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Ecologically based policy evaluation: application to ungulate management in New Zealand

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ABSTRACT

Introduced ungulates, e.g., deer and Himalayan tahr, are variously considered as both pests and resources in New Zealand. Much ecological research has occurred into these species and into the ecosystems in which they live. Concurrently, much has been done to develop 'management' plans for these species. We reviewed ecological research relevant to these ungulates and developed ecologically relevant criteria to assess the extent to which these have been considered in these plans. Nine criteria were developed within four thematic areas: ecological principles, objectives and outcomes, adaptive management, and use of science information. Four planning documents were then evaluated. All four poorly or at best marginally considered fundamental ecological principles: only the Himalayan thar control plan scored well in terms of having objectives and outcomes that were clearly ecologically based; the thar plan was very strong in terms of its commitment to implementing adaptive management; and, in terms of using the best available science both the thar plan and the deer issues and options paper scored well. Overall, ecological science and principles have not played major roles in the development of some of these plans, probably because ultimately they reflect political choices that are difficult to support with the available ecological research.

1. Introduction

Conservation of New Zealand's native plants and animals remains one of the country's main environmental issues (DoC and MfE, 2000). It is widely recognised that introduced pests (mainly predatory mammals such as ferrets *Mustela furo*, stoats *Mustela erminea*, cats *Felis catus* and hedgehogs *Erinaceus europaeus occidentalis*) and weeds are major contributors to the ongoing decline of the country's biodiversity (DoC and MfE, 2000). However, introduced ungulates (e.g. deer *Cervus* spp., pigs *Sus scrofa*, goats Capra hircus, Himalayan tahr[1] *Hemitragus jemlahicus* and chamois *Rupicapra rupicapra*) also contribute to habitat decline while at the same time being valued as recreational, tourism and commercial resources in their own right. These latter animals, known scientifically as ungulates, are the focus of much political debate, generally reflecting the divide between hunting interests and preservation groups. They have also been the focus of much scientific research over a very long period of time. Over that time, and amongst a range of researchers, both Riney (1956: 17) and then more recently

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[1] The scientifically accepted spelling is 'tahr' but in New Zealand legislation it is spelt as 'thar'. We use 'tahr' for all but these official references to the animal.

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Caughley (1989: 9) called for targeted research that clearly addressed management priorities and criteria in order to make informed choices. It continues to be argued that all too often government policy is created in a selected scientific vacuum, for largely political ends, or that for some other reason or combination of reasons science and management do not connect (Parliamentary Commissioner for the Environment, 2004). Thus, in this article we consider the adequacy of the science used to support current ungulate management policies and to evaluate the extent to which such research has influenced the New Zealand Government's changing rationale for management of wild ungulates. Such an evaluation might contribute to ongoing debates and strengthen the relationship between science and management (previously called for by both Riney (1956) and Caughley (1989)) and act as a focus to integrate competing interests in the policy debate.

In this article we:

- analyse the nature of the biophysical science research and its potential to answer key questions that might contribute to policy development;
- use this analysis to form the basis for a set of ecological criteria for ungulate policy evaluation;
- use these criteria to test four Department of Conservation ungulate planning documents;
- present our overall findings and conclusions.

Also in this article we carefully distinguish the terms 'preservation' and 'conservation'. Preservation in New Zealand is characterised largely by the expressed desire to protect everything indigenous at the expense of many things exotic. Conversely, conservation is typically seen as implying a balance, but certainly in favour of the indigenous. Non-government organisations, such as The Royal Forest and Bird Protection Society, are largely preservation oriented but so to, it can be argued (see Young, 2004: 13), is the Government's Department of Conservation.

2. Science contribution and how to convert this into evaluation criteria

Despite the small size of New Zealand's wildlife and ecological research community, a considerable body of information has accumulated over the past 150 years on the ecology, impact and management of wild ungulates in this country. Most of the published quantitative research has been produced by researchers working for government agencies such as the former Department of Internal Affairs, New Zealand Forest Service, and Department of Scientific and Industrial Research. With the restructuring of the New Zealand science community in the 1980s (see Memon, 1993), most ungulate research has been undertaken by the Department of Conservation (the government agency with responsibility for managing both public conservation land and for managing introduced mammals under the Wild Animal Control Act 1977), and Landcare Research, one of the Crown Research Institutes. In comparison with other developed countries, hunting organisations, preservation groups, universities and private research groups have contributed relatively few quantitative studies on New Zealand's wild ungulates, although these groups have often been active in the development of wildlife policy.

Our experience (e.g., Hickling, 1993; Hughey and Parkes, 1995) with ungulate policy and plan development, including considering public submissions on these policies and plans, indicates three broad issues or areas of concern that are raised consistently. These broad issues are: (1) the extent to which ungulate impacts on natural ecosystems are understood, (2) the extent to which we can set proper goals and targets for the management of wild ungulates, and (3) tactical issues concerning how best to achieve such goals. Each of these areas is now examined.

2.1. *The extent to which ungulate impacts are understood*

2.1.1. *Have the impacts of ungulates on vegetation been proven?*

There is substantial evidence that deer are responsible for compositional changes in New Zealand forest understories and that they hinder regeneration of woody plants. The first such studies were generally correlational; that is, the observed changes in vegetation coincided spatially and temporally with increased numbers of deer, and furthermore there was a positive relationship between the extent of vegetation modification and the abundance of deer (e.g., Holloway, 1950; Wardle and Hayward, 1970; Wardle, 1974). Similar observations have been made in native grasslands (e.g., Godley, 1976; Mills and Mark, 1977; Rose and Allen, 1990) and in forests in more recent years (e.g., James, 1974; James and Wallis, 1969; Mark, 1989).

Despite reasonably consistent findings, inferences from such studies need to be made with caution, because other environmental factors that affect vegetation dynamics also influence vegetation processes (Veblen and Stewart, 1980; Caughley, 1983; Stewart and Harrison, 1987; Stewart, 1988). Furthermore, when other wild mammals such as possums *Trichosurus vulpecula* or feral goats are present in a study area it can be difficult to partition out the relative impact of the various species (e.g., Pekelharing and Reynolds, 1983; Davis and Orwin, 1985; Rose and Platt, 1990).

Stronger inferences can be made from exclosure studies (e.g., Jane and Pracy, 1974; Wardle, 1990). These fenced vegetation plots, which exclude ungulates but allow access by possums and other small mammals, allow researchers to control for the influence of potentially confounding factors such as environmental effects and small-mammal browsing and seed removal. Such studies consistently demonstrate recovery of *palatable* understorey and woody seedlings within the exclosure relative to the outside (Allen et al., 1984; Stewart and Burrows, 1989). Comparison of the mainland situation with nearby islands free of browsing mammals (e.g., Veblen and Stewart, 1980) reveals similar patterns. The effect of exclosure plots on the dynamics of the 'less palatable' plant species is a critical issue, because the dominant canopy species in many of our forests are in this 'less palatable' category. Exclosure results for these species are more variable, and less straightforward to interpret.

Many overseas authors, and several from New Zealand (e.g., McKelvey, 1965, 1995; Wardle and James, 1973), have argued that questions about the adequacy of regeneration in replacing canopy can only be answered through detailed studies of canopy seedling demography. Only a few such studies have been undertaken in New Zealand, and with the exception of Allen and Allan (1997) and Allan (1997) none have directly compared seedling demography in browsed and unbrowsed situations. Allan (1997) used measurements of mountain beech seedling growth inside and outside of exclosures in high altitude forest of the Kaweka Range in the North Island of New Zealand to predict regeneration outcomes. Her conclusion was that mountain beech forest would regenerate on all sites, although regeneration would have been more rapid if deer numbers were lower.

2.1.2. *Do wild ungulates reduce ecosystem biodiversity*

Biodiversity has been defined in multiple ways by various authors. Biodiversity measures typically incorporate information on species richness (i.e., the number of different species in the area of interest) and on species abundance (see Krebs, 1998 for examples). They may also consider less easily quantified aspects such as the ecological interactions between species (pollination, seed dispersal and so on). The animal, plants and micro-organisms introduced to New Zealand in recent centuries have almost certainly increased the country's overall biological diversity. In the context of ungulate management it needs to be appreciated, however, that the generic term 'biodiversity' is often being used as shorthand for the more specific concept of *native species diversity*, which discounts the contribution made by the introduced organisms.

At a national level, it does not appear that ungulates have yet caused the true extinction of any native species, because there are almost always refuge sites that the herbivores cannot access (e.g., Nugent and Challies, 1988). Ungulates have clearly altered the relative abundance of species—but the effect of this in terms of biodiversity measures has not been quantified (although it has been speculated on; e.g., Fraser and Speedy, 1997). The effect is likely to be highly variable regionally.

Plant communities that evolved subject to vertebrate herbivory can come to be dominated by a reduced number of species if left unbrowsed (see Bradshaw et al. (2003) and Rooney et al. (2003) for an international perspective). These changes in the vegetation have flow-on effects for the associated fauna (e.g., McShea and Rappole, 2000). In such situations, low to moderate levels of browsing may often represent an 'intermediate disturbance' (sensu Connell, 1978) that helps to maintain biodiversity (e.g., Collins et al., 1998; Rooney et al., 2003). Empirical studies are lacking in New Zealand, but we expect that here too, overall biological diversity is typically higher in indigenous forests and grasslands subject to low or moderate herbivory than it would be the case if those systems were unbrowsed. (We expect there to be a reduction in biodiversity in heavily browsed systems.) The effects of vertebrate herbivory on less readily measured ecosystem parameters – such as 'interaction biodiversity' (Vázquez and Simberloff, 2003) and 'resilience' (Folke et al., 2004) – remain uncertain.

2.1.3. *Which introduced mammals are having the greatest impacts on New Zealand's wildlands*

Goats have a somewhat better ability than red deer *Cervus elaphus* to digest roughage, which led Nugent (1992b) to suggest that goats may have a more substantial impact than red deer (although similar to sika *Cervus nippon* and fallow *Dama dama*) on less-preferred plant species. Goats are more gregarious than deer and less likely to be hunted (Nugent, 1989, 1992b), so in the absence of government control goats are likely to have greater impacts than deer in the areas where they were abundant.

Nugent (1992b) argued that while possums can cause the death of susceptible canopy species, ungulates will have a more serious effect long-term if they prevent replacement of that canopy. Based on general size-diet relationships from overseas (Robbins, 1994) deer can be expected to eat a broader range of plant species than would possums.

Wong and Hickling (1999) reviewed the suite of introduced herbivores impacting on high-altitude habitats (i.e., tahr, chamois, red deer, hares, possums and feral goats) and concluded that any one of these species could potentially be the 'main' herbivore in a catchment, depending on the particular characteristics of the local habitat and the relative densities of the various herbivores. Given their body size, tahr have a higher per capita intake than any of the high altitude herbivore species other than red deer.

The impact of wapiti *Cirvus elaphus scoticus* on the Fiordland, southwest New Zealand, environment is a complex issue. The damage wapiti cause to the environment closely resembles damage caused by red deer (Nugent et al., 2001). As wapiti coexist with red deer throughout their entire range in Fiordland (Smith, 1974; Nugent et al., 1987), it is almost impossible to attribute damage as being caused by one species rather than the other. Indeed, wapiti and red deer hybridise and produce fully fertile offspring (Caughley, 1969; Batcheler and McLennan, 1977), which further confuses the issue. In this and other cases the need to assess two or perhaps more, i.e., multiple species, interactions adds to the complexity of establishing cause and effect and critical threshold relationships.

Several studies have considered the environmental effects of wild horses, which have a much more limited distribution than several of the other wild ungulates. Rogers (1991, 1994) assessed changes in rare plant habitat and tussock grasslands, using exclosure plots and photo-points, and identified a number of impacts. Exclosure plots located in valleys showed decreases in palatable tussocks (hard and silver) with some decrease in red tussock, and increases in low growing species such as *Hieracium*. In other cases, red tussock grasslands (on the hills) responded variably to horse browse, with snow tussock preferentially grazed. The effect of the horses on rare wetland plant species (e.g., *Carex berggrenii*, *Rannunculus recens*, *Amphobromus fluitans* and *Gnaphalium ensifer*) is considerable. Trampling by the horses affects the natural flushes and allows invasive exotic species to establish. Rogers (1991) concluded that basin bogs and flush zones are targeted by horses, and estimated a 15–20-year recovery period for rare species in the absence of grazing. He also noted that weeds, in particular heather (*Culuna vulgaris*) and *Hieracium* spp., are great threats to areas with less that 90% water and weed spread appears to be accelerated by horses' movements.

The research of Rogers (1991, 1994) prompted concern about the horses' ecological impacts (DoC, 1995). However, more recent studies have questioned some of these findings. For example, Linklater et al. (2000) suggest that the impact of deer on some exclosure control plots has been underestimated, and hence the impact of horses over-estimated. A further point of contention in wild horse studies involves carrying capacity estimates. One such study by Cameron et al. (2001) estimated that each horse requires a ca. 3.8 ha of short tussock grassland per annum. However, the 1995 DoC plan noted that this estimate did not consider the costs of growth or reproduction, nor the additional effects of grazers such as deer and rabbits. It remains unclear whether current horse densities and range are significantly impacting on the threatened species noted in Rogers (1991, 1994).

2.2. *Setting goals and targets for ungulate management*

2.2.1. *Will ungulate control help restore ecosystems to a natural state*

Deer and tahr reached very high densities in many habitats within a few decades of their liberation and initial spread (Clarke, 1976; Challies, 1990). They removed large amounts of plant biomass from their preferred habitats, and thereby lowered the subsequent capacity of those systems for supporting herbivory. In doing so, plant community composition changed, in some cases dramatically, from that which had existed prior to European settlement (Caughley, 1983). It is important to appreciate, however, that in most instances wild ungulate numbers are now far below the peak densities they attained, in part because of hunting pressure and in part because forage availability, and thus the carrying capacity of these habitats, has decreased. For example, Challies (1985) and Nugent (1992b) present pellet survey data suggesting that the average reduction in deer numbers nationally between 1960 and 1980 was in the order of 75%.

In general terms, ungulate control will allow the biomass of palatable plant species to rebuild. If a 'more natural' ecosystem is defined as one containing a higher proportion of native species, then removing introduced ungulates will certainly help achieve this. Alternatively, 'more natural' could be defined as a system in which biological processes unfold with minimal manipulation or direction by humans. By this definition, an ungulate management policy that requires perpetual human intervention to maintain lowered herbivore numbers would not be particularly desirable. 'Boom-bust' commercial harvest, or sporadic government control, would be more likely than recreational hunting to lead to unstable ecological biological processes (Parkes, 1988; Challies, 1991). An ungulate eradication campaign, if feasible, would obviously be the ideal approach to ecosystem restoration, because human intervention would only be required for a finite period (Bomford and O'Brien, 1995).

2.2.2. *Are ecosystem protection and game management compatible*

As a general principle of wildlife management, meat hunter success is maximised when ungulate populations are maintained at around 50–80% of the habitat's carrying capacity (when this is defined in terms of the biomass of edible foliage produced) (Caughley and Sinclair, 1995).

Ungulate-induced changes in vegetation communities are (by definition) minimised when ungulate densities are as low as possible, although it is important to note that relationships are seldom linear in nature and there are likely to be critical threshold relationships where certain animal densities trigger particular vegetation responses. Consequently, if ecosystem protection is to be defined operationally as a reduction in such herbivore-induced changes then it clearly will not be possible to simultaneously maximise hunter success and ecosystem protection on a single block of land. For this reason, DoC (1997) raised the option of a regional management system whereby different management objectives could be pursued on different blocks of land, depending on that land's ecological value and susceptibility. For example, Fiordland's wapiti provides an example of a low-density, remote herd that nevertheless continues to attract significant hunter interest—the low hunter success rate presumably traded off against other aspects of that hunting experience.

Since hunting certainly provides *some* conservation benefit (Nugent, 1992b; Nugent and Fraser, 1993) and even low-density ungulate populations do provide *some* hunting opportunities, a management scheme that incorporates hunting will produce a more favourable outcome (in terms of both objectives) than would a no-hunting scheme if no other form of ungulate control was implemented.

2.3. *Tactical issues*

2.3.1. *Is eradication of New Zealand's wild ungulates feasible*

There are technical, economic and sociological requirements that must be met for eradication of a wildlife population to be possible. Technical criteria outlined by Bomford and O'Brien (1995) include: the capability to target all individuals in the population; the ability to remove animals at a faster rate than their capacity to restore their numbers; and the ability to prevent immigration. To date, there has been no clearly articulated proposal regarding how these three criteria could be met for any of New Zealand's ungulates. Caughley (1989) bluntly stated that for red deer "it is not an option".

For red deer, the main difficulty is that their populations are so widespread that there would be insufficient resources at any one time to reduce the entire nation's deer population at a rate that exceeded their intrinsic rate of reproduction (>35% per annum; Nugent, 1992a). Alternatively, if smaller regions were targeted in a progressive manner, there are currently no methods that could eliminate the possibility of reinvasion of deer back into cleared areas (particularly given the likelihood of illegal releases of deer by groups opposed to eradication, and unintended escapes of deer from farmed herds; cf. Fraser et al., 1996).

Biological control of deer has been suggested, but it is certain that the international community would be vigorously opposed to any such initiative because of the potential risk to farmed and wild ungulates in other countries should the biological agent be inadvertently transported overseas. Furthermore, biological control agents act in a density-dependent manner and are not in themselves capable of eradicating their host populations (Hickling, 2000).

The wild tahr population is relatively small, confined to a restricted area of mountainland habitat, and consists of more-or-less gregarious groups that are susceptible to aerial hunting (Tustin and Challies, 1988), although on the West Coast of the South Island the species is now present in dense forest, sometimes down to low altitudes. Eradication of tahr may nevertheless well be *technically* feasible. In practice, however, it is very unlikely that there is sufficient political and public support for such an initiative to be adequately funded (it would be exceedingly expensive), nor for it to be able to target all tahr (since some are on private land, where they could be hidden or moved to circumvent eradication measures) (Parkes, 1988; DoC, 1991).

2.3.2. *Is a multi-species approach to control required*

Multi-species issues should always be considered in developing management plans, but multi-species control will not always be justified (Parkes and Nugent, 1995; Wong and Hickling, 1999; Forsyth et al., 2000). Given that funding is always limited, managers should aim to optimise the conservation benefits they can achieve with the funds they are allowed to expend—this inevitably involves a trade-off between controlling many introduced species in a few areas *versus* a few species in many areas. As shown throughout this review, this is a trade-off that will vary regionally.

Feral goats' impact is broadly similar to that of the other ungulates (Nugent and Challies, 1988), but goats can have pronounced impacts at certain sites as a consequence of their being more gregarious than most of the other species (Rudge, 1990). Unlike deer, goats are not usually subject to recreational hunting, so taxpayer-funded goat control is probably justified whenever they are numerous in areas where other ungulates are to be actively managed.

It is widely believed (e.g., Wallis and James, 1972) that deer and possums have a synergistic impact when invading new areas, in that deer thin the understorey and thereby provide improved access for possums. In certain forest types possums can cause premature canopy death that would exacerbate any negative effects ungulates might be having on canopy regeneration (Nugent, 1990). The relative importance of the two processes (defoliation *versus* suppression of regeneration) is likely to vary from area to area, with the balance of the two determining the likely importance of multi-species control.

3. The evaluation of recent developments in wild ungulate policy-making

New Zealand legislation provides little or no guidance to policy makers or managers regarding how scientific[2] findings of the type described above should be incorporated into environmental policy. However, based on the ecological issues considered in the previous section and broadly accepted policy design and evaluation principles (see for example Bührs and Bartlett, 1993: 28–30), the criteria presented in Table 1 can be posited as appropriate for evaluating existing policy documents relating to ungulate management. Each criterion has an associated rationale, and an explanation of how the extent to which the criterion has been met should be scored when undertaking an evaluation. The evaluation considers the following four policy documents (selected because they represent most of the advanced stages of planning amongst the range of ungulate species considered in this research):

- The *Himalayan thar management policy* (DoC, 1991).
- The *Himalayan thar control plan* (DoC, 1993).
- The *Issues and options for managing the impacts of deer on native forests and other ecosystems* (the *Deer options document*) (DoC, 1997).
- The *Policy statement on deer control* (DoC, 2001).

Generally speaking there is a hierarchy of planning documents. 'Issues and options' papers are sometimes used as the basis for informing the public about issues and then the range of options for addressing them. 'Policy' documents then provide the general intent of government with respect to the animal or issue in question. Control plans (produced under the Wild Animal Control Act 1977) then detail specific goals and objectives for the species. All of these planning documents incorporate a variety of forums for public input.

In Table 2 the criteria listed in Table 1 are used to evaluate these tahr and deer policy and planning documents. None of the documents score well across the three ecological principles' criteria, although the *Himalayan thar control plan* scores well in terms of reference to ecological processes and principles and in terms of clearly establishing ecological impacts attributable to the animal. The *Deer options document* is reasonable in both these areas and does consider multispecies interactions. The *Policy statement on deer control* is very poor in both these areas but is the only document of the four to consider, to a reasonable extent, multispecies pest interactions (albeit with a score of only 2 out of 5).

The *Himalayan thar control plan* achieved the highest score in terms of defining objectives and outcomes related to clear ecological benefits and responses. The *Policy statement on deer control* is deficient in this area and is reliant on 'a targeted approach', using a 'generic decision support framework' for prioritisation. This decision support system (DSS), which is still in preparation (Keith Johnson; DoC, 2001, pers. commun.), aims to provide an objective method of incorporating scientific information into DoC's decision-making processes. While this approach seems positive it would also imply, given DoC's very limited resources for pest control, that deer will not be able to be controlled in many areas because they will not be the highest-priority species in those areas (thus meeting Riley's (1956) call to clearly define critical areas across New Zealand).

The *Himalayan thar control plan* is very strong in terms of its commitment to the principles and practices of adaptive management, i.e., it attempted to ensure that the setting of objectives was based on clear ecological considerations. Monitoring of ecological parameters that are clearly linked to these objectives was required and managers were required to intervene where objectives were being compromised. In addition, the plan was flexible in terms of incorporating new research and monitoring findings. In contrast, both the *Deer options document* and the *Policy statement on deer control* are weak in the area of specific adaptive management application, although more recent initiatives (see Section 5) are generally positive in this respect.

[2] 'Scientific' here refers primarily to the ecological sciences. Sociological and economic research also make an important contribution to wildlife policy-making, but are beyond the scope of this paper.

Table 1 – Proposed ecological criteria for ungulate policy evaluation, with a rationale and scoring system for each

Criterion	Rationale	Score
Ecological principles		
Explicit references to ecological processes and principles	Environmental policy not based on ecological principles is unlikely to meet long term conservation goals For ungulate management this requires an understanding of, and reference to, the role of past and present browsing by animals in native plant communities	1. No ecological processes referred to 2. A few general ecological processes referred to 3. A few key ecological processes considered 4. Most key ecological processes considered 5. Reference made to all key ecological processes
Environmental impacts attributable to ungulate(s) are clearly established within an ecological context	Establishing clear policy direction and objectives is not possible if the problem is not framed within an appropriate context	1. Inappropriate or no relevant research findings used 2. Very few relevant research finding used 3. Some relevant research findings used 4. Relevant research findings used appropriately, but the studies cited are largely qualitative 5. Quantitative research findings used within an appropriate context
Multispecies interactions are considered and managed for in a hierarchical manner, with a clear focus on controlling those animals with the greatest impact on key ecological features	Undue focus on particular pest species without the considering the implications of other impacts may lead to inappropriate management and failed management interventions Requires research to have considered multispecies interactions and effects	1. No understanding of the multispecies context 2. Some understanding of the impacts of some of the wildlife species 3. Impacts of all key species are understood 4. Impacts of most species are understood 5. Full understanding of multispecies impacts, including interactions between species
Objectives and outcomes		
Objectives are prioritised based on the likely ecological benefits that will accrue from the planned management	In application of the most recent comparative legislation, the Fisheries Act, ecological requirements are given primacy over other criteria in terms of meeting environmental outcomes (Hughey et al., 2000). This priority is in accordance with the Biodiversity strategy (DoC and MfE, 2000)	1. No discussion of ecological benefits 2. Some implied ecological benefits, but these are not stated explicitly 3. Some objectives linked to specific ecological criteria 4. Most objectives linked to specific ecological criteria 5. All conservation objectives clearly linked ecological criteria, with *a priori* forecasting of the extent of the expected benefit
Outcomes are assessed in terms of measured ecological responses, rather than in terms of numbers of pests killed	A focus on killing pests, unless associated with an eradication plan, diverts attention from the desired outcome (i.e., reduction in environmental impact)	1. Outcomes unmeasurable 2. Outcomes measured in terms of numbers of pests killed 3. Some outcomes measured in terms of ecological responses, but responses hard to quantify 4. Majority of outcomes based on ecological responses, with some quantification possible 5. All outcomes explicitly based on directly measurable ecological responses
Adaptive management		
There is a commitment to monitoring using proven methods	A policy or plan that lacks a sound monitoring regime cannot be successfully implemented or refined (as there is no way to measure performance against desired objectives)	1. No monitoring 2. Inadequate monitoring (e.g., only pest kill is assessed) 3. Some commitment to monitoring ecological benefits 4. Good commitment to ecological monitoring, including broad details on implementation 5. A detailed ecological monitoring package is provided, with periodic evaluations timetabled in the plan

Table 1 (*Continued*)

Criterion	Rationale	Score
The policy or plan is flexible, so that the results of periodic evaluations can be used to improve management	Good management has feedback loops that allow managers to learn from their successes and failures	1. No reviews and no expectations of change over time 2. Some commitment to review, but no commitment to change 3. Some commitment to review, but changes difficult to make 4. Full commitment to periodic review, but changes difficult to make 5. Full commitment to reviews and facilitation of necessary changes
Use of science information		
The best available information is used in designing policy and implementing management—where possible this is peer-reviewed scientific literature	Biased or unreliable information provides a shaky foundation for policy and plan development and subsequent implementation	1. Inappropriate and out-of-context information used 2. Little or no relevant or peer reviewed information used 3. Some of the available and peer reviewed information used 4. Most of the available and peer reviewed information used 5. All available information used within a peer review framework
Where there is inadequate information to address key information requirements for plan development and implementation management agencies should commit themselves to appropriate research investment	Designing policy and plans in ignorance is dangerous	1. No commitment to identifying and addressing research needs 2. Little commitment to identify and address some research needs 3. Partial commitment to identify and address some research needs 4. Commitment to identify and address some research needs 5. Full commitment to identifying and addressing research needs

Only the *Himalayan thar control plan* received high scores across the range of criteria associated with the use of good research information in the development of policies and plans. The *Deer options document* presents interesting material but it is poorly sourced and there is inadequate analysis of where the strengths and weaknesses of existing research, associated with specific species and specific ecosystems, lie. The *Policy statement on deer control* is especially weak in two of the three 'quality of science' criteria and there are numerous examples of over-generalisation of research findings. The deer policy is strong in terms of identifying research needs but makes no commitment to ensure such work is actually done. The policy also lacks evidence of how careful application of research findings has informed the overall direction of policy (and therefore not meeting the concerns of either Riley (1956) or Caughley (1989)). The process outlined for ensuring a 'consultative' approach to the development of animal control plans appears reasonable, but there is insufficient information provided to indicate how priorities are going to be determined.

Based on this qualitative evaluation, the *Himalayan thar control plan* received the highest score (39 out of a possible 50), followed distantly by the *Himalayan thar management policy* (with 29 out of 50) and the *Deer options document* (28/50). The *Policy statement on deer control* had the lowest score (18 out of 50). This overall evaluation, from an ecological and management sciences' perspective, suggests that the *Himalayan thar management policy* and *plan* documents are both superior to the *Policy statement on deer control*. Of course, it may be argued that it is more appropriate to just compare the policy documents (given that a management or control plan should be more specific), but even then the *Policy statement on deer control* scores poorly compared for the *thar management policy*.

Detailed reference to relevant ecological research was a feature of both the *Thar management policy* and the *Thar control plan*. It is significant, however, that the research was not being used to justify the broad policy decision seeking sustained control using recreational hunting as the primary control tool. Rather, the research was put to use in establishing appropriate intervention densities for different land management units, and in justifying a hierarchy of control methods (recreational and safari hunting, commercial hunting and finally taxpayer-funded culling).

The broad policy decision to implement sustained control in a manner that accommodated recreational and tourist hunting arose as a consequence of the perceived positive social and economic benefits of this approach (NZFS, 1986, Draft Management Policy for Himalayan Thar, p. 3). In other words, the crucial policy decision was based on assessments of social and economic as well as ecological values. The central importance of these value judgements is evident in the continuing opposition to the policy by preservation-focused environmental groups such as The Royal Forest and Bird Protection Society and the Government's own conservation advisory group, the New Zealand Conservation Authority (Sage and Keey, 2001).

Table 2 – An evaluation of the contribution of ecological science to four recent New Zealand documents on ungulate policy

Criterion	Himalayan thar management policy (1991)	Himalayan thar control plan (1993)	Issues and options for managing the impacts of deer on native forests and other ecosystems (1997)	Policy statement on deer control (2001)
Ecological principles				
Explicit references to ecological processes and principles	Some, e.g., in relation to soil erosion and community composition. Some specific information is given, which enables the significance of the problem to be considered	Some, e.g., in relation to specific plant communities and the processes of threat and threat mitigation	Some but could have been more explicit on a species by species and ecosystem by ecosystem basis. Proposed a deer impact model but it is not sourced to key research findings	Some, e.g., in relation to successional processes including regeneration, canopy collapse and questions of equilibrium. Mostly very general and without specific examples
Score	3/5	4/5	3/5	1/5
Environmental impacts attributable to the ungulate(s) are clearly established within an ecological context	Yes, including reference to impacts on specific species (pp. 6–7)	Yes, very specific, using all key references	Generally yes but lacks specificity related to species and ecosystems. A theoretical deer impact/vegetation recovery model is proposed but no source of data points is given	Sweeping generalisations are made, without acknowledgement of historical changes in animal densities and between-area variation
Score	3/5	4/5	3/5	1/5
Multispecies interactions considered and managed for in a hierarchical manner	No (research on thar and chamois interactions was not available during policy development)	No (little research available at that time—although questions were being asked about interactions with hares and chamois)	Although relationship between deer and possum and goats given this is not then reflected in key management principles	Almost none (some consideration given in terms of future control needs/ priorities and future research needs)
Score	0/5	0/5	2/5	2/5
Objectives and outcomes				
Objectives are prioritised based on the likely ecological benefits that will accrue from the planned management	Yes and no – National Parks Act forced a ‘zero density’ policy in National Parks, irrespective of ecological priority – but in other areas control was prioritised on this basis	Yes and no – National Parks Act forced a ‘zero density’ policy in National Parks, irrespective of ecological priority – but in other areas control was prioritised on this basis	Only an overall goal suggested which appears based on sound ecosystem thinking	Talks about a ‘targeted approach’ using a ‘decision support system’ to deal with related pest priorities. However, major contradictions are evident (e.g., third paragraph of ‘this policy statement’ section)
Score	3/5	4/5	3/5	2/5
Outcomes are assessed in terms of measured ecological responses, rather than in terms of numbers of pests killed	Yes—the policy required that these be specified in the thar plan	Yes—very specific, given the information available at the time	Yes—although only in a very general context given the ‘issues and options’ focus of this report	Only for those areas where deer are to be entirely removed; otherwise no. Seems a significant loss of quality here compared to ‘issues and options report
Score	4/5	4/5	4/5	1/5
Adaptive management				
There is a commitment to ongoing monitoring, using proven methods	Yes—the policy required that these be specified in the thar plan	Yes—very specific, given the information available at the time	Seems to be a planned commitment to monitor but no clear adaptive management framework proposed	The intention to do so is stated, but no details nor commitment are provided
Score	4/5	5/5	2/5	2/5

The policy is flexible enough to allow for periodic reviews of science and management, with the results incorporated into revised management	Yes, the policy is reasonably explicit in requiring that there be reviews and changes in light of new information	Yes, the plan is designed to be adaptive, e.g., annual reports called for in relation to goals, implementation, monitoring (see Section 8, p. 43)	Implied by proposed priority setting system and planned monitoring but not stated clearly	Not discussed in relation to the need for new information to support policy reviews in future years
Score	4/5	5/5	2/5	3/5
Quality of science information used				
The best available information is used in designing policy and implementing management—where possible this is scientifically based and peer reviewed	Yes	Yes	Marginal—an excellent bibliography but mostly not referred to in the test. No overall or comparative analysis of which species and/or related ecosystems are best understood, etc.	No—research findings have been over-generalised and at times used outside of their proper context
Score	3/5	5/5	2/5	1/5
Where there is inadequate information to address key information requirements for planning and implementing management, the relevant agencies should commit themselves to appropriate research investment	Yes	Yes	Some commitment but apart from monitoring it is not clear where this is to be directed, although implied it will be via the priority setting decision support system	Yes, key research directions are identified, although no commitment is made to ensuring that this work gets done
Score	3/5	4/5	3/5	4/5
Best available range of ecological scientists assisted throughout policy/planning process	Yes in part-advice was sought prior to preparing the draft Policy, which was then sent on for political and other consideration	Yes—ecological scientists remain involved in annual management meetings	Yes—in part provided advice to the advisory group	Some input by a range of stakeholders early on—but thereafter left in the hands of policy makers and politicians. Some final decisions appear to be based on ' weight of opinion' from the submissions process
Score	2/5	4/5	4/5	1/5
Cumulative score	29/50	39/50	28/50	18/50

Unlike the *Thar management policy*, the *Policy statement on deer control* does not provide a detailed discussion of the relevant ecological issues and research. It could be argued that such discussion was provided in the *Deer options document* (DoC, 1997), but even this more detailed document had a tendency toward over-generalisation and failed to cite scientific literature to support the specific points made (the document contains a bibliography of 'relevant research' rather than a list of references cited).

The *Himalayan thar control plan* required detailed specification of intervention densities. Such detail would have been irrelevant in the *Policy Statement on deer control* because that document took the approach of ruling out game management models entirely, and simply left the 'detailed consultation and planning' implied by this decision to be done later after the development of DoC's decision support system. From this perspective, the lack of detailed research citations in the *deer policy* is perhaps understandable, if disappointing.

That said, it is clear that the change in policy direction evident between the thar and deer policy documents was not driven by research findings. The *Policy statement on deer control* is the expression of a political decision regarding the balancing of competing values, in this case a decision to give increased priority to the protection and restoration of native biodiversity. As the Ministerial foreword to the policy statement notes "... wild deer will continue to be valued as a recreational and commercial hunting resource, but under the Biodiversity Strategy the protection of our unique plants and animals and the places they live takes precedence over introduced species ..." (DoC, 2001).

The difference in policy thrust between the thar and deer policies is thus best explained as a result of a political de-emphasis of the social and economic benefits of recreational, safari and commercial hunting. We suggest that the long history and vexed politics of deer management is causing muddled conservation thinking, and is resulting in policy that is not making full use of available scientific research (a criticism also made by Caughley (1989)). If this approach is continued across the range of ungulate species, the outcomes for conservation management are unlikely to be satisfactory.

4. Discussion

In the past decade or so, there have been two significant developments in wild ungulate management policy. First, there is *the Himalayan thar management policy* (DoC, 1991) and *Himalayan thar control plan* (DoC, 1993) which, while still clearly focused on protecting indigenous conservation features, set about achieving this goal by implementing a form of game management that made significant accommodations to the interests of recreational and trophy hunters. Second, there is the *Policy Statement on deer control* (DoC, 2001) that firmly asserted the pest status of wild deer and specifically ruled out of consideration the types of game management discussed in the earlier public discussion document on deer policy (DoC, 1997).

In the context of this evaluation, the significant question is whether the change in emphasis evident between the 1991 thar policy and the 2001 deer policy is best explained as a response to new research indicating that deer pose greater conservation threats than tahr, or as a response to factors other than the research itself? We suggest the latter (as there is no particular evidence to suggest that Himalayan tahr are more amenable to game management within the New Zealand high country than are other wild ungulate species).

The notion of managing wild ungulate populations to achieve such benefits on less ecologically valuable lands arose within the multiple-use conservation model favoured within the New Zealand Forest Service. Such policies continued to be advocated by senior Forest Service staff such as J. Holloway (e.g., Holloway, 1988) when they were transferred into the Department of Conservation on its inception in 1987. The *Himalayan thar management policy* (DoC, 1991) is a logical development of this approach to ungulate management. The *Policy statement on deer control* (DoC, 2001), in contrast, represents the logical outcome of a different line of policy development that aims to intervene to restore the 'natural' state of New Zealand's biotic communities. This preservation and restoration approach to nature conservation has been widely supported by the New Zealand public because of their desire to see the protection of unique native bird species and other fauna, and the preservation of remaining native forest from logging.

The research findings do not decisively favour one or other of these policy approaches. Science cannot establish objectively what level of ungulate impact on a plant community is 'tolerable'. It is probable that all interested parties would agree that ungulate densities that led to complete canopy species collapse or significant soil erosion would be unacceptable on any part of the conservation estate. Such agreement means little however, given that 'biodiversity protection' and 'ecosystem restoration' – both of which are poorly defined – arguably require much lower ungulate numbers.

The research reviewed here supports an argument that eradication is an impractical objective for the widespread ungulate species, particularly red deer. This is significant for long term policy, because it argues against the likelihood of attaining the 'final solution' favoured by New Zealand preservation lobby groups (although not by the general public; Fraser et al., 1996). While the overall thrust of New Zealand conservation policy towards protecting native species and ecosystems has enjoyed considerable public support to date, this support cannot be assumed to extend to support for complete eradication of wild ungulates, as these are currently valued positively by many of the general public (Fraser et al., 1996).

5. Conclusions

This evaluation, the likes of which we have not found elsewhere in the literature, has discussed the growing body of ecological research and its influence on the development of wild ungulate management policy in New Zealand. Scientific research has over time provided progressively more rigorous and locally precise information on the impacts of wild ungulates on natural systems thus meeting, to some extent, the calls for this research from Riley (1956) and Caughley (1989). This research has not, however, proven decisive in determining the political balance to be achieved between the diverging objectives of native biodiversity preservation/restoration and game management. However, DoC's most recent initiative (see http://www.doc.govt.nz/Conservation/002~Animal-Pests/Deer-forest-study/index.asp#Deer accessed 14 March 2006), begun in 2003, was to begin researching adaptive management to restore New Zealand forests affected by deer. The research involves scientists, managers and interested forest users who are working together on experimental design, overseeing the work, and interpreting the results so that DoC will have a framework for doing adaptive management in the future. Such a collaborative approach may work toward addressing the sorts of shortcomings addressed in this evaluation, but probably only if the Department's fundamental preservationist stance shifts to a more encompassing conservation perspective.

Differing environmental values and conservation philosophies are at stake here. Scientific research is crucial in informing such values and then in implementing any particular policy approach that is chosen (as is the case for the vegetation and tahr population monitoring required by the *Thar policy*). However, scientific data showing that a particular vegetation association is being modified by ungulate browsing does not lead inevitably to the conclusion that active management is required to arrest that process. Value judgements come into play, determining what degree of modification will or will not be tolerated in a particular area.

New Zealanders who value introduced wild ungulates positively are concerned that DoC's emerging approach to statutory control of wild ungulate management marginalises these species and the interests that some New Zealanders have in them. It is hoped that this article will contribute to the development of effective long-term policy by highlighting the contributions, and limitations, of the available ecological research. Further research to improve knowledge of ungulate impacts, biology and monitoring will assist future management, but cannot in itself end the long-standing conflict over 'high-level' policy goals discussed above. The decisive policy determinants are linked to differences in stakeholders' environmental values and conservation philosophies, which leads them to different levels of tolerance for vegetation modification by wild ungulates. For there to be greater convergence in policy objectives, more sociological research and public debate regarding environmental values, ecological research and New Zealanders' conservation philosophy will be required (again reinforcing what Caughley called for in 1989). Nevertheless, the contribution that policy evaluation undertaken with a clear focus on ecological principles, as demonstrated here, should not be discounted and provides a basis for checking on the validity of that process, at least in a scientific sense.

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