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A case for multi-species management of sympatric herbivore pest impacts in the central Southern Alps, New Zealand

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Abstract: Five herbivorous introduced mammals are sympatric in the central Southern Alps. All of these species have the potential to affect conservation values, yet the Department of Conservation at present monitors and mitigates the impacts of only one. We outline ecological arguments for multi-species management of sympatric herbivore pest impacts and use the two-species system of sympatric thar and chamois to highlight the need for multi-species management of the central Southern Alps alpine pest community.

Keywords: Alpine; conservation; Himalayan thar; pest control; Southern Alps.

Introduction

Five introduced herbivores, Himalayan thar (*Hemitragus jemlahicus* Smith), chamois (*Rupicapra rupicapra* L.), red deer (*Cervus elaphus scoticus* Lönnberg), possum (*Trichosurus vulpecula* Kerr), and hare (*Lepus europaeus occidentalis* de Winton) presently co-exist (termed sympatric) in the alpine zone of the central Southern Alps. The Department of Conservation has a statutory obligation to control pests to minimise their impacts on indigenous biota (Holloway, 1993) but currently actively manages (i.e., monitors and controls) only one of these species (thar) in this region.

In this paper, we show that because (1) all five species are generalist herbivores with varying degrees of dietary overlap, and (2) habitat use by these species is known to overlap, the impacts of these species on conservation resources are likely to be cumulative to an unknown extent. That is, more than one of these species is likely to modify the distribution and abundance of a particular plant species. We describe why multi-species management of these pests is likely to deliver improved conservation benefit relative to the current single-species approach. We also outline the essential elements of a multi-species pest management plan for the central

Southern Alps alpine zone, that area normally covered by winter snow and above timberline, within the thar breeding range. The thar breeding range encompasses the Main Divide and associated lateral mountain ranges between Haast Pass and Whitcombe Pass (Department of Conservation, 1993).

The central Southern Alps' alpine pest community

Current densities and distributions of the five mammalian herbivores in the central Southern Alps reflect differences in the carrying capacity of alpine habitats for each species (Table 1), and their different histories of management and harvesting over the last 60 years. The current densities and distributions of the three ungulates have been determined largely by over 60 years of control and harvesting. Recreational hunters have taken variable annual harvests of deer since last century and of thar and chamois since the 1920s. Government-funded control of all three species began in the 1930s, continued until the 1960s for deer and chamois, and remains ongoing for thar (Department of Conservation, 1993). Justifications for this control have changed over time, and thus the priority species

Table 1. Attributes of five herbivore pests sympatric in the central Southern Alps alpine zone (? indicates unknown).

Species	Body weight (kg) ¹	Maximum density (number km ⁻²) ²	Variability in density ³	Maximum biomass (kg km ⁻²) ⁴	Habitat(s) used ⁵
Thar	45	>30	High	>1350	g, b, s
Chamois	31	5	High	155	g, s
Red deer	58	10	High	580	g, s
Possum	2.8	?	Low	?	s
Hare	3.5	<1	Low	<3.5	g

¹ Average of female and male (adapted from King, 1990).

² Figures based on King (1990), Flux (1967) and personal observations.

³ Relative spatial and temporal variability in density.

⁴ Product of biomass and maximum density.

⁵ Habitats are grassland (g), bluff (b) and shrubland (s); information based on Christie (1963), Guest and Wilkinson (1976), King (1990), Parkes and Thomson (1999), and the authors' unpublished data.

and where they were controlled has changed over time. Early campaigns were widespread and aimed to reduce competition with domestic stock; later campaigns were more focussed and were usually justified to mitigate supposed downstream water and soil quality effects (Caughley and Sinclair, 1994). Current official control of thar aims to safeguard broad conservation objectives by halting dispersal and keeping numbers below specified densities (Department of Conservation, 1993).

In the alpine zone, ungulates are highly vulnerable to helicopter-based hunting. Consequently, the advent of commercial harvesting of the ungulates for game meat in the 1960s reduced red deer, thar and chamois populations to very low densities (near zero in many places; see Parkes *et al.*, 1996). Current national harvests of deer and chamois from the central Southern Alps alpine zone are unknown but probably number only a few hundred each, mostly from the western Alps. After a moratorium imposed in 1983, commercial harvests of thar recommenced in 1995 and totalled *c.* 2 900 in that year (Parkes *et al.*, 1996).

Possum populations are controlled to protect conservation values over $\geq 10\,000$ km² of New Zealand (Parkes *et al.*, 1997) using a large number of control techniques (Cowan, 1990). However, none of the 250 ongoing control programmes occur in the central Southern Alps alpine zone. Few techniques are available to control hares (e.g., Parkes, 1984) and none have been tested in alpine habitats (Wong and Hickling, 1999). Hares are not targeted in any control operation for conservation reasons. The fact that possum control technology is much further advanced than that of hare control will shape the options available for multi-species management.

Current planning procedures

The Department of Conservation currently has national policies and specific plans for thar (Marshall, 1991;

Department of Conservation, 1993) and possums (Department of Conservation, 1994), although, as noted above, the latter has as yet no consequences for possums in the alpine zone. The planning and consultative process for the thar plan has been summarised by Hughey and Parkes (1996). The plan divides the thar breeding range (*c.* 7 000 km²) into two exclusion zones, which aim for zero thar density, and seven management units. The management units are based on different land tenures and vegetation types. Each management unit has a specified maximum allowable density of thar (≤ 2.5 thar km⁻²), with recreational and commercial hunting encouraged to maintain thar below that density; government-funded control in the seven management units is used only as a 'last resort'. All management units have conservation objectives based on maintaining "healthy plant cover, species diversity and regenerative capacity of plant communities" (Department of Conservation, 1993).

Densities of thar are monitored annually or biennially in more than 20 catchments spread throughout the seven management units (Department of Conservation, *unpubl.*). Thar are counted using binoculars and spotting scopes; chamois and red deer are also counted, if observed. Densities in these catchments are used to infer population density within each management unit.

Monitoring the impacts of thar on tussock communities is a major feature of the plan. Seventy-two permanent plots have been established in five catchments to monitor the impacts of different densities of thar on the vegetation; these plots are being remeasured every 2-4 years (Parkes and Thomson, 1999). No other government-funded monitoring of pest impacts in the central Southern Alps alpine zone is being undertaken.

The method used by the Department of Conservation to prioritise pest control operations changed in 1998 (C. Veltman, Department of

Conservation, Wellington, N.Z., *pers. comm.*). Previously, wild animal control plans prepared under the Wild Animal Control Act were used to prioritise expenditure. Managers now select sites and cost out the pest control that would improve the value of the site, and bid against other projects (C. Veltman, *pers. comm.*). The implication of this change for implementing multi-species pest management is discussed later.

The ecological basis for multi-species pest management

Niche theory (e.g., Gause, 1934; Diamond, 1978) states that when two or more species co-exist their habitat use and diet, and therefore impact on community structure, will not completely overlap. Indeed, differential resource selection is viewed as a fundamental process enabling co-evolved species to co-exist (Rosenzweig, 1981). This generality, however, has been derived from studies of natural communities. Introduced species can be expected to show greater niche overlap than co-evolved species because there has been insufficient time for competitive effects to shape the community (McNaughton, 1986).

Since most large mammalian herbivores are generalist feeders (Belovsky, 1986), there is likely to be considerable dietary overlap when introduced herbivores are sympatric. Thus, their impacts on particular indigenous biota can be expected to be largely cumulative. Because plant community composition, herbivore population density, and herbivore behaviour are spatially heterogeneous (Huntly, 1991), herbivore impacts will also be highly variable in space and time (e.g., see Hone, 1995). Control action is likely to amplify the variability of both herbivore behaviour (e.g., Douglas, 1971) and population density (Forsyth and Hickling, 1998; Forsyth, 1999).

In addition to the strong trophic links typical of herbivore-plant communities (Pimm, 1991) there will be interference competition and mutualistic associations (Moller, 1989). The latter interactions may be direct (e.g., behavioural interactions) or indirect (e.g., via nitrogen cycling altering plant distribution and abundance). There is growing evidence that indirect interactions may be just as important as direct ones in determining patterns and processes in some ecosystems (Hobbs, 1996).

The questions are what and how strong are these ecological interactions when important species in the community have not co-evolved? Competitive interactions between introduced species may be stronger than might be expected in co-evolved communities.

Furthermore, where two or more species strongly interact the effect on one species of managing the other should be considered (May *et al.*, 1979). Control operations that reduce a population may allow a competitor to increase. For example, a feral pig (*Sus scrofa* L.) population in tropical Australia doubled in numbers following the experimental removal of Asian buffalo (*Bubalus bubalis* Smith) due to release from interspecific competition; buffalo had been trampling the pigs' food supply (Corbett, 1995). An alternative possibility is that control of one species may lead to a decrease in another. An example would be reducing the density of a pest such that resulting changes in habitat structure make the habitat less suitable for another pest. Hare densities declined in the heavier alpine grasslands that developed following red deer and chamois control in the Harper-Avoca catchments, Southern Alps (Batcheler and Logan, 1963).

A simplified system – sympatric thar and chamois

Observations of seasonal habitat selection by sympatric thar and chamois in Carneys Creek demonstrated overlap in habitat selection; grassland and shrubland were generally preferred by both species in the seasons that these habitats were accessible (Forsyth, 2000). Thar preferred rock bluff and grass bluff habitats whereas chamois selected them in approximate proportion to their availability in all seasons except during winter (when they were preferred; Forsyth, 2000). Shrubland was especially preferred by both species in winter, when other vegetated habitats were largely unavailable. Scree and snow were generally avoided by both species.

Analysis of the diet of thar and sympatric chamois from the eastern Southern Alps indicated that both ate the same plant species, albeit in different proportions depending upon season. Overall, thar ate significantly more grasses and significantly less shrub and herb species than chamois (J.P. Parkes *et al.*, unpubl.). This suggested either that thar and chamois preferred different *species* within the same habitats, or that different *micro-habitats* were preferred. However, finer-scale analysis of habitat use might reveal significant differences in the vegetation communities of habitats used by thar and chamois. Although the results from Carneys Creek can only be extrapolated to the remainder of the sympatric thar-chamois range with caution, they suggest high seasonal overlap between thar and chamois in the use of some habitats, particularly grassland and shrubland.

Combined, the diet and habitat selection studies described above are strong evidence that the impacts of

thar and chamois on indigenous biota will sometimes be cumulative; both have the potential to modify the distribution and abundance of the same plant species. Hence, to protect plant species that are highly palatable to thar and chamois (e.g., *Gaultheria crassa* Allan; J.P. Parkes *et al.*, *unpubl.*) it may be necessary to manage both species.

Thar and chamois are both sexually segregated outside of the rut (Clarke, 1986; Forsyth, 1997; Shank, 1985), which is a characteristic of many north-temperate ungulates (Main and Coblentz, 1990). When segregated, the habitat selection and diet of male and female thar are significantly different (Forsyth, 1997; J.P. Parkes *et al.*, *unpubl.*), and such differences are also likely to be evident between male and female chamois. In addition, male thar are highly mobile during spring, summer and autumn whereas females are sedentary all year round (Tustin, 1990; Forsyth, 1999). These intersexual differences in diet, habitat selection and mobility complicate the management of these species at a variety of spatial scales.

There is anecdotal evidence that fast-dispersing chamois populations (Caughley, 1963) were later excluded from favoured habitats by increasing densities of thar. There is potential for chamois to increase following thar control (Forsyth, 1997). Forsyth and Hickling (1998) presented evidence that increasing densities of thar do exclude chamois from sites they had previously used. Observations of thar-chamois encounters in Carneys Creek indicated that chamois avoided thar by moving away from them when they were encountered, suggesting that interference competition may be important in this system (Forsyth, 1997). However, sustained grazing by high densities of thar may have also made dietary competition important prior to the advent of helicopter-based hunting (Forsyth and Hickling, 1998). These findings have important implications for management strategies. For example, eradicating (Parkes, 1989) or reducing thar to very low densities is likely to result in increased utilisation of *some* sites by chamois. (Although national eradication is not the goal of current management, this debate may well re-surface in the future.) If thar are eradicated or reduced to very low densities, managers will then need to allocate resources to monitor and perhaps control chamois.

Why multi-species management is needed

All five herbivores have the potential to impact on conservation values in the central Southern Alps alpine zone. These impacts are likely to be cumulative for some plant species in some habitats (see Table 1). The

particular pest(s) modifying conservation values at any site will depend on which plant species and associations are valued and on the biomass of the different pests (Parkes, 1994). For example, snow tussock is, judging by the proportion in their diet, more likely to be affected by thar (Caughley, 1970; Parkes *et al.*, *unpubl.*) and red deer (Lavers *et al.*, 1983; Rose and Platt, 1987) than by hares (Rose and Platt, 1992), chamois (Parkes *et al.*, *unpubl.*), or possums (which do not eat it at all; Parkes *et al.*, *unpubl.*).

Since many pest control methods are species-specific, managers require flexibility in allocating resources to control the appropriate pest(s). Management actions, like the impacts of different pests, occur at different scales in space and time. For example, there is a simple and affordable technique for widespread control of most thar and many chamois (helicopter-based shooting), but not for hares (because the relevant techniques are too expensive for any large-scale use that might be required; Wong and Hickling, 1999).

Integration of management therefore needs to be 'nested' within at least four levels of variation. The conservation resources that require protection will themselves vary in space, and dietary evidence indicates that the pest impacts will vary by species and perhaps location. The densities of the pest species will also vary in both space and time due to different 'equilibrium' densities and different harvesting regimes by commercial, recreational and/or government hunters. Furthermore, the available pest control techniques may be specific against particular pests and best-suited to application at different scales. Such an approach thus requires knowledge of the distributions of both the resource to be protected and the pest(s) likely to have an unacceptable impact on the resource. This could be relatively simple for resources that are locally restricted (e.g., within a single catchment), but is likely to be more difficult for more widespread resources.

The measure of success in managing the introduced herbivores of the central Southern Alps must be the state of defined conservation goals. Multi-species management would provide greater flexibility for managers to manage the spatially and temporally variable impacts of pests and resulting pest interactions.

We consider that multi-species management of herbivorous conservation pests should:

- specifically define the conservation resources to be protected (which species and where) and the level of protection (some measurable attribute of the resource) desired;
- identify the pests that most affect these resources (from dietary studies or by experimental manipulation of the pests);
- incorporate (i) some understanding of the

relationships between pest densities and their impacts, and important between-pest interactions, and (ii) an ability to improve these understandings as management proceeds (to set target densities of pests);

- provide sufficient organisational flexibility to sustain control (including management of other harvesters) of the appropriate pest specie(s).

We see three major benefits arising from multi-species management relative to the single-species approach. First, there will be improved conservation benefit because, where necessary, multiple species will be controlled (Parkes and Nugent, 1995) to protect conservation resources. Such integration is difficult to achieve under multiple single-species plans (Parkes and Nugent, 1995).

The second benefit will be reduced opportunity costs. Single-species plans sometimes result in pests being killed for little or no conservation benefit because another pest is also modifying the resource. An example would be control of thar, with the aim of maintaining tussock health, on leasehold land subject to intensive summer grazing by domestic sheep (*Ovis aries* L.). This action would have little conservation benefit, and should not be undertaken under a multi-species management approach unless sheep densities were also reduced.

Third, multi-species management will help avoid only nominated pests attracting funding, which can result in control operations that give less benefit than would control of an 'unfunded' pest elsewhere. Multi-species management aims to control the pest(s) that will give greatest conservation benefit.

Anticipated problems with multi-species management

Defining conservation values and criteria for monitoring their 'health' is problematic. This is a problem of applying human values to the natural environment (e.g., Wagner and Seal, 1992; Wagner *et al.*, 1995; McNaughton, 1996) rather than a limitation of multi-species management. Similarly, there are formidable problems in monitoring complex systems, especially those with inherent timelags (see Heywood, 1995). Consultation with the public and lobby groups could make the definition of conservation resources and associated levels of protection a lengthy process, but without opportunities for public input it is difficult to sustain control (Hughey and Parkes, 1996).

Identifying damaging pests from *in situ* monitoring of conservation resources may also prove difficult (e.g., Harding, 1996). We suggest that basic research

into impacts of the pests will help remedy this situation. Improved field techniques for monitoring both conservation resources and pest densities (e.g., Forsyth and Hickling, 1997) are also required.

Implementing multi-species management

The system of prioritising pest control operations now used by the Department of Conservation (see 'Current planning procedures') appears suitable for implementing multi-species management. However, the conservation resources and the desired levels of protection need to be explicitly defined before managers can reasonably define a 'site' in which to both monitor (the resource and pests) and perhaps conduct pest control. In the central Southern Alps, "specific values (resources) have not been identified in ecological terms for much of the range" (Department of Conservation, 1993). Hence, the new system appears to offer managers the flexibility to control any pest that modifies a resource, but until these resources are better defined it remains to be seen how *de facto* management will differ from the framework provided by the Himalayan Thar Control Plan.

Conclusions

The measure of success for managing the introduced herbivores of the central Southern Alps must be the status of defined conservation resources. Once defined, these resources need to be monitored such that spatial and temporal variation in the pest(s) modifying the resource can be detected. Sufficient organisational flexibility is required so managers can quickly control the particular pest(s) responsible for modifying the resource at the appropriate spatial scales. 'Control' should be defined as enacting management such that the defined level of protection of conservation resources is achieved.

We believe that a multi-species pest management plan offers several advantages over multiple single-species plans. First, enabling more than one pest species to be controlled will better protect conservation resources; single-species plans make this difficult. Second, there will be reduced opportunity costs by avoiding unnecessarily controlling pests that are not the primary cause of modification to conservation resources. Third, the political processes that can lead to the funding of control for only certain pests, such that higher-priority pest control is sometimes unfunded, will be circumvented.

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References

- Batcheler, C.L.; Logan, P.C. 1963. Assessment of an animal-control campaign in the Harper-Avoca catchment. *New Zealand Forestry Research Notes No. 27*: 1-27.
- Belovsky, G.E. 1986. Generalist herbivore foraging and its role in competitive interactions. *American Zoologist* 26: 51-69.
- Caughley, G. 1963. Dispersal rates of several ungulates introduced into New Zealand. *Nature* 200: 280-281.
- Caughley, G. 1970. Eruption of ungulate populations, with emphasis on Himalayan thar in New Zealand. *Ecology* 51: 53-72.
- Caughley, G.; Sinclair, A.R.E. 1994. *Wildlife ecology and management*. Blackwell Science, Cambridge, U.S.A.
- Christie, A.H.C. 1963. *The ecology of the chamois (Rupicapra rupicapra L.) in an alpine basin in southern Nelson*. M.Sc. thesis, Victoria University, Wellington, N.Z.
- Clarke, C.M.H. 1986. Chamois movements and habitat use in the Avoca River area, Canterbury, New Zealand. *New Zealand Journal of Zoology* 13: 175-198.
- Corbett, L. 1995. Does dingo predation or buffalo competition regulate feral pig populations in the Australian wet-dry tropics? An experimental study. *Wildlife Research* 22: 65-74.
- Cowan, P.E. 1990. Brushtail possum. In: King, C.M. (Editor), *The handbook of New Zealand mammals*, pp. 68-98. Oxford University Press, Auckland, N.Z.
- Department of Conservation. 1993. Himalayan thar control plan. *Canterbury Conservancy Conservation Management Series Number 3*: 1-68.
- Department of Conservation. 1994. *Department of Conservation national possum control plan*. Department of Conservation, Wellington, N.Z.
- Diamond, J.M. 1978. Niche shifts and the rediscovery of interspecific competition. *American Scientist* 66: 322-331.
- Douglas, M.J.W. 1971. Behaviour responses of red deer and chamois to cessation of hunting. *New Zealand Journal of Science* 14: 507-518.
- Flux, J.E.C. 1967. Hare numbers and diet in an alpine basin in New Zealand. *Proceedings of the New Zealand Ecological Society* 14: 27-33.
- Forsyth, D.M. 1997. *Ecology and management of Himalayan thar and sympatric chamois in the Southern Alps, New Zealand*. Ph.D. thesis, Lincoln University, Lincoln, N.Z.
- Forsyth, D.M. 1999. Long-term harvesting and male migration in a New Zealand population of Himalayan tahr *Hemitragus jemlahicus*. *Journal of Applied Ecology* 36: 351-362.
- Forsyth, D.M. 2000. Habitat selection and the co-existence of ungulates: alpine chamois and Himalayan tahr in the eastern Southern Alps, New Zealand. *Journal of Zoology (London)* (in press).
- Forsyth, D.M.; Hickling, G.J. 1997. An improved technique for indexing abundance of Himalayan thar. *New Zealand Journal of Ecology* 21: 97-101.
- Forsyth, D.M.; Hickling, G.J. 1998. Increasing Himalayan tahr and decreasing chamois densities in the eastern Southern Alps, New Zealand: evidence for interspecific competition. *Oecologia* 113: 377-382.
- Gause, G.F. 1934. *The struggle for existence*. Williams & Wilkins, Baltimore, USA. (Reprinted 1964 by Hafner, New York, U.S.A.).
- Guest, R.; Wilkinson, G.B. 1976. *The status of animals in the forest remnants of the Rangitata catchment*. New Zealand Forest Service, Christchurch, N.Z.
- Harding, M. 1996. A growth study of the alpine buttercup *Ranunculus godleyanus*. *Canterbury Botanical Society Journal* 31: 40-51.
- Heywood, V.H. (Editor). 1995. *Global biodiversity assessment*. Cambridge University Press, Cambridge, U.K.
- Hobbs, N.T. 1996. Modification of ecosystems by ungulates. *Journal of Wildlife Management* 60: 695-713.
- Holloway, J.S. 1993. Conservation pests: how can national values and objectives be quantified? *New Zealand Journal of Zoology* 20: 285-293.
- Hone, J. 1995. Spatial and temporal aspects of vertebrate pest damage with emphasis on feral pigs. *Journal of Applied Ecology* 32: 311-319.
- Hughey, K.F.D.; Parkes, J.P. 1996. Thar management - planning and consultation under the Wild Animal Control Act. *The Royal Society of New Zealand Miscellaneous Series* 31: 85-90.
- Huntly, N. 1991. Herbivores and the dynamics of communities and ecosystems. *Annual Review of Ecology and Systematics* 22: 477-503.
- King, C.M. 1990. *The handbook of New Zealand mammals*. Oxford University Press, Auckland, N.Z.
- Lavers, R.B.; Lee, W.G.; Wilson, J.B.; Mills, J.A. 1983. Foods of red deer in the Murchison

- Mountains, Fiordland, New Zealand. *New Zealand Journal of Ecology* 6: 151-152.
- Marshall, D. 1991. *Himalayan thar management policy*. Department of Conservation, Wellington, N.Z.
- Main, M.B.; Coblenz, B.E. 1990. Sexual segregation among ungulates: a critique. *Wildlife Society Bulletin* 18: 204-210.
- May, R.M.; Beddington, J.R.; Clark, C.W.; Holt, S.J.; Laws, R.M. 1979. Management of multispecies fisheries. *Science* 205: 267-277.
- McNaughton, S.J. 1986. Grazing lawns: on domesticated and wild grazers. *American Naturalist* 128: 937-939.
- McNaughton, S.J. 1996. Book review. *Journal of Wildlife Management* 60: 685-687.
- Moller, H. 1989. Towards constructive ecological engineering; the biological control of pests for the restoration of mainland habitats. In: Norton, D.A. (Editor), *Management of New Zealand's natural estate*, pp. 89-93. New Zealand Ecological Society, Christchurch, N.Z.
- Parkes, J.P. 1989. Eradication or control by sustained harvests - which option for thar? In: Norton, D.A. (Editor), *Management of New Zealand's natural estate*, pp. 45-48. New Zealand Ecological Society, Christchurch, N.Z.
- Parkes, J.P. 1984. Home ranges of radio-telemetered hares (*Lepus capensis*) in a subalpine population in New Zealand: implications for control. *Acta Zoologica Fennica* 171: 279-281.
- Parkes, J.P. 1994. Relative pestiness - species priorities and interactions. Are possums the problem? In: O'Donnell, C.F.J. (Editor), *Possums as conservation pests*, pp. 29-35. Department of Conservation, Wellington, N.Z.
- Parkes, J.; Nugent, G. 1995. Integration of national pest species control strategies. *Proceedings of the Australian Vertebrate Pest Control Conference* 10: 14-17.
- Parkes, J.P.; Thomson, C. 1999. Impact of Himalayan thar (*Hemitragus jemlahicus*) in the Southern Alps. *Science for Conservation* 132: 1-46.
- Parkes, J.; Baker, A.N.; Ericksen, K. 1997. *Possum control by the Department of Conservation - background, issues, and results from 1993-1995*. Department of Conservation, Wellington, N.Z.
- Parkes, J.P.; Nugent, G.; Warburton, B. 1997. Commercial exploitation as a pest control tool for introduced mammals in New Zealand. *Wildlife Biology* 2: 171-177.
- Pimm, S.L. 1991. *The balance of nature*. University of Chicago Press, Chicago, U.S.A.
- Rose, A.B.; Platt, K.H. 1987. Recovery of northern Fiordland alpine grasslands after reduction in the deer population. *New Zealand Journal of Ecology* 10: 23-33.
- Rose, A.B.; Platt, K.H. 1992. Snow tussock (*Chionochloa*) population responses to removal of sheep and European hares, Canterbury, New Zealand. *New Zealand Journal of Botany* 30: 373-382.
- Rosenzweig, M.L. 1981. A theory of habitat selection. *Ecology* 62: 327-335.
- Shank, C.C. 1985. Inter- and intra-sexual segregation of chamois (*Rupicapra rupicapra*) by altitude and habitat during summer. *Zeitschrift, für Säugetierkunde* 50: 117-125.
- Tustin, K.G. 1990. Himalayan tahr. In: King, C.M. (Editor), *The handbook of New Zealand mammals*, pp. 391-406. Oxford University Press, Auckland, N.Z.
- Wagner, F.H.; Seal, U.S. 1992. Values, problems, and methodologies in managing overabundant wildlife populations: an overview. In: McCullough, D.R.; Barrett, R.H. (Editors), *Wildlife 2001: populations*, pp. 279-293. Elsevier, London, U.K.
- Wagner, F.H.; Foresta, R.; Gill, R.B.; McCullough, D.R.; Pelton, M.R.; Porter, W.F.; Salwasser, H.; Sax, J.L. 1995. *Wildlife policies in the U.S. national parks*. Island Press, Washington D.C., U.S.A.
- Wong, V.; Hickling, G.J. 1999. *Assessment and management of hare impact on high altitude vegetation*. *Science Conservation* 116: 1-40