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OVERSEAS RESEARCH

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Front cover: Dave Latham with a large (16.5kg) male coyote trapped in caribou habitat (article P6). Photo by Eric Heinze.

P 2, 3 Photos: A. Byrom, C. Kolaczan, J.A. Soriano, P. Fisher .
P 3: Pregnant bandicoot (article P16). Photo by Alison Kuiter.

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In this issue...

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Small mammal dynamics in Serengeti, East Africa: implications of climate and land use change for a savannah ecosystem

In Issue 10 of *Kararehe Kino* (June 2007), Andrea Byrom and Wendy Ruscoe reported on a visit to the Serengeti Biodiversity Programme in Tanzania. The programme has been running at a variety of sites in Serengeti National Park for almost 45 years, and is run jointly by the Tanzanian Wildlife Research Institute and Professor Tony Sinclair of the University of British Columbia. It specifically seeks to understand (1) the factors affecting all species in the park and (2) links between the protected area and human populations in areas surrounding the park. Andrea and Wendy, with colleague Guy Forrester, have reviewed the long-term Serengeti data specifically for rodent populations as indicators of the impacts of climate change.

In African savannah ecosystems, changes in climate and land use are two key drivers of environmental change. Serengeti National Park, a savannah woodland, is a good system in which to investigate the effects of these drivers of global change on ecosystem processes. There, many processes are driven by rainfall, which falls in two wet seasons: the short season rains (November–December) and long rains (March–May). The wet/dry seasonal cycle is critical to the functional dynamics between large predators and their prey within the park, but relatively little is known about how climate drivers such as rainfall affect other components of the ecosystem. For example, not much is known about the distribution and dynamics of small mammals (primarily rodents) in the greater Serengeti ecosystem.

Andrea, Wendy and Guy combined the scattered data on rodent abundance over 1968–2008 with more intensive trapping data collected from 1999–2010. Rodent populations showed interannual fluctuations, remaining at low levels for several years and occasionally 'outbreaking' to spectacularly high (plague) numbers (*Fig. 1*). The data revealed a positive relationship between short-season rainfall and rodent outbreaks, presumably because higher rainfall increased ecosystem productivity.

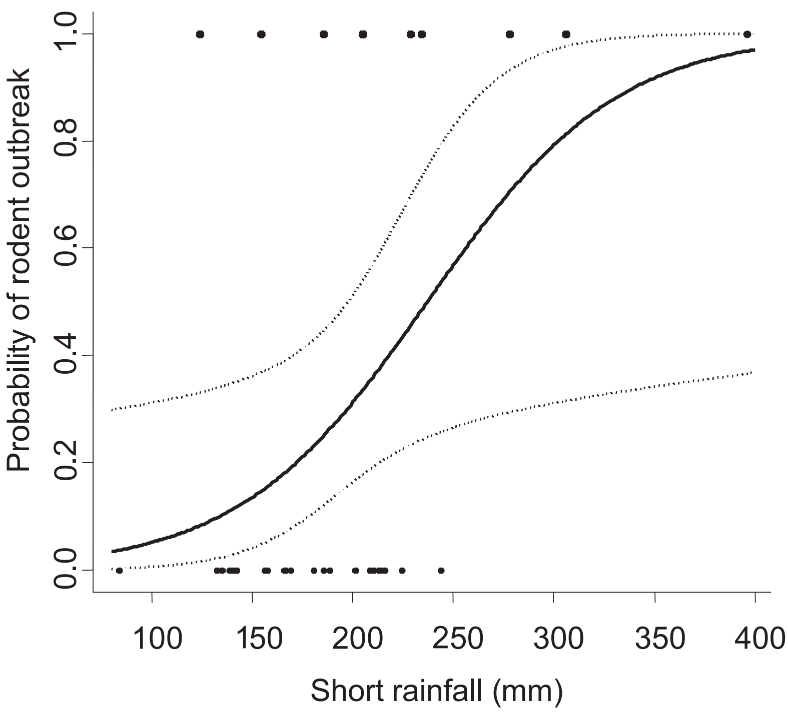

Fig 1. *Predicted relationship between rainfall and rodent outbreaks (1 = outbreak; 0 = no outbreak) between 1968 and 2010 in Serengeti National Park. Solid dark line represents the predicted relationship with dotted lines representing 95% confidence limits. Rainfall of more than 250 mm during the 'short rains' always results in an outbreak of rodents.*

Andrea, Wendy and Guy also looked at time series data on the abundances of small mammalian carnivores recorded between 1991 and 2010 and of black-shouldered kites between 1968 and 2010, and both groups showed peaks in abundance coincident with peaks in rodent abundance (*Fig. 2*). These observations suggest that the dynamics of rodents in the Serengeti savannah have important consequences for carnivores, particularly lesser-known ones such as the smaller cats, jackals, viverrids (members of the mongoose family), and birds of prey. Indirectly, rodent outbreaks in the natural ecosystem may help with the conservation of small mammalian carnivores and birds of prey because they provide pulses of food (prey) at critical times.

To the west and north of Serengeti National Park are agricultural areas and villages, where the primary crops are maize and millet. These areas are undergoing unprecedented development, with intensification of land use and human population growth of 2–5% per year. The dynamics of rodents in agricultural areas are also characterised by outbreaks, but unlike in the natural savannah, some rodents were always detected even during 'low' phases between outbreaks. Outbreaks cause significant economic losses because the rodents damage crops and stored grain. In outbreak years, rodents can also transmit diseases directly to humans (e.g. bubonic plague) and to domestic dogs and cats, which are then thought to transmit diseases back to wild carnivores (e.g. distemper, parvovirus, and rabies). In agricultural areas, therefore, rodents are regarded as pests. Climate change predictions for East Africa suggest that both the amount and variability of rainfall will decrease over the next two decades, which might mean fewer

Zebra and wildebeest grazing on the Serengeti plains.

rodent outbreaks both in agricultural areas and the natural savannah. This is good news for managing rodents in agricultural areas, and may help reduce disease outbreaks in wildlife and humans. On the other hand, as Andrea and Wendy have discovered, rodents are a vital part of the natural savannah ecosystem because they provide food for many threatened carnivore species. This sets up a complex conflict between predicting and managing for desirable outcomes for natural verses human-dominated ecosystems in East Africa.

The research on small mammals in the Serengeti has increased the known number of rodent genera from 28 to 32, and extended the geographic range of three native and one introduced rodent genus.

Riverine floodplains and woodlands had the greatest diversity of small mammals, with lower diversity on short grass plains and rocky outcrops (kopjes), and in villages and farms outside the park.

Travel for this work was funded by the Serengeti Biodiversity Program. The results have been written up as a chapter in *Serengeti IV* (due to be published in 2012) under funding from the Ministry of Science and Innovation (Programmes C09X0505 and C09X0909).

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Wendy Ruscoe and Guy Forrester

A team of international colleagues has contributed to research on rodents, carnivores, and birds of prey in the Serengeti. The team comprises: **Anthony Sinclair** and **Kristine Metzger** (Beatty Biodiversity Centre, University of British Columbia); **Stephen Makacha**, **John Bukombe** and **Joseph Nkwabi** (Serengeti Biodiversity Program, Tanzania Wildlife Research Institute); **Meggan Craft** and **Katie Hampson** (Division of Ecology and Evolutionary Biology, University of Glasgow); **Sarah Durant** (Institute of Zoology, Zoological Society of London); **Simon Mduma** (Tanzania Wildlife Research Institute, Arusha); and **Denne Reed** (Department of Anthropology, University of Texas).

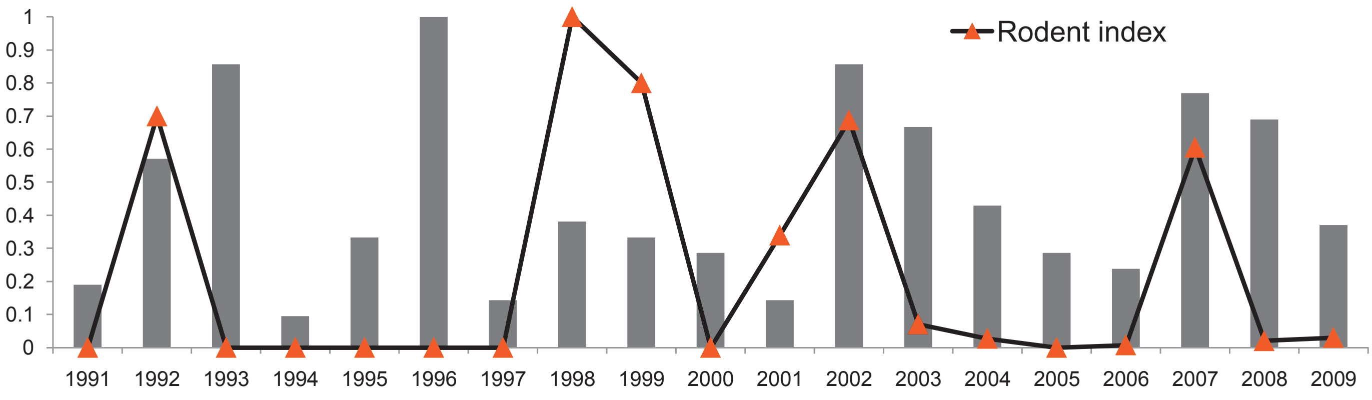

Fig 2. *Response of small carnivorous mammals such as cats, civets and jackals (grey bars indexed to 1) to rodent outbreaks in the Serengeti ecosystem.*

Coyotes *invade* woodland caribou range

Young female coyote hunting along a roadside in upland habitat adjacent to caribou range.

Coyotes were historically restricted to the Great Plains of the Midwestern and western United States. Over the past two centuries, they have expanded their geographic range to encompass much of North America, including the entire eastern seaboard, south into Mexico and Central America, and north to Alaska. Such range expansion is believed to have been facilitated by two synergistic factors: additional habitat associated with expanding areas of intensive human activity, and reduced competitive pressures following the extermination of wolves from much of North America.

Coyotes invaded the boreal forest in northern Alberta, Canada, within the last 10–30 years. Many people believe this range extension is due, at least in part, to recent increases in silvicultural and energy extraction activities, but this has not been quantified. Because threatened woodland caribou occupy peatlands within the boreal forest, conservationists are increasingly concerned about the potential role of coyotes as predators of caribou calves. To answer this, Dave and Cecilia Latham attached GPS radio collars to nine coyotes to assess their habitat selection, diet and spatiotemporal relationships with caribou, wolves and industrial activity in caribou range in north-eastern Alberta.

Dave and Cecilia found strong evidence to support the hypothesis that industrial activity has facilitated the expansion of coyotes into caribou range. Coyotes showed strong annual affiliations with all-season roads and oil and gas pipelines, as well as winter preferences for areas close to garbage dumps and human settlements. These areas provide coyotes with novel foods such as human refuse and road-killed animals. Coyotes may also select areas of high human activity because they provide a refuge from wolves, which are persecuted by people.

Interestingly, coyote home ranges included areas used by wolves, particularly in winter, which suggests that spatial segregation between the two species is only partial and that coyotes may accrue some benefit from wolves. Although wolves kill coyotes, they also provide coyotes with significant scavenging opportunities. Dave and Cecilia observed coyotes scavenging wolf-killed moose and white-tailed deer carcasses, particularly in winter when deep snow makes hunting the more common small prey species more difficult. Based on scat analyses, deer hunted and scavenged were common (29%) in the diet of coyotes. Small prey species such as mice and voles (44%) and muskrats (40%) were also common food, whereas caribou (2%) was rare. Conversely, for wolves, beaver (48%), deer (41%), and moose (19%) were the most abundant prey.

Coyotes were found throughout the study area, indicating generalist habitat selection. Some individuals showed strong preference for well-drained forests, milled forestry blocks, and towns adjacent to caribou range; other individuals selected caribou-preferred habitats (coniferous swamps and bogs). Coyotes were also strongly affiliated with areas near rivers and streams throughout the year, and to areas near lakes in winter. However, most coyotes in caribou range showed some degree of transience, be it low home range fidelity or long-distance dispersal, with the longest dispersal recorded being 164 km straight-line distance.

Coyotes, together with other predators of woodland caribou, present wildlife managers with a conundrum. At the population level, caribou are not important prey for coyotes –merely an incidental or secondary prey species. However, for caribou, incidental predation by coyotes, wolves and black bears can have a significant impact. Some coyotes apparently specialise in foraging in caribou habitat and these animals may contribute to low caribou calf survival. Caribou decline in Alberta has been attributed to low adult female and calf survival and subsequent low recruitment. Thus management actions to conserve caribou should also consider coyotes, in addition to wolves (primary predator).

This work was funded by the Petroleum Technology Alliance Canada (Alberta Upstream Petroleum Research Fund) and the University of Alberta.

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Female woodland caribou on an all-season road created for the extraction of oil.

Eradication of feral cats from Tasman Island

Tasman Island off the coast of Tasmania.

Tasman Island forms part of Tasman National Park off the coast of Tasmania. The island comprises 120 hectares of plateau and very steep cliffs and boulder fields. It is home to Australia's largest population of fairy prions. Despite such status, Tasman Island was, until very recently, also home to an estimated population of 32–50 feral cats that colonised the island about 70 years ago. It has been suggested by Tasmanian Parkes and Wildlife Service staff that the cats may have killed approximately 50,000 fairy prions and other seabirds each year.

To remedy this situation and to restore the island's natural values, Grant Norbury and Alan Saunders were contracted through Invasive Species International (ISI, Landcare Research; www.isinz.com) and in association with Tasmanian colleagues, to draft a plan to eradicate the cats. The eradication project was subsequently undertaken by the Tasmanian Parks and Wildlife Service. The plan was developed following a visit by the ISI team to the island. It proposed a mix of toxic baiting, trapping, and shooting in and around the boulder fields below the cliffs where many of the cats resided (*see photo*).

Hand and aerial baiting using the toxin para-aminopropiophenone (PAPP) in meat sausage baits began on 3 May 2010. Unfortunately, there were technical problems with the encapsulation of the toxin (some toxin was lost from the bait) so only 5 of 15 cats radio-collared before the control died from poisoning. Bait take by cats, however, was very good. Baits also contained the marker rhodamine B and 89% of the carcasses of cats retrieved by other means contained the marker, illustrating that the palatability, timing, and distribution of the bait was good. Baiting was followed by trapping with cage traps and padded leg-hold traps, which removed another 27 cats. The final control phase involved skilled rifle marksmen searching for surviving cats. No cats were seen, indicating that the population estimate for the cats at the start of the eradication programme was accurate. The last (supposedly) of the island's feral cats was trapped 12 days after baiting began. Field teams have visited the island each month since the control operation. They used permanently positioned remote cameras and cat-detecting dogs to look for live cats or for evidence of their presence from fresh bird kills, scats and footprints.

After 12 intensive searches between June 2010 and May 2011 Tasmanian Parks and Wildlife staff are confident that no cats remain on Tasman Island, although ongoing vigilance will be required. Recent surveys of shearwater breeding indicate that hatching success has jumped from fewer than 8% before the eradication to over 40% following eradication. The number of prions recorded by the remote cameras has also increased. The situation is looking very promising for the rapid recovery of seabird populations on Tasman Island.

One of the Parks and Wildlife objectives for this project was to develop expertise and capacity within the organisation to undertake further eradications. In addition to the more recent rodent and rabbit eradication programme on Macquarie Island, which involved several staff from the Tasman Island project, consideration is being given to further eradications of invasive species from other islands near Tasmania.

The Tasman Island cat eradication project, including preparation of the plan, was funded by the Tasmanian Parks and Wildlife Service.

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Alan Saunders

Which toxin is best for eradicating *rodents* on islands?

Since the 1980s, rats and mice have been eradicated from nearly 600 islands around the world mostly by using anticoagulant toxins. These have delayed symptoms that do not allow rodents to learn to avoid eating sufficient bait to get a lethal dose. The baits used are generally cereal-based pellets or blocks and are either broadcast from the air using a helicopter and sowing bucket or laid by hand as broadcast, trail, bait piles or in covered bait stations.

Brodifacoum, a second-generation anticoagulant toxin, has been most commonly used (72.5% of 546 attempts) while diphacinone, a first-generation anticoagulant toxin, has been used in 9.1% of all attempts. Brodifacoum has an advantage over most other anticoagulant toxins because rodents can acquire a lethal dose at a single feeding. However, it has disadvantages in that it persists in the bodies of rodents and is equally toxic to non-target species such as birds, which are therefore at risk if they eat baits or poisoned rodents. Diphacinone has advantages in that it is not as persistent in the bodies of rodents and is less toxic to birds, but the potential disadvantage that rodents have to eat baits each day over several days to obtain a lethal dose, which might allow some individuals to survive and an eradication attempt to fail.

In 2009, an attempt was made to eradicate Polynesian rats from the 129-ha Lehua Island in Hawai'i, using aerially-sown diphacinone baits. The attempt failed as live rats were found on the island later in 2009. In 2010, John Parkes and Penny Fisher were asked to see if they could diagnose why the attempt failed.

One possibility was due to the problems inherent in the toxin used, so John and Penny looked at whether the failure rates of rodent eradication programmes around the world correlated with the use of one or other of these two toxins. Subsequently more attempts came to light (see *Conservation Evidence* 8: 100–106) allowing some conclusions to be made:

- Over all attempts against any species of rat or mouse and using any method of sowing bait, brodifacoum had a significantly lower failure rate of 17% (54 of 322 attempts) than diphacinone at 33% (13 of 39 attempts).
- When bait was broadcast from the air, the difference was even greater with only 8% of brodifacoum attempts (12 of 149) failing versus 83% (5 of 6) for diphacinone.
- However, when the baits were applied using various ground-based methods, the failure rates of the two toxins were the same (24% or 42 of 173 for brodifacoum and 24% or 8 of 33 for diphacinone).

John and Penny concluded that for topographically difficult islands where access on foot cannot be gained over all areas, managers are left with aerial baiting as the only option and, on this evidence, with brodifacoum as the toxin of choice. They note, however, that the rather small sample size for the aerial use of diphacinone gives rise to some caution about this conclusion. So where the risk of poisoning non-target species is unacceptable and cannot be mitigated, managers might still use aerially-sown diphacinone baits and accept a higher risk of failure.

The precautionary strategy of over-baiting, with high bait sowing rates or using additional sowings in aerial baiting, to ensure all rodents are placed at risk, increases the risk to non-target species and may not actually be necessary for brodifacoum baits However, a precautionary strategy of over-baiting and additional sowings may be desirable when diphacinone baits are used.

Red-footed booby on nest on Lehua Island in Hawai'i.

Where ground-based methods are used to distribute the baits, either toxin seems to work well in achieving eradication. It is possible that precautionary over-baiting (replacing bait taken from bait piles or bait stations) does account for the equal success of diphacinone (relative to brodifacoum), i.e. over-baiting is an advantage for this toxin as it ensures the last rodent has access to bait at the end of its multiple-feed period.

Overall, John and Penny think some hard data on the spatial pattern of bait removal versus survival of rodents need to be collected, especially for aerial broadcast baiting, to see whether (1) lower bait densities and/or fewer sowing events are efficacious for brodifacoum and (2) more sowing events improve the success of diphacinone.

The review of the Lehua Island project was funded by the University of Hawai'i at Manoa, while the subsequent work to explore the past eradication attempts was funded under the auspices of Invasive Species International.

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Confirming successful eradication of rats from Isabel Island, Mexico

A central problem in the science of pest eradication is how to determine whether eradication has been successful. This is most problematic on offshore islands where access is often difficult and costly. One approach is to 'wait and see', in which a survey is conducted after enough time has elapsed for an easily detectable population to have grown from any survivors. Failure in this case means a renewed eradication operation to remove the recovered population. A better approach is to confirm success immediately following an operation, as failure in this case means that the few survivors are spatially localised and can be removed with low-cost mop-up operations. Here, Dean Anderson working with Araceli Herrera of the Conservación de Islas, México, use data from an eradication operation of black (ship) rats from Isabel Island, Mexico, to illustrate a spatial-survey model for confirming eradication.

Isabel Island (82 ha) is located in the entrance of the Gulf of California, Mexico (*Fig. 1*). The island supports a rich vertebrate biodiversity and is an important breeding site for nine species of sea birds. On 1 and 7 May 2009 compressed-grain bait loaded with the toxin brodifacoum was distributed by helicopter across the interior of the island, and by hand along the coast. At 12, 19, 24 and 30 months following the last baiting, 17 wax tags were deployed at 200m spacings to detect surviving rats (*Fig. 2*) and checked after 5 nights.

The spatial-survey model uses the detection-survey data in which no pests are detected. Dean and Araceli adopted a worst-case scenario for detecting failed eradication by assuming that a single pregnant female survived. Clearly a single animal is harder to detect than multiple animals, but a pest population can recover from a single mother. They asked the model: if a single pregnant female remained on the island, what is the probability that it would be detected with the array of wax tags deployed?

The model randomly placed the home-range centre of a pregnant rat on the island (*Fig. 2*). The probability that the array of wax tags would detect this female was then calculated, based on the home-range size of rats and the probability of a rat chewing a tag. If some months have elapsed since the eradication operation, the model estimates the probability of detecting her progeny, based on population growth rates and individual dispersal. Bayesian logic is subsequently used to produce a probability of eradication success, given no chewed wax tags.

Dean and Araceli incorporate the uncertainty associated with the parameters and propagate this uncertainty through to the results, which influence interpretation and management decisions. To do this, they repeated the model 1000 times and each time chose a new random starting location, and new values from each of the parameter distributions.

The first confirmation survey was conducted 12 months after baiting. Given the negative survey results at that time, the median probability of success was 0.91 (1.0 = 100% success), and the lower confidence

Fig 1. *Location of Isabel Island, Mexico.*

Looking across Isabel Island

J.A. Soriano / GECI archive

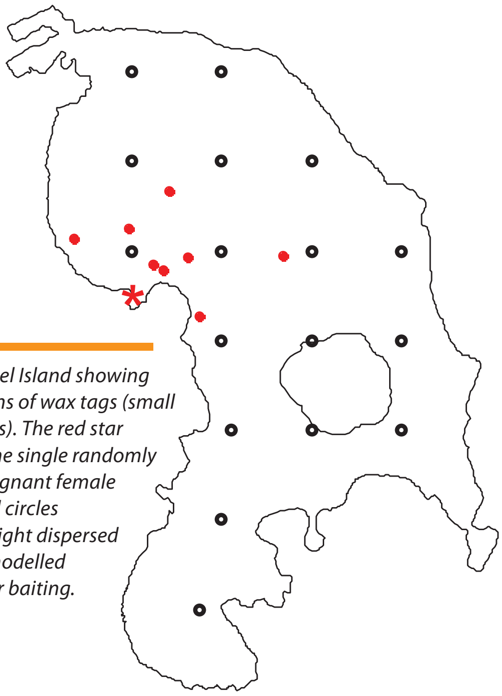

Fig. 2. *Isabel Island showing the locations of wax tags (small black circles). The red star indicates the single randomly located pregnant female and the red circles represent eight dispersed offspring modelled 1 year after baiting.*

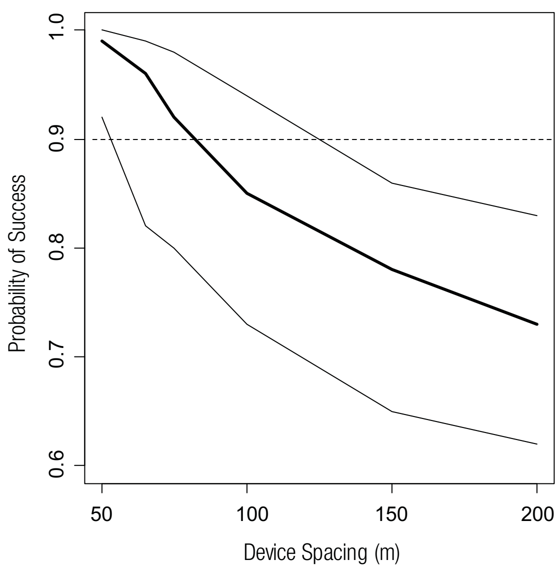

Fig. 3 *The median and 95% credible intervals (CI) of the probability of operational success decrease with increasing spacing of wax tags (devices). The horizontal dashed line is the threshold above which the lower 95% CI should be above.*

Table. *Median and 95% credible intervals (CI) of estimated probability of eradication following wax tag surveys.*

Probability of success after:	Median	Lower CI	Upper CI
12 months	0.91	0.69	0.98
19 months	1.00	0.99	1.00
24 months	1.00	0.99	1.00
30 months	1.00	0.99	1.00

interval 0.69, which indicated low confidence in success and high uncertainty (*Table*). All subsequent surveys indicated that the eradication had been successful. To achieve a satisfactory probability of success immediately following the initial operation, the wax tags needed to be spaced at 50m intervals (Fig. 3). This would require 16 times the actual number of wax tags deployed, or 272 wax tags.

Survey data from Isabel Island illustrates how the spatial-survey model can be used to make eradication projects more cost effective. A survey based on wax tags at 50m spacings conducted on the island immediately following baiting would have provided strong evidence of success and avoided the need to conduct subsequent surveys. More importantly, the model can be used prior to future operations to determine the survey effort required to confirm success. The benefits of this are clear. Funders are supplied with accurate estimates of project costs and objective measures of success. Further, if survivors are detected immediately after the operation, the small number present is likely to be easier to remove than a fully recovered population detected at a later date. Lastly, if the management team is confident of eradication success, subsequent restoration plans, such as the reintroduction of endangered species, can be implemented sooner rather than later.

This project was led by Conservación de Islas with the support of Mexican Government agencies and funding from national and international foundations.

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Assessing risk to non-target animals from brodifacoum bait in the Galápagos

The Galapágos Islands have a high international profile because of their unique biodiversity, including iconic species such as the giant tortoises. However, even such large, long-lived creatures are affected by invasive rodents, e.g. tortoise eggs and hatchlings are eaten by rats. As has been achieved in other islands around the world, significant benefits for endemic fauna and flora are expected if rats are permanently eradicated.

Rodent populations on many islands have been eradicated using cereal pellet bait containing the anticoagulant rodenticide brodifacoum, sown by plane or helicopter. The Galápagos National Park is using brodifacoum in a staged approach to eradicating the introduced rodents from selected islands, with the first two phases completed in 2007 and 2011. The next phase includes the island of Pinzón, which has a wild population of native tortoises.

Brodifacoum is a very effective rodenticide, with 'single feed' amounts of bait lethal to rodents. This high toxicity also poses an unwanted hazard to non-target mammals and birds that ingest bait (primary exposure) or live animals or carcasses that contain brodifacoum (secondary exposure). However, very little is known about the toxicity of brodifacoum to reptiles, including tortoises and turtles. As part of the planning for rodent eradication from tortoise habitat, Penny Fisher of Invasive Species International (Landcare Research) and colleagues at the Charles Darwin Research Station were commissioned to investigate the risk of brodifacoum to Galápagos tortoises on Santa Cruz Island, Galápagos, in March–April 2011.

In trials with captive Galápagos tortoises, relatively few showed interest in eating baits – the majority of the tortoises preferred their normal plant foods. This suggested that bait uptake by tortoises in field conditions is likely to be low when natural food is readily available. But because some tortoises did eat bait, blood samples were taken before and after the tortoises ate known amounts of brodifacoum relative to their bodyweight to indicate whether this was likely to affect them. An automated coagulometer was used to test the blood samples for clotting times, and to indicate any reduced ability of the blood to coagulate (a typical toxic effect of brodifacoum seen in mammals and birds). However, no significant changes to blood coagulation times in tortoises were measured over the 2 weeks following ingestion of brodifacoum. Overall, tortoises appeared to have higher normal blood coagulation times than those of mammals, supporting the idea that, in comparison to mammals, tortoises have a relatively low susceptibility to brodifacoum toxicity. In the context of the aerial bait application rates to be used in the upcoming rodent eradication programmes, tortoises weighing more than 20 kg would be unlikely to encounter and eat enough bait to harm themselves.

Bait trials with other Galápagos reptiles (lava lizards, geckos and snakes) were also undertaken, with small numbers of all three species brought into the laboratory and offered baits. Some of the lava lizards sampled very small quantities of bait but this did not produce any visible adverse effects on them, e.g. on bodyweight, food intake or behaviour. None of the geckoes or snakes showed any interest in eating bait over a 5-day period. To simulate secondary exposure to brodifacoum, lava lizards were also offered live cockroaches that had been feeding on bait and contained residual concentrations of brodifacoum in their gut. Most of the lizards ingested small amounts of brodifacoum in this way, but again no adverse effects were evident over the following 3 weeks. Because of the small sample sizes in this trial, limited conclusions can be drawn regarding non-target risk to reptiles, but Penny believes the results indicate that lava lizards are less susceptible than mammals to brodifacoum toxicity. However, it is possible that some lizards could eat sufficient bait or contaminated invertebrates to be lethally poisoned, and this requires further investigation. No conclusions about the toxicity of brodifacoum to the gecko or snake species tested can be drawn from the 'nil exposure' results, but it seems unlikely that either would be at risk of primary exposure through bait ingestion.

These results will be used to update non-target risk assessments for the planned rodent eradications, and to assist in the design of on-ground monitoring protocols for non-target species during and after the operations.

This work was supported by the Galápagos National Park, the Charles Darwin Research Station and Island Conservation.

In trials to assess non-target risk, captive Galapagos tortoises were presented with food containing the rodenticide brodifacoum.

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Managing invasive species in a biodiversity hotspot: the Juan Fernández Archipelago, Chile

Large areas of the Archipelago are denuded and eroded to bare rock.

Globally, species are disappearing at an alarming rate. Nowhere is this more evident than on islands, where over 90% of recorded bird and reptile extinctions and around two-thirds of plant and mammal extinctions have occurred. Many of these losses are attributable either directly or indirectly to invasive species.

Recently Al Glen and Alan Saunders took part in a study on how to minimise the impacts of invasive species on the flora and fauna of the Juan Fernández Archipelago, a cluster of three islands several hundred kilometres west of mainland Chile and home to around 700 people. It is also home to a spectacular and unique range of plants and animals, and is recognised as a global biodiversity hotspot. Over 60% of the native plants occur nowhere else on Earth. In addition, 6 of the 7 native land birds occur only on the islands, and some of these species, such as the Másafuera rayadito and the Juan Fernández firecrown, are critically endangered. Threatened seabirds such as petrels and shearwaters also breed on the islands. These outstanding natural values have led to the Archipelago being designated a national park and a UNESCO biosphere reserve.

However, the islands are rapidly being degraded by invasive plants and animals. Weeds such as blackberry and Chilean wineberry are displacing native plants, altering entire communities and threatening many native species with extinction. Rats and mice eat native seeds and seedlings, preventing forest regeneration and endangering remaining areas of forest. Introduced rabbits, goats and cattle not only disperse seeds of introduced species but also overgraze native vegetation and trample the soil, causing severe erosion and further loss of vegetation. The combined impacts of these herbivores have reduced some areas to a lifeless moonscape (*Fig. 1*). Cats and coatis (a South American relative of the raccoon) prey upon critically endangered native birds. The gravity of these impacts led the International Union for Conservation of Nature (IUCN) to list the archipelago as one of the world's most threatened protected natural areas.

Al and Alan were members of an international team of scientists that investigated how to manage the invasive species in the archipelago and halt the decline of its biodiversity. The team adopted a broad approach, covering invasive plants, mammals, birds and invertebrates. Members visited the archipelago in May and November 2010 to consult with the local community and management

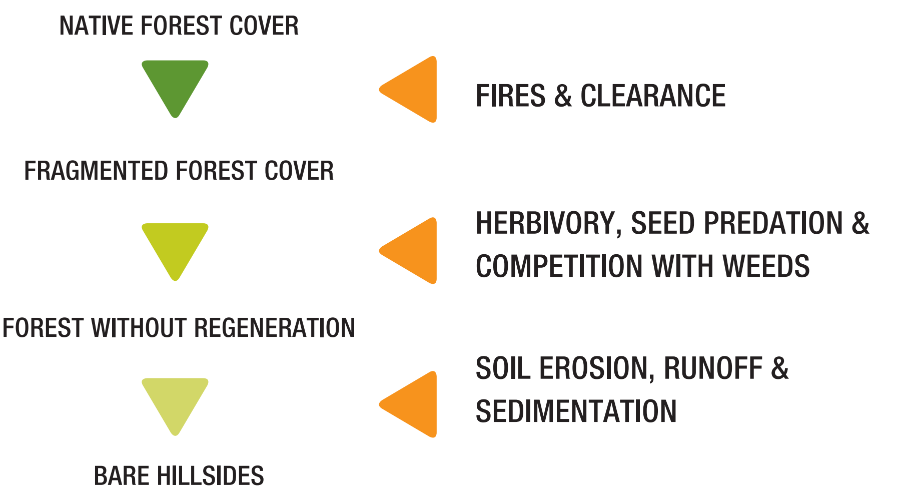

Fig 1. *The processes degrading native forests in the Juan Fernández Archipelago.*

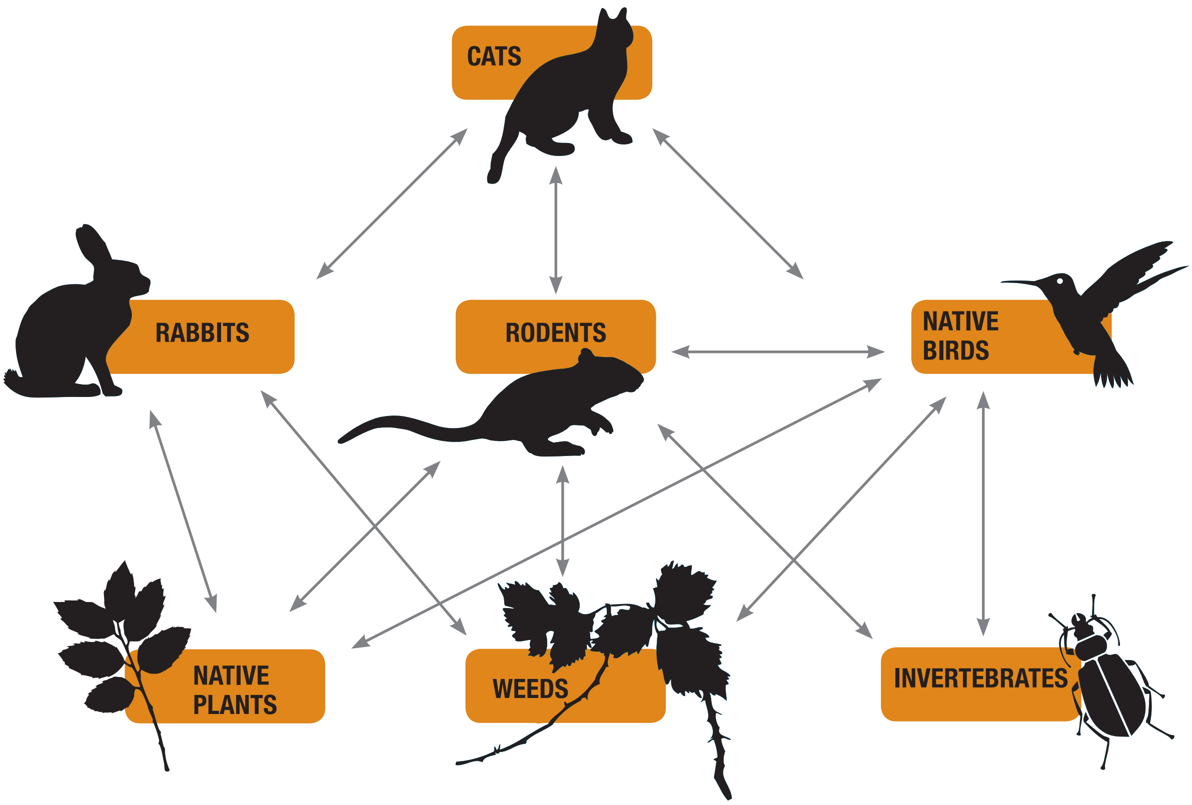

Fig 2. *Food web involving selected native and invasive species in the Juan Fernández Archipelago. Arrows indicate that one species (or group of species) feeds on or provides a source of food for the other. Changes to the system can flow from the top down (e.g. removal of cats leading to reduced predation on native birds) or from the bottom up (e.g. removal of rodents and rabbits leading to reduced availability of prey for cats).*

John Sawyer

Grazing and trampling by introduced herbivores have led to severe erosion in some areas.

agencies, and to see first-hand the impacts of the invasive species. The team judged that restoration of the islands is feasible but will involve significant costs and risks. Because a wide variety of invasive species are well established in the archipelago, the invaders are likely to interact with one another, and with native species (*Fig. 2*). A multi-species approach is therefore thought to be necessary so that attempts to manage one pest do not exacerbate the impacts of others. For example, removing goats and rabbits could allow weeds to grow unchecked. Island biosecurity will also be important to prevent further introductions of invasive species.

There are also complicating social challenges in managing invasive species on inhabited islands. The project must be acceptable to, and supported by, the local community and they must be engaged in both planning and execution stages. Public safety must be assured. Fortunately the team observed a large measure of awareness and support for the management of at least some of the invasive species present.

Managing diverse communities of invasive plants and animals, and community expectations, for island restoration presents major challenges. However, as much of the world's biodiversity is found on such islands, it is a challenge that must be met.

This work was commissioned and funded by Island Conservation.

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Alan Saunders

Effects of predator control on native mammals: Glenelg Ark, Victoria

Red foxes became established in Victoria in the early 1870s after being deliberately introduced into Australia in 1855. In forested areas, where rabbits are relatively scarce, foxes prey on native animals, especially small mammals and ground-dwelling birds.

The Glenelg Ark project was established by the Department of Sustainability (DSE) and Parks Victoria in 2005 to facilitate the recovery of native Australian mammal populations considered at risk from predation by foxes. The project comprises an ongoing programme of fox control over 100,000 hectares of State forest and national park in the Glenelg region of south-western Victoria. Here, Andrew Gormley, working with Alan Robley from the Arthur Rylah Institute, DSE, reviews the effectiveness of the project.

Glenelg Ark was divided into six areas (*Fig. 1*): in three areas, foxes were controlled (Treatment Monitoring Areas; TMAs), and in three adjacent (paired) areas were not controlled (Non-treatment Monitoring Areas; NTMAs). In each TMA, foxes were continuously baited with buried 1080 bait (FoxOff™) set out at 1-km intervals and 50–80 bait stations per area. Indices of fox abundance (percent bait take) clearly demonstrated reduced populations in the three TMAs, and no reduction in the three NTMAs.

The monitoring programme also involved measuring site occupancy of three species eaten by foxes: long-nosed potoroo, southern brown bandicoot and common brushtail possum. The expectation was that site occupancy would become higher in the TMAs compared with the NTMAs as numbers of foxes were reduced. This approach also enabled researchers to estimate the rate at which unoccupied sites were colonised by prey species and whether occupancy persisted from one year to the next.

In 2005, 40 monitoring stations, each consisting of nine hair-tubes, were established in each area. These were monitored once a day for four consecutive days each year until 2010. The repeat sampling provided an unbiased estimate of occupancy by accounting for the detection probability of each species (provided it is present at a site).

Andrew and Alan believe the results to date suggest that continuous broad-scale fox control has had some benefits for small mammals. However, the results have been mixed (*Fig. 2*). Southern brown bandicoots have a significantly higher rate of occupancy in one of the TMAs compared with the NTMAs, although only a relatively low percent (c. 20%) of potential sites are occupied. Occupancy has been constant from year to year. Long-nosed potoroos occupy a higher percentage of sites in one of the TMAs (compared with the adjacent NTMA) and numbers are increasing: but there is little difference in the other paired sites. Brushtail possums have much higher rates of occupancy in one of the TMAs (near 80%), and greater occupancy in one of the NTMAs (Hotspur compared with Mt Clay).

If foxes are the key limiting factor for these prey species, then the prey species could be expected to respond in a more or less uniform manner across all TMAs, albeit at different rates. However, this is not the case, with data suggesting that (1) fox control has not reduced predation pressure sufficiently at some sites to allow prey populations to recover, (2) that predation by feral cats and/or other predators (e.g. quolls, raptors) has taken the place of fox predation, and (3) that resources (i.e. food and shelter) are limiting. Cat control and monitoring at Lower Glenelg National Park has shown that feral cat populations are higher in TMAs, supporting the theory that cats may have replaced foxes as the apex mammalian predator.

These variable results also suggest that greater understanding of top-down and bottom-up processes, and of feral cat predation may lead to more effective and targeted management of vulnerable species.

Future efforts at Glenelg determine the relative effectiveness of alternative methods for assessing differences in fox abundance between treated and non-treated sites, and

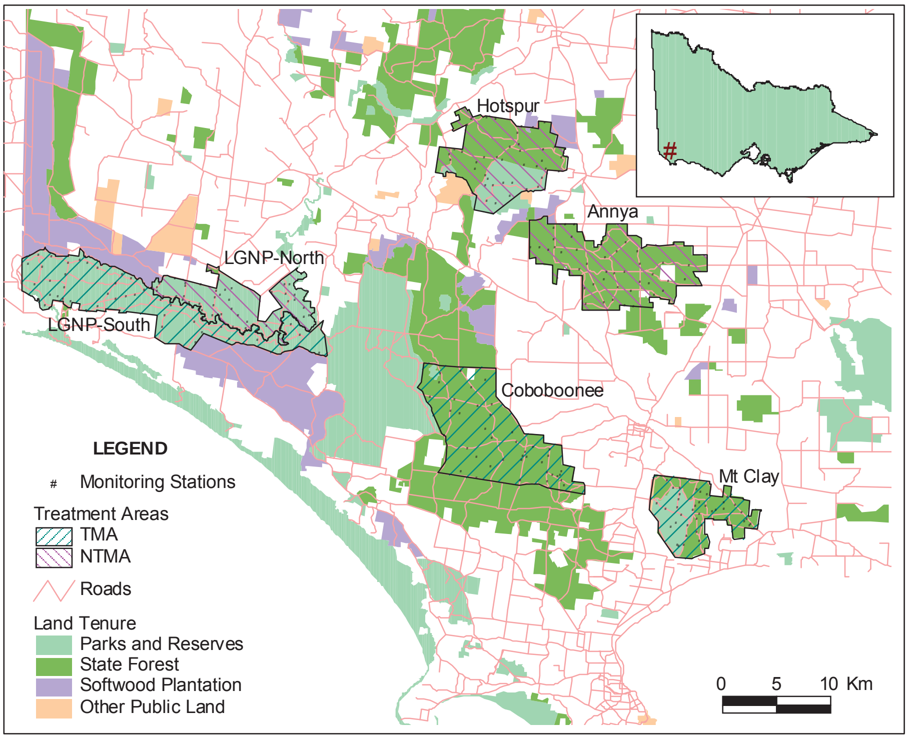

Fig 1. *Locations of the six monitoring areas. Inset map shows their approximate location within Victoria.*

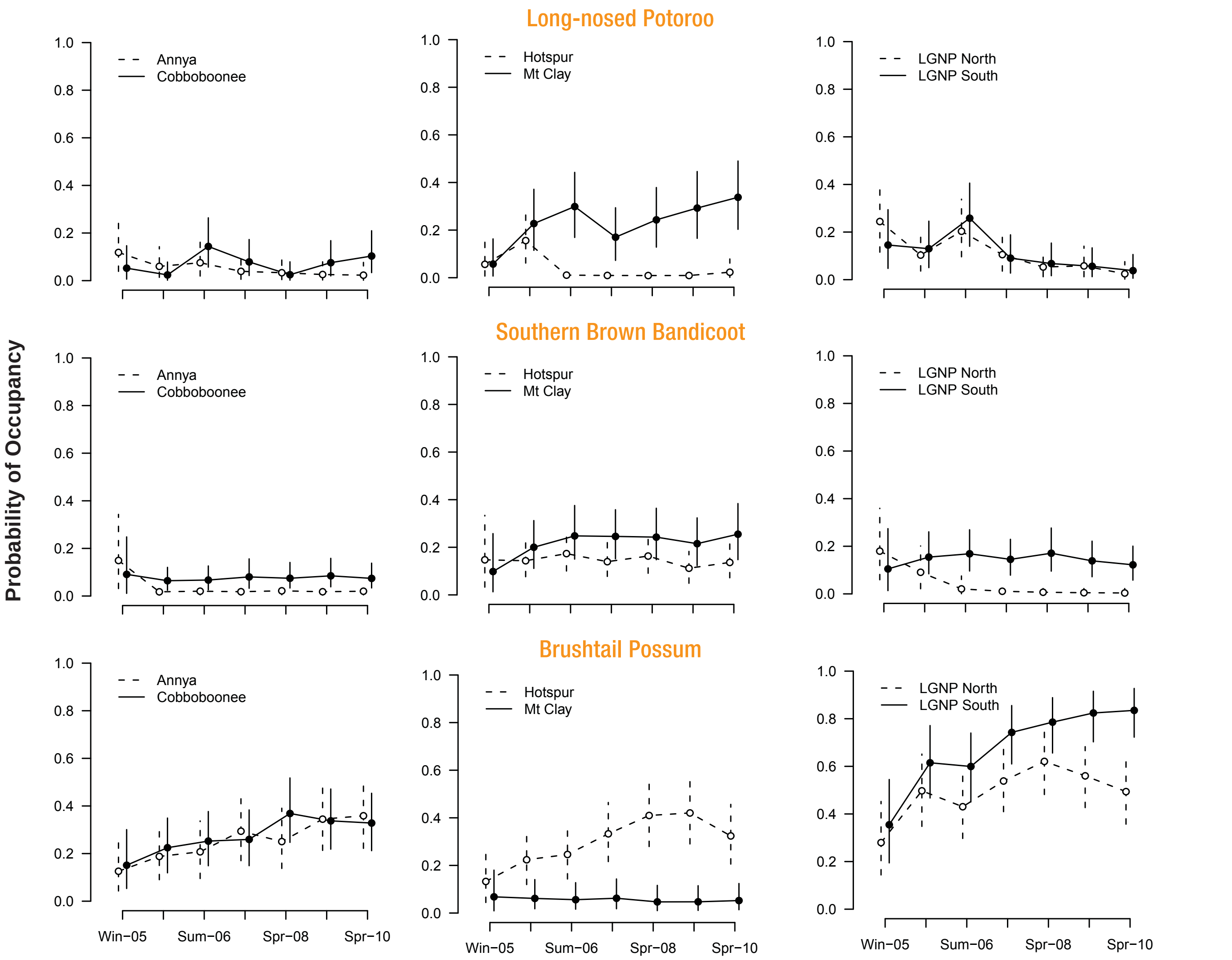

Fig. 2. *Occupancy rates for the three target (prey) species monitored at each of the three paired areas. TMAs are shown by solid lines and NTMAs by dashed lines.*

examine the influence of variables such as rainfall, fire history and vegetation patterns on rates of persistence and colonisation by prey species.

This study was funded by the Department of Sustainability and Environment, Victoria and Parks Victoria.

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Reference

http://www.dse.vic.gov.au/plants-and-animals/invasive-species/weeds-and-pests-projects/glenelg-ark

Fox in Glenelg Ark at a baited remote camera trap, used as part of the wider study. Photo taken with a DSE remote camera.

Do coccidian and nematode infections influence immunity against myxomatosis and rabbit haemorrhagic disease in European rabbits?

Study site with predator-proof fence and artificial warrens.

Wild animals are often infected with several types of parasites whose interactions determine the host's fitness and the epidemiology of disease. Carlos Rouco and colleagues studied these interactions in rabbits in southern Spain, the original home of rabbits. Over the last 50 years, rabbit populations have declined dramatically on the Iberian Peninsula, due largely to the arrival of myxomatosis (MYXO) in the 1950s and rabbit haemorrhagic disease (RHD) in the late 1980s. The additive effect of these viral diseases has, in some less-favourable areas, led to rabbits becoming extinct. For example, 5 years after the arrival of RHD, Spain's wild rabbit population halved.

In this study, Carlos and his colleagues tested whether a microparasite (a coccidian) and a macroparasite (a gastrointestinal nematode) influence the ability of rabbits to generate an immunologic response against MYXO and RHD. Infections of MYXO, RHD and coccidia result in a decrease of specialist (*Th1*) cells in the rabbit that generate effective antiviral responses. On the other hand, macroparasites such as nematodes mainly produce a different (*Th2*) cellular response. Furthermore, the *Th1* response blocks the *Th2* response and vice versa, and in theory only one response can happen at any one time. The team hypothesised that individual rabbits with high parasite loads have a reduced ability to sero-convert (the process of developing immunity) against both MYXO and RHD. Additionally, since coccidia and

Restocking plot, predator-proof fence, and collecting blood samples from the study rabbits. (Photos by Alex Bertó and Carlos Rouco) viruses are under the same immunologic regulation, coccidia would have less effect than nematodes on the immunosupression of both viral diseases.

The team took advantage of an experimental rabbit restocking programme in Hornachuelos Natural Park (Andalusia, Spain), where rabbits were released in predator-proof 4-ha fenced plots. On each plot, 30 evenly distributed artificial warrens, consisting of piles of stumps and rocks covered with loam and branches, were built above ground (see photo). Near each warren, water and commercial food pellets were freely provided. Rabbit abundance was monitored via counts of their faecal pellets; their antibody status by taking blood samples from 563 rabbits during seasonal captures; and their coccidian and nematode loads from studies of fresh faecal pellets.

Coccidian loads, nematode loads, and season explained the sero-conversion rates for MYXO (*Fig.*). The pattern for RHD was less clear as the best model of rabbit abundance, coccidian loads and nematode loads was no better at explaining sero-conversion than using the average rates (null model). Sero-conversion against MYXO was low when coccidian loads were high (*Fig.*), suggesting that rabbits with high microparasite loads would be unlikely to mount a good immunological response against MYXO.

Coccidian infections are the main cause of intestinal disease in rabbits. These infections are quite prevalent in rabbit populations and cause high mortality. Furthermore, the growth potential of young rabbits recovering from coccidiosis is severely compromised, which further reduces their immune responses. In spite of this, the trade-off of *Th1* against *Th2* may not be the only way the rabbit immune system responds when co-infections occur. Contrary to expectations, nematode load seems to play a minor role as this explained only 1.4% of the variance in the data.

A healthy European rabbit (above) radio collared to evaluate the survival of the population as part of the restocking program and a rabbit severely affected with myxomatosis (below). In typical cases where the rabbit has no resistance to the disease, death may take place from 2 - 14 days.

Carlos and his colleagues suggest that coccidiosis plays a key role in rabbits' immunologic responses to MYXO, and has important implications for disease management aimed at either increasing rabbit populations in areas where they are scarce, or for reducing populations where they are considered a pest.

The work was funded by an IPA-CSIC contract through projects 20070687_5 and 20091418.

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Fertility control *vaccines for possums: progress, challenges and prospects*

Jane Arrow

Vaccine being applied to the external surface of the nose and into the mouth to simulate the natural feeding behaviour of possums.

Worldwide there is a lot of interest in developing humane non-lethal methods of pest control. In New Zealand research is focused on fertility control and aims to develop publicly-acceptable immunocontraceptive vaccines suitable for delivery in bait to free-living possums.

Since 2000, Janine Duckworth and her team at Landcare Research, in collaboration with Karen Mate and Carmen McCartney from the University of Newcastle Australia, have tested a range of injectable vaccines targeting the possum egg coat or zona pellucida (ZP). They have identified several marsupial-specific ZP proteins that prevent the fertilisation of eggs in possums (*Table*) but which have no effect on the fertility of bird and non-marsupial mammal species such as chickens and mice. Janine's team have also assisted Lynne Selwood from Melbourne University to identify molecules that play a key role in the development of possum embryos. Some of the molecules from the early embryo's appear to be unique to marsupials and injectable vaccines targeting two of them (proteins CP4 and VAP1) cause long-term infertility in treated female possums.

Table. *Effect of vaccination by injection with possum-derived zona pellucida (ZP) antigens on the fertility of female possums following superovulation and artificial insemination.*

Vaccine antigen	Reduction in number of possum embryos relative to controls
possum ZP3 protein	80% ↓
possum ZP2 C-terminal protein	72% ↓
possum ZP2 N-terminal protein	75% ↓
possum ZP3-peptide	60% ↓
possum ZP2- peptide	64% ↓

Vaccine delivery to free-living possums has been a major challenge. Two delivery systems have been evaluated. First, in collaboration with Petra and Werner Lubitz at the University of Austria, bacterial ghost vaccines (BGs – particulate vaccines derived from non-living empty cell envelopes of gram-negative bacteria) engineered to express possum ZP molecules have been shown to significantly reduce both the fertilisation rate of artificially inseminated possums and the conception rates of naturally bred possums when the BG vaccine is delivered via oral or eye/nose routes. However, the initial promise of this work has not been fulfilled, as the team has been unable to sufficiently improve the intensity and longevity of the immune response to make the BG vaccines practical for field application. This is despite developing new forms of BGs capable of expressing the ZP antigen at higher levels, and encapsulated formulations to prevent the breakdown of proteins by enzyme and gastric acid degradation in the gastrointestinal tract.

Recently, therefore, the team reviewed potential delivery systems for fertility control vaccines in possums, and identified replication-limited poxviruses (such as recombinant vaccinia virus) as a potentially promising approach to developing an oral vaccine for possums. This choice was based on the highly successful oral rabies vaccine used to control rabies in wildlife in the USA and Europe for the last 20 years. As the first step in evaluating this live vaccine approach, in collaboration with Steve Fleming from the University of Otago, possums were exposed to a recombinant vaccinia virus expressing a model protein. The virus was applied to the external surface of the nose and into the mouth; a route of delivery designed to simulate the natural feeding behaviour of possums. The recombinant vaccinia virus established a short-term infection, and 14 of 15 treated possums developed antibody responses to the model protein. This is the first report of an Australian marsupial demonstrating an immune response to a recombinant antigen in a vaccinia virus.

The potency and longevity of vaccinia-based vaccines expressing an immunocontraceptive antigen in possums are yet to be confirmed. However, these initial results, and the extensive safety and efficacy precedents set by the commercial oral rabies vaccines used overseas, highlight the promise of recombinant vaccinia as a vaccine delivery system for fertility and disease control in possums and other marsupials. Janine's team now has two pieces of the possum control puzzle: antigens that reduce possum fertility plus a potential means of delivering these proteins immunologically to possums via an oral route. The key to advancing the live vaccine concept for possum fertility control research to reality will be adequate funding to put these two components together. Following the closure of the Possum Biocontrol Outcome Based Investment funding stream (OBI) last year, this proof of concept research has been funded by Landcare Research. The challenge is to secure ongoing funding to support the research needed to move the fertility control vaccine from concept to reality.

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Flooded rice paddies in Cambodia.

Reviewing control options for rats in South East Asia

Over the last few years, Wendy Ruscoe has been contracted by the Australian Centre for International Agricultural Research (ACIAR) to undertake end-of project reviews for 'rats-in-rice' projects funded by ACIAR for:

- A systems approach to rodent management in upland environments in Lao
- Farmer-based adaptive rodent management, extension and research in Cambodia
- Implementation of rodent management in intensive irrigated rice production systems in Indonesia and Vietnam.

The aim of all these projects has been to reduce the damage done to rice and rice stores by native pest rodents. Wendy reviewed both the science and management recommendations in collaboration with the project scientists. The projects included ecological understanding of rodent biology, reproduction and movement in cropping systems and how this knowledge has been used to better manage pest rodents with traditional (non-poison) methods which conserve non-pest species. The control practices developed by the scientists involve whole-community actions timed to the biology of the rats and the cropping cycle. Wendy travelled to the rice-growing communities to ask them (1) how methods of rodent control had changed over the duration of the project, (2) if the amount of rice they were able to grow and store had changed, and (3) how increased production had changed their lives. Farmers spoke of increased food for their families, less money being spent on poisons, and increased community awareness as community members had to work together in their fight against rats.

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Analysing samples for vertebrate pesticides

Landcare Research's toxicology laboratory specialises in analysing environmental samples for traces of vertebrate pesticides, in particular 1080, cyanide and brodifacoum. Its clients typically include local authorities, pest control companies, other laboratories, government departments and universities, but it also analyses samples for international clients.

Biological samples coming into New Zealand are subject to permits from MAF, and the laboratory is experienced in facilitating these arrangements with clients with appropriately accredited containment. Samples to date have been highly varied and have included innocuous plant material, meat baits, rat and dog urine, mouse whiskers, blood and liver tissues, whole crabs and horse stomach contents. In particular, overseas clients recognise the laboratory's long history and experience in analyses for 1080 and anticoagulant rodenticides in vertebrate tissues, water and soil samples.

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Lynn Booth analysing samples in the lab.

Alternatives for the control of mammalian pests in Tasmania

In 2006, a team led by Bruce Warburton reviewed the research needs of a programme established to determine alternatives to 1080 for the management of browsing damage by mammals in Tasmania. The team identified a number of key research projects and these formed the basis of a 4-year, $4 million research programme funded by the Tasmanian State Department of Primary Industries and Water.

Between March 2010 and August 2011, Dave Morgan was contracted to conduct an independent review of the research undertaken. He reported that the programme had invested in a wide range of relevant research and extension to meet its strategic objectives, and had delivered good-to-excellent value for money on all investments despite the influence of a number of powerful constraints (e.g. the short-term and broad focus of the programme, the complexity and variability of affected ecosystems, and public disapproval of lethal control). The most significant achievements of the programme were:

- A better understanding of the utility of existing control options (fencing, shooting, and trapping) based on refinements in techniques, assessment of costs, and production of 'best practice' information
- The trialing of Feratox, a cyanide-based pesticide for controlling wallabies
- Quantification of the relationship between native browsing mammals and damage on farmland
- Growing recognition of the need to manage browsing mammals at a landscape scale.

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Illustrating the difficulty of managing Bennett's wallabies in the farming landscape, this exclusion grid initially worked, but over 2 months many wallabies learnt to avoid it by crawling around the terminal fence posts. Wings (as shown) were attached to the posts, but within a week a large number of wallabies had learnt to crawl across the grid.

Rat versus rat to prevent re-invasion

At present, invasive black (ship) rats occupy patches of remnant native bushland around Sydney Harbour. They are hosts for the lungworm *Angiostrongylus cantonensis*, which can also infect humans, and they prey on a variety of Australian native species in the same way they cause major ecological problems in New Zealand. Although local control of rats is technically feasible, the benefits of control are lost rapidly due to reinvasion from surrounding suburbs. Professor Peter Banks and his team from the University of Sydney, with input from Andrea Byrom and Roger Pech of Landcare Research, are experimenting with a novel solution to this problem. The idea stems from PhD research conducted several years ago by Vicki Stokes (supervised by Peter Banks, Roger Pech and Dave Spratt) who showed that competition between black rats and native bush rats is very evenly balanced. The species that gains a temporary advantage in occupying an area is able to hold its ground indefinitely. So, in July–August this year, black rats were removed from four sites around Sydney Harbour. In mid-August, bush rats from a nearby national park were translocated to the removal sites and over the next year their ability to repel invading black rats will be monitored using a combination of techniques including chewcards, cameras, and live-trapping. If successful, the experiment will demonstrate how using, or perhaps enhancing, the competitive ability of native species can result in long-term, sustainable exclusion of invasives from urban areas without the need for poisons or traps.

For more information on the Sydney Bush Rat project, visit: http://www.sydneybushrats.com/

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Andrea Byrom

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