Integrating the management of introduced mammal pests of conservation values in New Zealand

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Thirty-one species of mammals have established wild populations in New Zealand since humans arrived ca 1,000 years ago. Some are implicated in the extinctions among the native biota, many are still causing changes to native ecosystems, and a few cause significant economic losses. This paper summarises the general nature of pest problems and the current framework for managing pests of conservation values in New Zealand. It then discusses some options to better integrate within and between the policy, strategic and tactical levels of the management framework. Appropriate integration will improve outcomes when dealing with pest species affecting many different conservation resources.

Key words: introduced mammals, New Zealand, integrated management, pests, pest control, conservation

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The New Zealand archipelago extends from the Kermadec Islands at 29°S to Campbell Island at 52°S. It is made up of over 700 islands of over 1 ha with the North (112,000 km²) and South Islands (139,000 km²) being the largest. Its native biota consists of ancient continental species and the typical insular, fragmented biota that have evolved and arrived since the main islands separated from Gondwanaland 80 million years ago. New Zealand also has a growing number of exotic species that arrived with humans beginning about 1,000 years ago. The result is that New Zealand is now probably more biologically diverse than it has ever been, e.g. with 90 of 256 extant species of terrestrial vertebrates and 1,893 of 3,884 extant species of higher plants being exotic. However, this increase has been at the expense of global biodiversity as many native species have become extinct, particularly birds and amphibians, which have lost about 50% of their pre-human species (Holdaway 1989).

Some of the 31 species of wild and feral mammals introduced by people (King 1990) have been a significant factor in these extinctions. Fortunately, the probability of new mammal species establishing wild populations in New Zealand is low. The last deliberate introductions for release into the wild were made in 1907 when chamois *Rupicapra rupicapra* and rusa deer *Cervus timorensis* were released. The risks are unknown, but probably low, that new mammal species will establish wild populations from escapes by domestic animals such as llama *Lama glama* or pets such as chinchilla *Chinchilla brevicaudata* now held legally in the country. The risks from illegal introductions, or from accidental introductions from shipwrecks or from animals stowing away in cargoes are also low. Unfortunately, the process of dispersal within New Zealand, both natural and human-assisted, of many of the current species is an ongoing problem (Fraser 1994), and in general nearly all the remaining native ecosystems (ca 40% of the country, with most of this in conservation reserves) continue to suffer from the impacts of exotic mammals (Rogers 1995). A few mammal species are also significant pests of production values and these are actively controlled by landowners with varying degrees of assistance from Government agencies. For example, European rabbits *Oryctolagus cuniculus* are a major problem in drier pastoral areas (Williams 1993), and brushtail possums *Trichosurus vulpecula* are a primary vector for spreading bovine tuberculosis to domestic stock (Livingstone 1993).

On the positive side, New Zealand has had considerable success in eradicating exotic mammals from smaller islands (Veitch & Bell 1990), and has protected some conservation and production values by control sustained for many decades of some pest populations on the main islands (e.g. Parkes 1990, Williams 1993). Further, New Zealand has recognised its international responsibilities

to protect indigenous biodiversity (Anon 1995a) and is allocating increasing budgets to agencies, such as the Department of Conservation (DoC), for pest control.

This extra money is welcome but insufficient to deal with all pests on all land with conservation values. This paper explores some of the issues that need to be integrated in a general planning framework if the national conservation benefits of pest control are to be maximised.

Management and control of pest species

The nature of pest problems

A prerequisite for successful pest management is that decision makers understand the overall nature of the problem. All pest problems have four interacting elements: a resource, a pest that adversely affects it, people who value the resource, and people who manage the pest. The relationships between resources and pests (impacts) require answers to basic questions such as "is the animal really a pest?" and "how does the number/quality of the resource change as pest numbers change?". The relationships between pests and people (pest management) determine how pests are controlled and whether the costs are justified by the assumed benefits to the resource. The relationships between people (everyone with an interest) and resources require answers to the social and economic questions of who values the resource, who benefits from pest control, who exacerbates pest problems, and therefore who pays?

The history of pest control in New Zealand (and elsewhere) is littered with pest programmes that failed or were not sustained because one or more of these elements were misunderstood or ignored. For example, in New Zealand past deer (mostly *Cervus elaphus*) control campaigns misunderstood the nature of their impacts (Caughley 1989), and past rabbit control first demanded an impossible strategy of eradication, and then allowed one group of beneficiaries (pastoral farmers) to control the use of budgets provided by a wider group of beneficiaries (taxpayers) (Williams 1993).

Current legal system

Before the late 1980s, most New Zealand policies and laws on pest control focused on the pests and how to control them. This focus often led to poor results as managers mistook means for ends, and goals were framed largely in terms of operational success rather than in terms of any benefits. Goals that were related to resource protection were usually stated in such vague terms (e.g. 'wise land use') as to be immeasurable and so useless as a guide to success or failure (Caughley 1989). The New Zealand DoC was formed in 1987 and its new Act, the Conservation Act 1987, stresses that indigenous resources be preserved and protected. This implies that introduced biota are pests only where and when they adversely affect valued resources and thus the Act requires managers to measure the success or failure of pest control explicitly in terms of benefits to the resource.

Current management systems for control of conservation pests

Five planning and budgeting frameworks for pest control are currently used to control pests on the conservation estate.

Island eradications

About 100 mammal populations have been eradicated from the 700 islands in New Zealand (Veitch & Bell 1990). In the past islands or pests were targeted as much by the enthusiasm of individuals as by any formal plan. With increasing confidence of success due to new technologies and experience, DoC now has formal plans that prioritise the eradication of mammals from islands (e.g. Anon 1995b). This system will be terminated by success as New Zealand is rapidly running out of islands on which eradication is possible, i.e. islands where reinvasion is not certain.

National pest species plans

Control operations, mostly against herbivorous mammals, were conducted for many decades by Government agencies. Currently, control operations against feral goats *Capra hircus*, possums, and Himalayan thar *Hemitragus jemlahicus* are conducted by DoC under national plans. Each species has a tagged annual budget (NZD 3.7 million for goats, NZD 10.5 million for possums, and NZD 0.1 million for thar in 1995/96; NZD 1 = USD 0.68). The process used for the national goat plan is typical. All 500 discrete areas of conservation estate known to have feral goats (20,000 km^2) were ranked, and the tagged annual budget allowed control to be continued or begun in 150 of these areas (about 10,000 km^2). To date, 14 populations have been eradicated in 39 operations that specified this as a strategic goal (Parkes 1993a).

Single species conservation

The Department has categorised at least 96 plant and 194 animal species as threatened, using the IUCN Red Data Book categories of risk (Molloy & Davis 1992). To date DoC has developed 44 Threatened Species Recovery Plans that include identification of threats such as mammalian pests, and allocates a significant (but unmeasured) part of its annual budget of about NZD 15 million for threatened species to related pest control. The single pro-

tected species system arose from projects developed by the now-disbanded Wildlife Service, an agency that had few land managing responsibilities. Its successor, the Department of Conservation, manages 30% of the country and this change in role has engendered an ongoing debate on how to prioritise the at-risk species for *in situ* or *ex situ* protection, and how to integrate this system with wider ecosystem management goals (e.g. Towns & Williams 1993).

Mainland 'islands'

The Department has successfully protected endangered species, such as the wattled crow *Callaeas cinerea* by intensive control of mammals that compete for food (goats and possums) or prey on the birds (ship rats *Rattus rattus* and possums) (Innes et al. 1995). The Department intends to expand this system of highly managed mainland sites, and currently has 14 areas (from 100 to 5,000 ha) under consideration for both pest control and reintroduction of native biota. The intensity and technical difficulty, and thus expense, of the control means that only small areas can be treated. There is also ongoing debate between the idealists who wish to see all introduced biota eradicated or controlled at each site (Lynch 1995) and the pragmatists who wish to see just the critical or worst pests eradicated or controlled, and therefore more sites managed (Parkes 1993b).

Control by other agencies

Some mammals on the conservation estate are seen by some people as resources rather than pests (e.g. deer, feral pigs *Sus scrofa*, Himalayan thar, chamois). Hunting by recreational (Nugent & Fraser 1993) or commercial (Parkes et al. 1996) hunters is sometimes sufficient to reduce mammal populations enough to protect conservation values. Other mammals on the conservation estate (e.g. possums and rabbits) are controlled by neighbouring landowners or other central or regional government agencies because they impose external costs on adjacent land. For example, Government allocates the Animal Health Board (an agency charged with eliminating bovine tuberculosis from domestic stock) an extra NZD 7.9 million per year to control possums on the conservation estate.

Discussion

Integrating the systems

If DoC could start afresh, the four pest planning systems it uses could be integrated by selecting the places with the best conservation values and controlling the critical pests at each. The Department cannot start afresh but some pragmatic rules can be used to at least integrate future decisions on which pests to control where. For example, the biophysical system to be managed can be mapped as a series of spatial layers and the varying degrees of coincidence of resources, pests, and management constraints used in making decisions. For example:

- The distribution of resources to be protected must be the base layer against which all other decisions are made. Ecosystems with a predominant indigenous character are patchily distributed within New Zealand's man-made ecosystems of introduced pastures, crops, urban areas, and exotic forests often with few native species. The native ecosystems vary from tiny remnants as 'islands' in seas of exotic ecosystems to large, landscape-scale areas. The Department has systems to rank threatened species (Molloy & Davis 1992) and places (Parkes 1993a) and is currently attempting to develop a generic system to rank ecosystem, habitat, and species values under various threats (T. Stephens, pers. comm.).
- Pest species (and other threats) are also distributed at different scales. Some mammals are almost ubiquitous in all habitats (e.g. possums), others are widespread but patchily distributed in many habitats (e.g. feral goats), others are widespread but only in some habitat types (e.g. hares *Lepus europeaus* in grasslands), and others are localised (e.g. feral horses *Equus caballus*). A partial integration is achieved among the 'national pest species' feral goats and possums by applying rules of coincidence using the ranking decisions on feral goat control as the base map against which to decide between potential possum control operations at otherwise equally valued/threatened places. For example, possums would be controlled in places of equal value but without goats before places with goats under control before places with uncontrolled goats. Goats form the base map because they are patchily distributed, more manageable than possums, and are arguably worse conservation pests than possums (Parkes 1993b).
- The technical and logistical limitations of control technologies and the biology of the pest species (e.g. rates of increase, dispersal) impose scales of manageability on each pest species.
- Since DoC is not starting afresh, the history of control needs to be considered when making decisions.

Integration of pest control between agencies depends on the spatial and temporal coincidence of their separate problems, e.g. the presence of highly valued or threatened conservation resources and bovine tuberculosis.

Strategic integration

Pest control strategies, in the sense used here, are distin-

guished by the need, or not, for ongoing control action to protect the resource, i.e. where a single management action or set of actions with a definite end point results in the permanent protection of the resource, or where the control action must be sustained in perpetuity to protect the resource, or where no action is possible or justified. Strategic integration only makes sense where the effects of control actions against a pest are additive and necessary to achieve goals.

One-off actions

The best solution is to ensure that no problem exists by keeping pests out of the country or stopping their spread within the country. Border control is relatively easy for an island nation such as New Zealand, but the inability of Government to regulate the legal importation of exotic biota not specifically excluded, e.g. chinchilla, led to the development of a new law, the Hazardous Substances and New Organisms Act, to regulate the importation of new biota. It is illegal to capture and release mammals already in New Zealand. Such releases have little biological consequence for ubiquitous pests, but control agencies attempt to ensure that patchily distributed species are not liberated into new areas, and species restricted to one island are not moved to another (e.g. Himalayan thar and chamois are only in the South Island, while dama wallabies *Macropus eugenii* are only on the North and Kawau Islands).

Eradication of a pest population requires that all animals can be put at risk, that they can be killed at a rate faster than their rate of increase at all densities, and that there be no immigration (Parkes 1990). Eradication is often proposed as an idealistic policy, irrespective of its practicality, to reinforce the negative status of exotic animals (e.g. Lynch 1995) or to encourage managers (e.g. Coman 1993). Such policies have been rejected in favour of more pragmatic ones in New Zealand (Holloway 1993) and Australia (O'Brien & Braysher 1995) largely because their attempted implementation precludes feasible options.

Biological control and habitat manipulations may also give permanent benefits for the single action of introducing a control agent or changing the habitat in some way to make it less suitable for the pest.

A one-off strategy of last resort is to remove the resource from the pest. For example, New Zealand managers removed endangered birds, such as the kakapo *Strigops habroptilus*, to cat-free islands when they could not eradicate feral cats *Felis catus* from the area with the last remnant population of the parrots (Powlesland 1989).

Sustained actions

If the pest problem cannot be solved by a single management action, managers are left with the strategically complex option of sustained control. Unlike one-off options, sustained control requires a much fuller understanding of the nature of the problem if the control is to succeed. At a minimum managers must be able to:

- Identify the pest/resource relationship to determine how few pests is few enough to protect the resource but avoid killing more than is necessary. Overkill has opportunity costs because of increasing marginal costs of control at low densities (e.g. Hone 1990).
- Identify the pest/control relationship to determine the frequency and intensity of control required.
- Organise potential control agents, e.g. recreational hunters (Nugent & Fraser 1993), commercial hunters (Parkes et al. 1996), or official control agencies, and apply the appropriate control techniques.
- Measure the response of the resource to known management to check that the right pest has been targeted (e.g. see Caughley (1994) for an example of misdirected control of pests on Lord Howe Island), and to ensure budgets are justified and sustained.

Generally, few of these factors are known *a priori* and managers must rely on careful monitoring or research-by-management to adjust plans and future actions.

Tactical integration

The choice of methods available to control pest species varies widely but all methods come with inherent constraints (e.g. cost, efficacy, social acceptability) with the optimum frequency and intensity of actions determined by the pest/resource relationship. A common flaw in pest management is to let the technical constraints on preferred (e.g. cheapest) control methods determine the frequency and intensity of their use.

Options for tactical integration exist where a single control method kills several pests. This integration does not necessarily continue at the strategic level of frequency and intensity of action unless all the pests are eradicated (e.g. both the target rabbit population and mice *Mus musculus* were eradicated by poisoning with pindone baits on Enderby Island in the subantarctic), or the frequency of ongoing control required is the same for all species or driven by that with the largest intrinsic rate of increase. For example, aerial poisoning using 1080 baits for possum control also routinely reduces ship rat populations by over 90% (Innes et al. 1995). Tactical integration is restricted to this initial control phase as the rodents recover within a few months while the main target usually takes several years to reach unacceptable densities.

Table 1. Estimated budget (in NZD million) spent on and distribution (in km^2) of mammalian pests controlled by the New Zealand Department of Conservation in official control operations during 1995/96.

Pest species	Estimated budget	Area with pest (km^2)	% area controlled in DoC operations
Possum *Trichosurus vulpecula*	11.1	270,000	10%[1]
Feral goat *Capra hircus*	3.6	30,000	30%
Red deer *Cervus elaphus*	0.1	90,000	5%
Rabbit *Oryctolagus cuniculus*	0.5	150,000	1%[1]
Himalayan thar *Hemitragus jemlahicus*	0.1	7,000	10%
Predators (mustelids and cats)	unknown[2]	270,000	<1%
Rodents (four species)	unknown[2]	270,000	<1%

[1] Excludes areas where possums are controlled by other agencies for bovine tuberculosis control, and where rabbits are controlled as agricultural pests.
[2] Pest control costs cannot be separated from the Threatened Species or Island Management budgets.

Logistics

Annual national budgets allocated for control of conservation pests in New Zealand are little influenced by any cost-benefit analysis, i.e. given a resource to protect from a pest how much money should be spent to maximise benefits, but fluctuate with political priorities. Currently pest control is given increasing priority but still budgets are sufficient to act against only a few pest species in a few places (Table 1). Managers must therefore use a cost-effectiveness approach to allocate these budgets, i.e. given NZD x where should it be spent to maximise benefits? The risks inherent in fluctuating national budgets for pest control can be reduced by estimating the likely minimum annual budget, from past years, and allocating this to the highest priority sustained control operations. Budgets over this minimum can be divided between operations requiring one-off strategies and lower-priority sustained control operations with a risk of the latter being abandoned.

Conclusions

Planning systems to protect indigenous ecosystems from the multitude of threats they face in New Zealand has proved a difficult task even when impacts are understood and techniques are available to remove or manage the threat. Some of the lessons learnt or being learnt over the past 150 years are:

- It is best not to take risks and keep potential pests out of the country.
- Few pest operations will be sustained unless those who pay are those who benefit.
- Pragmatic strategies are better than idealistic ones.
- Complete integration across all species will maximise local benefits at the expense of national benefits.

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