POSSUMS AS CONSERVATION PESTS

Proceedings of a Workshop on Possums as Conservation Pests
organised by the
Possum and Bovine Tuberculosis Control
National Science Strategy Committee

Christchurch, New Zealand
29 – 30 November, 1994

Compiled by
Colin F. J. O'Donnell

1995

PO Box 10-240
Wellington, New Zealand

ISBN 0-478-01670-0

National Library of New Zealand
Cataloguing-in-Publication data

Possums as Conservation Pests (1994 : Christurch, N.Z.)

Possums as conservation pests : proceedings of a workshop on possums as conservation pests organised by the Possum and Bovine Tuberculosis Control National Science Strategy Committee, Christchurch, New Zealand 29 – 30 November, 1994 / compiled by Colin F. J. O'Donnell. Wellington, N.Z. : Dept. of Conservation, 1995.

1 v. ; 30 cm

ISBN 0478016700

1. Trichosurus vulpecula--Control--New Zealand. 2. Pests--Control--New Zealand--Congresses. I. O'Donnell, C. F. J. (Colin F. J.), 1958- II. National Science Strategy Committee on Possum/Bovine Tuberculosis Control. III. Title.

599.20993 20

zbn95-13813

Prepared by Science & Research editor Lynette Clelland.
Cover design by Erika Mackay.

CONTENTS

SUMMARY

A workshop on the role of possums as conservation pests was run by the Possum and Bovine Tuberculosis Control National Science Strategy Committee in Christchurch between 29 and 30 November, 1994.

The workshop examined issues relating to four main questions:

1. What effects are possums having?

2. How best to spend possum control monies to achieve most conservation goals?

3. Can damage thresholds be identified?

4. How can possum control technologies to protect conservation values be improved?

Background papers were presented and major issues and information needs and broad research priorities were identified for each question.

RECOMMENDATIONS

Effects of possums

1. Long term studies are needed if the impacts of possums on conservation values are to be understood, as effects take many years to demonstrate.

2. The relative role of possums as predators of, and competitors with, indigenous flora and fauna, and their relative impacts compared with other pests needs investigation.

3. The value of using, and suitability of, key indicator species to identify and monitor possum impacts on ecosystems needs to be assessed. Basic research on ecosystem ecologies is still required to identify potential indicator species.

4. Social research is needed to evaluate how the public perceive the impact of possums on New Zealand ecosystems.

5. There is a need for computer models which predict impacts of possums on all aspects of forest ecosystems.

How best to spend conservation monies

6. Some fine tuning of the current system for identifying priority areas for possum control is needed.

7. The concept of ecological scalars for assessing costs and benefits of possum control operations should be investigated, with the hope that a single, cumulative, index can be developed.

Identification of damage thresholds

8. Considerably more data on native species responses are required, and more research by management is needed to determine the effects of possum control operations on the species and ecosystems being protected.

9. Complementary research approaches which blend both long and short term studies, and empirical and predictive models, are needed to identify rigorous damage and intervention thresholds with which to guide management.

10. Improved tools are needed for measuring ecosystem health.

Development of control technologies

11. Further research on developing and refining existing control techniques and assessing new techniques is required.

12. Social research is needed to determine the status of public understanding and acceptance of control technologies.

13. Research is needed on the effectiveness of multispecies control regimes.

14. Research is needed on integrating control techniques.

INTRODUCTION

The aim of this workshop was to co-ordinate and identify the research needed to reduce the threat of the introduced brush-tailed possum (*Trichosurus vulpecula*) to native forest ecosystems, wildlife and threatened species. The meeting was the fourth run by the Possum and Bovine Tuberculosis Control National Science Strategy Committee, but the first to look at possums as conservation pests. Possums are a major threat to conservation in New Zealand, browsing on native vegetation, and preying on native wildlife.

The workshop examined issues relating to four main areas:

1. What effects are possums having?

2. How best to spend possum control monies to achieve most conservation goals?

3. Can damage thresholds be identified?

4. How can possum control technologies to protect conservation values be improved?

Dr Richard Sadleir, Director of the Department of Conservation's Science and Research Division welcomed participants and chaired the workshop.

The Hon. John Falloon, Minister of Agriculture, stressed the importance of developing alternative strategies for possum control. Government is very concerned with the threats possums pose. They are an "ecological time-bomb", damaging the environment to unacceptable levels. The Ministers of Science, Conservation and Agriculture are working closely on the issue. There is a strong need also for Government Departments, Regional Councils, farmers and the public in general to work together. It is important to develop a comprehensive strategy from all interested sectors to see if we can carry out effective control faster. Public advocacy cannot be under-emphasised.

Mr Mike Cuddihy, Regional Conservator, Department of Conservation, Canterbury, welcomed participants to Christchurch and the workshop. He posed two issues for participants to consider during the workshop. Firstly, how close are we to losing the use of chemicals to control the massive threat of possums? The public rightly perceive that contaminants in the environment are bad, and they need to be actively assured about the use of 1080. Secondly, Mr Cuddihy emphasised the need for research to be aimed at guiding and assisting conservation managers in their day-to-day operations. Possums are both nest predators and competitors for food. Mr Cuddihy cited the example of the Chatham Island parea (pigeon) as a successful example of predator and browser management. Parea have increased from less than 10 to over 150 in the Tuku area on Chatham Island since management started. However, further improvements in the effectiveness of operations id needed – the efficacy of control could still be improved and significant cost savings made.

Proceedings of a Workshop on Possums as Conservation Pests. Possum and Bovine TB Control NSS Committee
29 – 30 November 1994, Christchurch

EFFECTS OF POSSUMS ON THE NATIVE FLORA

Graham Nugent

Manaaki Whenua – Landcare Research, P.O. Box 31-011, Christchurch.

INTRODUCTION

Possums are seen as a conservation pest because they "damage" (change) the structure and composition of native ecosystems, particularly forests. For forest conservation the three fundamental questions are **"What needs protection?", "When does it need it?"** and **"How much protection does it need?".** This paper deals primarily with the first question, and focuses on vegetation change in two contexts – the nature of the possum impact process, and the relative susceptibility of communities, species, and individuals to possum browse. Key knowledge gaps are identified.

OVERALL IMPACTS

Possums apparently consume about 21,000 tonnes of vegetation per day (presumably 300 g wet wt. consumption x 70 million possums). This oft-quoted figure is frequently used to depict possum as a rapacious consumer of all things green, but that implication ignores the daily foliage production of 300,000 tonnes for forests alone (7.5 million ha x 15 tonnes wet wt of foliage/ha/yr). These "back-of-a-cigarette-packet" calculations are consistent with data on foliage production and use in podocarp-hardwood forest at Waihaha, West Taupo – the possum population there uses only a few percent (<15%) of the annual foliage production of any of the 15 most common plants, including totara, kamahi and toro (their main foods; Fig. 1; unpubl. data). Possums do not threaten total (national) deforestation – for the bulk of New Zealand's forest, the process is one of compositional rather than structural change.

IMPACT PROCESSES

There are three broad impact processes:

Figure 1 Annual production and use of foliage by possums for the 16 most common plant species at Waihaha, West Taupo.

Catastrophic dieback: Dieback of all or most of a forest canopy over a short period is undoubtedly the possum impact process with the highest public profile. Historically, most research and management has been directed at understanding and ameliorating this process, which affects forest dominated by just a few possum-preferred species, such as the *Metrosideros* and/or kamahi dominated forests of Westland and elsewhere (Batcheler and Cowan, 1988). The relationship between dieback and the timing of possum invasion has been subject to much debate (Veblen & Stewart, 1982; Batcheler, 1983), but there now appears to be little dissent from the notion that catastrophic dieback is typically (but not always) caused by possums about 15-25 years after they colonise an area (Batcheler and Cowan, 1988; Rose, Pekelharing & Platt, 1992), which is about when their numbers reach an unsustainably high peak before dropping to lower levels (the irruptive oscillation; Thomas *et al.* 1993). Susceptibility to catastrophic dieback varies between areas, depending on factors such as stand history, age, diversity, substrate type, and landform (Leutert, 1988; Payton, 1987).

Key questions are whether catastrophic dieback would still occur if the irruptive peak could be flattened or eliminated (or would dieback still occur as numbers built back up to the sustainable carrying capacity after control?). Would the impact process convert from catastrophic dieback to one of much more gradual canopy depletion, but with much the same long-term result? Are the few remaining relatively unmodified forests (mainly in the northern half of the North Island) predisposed by composition and other factors to catastrophic dieback? Arguably, however, so few unmodified areas remain that there is now little point in improving our understanding of that process in a generic sense, particularly since outcomes are likely to be area-specific.

Gradual depletion: In more diverse communities with a greater mix of palatable and unpalatable species the main initial impact process is one of gradual, possibly episodic, depletion. Possums selectively remove some species over many decades, resulting in compositional shifts (Campbell 1990). The greatest shifts are likely in mixed broadleaf forests in which possum-preferred species are abundant, but even in the least susceptible forests type some minor species disappear (e.g., mistletoes in beech forest). Gradual depletion probably also continues in areas where catastrophic dieback has occurred, but which still contain preferred species in canopy remnants.

One case study is in Orongorongo Valley, where possum numbers have been stable over the last 25 years, and possibly since the 1940s (M. Efford pers. comm.), yet since the 1940s many of the most favoured foods such as fuchsia and titoki have virtually disappeared from the diet (Fitzgerald, 1976) and many have declined in abundance in the forest (Campbell 1990). Kamahi and tawa have continued to decline since, but others are increasing (Fig. 2; J. Alley, unpubl. data). For northern rata at least, the depletion process appears to have been episodic rather than continuous – Meads (1976) documented a spate of mortality in the early 1970s, but few have died since.

The key question is whether the process continues indefinitely until all possum-preferred species are completely eliminated, or whether some equilibrium is reached in which at least some possum-preferred species remain as a substantial component of the forest. Obviously possums can only persist if adequate forage is available, and if all forage was foliage, then carrying capacity might be determined by the attainment of an equilibrium between production and use. However possums do not use all available forage uniformly, even within species – an individual rata tree can be completely defoliated, but its neighbour untouched until later (Leutert 1988). Thus although the population as a whole might withstand possum browsing if it were spread evenly across all species, depletion continues because individuals within species are selectively targeted. In addition, possums can rely

Figure 2 Changes in the number of stems >30 cm dbh on a permanent plot in the Orongorongo Valley between 1969 (shaded bars) and 1994 (black bars).

heavily on fruit and flowers (Cowan 1990), which in some situations may sustain the population at levels significantly above that sustainable by foliage alone. For example, the abundance and extensive use of hinau fruit in the Orongorongo Valley might underpin the moderately high densities of possums there (7/ha; M. Efford, pers. comm.) compared to the 3/ha we find in mixed broadleaved-conifer forests in Waihaha or Hunua (unpubl. data). If fruit availability results in a higher post-peak carrying capacity, then the progressive depletion could well continue much further down the list of candidate species, particularly where the abundance of the fruit-producing species is not itself under threat, or is even increasing, as a result of possum browsing (eg. the numbers of established hinau are increasing in the Orongorongo valley, rather than decreasing, J. Alley, unpubl. data). Our lack of understanding of the nutritional and non-nutritional factors limiting post peak possum densities is, in my opinion, one of the major information gaps.

Inhibition of regeneration: Management and research to date has focused primarily on the fate of existing or established trees. With the majority of areas already heavily modified, however, it is clear that recovery from present damage must ultimately depend on providing adequate protection of the desired regenerative processes. Possum impacts on regeneration are poorly understood – on Kapiti Island, Atkinson (1992) reports possum browsing and killing of northern rata, tawa, and fuchsia seedlings, although a few specimens of each typically persisted. The paucity of information is partly the consequence of the historical focus on the much more immediate and obvious changes in canopy condition, but also because they are typically confounded and not easily separated from those of ungulates (deer, goats, chamois) which are almost universally sympatric with possums. If ungulates are present in moderate to high numbers regeneration of most possum preferred species is suppressed, but some such as kamahi can regenerate profusely after dieback if ungulates are absent (e.g., Allen & Rose 1983), and many establish readily as seedlings and saplings within exclosures that exclude ungulates but not possums (Nugent, 1992). For the few possum-preferred species that are not palatable to ungulates, such as totara, possums do not appear to affect the growth of young seedlings (unpubl. data).

Key questions are therefore how (or whether) possums affect regeneration (including flowering and seeding) of preferred plants, and for those not severely affected early in their life histories, whether possum impacts become severe before the species reaches an age at which it produces sufficient seed to perpetuate the species. Answers will clearly vary between species, and between communities and areas (again depending largely on mix of species present and on possum carrying capacity).

SUSCEPTIBILITY

Differences between communities: The relative susceptibility of various forest types has now been largely identified by history. At one extreme, possums have little affect on simple beech forest with few preferred species, and at the other, cause catastrophic dieback or major compositional shifts in *Metrosideros*- and/or kamahi dominated types. The only major uncertainty is perhaps the susceptibility of the diverse and unique forests in Northland (where possum have only recently colonised).

For the most severely affected communities, the key issue is whether the change is reversible (i.e., whether possum removal would result in the forest returning to the original type or continue to develop into some alternative type). The research needed includes further development of conceptual and predictive models of forest development, and, as noted above, far better understanding of the effects of possum browse on existing trees and on the regenerative ecology of individual species.

Differences between species: Again, the species most threatened by possums are now well known, and probably fall into two main groups: (i) common species that are major stand components and whose loss or severe diminution in abundance fundamentally changes the nature of the stand or community (e.g., Kamahi, *Metrosideros* spp, fuchsia, totara, kaikawaka); and (ii) species that are rare and could be driven to local or national extinction by possums, such as some mistletoe species and *Dactylanthus*.

For some commonly browsed species, the impact of possums is not yet certain. For totara, for example, possums are implicated in their dieback, but totara in areas without possums are also often in poor health, and possums do not appear to affect totara seedlings. Tawa is another canopy dominant for which the picture is not entirely clear.

Differences within species: Some species vary widely between areas in their apparent ability to tolerate possum browse – fuchsia in the eastern South Island appears far less palatable to possums than fuchsia elsewhere (Batcheler 1983), and the less palatable forms have lower nutrient concentrations than more palatable forms (P. Sweetapple, unpubl. data). It is not yet clear whether this variation is genetic or phenotypic, but if browse tolerance does have a genetic base, then concern for the long-term survival of threatened species is lessened. Issues arising are whether the loss of genetic diversity within a species is of sufficient conservation concern to warrant possum control, and whether it is appropriate to hasten the spread of browse tolerant forms.

RESEARCH DIRECTIONS

Funding for conservation is scarce. It is therefore critical to identify not only what is threatened but the severity of the threat. It is also critical that we identify which of the threatened species is most valued by the community and why. The ecological research suggested below therefore needs to be underpinned by sociological research, and by the development of a unifying theoretical framework that combines the principles of biodiversity conservation with community values to identify the priorities for protective action.

The four main "impacts" questions, in my opinion, are:

1. Why do possum impacts vary so widely between areas, through time, and within species?

- What determines "post-peak" carrying capacity and, consequently, how does that affect the severity or length of the impact process?
- What determines the variation in browse tolerance apparent for some key species?

2. What impacts do possums have on regenerative processes?

- How are possum impacts on flowering, seeding, and seedling growth modified by the presence of ungulates and rodents?

- Is it more important to protect regenerative processes than to save existing trees?

3. **What are the long-term consequences of inaction (i.e., no control)?**
   - What communities and species are threatened long-term? and how severely?
   - When is compositional change likely to stabilise?
4. **Is the compositional change reversible?**

The relationship between possum impacts and their density when the population is controlled is also of key importance, but is not discussed here.

REFERENCES

Allen, A.B. & Rose, A.B. 1983. Regeneration of southern rata (*Metrosideros umbellata*) and kamahi (*Weinmannia racemosa*) in areas of dieback. *Pacific Science* 37: 433-42.

Atkinson, I.A.E. 1992. Effects of possums on the vegetation of Kapiti Island and changes following possum eradication. Contract report for the Director, Science and Research, Conservation Sciences Centre, Department of Conservation. DSIR Land Resources Contract Report No. 92/52. 68 p.

Batcheler, C.L. 1983. The possum and rata-kamahi dieback in New Zealand: a review. *Pacific Science* 37: 415-26.

Batcheler, C.L. & Cowan, P.E. 1988. Review of the status of the possum (*Trichosurus vulpecula*) in New Zealand. Contract report for the Technical Advisory Committee (Animal Pests), Ministry of Agriculture & Fisheries, Wellington. 129 p.

Campbell, D.J. 1990. Changes in the structure and composition of a New Zealand lowland forest induced by brushtail possums. *Pacific Science* 44: 277-296.

Cowan, P.E. 1990. Fruits, seeds and flowers in the diet of brushtail possums, *Trichosurus vulpecula*, in lowland podocarp/mixed hardwood forest, Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology* 17: 549-566.

Fitzgerald, A.E. 1976. Diet of the opossum (*Trichosurus vulpecula* (Kerr)) in the Orongorongo Valley, Wellington, New Zealand, in relation to food-plant availability. *New Zealand Journal of Zoology* 3: 399-419.

Leutert, A. 1988. Mortality, foliage loss, and possum browsing in Southern rata (*Metrosideros umbellata*) in Westland, New Zealand. *New Zealand Journal of Botany* 26: 7-20.

Meads, M.J. 1976. Effects of opossum browsing on northern rata trees in the Orongorongo Valley, Wellington, New Zealand. *New Zealand Journal of Zoology* 3: 127-39.

Nugent, G. 1992. The conservation role of commercial deer hunting. Unpublished Forest Research Institute contract report FWE 92/3. 49 p.

Payton, I.J. 1987. Canopy dieback in the rata (*Metrosideros*) – kamahi (*Weinmannia*) forests of Westland, New Zealand. Pp. 123-136 *in* Fufimori, T. & Kimura, M. (eds.). Human impacts and management of mountain forests. *Proceedings of the 4th IUFRO Workshop* P1.07-00 (1987) Forestry and Forest Products Research Institute, Ibaraki, Japan.

Rose, A.B., Pekelharing, C.J. and Platt, K.H. 1992. Magnitude of canopy dieback and implications for conservation of southern rata-kamahi (*Metrosideros umbellata-Weinmannia racemosa*) forests, Central Westland, New Zealand. *New Zealand Journal of Ecology* 16(1): 23-32.

Thomas, M.D., Hickling, G.J., Coleman, J.D. and Pracy, L.T. 1993. Long-term trends in possum numbers at Pararaki: evidence of an irruptive fluctuation. *New Zealand Journal of Ecology* 17 (1): 29-34.

Veblen, T.T. & Stewart, G.H. 1982. The effects of wild animal on New Zealand forests. *Annals of the Association of American Geographers* 72: 372-97.

THE IMPACTS OF POSSUMS ON NATIVE FAUNA

John Innes

Manaaki Whenua – Landcare Research, Private Bag 3127, Hamilton

SUMMARY

Recent examples of possums impacting on individual native animals or on their populations have come from studies of the prey rather than the possums. Basic research on selected native animal populations should be expanded. Remarkably little is known of the causes of death of native animals, including those vulnerable to possum browse, predation or killing. Partly this is because there are so few good field techniques available to the researchers who do this work. The only tool I can envisage which can possibly transform the face of this task is electronic surveillance. Creative thinkers with electronics skills outside DoC and Landcare would at present be unaware of our need for these advances. Applied developmental research in this field should be funded.

Ultimately, pest control has to be effective in a community setting, most commonly on the mainland. Single factor studies have revealed that New Zealand ecosystems are complex and interactive and so predator-prey interactions must now be studied at the community or ecosystem level. We need some well-designed large-scale community experiments focusing on integrated pest control and the responses of native flora and fauna. In this way, I predict that the impact of possums on native fauna will be seen to be considerable, but complex and variable.

INTRODUCTION

Although they are mainly herbivorous, brushtail possums *(Trichosurus vulpecula)* impact on native animals as well as plants. They can do this directly by predation, killing or disturbance, or indirectly by eating parts of plants which are also eaten by native species (competition). However the relationships between possums and the affected native species are unlikely to be simple. Possums are part of a complex biological community in which they and introduced wasps, rodents, ungulates, mustelids and feral cats are linked with native flora and fauna via food and habitat webs. Both possum browsing and possum control have repercussions for the rest of the community, which may advantage or disadvantage different native animals.

PREDATION AND KILLING

Predation implies ingestion of the prey, although possums are now known to have killed both kokako *(Callaeas cinerea wilsoni)* and brown kiwi *(Apteryx australis mantelli)* without eating them.

Cowan & Moeed (1987) found that half of the possum faeces they examined over a 5-year period from the Orongorongo Valley contained invertebrate remains, especially of the larger stick insects, wetas, cicadas and beetles. They concluded that the consumption of invertebrates was opportunistic rather than accidental, and that species most at risk were "small localised populations of large-bodied relatively sluggish nocturnal species with high detectability." Large native *Powelliphanta* snails have since proved to be such species; initially possums were unsuspected, but feeding trials finally showed that they neatly chewed through the side of the shell and removed the animal (K. Walker, unpub. data).

As with *Powelliphanta*, the recent discovery that possums kill kokako eggs and chicks came from studying the prey (kokako) rather than the predator (possums). By strong circumstantial evidence or direct observation, possums are now known to have killed eggs, chicks or adults of at least six native bird species, including kokako, brown kiwi, kahu *(Circus approximans*), fantail *(Rhipidura fuliginosa)*, N.I. saddleback *(Philesturnus carunculatus rufusater)* and kereru/kukupa *(Hemiphaga novaeseelandiae)* (Brown *et al.* 1993; H. Robertson, J. McLennan pers. comm.). Whether these are isolated events or the tip of an iceberg is yet to be determined, but then, the evidence that rats, cats or stoats are important predators at forest bird nests is also still largely circumstantial.

Why were possums not discovered to be bird nest predators until 1991? It is possible, but unlikely, that the behaviour is new. Perhaps only a few individual "rogue" possums have learned to do it. It is more likely that the chance of a human directly observing such a predation, at night and up a tree, is negligible. Furthermore, sign left after previous predations by possums may have been mistaken for that of ship rats *(Rattus rattus),* and if possums do not ingest eggshell or feathers, then this aspect of their diet will not be revealed by gut or faecal analysis. The key factor in this discovery was developing a time-lapse video system which filmed all visitors to kokako nests, by day and by night – the first time for any bird in New Zealand (Innes *et al.* 1994). Possums caused the failure of four of 19 filmed nests, and were probably responsible for 10 of 33 predations during the 4-year study.

Increased funding of application-targeted wildlife surveillance research and development would yield further breakthroughs. An example of a high priority need is a remote sensing system which immediately signals the death of an individual animal, enabling a researcher to locate it promptly and eventually determine the relative importance of different mortality agents. Even better would be a tiny implanted system which, like an aeroplane's "black box", records sufficient attributes of the animal to tell us how it died. While both DoC and Landcare Research (via Sirtrack Ltd) have creative electronics staff focusing on wildlife applications, there is huge scope for increased basic research into product development rather than manufacture.

Only by researching the fates of large samples of native bird nesting attempts in different habitats and with different predator guilds will the actual prevalence of possum predation, killing and disturbance of nesting birds become known. The requirement is just as acute for wetas, snails, lizards, non-nesting birds, and so on. More basic research is needed into the fates of selected native animals at the individual and population level.

COMPETITION AND HABITAT DESTRUCTION, BY BROWSE

The reduction in biomass of preferred food plants by possums probably deprives native animals of food and reduces their numbers. The cause-and-effect links involved in competition between possums and native animals are difficult to verify, because they are indirect.

Invertebrates are especially likely to be affected because many are dependent on one or a few plant species (Dugdale 1975). For example, pohutukawa *Metrosideros excelsa* which is browsed heavily by possums (Hosking & Hutcheson 1993) has five host-specific scale insects (R. Henderson, T. Crosby pers. comm.). Since there are some 20,000 insect species in New Zealand, cf 2,400 vascular plants and 300 birds, invertebrates contribute more than other groups to biodiversity and in fact provide the bulk of animal biomass in New Zealand forest ecosystems. Some invertebrate species are also very vulnerable to extinction, being restricted to a single habitat remnant (Ramsay *et al*. 1988).

Less directly, possum feeding may also limit bird populations by targeting fruits, seeds and flowers of plants (Cowan 1990) and so impacting heavily on the crop available to other species (Cowan & Waddington 1990).

POSSUM CONTROL IN A (BIOLOGICAL) COMMUNITY SETTING

A key question for conservation managers is: Will known prey or competitor populations increase if possums are controlled? It seems self-evident that they will, but they may not, for several reasons. The minimum possum density at which possums still limit the prey might be very small (a low damage threshold), less than that obtained by control. However prey may not increase even with possums at zero density. The control methods themselves might impact on the prey as well as the possums. Also, there may be unexpected repercussions ("ecological whiplash") from other species which complicate interpretation of the outcome.

Aerial 1080 poisoning was first used to assist kokako at Mapara (King Country) in 1990. This also killed nearly all ship rats (Innes *et al*. in press). Coincidentally, stoats *Mustela erminea* which previously mainly ate rats, then mainly ate birds after rats became unavailable (Murphy & Bradfield 1993). Murphy and Bradfield suggested that the stoats may thus have eaten more kokako as a direct result of the successful kill of ship rats, themselves probably the most frequent kokako nest predator.

Possum impact on native fauna must ultimately be researched at the community level, although studies of possum and prey individuals and populations will always be necessary to understand the bigger picture. Community responses can be researched by:

a) Eradicating possums on islands. This enables researchers to see prey response with possums at zero density, which may show a "best possible" outcome for mainland recovery. When possums were eradicated from Kapiti Island between 1980 and 1986, fruit- and nectar-eating birds increased conspicuously (Robertson & Beauchamp unpub. data). However these increases were in the absence of ship rats and stoats, two widespread predators which may alter outcomes on the mainland.

b) Moving ahead of the colonisation front. Possum populations are still pre-peak in parts of South Westland, Coromandel and Northland. This represents a good opportunity to study vegetation, invertebrates and other fauna before and after peak possum impacts occur.

c) Sustaining reduced possum density at a mainland site. Most communities in which possums are conservation pests are on the mainland, so research should focus on recovering mainland ecosystems. Fauna response to possum control on the mainland is likely to differ to that on islands, because on the mainland zero density is virtually never attained, and because mainland communities have more introduced pest predators and herbivores which are involved with interactive ecological relationships with possums.

We need more applied research at the community or ecosystem level, rather than looking at single factor relationships such as the impact of possums on seedfall, or on kokako. This is not to imply that the single factor studies have not been useful or applied, or that the researchers who did them were unaware of the complexity of the system they were studying.

Manipulating whole communities as an experiment is by necessity large-scale, longish term and expensive. There are also design constraints; traditional ideas of adequate sample size are simply impossible to implement. However there is already a big literature on ecosystem perturbations. In 1985, Sih *et al*. reviewed 139 publications describing field experiments in the fields of predation, competition and prey communities. The journal Ecology devoted an entire issue (Volume 71, Issue 6) to "Statistical analysis of ecological response to large-scale perturbations" in 1990. The SCOPE (Scientific Committee on Problems of the Environment) committee reviewed this area in a book called "Ecosystem Experiments" (Scope 45; John Wiley & Sons, Chichester, England; 1991). A necessary component of this approach is that management programmes themselves become part of a wider research agenda. Management is then regarded as testing a hypothesis rather than merely implementing an expected outcome.

ACKNOWLEDGEMENTS

I thank Bruce Burns, Trevor Crosby, Rosa Henderson, Mark Smale and Eric Spurr (Manaaki Whenua - Landcare Research); Paul Jansen, Greg Sherley, Hugh Robertson and Kath Walker (Department of Conservation) and John Hutcheson (Forest Research Institute) for help with this paper.

REFERENCES

Brown, K., Innes, J. and Shorten, R. 1993. Evidence that possums prey on and scavenge birds' eggs, birds and mammals. *Notornis* 40: 169-177.

Cowan, P. E., 1990. Fruits, seeds, and flowers in the diet of brushtail possums, *Trichosurus vulpecula*, in lowland podocarp/mixed hardwood forest, Orongorongo Valley, New Zealand. *N.Z. Journal of Zoology* 17: 549-566.

Cowan, P.E. and Waddington, D.C. 1990. Suppression of fruit production of the endemic forest tree, *Elaeocarpus dentatus*, by introduced marsupial brushtail possums, *Trichosurus vulpecula*. *N.Z. Journal of Botany* 28: 217-224.

Cowan, P.E. and Moeed, A. 1987. Invertebrates in the diet of brushtail possums, *Trichosurus vulpecula*, in lowland podocarp/broadleaf forest, Orongorongo Valley, Wellington, New Zealand. *N.Z. Journal of Zoology* 14: 163-177.

Dugdale, J.S. 1975. The insects in relation to plants. Pp. 561-589 *in:* G.Kuschel (Ed.) *Biogeography and Ecology in New Zealand.* Dr W. Junk, The Hague: 689 pp.

Hosking, G. and Hutcheson, J. 1993. Pohutukawa (*Metrosideros excelsa*) health and phenology in relation to possums (*Trichosurus vulpecula*) and other damaging agents. *N.Z. Journal of Forestry Science* 23: 49-61.

Innes, J., Crook, B. and Jansen, P. 1994. A time-lapse video camera system for detecting predators at nests of forest birds: a trial with North Island kokako. Pp. 439-448 *In: Proceedings of the Resource Technology '94 Conference*, University of Melbourne, Australia: 714 pp.

Innes, J., Warburton, B., Williams, D., Speed, H. and Bradfield, P. In press. Large-scale poisoning of ship rats (*Rattus rattus*) in indigenous forests of the North Island, New Zealand. *N.Z. Journal of Ecology.*

Murphy, E. and Bradfield, P. 1993. Change in diet of stoats following poisoning of rats in a New Zealand forest. *N.Z. Journal of Ecology* 16: 137-140.

Ramsay, G.W., Meads, M.J., Sherley, G.H. and Gibbs, G.W. 1988. Research on terrestrial insects of New Zealand. *Wildlife Research Liaison Group, Research Review* 10: 49 pp.

Sih, A., Crowley, P., McPeek, M., Petranka, J. and Strohmeier, K. 1985. Predation, Competition, and prey communities: a review of field experiments. *Annual Review of Ecology and Systematics* 16: 269-311.

LONG TERM FOREST DYNAMICS AND THE INFLUENCE OF POSSUMS AND GOATS ON KOHEKOHE (Dysoxylum spectabile) FOREST IN THE KAUAERANGA VALLEY, COROMANDEL PENINSULA. – SOME PRELIMINARY RESULTS.

John Ogden and Chris Buddenhagen

School of Biological Sciences, University of Auckland

SUMMARY

Tree recruitment, mortality and basal area growth was monitored on two 30 x 40m plots in forest dominated by kohekohe (*Dysoxylum spectabile*) in the Kauaeranga valley, Coromandel peninsula from 1984 to 1994. Kohekohe basal area has declined by 51 - 58%. The kohekohe seedling population has declined by an order of magnitude. Other species known to be palatable to possums have also declined (e.g., *Cyathea medullaris*). Tree ferns (other than *C. medullaris*) have increased in biomass (height and basal area). Overall the forest has reduced biomass by 5 to 20% in ten years. These changes are mainly a result of possum-induced mortality of the main canopy tree, kohekohe. If current trends continue the future forest will lack this species, and be of a lesser biomass, with reduced biodiversity and structure.

INTRODUCTION

Catastrophic forest disturbance through windthrow, vulcanism, landslipping, flooding or fire probably has a return time of less than 1000 years for any hectare of forest throughout New Zealand (cf Bray 1989). As a result patches of forest are periodically synchronised, as light demanding species regenerate abundantly following the disturbance. This imposes a long-term periodicity in forest dynamics, with periods of biomass accretion after disturbance being followed several centuries later by phases of decline as the original tree cohorts are replaced by subsequent cohorts of (often) less light demanding species. These phases of decline may be 200 to 600 years after the synchronising disturbance, depending on the longevity of the species involved. Introduced browsing animals, especially those attacking the canopy, will have a different effect depending on the timing of their impact in relation to the stage of this vegetation cycle. Presumably possums will have their greatest or most apparent impact on forest which is about to enter the senesce phase. However, we know insufficient about most forest systems in New Zealand to be able to readily assess the forest phase.

Possums and goats have had a major impact on the vegetation of the Kauaeranga valley. Rata (*Metrosideros robusta*) death commenced in the lower part of the valley in the 1970s, probably shortly after the arrival of possums. The earliest recorded release of possums near to the Kauaeranga Valley site was made at the Karangahake Gorge in 1915 (Pracey 1974) which is approximately 40km away. One estimate of the rate of spread of possums was made for South Island forests in the Fox catchment of 0.8-1.6km/yr (Pekelharing and Reynolds 1983). If possums spread at a similar rate they might have been present in Kauaeranga Valley between 1940 and 1965 and more numerous between 1950 and 1975. Since 1980 many large emergent rata have died. In the middle reaches of the valley fuchsia (*Fuchsia excorticata*) has also been much reduced, though viable seeds are still common in soil samples. During the 1980s the majority of large fivefinger trees (*Pseudopanax arborea*) in the vicinity of the Kauaeranga Education Camp were defoliated and died. Possum damage became progressively more noticeable through the 1980s. The goat population has increased dramatically on the slopes of Table Mountain since the mid 1980s.

Kohekohe is a canopy dominant tree in mixed mid-altitude forest in the Kauaeranga Valley. The forest type contains up to 15 tree species (> 10 cm dbh) per hectare, five tree fern species and nikau palms. Angiosperms predominate in the canopy. The light demanding nature of the seedlings of some of these (e.g., *Weinmannia silvicola*), and a scattered population of tall *Cyathea medullaris*, suggest that large scale disturbance has been a feature of these forests in centuries past (e.g., on plot 6). Kohekohe seedlings, however, grow best at intermediate light levels (Wright 1993, Court & Mitchell 1988, 1989), and kohekohe populations show size frequency distributions indicative of "continuous regeneration" (cf Lusk & Ogden 1992). Moreover, kohekohe seedlings seem to be avoided by goats. Consequently, kohekohe is potentially a long-term component of the forest canopy, and a decline in its abundance is unlikely to be due to cohort senescence in the way that a decline in rata or kamahi might be (Stewart & Veblen 1982). In this respect kohekohe can be regarded as a critical indicator of the "health" of the most diverse forests of New Zealand, the lowland and lower-montane forest of the northern North Island.

Starting in 1980, eleven long-term study plots have been set up in various forest types in the Kauaeranga valley. Three of these plots, commenced in 1984, are in Kohekohe (*Dysoxylum spectabile*) forest on the slopes of Table Mountain. This paper is a preliminary account of the results from two of these Kohekohe dominated plots.

The long-term plot work is supplemented by comparisons of kohekohe population size structures at Parakao (Northland) and on Little and Great Barrier Islands. Little Barrier Island lacks both possums and goats, while Great Barrier lacks possums, and the goat population has recently been eliminated in the study area. These results, and others on seedling survivorship and canopy condition in the different sites will be reported in an MSc thesis (C. Buddenhagen, University of Auckland, 1995).

METHODS

Each plot comprised eight contiguous 5 x 30 m strips on which all trees > 10cm diameter (dbh) were tagged and measured. All tree ferns and palms > 1m in height (trunk) were also tagged and measured. The position of all these, and smaller trees, was recorded on a detailed map of the whole 40 x 30m area. Seedlings were counted on all strips and classified as "small" (< 30cm height) or "established" (30 - 100 cm height). The plots were measured in 1984, 1987, 1989, 1991 and 1994. Seedlings were also counted on all occasions.

RESULTS

The results have been analysed for two plots (plots 6 and 7), but are presented in detail only for plot 6. The complete data set, and other results on seedling survivorship and canopy condition in the different sites, will be reported in an MSc thesis (C. Buddenhagen, University of Auckland, 1995) and subsequent publications.

Over the ten year period changes occurred on both plots through mortality, recruitment (to the tree class) and diameter growth of survivors. The results can be expressed in terms of changes in the number of individuals or changes in basal area. The basal area data are presented in Table 1 as an example of the type of data available. Tree ferns, palms (*Rhopalostylis sapida*) and trees are considered separately.

Overall tree ferns increased in abundance over the ten year period. Numbers per hectare increased from 858 (54% stems 1984) to 875 (62% stems 1994). Most of this increase was in *Dicksonia squarrosa*. *Cyathea medullaris* showed a dramatic decline (33%) through mortality with no compensatory recruitment. Identical trends occurred in the nearby plot 7 where the initial density of tree ferns was lower (33% stems in 1984, 38% in 1994). Nikau palms also declined in plot 6, but in the much higher palm population in plot 7 (333 palms ha-1) deaths and recruitment were balanced.

Table 1 Basal area changes (m^2.ha-1) on plot 6.

Kohekohe was numerically the most important canopy tree on both plots. In 1984 kohekohe comprised 49% of the canopy tree stems on plot 6 and 51% on plot 7. Total kohekohe tree numbers on plot 6 declined from 650 to 483 ha-1 (a 26% decline). On plot 7 tree numbers declined from 583 to 467 ha-1 (20% decline). On both plots most of this decline was due to kohekohe mortality. Kohekohe declined in numerical abundance by 39% on plot 6 and by 44% on plot 7. The surviving kohekohe all showed signs of severe browsing, with less than 10% canopy foliage remaining on all trees. The other main canopy trees also declined (e.g., *Weinmannia silvicola* in plot 6). Tree fall created a large gap in plot 7 and several gaps in the immediate vicinity of the plot. Only subcanopy trees showed a small increase (*Melicytus ramiflorus* in plot 6 and *Hedycarya arborea* in plot 7).

The basal area changes (Table 1) are similar to the numerical shifts, but are probably a better reflection of the biomass changes. Tree ferns comprised a large proportion of the basal area on both plots (40% plot 6, 18% plot 7). Both plots showed an increase, except for *Cyathea medullaris*, which declined on plot 7 but increased slightly on plot 6 due to the basal growth of the survivors.

Tree basal area declined from 48 to 42m2.ha-1 (a 14% decline) on plot 6, and from 67 to 46m2ha-1 (31%) on plot 7. As with stem numbers, most of this overall decline can be accounted for by death of kohekohe. In ten years kohekohe basal area has been reduced by 51% in plot 6 and 58% in plot 7. *Weinmannia silvicola* has shown a slight increase in basal area on plot 6, but the other canopy trees on plot 7 (*Beilschmiedia tawa* and *Laurelia novaezelandiae*) have declined. Total (tree plus tree fern) basal area changes indicate a total loss of biomass of the order of 5% (plot 6) and 23% (plot 7). The high value on plot 7 is largely a result of the death of one large tree, but this is not unrepresentative of the events in the surrounding forest.

Data on seedling numbers (means of plots 6, 7 and 8) are given in Fig 1. Small seedlings have declined in abundance on all the plots, though the less abundant seedlings in the 30 - 100 cm height range have remained largely unchanged. The most unequivocal decline is shown by kohekohe, which has reduced by an order of magnitude. Nikau seedlings were especially abundant at the start of the study, but only c. 25% of these remain. Other species (e.g., *Hedycarya arborea*) show some reductions.

DISCUSSION

Figure 1 Changes in seedling populations of three species on plots 6,7 and 8. The points are the means of the three plots. Seedlings were <30 cm height, established seedlings 30-100 cm height.

The data from the two plots discussed here indicate a period of massive canopy mortality. Although it is possible that the areas studied were in the senescent phase of the forest cycle in 1984, there is no doubt that the accelerated collapse documented can be accounted for largely by death of kohekohe as a result of defoliation by possums. This mortality has affected all sizes of kohekohe, although some trees in the size range 5 - 10cm diameter (not included in these figures) remain healthy. Small kohekohe seedlings have also declined dramatically, although the more established seedling population (30 - 100 cm height) has remained. This can be accounted for by reduction in seed input due to possum browse of kohekohe inflorescences on stressed trees. Possum sign has increased noticeably in the area since the mid 1980s. In addition to kohekohe, *Cyathea medullaris* and *Pseudopanax arborea* are both heavily browsed. Nikau inflorescences are also eaten (cf Cowan 1991). In close proximity to the plots some large rata trees are dying through defoliation. *Weinmannia silvicola* also shows some signs of canopy loss, though this is not yet serious.

If the trends documented are to continue it is apparent that kohekohe, formerly the dominant canopy species in the area studied, will be almost entirely lost as a canopy tree within the next 10 - 15 years (cf Campbell 1990). The falling trees create canopy gaps, which are then favoured by goats. Goats browse seedlings, saplings and damaged trees in the gaps. Already the common shrub *Coprosma grandifolia* is dying out through ring-barking. *Melicytus ramiflorus* is also badly damaged, but surviving.

The main response of the understorey to the increased light levels resulting from canopy mortality has been in the tree ferns. All tree ferns, except the canopy forming and highly palatable *Cyathea medullaris*, have increased. Tree-ferns and palms, especially *Dicksonia squarrosa*, cast heavy shade and create a difficult environment for tree seedling establishment, because their fronds cover the forest floor in a dry layer. Falling fronds also impact directly on small seedlings. This change in the sub-canopy layer may be a reason for the decline in seedling abundance, although direct browsing by goats and possums, and the reduction of seed input might also be responsible. Kohekohe, however,seems to be unpalatable to goats (Court 1985), so that the decline in kohekohe seedlings is likely be a result of the death of the seed source. It is also noteworthy that possums browse the flowers and young inflorescences of kohekohe.

We emphasise that the changes documented on these plots are not simply changes in species composition. Rather they indicate a total loss of biomass of the order of 5 to 20% in ten years. The canopy is opening up, tree ferns are increasing in height and abundance, and the tree seedling pool is declining. These changes are being driven largely by possum-induced mortality of the main canopy tree, kohekohe. If current trends continue, the future forest will lack this species, and be of a lesser biomass, with reduced biodiversity and structure. The long-term combined effects of goats and possums seem capable of reducing this high basal area tiered forest to a tree fern dominated shrub-land.

ACKNOWLEDGEMENTS

Howard Choat, Neil Mitchell and Richard Serra helped in the initial setting up of these plots and in several subsequent enumerations. Tree remeasurement has generally been by undergraduate and masters students in Ecology at Auckland University, who have often worked in appalling weather conditions. Thanks to all concerned, especially Craig Bishop and Shane Wright.

REFERENCES

Bray, J.R. 1989. The use of historical vegetation dynamics in interpreting prehistorical vegetation change. *Journal of the Royal Society of New Zealand* 19: 151-160.

Campbell, D.J. 1990. Changes in the structure and composition of a New Zealand lowland forest inhabited by brushtail possums. *Pacific Science* 44: 277-296.

Court, A.J. 1985. Aspects of the Ecology of *Dysoxylum spectabile*. Unpublished MSc. Thesis, University of Auckland, N.Z.

Court, A.J. and Mitchell, N.D. 1988. The germination ecology of *Dysoxylum spectabile* (Meliaceae). *N.Z. J. Bot*. 26: 1-6.

Court, A.J. and Mitchell, N.D. 1989. Growth responses of *Dysoxylum spectabile* (Meliaceae) to a shaded environment. *N.Z. J. Bot*. 27: 353-357.

Lusk, C.H. and Ogden, J. 1992. Age structure and dynamics of a podocarp-broadleaf forest in Tongariro National Park, *J. Ecol*. 80: 379-93.

Pracey, L.T., 1974. Introduction and Liberation of the Opossum (*Trichosurus vulpeca*) into New Zealand. Government Printer, Wellington. *New Zealand Forest Service Information Series No. 45*.

Pekelharing, C.J. and Reynolds, R.N. 1983. Distribution and abundance of browsing mammals in Westland National Park in 1978, and some observations on their impact on the vegetation. *N.Z. J. For. Sci.* 13: 247-265.

Stewart, G.H. and Veblen, T.T. 1982. Regeneration patterns in southern rata (*Metrosideros umbellata*) - kamahi (*Weinmannia racemosa*) forest in central Westland, New Zealand. *N.Z. J. Bot.* 20: 55-72.

Wright, S.D.T. 1993. The comparative regeneration ecology of three tree species in northern New Zealand. Unpublished Ph.D. Thesis, University of Auckland.

PRIORITISATION AND OPTIMISATION

K.W. Janson

Department of Conservation, P.O. Box 10 420, Wellington

SUMMARY

Principles of introduced animal management have progressed markedly over the past 30 years. The prioritisation of areas for possum control is a major step forward, but the challenge now is to integrate this with other management priorities to obtain the optimal conservation benefit for each management unit.

Put simply, we need to change our terms of reference from what is that problem doing in those areas but to what is happening in that area as a result of those problems.

In this way a management regime, which may include possum control, can be tailored for each priority area. Such a regime would allow for the optimisation of conservation benefit and provide a foundation on which to base the next paradigm.

INTRODUCTION

Since the introduction of animals to New Zealand in the 1800s, there have been a progression of paradigms on their management. These paradigms have been, sequentially: protection, harvesting, eradication, control and, currently, prioritisation. These changes in our view of introduced animals and their place in our landscape acknowledges the lack of understanding of biological processes and the impact of introduced animals. Consequently, it indicates the steep learning curve we are on in developing pest management strategies.

In this paper I would like to concentrate on the current paradigm of prioritisation and explore the forthcoming paradigm of optimisation.

PAST PARADIGMS

I do not wish to discuss the introduction, spread, and changing attitudes toward introduced animals. These aspects of animal control have been covered elsewhere in more depth than I could hope for here (e.g., Wodzicki, 1950). However, I would like to make reference to a series of quotes that illustrate the evolution of increasingly complex pest management concepts, culminating in the current paradigm of prioritisation.

"Encourage the importation of animals not native to New Zealand which would contribute to the pleasure and profit of the inhabitants, when they became acclimatised and were spread over the country in sufficient numbers"
Colonial Parliament, 1861 (cited in Wodzicki, 1950)

"there need ... be no fear that opossum can ever increase in numbers as the rabbit has increased in New Zealand"
Kirk, 1920

"there are those in favour - a considerable majority - and those who decry these animals"
Cockayne, 1926

"Extermination is Government policy. If it were not, then it would be control. And who would determine the level of control?"
Poole, 1962

"to control [deer] at a level indicated as sufficiently low by the condition of the vegetation"
Poole, 1964

"the impact of wild animals on conservation values varies in both degree and acceptability according to the intrinsic nature of the ecosystem, and the status accorded to it."
Holloway, 1988

"We have to decide what is tolerable, prioritise conservation values over the estate and set densities which do not unduly compromise these values, and organise the control and hunting agents to help protect these values"
DOC Thar Control Plan, 1993

These quotes are not provided to show the wisdom of hindsight, but as a reminder that we should always be critical of our current approach and be seeking to develop new paradigms better able to cope with the complexity of introduced animal management. With that in mind, let us examine our current paradigm – prioritisation.

PRIORITISATION

Prioritisation requires that all lands on which the pest species occurs are scored according to the values that are to be protected and the impact on those values, both actual and potential, by possums.

To achieve this, all lands administered by the Department were first split into management units. A management unit being a cohesive block with distinct boundaries that encompasses species or habitats worth conserving. The values in the management unit must be viable and the area must be such that control can be undertaken over the whole area simultaneously.

Once the management unit, with its biological values, has been established, the values can be scored. The prioritisation system used by the Department for possum control was developed from work by Elliott and Ogle (1985), Shaw (1988) and Parkes (1990). The system ranks areas on a scale of 1-6 with criteria that relate to both the species and the ecosystem values present. For example, an area can be ranked a 6 if either;

1.it contains a nationally endemic plant species OR;
2.the plant community is better represented in the ecological District than any other district in the country.

Once the plant and animal values have been scored in this way, their vulnerability to possums is established using a scoring system of 1-3.5 (where 1 = plant/animal unaffected by possums and 3.5 = some plant/animal is at risk of national extinction).

The highest of the plant/animal scores is then multiplied by its vulnerability to gain the primary ranking. Where more areas attain the same score than there are funds to control possums on, a secondary sort is undertaken to give extra points for a variety of factors. These factors include both the plant and animal scores being high rather than just one, the site has other conservation priorities, there being a longer time to recolonisation in one area or the area is one of high public use.

Once the rankings have been finalised, funding can be allocated in such a way as to gain the greatest efficiency by rotating it between the management units.

OPTIMISATION

This brings us to the forthcoming paradigm – optimisation. Optimisation has two forms. First, there is operational optimisation that deals with gaining increased efficiency from possum control operations. This can be through lowering the costs of conducting control or by timing control in such a way as to lengthen the time between control actions.

However, of more importance, is what I will refer to as conservation optimisation. This deals with deciding whether possum control is the most appropriate management regime to be conducting in that management unit in the first place.

One of the major problems with the prioritisation paradigm is that we tend to see all conservation problems as possum problems and then find a possum control solution to that problem. For example, a coastal pohutukawa remnant, known to contain moderate possum numbers starts to collapse. A study is undertaken that shows that possums are browsing on the trees and that if the possums are removed the trees will survive. As a result, possum control is undertaken every 3 years for the next 20 years. However, what the study has failed to show, because the question was never asked, was that damage to the pohutukawa was also occurring as a result of people lighting camp fires underneath the trees in summer and stock trampling the roots in winter. Maybe, moving the camping area away from the trees or fencing the area to prevent stock would also have protected the trees, and at far less cost.

By developing a prioritisation system for possum control, we start to look at the affect of possums on native flora and fauna out of its context of being only one of a raft of species impacting on conservation values. When areas are prioritised for possum control, the common factor for each area is the possum and this becomes the focus for management.

The management unit becomes subservient and is merely where the control of possums takes place. Even with monitoring of the flora and fauna after operations, the focus is still on possums control – if the flora and fauna recover, the management option was clearly the right one; if they do not recover, the level of possum control was not correct.

Although no one would argue that possums are not a, if not the, significant problem facing native flora and fauna, are they the most significant problem in all the areas that are undergoing possum control?

To avoid this situation, we need to know the cost/benefit relationship of undertaking possum control compared to controlling other browsers such as goats and deer. Similarly, how does this cost/benefit relate to other management problems such as the control of predators, weeds, and statutory planning mechanisms.

As there are a multitude of problems impacting on each management unit, it becomes evident that the common factor is the site and that to optimise the conservation benefit for a particular site, a system needs to be developed that will provide a biological cost/benefit analysis of different management options.

REFERENCES

Cockayne, L. 1926: Monograph on the New Zealand Beech Forests. *N.Z. State Forest Service Bulletin No.4, Part 1*. Govt. Printer, Wellington.

Elliott, G.P. Ogle, C.C. 1985: Wildlife and wildlife habitat values of Waitutu Forest, Western Southland. *Department of Conservation Fauna Survey Unit Report No.39*. 108p.

Holloway, J. 1988: The Future of Wild Animals: A Department of Conservation Viewpoint. Seminar 2000 - The Future of New Zealand's Wild Animals. Pp 10-19.

Kirk, H.B. 1920: Opossums in New Zealand. *Appendix to Journals, House of Representatives, New Zealand*, H 28.

Parkes, J.P. 1990: Procedures for ranking and monitoring feral goat (Capra hircus) Control Operations. Unpublished Forest Research Institute Contract Report. 45p.

Poole, A.L. 1962: Ecology and the administrator. *Proc. NZ. Ecol. Soc.* 10: 73-77

Poole, A.L. 1964: Report of the Director-General of Forests for the Year Ended 31 March 1964. *Append. J. House Repres. NZ C3.*

Shaw, W.B. 1988: Botanical Conservation Assessment of Crown Lands in the Urewera/Raukumara Planning Study Area. Unpublished Forest Research Institute Contract Report. 140p.

Wodzicki, K.A. 1950: Introduced Mammals of New Zealand. *DSIR Bulletin No.98*, Wellington, NZ.

RELATIVE PESTINESS – SPECIES PRIORITIES AND INTERACTIONS. ARE POSSUMS THE PROBLEM?

John Parkes

Manaaki Whenua – Landcare Research, P.O. Box 31-011, Christchurch

INTRODUCTION

New Zealand's 31 species of free-living mammals are conservation pests to varying degrees, but only a few species are actively controlled on the conservation estate. Which species get controlled is decided by a mixture of rational choice (some are seen as worse pests), manageability and scale (some can be controlled and others cannot), and history (some have been managed in the past).

There is a general belief that conservation outcomes would be improved if more mammals were managed as pests and/or if the management of those now controlled was better integrated. This belief fits well with holistic views of the world (e.g., the Gaia hypothesis; Lovelock 1988), with our international commitments (e.g., the Rio Biodiversity Convention), and is supported to some extent by many managers and scientists (e.g., Braysher 1993; Norton 1993). However, the belief has not been critically examined to test whether integration would increase benefits to conservation as claimed, particularly on mainland areas where pests cannot be so easily eradicated as on islands.

THE OPTIONS TO INTEGRATE

Three broad systems could be used to plan the control of conservation pests when funds are fluctuating, and insufficient to control all but a few pests in a few places (Table 1).

Table 1 General options to integrate the management of conservation pests.

OPTION 1: WORST PESTS – PRIORITY PLACE SYSTEM (THE PRESENT NPP SYSTEM)

The present system allocates tagged money (called National Priority Pool, NPP) for control of a few pest species perceived to have the worst overall impact on conservation values, and that (unlike deer, thar, chamois or pigs) are not harvested by other means, and for which extensive control can be sustained with the technology available. Control is conducted in the highest priority places (Parkes 1994). The "few pests" are possums and feral goats, which between them consume over 90% of the money allocated for pest control by the Department of Conservation (DoC).

In general, the problem with the present system is its inflexibility to deal with problem populations of pests other than the few nationally targeted species.

OPTION 2: PRIORITY PLACE – CRITICAL PEST SYSTEM

An alternative system would identify the best places and control whatever pests were critical to the protection of the assets at those places. This would require reallocation of resources away from possums and goats if these were not critical pests at some places.

In general, the problem with this model is identifying which pests are critical at each selected site. There are on-site costs if we do not kill the critical pest, and opportunity costs (i.e., we would have been better spending the money on another pest or place) if we kill non-critical pests.

Figure 1 Major food plants of deer and possums, Waihaha, west Taupo.

Figure 2 Effect of different densities of deer and possums on the regeneration of Kamahi (after Nugent *et al*. in prep.).

OPTION 3: A BEST PLACE – ALL PEST SYSTEM (THE MAINLAND "ISLAND" SYSTEM)

An extreme option would be to control all introduced biota at the best places. This idealist's model has no on-site costs of error, but has certain and huge opportunity costs. A solution to allow control of some pests at all places is to develop successful biological controls.

In my opinion, DoC should leave mainland island schemes to others (e.g., the proposal to fence the Karori Reserve; Anon 1994), and restrict its island management to real islands. An island in this sense is a place where a single time-limited management regime can be implemented for the entire pest population. The time-limit constraint generally means the pest must be eradicated and immigration stopped.

Integration of management between pests within option 1 depends on whether goats or possums should form the base map for strategic ranking, i.e., which pest is the worst and/or most manageable nationally? Integration within option 2 depends mostly on correctly identifying the critical pest(s) at each highly-ranked site.

POSSUMS AS CRITICAL PESTS

I wish to discuss the relative impacts of possums and other sympatric pests for which we have some data, i.e., to explore the circumstances under which possums might be critical pests in the sense of the priority place – critical pest option.

POSSUMS VERSUS UNGULATES IN FOREST HABITATS

The long-term structure and composition of forests depends on regeneration, and the evidence of exclosures and some experimental work by Nugent *et al.* (in prep.) shows that most plant species regenerate irrespective of their palatability to possums in the presence of uncontrolled possums, but only species unpalatable to ungulates regenerate at ground level in the presence of ungulates (Figs. 1 and 2).

These results show that although possums prefer kamahi, they have no effect on its regeneration. Deer also eat kamahi which does not regenerate until deer densities are below some threshold (an important result). The long-term fate of the forest thus depends mainly *on the level of deer control*.

The management consequence of this is that ungulates should form the base map for decision making under option 1 because they are generally worse pests, and are certainly more manageable than possums because they are patchily distributed. In other words, the allocation rule is that *there is often little point in controlling possums in the absence of ungulate control, but there can be benefits in controlling ungulates in the absence of possum control.*

POSSUMS VERSUS UNGULATES IN ALPINE GRASSLANDS

Figure 3 Diet of sympatric thar, chamois, and possums from the Rangitata/Rakaia catchments (after Thomson, Parkes & Coleman 1994, unpubl. Landcare Research contract report).

All the herbivores in grasslands have permanent access to all (or most) of the food. A study of the diet of sympatric thar, chamois, and possums in the Southern Alps showed thar ate mostly grass, chamois mostly herbs, and possums mostly fruit and herbs (Fig. 3). In this case the worst pest depends on what plants are most valued and on the biomass of the different mammals. The biomass of possums is unknown, but unlikely to approach that of thar.

POSSUMS VERSUS OTHER PREDATORS

Recent research has implicated possums as predators on birds, and they may be significant predators on the eggs and nestlings of kokako (Brown *et al.* 1993). They also prey upon invertebrates, including endangered land snails (Elliott 1994, unpubl. Landcare Research contract report). Whether possums are generally worse than other arboreal predators such as ship rats and stoats is unknown.

MANAGEMENT PROBLEMS TO BE SOLVED

Pest management has usually failed, or has not been sustained, when the goal is vague and unmeasurable. The goals for DoC are broadly determined by the Conservation Act as "natural resources with intrinsic values". The department is attempting to quantify the values placed on natural resources at places, weight them according to the degree of threat posed by things like pests, and according to the risks and opportunities when the resource – pest system is managed (e.g., T. Stephens, pers. comm.). It is attempting to do this in the absence of complete information of what natural resources are present in most places, of any agreed system to measure intrinsic values, of what their long-term fate might be under present and potential threats, and with inadequate resources to manage the threats and risks (let alone the opportunities for restoration) even when the technical tools to do so are available.

Potential management problems loom for DoC if it attempts to move from the worst pest – priority place model to the priority place – critical pest model. Unless more money is allocated, the consequences will be (1) abandonment of lower ranked goat and possum operations (I would favour dropping some possum control) to fund the new operation against other pests, and (2) a shifting series of pest control operations, few of which are sustained, as new *bete noire* are fingered by managers and lobbyists – magpies and mynas are the latest candidates nominated by the Forest & Bird Society.

RESEARCH PROBLEMS TO BE SOLVED

Some priority research gaps are, within the context of an assumed move from the worst pest model to the critical pest model for allocating resources, and focusing on possum research:

1. Impacts of possums as predators

The role of possums as predators on birds, insects, and snails needs to be investigated, and at three levels: what species do possums eat, does this predation affect the eaten species at a population level, and are possums the critical predator involved. These impacts are less-well understood than those on plants and need urgent study, especially as potential prey are often used in the National Possum Plan to justify possum control in areas where possums are sympatric with other predators such as rodents, mustelids, feral cats, and feral pigs.

2. Impacts of possums as herbivores

(a) Impacts on plant species: There is still a need to measure the impact of unmanaged and controlled possum populations on some plant species, particularly on rare or endangered species such as *Dactylanthus*, their role as a frugivore, and on intraspecific variations in palatability of some favoured plants. Such impacts can justify control action in its own right, but an understanding of the impacts can enable the plant to be used as a performance measure of control success.

(b) Impacts on communities: The fate of the large areas of rata/kamahi forest in Westland with uncontrolled possums and harvested ungulates needs investigation.

ACKNOWLEDGEMENTS

Much of the research upon which this summary is based was funded by the Department of Conservation, and the ideas on integration are being expanded in a report for the Estate Protection Policy Division of the department (Parkes and Nugent, in prep). I thank Graham Nugent and Oliver Sutherland for comments on drafts of this summary.

REFERENCES

Anon 1994: Imagine a wildlife sanctuary for Wellington. Karori Sanctuary Trust Committee, 4 p.

Brown, K., Innes, J. and Shorten, R. 1993. Evidence that possums prey on and scavenge birds' eggs, birds and mammals. *Notornis* 40: 169–177.

Braysher, M. 1993. Managing vertebrate pests: principles and strategies. Australian Government Publishing Service, Canberra. 58 p.

Lovelock, J. 1988. The ages of Gaia: a biogeography of our living Earth. Oxford University Press, London. 252 p.

Norton, D.A. 1993. Mainland habitat islands: a vision for New Zealand nature conservation. *West Coast Conservancy technical report series* no. 2, 9 p. (Unpublished).

Nugent, G., Fraser, W. and Sweetapple, P. in prep. Comparison of red deer and possum diet and impacts in podocarp-hardwood forest, Waihaha, west Taupo. Landcare Research contract report.

Parkes, J.P. 1994. Management of pests of conservation values in New Zealand. Landcare Research contract report LC9394/73, 50 p. (Unpublished).

Parkes, J.P. and Nugent G. in prep. Options to integrate the management of mammalian pests of conservation values in New Zealand. Landcare Research contract report.

Thomson, C., Parkes, J.P. and Coleman, M.C. 1994. Management of thar (ii) Diet of thar, chamois, and possums. Landcare Research contract report LC9394/96: 23 p (unpublished).

POSSUMS AS CONSERVATION PESTS - ECONOMIC MANAGEMENT: IDENTIFICATION OF RESEARCH PRIORITIES

Ross Cullen

Department of Economics and Marketing, P.O. Box 84 Lincoln University

INTRODUCTION

There are limited resources available for species conservation activities in general, and for suppression of pest numbers in particular. Economists are always interested to observe how scarce resources are used, supposedly in pursuit of stated objectives, and species conservation provides an obvious area for New Zealand researchers to investigate. Economic analysis of reasonably similar activities, weed control, insect and other predator controls – all generally "yield reducers" – have been quite extensively researched overseas. Cullen (1994) provides a generally critical commentary on New Zealand research on those topics.

There are reasonably large, and increasing amounts of expenditure directed at possum control for conservation purposes, and this activity can be scrutinised by applying the tools of economics. The general area is known as project appraisal, or less accurately, as Cost Benefit Analysis. About sixty years worth of effort on project appraisal has honed our understanding of the questions to be asked, and the techniques available for generating answers to those questions.

WHAT ARE THE ECONOMIC RESEARCH QUESTIONS?

The basic questions which can be asked of these programmes include:

1. Subject to meeting various safety and environmental standards, are stated objectives being achieved in least cost ways? Cost effectiveness studies can check to see if possums are being killed at lowest possible cost, and if species are being conserved at lowest possible cost.

2. Are the costs of these programmes greater than, less than, or equal to the benefits attained from these programmes? Cost benefit analysis is used to determine if the use of resources in some activity is justified by the payoff from the activity.

3. What is the appropriate level of expenditure each year on these activities? Conservation programmes are ongoing activities, and static or one year analyses of these expenditures may not focus attention in the right topics if the important consideration is how much to spend each year on an area. Optimal control techniques can be used to study those issues.

4. Are expenditures being made on the most appropriate targets or are there (even) better ways of using the resources? Dynamic bioeconomic models can be developed to shed light on those questions.

WHAT ECONOMIC RESEARCH HAS BEEN COMPLETED?

Asking questions is usually very easy, providing satisfactory answers to the questions is typically very much harder. There have been expenditures on "possum control" activities in pursuit of conservation objectives for twenty years of more, but formal economic analysis of these activities appears to have commenced in 1991. This situation is not unique to species conservation, activities, but wherever significant economic issues arise it is worth considering if professionals should be asked to review or complete the appropriate economic analyses.

In 1991, even obtaining the most rudimentary data to complete a cost effectiveness study of "knockdowns" proved very difficult. The recommendations from Review of Department of Conservation possum control operations in West Coast Conservancy include ... "Expenditure on control operations should be recorded to allow adequate auditing. All costs ... must be recorded for each operation." and "Sufficient auditing procedures should be set in place to ensure all monies allocated to Conservancies for possum control are in fact used for that purpose" Warburton et al (1992).

In the two years since publication of that report there has been some progress in the quality and amount of information collected on costs of these knockdown operations. Parliamentary Commissioner for the Environment (1994), Table A.16, lists data on costs and outcomes for 54 control operations which are germane to species conservation. The basic messages on the relative merits of ground control versus aerial control operations for knockdown, seem reasonably clear Warburton and Cullen (1993). Peer reviewed cost effectiveness studies should be completed as technologies change and costs change, and to establish more clearly the most effective techniques in varying terrain, climates, population densities, etc.

Cost effectiveness studies of sustained control programmes seem an obvious area for future research.

Completion of a quality cost benefit analysis study is often an order of magnitude more difficult than is a cost effectiveness study. While enumeration of costs can be tricky, evaluation of the benefits of species conservation activities requires considerable understanding of non market valuation techniques, and considerable skill in designing and completing eg a Contingent Valuation Method study. Comparable studies have been completed in many countries on a vast range of topics Mitchell and Carson (1989), but only one pair of researchers appear to have attempted a pilot non market valuation study on "possum control" operations for species conservation Kerr and Cullen (in press). Without such studies managers must guess what the magnitudes of the economic benefits are from pest control programmes. Thus managers, and taxpayers who pay for these activities, can have little idea whether the benefits of pest control really are greater than their costs, and equally they have little idea whether the expenditures on pest control in one location would provide more or less benefit if they were instead applied elsewhere on the conservation estate.

Long term programmes such as species conservation programmes require analysis by tools which recognise the dynamic aspect of those activities. Some rudimentary work examining the discounted costs over thirty years, of various possum control strategies, are contained in Warburton *et al* (1992). The undiscounted costs of various possum control strategies have been examined by Efford (1991) cited in Department of Conservation (1994) The first theoretical work on this topic has been completed Tu and Wilman (1992). Optimal control theory is being applied to possums and TB control programmes (Bicknell, unpublished), and might well be applied to possums and species conservation programmes.

When scarce resources can potentially be applied to the control of possums on many conservation areas, some type of modelling or simulation is required to determine which overall programme of activities will provide the greatest net benefits. Simulation gaming methodologies have been proposed by Scrimgeour (1994) and are used for this purpose by Moyle (unpublished). This approach holds some promise of providing valuable insights into ways to improve the overall pattern of use of taxpayer funds for species conservation.

CONCLUSION

A wide range of tools can potentially be employed to provide answers to economic questions about species conservation programmes. We have some idea about the cost effectiveness of various knockdown techniques, but economic analysis of species conservation programmes is still in its infancy with almost no peer reviewed research published. Within Universities there is some ongoing economic research into species conservation activities. Non-University research funders must now judge whether they too should support economic analysis of these issues.

REFERENCES

Bicknell, K.B. Unpublished PhD study.

Cullen, R. Measuring the costs and benefits of plant protection. Proceedings of New Zealand Plant Protection Society symposium, 1993. "Plant Protection: Costs, Benefits and International Trade": 89-94.

Department of Conservation, 1994. National Possum control plan 1993-2002, Department of Conservation, Wellington.

Kerr, G.N. and Cullen, R. 1995 in press. Public preferences and efficient allocation of possum control budget. *Journal of Environmental Management*.

Mitchell, R. and Carson R.T. 1989. Using surveys to value public goods. Resources for the Future, Baltimore.

Moyle,B. Unpublished PhD study.

Scrimgeour, F. 1994. Investment in forest protection: How should funds be spent. Paper presented to New Zealand Association of Economists Conference.

Tu, P.N. and Wilman, E.A. 1992. A generalised predator prey model: Uncertainty and management. *Journal of Environmental Economics and Management* 23(2): 123-138.

Warburton, B., Cullen, R. and McKenzie, D. 1992. Review of Department of Conservation possum control operations in West Coast Conservancy. FRI Contract Report FWE 91/62.

Warburton, B. and Cullen, R. 1993. Cost effectiveness of different possum control methods, Landcare Research Contract Report No. LC9293/101.

Proceedings of a Workshop on Possums as Conservation Pests. Possum and Bovine TB Control NSS Committee
29 – 30 November 1994, Christchurch

TOWARDS A POSSUM/VEGETATION MODEL

N.D. Barlow

Biological Control Group, AgResearch, PO Box 60, Lincoln

INTRODUCTION

No model currently exists for the interaction between herbivores and vegetation in New Zealand, nor is any research currently being funded to develop one. This brief presentation outlines a possible approach.

Such a model would, as a basic minimum, need to include:

1. A division of the vegetation into classes according to its palatability or acceptability to the herbivores considered

2. Vegetation growth/succession by classes

3. Possum (or other herbivore) population growth as a function of vegetation palatability and quantity

4. Vegetation removal rate through herbivory by classes

Components 2, 3 and 4 are considered in slightly more detail in the acetate copies below:

Likely data needs are:

* Standing biomass of green vegetation in different palatability classes, for different forest types (and for different current densities of browsing herbivores)

* Recovery rate of vegetation (each class separately) in
the absence of browsing (e.g., following control of herbivores) - forest succession

* Rate of decline of vegetation (each class separately) in relation to possum density

* % vegetation class in diet versus % of that class in the environment

* Possum density in relation to vegetation quality and quantity

(* Possum daily intake in relation to quality x quantity of vegetation)

VEGETATION GROWTH

The equation (Fig. 1) shows the rate of increase in vegetation in palatability class **i** (**dV_i/dt**) as a logistic (S-shaped) function of the current amount in that class and the total in all classes (**V**) relative to some "ceiling yield" of total vegetation (**K**). The specific (per unit biomass) rate of increase of each class is given by the parameter **r_i**. This particular model would predict that if the most palatable class, say **V_1**, was once substantially depleted then it would never recover; the available "space" (1 - V/K) would be filled mainly by growth of the less palatable classes 2 and 3. In fact this model has the intrinsic limitation that the final balance of vegetation is determined by the initial quantities present and their rates of growth; more seriously, the balance is unstable in that repeated perturbations reducing total vegetation below **K** will allow the component with the highest rate of increase to eventually dominate. Clearly this simple model needs refinement.

POSSUM POPULATION GROWTH

Figure 1 A vegetation growth model

Figure 2 A possum population growth model.

This equation is a logistic one (Fig. 2), similar to that for vegetation, relating the rate of increase of possums ($\mathbf{dN/dt}$) to their current density ($\mathbf{N}$) and a maximum density for the habitat ($\mathbf{b\Sigma f_iV_i}$). This formula for the maximum density assumes that it is proportional to the number of dens per hectare (included in the parameter $\mathbf{b}$) and the quantity x quality of vegetation available ($\mathbf{\Sigma f_iV_i}$ where $\mathbf{f_i}$ is a palatability factor between 0 and 1, 1 being most palatable).

VEGETATION CONSUMPTION, OR REMOVAL RATE THROUGH HERBIVORY

The first part of this component relates overall herbivore intake to quantity and quality of the vegetation available (Fig. 3). In practice such a relationship, with its parameter $\mathbf{a}$, may be hard to establish, and to a first approximation the total intake per unit time ($\mathbf{I}$) could be assumed to be constant as measured in captivity or in the field. The second part of the consumption component then partitions this intake between vegetation classes according to their quantities in the environment and their palatabilities. This is achieved through the second and third equations on the "Vegetation Consumption" acetate copy below, where for simplicity there are assumed to be only two classes of palatable vegetation. If there are more classes recognised then the third equation ($\mathbf{I_1/I}$ as a function of $\mathbf{V_1/V}$) is simply replicated for the additional classes ($\mathbf{I_2/I}$ as a function of $\mathbf{V_2/V}$, determined by the parameter $\mathbf{f_2}$, etc). In general, the more palatable the vegetation class, the more curved the line in the bottom figure on the acetate, and the greater the proportion of that class in the diet for any given proportion in the environment.

Figure 3 A vegetation consumption model.

Figure 4 offers some guesses for parameter values and the data needs for a model like the one described, most of which would seem feasible to obtain. The last requirement, for possum intake in relation to vegetation quality and quantity, would not apply if the simplifying assumption were made that total intake is constant. We know that it cannot be in practice since the possums would then never be food-limited, but we by-pass this problem by relating possum population dynamics directly to the observable vegetation characteristics.

Finally, two strategic or philosophical considerations are relevant. Firstly, while it is important to prioritise research and avoid generating meaningless wish-lists, it is also important to acknowledge that a balanced portfolio of research is necessary, which includes basic or "underpinning" work as well as that likely to yield relatively immediate answers to immediate management problems. If priorities are always assigned on the basis of immediate relevance and perceived returns, then the more basic research will never be funded and we will always be in reactive rather than proactive mode. Today's "wish-list" driven by obvious gaps in understanding may be tomorrow's "need-list" driven by an unexpected management problem, and the quantitative dynamics of native vegetation subject to herbivory would seem to be one of these obvious gaps in understanding. The second, related point concerns a growing tendency to seek public opinion as a significant input to the setting of research priorities. While the ideal mechanism for setting science priorities is not obvious, public opinion is sufficiently ephemeral and malleable to suggest that it is treated with extreme caution; perhaps we should be leading it rather than following?

Figure 4Some parameter estimates for a possum-vegetation model.

Proceedings of a Workshop on Possums as Conservation Pests. Possum and Bovine TB Control NSS Committee
29 – 30 November 1994, Christchurch

ACTION THRESHOLDS AND TARGET DENSITIES FOR POSSUM PEST MANAGEMENT

Graham J. Hickling

Department of Entomology & Animal Ecology, PO Box 84, Lincoln University

SUMMARY

The goal of possum control on conservation lands is not to kill these pests, but to conserve ecological diversity. However, the concepts of an *action threshold* (the possum density above which the initiation of control is warranted) and a *target density* (which a particular control operation is expected to achieve) can assist in setting control objectives for specific areas. However, there is little data to demonstrate the link between possum control and ecosystem protection. It will be necessary, therefore, to begin by setting more-or-less arbitrary action thresholds and target densities so that operational performance can be assessed. These thresholds and targets should be subsequently adjusted as the results of ecosystem monitoring come to hand.

INTRODUCTION

The concept of an ecological damage threshold is implicit in fundamental questions asked about a possum control operations:

- when should control be initiated?
- what intensity of control is required?
- has the control work been successful?
- when will further control be needed?

Damage thresholds are thus important in setting objectives for control operations, and in subsequently assessing the effectiveness of the work (Fig. 1).

The *goal* of possum control is not to kill these pests, but to protect valued natural resources from their impacts. Thus the goal of the National Possum Control Plan (NPCP) is *"to conserve all extant species of native plants and animals and representative examples of natural biological communities and ecosystems against possum damage"* (EPPD 1994). This concept can be more conveniently expressed as conservation of "ecological diversity",

Figure 1 A typical management control paradigm (adapted from Tomkins 1978).

a term that encompasses not only the diversity of species in a management area (e.g., kereru and miro), but also the functional relationships among those species (e.g., fruit-eating and seed dispersal). The need for, and success of, a possum control operation is thus determined by the extent to which it will help conserve the ecological diversity of a given area.

ACTION THRESHOLDS

The NPCP aims to be as cost-effective as possible over the next 10 years (EPPD 1994), which requires setting *specific objectives* concerning which areas should be controlled. Dent's (1991) concept of an "action threshold" (i.e., a possum density above which the initiation of control is warranted) is one possible approach to setting these objectives.

In principle, the action threshold for implementing possum control is easily calculated (Eqn. 1).

$$\text{Threshold for Area A} = \frac{\text{Cost of control} \div \text{\%kill anticipated}}{\text{Cost of damage per possum in area A}} \qquad \textbf{Eqn. 1}$$

For example, if each possum was thought to cause \$5 damage to rata/kamahi forest each year, then the action threshold for a \$20 per ha aerial control operation with an anticipated 85% kill rate would be:

Threshold = (\$20 per ha) ÷ 0.85 ÷ (\$5 per ha per possum)

= 4.7 possums per hectare

Action thresholds will be lowest in the indigenous areas that we value most highly, and in those most susceptible to possum browse. These areas are where possum damage is most "costly". Perhaps less obviously, when possum numbers rise in an area it will be justifiable to use a high-kill technique (e.g., aerial 1080) at an earlier date than making the equivalent expenditure on a lower-kill technique (e.g., ground hunting).

The limitations of this simple action threshold concept are obvious, but serve to highlight some important "unknowns" that are confounding our ability to manage possums effectively on conservation lands. The first is the unknown dollar value that the average taxpayer would place on possums' impact on New Zealand's ecological diversity. Preliminary studies of the public's "willingness to pay" for such control suggests that currently we may be underestimating the perceived costs of possums' impact on the conservation estate (Cullen 1992).

A more fundamental problem is the unknown relationship between possum abundance and their impact on ecological diversity. The simple model represented in Eqn. 1 assumes that this relationship is linear, which implies that the one-hundredth possum to arrive in an area causes the same amount of damage as did the first (Fig 2a). This assumption is implicit in the oft-heard opinion that "any possum control is better than none".

Real abundance/impact relationships are almost certainly non-linear. Possums exhibit clear preferences for certain palatable species, and the distribution and abundance of such species is non-random in the habitats in which they are occur. Maximum response to herbivore control will therefore occur at different levels of herbivore abundance, depending on the susceptibility of each plant species. Figure 2b suggests one way in which ecological impact might vary in relation to possum abundance.

Figure 2 a) Linear and b) non-linear relationships between ecological impact and possum abundance in a hypothetical habitat (after Nugent 1992). In b) the ecological benefits from possum control will be the greatest in the region of the dashed lines, so these possum densities could represent ecological action thresholds.

The implication of Fig. 2b for possum management is that, in this scenario, limited control would produce a greater benefit at some densities than at others. This alters the "cost" function in Eqn. 1, and thus the location of the action thresholds.

ACTION THRESHOLDS AND TARGET DENSITIES

At mainland control sites, the objective of possum control generally will be a long- rather than short-term reduction of possums below the action threshold. (An exception might be a strategy aimed at allowing pulsed regeneration of a dominant plant species at multi-year intervals). Usually, there will be intervals of several years between successive operations because time is needed to organise and implement large-scale control. There also may be advantages in lengthening the period between successive operations to prevent pest resistance to repeated control (Hickling 1994). When control will be repeated in this manner, it may be acceptable to tolerate possum numbers rising to a higher action threshold for a short period, because subsequent intensive control will push it well below that threshold (Fig. 3).

Figure 3 Changes in abundance of a hypothetical possum population subject to sustained annual control (solid line) and more intensive 3-yearly control (dashed line). When applied to a single plant-herbivore model (*PossumPak*; Hickling and McAuliffe, 1993) these two control strategies produced similar levels of vegetation recovery.

When control is infrequent, we may be able to set a relatively high threshold for action provided we also set a sufficiently low target density to be achieved when we do control. The relationship between the action threshold, target density, and frequency of control will be determined by the speed of the ecological response to lowered possum abundance (e.g., Fig. 4).

Figure 4 The influence of the interval between control operations on the action threshold and target density required to generate a standard vegetation response in a simple plant-herbivore model (see Fig. 3).

DETERMINING THRESHOLDS AND TARGETS

Given the complexity of the ecological systems that we are attempting to manage, it seems inevitable that action thresholds for possum control will differ markedly between habitat types, and field staff will need to determine them largely through trial and error.
A possible procedure for identifying cost-effective combinations of action threshold, target density, and control strategy is presented here (adapted from Reichelderfer *et al.* 1984):

- for a range of possum densities, habitat types and control strategies, measure ecological diversity using a suitable index;
- beginning in the areas with the highest possum densities, undertake sustained possum control to a range of arbitrary target densities for (say) 10 years;
- after this period, calculate the trend in the diversity index in each area and regress this against the cumulative, discounted cost of control.

This method relies on the availability of a reliable index of ecological diversity. If it is to be used at a regional or district level, this index must be simple, robust, and cheap. Monitoring will inevitably be confined to only a few species, which should be selected using the following criteria:

- dominant species, which determine overall ecosystem structure;
- keystone species, which play a major role in the ecosystem structure that is disproportionate to their own abundance;
- susceptible species, which will be the first to respond to increasing possum numbers.

Vegetation monitoring techniques that address some of these points have been developed, and are currently being evaluated by field staff in some Conservancies (I. Payton, pers. comm.).

COST-EFFECTIVE CONTROL TACTICS

Once target densities have been set, cost-effective combinations of control tactics can be sought. Detailed discussion of this is beyond the scope of this paper. However, modelling studies (e.g., Fig. 5) do reveal some general principles which are probably relevant to the field situation:

- •costly, high-kill techniques should be used first, so as to reduce the possum population as rapidly as possible;
- •cheaper, less effective control methods can then be used to delay population recovery during the "maintenance" phase;
- •it may be cost-effective to defer maintenance control in some years;
- •maintenance control techniques should be varied to minimise behavioural resistance.

Figure 5 An example of a cost-effective strategy for holding a hypothetical possum population close to its target density (set at 20% of pre-control possum numbers).

THE ROLE OF THRESHOLDS AND TARGETS IN PERFORMANCE ASSESSMENT

It is impossible to implement the management control paradigm shown in Fig. 1 without information on the benefit that the control work achieves in terms of ecological diversity. Despite decades of research demonstrating the negative effects of possums on our ecosystems (e.g., Campbell 1990, Rose *et al.* 1993), there is as yet almost no published data that assists us in investigating the relationship between control intensity and vegetation protection. Eradication of possums from islands has clear benefits (I. Atkinson, unpublished report), but this does not assist in determining action thresholds for sustained control on the mainland. Similarly, Pekelharing and Batcheler (1990) provide data on the benefits of control during an irruptive increase in possums, but this is difficult to relate to sustained management of post-peak populations.

Action thresholds and target densities may have to be relatively arbitrary at first, but they will provide a basis for ongoing performance assessment of possum control strategies and staff. These arbitrary thresholds should be able to be refined progressively as ecological monitoring data come to hand.

CONCLUSION

We do not know what action thresholds and target densities are required if possum control is to succeed in conserving current levels of ecological diversity on our conservation lands. The ecological interactions involved are probably so complex that such thresholds will have to be set by trial and error. Even this will not be possible if we do not begin to monitor ecosystem responses to possum control using reliable methods over a wide range of control situations.

Until more data can be gathered to demonstrate the link between possum control and ecosystem protection, regional conservation staff will in an invidious position in trying to justify their possum management strategies to the anti-1080 lobby, commercial possum hunters, cost-cutting accountants and politicians, and a sceptical public.

REFERENCES

Campbell, D.J. 1990. Changes in structure and composition of a New Zealand lowland forest inhabited by brushtail possums. *Pacific Science* 44: 277-296.

Cullen, R. 1992. Vegetation protection: some economic analyses. *Proceedings of the New Zealand Association of Economists Annual Conference 1992,* Hamilton.

Dent, D. 1991. *Insect pest management.* CAB International, Wallingford. EPPD. 1994. *National possum control plan*. Estate Protection Policy Division, Department of Conservation, Wellington.

Hickling, G.J. 1994. Behavioural resistance by vertebrate pests to 1080 toxin: implications for sustainable pest management in New Zealand. Pp. 151-158 in Seawright, A.A., Eason, C.T. (eds.) *Proceedings of the Science Workshop on 1080.* Royal Society of New Zealand Miscellaneous Series 28.

Hickling, G.J., McAuliffe, R.J. 1993. Principles of vertebrate pest management: a computer-aided learning approach. *Proceedings of the New Zealand Ecological Society Annual Conference (abstract). Auckland.*

Nugent, G. 1992. Deer hunting v. conservation – reaching a compromise. *What's New in Forest Research* 214: 1-4.

Pekelharing, C.J. and Batcheler, C.L. 1990. The effect of control on brushtail possums (*Trichosurus vulpecula*) on condition of a southern rata/kamahi (*Meterosideros umbellata/Weinmannia racemosa*) forest canopy in Westland, New Zealand. *New Zealand Journal of Ecology* 13: 73- 82.

Reichelderfer, K.H., Carlson, G.A. and Norton, G.A. 1984. Economic guidelines for crop pest control. *FAO Plant Production and Protection Paper 58*. FAO, Rome.

Rose, A.B., Pekelharing, C.J., Platt, K.H. and Woolmore, C.B. 1993. Impact of invading brushtail possum populations on mixed beech-broadleaf forests, South Westland, New Zealand. *New Zealand Journal of Ecology* 17: 19-28.

Tomkins, C.R. 1978. *Achieving economy, efficiency and effectiveness in the public sector.* Institute of Chartered Accountants of Scotland, Kogan Page.

INFRARED CAMERA TRIAL TO IDENTIFY POSSUM AND OTHER FERAL/WILD ANIMAL DENSITY/LOCATION

Paul Livingstone

Animal Health Board, PO Box 3412, Wellington

INTRODUCTION

A *A 1 RM 500 Mitsubishi Electric* infrared camera with a 512x512 resolution was hired from Mitsubishi. This detected thermal images in the >3µm range. It was attached in a slightly forward of vertical aspect beneath a Hughes 300C helicopter.

Thermal images captured by the camera were recorded on a Super VHS video recorder, with a resolution of 400 lines. The video tape had real time burnt onto each frame.

A *Trimble 1* Differential Global Positioning System (DGPS) was used to record latitude and longitude. The area to be surveyed was flown during the day and information recorded using an on-board 486 laptop. Then at night, when the infrared sensor was used, the pilot flew using the DGPS information, which was time bound to the super VHS recorder. At the end of each nights operation, the DGPS information was supposed to be sent through a modem to MAF Quality Management at Ruakura. They had developed a programme to turn the data into a GIS format.

Similarly, the video tapes were supposed to be edited using a frame stilling Job and Shuttle mechanism the following day. The time from frames containing thermal images and species observed were to be entered into a data set which was also to be sent to MAF Ruakura to be joined through the time factor into the GIS data set, such that the output was a map of the area flown showing the location of animals observed. I say supposed because it didn't work out like that.

DIFFICULTIES IDENTIFIED

The camera was hired for 30 days, but the period was extended to 35 days. Largely due to weather conditions, thermal imaging was only possible for about 12 part nights. There were two periods when the camera stopped working, due to a sticking lens which was able to be fixed. The base station for the DGPS drew a huge amount of power, and even though the batteries were continuously being charged, the base station could drain them within 2.5 hours. Thus on a number of nights, the DGPS system failed and the data was collected using compass bearings, which obviously could not be connected to the DGPS system. Also the protocol required the pilot and camera operator to fly for 4 – 6 hrs each night. This proved too dangerous. The pilot could only concentrate for about 3 hrs maximum and the camera operator found continued concentration difficult. They suggested that 2 teams should be used for future operations. Teams would swap at refuelling.

INFRARED IMAGING – THE PROTOCOL

This was a state of the art, very sensitive camera, which we were told is used in the nose-cone of the shuttle. It detected possums, but the intensity of the image depended on the amount of foliage between the possum and the camera. If a possum was at the top of the tree, it appeared on the video tape as a white, rather short fuzzy beam (the tail – probably because there is no hair on its underside). The rest of the animal could be distinguished as a paler image. However, if the possum was in foliage, a thermal image may only be visible for 3 – 5 frames and would appear as a greyish spot. Also, if a possum was to the side of the swath, rather than in the middle of the swath, it may only appear in a limited number of frames and this would again cause problems in detection. It took real skill to identify some possums. However, flying at night ensured that rocks and trees were not radiating heat to confuse the viewer.

The camera was standardised by flying over a tree that contained 4 possums in separate cages at various heights and degrees of foliage protection. The camera always picked up 2 of the 4 possums and saw 4 possums about 60% of the time. Standardisation trials identified that a height of 300ft AGL, a speed of 23 knots/hr or 36 km/hr and the 50 mm lens (gave a swath width of 50m) was the best combination for our use.

The protocol then required the operators to FLIR a 20 ha podocarp forest block in the Orongorongo valley where possum density was known, by flying the area 5 times per night for 5 nights, (i.e., a total of 25 counts on the block). The objective was to identify the accuracy and variability of detection. Largely because of weather conditions, the total area was only able to be flown once and that was early on in the night. One hundred and six possums were recorded in the area. Phil Cowan (Landcare Research scientist) estimates that this was about 40% of the known numbers in the block.

The camera was also tried out over gorse and low scrub (manuka) blocks and the operator believed that because of the nature of the vegetation all possums in the swath would have been seen. However, actual numbers in the area were not known.

Because of continuing poor weather conditions, the trial shifted to the central North Island where the protocol aimed to compare possum numbers in an area that had been controlled with numbers in an area where they had not been controlled. I have not seen the data from this area and so cannot compare the results obtained with the results from another monitoring method. However, the camera did identify two locations in the controlled area where possums had not been killed. Seven possums were seen in 1 area and 11 in the other. This information was relayed to the Pest Controller who was then able to intensively target these two areas.

Because of time constraints, further work planned for the central North Island and Kopuatai Swamp were cancelled and the operation moved to Rangitoto Island.

The Department of Conservation's policy is to eradicate Bennett's wallaby and possums off the 2300 ha island. The island was poisoned with 1080 in June 1992 and an estimated 90%

of possums were killed. (Honey production subsequently rose from 2.5 tonnes to 17 tonnes.) DoC has since employed ground hunters to eradicate the balance of possums and wallabies off the island. It therefore provided an ideal opportunity to use the infrared camera. Because of poor weather, the operators were only able to cover 65% of the island, but it was the part where the hunters considered that they had eradicated the possums. The camera located about 50 possums and about 15 wallabies in the area. Another 40 images were seen but species could not be discriminated. Possums were clustered in 3 relatively largish areas (0.75k x 0.75k). On showing these areas to the hunters they identified them as being the ones where they had used "soft catch" traps (traps with rubber pads over the jaws to minimise the damage to the possums leg).

WHERE TO FROM HERE?

Even though the protocol was not able to be followed, the data obtained indicates that thermal imaging is a tool that shows promise and needs further evaluation. It was also suggested that digitising the image would allow poor/faint images to be enlarged and coloured, hence providing better definition of the animal image.

Recommendation: That funding be made available to undertake further infrared monitoring as part of a comparative monitoring trial in May/June 95.

POTENTIAL VALUE OF INFRARED SENSING

a) As a monitoring technique. Current techniques for monitoring an area of 5000ha vary in cost from $30,000 – $50,000. A rough estimate using the infrared camera suggest that the area could be monitored for about $12,000. Nationally, monitoring costs about $1.4 million for both DoC and the AHB. Thus any savings will benefit control.

b) To identify where maintenance control should be targeted. Currently, maintenance control entails placing 1080 baits every 10 m along the bush pasture margin and around all trees in the area. The infrared camera though provides an alternative. By flying the bush/pasture margins, build-up of possum numbers can be identified and maintenance can be specifically targeted to those locations. These scenarios need to be costed.

c) To monitor possum population densities in large areas of exotic forest prior to initial aerial control. This could identify areas with low densities, where control is not economically justified.

Proceedings of a Workshop on Possums as Conservation Pests. Possum and Bovine TB Control NSS Committee
29 – 30 November 1994, Christchurch

CONTROL TECHNOLOGY APPLICATION – WHAT CURRENTLY LIMITS OUR EFFECTIVENESS

Simon Kelton

Department of Conservation, Waikato Conservancy, Private Bag, Hamilton

INTRODUCTION

Possums are arguably the greatest threat to New Zealand's indigenous forests and their fauna. Despite increased public awareness of the possum problem and greatly increased funding for possum control, possums continue to extend their range. In their review of the status of the possum in New Zealand, Batcheler and Cowan (1988) estimated there to be almost 70 million possums nationwide. This figure has been used to great effect to heighten public awareness of the scale of the possum problem. In a 1991 survey (Sheppard and Urquhart, 1991) 89.9% of the public perceived possums to be a serious problem in New Zealand.

In its 10 year Possum Control Plan, the Department of Conservation (DOC) has set a goal " ...to conserve all extent species of native plants and animals and representative examples of natural biological communities and ecosystems against possum damage, as cost effectively as possible..." (Department of Conservation, 1994).

Since DOCs inception in 1987, its possum control budget has increased twenty fold to $6 million annually. Even so, controlling possums to a level compatible with conservation values is currently technically and financially possible on less than 2% of the Conservation Estate.

There are several key areas of concern in relation to what currently limits the effectiveness of control technology application. They are: the limitations of control technology itself; present management control strategies and socio-political acceptance of possum control and control methodology.

CONTROL TECHNOLOGY – AERIAL 1080 OPERATIONS

For effective possum control to be achievable, assuming the level of control required is known and the means to measure appropriate damage thresholds exists, the control technique employed must ensure that the highest possible proportion of the target population is exposed to it.

Second, the highest possible proportion of those individuals exposed to the technique must be susceptible to it.

At present, options for controlling possums to low densities and on the scale required to achieve conservation goals are limited to aerial application of either 1080 carrot or pollard baits, ground control using traps and cyanide or bait stations using 1080 or brodificoum baits.

By 1986, the main reasons some possums survived aerial operations were identified, including; sub lethal toxic loading, undersize sub lethal baits, non-learned behavioral aversion to 1080, and failure to encounter bait (Morgan *et al*., 1986). A study by Morgan (1990) showed 95% of possums encountering a correctly prepared bait should eat it and subsequently die.

Improvements in bait quality and the recent development of Differential Global Positioning Systems have overcome many the of variables which previously reduced the effectiveness of aerial control operations. However, there are still several areas where improvement is required.

Innate behavioural aversion to 1080 is an area where further research is required. 1080 is currently the only toxin available for use in aerial baiting and unless it can be effectively masked, there will always be some surviving individuals within target populations.

It seems researchers are still debating the pros and cons of various concentrations of cinnamon as a mask in 1080 bait preparations. Following advice from one scientific quarter, Waikato Conservancy moved to using 0.15% 1080 baits with a 0.5% cinnamon loading. A different research arm then suggested the 0.5% cinnamon concentration could be acting as a deterrent to possums. This inconsistency requires urgent attention to bait specification guidelines.

Another inconsistency exists where research is inadequate in relation to the susceptibility of non target species. For example, a recent telemetry study of 21 kaka at Pureora Forest Park, through an aerial 1080 carrot operation (T. Green pers. comm.), has demonstrated that carrot bait presents an acceptable risk to kaka. However, there are no robust data on the possible risk posed by pollard bait to this species. Conversely, for kokako, it is now accepted that pollard operations pose a minimal risk, but the risk posed by carrot bait is unquantified. The dilemma for Waikato Conservancy is both kokako and kaka inhabit the North Block of Pureora where a large scale aerial 1080 carrot operation is proposed in 1995 for bovine TB control purposes. The lack of robust data poses the question of whether the operation should proceed or should it be postponed until adequate research has been done.

Another factor limiting the effectiveness of aerial 1080 operations is learned aversion to 1080 (Hickling, 1994) and possibly bait types (Cheryl O'Connor pers. comm.) in some possum populations exposed to repeated aerial 1080 operations. Until an alternative toxin, suitable for aerial application, or a cost effective ground based technique becomes available, there exists little hope of maintaining these populations at the desired low densities into the future.

Operations undertaken in winter are prone to inefficiencies through difficulties associated with bait supply, availability of aerial contractors, access to airstrips and "down-time" while waiting for suitable weather. Waikato Conservancy waited 24 weeks from 1 June 1994, before obtaining a forecast enabling the Waipapa operation at Pureora to proceed.

Bait acceptance trials conducted at Waipoua in December (Warburton, 1994) and the Rangitoto Island operation carried out in November (DOC, 1990), suggest the argument that availability of alternative food sources limits bait take, may require closer scrutiny. Perhaps winter operations are a carry over from Animal Health work where operations conducted in spring may cause unacceptable disruption to farm management.

Differential GPS has resulted in major improvements in bait coverage, enabling application rates to be reduced, thereby lowering operational costs. Morgan (1993) estimates that applying pollard baits at 3 kg/ha would reduce operational costs by a third when compared with a sowing rate of 10 kg/ha.

Current differential GPS systems, however, only provide information to the pilot regarding flight paths, start and completion points of each run and a record of where the aircraft has actually flown. It is up to the pilot to log on and log off the system as the bucket or hopper is operated and to check that baits are actually being dispensed. There is, therefore, still potential for gaps in bait distribution to occur due to human error.

The ability of current bait delivery systems to be calibrated to perform consistently at lower sowing rates, is also a limiting factor to effective bait application.

GROUND BASED TECHNIQUES

Trapping, using professional hunters on wages or performance based contracts, has been used successfully to achieve satisfactory conservation outcomes in a number of areas (Hughes, 1994). Most professional "trappers" combine the use of leg hold traps and cyanide as their method of operation.

Contrary to the Parliamentary Commissioner for the Environment's view, the experience in Waikato Conservancy shows contract trapping is not as cost effective as aerial 1080 operations. No areas exceeding 1000 hectares in size have been successfully trapped within contract deadlines.

Access, topography and vegetation type are key limiting factors, along with trappers "skill levels" and attitudes. There appears to be a shortage of highly skilled trappers willing to undertake contract trapping operations and it is often difficult to change their thinking from "commercial trapping" ethos to "conservation trapping" where thorough systematic coverage of the entire block is required. In the Waikato Conservancy, many trappers underestimate the level of effort required to meet target densities.

Trapping has its place as a possum control tool but it may be at a cost higher than alternative methods.

The use of bait stations is being investigated as an alternative possum control method to aerial 1080 operations and trapping. Research carried out by Thomas (1994) investigating the use of bait stations shows that bait stations, placed in a 150 x 150 m grid, pre-fed with non toxic baits before filling with 1080 baits can achieve similar reductions in possum numbers as aerial 1080 application.

The potential for this technique is promising. Less toxic bait is used, the baits are contained within the stations, thereby reducing the risk of exposure to non target wildlife species, and although labour intensive, the technique does not rely on skilled personal to set the stations.

Similar limiting factors as apply to trapping are likely to limit the use of bait stations viz access, vegetation type and topography. Also at present, there are only two toxins available for use in bait stations, 1080 pollard and Talon Possum bait.

To reduce the costs of this possum control method, the requirement to revisit and refill bait stations needs reducing. The development of a bait with a long field life would reduce labour costs but the problem of innate and learned bait aversion towards the two available toxins still remains.

The chronic nature of Talon also limits its use in high density possum population situations due to the large amount of bait consumed. The development of encapsulated toxins may overcome some toxin aversion responses.

PRESENT MANAGEMENT CONTROL STRATEGIES

Although the technology exists to produce high initial "knock down" of possum populations, there are no suitable maintenance control strategies to achieve the Department's goal in the longer term.

Most conservancies undertaking possum control operations have entered into a programme of periodic intensive control on a 3 to 10 year cycle. This strategy mimics the classic predator prey "boom and bust" cycle and may not necessarily result in the long term protection of conservation values, e.g., *Dactylanthus taylorii*. The control interval in most cases has not been derived from a knowledge of population dynamics, nor an understanding of threshold densities at which unacceptable damage is likely to occur.

At Mapara Wildlife Reserve where a sustained control programme, based on a high initial "knock down" followed by regular maintenance, in this case an aerial 1080 operation followed by annual trapping and/or bait station programmes, there are problems with the labour intensive nature and therefore cost of follow up maintenance control. There is also potential for learned bait aversion behaviour to develop. Another potential problem in a low density population situation, is for the fecundity of the residual population to increase (Batcheler and Cowan, 1988).

For maintenance control of low density possum populations, the use of bait stations appears promising, provided a range of toxins in long life bait formulations become available.

FUTURE/LONG TERM STRATEGIES

Traditional control methods will never provide cost effective control over the whole of New Zealand, so new control technologies, that will have substantial and sustainable impacts on the national possum population are required (Jolly, 1994). Biotechnological bio-control offers hope for the 21st century but a critical possum problem exists right now.

SOCIO-POLITICAL LIMITATIONS

In this age of MMP and political awareness, public opinion about control technology, even if ill informed, can have a major impact on our management practices. Its influence is often underestimated but it can lead to the redirection of resources (e.g., Task Force Green possum control schemes), the delaying of operations, the soaking up of an inordinate amount of personnel resources in attending public meetings, conducting additional monitoring to allay public concerns about non target species impacts or water quality, through to providing responses to ministerial letters.

Much public debate has been generated in relation to the use of 1080 in New Zealand and there is a perception that "indiscriminate" aerial application of baits threatens human health, non target animals, hunting opportunities and disrupts farm management.

There are also animal welfare lobbyists who, in addition to being anti-toxins, may also be anti-trapping or even anti-possum control *per se*.

To a large degree, public perception about the use of possum control techniques is likely to be a reflection of the information the public has available on which to base a judgement.

In the 1991 survey of public opinion on pest control in New Zealand (Sheppard and Urquhart, 1991) most people considered shooting and trapping to be the best possum control methods. Frequent calls are heard for bounty schemes to be reintroduced. The question must be asked why are managers and scientists alike failing to get through to the public on these fundamental possum control issues?

As the Parliamentary Commissioner for the Environment (Hughes 1994) pointed out in her review of possum management in New Zealand "the public view of the risks (real, unknown or perceived) by using pesticides is also influenced by a history of 'safe' chemicals proven 'unsafe' or persistent in the environment over time (e.g., DDT, Thalidomide, PCB's, PCP, Agent Orange). Regardless of the specifics of each case, this has in general reduced the level of public trust in government officials and scientists."

It is easy to dismiss some of the anti groups arguments as being "off the wall" but unless satisfactory answers are provided that stand up to public scrutiny, they will continue to make political milage with emotive arguments and managers will find it increasingly difficult to use existing or new technology for possum control.

REFERENCES

Batcheler, C.L. and Cowan, P.E. 1988. Review of the Status of the Possum in New Zealand. Unpublished contract report commissioned by Technical Advisory Committee (Animal Pests).

Department of Conservation 1994. National Possum Control Plan : A strategy for the sustainable protection of native plant and animal communities 1993-2002. Estate Protection Policy Division, Department of Conservation, Wellington.

Department of Conservation 1990. Rangitoto Pest Eradication Report. Phase 1 : Air Drop of 1080. unpublished Department of Conservation report. Auckland Conservancy.

Hickling, G.J. 1994, in press. Behaviourial resistance implications for sustainable pest management in New Zealand. *N.Z. Journal of Zoology*.

Hughes, H.R. 1994. Possum Management in New Zealand. Office of the Parliamentary Commissioner for the Environment.

Jolly, S. 1994. Possum control for the 21st Century . *Forest and Bird* Issue No.272, May 1994.

Morgan, D.R., Batcheler, C.L. and Peters, J.A. 1986. Why do possums survive aerial poisoning operations? Pp 210-214 in *proceedings of the 12th Vertebrate Pest Conference*, San Diego, California.

Morgan, D.R. 1990. Behaviourial responses of brush-tail possums, *Trichosurus vulpecula*, to baits used in pest control. *Australian Wildlife Research* 17: 610-613.

Morgan, D.R. 1994. Improved cost-effectiveness and safety of sodium monofluoroacetate (1080) possum control operations. In Seawright, A.A. and Eason, C.T. (Eds.), Proceedings of the science workshop on 1080. *The Royal Society of New Zealand, Miscellaneous series 28*. 178p.

Sheppard, R.L. and Urquhart, L.M. 1991. Attitudes to pests and pest control methods, *Research Report No 210*, Lincoln University, Canterbury.

Thomas, M.D. 1994. Possum Control in Native Forest using sodium monofluoroacetate (1080) in bait stations. *Proceedings of the 47th Plant Protection Conference*: pp 112 - 116.

Warburton, B. 1994. The potential effectiveness of aerially sown 1080 baits for controlling low density possum populations. Landcare Research Report Number LC 9394/112.

WHERE SHOULD WE BE WITH POSSUM CONTROL IN 2005? – A RESEARCHER'S PERSPECTIVE

David R. Morgan

Manaaki Whenua – Landcare Research, PO Box 31-011, Christchurch

INTRODUCTION

Possum control as a sustainable conservation practice in future will become increasingly complicated by considerations other than the choice of control technique. In outlining where we should be with possum control and research in 2005. I will therefore firstly describe the broad context in which possum control will be placed. I will then discuss some of the technical means of achieving sustainable possum control, before finally narrowing in to speculate about the actual control methods that we may be using 10 years from now.

THE CONTEXT FOR POSSUM CONTROL IN 2005

The context (Fig. 1) we will be working in will be based on information that will be used in a decision making process involving an increasing community input (Williams 1994). Knowledge of the ecology and ethology of the possum will be used to define **Where and When** possum control is required. The type of information being generated on impacts is currently utilised mainly by DoC managers to establish priorities for control. However, by 2005 there will have been a shift in emphasis from the department to the community in making these decisions about **Why** one area should receive protection over another. This will happen as a result of a growing awareness of the conservation values being threatened by possums and an increase in community ownership of "the problem". The community's aspirations, representing the mixture of cultural values, are difficult to synthesise but a start has been made in assessing attitudes towards wildlife through community surveys. Similar surveys will be necessary on perhaps a smaller scale so that conservation practice can be designed to hopefully satisfy both national and local wishes.

Figure 1 The context of possum control in 2005.

Also at the base of this framework is the development of possum control technology that tells us **How** possum control **may** be achieved. While the range of control technologies is likely to expand as a result of the large amount of research being done, it will be increasingly necessary to find publicly acceptable means of control. Much of the current impasse over 1080 is probably due to lack of public involvement in possum control in the past and so, as the community adopts greater ownership of the problem, motivation to accept new technologies may be greater. There is likely, however, to be more debate of both the ethics of **How** control is achieved and also the question of **Who** should actually do the control. Whether we view the possum as a pest or a resource, or something in between, research has already demonstrated that there is a role for skilled hunters to play in controlling possums (Morgan & Warburton 1988). As more companies become interested in the development of control technologies, it is likely that some will become specialised in applying these technologies.

There will therefore be a growing need for research at this macro level to assist DoC managers and others in balancing community wishes against the available budgets for control, which will be influenced by public attitudes through the democratic process. The legal framework (i.e., RMA and Biosecurity Act) is already in place to assist the final stages of synthesising these various considerations into a sustainable pest control strategy and in turn sustainable conservation.

TECHNICAL BASIS OF SUSTAINED POSSUM CONTROL

By 2005, the central concept in planning possum control for conservation purposes will be sustaining control in the long term. For control to be both ecologically, economically, and politically sustainable, it is essential that planning is as realistic as possible and this depends largely on how PREDICTABLE the effects are of the control tactics used. The technical basis for improving predictability comprises a number of research and operational elements (Fig. 2).

Figure 2 Elements required to support sustainable possum control.

The Total Quality Management approach now being adopted in the possum control industry will have come to fruition. This approach to management attempts to maintain high standards through systematic adherence to procedures, with the result that poor performance or failure is avoided. The personnel involved in implementing control, whether they are employed by DoC, other agencies or private companies will require certification of having undergone formal training in the technology and practice of possum control. All operational methods will be clearly defined by Standard Operating Procedures and monitored using Quality Assurance and performance monitoring that in themselves will be based on validated, legally defensible techniques.

Much greater integration of research and management will be being practised than now to gain reliable information on a relevant scale. Parts of operations will be routinely established to test new control methods, with experiments being replicated to determine the generality of the results, and hence predictability of the new methods. Experiments will increasingly combine different control methods, objectives and target pests in the Integrated Pest Management approach described by Coleman (1993) and already widely adopted against insect pests.

Such research will provide more and better data for modelling the outcome of control practices. The models are likely to have become more multidimensional by 2005 embracing not only the post-control dynamics of pest populations, but the economics of achieving sustained control under various control scenarios, and the effects on success of environmental variables such as climate, vegetation dynamics, and the phenology of possum dietary plants.

POSSUM CONTROL METHODS IN 2005

I believe we will still be largely reliant on chemical control in 10 years time, supplemented by mechanical control, and we may just be starting to see the first field trials of new biological control techniques (Fig. 3).

Figure 3 Possum control technology in 2005.

Chemical control We will probably have moved away from 1080 if the public opposition to its use continues. The lessen to be learned from the controversy surrounding the use of 1080 is that we must take the public along with us in developing new control methods. However, I believe we will still be using toxic baits by aerial and ground application of baits, but we will have more precise control over the effects of these operations. Minimum amounts of bait will be used to ensure success. New bait types will permit the selection of field life to suit different climates or to suit use in either bait stations (long-life) or aerial operations (usually short life). They will be made target specific by, firstly, the incorporation of additives that deter non-targets but not possums, and secondly, by incorporating a "designer" toxin which targets a unique metabolic pathway in the possum rendering it more vulnerable than other animals. The possums vulnerability to cholecalciferol (Eason 1991) as a result of its unusual calcium metabolism exemplifies this approach. Toxins will be approved for use only if they meet defined standards of humaneness. Bait application will be by GPS-guided aircraft but the GPS will be linked to bait output sensors so that output documents both flight-paths and bait output. Scanning of output for areas missed will conveniently be digitised into a guidance programme for pilots to follow in subsequently completing coverage. The new technology of thermosensing may also be used for subsequently identifying pockets of survivors for treatment with a different bait/toxin combination known to be effective against bait-shy possums.

Sometimes it may be more economic to protect plants rather than kill possums, particularly in small vulnerable reserves close to large possum populations. Here, we may be able to impart the chemical protection lacking in many native plants by treating them with systemically incorporated repellents based on toxic secondary plant compounds or other aversive-conditioning compounds.

Traps Traps will be used that meet internationally agreed standards for humaneness (based largely on NZ research). A variety of kill traps will be in use that either break the possums neck, or kill by electric-shock or lethal injection.

Biological control While much progress on biological control will have been made by 2005, it is unlikely that a new control method will be available by then. We may be at the stage of establishing field trials of new biotechnology such as fertility control agents delivered either by a viral vector or in a bait. Another, older form of biological control is manipulation of the habitat. While this is likely to be important in the farming situation for restricting the spread of Tb, there may be less opportunity for exploiting it for conservation. However, where habitats are being restored by replanting, we should be able to replant with unpalatable varieties of normally vulnerable plants.

SUMMARY OF RESEARCH NEEDED UNTIL 2005

Possum control in 2005 will have become more of a responsibility for the wider community who will strongly influence where and how it is done. The research required to underpin possum control that is ecologically, economically, and socially sustainable should include:

Social and strategic research

- community attitudes to possums and effects on conservation (by surveys and stakeholder workshops or huis at both the national and local scale)
- strategic development of the possum control industry and employment
- development of integrated control strategies
- ethics of control technologies

Ecological research

- possum impacts (to aid prioritisation at both the national and local scale)
- chemical ecology (naturally occurring deterrents/attractants for use in control)
- sociobiology (to underpin biocontrol)
- ecology of unmanaged ecosystems (what happens when we do nothing?)

Control technology research

- definition of TQM standards and protocols throughout the industry
- alternatives to 1080 and new delivery systems
- improved precision in chemical control ("minimum use", target specificity, predictable field-life, thermosensing, systemic repellents)
- humane traps
- RbM experiments on a relevant scale to test new techniques and strategies (e.g., IPM)
- multi-dimensional modelling embracing population dynamics, economics, climate, vegetation dynamics, phenology etc.
- biotechnologies for longer term solution (fertility, diseases, habitat manipulation)

REFERENCES

Coleman, J.D. 1993. The integration of management of vertebrate pests in New Zealand. *New Zealand journal of zoology* 20: 341-346.

Eason, C.T. 1991. Cholecalciferol as an alternative to sodium monofluoroacetate (1080) for poisoning possums. *Proceedings of the 44th New Zealand Weed and Pest Control Conference 1991*: 35-37.

Morgan D.R. and Warburton, B. 1987. Comparison of the effectiveness of hunting and aerial 1080 poisoning for reducing a possum population. Unpublished Forest Research Institute Report. 23p.

Williams, J.M. 1994. Food and fibre markets and societal trends: implications for pest management. In Seawright, A.A; Eason. C.T. (eds.), Proceedings of the science workshop on 1080. *The Royal Society of New Zealand Miscellaneous series 28*. 178 p.

Proceedings of a Workshop on Possums as Conservation Pests. Possum and Bovine TB Control NSS Committee
29 – 30 November 1994, Christchurch

POSSUMS AS CONSERVATION PESTS

IDENTIFICATION OF RESEARCH PRIORITIES: WORKSHOP CONCLUSIONS

Compiled by
Colin F.J. O'Donnell

Science & Research Division, Department of Conservation, Private Bag, Christchurch

TOPIC 1

WHAT EFFECTS ARE POSSUMS HAVING?

Issues and information needs

– Still need information on what impacts possums are having on ecosystems and species, especially as the role of possums as predators and competitors with fauna has only recently been recognised.

– Need to understand the considerable variability of possum damage on the same plant species in different regions. For example, what factors predispose plants such as mistletoes or fuchsia to selective browsing in some areas but not others? What is the full extent of this variability?

– What are the multispecies impacts of controlling possums? What are the flow on effects to other elements of the ecosystem, e.g., effect on behaviour of other predators and competitors after control.

– Need to use management operations as experiments to assess relative impacts and success of possum control, and then alter management practices as new information comes to hand.

– Need a consistent national system for monitoring impacts of possums and recording the efficacy of possum control operations to allow, eventually, for comparisons between operations.

– Need to identify key threatened species in both high and low priority areas for control.

– How best can the public be informed about the effects of possums and the need for their control?

Main Recommendations

1. Long term studies are needed if the impacts of possums on conservation values are to be understood.

Explanation: Long term studies on scales of >30 years are needed to understand the impacts of catastrophic events caused by possums, whether or not plant regeneration cycles are impacted on, regional variability of impacts and the overall effect of predation and competition on long term viability of fauna populations. Knowledge of the natural fluctuations of flora and fauna populations in the absence of possums is still needed to fully evaluate risks. A few sites are needed where the repercussions of possum control are monitored at the community level. Assessment of how past or existing research programmes contribute needs to be undertaken. An experimental approach using paired comparisons between different combinations of areas with no possums, and different control treatments is recommended.

2. The relative role of possums as predators of, and competitors with, indigenous flora and fauna, and their relative impacts compared with other pests needs investigation.

Explanation: The relative impacts of predation and competition need to be understood because both may not impact, at least to the same degree, on the long term viability of each threatened fauna and flora population. Likewise, where more than one predator is involved in the decline of a species, only one may be critical to the viability of that species. Consequently, recovery of a threatened species may not be dependent on management of all threats.

3. The value of using, and suitability of, key indicator species to identify and monitor possum impacts on ecosystems needs to be assessed. Basic research on ecosystem ecologies is still required to identify potential indicator species.

Explanation: Having a limited suite of key species or ecosystem processes which indicate the current level of ecosystem health or level of recovery after a control operation would be valuable. However, no assessments seem to have been made of whether indicator species are present which would fulfil this role. Threatened species have often been cited as indicator species without full assessments of whether their population trends do mimic overall trends in ecosystem biodiversity.

4. Social research is needed to evaluate how the public perceive the impact of possums on New Zealand ecosystems.

Explanation: A properly structured survey of what the public think about the possum issue, public discussion documents, and assessment of public response is needed. It should be recognised that such "action research" could actually alter the perceptions of society during the period of the research programme. Such research would form the basis of more public education and information transfer.

5. There is a need for computer models which predict impacts of possums on all aspects of forest ecosystems.

Explanation: Models can provide valuable tools for developing key questions which need investigation, indicating which baseline ecological data need collection, and predicting relative impacts of different possum-induced processes of decline and time frames for action. At the same time, though, there is still a need for baseline ecological information to feed into models before reasonable predictions can be made.

TOPIC 2

HOW BEST TO SPEND POSSUM CONTROL MONIES TO ACHIEVE MOST CONSERVATION GOALS?

Key Issues and Information Needs

– How are all the facets of ecosystem quality, value and vulnerability measured?

– Ranking should be done in terms of overall benefits of the operation as well as existing values.

– Constant re-evaluation of existing rankings is needed as new information comes to hand.

– Ranking should consider how or if the operation could be integrated with other conservation management or animal health programmes – some operations could be considerably more valuable and cost-effective if done that way.

– Feasibility of multi-species control operations should be investigated as money may be more effectively used this way, although because different pests have different recovery rates follow-up control may be difficult.

– Greater emphasis should be put on ecological communities and less on single species when ranking areas.

– Opportunities for local community input into ranking priorities should be investigated.

– Economic approaches to assessing costs and benefits need investigation.

– Considerably more data are needed to undertake cost effectiveness studies, but pilot studies could be started.

– More information on measuring and defining "susceptibility" of ecosystems to possum damage is required.

– Social research to assess public concerns is needed in order to define overall goals for possum control.

Main Recommendations

1. Some fine tuning of the current system for identifying priority areas for possum control is needed.

Explanation: A priority ranking system needs to contain elements that fully appreciate the very diverse ecological values that are often being weighed up against each other. Managers need to be assured that they are fully aware of all existing relevant information when setting the priorities. It was considered that more emphasis should be put on ecosystem value components of the priority ranking system than is done at present. Whether the system could be more land unit rather than ecosystem based could be investigated. Quantification of costs and benefits of operations managed in different ways in the past could help in setting priorities better in the future.

2. The concept of ecological scalars for assessing costs and benefits of possum control operations should be investigated, with the hope that a single, cumulative, index can be developed.

Explanation: Managers need measures to assist in determining the values of prospective possum control operations and for measuring whether the objectives of each operation have been met. Development of ranking models requires measures of the ecological benefits, prospects for reversal of degradation, economic effectiveness and cost-benefit analysis and how the public values proposed control operations.

TOPIC 3

CAN DAMAGE THRESHOLDS BE IDENTIFIED?

Key Issues and Information Needs

– The concept of thresholds is essential for management, but definitions of thresholds at which to commence possum control are needed for a wide range of conservation objectives, particularly as these thresholds may change over time.

– Need more ecosystem monitoring associated with possum control, looking at a wide range of species.

– Are there suitable soil and water quality indicators of possum damage to ecosystems?

– Agreed minimum requirements and standardised methodology for monitoring operations is needed.

– Need to review theoretical literature on the use of indicator species for measuring ecosystem health and reversal of damage.

Main Recommendations

1. Considerably more data on native species responses and more research by management are required to determine the effects of possum control operations on the species and ecosystems being protected.

Explanation: Managers need to be able to measure the effectiveness of control operations on target communities and species (threshold at which trend of decline has been reversed), and to refine both the initial threshold they deem intervention is required and target thresholds for successful operations in the future. Research by management is a mechanism by which as much as possible can be learnt from on-going control operations and thus incrementally improve effectiveness with each new operation. There is information on responses to possum control for only a limited number of species. The application of standard methodologies to on-going control operations will supply information on the responses to management of a much wider range of species and communities.

2. Complementary research approaches which blend both long and short term studies and empirical and predictive models are needed to give rigorous damage and intervention thresholds with which to guide management.

Explanation: Thresholds are useful for identifying when a control operation is needed and to measure the subsequent effects of the operation. However, thresholds at which action is required will be very variable, depending on which conservation values are being targeted. Intervention levels for threatened species and for overall community restoration may be very different. Damage thresholds are multidimensional, and could depend as much on other threat processes at work in an area (e.g., impacts of other predators and browsers present). Thresholds could be developed based on which species or ecosystem processes are most susceptible to possum impacts. Long-term research should aim at studying and modelling interactions between vegetation dynamics and herbivory. Short-term research should aim at empirical measurement of the impacts of control. Responses of suitable treatment and non-treatment areas need to be compared.

3. Improved tools for measuring ecosystem health are needed.

Explanation: The selection of suitable indicators (indicator species, processes or measures of ecological diversity) is needed to measure ecosystem responses to possum control operations. However, research is needed to formulate appropriate indices. A comprehensive understanding of the relative vulnerability of various plant and animal species to possum influence at various possum densities is needed. Need to establish relationship between indicators, possum densities and "unacceptable damage". Both structural (e.g., canopy damage) and functional (e.g., effects on populations) indicators may be needed.

TOPIC 4

HOW CAN POSSUM CONTROL TECHNOLOGIES TO PROTECT CONSERVATION VALUES BE IMPROVED?

Key Issues and Information Needs

– Improvement of technology in two areas is needed: initial control and sustainability of on-going control. Improvements should aim at reducing costs while increasing efficiency of control.

– More research on the impacts of toxins on non-target species is required. Testing of non-target impacts of new toxins being introduced is needed at an early stage.

– There are continuing problems with using new technologies such as GPS navigation and guidance of aerial sowing.

– Is pre-feeding an essential part of all possum control operations? If not, then considerable monies could be saved.

– There is a need for bioeconomic models to compare the relative efficiencies of aerial, ground based bait station and trapping operations, in the full range of circumstances (e.g., forest types, possum densities, geographic areas).

– Need a greater understanding of the influence of patchiness of possum densities and behaviour on large scale control operations. Could targeting patches lead to more effective control?

– Need to identify and characterise routes of recolonisation after initial control operations.

– Need to understand seasonal constraints on control operations more fully.

– Quality control and auditing of operations should be looked at.

– Could explore the potential role of habitat manipulation in reducing numbers and recolonisation.

Main Recommendations

1. Further research is required on developing and refining existing control techniques, and assessing new techniques.

Explanation: Refinement of current techniques used for both the initial "knock-down" control operation, and for subsequent "maintenance" operations is needed to improve the effectiveness of control. Prescriptions for maintenance operations and the role of pre-feeding in particular need further development. New and perhaps novel techniques for improving possum control should be investigated. Areas that warrant investigation include improved attractants or repellents, bait quality and preparation, long-life baits, biocontrol and biocide agents, new and humane trap designs, new ways of dispensing toxins and effectiveness at different possum densities. Repeatability and validity of new techniques needs to be thoroughly tested. Management operations using new techniques need to be monitored effectively.

2. Social research and advocacy are needed to determine how to achieve public acceptance of control technologies that are being used.

Explanation: The scientific community generally accepts that current techniques using toxins and traps are among the most humane and effective available. The ecological benefits of using these techniques out-weigh the costs of not undertaking these control operations. However, some public perceptions differ, and some conflicts have been identified. The scientific community needs to understand public perceptions more fully and develop effective techniques for conveying their information to the public.

3. Research on the validity of multispecies control regimes is needed.

Explanation: Control operations may be more cost-effective if more than one pest species can be controlled in an area at once (e.g., other predators and browsers such as stoats, cats, rats, deer). More information is needed on the consequences of multi-species control and effective prescriptions (e.g., timing) are needed to optimise the effect of the control operations.

4. Research on integrating control techniques is needed.

Explanation: Currently a range of techniques is being used for possum control (ground and aerially applied toxins, different ground trapping regimes, private and subsidised trapping). Different techniques, or combinations of them, may be more effective indifferent situations. These situations probably vary geographically, in different forest types, and depending on the objectives and timing of control operations. Effective prescriptions need to be developed to guide managers.

ACKNOWLEDGEMENTS

The workshop was convened by Phil Cowen (Landcare) and Richard Sadlier (DOC) and chaired by Richard Sadlier. Sharon Foss (MORST) took a major role in organisation and Jocelyn Berney (MORST) also assisted.

The Possum and Bovine Tuberculosis Control NSSC thanks the Department of Conservation for the financial support of the workshop and also wishes to thank all speakers and those who chaired or reported on each workshop session.