses, and seeds are likely to affect lizard and mouse populations. Mice are predators and potential competitors with lizards so the net effect of destocking could be detrimental for some lizard species, or be beneficial for species that respond to increased vegetation cover.

Grant and colleagues suggest that species conservation in particularly dry environments may be better served by addressing 'bottom-up' processes, such as food and habitat quality, rather than top-down processes such as predation.

Hypothesis 4: Predator removal is poorly done. The simplest explanation may be that the predator removal was ineffective at maintaining predator abundances at low enough levels. This is because despite intensive trapping, there was no clear evidence of a decline in the abundance of cats and mustelids throughout

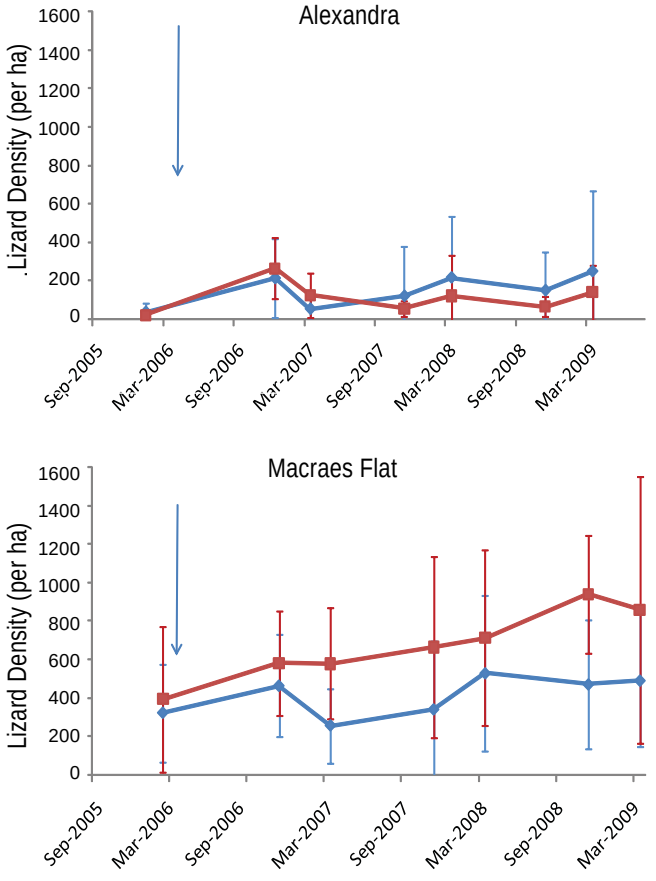

Fig 2. *Trends in lizard population densities at the Alexandra and Macraes Flat sites with (blue line) and without (red line) predator trapping (means ± 95% CL). Arrows indicate start of trapping.*

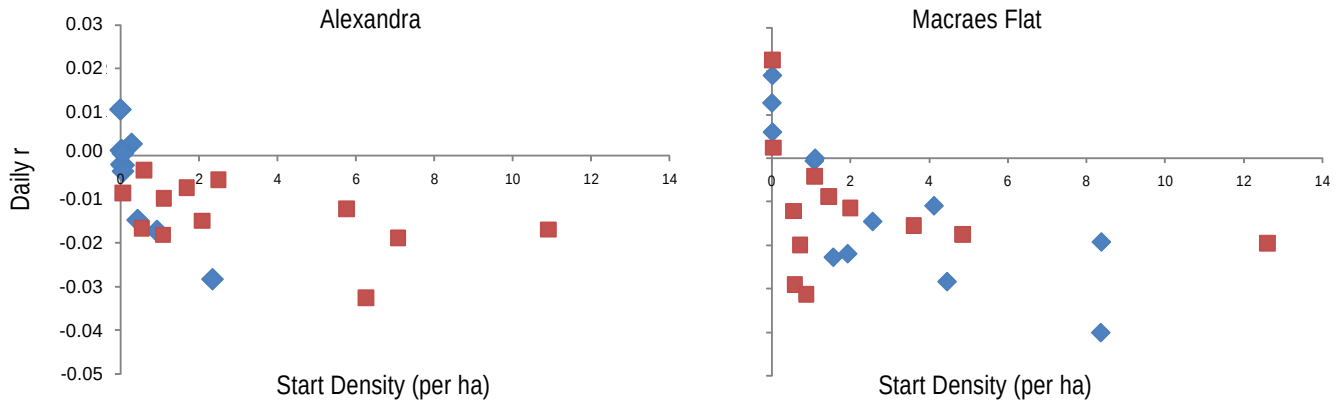

Fig 3. *Daily population growth rates (r) of mice during winter with (blue points) and without (red points) predator trapping, plotted against the density of mice in autumn.*

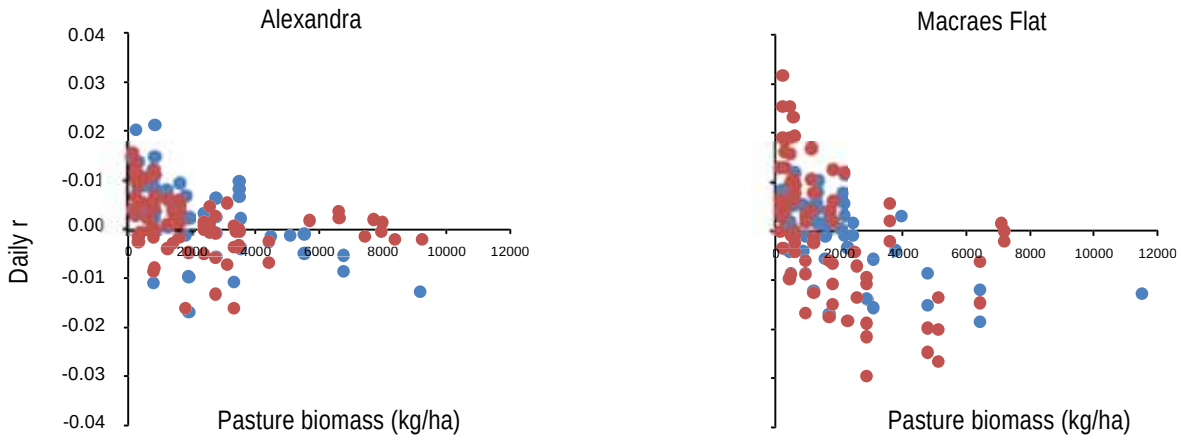

Fig 4. *Daily growth rates (r) of pasture with (blue points) and without (red points) predator trapping (pooled for spring, summer and autumn/winter periods), plotted against the initial pasture biomass.*

the 3-year study, presumably because the areas were too small to overcome their constant immigration.

The possibility of poor trapping efficacy of top predators in this experiment means Grant and his team cannot reject the first three hypotheses dealing with lack of top-down regulation. While this is frustrating, the lessons learnt are valuable for ecological restoration. In particular, there are management-scale thresholds that are broadly governed by the mobility of the target pest species, and pest management resources are likely to be wasted unless control operations exceed this area threshold, or small control areas are protected by predator-proof barriers. This study indicates that predator control of less than 650 ha will be insufficient to overcome their immigration. Therefore, control strategies that are cognisant of operational scale and the mobility of the targeted pest species are more likely to achieve successful outcomes.

This work was funded by the Ministry of Science and Innovation (Programmes C09X0505 and C09X0909).

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James Smith, Andrea Byrom, Roger Pech, Dean Clarke and Guy Forrester

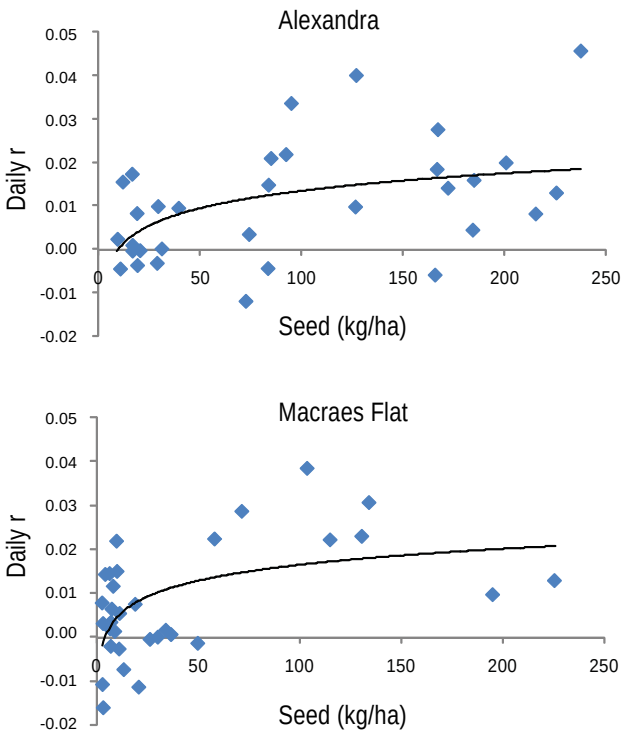

Fig 5 *Daily population growth rates (r) of mice between spring and autumn in relation to grass seed abundance at the Alexandra and Macraes Flat sites.*

Response monitoring and cost–benefit analysis drives *adaptive management* of *critically endangered skinks*

The Department of Conservation (DOC) has over the last six years expanded its protection of critically endangered grand and Otago skinks from an experimental scale to an area providing medium-term security for both species. This has been made possible by accurate monitoring of populations of skinks to detect trends under different management regimes. Once effective management options were identified, cost–benefit analysis and metapopulation modelling were used to plan the extended control area.

Grand and Otago skinks (GAOS) are two of New Zealand's largest and most threatened lizards. Both are endemic to Otago and closely tied to deeply-incised schist rock tors, which they use for thermoregulation and refuge from threats. Both are now restricted to a small fraction of their historical range. In 2005, DOC's GAOS Recovery Programme (involving Andy Hutcheon and colleagues) embarked on a 5-year science-by-management experiment at Macraes Flat to test the hypothesis that introduced mammalian predators were a cause of the decline of both species. All mammals were removed from a site enclosed by mammal-proof fencing, while other sites were located at the core, periphery and outside an intensive trapping operation covering 2100 ha and targeting weasels, stoats, ferrets, cats and hedgehogs.

Skink populations were monitored using 'photo-resight', with model fitting using program MARK. The unique markings of individual skinks allowed them to be matched across survey sessions within and between years to estimate abundance and survival.

By the end of the third monitoring season of the 5-year multi-treatment trial, the combination of the rapid response by both species of skinks and tight confidence intervals on their abundance estimates made it clear that both treatments worked: skink numbers increased both inside mammal-proof fences and when protected by a 1.5-km buffer of trapping (*Fig. 1*). With two tools demonstrating effectiveness, the next adaptive management step was to protect a larger expanse of skink habitat.

Cost–benefit analysis showed that, for areas greater than 10 ha, trapping gave the best return on dollars invested (*Fig. 2*). This analysis took account of the capital charge and depreciation costs associated with fencing when compared with the otherwise higher annual running costs of extensive trapping. The non-homogeneous nature of skink habitat at Macraes Flat was captured in a metapopulation model that both guided the selection of areas for testing the two protection approaches and identified opportunities to use local translocations to kick-start grand skink populations in newly protected habitat.

Between 2008 and 2010, trapping at Macraes Flat more than doubled in extent, and now covers 4600 ha and uses a thousand traps in a mix of six trap types and three different baits. Drop in catch rate of the various predator species from the edge towards the centre of the trapping operation is presumed to correlate with a reduction in predator densities and explains why the populations of skinks are able to recover under this control regime.

James Reardon

Otago skinks born within DOC's mammal-proof fence.

James Reardon

A grand skink basking on rock habitat.

James Reardon

Typical GAOS habitat: deeply incised schist rock in dry tussock country.

Nathan Whitmore

Grand skink g03009 after an encounter with a stoat. Direct evidence of predation by cats has also been observed.

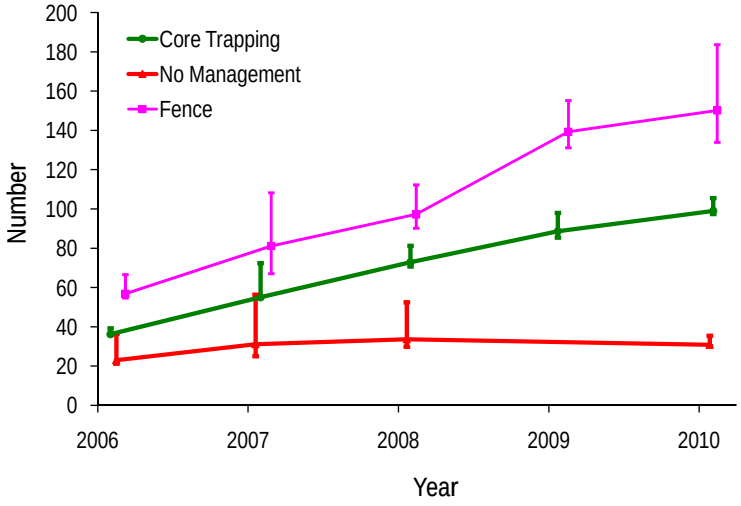

Fig. 1 *Monitoring results of Otago skinks. Grand skink monitoring tells a similar story, but with a catastrophic decline at the non-treatment site. Unmanaged populations appear to exhibit stability punctuated by episodic decline from which they do not recover. Error terms are +-95%CL.*

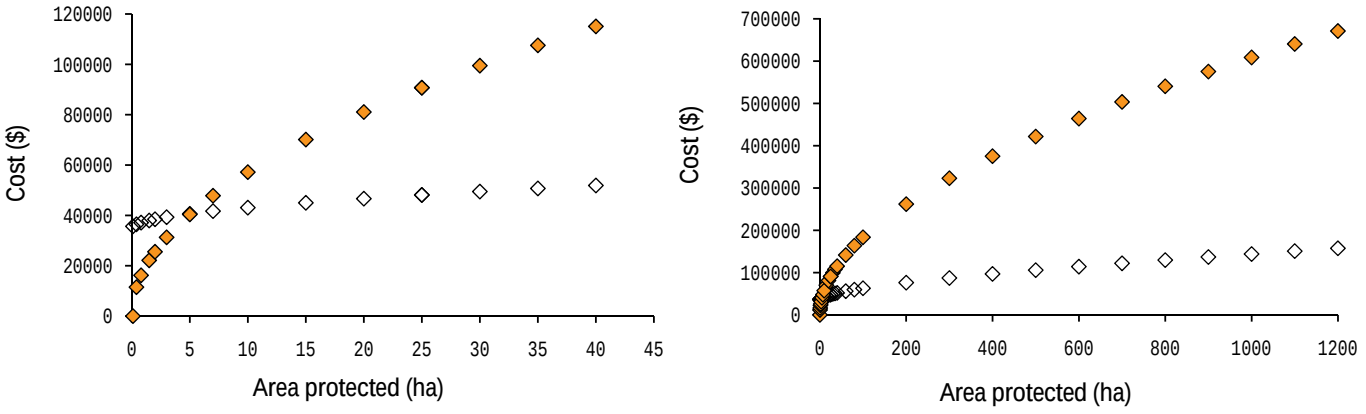

Fig. 2 *Cost per unit area protected for the two methods shown to be effective at Macraes Flat (open points indicate trapping, orange points indicate fencing) for areas of <45 ha (left) and up to 1200 ha (right). For small areas (left), the buffering needed with trapping makes fencing more appropriate. Note different scales on the y axis.*

Riki Mules

Les Judd

Same skink, different years. The unique markings of this Otago skink allow him to be matched up in the field records.

Good design and robust monitoring has demonstrated the effectiveness of both management systems. This, in conjunction with modelling, supported the decision to extend protection across populations at Macraes Flat. To complete the good-news story for these two iconic species, Andy and his team need new tools to effectively control invasive predators over a landscape scale and allow service frequencies of traps in months rather than days or weeks. Such innovations would reduce costs and allow protection of skinks in places that are less accessible.

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Grant Norbury and Nathan Whitmore (DOC)

Possum ecology: diet, home range, movement patterns and denning

Carlos Rouco downloading GPS data from a recaptured collared possum.

Little is known about the ecology of possums in New Zealand's drylands, despite possums being common there and subject to control over vast areas to mitigate their spreading of bovine TB. Here, Carlos Rouco and Al Glen describe studies of possums in two dryland regions of the South Island. On Molesworth Station they examined the summer diet, feeding preferences, denning behaviour and survival rates of possums, while in Central Otago they studied possum densities, denning behaviour, and home ranges.

The summer diet of possums at Molesworth was dominated by forbs and sweet briar, both of which were eaten in large amounts relative to their availability. Possums also strongly preferred crack willow, which was uncommon in the study area and eaten only occasionally but in large amounts. Dens of 29 radio-collared possums were mostly found under sweet briar, followed by in or under rocky outcrops. Activity areas of possums based on den locations varied from 0.2 to 19.5 ha (mean = 5.1 ha). Annual survival of radio-collared individuals was 85% for adults and 54% for subadults.

In Central Otago, population estimates were derived from capture–mark–recapture methods at two sites: one with higher shrub cover (51%) than the other (20%). Possum densities were greater at the high-shrub-cover site (1 per hectare, 95% CI 0.80–1.26 ha) compared with that at the low-shrub-cover site (0.54 per hectare, 0.42–0.67 ha). Moreover, possums were significantly heavier at the high-cover site. Because shrubs such as sweet briar are an important source of food and shelter for possums, their availability is likely to play an important role in determining possum carrying capacity.

Fourteen adult possums were radio-tracked at the high-shrub-cover site. Shifts in den sites were very frequent, with the maximum number used by a single possum being 26 (from 31 location fixes). Rocky outcrops were more common in this region compared with Molesworth, and most dens (61%) in Central Otago were in or under rocks, 34% were under shrubs, and 4% in rabbit burrows. Home ranges based on den site locations were similar to those at Molesworth but were larger for possums living in open areas compared with those living in gullies (6.8 and 0.9 ha, respectively). In Central Otago, home ranges based on night-time activity were 10 times the size of those based on den locations (*Fig.*).

The ecology of possums in these two study sites differed from that of other studies of possums in forest or farmland habitats. Possum densities in drylands were 3 to 13 times lower than those estimated for mixed podocarp–broadleaved forest, but were similar to those recorded in *Pinus radiata* or beech forest.

Home ranges in drylands were similar to those recorded in farmlands (26–31 ha), but larger than those recorded in mixed podocarp–broadleaved (0.5–3.9 ha), *Pinus radiata* (0.7–1.4 ha) or beech forest (1.7–5.6 ha). Carlos and Al believe such differences reflect the generally lower availability and more patchy distribution of resources in drylands. Their results suggest that invasive willow and sweet briar may facilitate possum abundance by providing abundant food and shelter. This information will be useful for modelling and managing the impacts of possums in dryland habitats, and should increase the efficiency and effectiveness of ground control of possums there.

This work was funded by the Ministry of Science and Innovation (Programme C09X0909: Invasive Mammal Impacts on Biodiversity).

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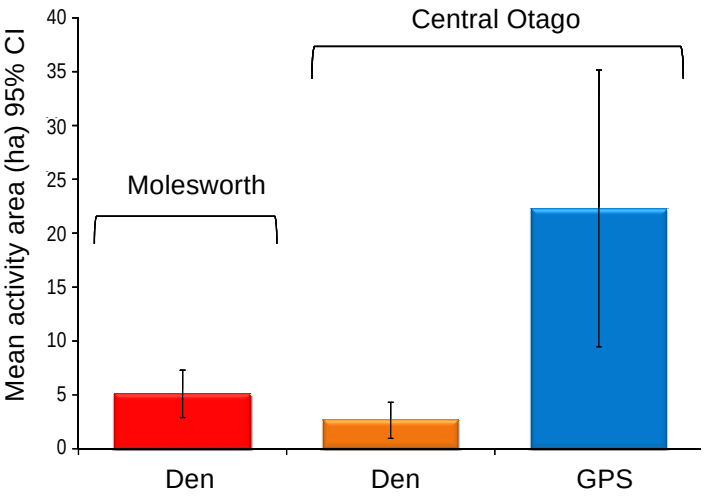

Fig. *Mean (± 95% CI) home range of radio-collared possums based on den site locations from Molesworth (N = 29 possums) and Central Otago (N = 13 possums), and GPS night-time locations from Central Otago (N = 9 possums).*

Impact of rabbits (and sheep) on drylands

Regional pest management strategies for rabbits set indices of rabbit density above which landowners are generally obliged to conduct rabbit control. Most strategies set these trigger points at an index of 3–4 on the McLean's Scale (an exponential index of 1 to 10 based on rabbit sign). In the Mackenzie Basin, a McLean's Scale Index of 3 translates to about 2 rabbits/km and an index of 4 equates to about 8 rabbits/km on the alternative spotlight-count index. While the relationships between the indices and actual rabbit densities are unclear, these trigger indices are based on the expectation that rabbits at such densities (and before the outbreak of rabbit haemorrhagic disease) rapidly increase to very high levels unless control is instituted. If the decision to control is left too late, the costs of control are substantial.

Such input-based justification for control is weak when arguments arise as to the real benefits of rabbit control. Surprisingly, few people have measured the effect of changing rabbit densities on vegetation growth, at least in the rabbit-prone drylands in the eastern South Island. John Parkes and colleagues set out to remedy this: they measured vegetation growth across seasons at six sites in three places in Otago using a series of plots that allowed access by both rabbits and sheep, just rabbits, and neither rabbits nor sheep. The team knew the density of sheep at each site and indexed rabbit density (rabbits/km) on spotlight routes across the sites. They then used the data to model the effects of changing rabbit and sheep numbers on the seasonal growth rate of the vegetation.

To illustrate model predictions, on the two most degraded sites (in the foothills of the western Dunstan Mountains), if there were neither sheep nor rabbits present, pasture biomass was predicted to grow in spring, just grow in summer, and decline in winter. If there were no sheep but the number of rabbits varied from 5, 10, and up to 50 rabbits/km, then pasture growth was predicted to stop in summer at 5 rabbits/km, almost stop in spring and decline in summer and winter at 10 rabbits/km, and not grow in any season at 50 rabbits/km. This same pattern was revealed at the less degraded sites in the foothills of the Old Woman Range and in eastern Otago at Macraes Flat, although the model predicted some pasture growth in spring and summer even at 50 rabbits/km.

John's team also used the model to predict maximum stocking rates for sheep in each season given different rabbit densities but still allowing for at least zero or some pasture growth. On the most fertile site, some sheep could be grazed even where rabbit densities exceeded about 30 per kilometre, except in winter. On the least vegetated site, a few sheep could be grazed where densities were below 10 rabbits/km but only in spring (*Fig.*).

Using this approach, for example, a farmer that needed at least 5 ewe-equivalents/ha to farm profitably, and did not wish to see a reduction in pasture biomass between years, could achieve this stocking rate year-round on the most productive dryland sites studied if rabbits were held below about 5 per kilometre, but only in the spring on the least productive sites. Therefore, as a rule of thumb, setting intervention triggers at McLean's Scale 3–4 seems about right

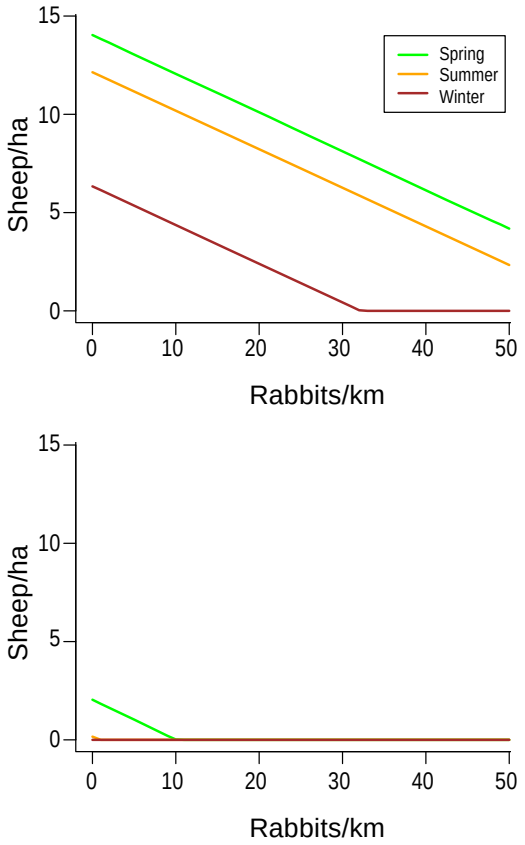

Fig. *Maximum stocking rates for sheep at the most (top) and least (bottom) vegetated sites for spring, summer and winter under varying rabbit densities. Note: the summer and winter lines coincide at zero sheep per hectare on the least vegetated site.*

for land with moderate amounts of vegetation but is unlikely to allow badly degraded land to recover, or to support sustained sheep grazing at economic stocking rates.

The team next seeks to partition pasture growth by species (palatable and unpalatable) and turn their estimates of benefit (ewe-equivalents/ha) into some measure of on-farm economic benefit (the value per stock unit) to compare with the costs of various forms of rabbit control. This approach will demonstrate whether control on one part of the farm is being 'subsidised' from other parts of the farm or requires input from external funders, and whether investment in research to make rabbit control (especially expensive aerial poisoning, which is required for rabbits at high densities) more efficient and so reduce the need for subsidies.

This work was funded by the Ministry of Science and Innovation.

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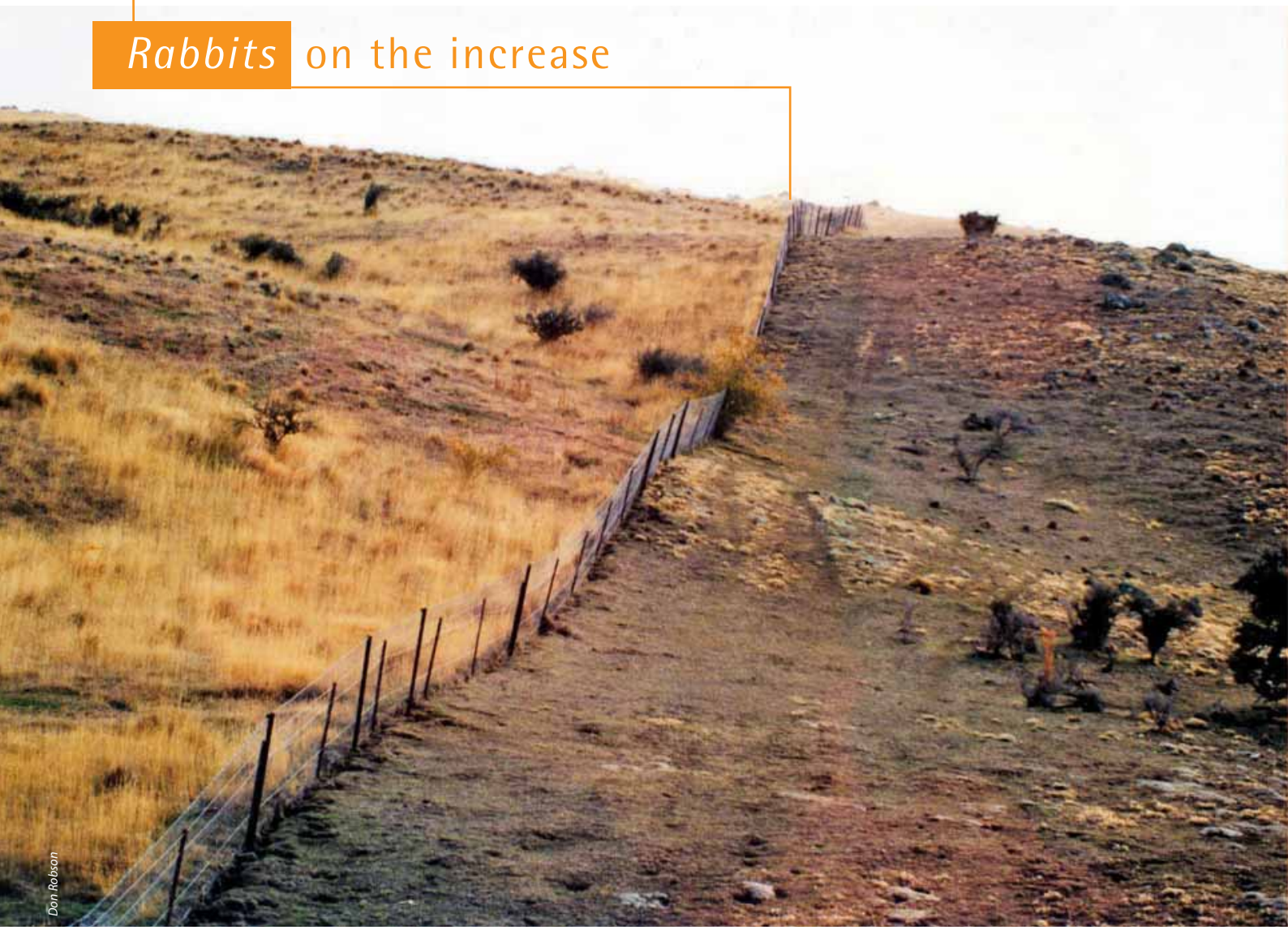
Michael Scroggie (Arthur Rylah Institute in Melbourne) developed the model.

Rabbits on the increase



Don Robson

Dryland habitat in Central Otago with (right) and without (left) rabbits.

It is somewhat intriguing that in the Chinese Year of the Rabbit, there is growing concern about the numbers of rabbits infesting our drylands. In 1997, rabbit numbers over large areas of New Zealand were decimated by rabbit haemorrhagic disease (RHD). However, in the intervening years their numbers have recovered, due mainly to rabbits developing immunity to the RHD virus.

Such increases in rabbit numbers have led to a resurgence in the use of conventional control tools, including baiting with either 1080 or pindone. Landowners are required to control rabbits when numbers exceed specified population levels (see Parkes et al. p. 17 in this issue) and some landowners are again incurring high rabbit control costs.

It is therefore perhaps not coincidental that for the first time in more than 10 years, Landcare Research scientists, led by Bruce Warburton, have received funding from the Crown to extend recent research on possum control to the control of rabbits.

The research has three main strands: (1) reducing the cost and amount of toxic bait used in aerial baiting, (2) identifying cost-effective strategies currently used by farmers for secondary control, and (3) understanding the toxicology of pindone poisoning in order to reduce the cost of application and impacts on non-target species.

As a first step, published papers and reports from previous relevant research were catalogued within a searchable web-accessible bibliography (http://rabbits.landcareresearch.co.nz). The catalogue helped identify key research that could be used to update current best practice for controlling rabbits with aerially sown 1080-carrot bait. Such control typically involves sequential sowings of 20–40 kg each of prefeed (non-toxic) and toxic bait per hectare, depending on rabbit density, and costs up to $100 per hectare. Based on research into baiting for possums, Bruce believes that current bait sowing rates and control costs for rabbits are too high and can be significantly reduced.

To test this hypothesis, Bruce and his team are working with staff from Regional Services (Otago Regional Council) to develop and run a series of trials this winter to test a range of different bait sowing rates and applications (*Table*). Even if the lowest toxic sowing rates (i.e. treatments 5, 6, 7 in the *Table*) are not effective, the team is confident treatments 3 and 4 will be. If so, the cost of control should be reduced by as much as 50% and the sowing rate of bait by 66%.

Some farmers undertake secondary control of rabbits to slow or halt population recovery. To determine how control is currently being carried out, farmers are being interviewed by James Smith to identify the control methods they use based on variations in habitat, percentage cover, farming practices, and the density of rabbits on their property. Preliminary results show that investment in rabbit control varies greatly; some farmers have long-standing control programmes costing tens of thousands of dollars per year, whereas others invest very little, instead relying on the RHD virus and the efforts of meat shooters to suppress rabbit numbers.

Farmers and rabbiters engaged in control use a wide range of tools to limit rabbit populations. Shooting is the most common control method used, though its application varies. For example, in areas where access by 4WD or motorbike is possible, night shooting is effective when rabbit densities are low. On steeper, less accessible country, rabbits are shot from helicopters. Other complementary methods include fumigation of burrows and patch-poisoning with pindone.

Pindone (a first-generation anticoagulant toxin) is used by some farmers and contractors to control rabbits because of the regulatory and stock-withholding-period requirements when using 1080. However, baiting with pindone raises concerns over toxin residues and risk to non-target species. Penny Fisher has been assessing the residual concentrations of pindone in tissues from caged rabbits after they have eaten a lethal amount of pindone and has found relatively high levels of the toxin in rabbit liver and fat. Tissue testing is ongoing, and the final results will be used to review assessments of risk to non-target species that prey on or scavenge rabbits, such as Australasian harriers and dogs.

Table. *Sowing rates of prefeed and toxic bait and flight-path spacing for each treatment (T1–T7). SR = sowing rate. Note T1 is current best practice as applied by Regional Services.*

	Prefeed 1 SR (kg/ha)	Prefeed 2 SR (kg/ha)	Toxic bait SR (kg/ha)	Flight-path spacing (m)	Approximate cost/ha	Quantity of bait relative to T1
T1	30	30	30	25	$75	100
T2	30	30	10	75	$56	33
T3	30	10	10	75	$40	33
T4	30	10	10[1]	75	$40	33
T5	30	10	5	75	$39	10
T6	30	10	5	75	$39	10
T7	10	10	5	75	$23	10

[1] The difference between T3 and T4 is that the swath width of toxic bait in T4 is reduced from 25 to 10 m.

This work is funded by the Ministry of Science and Innovation (Programme C09X1007).

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Don Robson

Prototype interactive, multi-species model for *invasive mammals*

The drylands of Otago are a complex interactive ecosystem involving native animals dependent on highly variable plant and invertebrate food sources in a modified landscape consisting predominantly of tussock grassland, semi-improved pasture, and regenerating shrub. Within this system, native animals are threatened by introduced cats, ferrets, stoats and hedgehogs, supported at high levels through predation of introduced rabbits, hares, mice and rats. Left unmanaged, such threats are likely to drive the remaining, often fragmented populations of native animals to extinction.

Predator control by the Department of Conservation in predator-proof-fenced areas such as at Macraes Flat has clearly demonstrated how the removal of predators can prevent extinction of critically endangered native skink populations and, in some cases, lead to their restoration (see Hutcheon et al. pp. 14–15 in this issue). However, whether predator control is a sustainable management strategy for skink populations outside predator-proof-fenced areas is unclear. With highly mobile species such as cats and ferrets, achieving a sufficient spatial scale of their suppression in open landscapes is likely to be extremely costly to maintain for long periods. Also, with multiple interacting predator species, control of one, or just a subset of predators, could lead to the release of others, with potentially greater impacts on native species.

In systems such as the drylands of Otago, field surveys and trials are usually insufficient on their own to explore such issues. If management options are to be assessed in a meaningful and robust manner, a formal framework is required to gauge understanding and guide research. One such framework is mathematical modelling. The process of constructing models rapidly identifies knowledge gaps, and model simulations generate predictions for field testing. For both these reasons, Dan Tompkins and colleagues have been developing a computer simulation model for vertebrate pest communities in New Zealand's drylands (*Fig.*).

The two questions initially addressed by the team are: (1) what are the important knowledge gaps in their understanding of this system, and (2) will control of single predator species lead to increased numbers of other predators? Model construction was based on data from experimental trials recently conducted at field sites near Macraes Flat and Alexandra (see Norbury et al. pp. 12–13 in this issue), complemented by other sources where necessary. Only mouse, rabbit, cat and ferret populations, and total pasture and pasture seed biomass, were modelled at this stage to make the exercise manageable. Possums, hares and sheep were included as fixed populations, with constant levels of pasture consumption assumed for these species.

Confidence in different model components and parameters was scored on a qualitative scale: 'High confidence' indicated data or processes (e.g. food consumption rates) that had been robustly quantified with potential confounding factors accounted for; 'Medium

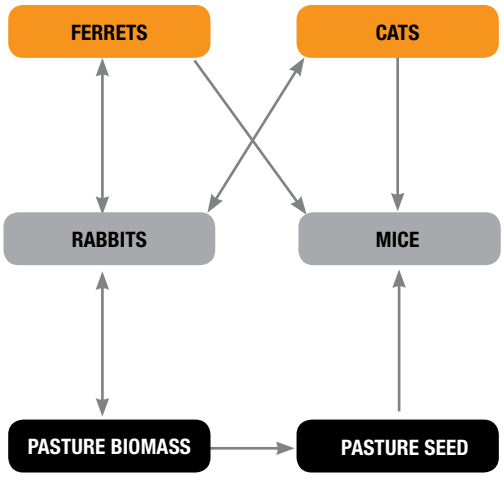

Fig. *Food web used in the model. Arrows indicate interactions between components.*

Tall tussock at Macraes Flat.

confidence' indicated the same for data or processes derived from other systems; 'Low confidence' indicated data or processes (a) for which confounding factors had not been adequately accounted for, (b) which have been obtained by model fitting to observed population or community patterns, or (c) had been estimated based on expert opinion. This exercise demonstrated that even for just the core subset of species (*Fig.*), there is only low to medium understanding (*Table*). In particular, focused studies are needed to obtain (1) unconfounded life-history details for rabbits and mice, (2) accurate functional responses of the predators to their prey species, and (3) determinants of pasture seed production.

Examples of the team's model predictions at this preliminary stage are that the complete removal of cats (but no other predators) should lead to a slight increase (~10%) in mice and moderate increases in both rabbits (~20%) and ferrets (~20%), while complete removal of ferrets only should lead to a similar increase (~20%) in rabbits and a slight increase (~10%) in cats. However, a lot more research is needed before the model can be considered sufficiently well founded to inform conservation management in the Otago drylands.

This work was funded by the Ministry of Science and Innovation (Programmes C09X0505 and C09X0909)

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Table. *Confidence in different model components.*

MODEL COMPONENT	CONFIDENCE	NOTES
Pasture production	Medium	Herbivore-free measurements
Pasture consumption by rabbits	High	Functional response to pasture
Pasture seed production	Low	Pattern fitting to data at a different site
Rabbit numerical response	Low	Potential confounding factors (e.g. predators)
Rabbit predation by cats	Medium	Quantified allometric relationship
Rabbit predation by ferrets	Low	Rescaled allometric relationship
Mouse numerical response	Low	Potential confounding factors (e.g. predators)
Mouse predation by cats	Low	Rescaled allometric relationship
Mouse predation by ferrets	Low	Rescaled allometric relationship
Cat numerical response	Medium	Based on data from several other sites
Ferret numerical response	Medium	Based on data from several other sites

Mythbusters –

can predators control rabbits in New Zealand?

Welcome to a new section of *Kararehe Kino*. Here, and in subsequent issues, we aim to scrutinise myths, beliefs and dogma surrounding the ecology and management of vertebrate pests. Our aim is to see how well some widely held views match up with available scientific evidence. In this issue, and in keeping with the 'drylands' theme, Grant Norbury and colleagues tackle the question **'can predators control rabbits?'**

A common refrain from farmers is that 'predator control results in more b!@@%y rabbits'. That belief is often used as an argument against the control of ferrets to prevent the spread of TB and the control of cats and mustelids to protect native fauna. Such assertions need to be examined in the light of relevant ecological principles and evidence to find out whether they are soundly based, and if so, under what conditions.

Whether or not predators can *help* to control rabbit populations depends on the favourability of the habitat for rabbits and on causes of mortality other than predation. In moist, lowland areas, predators do appear to play a role in suppressing rabbit numbers. In trials in the Wairarapa and in North Canterbury, predator numbers were reduced and the subsequent change in rabbit numbers recorded. In North Canterbury, rabbit numbers declined during an outbreak of rabbit haemorrhagic disease (RHD), but declined least where predators were controlled. In the Wairarapa, rabbit numbers increased when predators were removed, although this study was confined to a single 8-ha enclosure. In both these trials, predators helped to suppress rabbit populations that already had been reduced by diseases such as RHD and coccidiosis or by adverse weather conditions (young rabbits often drowned in their nests). In both areas, rabbits breed almost year-round, and the continuous supply of baby rabbits helps sustain predators year-round. As neither study was replicated, the results must be interpreted cautiously. Nevertheless these studies show that in some circumstances predators and disease can provide substantially better control of rabbits than disease alone.

The situation is very different in drylands, as they provide ideal conditions for rabbits; namely, a dry climate and relatively lower incidence of diseases. Here, experiments have shown that predator control has little, if any, impact on rabbit abundance because in most years rabbits out-breed any off-take by predators. The number of rabbits determines the abundance of predators in this environment, rather than the other way around.

Predator–prey theory can help in understanding these differences. Grant and his colleagues show this schematically by graphing (1) the rate at which juvenile rabbits are recruited into the population in the absence of predators, and (2) the rate at which rabbits are killed by predators (*Fig.*). When the recruitment rate equals the kill rate, rabbit numbers are generally stable. Where recruitment exceeds predation, rabbits increase and where predation exceeds recruitment, rabbits decrease. In drylands, recruitment of rabbits is normally high (blue line in *Fig.*) and naturally declines with increasing population density as competition for food and shelter increases. Predation rates (red lines) tend to decrease at low densities because some rabbits always avoid predators, and at high densities because predators can eat only so many rabbits in a day. Importantly,

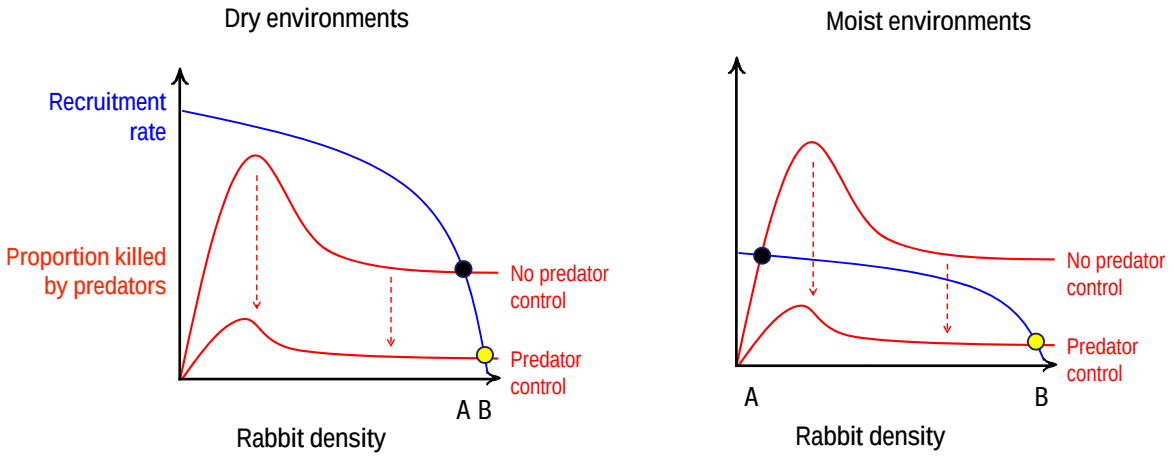

Fig. *Rabbit recruitment rates in the absence of predators (blue lines) and predation rates (red lines) as a function of rabbit population density in dry (left) and moist environments (right). Predator control lowers the predation curve, which increases rabbit densities from A to B.*

Monitoring predator numbers in the Macraes Flat area.

in drylands, recruitment almost always exceeds predation, so populations increase until recruitment is balanced eventually by predation (density A in *Fig.*). Where predator numbers are controlled (lower red line), rabbit densities increase only marginally to B, i.e. there is no outbreak of rabbit numbers.

The situation is very different in moist environments. There, the recruitment rate is generally lower than the predation rate (because of other mortality factors), and populations tend to stabilise at lower densities around A. But note what happens now when predators are controlled in this environment – rabbit populations can increase markedly to point B.

Of course, the relationships shown in the figure apply only during the rabbit breeding season. During the non-breeding season, the size of the rabbit population is determined solely by survival rates. Data collected in all areas of New Zealand show that **all** mortality factors combined cause a density-dependent decline in rabbits over winter: high density populations at the start of winter decline rapidly, and low density populations decline slowly. The result is that rabbit populations start the breeding season in each area at roughly the same density each year. In ecological terms, this tends to stabilise rabbit populations ensuring their persistence in the long term.

These relationships help explain what is observed when predators are controlled in rabbit-occupied lands, but the question landholders will ask is 'in which of these two environments does my property fall?' It won't always be one or the other, because there is a land gradient of favourability for rabbits. It's really only at the environmental extremes where the response of rabbits to predator control becomes clear. So, is the myth busted? 'Almost always yes' for drylands, and 'usually no' for habitats that are less favourable for rabbits.

This work was funded by the Ministry of Science and Innovation (Programmes C09X0909 and C09X0910).

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Andrea Byrom, Bruce Warburton, Wendy Ruscoe and Roger Pech

Some recent vertebrate-pest-related *publications*

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