The Conservation Role of

Commercial Deer Hunting

Investigation No: 625
Key Output No:4.2

G. Nugent

Forest Animal Ecology Section
Forest & Wildland Ecosystems Division
Forest Research Institute
P.O. Box 31-011, Christchurch

Forest Research Institute Contract Report: FWE 92/3

PREPARED FOR:
Director, Science and Research
Conservation Sciences Centre
Department of Conservation

DATE: June 1992

CONDITIONS RELATING TO USE OF CONTRACT REPORTS PREPARED BY THE FOREST RESEARCH INSTITUTE

This report has been produced under contract to a Client and is issued subject to the conditions of that contract. These documents may not be reproduced, stored in a retrieval system, or transmitted in whole or in part, in any form, or by any means, without the prior written permission of both the Client and the Director, Forest Research Institute[1], PO Box 31-011, Christchurch (to whom requests should be addressed in the first instance).

The Client may copy or reproduce this report in full, for their own internal purposes.

This report does not imply approval by the Forest Research Institute of any item for a particular purpose, and therefore no statement or advertisement shall state or imply approval by the Forest Research Institute.

1 The Forest Research Institute was dis-established on 30 June 1992. Approvals should therefore be obtained from the General Manager, Weeds and Pests Division, Landcare Research New Zealand Ltd, P.O. Box 31-011, Christchurch

CONTENTS

1. EXECUTIVE SUMMARY (FINAL)

KEY OUTPUT: 4.2
INVESTIGATION NO: 625

INVESTIGATION TITLE: The conservation role of commercial deer hunting.

STUDY VENUE: National

INVESTIGATION LEADER: G. Nugent, Forest Animal Ecology Section, Forest Research Institute, PO Box 31-011, Christchurch

INVESTIGATION STATUS: Completed

CLIENT: DOC, Science and Research Division

FINISH DATE: June 1992

INVESTIGATION OVERVIEW:
The impacts of deer on conservation values, the role of commercial deer hunting in limiting those impacts, and the consequences if the industry should fail were assessed for the Department of Conservation by the Forest Animal Ecology section, Forest Research Institute, Christchurch, between July 1990 and June 1992

OBJECTIVES:

- To review the nature and importance of deer impacts on conservation values.
- To assess the historical role of commercial deer hunting in limiting deer impacts, the likelihood that commercial hunting may soon cease, and the conservation consequences.
- To evaluate DOC's options for deer control in relation to commercial hunting.

MAIN FINDINGS:

- Deer are mainly confined to 59 000 km^2 of forested mountainland, and over 90% of the conservation estate is within the deer range.
- Deer can severely modify native ecosystems. Native vegetation is unlikely to respond evenly to deer control - small reductions will protect the least vulnerable species, but virtual removal of deer is required before the most vulnerable species can begin to recover.
- Deer impacts are broadly similar to those of goats, but deer have a far less immediate effect on susceptible tree species than do possums. Long term, however, ungulates may have a more severe and pervasive effect than possums on the regeneration processes that ultimately determine forest composition.
- Commercial venison recovery has reduced the national deer population by approximately 75% since 1960, with near total-removal from unforested areas. However the industry is now collapsing. Only 12 800 deer were processed in 1991 compared with nearly 30 000 in 1989, and all three main processing plants are likely to stop processing wild deer in 1992.
- If commercial hunting does cease, an increase in deer numbers is inevitable. Recreational hunting alone could provide moderate control in a few, mainly North Island, areas but little control in many remote South Island areas. Commercial hunting appears to provide conservation benefits at least equivalent to those provided by DOC's goat control program.

- Sustained control of deer for specified conservation goals is the only strategic option available to DOC. If DOC wishes to maintain the conservation benefits provided by commercial hunting, it could either support commercial hunting, enhance recreational harvests, or kill deer itself. Nationally DOC would need to spend up to $1.5 million annually in perpetuity killing deer itself to maintain the status quo. Providing short-term (2-3 y) support for commercial hunting could substantially reduce this cost long term, though that cannot be guaranteed. It is highly unlikely that enhancing recreational harvests would be as cost effective nationally.

CONCLUSION AND RECOMMENDATIONS:

- Commercial hunting provides significant conservation benefits. The imminent exit of the main processers from the industry means DOC must either accept the loss of some of those benefits, or attempt to retain them. If the latter, DOC must allocate some funding to deer control. If DOC does fund deer control, a national control plan along the lines of the goat and possum models is urgently required.
- To determine how much (if any) needs to be spent on deer control at present deer densities DOC should compare nationally ranked priorities for deer control with those for goats, and, to a lesser extent, with those for possums. To assess how much additional funding is needed to retain the benefits commercial hunting provides, DOC should then re-evaluate what its priorities for deer control would be if deer densities returned to somewhere near 1950s levels, and again relate those priorities to current spending on goats and possums.
- As a practical guideline, all present benefits could be retained for less than $1.5 million annually, so it is recommended that this be the maximum spent on deer control unless the intent is to further reduce the overall level of deer-induced damage on the conservation estate.
- Provided DOC does wish to maintain some or all of the benefits provided by commercial hunting, and has the resources to usefully do so, DOC should consider supporting the industry for 2-3 years. The mechanism for support should be decided after consultation with operators, processers, and conservancies, but it is recommended that DOC use the opportunity to gather information about the deer population, that any "subsidy" be targeted at female deer (if possible), and that a mechanism for recovering the "subsidy" should prices rise above $3.00/kg be considered. If the existing industry (or its replacement) is not self-supporting or close to self supporting within 3 years DOC should consider killing deer itself. Enhancing recreational harvests is likely to be of limited use.
- Provided DOC does begin funding deer control (directly or indirectly), an affordable system for monitoring deer impacts should be developed to determine whether control objectives are met.
- The relative impact of the various ungulate species and possums on vegetation regeneration should be investigated. Arguments advanced in this report suggest a dominant role for ungulates, but this needs verification. If deer are most important, DOC spending should reflect that. The non-linear model of deer impacts presented in this report also needs verification.

2. INTRODUCTION

The impacts of deer on conservation values, the role of commercial deer hunting in limiting those impacts, and the consequences should the industry fail, were assessed for the Department of Conservation by the Forest Animal Ecology section, Forest Research Institute, Christchurch, between July 1990 and June 1992

3. BACKGROUND

Seven species of deer liberated in New Zealand since 1850 have established wild populations (King 1990). Economic and conservation damage caused by deer became apparent as deer numbers increased, and State-funded attempts to alleviate this began in 1926, with variable success. After 1960, an export market for venison developed, and the subsequent commercial deer harvests reduced most deer populations to low levels (Challies 1985), reducing the apparent need for State-funded control in all but a few areas. Since 1987 commercial harvesting has become increasingly less profitable, and could soon cease, prompting concern that deer could again become a major conservation problem.

This report examines the conservation role of commercial deer hunting and its prospects for the future. Information for this review was obtained from published material, unpublished reports, departmental files, and discussions with hunters, processers, ecologists, and others involved in deer hunting or management.

4. OBJECTIVES

- To assess the nature and importance of deer impacts on conservation values.
- To assess the historical role of commercial deer hunting in limiting deer impacts, the likelihood that commercial hunting may soon cease, and the conservation consequences.
- To evaluate DOC's options for deer control in relation to commercial hunting.

5. MAIN FINDINGS

5.1 The deer problem

5.1.1 Current status

Wild deer occupy approximately 140 000 km^2 (Fig. 1a), but over half of this is tussock grassland, pasture, or shrub/grassland mixtures (Table 1) that contain very few deer because deer in unforested areas are extremely vulnerable to hunting from helicopters. The "real" range at present is the 59 000 km^2 of tall forest, the main components of which are beech or beech-broadleaved forest (41%), mixed podocarp-broadleaved-beech forest (26%), podocarp or podocarp-broadleaved forest 14%), and exotic forest (14%). "Pure" broadleaved forest comprises only 5% of the forested deer range.

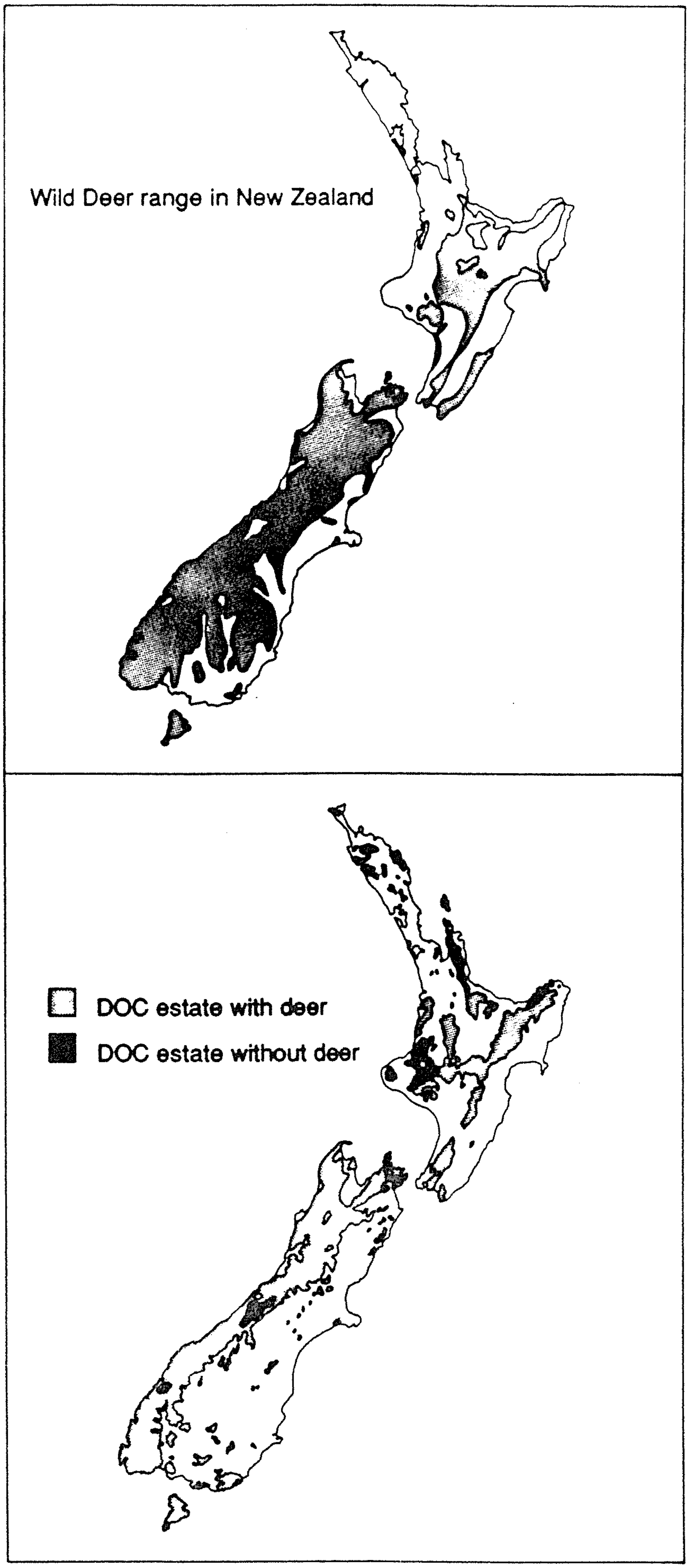

Fig. 1. Approximate wild deer range for (a) all of New Zealand, and (b) in relation to the DOC estate. Small reserves are not shown.

TABLE 1. Approximate relative abundance of main vegetation types for New Zealand, the deer range only, and the DOC estate within the deer range. The data were derived by combining maps of the deer range (Fig. 1) and vegetation types (from Newsome 1987), and visually estimating the proportion of each vegetation type within the deer range.

	% of total area		
	All NZ	Deer range	DOC deer range
Mainly unforested			
Pasture or crop land	28	6	2
Tussock	12	21	9
Grass/shrubland	19	22	13
Forest/shrub/grassland	7	7	8
Swamp/dunes/subalpine	1	2	2
Unvegetated	3	0	0
Forested			
Podocarp/podocarp-broadleaved	6	6	11
Podocarp-broadleaved-beech	7	11	20
beech/beech-broadleaved	9	17	31
Broadleaved	2	2	3
Exotic	5	6	0
Total	100	100	100
Total Area (km^2)	266 500	140 800	70 000
Unforested	191 000	82 000	23 000
Forested	75 000	59 000	46 000

Half the total deer range is administered by DOC, and less than 10% of DOC land is outside established deer range (mainly in the northern and western North Island; Fig. 1b). About two-thirds of the DOC deer range is heavily forested, 47% by beech-dominated associations (Table 1), and most of the DOC deer range (73%) is in the South Island.

Deer were introduced primarily for sport, and although interest in deerstalking probably declined in the 1970s it may now be increasing again (Nugent 1991). At present about 37 000 New Zealanders spend a total of about $30 million annually on ground-based deer hunting, each individual hunting deer on an average of 10 days each year, and harvesting just over one deer each (G. Nugent 1989a, unpubl. FRI contract report). Deer clearly remain an important recreational resource.

Deer are also a commercial resource, and about 3000 New Zealanders derive some income from wild deer, but only about 200 are likely to derive a significant proportion of their income from deer hunting (op. cit.). In 1989, venison processers paid about $5 million to hunters, but only about $1.5 million in 1991 (various unpubl. industry data). At a guess guided hunting, illegal venison sales, and velvet and live deer sales are worth another $1-2 million annually.

In contrast to these "positive" hunting values, deer can dramatically modify the structure and composition of the indigenous vegetation, compete directly or indirectly with the native fauna for habitat and food, and, possibly, affect water and soil values (sections 5.1.2, 5.1.3). Because DOC is obliged, under the Conservation Act, to preserve and protect New Zealand's natural resources, these deer-induced impacts are viewed as undesirable. Although some hunters have argued that introduced deer are also a natural resource to be conserved (Hodder, 1990), the Act was not intended to include protection of introduced wild animals (Holloway, 1989), and deer are therefore pests in conservation terms.

One challenge to this view is the argument that the truly pristine (i.e., pre-human) vegetation of New Zealand was a plant-herbivore (moa) system, which is certain to have more closely resembled a plant/deer system than a system with no browsers at all (Caughley 1989a). That argument has yet to influence popular perception or departmental policy in any significant way.

The Wild Animal Control Act provides DOC with the power to control and even eradicate deer, within the dictates of "proper land use". These criteria have not been specified in law for non-DOC land, but for National Parks (31% of the DOC estate; Table 2) and for most Reserves (14%) the respective Acts specify that, as far as possible, introduced species shall be exterminated, except where the Minister (for Reserves) or the Authority (for National Parks) determines otherwise. For the remaining conservation estate, the Conservation Act is less specific on the treatment of introduced species, but the similarity of purpose in the Conservation, National Parks, and Reserves Acts means DOC is legally obliged to control deer at "the lowest level that can be practically achieved and maintained given the management tools and financial resources available" for the entire conservation estate, as suggested by Holloway (1989).

TABLE 2. Approximate areas (km^2) of DOC estate within each conservancy, by tenure, derived from data supplied by each conservancy. In some instances the figures are "best guesses" by conservancy staff.

Conservancy	National Parks	Reserves	Other	Total	% total
Northland	0	300	1050	1350	1.8
Auckland	0	198	210	408	0.5
Waikato	0	280	2050	2330	3.1
Bay of Plenty	0	371	1353	1724	2.3
East Coast	2070	260	1770	4100	5.4
Hawkes Bay	0	29	1708	1737	2.3
Tongariro/Taupo	750	95	1355	2200	2.9
Wanganui	1070	230	1200	2500	3.3
Wellington	0	87	1728	1815	2.4
NORTH ISLAND	3890	1850	12424	18164	24.1
Nelson	1244	2791	5667	9702	12.9
West Coast	3377	2599	11549	17525	23.3
Canterbury	1343	566	5510	7419	9.9
Otago	1777	222	1835	3834	5.1
Southland	12100	2934	3634	18668	24.8
SOUTH ISLAND	19841	9112	28195	57148	75.9
NEW ZEALAND	23731	10962	40619	75312	100.0

5.1.2 Harvests, population size, and species

In 1988, an estimated 73 000 deer were harvested of which 75% were taken by ground-based hunters (G. Nugent 1989a, unpubl. FRI contract report). In addition a further 6-11% are likely to have been mortally wounded but not recovered (op. cit.), and perhaps 2-3% of the population may die naturally each year of non-hunting causes (G.Nugent, unpubl. data). The national deer population appears to be increasing gradually at present (section 5.2.6)), implying that births slightly exceed deaths. Assuming productivity is, on average, about 35% (Challies 1985), these data suggest the breeding population of wild deer is about 250 000.

The 1988 harvest consisted mainly of red deer (*Cervus elaphus scoticus*, 81%), sika (*C. nippon*, 10%), fallow (*Dama dama*, 6%), and white-tailed deer (*Odocoileus* *virginianus*, 2%). Too few rusa (*C. timorensis*), sambar (*C. unicolor*), and wapiti (*C. e. nelsoni*) were taken for them to be of major consequence in conservation terms.

Red deer comprised 93% of the deer taken by helicopter, but only 76% of the ground-based harvest, because their larger body size makes red deer more commercially attractive than any of the three most common minor deer species.

5.1.3 Deer impacts on conservation values

(a) Deer impacts on vegetation in the absence of control: The long-term effect on native vegetation of uncontrolled deer populations is not known, because no deer populations have remained unhunted and deer have seldom been present for more than a hundred years, far less than the life span of many plant species. However, the likely nature of these effects can be inferred from observations and measurements made during the establishment and subsequent development of the various New Zealand herds. With no predators other than man and a relatively mild climate, the density of unhunted populations would ultimately be determined by food supply, but only after the population had been through what is known as an "eruptive oscillation".

When deer first colonised new areas, food was abundant and the populations usually increased rapidly until food became scarce (Holloway 1950; Wardle 1984). Unhunted deer populations usually exceeded the density sustainable by annual food production (because they ate the "capital" forage resource as well as the annual "interest"), so that an initial peak was usually followed by a decline in density to some more stable equilibrium between deer consumption and plant production (carrying capacity; Caughley 1980). Historically, the time between initial colonisation and the population crash was typically 25-30 years (Caughley 1980), and most deer populations in New Zealand are now "post-peak".

At carrying capacity, the rate of increase is zero (births = deaths). Harvesting the population automatically reduces deer density, but this increases the food available per deer, so that births increase. Unless the harvest is sustained, the population therefore tends to return to carrying capacity, that tendency growing stronger as the level of control (i.e., the reduction below carrying capacity) increases (Caughley 1989b).

The impact of deer on the native vegetation varies between areas because deer have marked food preferences and vegetation composition varies between areas. In forests, deer prefer most of the broadleaved hardwood tree species (such as various *Pseudopanax* spp, pate (*Schefflera digitata*), and broadleaf (*Griselinia littoralis*) and some ferns (such as the hen and chicken fern (*Asplenium bulbiferum*)). The beeches, podocarps, and remaining subcanopy trees, shrubs, ferns, herbs, and grasses, are usually less preferred but are edible, though a few species such as pepperwood (*Pseudowintera colorata*) and crown fern (*Blechnum discolor*) are almost never browsed.

Before deer colonisation many forests had a dense understorey with many of the most preferred species being abundant. When deer colonised such forests, they initially focused on these species, but switched to less palatable species as densities increased, and at peak densities virtually eliminated the forest understorey in many areas (Wardle 1984). This, and the death of adult trees of the few species ring-barked by deer (such as pate), initially reduced stem densities, but the reduced competition for light and space permitted some of the least preferred species to increase (op. cit.). The near-total suppression of forest regeneration seen at peak deer densities suggested deer would cause widespread deforestation, but that is now viewed as unlikely (Veblen & Stewart 1982). The most common canopy dominants (the beeches and podocarps) are not highly preferred species, so that their widespread regeneration was often severely inhibited only when previously accumulated food reserves permitted browsing pressure to reach unsustainably high levels (Wardle 1984).

Although widespread total deforestation is unlikely, a small percentage of forests are dominated by rata (*Metrosideros umbellata*), kamahi (*Weinmannia racemosa*), or some other deer-preferred shrub-hardwood species, and these species also often form the canopy on seral sites within beech and podocarp forest and dominate the understorey. Even low densities of deer prevent the regeneration of many of these species (see examples in Appendix 9.1), which can thin the understorey and eventually result in localised canopy dieback. The most extensive example of deer-induced dieback is that of sub-alpine scrub dominated by *Olearia colensoi* in the Tararua Range (Holloway *et al.* 1963).

Overall, the main impact of deer has been to substantially change forest composition. For shrubs, ferns, herbs, and grasses the effect was "immediate", but for most tree species the decline in abundance has been more gradual, resulting from poor regeneration (except species killed by bark-biting). Deer alone seldom eliminated species because most can survive (albeit at much reduced densities) on inaccessible sites such as bluffs, or as epiphytes.

If forest deer populations had remained completely uncontrolled, many preferred shrub-hardwood tree species would have virtually disappeared and been replaced by an understorey consisting of a few unpalatable species (Veblen & Stewart 1980). Even less preferred species would probably be adversely affected, particularly on sites where such species are at their ecological margins (timberline sites for beeches, for example; Wardle 1984).

In tussock grassland, the pattern of deer impacts has been similar to that in forests. Here deer prefer the large-leaved herbaceous species (such as *Anisotome haastii* and *Ranunculus lyalli*) where these are available (Lavers 1978). *Chionochloa pallens* and *C. flavescens* are the most preferred snow tussocks, and *Poa colensoi* is probably the most important other grass species (Gibb & Flux 1973). Heavy browsing by deer in eastern Fiordland dramatically reduced the abundance of large herbs, and also the abundance of preferred tussock species, resulting in increased amounts of bare ground and greater invasion by introduced species and the more browse resistant elements of the native flora (Rose & Platt 1987). The vigour and frequency of flowering of surviving tussocks was also reduced.

(b) Severity of impact: deer vs other introduced herbivores: Most deer species in New Zealand appear to have similar food preferences (Nugent 1990a), but differ in their ability to digest roughage. Hoffmann (1985) considered sika and fallow better roughage digesters than red deer, which in turn are better than white-tailed deer. Deer and goats (*Capra hircus*) also have similar dietary preferences (Nugent & Challies 1988), with goats considered by Hoffmann (1985) to be equivalent to fallow and sika in their ability to digest roughage. This means that goats, fallow, and sika can have a potentially greater impact than red deer, but that greater impact would occur only at moderately high animal densities and would mainly affect less-preferred species. The almost universal presence of deer on conservation land, therefore, suggests that deer are, potentially, a greater threat than the more patchily distributed goats. Unlike deer, however, goats are, at present, seldom controlled by private hunting, so that without State-funded control their impacts would be (locally) more severe.

Deer and possums (*Trichosurus vulpecula*) eat much the same range of species (Leathwick *et al.* 1983), though their preferences differ. The most important difference, however, is that the arboreal possums have access to and can affect all vegetation tiers, whereas deer can directly affect only the vegetation in the browse tier (apart from a few species they ringbark). Possums can cause the death of susceptible shrub-hardwood forest canopies (Batcheler 1983), particularly when the canopy is predisposed to dieback by factors such as forest structure and composition (Stewart 1989). Their effect in these forests is, therefore, more immediate and, in the short term, apparently more devastating than that of deer. Once possums have killed a canopy, deer may then prevent its replacement (New Zealand Forest Service 1984).

Long term, however, forest composition is determined by regeneration patterns. Although possums do affect regeneration - the removal of possums on Kapiti has resulted in a greater number of seedlings of fuchsia (*Fuchsia excorticata*) and a few other species (Atkinson 1985) - they generally have a relatively minor effect on regeneration compared to ungulates (L. Pracy, cited in Ryan 1990). The most compelling and least controvertible evidence of this is provided by deer exclosure studies. These almost invariably show a substantial recovery of nearly all species within the exclosure (despite possums having access), but a minimal or relatively minor recovery outside, even when deer densities outside have been reduced well below carrying capacity (Jane & Pracy 1974; Allen *et al.* 1984; Stewart 1988, unpubl. FRI contract report; Llewellyn 1988, unpubl.; Speedy 1991, unpubl.). Further evidence is provided by the establishment of many deer-preferred species as epiphytes but not at ground level when both deer and possums are present (Stewart 1986; Stewart & Burrows 1989).

Some species appear to recover from initial devastation by possums. Historically fuchsia has been severely affected yet the species remains abundant in many parts of Canterbury and Otago (personal observations) even though possums have been present for more than 100 years. Possum browsing on seedling southern rata (*Metrosideros umbellata*) is rare once possums have passed peak densities (J. Coleman, pers. comm.).

The diet of mammalian herbivores is usually composed of relatively few plant species that comprise only a small subset of the plant species available to them, and dietary species richness decreases with decreasing herbivore size (Freeland 1991). Deer are therefore likely to have a greater effect on a wider range of the plants to which they have access than are possums - possums never completely ate out a forest understorey in the way deer sometimes did. This limited and somewhat circumstantial evidence indicates that possums probably affect a narrower range of species than deer, and that their impact is mainly on established trees rather than on regeneration.

It is likely that over three-quarters of the forests administered by DOC contains post-peak populations of both deer and possums, indicating that both species have already had their greatest impact in these forests. Even if further deterioration is likely, it is self-evident that vegetation recovery will ultimately depend on regeneration patterns. Almost all the species palatable to possums are palatable to ungulates, and many will regenerate freely only at very low ungulate densities. It is argued, therefore, that ungulates generally outrank possums as the main determinant of ongoing animal-induced changes in "post peak" forests. Possum control alone will not permit any significant recovery in regeneration, but can provide "short-term" (i.e., one generation) benefits for already established trees. In contrast, removal of ungulates will permit the substantial recovery evidenced in exclosure studies, even if no possum control is done. The implication, then, is that long-term protection of forest diversity will always require ungulate control. Possum control without ungulate control will be worthwhile where possum impacts have not yet been fully expressed, or there are key wildlife or vegetation values that need immediate protection from possums. Ultimately, however, ungulate control will also be needed in these areas.

(c) The effectiveness of control in reducing deer impacts on vegetation: The virtual elimination of deer from unforested areas (section 5.2.6) has resulted in a substantial recovery. That recovery began soon after initial reductions in deer density - in eastern Fiordland some regrowth of heavily browsed tussocks was apparent just 2 years after a reduction in browsing pressure (Rose & Platt 1987). A decade later, further tussock regrowth had occurred, large herbs were becoming abundant, and there was prolific establishment of snow tussock seedlings (op. cit.).

In Mt Aspiring National Park there was a similar recovery over the 13-16 year period to 1986, but continued recruitment of preferred species indicated the recovery was not complete (Mark 1989). These results suggest that even with near total removal of deer, full recovery will probably take two or more decades. The effect of partial reductions is not known, but it seems likely that even moderate numbers of deer would inhibit recruitment of both the large-leaved herbs and of the preferred snow tussocks.

Exclosure studies (Jane & Pracy 1974; Allen *et al.* 1984; New Zealand Forest Service 1984; Stewart 1988, unpubl. FRI contract report; Speedy 1991, unpubl.) show that a similarly dramatic response would also occur in forests if deer could be completely removed, but that has not been achieved.

It has sometimes been presumed that reducing deer density would reduce their impact in some linear fashion (i.e., for each unit of reduction in deer density there would be an equivalent increase in vegetation recovery). However once a forest understorey has been depleted, very few deer can prevent its recovery (Wardle 1984). The relationship between deer density and deer impacts on regeneration is therefore likely to be non-linear. My "conceptual model" of the relationship (illustrated schematically in Fig. 2) is explained as follows: Even at low deer densities, the biomass of new seedlings of highly preferred species is quickly reduced to near zero, but for more browse-resistant or less palatable species the relationship is more linear, and least preferred species are affected only at high deer densities, or not all (Fig. 2a). If all species in an area are similarly preferred the overall (or average) "response curve" will probably be approximately linear (Fig. 2b). Where the species present differ widely in palatability, the overall response curve may not be linear, and could even have a flattish mid-section (Fig. 2c). I consider a non-linear response is likely in most New Zealand forests because deer there often rely heavily on litter-fall which tends to divide species into two main groups (either more or less preferred than litter-fall; Nugent & Challies 1988; Nugent 1990a). The idea of a reduction in deer density sometimes having no effect on regeneration is best illustrated by the possibility that such a reduction could sometimes simply mean deer ate less litter-fall.

The implications for deer control are that a relatively small reduction in deer density from carrying capacity will protect the less preferred species (which include most beeches and most podocarps). There will always be some additional increase in regeneration with any further decrease in deer density, but over the middle range of deer densities the response may sometimes be very small (if the response pattern is of the type depicted in Fig. 2c). Protection of the most highly preferred species requires the near-total removal of deer. Managers must, therefore, be able to identify which species they wish to protect to justify deer control - action sufficient to protect beeches will not protect broadleaf.

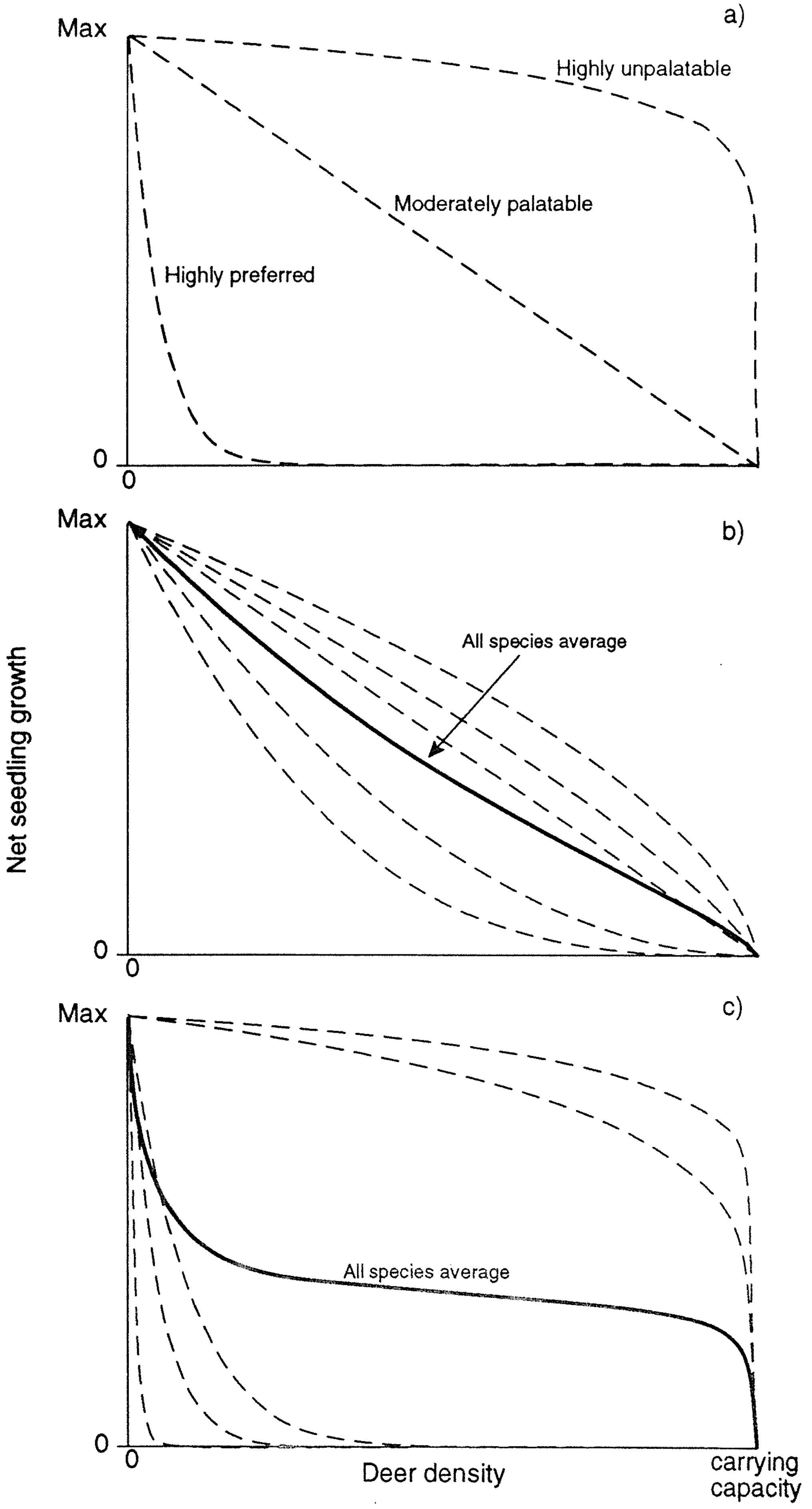

Fig. 2. A model of deer impacts in relation to density for (a) different types of individual species (b) a flora in which all species have similar palatabilities (c) a flora in which there are two main groups of species (preferred and not preferred).

(d) Deer impact on the fauna: Little is known about deer impacts on the indigenous fauna, but it is likely that the thinning of forest understoreys modified invertebrate habitat. It is also likely that this has severely affected bird populations (Diamond & Veitch 1981). Deer compete with several threatened bird species for food, either directly, as with takahe (*Notornis mantelli*; Mills *et al.* 1977), or indirectly, as with kokako (*Callaeas cinerea*; Leathwick *et al.* 1983). Although predators and arboreal competitors such as possums have probably had a more immediate effect on bird populations, the gradual elimination of many hardwood trees by deer will eventually deprive surviving bird populations of a key food source (Wardle 1984).

If these largely assumed impacts on the fauna (particularly birds) were better quantified and recorded the perception of deer as a conservation pest would be heightened, in my opinion. Takahe aside, there is virtually no information on the value of deer control in protecting native animals, nor any data indicating the likely level of control required.

5.1.4 Other impacts

Although competition with domestic stock was previously important in changing settlers' perception of deer as a desirable resource to a view of them as pests (Caughley 1983), the low deer numbers outside forests means such competition is now inconsequential. Although such competition could conceivably increase substantially if commercial hunting ceased, it seems unlikely that it would be viewed as a conservation problem.

The belief that deer-induced deforestation was likely and would result in accelerated erosion was once an important justification for deer control. However, forest cover apparently plays a relatively minor role in determining overall erosion rates, so that this justification seems less valid at present (Caughley 1983). In contrast, Hicks (1991) reported that forest cover reduced the incidence of slipping on the East Coast during Cyclone Bola. As uncontrolled deer populations can cause localised forest dieback, it seems that deer could, potentially, affect soil and water values in some circumstances. If so, this would be viewed as an adverse impact in conservation terms.

High levels (>10%) of bovine tuberculosis (Tb) have been reported in some wild deer

Tb in deer populations is probably disadvantageous in conservation terms, unless it results in substantial spending on wild deer control by agricultural interests.

5.2 Commercial hunting - history, status, and impact

5.2.1 History

Commercial hunting began soon after deer were introduced (Lane 1982), but venison recovery did not begin in earnest until the late 1950s. The development of the industry is described by Bennett (1979), Caughley (1983), Challies (1985, 1991), and others.

The number of deer carcasses exported annually peaked in 1973 (Fig. 3), but then declined as deer became scarcer. However, the smaller harvests of the late 1970s continued to reduce deer populations (Nugent *et al.* 1987; Challies 1991), indicating that mortality from these and the unknown recreational harvests exceeded births. From the late 1970s and early 1980s the development of deer farming created an intense demand for founding stock. Helicopter operators in particular switched to live capture, and venison recovery declined even further. By 1988, demand for live animals had abated and live capture virtually ceased. Helicopter operators reverted to venison recovery alone (Challies 1991). The number of deer carcasses processed by game depots increased from around 13 000 in the mid 1980s, to nearly 30 000 in 1989, but then declined to 23 000 in 1990 and 12 800 in 1991 (Fig. 3).

5.2.2 The processing industry

(a) Main companies: As the supply of wild deer declined during the 1980s the number of processing companies declined to just two; Taimex Trading Co. Ltd (TTC) and Mair Venison Ltd (MVL). Mair Venison Ltd operates the sole North Island plant at Rotorua, and collects deer from a network of depots, which historically was serviced all year round and once covered most of the North Island deer range, but which is now much reduced. The network closed temporarily in winter 1991, and may soon (from June 1992) close permanently. Many hunters now deliver carcasses direct to the factory, for which they are paid a premium (c. an additional 50¢/kg carcass weight).

In the South Island, MVL and TTC co-operated to collect carcasses from a similar network of depots. About half the carcasses (mainly from the Haast area) were processed by MVL at its plant in Hokitika. The remainder were processed for TTC at the Venison New Zealand (VNZ) plant at Mossburn in Southland, at a fixed rate ($2.20/kg pack weight in spring 1991). In early 1991 the declining supply of wild deer forced, first, the closure of some depots in Nelson, Marlborough, and Canterbury, and then the dissolution of the joint-venture collection company in winter 1991. However, TTC continued to buy carcasses delivered by hunters to the Mossburn plant, and in spring 1991 reopened a single depot at Te Anau. Mair Venison Ltd currently operates depots along the West Coast and also collects from Blenheim and Nelson in the north, but not from Kaikoura and Canterbury.

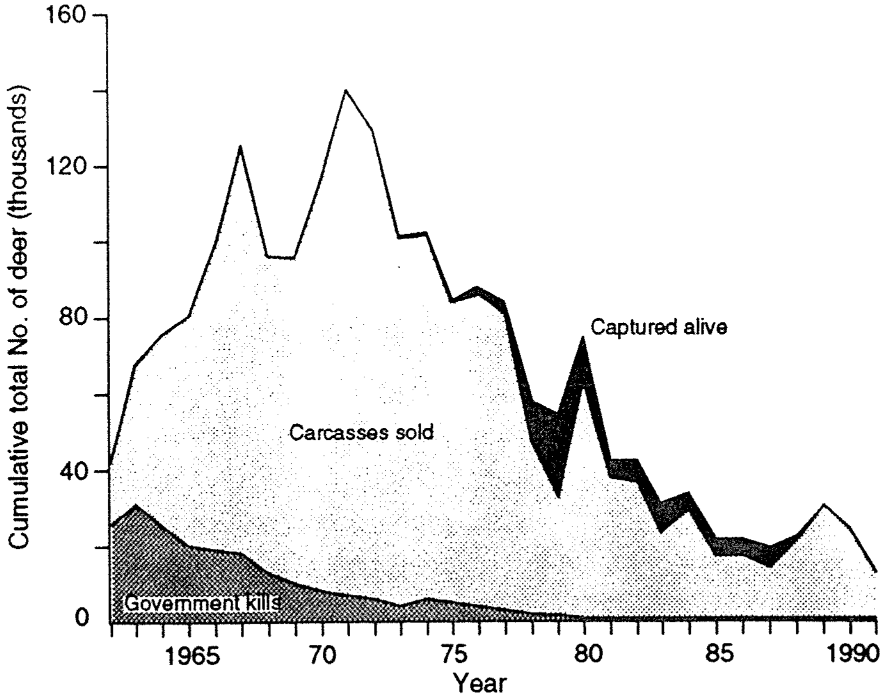

Fig. 3. Known State-funded deer kills and commercial harvests.

The greatest threat to the main companies is an European Community stipulation that by 1993 farmed and wild deer must be processed separately. Because Europe (and Germany in particular) is the main market for venison, marketing options for farm venison processed at a plant that also processes wild deer are much reduced. All three processing plants also process farm deer, but only Rotorua has separate facilities for wild and farmed deer. The Mossburn and Hokitika plants continue to process wild deer at present because the companies can adequately supply the German market (to which the directive already applies) with farm venison from other "farm-only" plants. In addition, the European market is proposing more intensive inspection procedures that are likely to require substantial modifications to existing plants. These directives mean that present processers are faced with either upgrading present facilities (which would still have limited markets for farm venison, their main business), or building separate facilities. Alternatively, they could cease processing wild deer.

A sharp decline in the prices received for venison products also threatens main company viability. As an indication of this, the price per kilogram paid for bone-in haunch landed in Germany varied between NZ$6 and $12 between 1985 and early 1990, but in 1991 dropped as low as $5/kg (M. Rice, pers. comm.). Similarly, the prices paid by processers for farm deer in New Zealand fell from over $7/ kg dressed carcass weight in late 1989, to less than $3.50 in winter 1991. One reason for the declining prices is the greatly increased farmed deer kill, which is expected to exceed 300 000 in 1992. Also the amount of "East German" and Polish venison supplied to the main "West German" market is thought to have doubled as the decline of communism freed up trade. For the foreseeable future, these factors will probably tend to keep prices low, although the fall in the exchange rate in late 1991 undoubtedly helped stabilise prices at a time of year when they normally decline (M.Rice, pers. comm.). The low prices have resulted in low harvests, and the two combine to make it difficult to justify the investment required to either upgrade existing plants or establish new ones.

For MVL the ownership of two processing plants and depot networks incurs substantial fixed costs. The cost of processing each deer, therefore, increases as the number of deer processed falls. In contrast, TTC's fixed cost is relatively small, so this company has probably been less severely affected by the recent fall in harvests.

(b) Minor processers: Other processing operations are small. The legal operations mainly involve helicopter operators having deer processed at an existing game packing house and selling the venison domestically. Other hunters illegally process carcasses themselves and sell on the "black" market. One North Island operator has approvals and facilities to begin processing up to 1500 deer annually for domestic consumption, but has yet to finalise markets. These activities ensure that some commercial hunting would continue even if the main companies cease, and they probably account for 3000-5000 deer annually at present.

(c) Economics and marketing: The price per kilogram (carcass weight) paid to hunters is only about one-third the average price per kilogram of end-product. In late 1990, hunters were paid about $3.00/kg carcass weight, and carcass collection cost another $1/kg ($0.20 agent fee, $0.20 cartage, $0.60 administration), resulting in a pay out of $4.00/kg carcass weight delivered to the factory (M. Rice, C. Taylor, pers. comm.). About one-third of carcass weight is lost during processing, processing and inspection fees cost about $2.00/kg (dressed weight), and freight to Europe (with insurance) costs about $0.70/kg, resulting in a total cost of $8.70/kg delivered overseas. This is reduced somewhat by the value of by-products (skins, tails, sinews, and pizzles, which are together worth up to about $50 per deer or $1/kg carcass weight).

The main companies further streamlined operations in 1991 to reduce collection costs. Depots were closed during winter, and fewer depots opened in spring. Also, the price differential favouring large cleanly-shot animals was increased to increase the yield of venison per carcass. Despite this, it is clear that present payments to hunters ($2.50) can, at best, be barely economic (let alone profitable) given present end-product prices in Germany.

Although many hunters believe little has been done to promote wild venison, it is likely that well-established companies such as MVL and TTC have already found all easily developed markets. Although several helicopter operators have investigated export options, none have yet been successfully established.

The Game Industry Board (GIB) actively and widely promotes venison as a lean fat-free game meat, but it also emphasises the consistency of flavour, reliability of supply, and hygienic killing processes relating to farm deer, features which tend to disadvantage wild venison. Such promotions may reduce the European demand for wild venison, and it is likely that developing markets will also prefer the milder farm product. Since farm venison comprises 95% of the total venison exported, this marketing emphasis will not change.

New Zealanders are not traditional consumers of game, so the market is small, and although venison is increasingly popular, the milder farm venison is likely to be preferred. The small size and number of operations supplying wild venison to the domestic market, and the dubious legality of some of them, suggests they are only marginally viable. One avenue I consider worth exploring would be to try to convince New Zealand environmentalists to eat wild venison (at premium prices compared to other meats and farmed venison) to help prevent deer eating native forests.

5.2.3 The hunters

a) Helicopter operators: Helicopter-based hunting is marginally viable, but the lifestyle and nature of the work continues to attract many helicopter operators. The number of operators, types of machines, and harvest in 1987/88 are described in detail by Challies (1991). Of the 60 licencees (69 helicopters) issued, eight were not used, and 16 took fewer than 100 deer. Only 12 took more than 500 deer (max. 1360). Of the 19 410 deer taken, 60% were helicopter-shot carcasses, 5% were ground-shot carcasses, and the remainder were captured alive either from helicopter (28%) or pens (7%).

Since then live capture has effectively ceased, and the number of operators involved has declined further to about 50, with only about six "full-time" operators remaining in 1991. Several of these run their own chillers, or deliver direct to the factory, and thereby obtain premium prices, explaining how they continue to operate regularly when others do not.

Helicopter running costs vary, but even the smallest usually cost more than $200 per hour, and hunters must average at least two deer per hour at present prices to cover costs. Strong seasonal variation in the attainable harvest rate (Fig. 4a) means that the minimum required harvest rate will almost always be achievable on a few days each year even if prices fall as low (say) as $1.00/kg. If operators have sufficient other work to remain in business (which appears so for most), venison recovery is likely to remain profitable on a few occasions each year provided there are buyers for the carcasses. The continued existence of the industry in its present form, therefore, hinges mainly on the viability of main processers, and much less on the viability of venison recovery as a full-time occupation.

Because most part-time operators do not appear heavily dependent on venison recovery and are likely to remain in business without it, there is unlikely to be a rapid loss of present hunting expertise, even if the industry fails temporarily.

(b) Ground-based hunters: In 1988, there were about 3000 ground-based commercial hunters, and these harvested about 18 000 deer (Nugent 1989b unpubl. FRI contract report). Of these deer about 3000 were captured live, c. 10 000 were sold (only 7000 to legitimate depots), and the remainder were taken "recreationally". The closure of many depots and very low prices for lightweight deer since 1988 have affected ground-based hunters even more seriously than helicopter operators. It is not known whether these hunters have reduced their harvests or just the number actually sold, but the former seems most likely. As with helicopter-based hunters, some hunters will continue to sell deer even if prices are low, provided there is someone to buy them.

5.2.4 Administration of commercial hunting

DOC does not control ground-based commercial hunters (except to prohibit commercial hunting in Recreational Hunting Areas) but does control helicopter hunting by limiting the number of Wild Animal Recovery Service (WARS) licences issued (Challies 1991). In 1990 this was extended to include harvest quotas, but falling prices meant many operators did not achieve the minimum harvests set. The thrust of this extension was mainly to ensure allocation of licences was objective and "transparent", rather than a move toward the single-operator block system recommended by Challies (1991) (G. Adams, pers. comm.).

An important premise of that recommendation was that the elimination of competition between operators would increase operator viability, but the actual "cost" of such competition is unknown. Operators in two areas (the Tararua Range and the Wapiti Area) in which there is no competition at present do not appear to

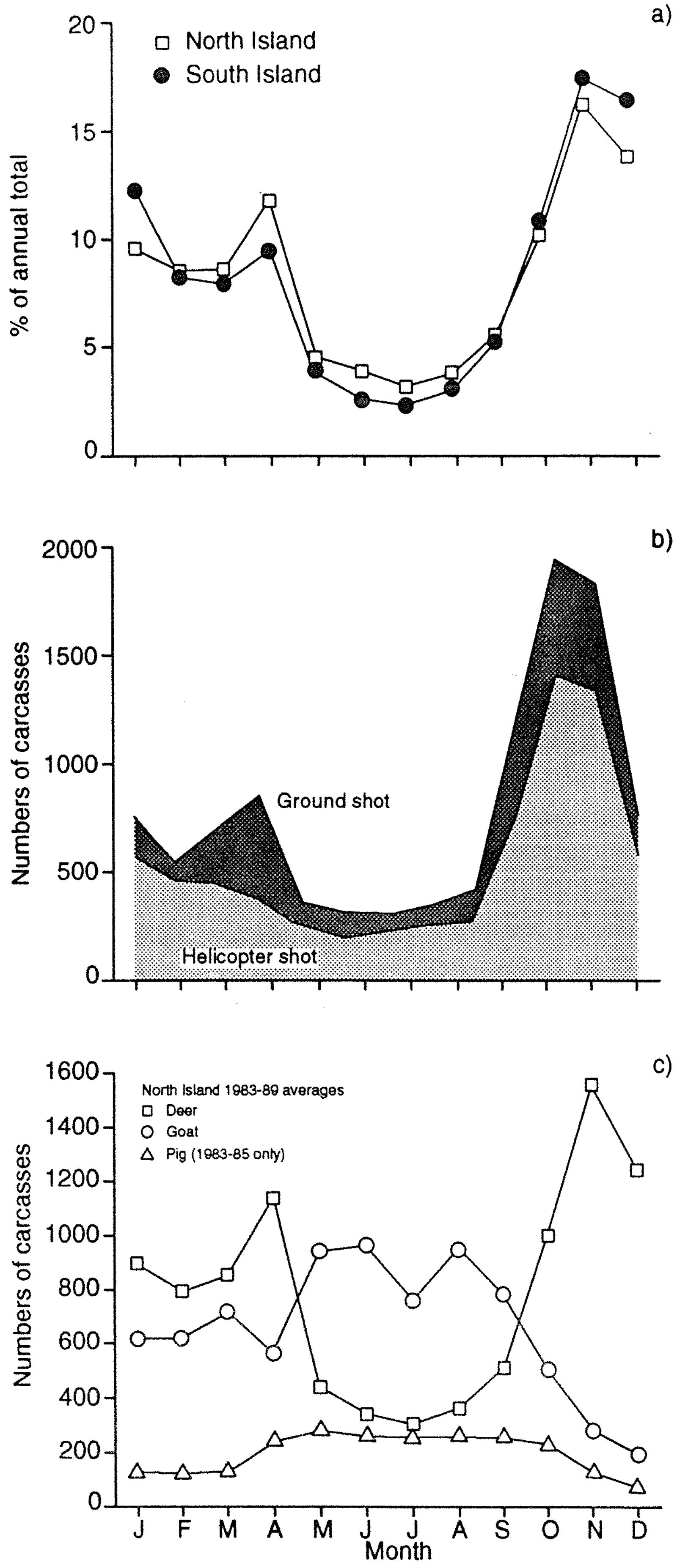

Fig. 4. Commercial deer harvest patterns. (a) Monthly harvest in each island averaged over the 1983-1990 period. (b) Monthly harvest in the South Island in 1988 by harvest type. (c) Average monthly harvests in the North Island of deer and goats (for the 1983-1990 period), and of pigs (for the 1983-1985 period).

Overall, DOC's administration probably adversely affected the industry in 1991. Licence fees and associated costs obviously slightly reduce operator profitability. In addition, the viability of individual operations changed rapidly (because of reduced prices, operator fatality, etc.), yet the legal processes for changing the operators within blocks were sometimes too time consuming to permit rapid replacement of non-performing operators. Total harvest was, therefore, probably lower than it might have been.

5.2.5 The harvests

The seasonal peak in commercial harvests is in spring, with a secondary peak in autumn when rutting deer become vulnerable, particularly to ground-hunters (Fig. 4a,b). In contrast, harvests of pigs, goats, and chamois have historically tended to be largest in winter (Fig. 4c), which helped processing plants operate continuously (and therefore more efficiently). However, few pigs are now processed in the North Island, and few goats or chamois in the South Island.

The autumn peak is slightly higher and the spring peak slightly lower in the North Island than in the South Island (Fig. 4a), possibly reflecting greater ground-based harvests in the North. In the mid 1980s, more deer were shot in the North Island than in the South Island (Fig. 5), but more were caught alive in the South Island (Challies 1991). Since live capture ceased this has reversed (Fig. 5). In 1991, about 0.3 deer were harvested per km^2 of DOC deer range in the North Island compared with less than 0.1 deer/km^2 in the South Island. For comparison, the estimated recreational harvest from the DOC deer range in 1988 was about 20 000 (1.3 deer/km^2) in the North Island, and about 10 000 (0.2 deer/km^2) in the South (G. Nugent, unpubl. 1988 survey data).

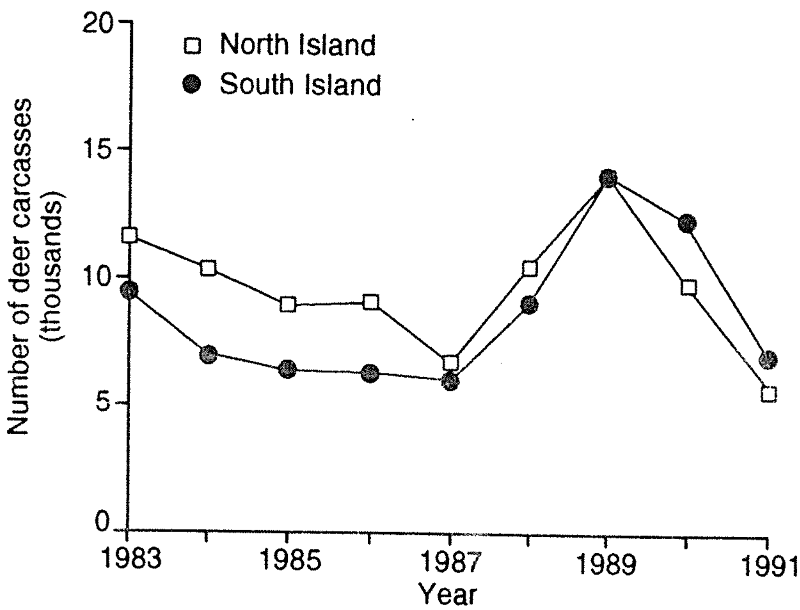

Fig. 5. Annual harvest of wild deer in each Island 1983-1990.

Overall, deer carcass weights (skin off) averaged 45 kg for the 21 months to September 1991 (males 48.9 kg, females 39.5 kg), and were slightly higher in the South Island. The smaller-than-average drop in prices paid for heavy deer resulted a 4-kg increase in average carcass weight between early 1990 and early 1991, and the sex ratio changed from 52% male in 1990 to 57% male in 1991. This indicates the reduction in female harvest has been even greater than the overall reduction.

5.2.6 Impact on deer populations

(a) Overall: During the 1950s an average of 66 500 deer skins were exported annually. Skins were only ever worth recovering from some of the deer shot (Challies (1985) reports 38%) so the annual deer harvest must have exceeded 100 000 deer annually. Caughley (1983) estimates there were only 13 000 private shooters at that time, but that is clearly too low, as about 3000 high-powered rifles were imported annually during the decade (Nugent 1991) - an inordinate amount of firepower for just 13 000 hunters.

The number of deer carcasses exported annually seldom exceeded 100 000 (Fig. 3), yet this reduced the population dramatically (Challies 1985). A summary of all available pellet survey data (Fig. 6) suggests pellet frequencies declined by about 75% between 1960 and 1980, though the data for successive years are not strictly comparable. The breeding population in the late 1950s cannot, therefore, have been much more than 1 million deer.

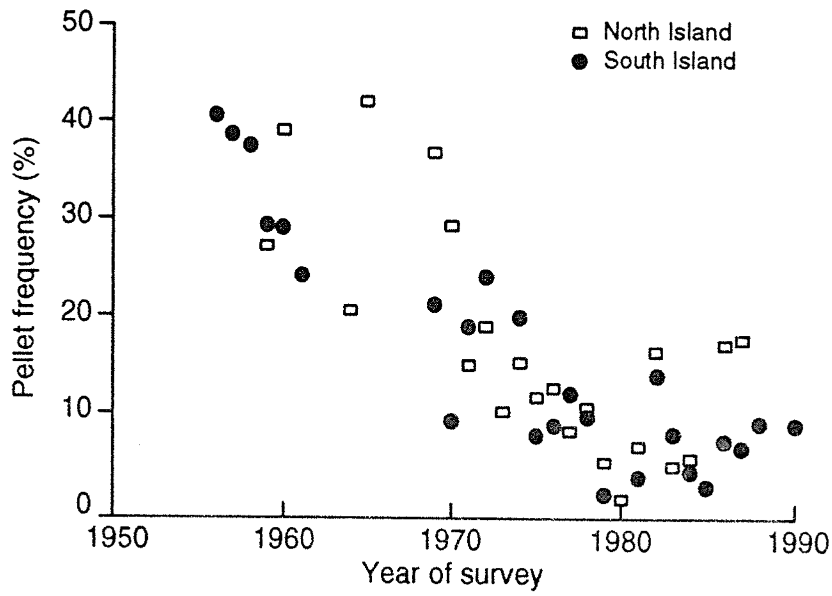

Fig. 6. Overall trends in deer density from pellet surveys. All reported indices of pellet density were converted to pellet frequencies (if possible) and averaged, separately for the North and South Islands, for all the areas surveyed in any one year. For recent surveys, only those of areas subjected to continued commercial hunting were included.

The 75% reduction, together with assessments of deer forage biomass (Nordmeyer & Evans 1985; Nugent 1990a), and high country stocking rates for sheep, combine to suggest post-peak carrying capacity is 20-40 deer/km^2 in forests and 30-50/km^2 in tussock grassland. The carrying capacity of the entire wild deer range is, therefore, in excess of 3 million deer, but pre-commercial harvests, competition from other herbivores and domestic stock, and the relatively recent colonisation of marginal areas, meant that this was never reached.

(b) Model of deer populations: An "accounting" model of the national deer population was developed to investigate and illustrate likely outcomes if hunting patterns were to change. I assumed that a national breeding population of 250 000 deer in 1991 occupied 59 000 km^2 of forest. Simulated recreational and commercial harvests were subtracted from this initial population and net recruitment (births-deaths) added for each successive year up to 2020. Net recruitment was assumed to decline as the deer population approached the assumed carrying capacity (30 deer/km^2), in accordance with the logistic equation. Recreational harvests were assumed to be linearly related to both deer density and hunting effort. I assumed a present recreational hunting effort of 35 h/km^2/yr, and a present recreational harvest of 40 000 (G. Nugent, unpubl. 1988 survey data). Commercial harvests were assumed to be related to harvest rate (again taken to be a linear function of deer density) and venison price. Simulations did not include any State-funded harvests.

Initial simulations treated the entire country as a single hunting system with all variables having the same values in all areas at any one time. Should all hunting cease, perhaps as a result of pressure from the anti-hunting lobby, the deer population would, in the absence of any other predators, rise to carrying capacity within 20 years (Fig. 7a), which for the forested deer range is assumed to be about 2 million deer. If commercial hunting ceases, but recreational hunting continues at present levels, the model predicted a three or four-fold increase in deer density to near half the carrying capacity (Fig. 7a,b). Note that recreational hunting alone is predicted to provide a similar level of control to that attained by the combination of recreational and State-funded hunting in the 1950s. The accuracy of this prediction cannot be verified, but improvements in transport systems, cheaper firearms, and a larger human population make it likely that recreational hunting would be more effective than in the 1950s. To prevent the deer population increasing from present levels in the absence of other harvests would require more than double the present recreational hunting effort.

I assumed that an average price of $3.50/kg paid to hunters would result in a commercial harvest of 30 000 deer (total payout c. $5.2 million), and that this, in conjunction with present recreational harvests, would maintain the present population (Fig. 7b). If prices remain below this, some increase in deer density is inevitable, but unless prices fall below $2.00/kg the increase will not be great. At represents what is likely to happen if the main processers quit, but minor processers and "black- marketeers" continue. At the present prices of about $2.50/kg, the model predicts a commercial harvest of about 14 000 deer (total payout $1.5 million) and a 30% rise in deer density over the next decade. To halve the population using commercial hunting would require increasing the price to $7.00/kg (total payout in the first year $25 million).

The model was subsequently extended to include variation between regions in factors such recreational hunting effort, deer density, and vulnerability of deer to helicopters. The average or "national" outcomes did not change greatly from the predictions above. What did differ widely was the predicted deer densities within each region. In regions easily hunted by helicopter that were remote (low recreational effort) and had low present deer densities, deer densities are predicted to approach carrying capacity if prices drop below $2.00/kg (the nominal Wapiti Area example in Fig. 7c). In areas not easily hunted by helicopter and with moderate recreational hunting pressure, deer densities are predicted to increase, but would remain well below carrying capacity even if commercial hunting ceased (Urewera, Fig. 7c). In areas with high recreational hunting pressure, the increase is predicted to be even more gradual (Tararua, Fig. 7c). These results suggest that although harvests and the economics of harvesting can be usefully discussed in terms of national totals, the conservation consequences can be assessed only at the local level.

(c) Regional variation in impacts: The impact of commercial hunting has varied widely. The range of impacts can only be described in general terms here, but these generalisations are based largely on the more detailed descriptions (and information sources) of 10 areas chosen to encompass the extremes that are presented in Appendix 9.1.

Commercial hunting has been particularly effective (in conservation terms) in the South Island. This is because most forested areas there are interspersed with extensive unforested valley flats, slips, or subalpine tussock and scrub, habitats in which deer are extremely vulnerable to helicopter-based hunting.

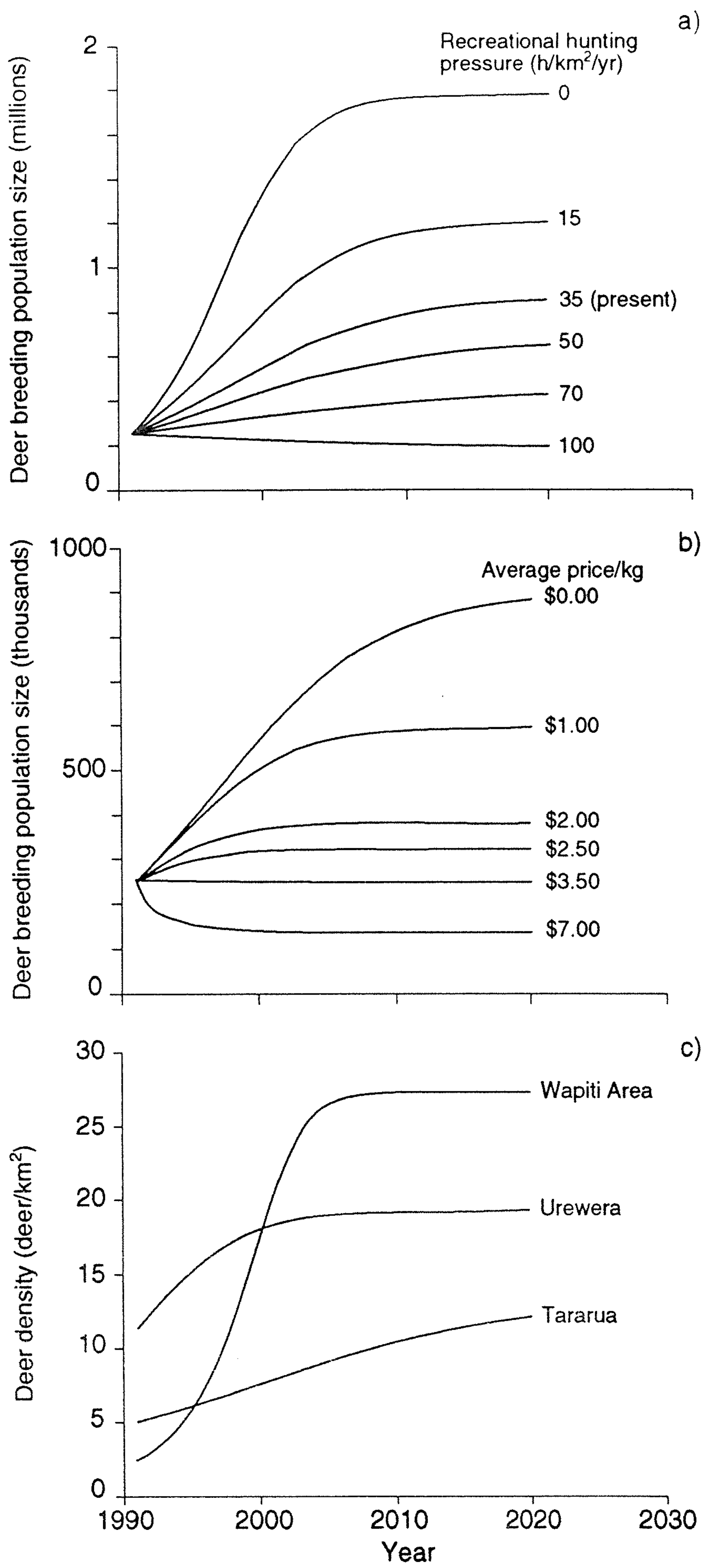

Fig. 7. Predicted changes in national or local deer populations: (a) No commercial harvests and recreational effort varied between zero and three times present levels; (b) Present recreational hunting effort and average prices paid to commercial hunters varied between 0 and three times present levels; and (c) No commercial harvests and different initial deer densities and recreational efforts.

Such hunting had virtually eliminated deer from above timberline by 1975 (as illustrated in Fig. 8a), and this habitat has generally recovered well in the ensuing 15 years (see the Wapiti Area, Mt Aspiring, and West Nelson examples in Appendix 9.1), except, of course, where sheep, chamois, or thar remain present. In the adjacent forested areas, however, densities range from near zero where forest cover is most patchy (West Nelson, and also much of Canterbury) to over 6 deer/km^2 where cover is most complete (western parts of Fiordland), and vegetation recovery varies accordingly. The beeches and podocarps are now little affected by deer, but the most highly-preferred species have seldom or nowhere regained their former abundance.

The Wapiti Area, Mt Aspiring, and West Nelson examples combine to suggest that abundant regeneration of the most highly preferred species probably requires deer densities below 2 deer/km^2, and I drew a similar conclusion from a forage availability and diet study in the Blue Mountains (Nugent 1990a). The examples in Appendix 9.1, and the data used to produce Figure 6 (derived from over 100 survey reports) indicate that most South Island deer densities probably fall within the 2-5 deer/km^2 range. These low densities make it likely that a limited recovery of highly preferred species has occurred in most areas (particularly under windthrown debris or on steeper slopes not readily accessible to deer), but that the recovery will usually be far from complete.

Two examples illustrate South Island situations in which commercial hunting does not now occur, either because it is prohibited (Blue Mountains) or because it is uneconomic (Stewart Island). In both areas, deer densities are well above the South Island average (Fig. 9). In the highly accessible Blue Mountains helicopter-based hunting was never permitted, but ground-based hunting (recreational and commercial) alone reduced deer density by 80% between 1960 and 1980. Recreational hunting alone subsequently further reduced the population slightly after 1980, even though combined recreational and State-funded hunting had been ineffective in 1960. This confirms that recreational hunting had become more effective since 1960. The other important result from the Blue Mountains was that in forest habitats very low deer densities (<2 deer/km2) were attained only near (within 1 km) of roads, the level of control falling rapidly with increasing remoteness. On the much more remote Stewart Island most hunting areas are accessible only by boat or aircraft, and deer densities were never reduced to low levels even when commercial hunting was economic. They may have increased somewhat during the 1980s despite continued recreational pressure. However, this continued pressure now appears to be holding the population at 50-75% of carrying capacity. In both these areas, the level of control will not permit a major recovery of highly preferred plant species, but should adequately protect many of the canopy species.

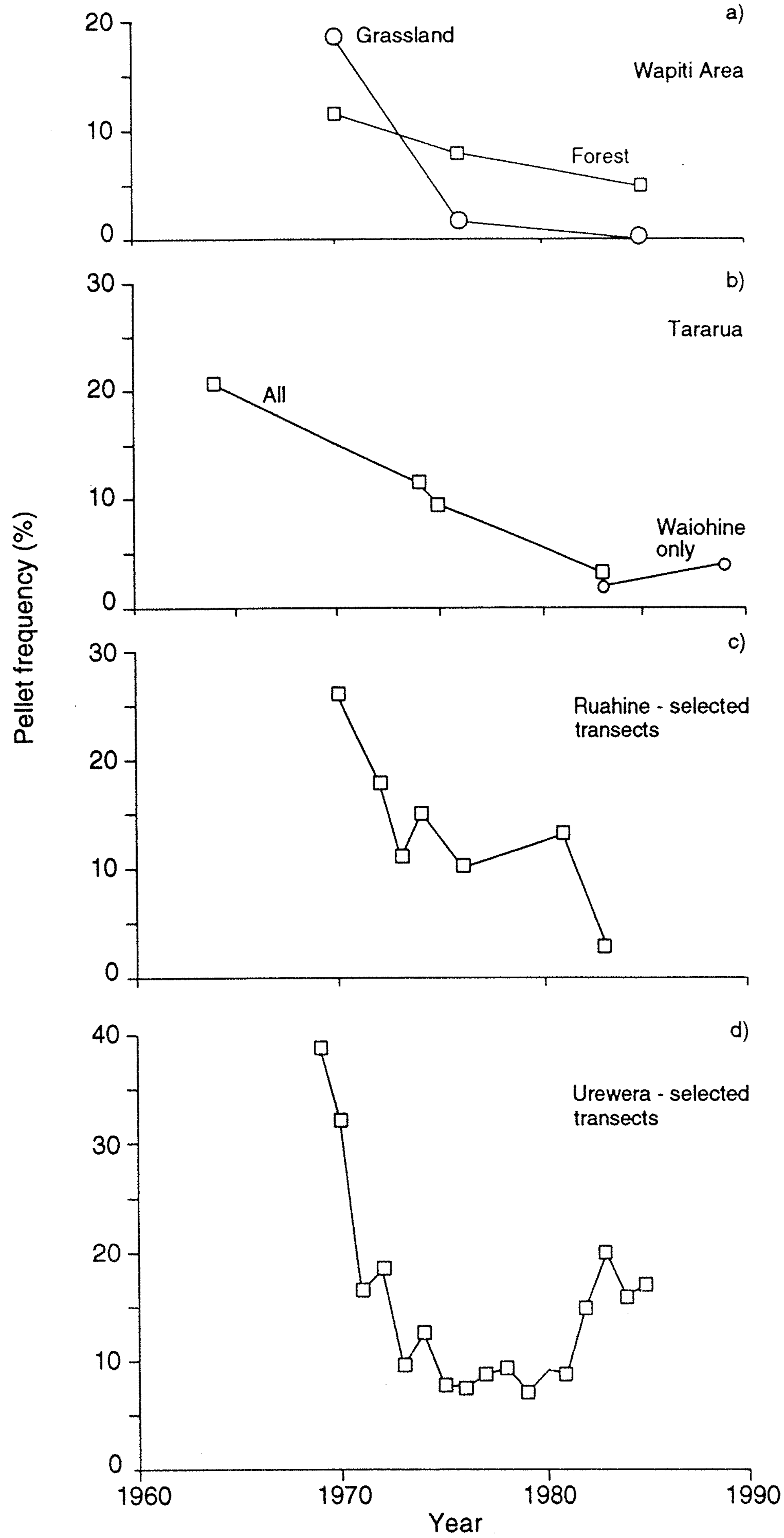

Fig. 8. Regional examples of reductions in deer densities; (a) Wapiti Area, Fiordland (Nugent *et al.* 1987); (b) Tararua Range (Handford 1989, unpubl.); (c) Ruahine Range (Oaks 1983, unpubl.); (d) Urewera range (Jane 1979, unpubl.; Beadel 1988).

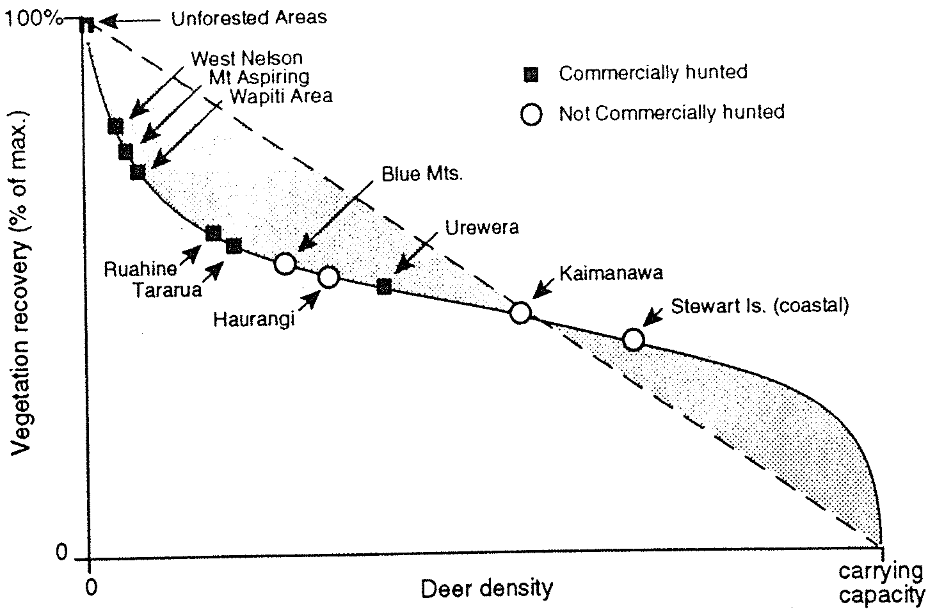

Fig. 9. Guessed deer densities and positions on a theoretical vegetation response curve for specific areas. The shape of the response curve is likely to vary between areas, from more-or-less linear in simple vegetation, to highly-plateaued in complex shrub-hardwood forest.

In the North Island deer densities generally appear to be higher than in the South (Fig. 6), consistent with more deer being harvested in the North Island each year (section 5.2.5) even though the area of deer range is smaller (Fig. 1). Marginal areas and well-roaded exotic forests aside, deer densities in the North Island forests appear to range between 5 and 15 deer/km^2 (Appendix 9.1 and the data used for Fig.6). Densities are probably lowest in the Ruahine and Tararua Ranges (Fig. 8b,c), both of which have substantial unforested areas, and highest in the Urewera Ranges (Fig.8d). Commercial venison recovery began later in the North Island than in the South Island, and several of the examples in Appendix 9.1 suggest State-funding and recreational hunting had already reduced deer populations before 1960. Commercial harvests may therefore have tended mainly to replace the former State-funded harvests rather than dramatically increase overall harvest. During the 1980s, live capture was more difficult in the more uniformly forested North Island than in the South Island (numerous helicopter operators, pers. comm.), and deer densities in at least some North Island forests drifted upward (Fig. 8b,d).

As in the South Island, deer densities in areas not commercially hunted are above average (Kaimanawa and Haurangi; Appendix 9.1, Fig.9), but there appears to be a greater level of control than on Stewart Island. This undoubtedly reflects the much higher hunter density in the North Island - a ratio of over 2.6 hunters/km^2 of forested deer range on DOC estate in 1988 compared with about 0.4 for the South Island (G. Nugent, unpubl. data). The North Island forests would also be more accessible, on average, than those in the South Island.

The examples in Appendix 9.1 suggest there is little regeneration of highly preferred plant species in the main North Island forests. However, there has often been a significant recovery of less palatable species, and the understorey is now thick in many areas. Some of this recovery was inevitable, particularly where goats and cattle have been removed, but some of it depends on low-to-moderate deer densities being maintained.

To summarise the above information, each of the 10 example areas in Appendix 9.1 is placed in its most likely position on a theoretical response curve (Fig. 9). Although both the shape of the response curve and the actual deer densities for each area are open to debate, I consider there is enough published, unpublished, and anecdotal data available to support my positioning of these areas on the graph. The most important point is that all deer populations are subject to at least moderate control, even where commercial hunting does not occur. The level of control under recreational hunting alone is, overall, substantially lower than under commercial hunting, but the few areas subject to intense recreational hunting pressure have lower deer densities than some that are commercially hunted.

In attempting to predict the likely impact on forest vegetation if commercial hunting were to cease, the first consideration is whether deer density in a particular area would change. For the Blue Mountains, Stewart Island, Kaimanawa, and Haurangi areas, big changes are unlikely. For the Tararua Range a moderate increase might be expected, as recent commercial harvests comprise about 20% of the total (Appendix 9.1). In the more remote Urewera Ranges, deer density could conceivably double. In the South Island, the smaller human population, greater area of deer range, and greater remoteness makes it likely that most populations would increase dramatically, sometimes from near zero to near carrying capacity.

How these changes actually affect the vegetation depends on the shape of the response curve. If the overall response curve is linear (dotted line, Fig.9) the degradation in the vegetation will be approximately proportional to any increase in deer density. If it is non-linear (solid line Fig. 9), as I believe (section 5.1.6), the mainly North Island areas that lie in or near the flattish midsection of the curve may show relatively little vegetation change - the Kaimanawa and Haurangi examples suggest recreational hunting alone could prevent densities reaching the high levels that affect the least preferred species. In contrast, the variable but sometimes significant recovery of the most vulnerable species in many South Island forests would probably be lost even if deer numbers increase even slightly, yet a substantial increase is expected. It is also possible that even the least vulnerable species would eventually be threatened in many South Island forests.

For large unforested areas, there are two possible outcomes. If helicopter-based hunting ceases completely, it is likely that deer will rapidly reinvade many of these areas, but if it continues at even a very low level (as expected), extreme vulnerability of deer in this habitat means densities there would remain quite low. Because some reserves of palatable vegetation have already accumulated, such low densities would probably have little impact.

5.2.7 The conservation value of commercial harvests

Recreational and commercial harvests substantially lessen the degree or rate of modification in ecosystems that the Department is obliged to protect and preserve. Such private harvests therefore produce conservation benefits even though that is not their primary purpose.

Recreational hunting involves about 50 000 New Zealanders, 75% of whom actually hunt in any one year. Their interest in hunting is probably determined by some combination of social factors (such as an interest in outdoor activity or participation by friends or family) and also by the cost of hunting. These factors seem intrinsically more stable than either venison prices or the level of government funding available. Recreational harvests should therefore be seen as providing a base level of control to which commercial or State-funded harvests add. The benefits of commercial hunting should therefore be viewed as the difference between present benefits and those achievable (at no cost to the Department) by recreational hunting alone.

As broad generalisations, I consider recreational hunting can be credited with protection (from deer) of the least vulnerable plant species in moderately accessible forests (which probably includes the canopy species in some beech forests). It also provides limited protection of moderately vulnerable species in a few highly accessible areas.

Above and beyond that base level of protection, commercial hunting can be credited with near total protection of even the most vulnerable species in unforested areas, and substantially greater protection of moderately vulnerable species in most forests. It also ensures that the least vulnerable species are well protected even in the most remote forests.

The monetary value of these benefits is difficult to estimate. Very little is spent on deer control at present whereas in 1960 the New Zealand Forest Service spent nearly $4 million ($1992) on noxious animal control. Assuming at least half this was spent on deer control, it could be argued that commercial hunting saves the government several million dollars annually. Unfortunately, an unknown proportion of that "saving" relates to deer control DOC would no longer consider necessary (such as reducing deer numbers in Kaingaroa forest).

Direct methods for estimating the conservation value of commercial harvests do exist. The contingent valuation method, for example, could be used to determine what the public would be prepared to pay (perhaps by way of increased taxes) to ensure that deer impacts remained at present levels rather than return to those apparent in the 1950s (a convenient approximation of the outcome expected if commercial hunting ceases; section 5.2.6). Such direct approaches are beyond the scope of this review.

A less direct and more subjective approach is to compare the benefits private hunting provide with those achieved by DOC-funded goat control operations. The two species pose much the same threats to conservation values (section 5.1.2), and DOC at present spends $3.7 million annually to control goats. Roughly half this is spent in areas that contain low-to-moderate densities of deer, yet very little of the control effort there is directed at deer (J.Parkes, pers. comm.). The best possible conservation outcome in such areas is therefore a low density of ungulates, an outcome that must be deemed acceptable since at least $1.5 million is currently spent trying to achieve it. The private harvests that ensure that deer remain at these acceptably low levels would therefore seem to be equal conservation value. In addition, deer occupy far more of the conservation estate than goats, so it is certain that substantial benefits also accrue in the large areas not inhabited by goats. Although such arguments are conjectural, they strongly suggest that the benefits of private deer harvests match those at present provided by DOC's goat control operations.

This appraisal could be refined by replicating the procedures used to develop national control plans for goats and possums. These are based on a prioritisation process that scores each area on the basis of the conservation values it contains, then weights those scores according to how badly the particular conservation values are threatened by the particular pest. Control funds are then allocated to the areas with the highest weighted scores.

For deer three sets of scores could be derived; one for the risk at present deer density, one for the predicted risk in the absence of commercial hunting, and one for the predicted risk in the absence of any hunting. Comparison of these weighted scores would provide some measure of the degree to which private harvests had reduced the threat to conservation values, and the relative importance of contributions that commercial and recreational harvests had made to such reductions. Comparison of the sets of "deer" scores with the "goat" scores would indicate where deer impacts (either present or predicted) outranked goat impacts in the lowest priority areas that currently receive goat control funding. Because some possum control spending will also ultimately be wasted unless present deer control is maintained (section 5.1.2) the estimated benefit would be conservative. In the absence of such an appraisal, it is difficult to accurately assess the contribution that commercial hunting alone makes to the overall benefit provided by private hunting. In my opinion, the very high level of control that commercial hunting provides in some areas (particularly alpine grassland) strongly suggests that its contribution is much more than half of the total.

5.3 Options

5.3.1 Strategic options for deer management

DOC has three broad strategic options for the management of wild animals: do nothing, eradication, or management at specified densities (J.Parkes 1988, unpubl. FRI contract report). Doing nothing seems not to be an option for deer in light of DOC's obligation to preserve and protect native ecosystems (section 5.1.1). Eradication is also not an option, at least for mainland New Zealand, because the widespread farming of deer ensures some would always escape to recolonise the conservation estate.

Management at specified densities could either mean control (management aimed at indigenous conservation goals) or management for hunting. However, departmental policy has been that management for hunting is not an option except where doing so helps achieve conservation goals (Holloway 1989). Control to specified densities to achieve conservation goals therefore appears to be the only strategic option available to DOC.

At present, DOC's only published deer control policy is that "..throughout the estate, the level of wild animal population that should be the goal of management is the lowest level that can practically be achieved and maintained in the long term .." (Holloway 1989). For goats and possums, such generalised policies couched in terms of animal densities have been replaced by national control plans that emphasize protection of specified conservation goals in specific areas. It is likely that such a plan will eventually be developed for deer, particularly if DOC increases its direct involvement in deer control.

5.3.2 Deer control options

DOC's options depend on whether commercial hunting remains viable. If it does, support of the industry is unnecessary. If the yet-to-be-developed deer control plan requires greater control that currently exists in a particular operational area, DOC can, independently for each area, explore mechanisms for increasing recreational or commercial harvests from that area, and compare that with the cost of direct Sate-funded control.

If commercial hunting cannot remain viable without support, retention of present conservation benefits will obviously need some DOC action. The options are:

- DOC provides sufficient support to ensure that the commercial industry survives (either nationally, or for individual processing plants).
- DOC encourages additional recreational harvesting to replace some or all of the former commercial harvests.
- DOC replaces some or all of the former commercial harvests by killing deer itself.

(a) Potential mechanisms for supporting commercial hunting: Helicopter operator viability could be increased indirectly by reducing competition between operators, reducing those costs over which DOC has control (such as WARs licence fees), or changing taxation regimes (to non-payment of withholding tax at time of sale). These indirect measures are unlikely to increase operator profitability (and therefore their harvests) enough to make the main processers viable.

In contrast, direct subsidy of hunters undoubtedly has the potential to ensure hunting remains economically viable if the payments were large enough. Because industry viability depends on the processers rather than the hunters, any subsidy would have to either substantially increase harvest (and therefore the economies of scale for processers) or permit processers to reduce their payments to hunters (or both). There are many potential hunter support mechanisms: subsidies for the price paid per kilogram, or the price paid per carcass, or carcass collection, or fuel. Alternatively DOC could pay for information (number, location, age, and sex) or material (jawbones, uteri) from killed deer - this would improve knowledge of the deer population, and is less likely to be misconstrued as a production subsidy by foreign governments (which could impose countervailing duties).

An indication of the potential annual cost of hunter subsidy is provided by the discrepancy between present prices and those required to produce an annual commercial harvest of 30 000 deer (the harvest I consider necessary to maintain present deer densities). Comparison of 1991 and 1989 harvests suggests the discrepancy is about $50 per deer, so a harvest of 30 000 would cost DOC $1.5 million and processers about $3.5 million. Restricting such a payment ($50/deer) to females alone would result in a lesser harvest (20 000-25 000), but one that would probably prevent a population increase and cost only $0.8-1.0 million nationally. Restricting any subsidy to the South Island (73% of the deer range) would reduce these costs by half. Restricting the subsidy to DOC land only would reduce the subsidy required by 20%, but this would be difficult to police.

The level of hunter subsidy needed to ensure existing processers continue is unclear, because the major threat to viability is the European directive requiring separate processing of farm and wild deer, rather than factors such as harvest size and hunter payments. My assessment is that the existing processers would need to be confident of obtaining 7000-10 000 deer annually for a particular processing plant before they would consider the necessary investment. An alternative to hunter subsidy is that DOC subsidise the upgrading of present facilities or the building of new facilities. This would have the advantage of being a once-only rather than an annual expense.

Another possibility is a supplementary minimum price scheme. When market prices were above an agreed minimum level, some of the "surplus" would be retained, and the fund thus established would then be available to support prices when they fell below the minimum level. The minimum hunter payment would need to be above $3/kg carcass weight to maintain main processer viability, so that the fund would go immediately into deficit if started now. DOC's role would, therefore, be to underwrite the scheme in some way, either by providing start-up capital, or by acting as guarantor for any monies borrowed.

As an alternative to direct subsidies aimed at existing processers, DOC could assist minor (or new) processers to develop domestic or export markets by assisting with preliminary investigations, by providing venture capital (or capital guarantees), and by ensuring that such operators have access to a sufficient supply of wild deer. Promoting wild venison overseas would need to counter the emphasis of Game Industry Board marketing and, therefore, is probably not desirable in view of the relatively small amount of wild venison produced. Success in finding domestic markets for minor processers would further reduce main processer viability, so should be considered only if main processers cease or are not supported. Development of markets takes time, so probably would not improve industry viability in 1992, but could be a useful long-term support mechanism.

The strongest argument in favour of support is if the present problems are temporary. If the industry collapses the capital expenditure needed to re-establish the industry once (if) prices improved would be far higher than the value of the historically-depreciated infrastructure now in place. During the period between the collapse and eventual re-establishment of a major processing industry, deer numbers would increase. The aim of any support would be to either ensure present industry continues, or that it is replaced far sooner than would occur on economic grounds alone. This would prevent a major fluctuation in deer numbers from wiping out all the conservation gains made to date, without committing the Department to a perpetual expense .

In summary, the main advantage to DOC for any of the potential support mechanisms above is that they could substantially reduce the cost of retaining present conservation benefits (should DOC wish to do so). Disadvantages are that it would probably cost several million dollars over the next few years, that the potential saving in deer control costs might not eventuate, and that deer are killed where it is most economic to do so (not necessarily where control is most needed).

(b) Potential mechanisms for enhancing recreational harvests: The methods by which recreational harvest could be increased are varied, and include subsidisation of travel costs, payment of bounties, hunting competitions, construction of new huts or tracks, provision of helicopter landing sites in densely forested areas, and education campaigns. Of these, few have been objectively assessed in New Zealand. A hunting competition in which prizes were given to hunters who shot specially marked goats successfully increased recreational goat harvest on Mt Taranaki (Boardman 1992 unpubl.). A wide-ranging effort to increase recreational hunter interest in the Kaimanawa RHA that included providing better access to parts of the RHA appears to have increased hunter interest in the area (C. Speedy, pers. comm.) but deer numbers there are still high compared to commercially hunted areas

(Fig. 9). Such approaches might not be as successful in areas where deer densities are low. Neither is it known whether such methods would increase overall harvest (rather than simply shift the focus of hunters' attention between areas).

In the absence of any information on suitability or cost effectiveness of such methods applied on a national scale, perhaps the best insight into the probable overall usefulness of recreational hunting as a means of replacing commercial harvest is provided by an examination of hunter spending. In 1988, 37 500 ground-based deer hunters incurred over $13 million in non-capital expenses (i.e., excluding firearm and vehicle purchases; G. Nugent, unpubl. survey data), an average of $350 per hunter. If a total of $1.5 million annually (see below) was provided by way of direct subsidy to recreational hunters it would reduce their costs by only 11%, a reduction that seems unlikely to increase recreational hunting effort and harvests significantly. Though there are probably much more effective ways of enhancing recreational hunting effort than by direct financial subsidy, these figures suggest it would require several millions of dollars to double recreational hunting effort.

Even if recreational harvests could be increased, the increase would not exactly replace commercial harvests. In particular, the recreational hunting pressure needed to maintain low deer densities in (for example) remote South Island forests would be many times more than is currently exerted (K.W. Fraser, 1992 unpubl. FRI contract report FWE 92/24). In order to maintain the status quo, present recreational hunting effort would therefore not only have to be increased, but also substantially redirected into areas with very few deer that at present have little appeal to recreational hunters.

The primary advantage of this option is that it would be more acceptable to recreational hunters, and therefore less controversial, than other options. The main disadvantage is that the large numbers of individuals involved and their diverse motivations make recreational hunting an unwieldy control force. It appears unlikely to be more cost effective than the other options on a national scale, though there is too little information to be certain of that. Another possible disadvantage is that hunting and the use of firearms in general is becoming increasingly controversial.

(c) Direct funding of deer control: DOC could resume killing deer itself. The techniques most likely to be suited to this are ground-based hunting, use of helicopters, or poisoning. History strongly suggests that in all except the most completely forested areas, helicopter-based hunters would be more effective and efficient than ground-based hunters, though there is no documented proof of this. A foliage-bait poisoning trial on Stewart Island proved the poisoning was able to almost eliminate a high-density white-tailed deer population in a single operation, and indicated that poisoning was likely to be more cost-effective than ground-based hunting for high density populations (Nugent 1990b, unpubl. FRI contract report FWE 90/20). The technique has been less successful at reducing a low-density

population of red deer on Secretary Island, and its cost-effectiveness relative to ground-based hunting for low-density populations is unclear (W. Chisholm, pers. comm.).

Regardless of whether poisoning or ground-based hunting would be more cost effective, helicopter-based hunting can (and does) provide a high level of control over much of the conservation estate. It is therefore useful to assess what it would cost DOC to exactly replace present commercial harvests by using helicopters to kill but not recover deer.

In 1989 hunters were paid nearly $5 million for the nearly 30 000 deer harvested. Typically only about half the flying time spent by commercial hunters is spent actually finding and killing deer (average of guesses provided by 15 operators), so DOC could reasonably expect to exactly replicate the 1989 harvest for about $2.5 million if carcasses were not recovered. However, DOC would not operate outside the conservation estate, would preferentially target female rather than male deer, and would eliminate harvest inefficiencies resulting from operator competition. These measures would, in my opinion, reduce the cost of maintaining present conservation benefits to less than $1.5 million annually. The cost could possibly be reduced even further if it were decided that recreational hunting alone provided adequate protection in some areas (such as some central North Island forests).

The main advantage of this option is that deer would be killed only where control was needed. Its main disadvantage is that it would destroy any prospect of the commercial industry retaining its viability. The department would then be committed to funding deer control in perpetuity. A further disadvantage is that recreational hunters are likely to object strongly to large-scale DOC-funded killing-to-waste, particularly if poisoning were one of the techniques used.

5.3.3 Choosing an option

Before DOC can choose an option, it must first decide whether it wishes to retain the benefits commercial hunting provides, and how much it is willing to spend to so. Those decisions can either be made immediately based on the appraisal in section 5.2.6 (or an extended form of it) or they could be made after the development of a national deer control plan that specifies deer control objectives and their priority in each area, and the degree to which commercial hunting meets those objectives. The time required for the latter process would preclude supporting the existing main processers as an option because they are likely to cease operation within 1992.

If DOC does decide to retain all of the benefits provided by commercial hunting, it must be prepared to meet some, possibly all, of the costs of that control in perpetuity. My estimate of the maximum cost of killing enough deer itself ($1.5 million annually) indicates the scale of the commitment required, and provides a yardstick against which other options can be judged. Supporting either recreational or commercial hunting would be worthwhile if doing so reduces the scale of the financial commitment required from DOC in the long term.

For commercial hunting the question is whether short-term financial support of up to $1.5 million annually would ensure the industry is successfully re-established to the extent of being fully self-supporting or, at least, require far less support than the cost to DOC of doing the control itself. Though that question cannot be answered, choosing to support the industry in this manner would not jeopardise DOC's ability to choose another option later and would "hold the line" in terms of retaining current conservation benefits.

For recreational hunting, the cost of increasing harvests to the desired level cannot be estimated at all, making it difficult to choose this option. Choosing this option might also make it politically difficult to choose another option later.

If DOC chooses to kill deer itself, or to enhance recreational hunting, it can choose between these options independently for each operational area. For the commercial support option, however, enough support must be provided across enough areas to ensure individual processing plants remain viable, i.e., the decision of whether or not to support commercial hunting cannot be made in isolation for each operational area or forest tract.

6. CONCLUSIONS AND RECOMMENDATIONS

Commercial hunting provides significant conservation benefits. The imminent exit of the main processers from the industry means DOC must either accept the loss of those benefits, or attempt to retain them. If the latter, DOC must allocate some funding to deer control. If DOC does fund deer control, a national control plan along the lines of the goat and possum models is urgently required. All major forest tracts need to be ranked in order of priority for deer control, and this process should include the development of deer population and impact models for each area.

To determine how much (if any) needs to be spent on deer control at present deer densities DOC should compare nationally ranked priorities for deer control with those for goats, and, to a lesser extent, with those for possums. To assess how much additional funding is needed to retain the benefits commercial hunting provides, DOC should then re-evaluate what its priorities for deer control would be if deer densities returned to somewhere near 1950s levels, and again relate those priorities to current spending on goats and possums.

As a practical guideline, all present benefits could be retained for less than $1.5 million annually, so it is recommended that this is be the maximum spent on deer control unless the intent is to further reduce the overall level of deer-induced damage on the conservation estate.

Provided DOC does wish to maintain some or all of the benefits provided by commercial hunting, and has the resources to usefully do so, DOC should consider supporting the industry for 2-3 years. The mechanism for support should be decided after consultation with operators, processers, and conservancies, but it is recommended that DOC use the opportunity to gather information about the deer population, that any "subsidy" be targeted at female deer (if possible), and that a mechanism for recovering the "subsidy" should prices rise above $3.00/kg be considered. If the existing industry (or its replacement) is not self-supporting or close to self supporting within 3 years DOC should consider killing deer itself. Enhancing recreational harvests is likely to be of limited use.

Provided DOC does begin funding deer control (directly or indirectly), an affordable system for monitoring deer impacts should be developed to determine whether control objectives are met. Private hunter kill-rate data could provide cheap overall information on deer populations trends that would complement more detailed local studies. The Wapiti Area, Arawhata, Ruahine, and Urewera areas are suggested as potential sites for such studies.

The relative impact of the various ungulate species and possums on vegetation regeneration should be investigated. Arguments advanced in this report suggest a dominant role for ungulates, but this needs verification. If deer are most important, DOC spending should reflect that. The non-linear model of deer impacts presented in this report also needs verification.

7. ACKNOWLEDGEMENTS

I thank all those who provided information and ideas for this report, particularly the many hunters and those involved in the processing industry. I also thank J. Parkes, A. Griffiths, W. Fraser, B. Warburton, and J. Coleman for their comments on initial drafts, and J. Orwin for editorial help.

8. REFERENCES

Allen, R.B.; Payton, I.J.; Knowlton, J.E. 1984: Effects of ungulates on structure and species composition in the Urewera forests as shown by exclosures. *New Zealand Journal of Ecology 7:* 119-130.

Atkinson, I.A.E. 1985: Botanical reasons for eradicating possums from Kapiti Island. Department of Scientific and Industrial Research, Botany Division, Internal Report No. 518 (unpubl.).

Bathgate, J.L. 1976: Blue Mountains fallow: a population census. New Zealand Forest Service (Southland) report (unpubl.).

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

Beadel, S.M. 1988: Wild animals of the Urewera forest 1980-87. Department of Conservation (Rotorua) Technical Report Series No.7.

Bennett, M. 1979: *The Venison Hunters*. Reed, Wellington.

Boardman, B. 1992: Analysis and discussion of results: Department of Conservation Mt Egmont trophy goat hunt 1991-1992. Department of Conservation (Wanganui) report (unpubl.).

Brabyn, L.K. 1988: Resurvey of the forests of the Kaimanawa Recreational Hunting Area. Department of Conservation (Turangi) report (unpubl.).

Brady, P.J. 1987: Changes in the Tararua Ranges silver beech forest. Department of Conservation (Wellington) draft report (unpubl.).

Caughley, G. 1980: What is this thing called carrying capacity? *In:* Boyce, M.S.; Hayden-Wing, L.D. (eds.) *North American elk: Ecology, behaviour, and management.* pp 2-8. University of Wyoming.

Caughley, G. 1983: "*The Deer Wars*". Heinemann. 187 p.

Caughley, G. 1989a: Plant herbivore interactions. Pp. 51-52 *in:* Newton, A.E. (ed.) *The future of New Zealand's wild animals.* Seminar 2000 Proceedings. New Zealand Deerstalkers Association, Christchurch.

Caughley, G. 1989b: Control of wild animals. Pp.101-103 *in:* Newton, A.E. (ed.) *The future of New Zealand's wild animals.* Seminar 2000 Proceedings. New Zealand Deerstalkers Association, Christchurch.

Challies, C.N. 1985: Establishment, control, and commercial exploitation of wild deer in New Zealand. *In:* Fenessey, P.F.; Drew, K.D. (eds.) "Biology of Deer Production." *Royal Society of New Zealand Bulletin 22:* 23-26.

Challies, C.N. 1991: Status and future management of the wild animal recovery industry. *New Zealand Forestry 36(1):* 10-17.

Cunningham, A. 1966: Catchment condition in the Ruahine Range 1962. Forest Research Institute, Protection Forestry Division, Branch Report 23 (unpubl.).

Davidson, M.M.; Kean, R.I. 1960: Establishment of Red-deer range in the Tararua Mountains. *New Zealand Journal of Forestry 8(2):* 293-324.

Davis, M.J.; Orwin, J. (eds) 1985: Report on a survey of the proposed Wapiti area, West Nelson. *Forest Research Institute Bulletin 84.*

Diamond, J.M; Veitch, C.R. 1981: Extinctions and Introductions in the New Zealand avifauna: cause and effect? *Science 211:* 499-501.

Elder, N.L. 1962: Vegetation of the Kaimanawa Ranges. *Transactions of the Royal Society of New Zealand (Botany) 2:* 1-37.

Elder, N.L. 1965: Vegetation of the Ruahine Range: an introduction. *Transaction of the Royal Society of New Zealand (Botany) 3:* 13-66.

Fraser, K.W. 1992: Impact of commercial venison operations on red deer numbers and local distribution in the Arawhata Valley, South Westland. Forest Research Institute contract report FWE 92/24 (unpubl.).

Freeland, W.J. 1991. Plant secondary metabolites: biochemical coevolution with herbivores. Pp 61-82 *in:* Palo, R.T; Robbins, C.T. (eds.) *Plant defences against mammalian herbivory.* CRC Press, Boca Raton.

Gibb, J.A. & Flux, J.E.C. 1973: Mammals. Pp. 334-371 *in:* Williams, G.R. (ed). *The natural history of New Zealand.* Reed, Wellington.

Griffiths, A.O. 1976: The forests of the Tararua Range - their condition and trends. Forest Research Institute, Protection Forestry Division, Branch Report 133 (unpubl.).

Handford, P. 1989: Wild animal status in Tararua Forest Park 1988/89. Department of Conservation (Wellington) draft report (unpubl.).

Handford, P.A. 1991: The distribution and abundance of introduced browsing animals in Haurangi Forest Park. Unpubl. Department of Conservation (Wellington) draft report (unpubl.).

Hicks, D.L. 1991: Erosion under pasture, pine plantations, scrubland and indigenous forest, a comparison from Cyclone Bola. *New Zealand Forestry 36(3):* 21-22.

Hodder, D. 1990: Letters to the Editor. *New Zealand Rod and Rifle 11:* 9.

Hoffman,R.R. 1985: Digestive physiology of the deer. Their morphophysiological specialisation and adaption. *In:* Fenessey, P.F.; Drew, K.D. (eds.) "Biology of Deer Production." *Royal Society of New Zealand Bulletin 22:* 393-408.

Holloway, J.T. 1950: Deer and the forests of western Southland. *New Zealand Journal of Forestry 6:* 123-137.

Holloway, J.T.; Wendelkin, W.J.; Morris, J.Y.; Wraight, M.J.; Wardle, P.; Franklin, D.A. 1963: Report on the condition of the forest, subalpine scrublands, and alpine grasslands of the Tararua range. *New Zealand Forest Service Technical Paper 41.*

Holloway, J. 1989: The future of wild animals : A department of Conservation viewpoint. Pp. 10-20 *in:* Newton, A.E. (ed.) *The future of New Zealand's wild animals.* Seminar 2000 Proceedings. New Zealand Deerstalkers Association, Christchurch.

James, I.L.; Beaumont, P.E. 1971: A survey of the vegetation of the Southern Ruahine Range. Forest Research Institute, Protection Forestry Division, Branch Report 80 (unpubl.).

Jane, G.T.; Pracy, L.T. 1974: Observations on two animal exclosures in Haurangi forest over a period of twenty years (1951-1971). *New Zealand Journal of Forestry 19:* 102-113.

Jane, G.T. 1979: Forest trends and condition in the Northern Urewera. Unpubl. New Zealand Forest Service (Rotorua) report.

Jenkins, C.M. 1981: Animal population survey of the southern Kawekas and NE Ruahines. New Zealand Forest Service (Napier) report (unpubl.).

King, C.M. 1990: *The handbook of New Zealand mammals.* Oxford University Press, Auckland.

Lane, R. 1982: The history of the South Kaipara fallow deer herd. *New Zealand Wildlife 9(66/67):* 22-30.

Lavers, R.B. 1978: The diet of red deer (*Cervus elaphus*) in the Murchison Mountains : A preliminary report. Pp. 187-198 *in:* Seminar on the takahe and its habitat, 1978. Fiordland National Park Board.

Leathwick, J.R.; Hay,J.R.; Fitzgerald, A.E. 1983: The influence of browsing by introduced mammals on the decline of North Island kokako. *New Zealand Journal of Ecology 6:* 55-70.

Llewellyn, M. 1988: Impact of Dama wallaby on kanuka dominant forest at Lake Okataina as shown by exclosures. Department of Conservation (Rotorua) report (unpubl.).

Lovelock, B.A. 1987: Northern Stewart Island wild animal survey 1986. Department of Conservation, Invercargill.

Mark, A.F. 1989: Responses of indigenous vegetation to contrasting trends in utilisation by red deer in two south western New Zealand National Parks. *New Zealand Journal of Ecology 12(Suppl.):* 103-114.

Mills, J.A.; Mark, A.F. 1977: Food preferences of the takahe in Fiordland National Park, New Zealand, and the effect of competition from introduced red deer. *Journal of Animal Ecology 46:* 939-958.

Moore, E.D. 1976: The subalpine shrublands of the Tararua range. Forest Research Institute, Protection Forestry Division, Branch Report 139 (unpubl.).

New Zealand Forest Service. 1984: Deer control and vegetation response on Stewart Island. *What's New in Forest Research 126.* Forest Research Institute, Rotorua.

Newsome, P.F.J. 1987: *The vegetative cover of New Zealand.* Wright & Carman, Lower Hutt.

Nordmeyer, A.H.; Evans, G.R. 1984: Forage in the forests and grasslands. Pp. 127-138 *in:* Davis, M.R. & Orwin, J. (eds.) Report on a survey of the proposed Wapiti area, West Nelson. *Forest Research Institute Bulletin 84.*

Nugent, G. 1988: Successful control of fallow deer by recreational hunters in the Blue Mountains, Otago. *New Zealand Journal of Forestry Science 18:* 239-252.

Nugent, G. 1989a: Hunting in New Zealand in 1988: Survey Results. Forest Research Institute contract report (unpubl.).

Nugent, G. 1989b: An assessment of wild big-game harvests and their commercial utilisation. Forest Research Institute contract report (unpubl.).

Nugent, G. 1990a: The diet of fallow deer (*Dama dama*) and forage availability in the Blue Mountains, Otago. *New Zealand Journal of Ecology 13:* 83-95.

Nugent, G. 1990b: A review of options to manage white-tailed deer *Odocoileus virginianus* on Stewart Island. Forest Research Institute contract report FWE 90/20 (unpubl.).

Nugent, G. 1991: Hunting Firearms in New Zealand. *New Zealand Rod and Rifle:* 25-27.

Nugent, G.; Challies, C.N. 1988: Diet and food preferences of white-tailed deer in north-eastern Stewart Island. *New Zealand Journal of Ecology 11:* 61-73.

Nugent, G.; Parkes, J.P.; Tustin, K. 1987: Changes in the density and distribution of red deer and wapiti in northern Fiordland. *New Zealand Journal of Ecology 10:* 11-21.

Nugent, G.; Sweetapple, P. 1989: The impact of three deer hunting regimes in north-eastern Fiordland. *New Zealand Journal of Ecology 12:* 33-46.

Oaks, T.J. 1983: Animal survey of the Ruahine Range 1982-1983. New Zealand Forest Service (Palmerston North) report (unpubl.).

Parkes, J.P. 1988: A review of options to manage Himalayan thar *Hemitragus jemlahicus* in New Zealand. Forest Research Institute contract report (unpubl.).

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:* 23-34.

Ryan, C. 1990: Down to earth. *Terra Nova 1(1):* 50-51.

Smith, M.C.T. 1974: Biology and management of the wapiti (*Cervus elaphus nelsoni*) of Fiordland, New Zealand. New Zealand Deerstalkers Association.

Speedy, C. 1991: The effects of recreational hunting pressure on mountain beech forest habitat quality in Kaimanawa Forest Park, central North Island, New Zealand. Department of Conservation (Turangi) report (unpubl.).

Stewart, G.H. 1986: Forest dynamics and disturbance in a beech/hardwood forest, Fiordland, New Zealand. *Vegetatio 68:* 115-126.

Stewart, G. 1988: Forest dynamics and deer browsing in *Nothofagus* forests of the Blue Mountains, West Otago. Forest Research Institute contract report (unpubl.).

Stewart, G. 1989: Ecological considerations of dieback in New Zealand's indigenous forests. *New Zealand Journal of Forestry Science 19(2/3):* 243-249.

Stewart, G.H.; Wardle, J.A.; Burrows, L.B. 1987: Forest understorey changes after reduction in deer numbers, northern Fiordland, New Zealand. *New Zealand Journal of Ecology 10:* 35-42.

Stewart, G.H; Burrows, L.E. 1989: The impact of white-tailed deer *Odocoileus virginianus* on regeneration in the coastal forests of Stewart Island, New Zealand. *Biological Conservation 49:* 275-293.

Veblen, T.T.; Stewart, G.H. 1980: Comparison of forest structure and regeneration on Bench and Stewart Islands, New Zealand. *New Zealand Journal of Ecology 3:*50-68.

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

Wallis, F.P.; James, I.L. 1969: Introduced mammals in the northern Urewera forest. Forest Research Institute, Protection Forestry Division Branch Report 58 (unpubl.).

Wardle, J.A. 1984: *The New Zealand Beeches. Ecology, utilisation and management.* New Zealand Forest Service.

Willemse, P.N. 1985: Mount Aspiring National Park wild animal trends. New Zealand Forest Service (Southland) report (unpubl.).

9. APPENDIX

Appendix 9.1: Ten examples of the varying impact of commercial hunting

The five examples from each Island include two in which commercial hunting is prohibited or uneconomic. Reported measures of deer density have been standardised in terms of pellet frequency, or deer/km^2, the latter sometimes being estimated from reported harvests.

1. **Wapiti Area, Fiordland.** This 80 000 km^2 area contains mainly beech-dominated forest with extensive unforested areas in the east. Red deer and wapiti are present, with very low numbers of chamois, and with possums around the eastern fringes. In the 1960s the New Zealand Deerstalkers Association attempted to protect the wapiti strain by selectively culling red deer and hybrids, but apparently had little effect on deer density (Smith 1974). Venison harvesting began in 1972. Above timberline, deer density had been dramatically reduced by 1975, and was zero by 1984 (Fig. 8a; Nugent *et al.* 1987). Smaller reductions occurred in the forest, densities in 1984 ranging from 2.4/km^2 in the east (where there are extensive unforested areas) to 6.4/km^2 in the west (<2% unforested). By 1987 densities in the eastern forest were lower still (2/km^2), and in the nearby Murchison Mountains, State-funded hunting combined with commercial recovery had achieved densities of 1/km^2 (Nugent & Sweetapple 1989).

   Above timberline, tussock cover and the abundance of large-leaved herbs had increased dramatically by 1984 (Rose & Platt 1987). In the eastern forests understorey stem densities had also increased by 1984 (Stewart *et al.* 1987). Although the increase included some highly palatable species, these were mostly less than 75 cm tall and were still less abundant than in unmodified forest.

2. **Mt Aspiring National Park.** This 2870-km^2 area also contains mainly beech forest and has extensive tussock areas. Red deer and also a few white-tailed and fallow deer are present, as are low numbers of goats, chamois, and thar. Possums are only now completing their colonisation of the area. This area was one of the birthplaces of commercial venison recovery.

   In the west, pellet frequencies declined from 18.8% in 1972 to just 2.5% in 1983-84, while in the east pellet frequencies halved between 1978-79 and 1983-84 (to 1%; Willemse 1985 unpubl. NZFS report). No pellets were recorded above timberline. Mark (1989) reported a widespread recovery above timberline by 1986. In the forests, ground cover had generally increased, beech species were regenerating freely, and even highly-palatable species were rarely browsed.

   In the Arawata Valley in the west, deer density declined from approximately 40/km^2 in 1970 to about 5/km^2 in 1985 (Challies 1991). In 1990, densities appeared similar to those in 1985, and the vegetation recovery there appears similar to that elsewhere in the park, despite the higher-than-average deer densities (8.8% pellet frequency in 1990; W. Fraser, pers. comm.).

3. **West Nelson.** This 930-km^2 area in was surveyed in 1982-83 as a potential site for a wild wapiti population (Davis & Orwin 1985). It contains mainly beech forest and tussockland. Deer, goats, and possums are present, and domestic stock once grazed many parts of it. Commercial hunting began about 1963, and helicopters were first used in 1967. Helicopter recovery rates declined from

about 12 per flying hour in 1967 to about 2-4 per hour in 1976. About 700 deer were taken by helicopter in 1982 (0.75/km^2), and the breeding population was estimated at 1400 deer (plus about 1000 goats). Pellet frequencies were generally below 5% and deer densities varied between 0.4 and 2.5 deer/km^2 of forest. Deer use of grassland was negligible.

The high-altitude grasslands had been much modified by grazing and fire, but a high proportion of vegetative ground cover and moderate frequencies of highly palatable herbs indicated some recovery. In the forest, however, some species were failing to regenerate even in the communities most lightly used by deer. Less palatable species were making some recovery, and the beeches were generally little affected by deer.

4. **Blue Mountains.** This 227-km^2 area contains fallow deer, pigs, and possums, and was never hunted by helicopter. Half the area has been converted to pine forest.

   Despite intensive State-funded hunting, deer densities remained high until 1960, but over the next 20 years recreational and commercial ground-based hunting reduced densities by an estimated 80% (Nugent 1988). Commercial hunting was prohibited in 1980, and recreational hunting alone further reduced deer densities till 1985. The average deer density in 1985 was about 7.5/km^2 of forest, but ranged from only about 2/km^2 in the exotic forest to over 10/km^2 in beech forest. This variation mainly reflected accessibility to hunters (nearness to roads). Even the most remote parts of the RHA were all within 3-4 km of a road, yet densities in such areas exceeded 15/km^2.

   Historically, deer impeded beech and pine regeneration (Bathgate 1976, unpubl. NZFS report; Nugent 1990), but these species were rarely eaten in the 1980s. Tall seedlings of highly-preferred hardwood species remained rare in beech forest, but were common within deer exclosures (Stewart 1989, unpubl. FRI contract report) and in exotic forest areas where densities were less than 1-2/km^2 (personal observations).

5. **Stewart Island.** The forests of this 1730-km^2 island are mainly podocarp or shrub-hardwood associations. White-tailed deer are common, red deer are rare, and possums are present throughout. State-funded control began in 1926, and commercial hunting the 1960s and 1970s focussed mainly on the larger-bodied red deer (Nugent 1990b unpubl. FRI contract report FWE 90/20). Total harvests (commercial and recreational) declined from about 3000 in the late 1960s to about 1500 in 1988. Since 1980 commercial harvests have been minimal, and deer densities rose despite continued recreational hunting, with densities in 1986 estimated to be 18 deer/km^2 for the north-western coastal strip, but only 5/km^2 further inland (Lovelock 1987). The herd's reproductive performance suggests it was at about 75% of carrying capacity.

   Deer make little use of the higher altitude forests, subalpine scrub, or alpine associations, and have little effect in these areas. The coastal forests, however, have been much modified (Stewart & Burrows 1989). Although canopy composition has apparently changed little (except for small areas of coastal dieback) seedlings and saplings of sub-canopy hardwoods are generally absent, yet these are abundant on the nearby deer-free Bench Island.

6. **Haurangi.** The 193-km^2 Forest Park has only a small unforested area, with its forests being a variety of beech and hardwood-dominated communities. Red deer, possums, and pigs are present, and numbers of goats and cattle were once high. Some commercial hunting occurred in the 1970s but was prohibited after 1982.

   Over most of the area pellet frequencies averaged 5.3% for the 1980-87 period, with no clear up or down trend, and deer density was estimated at 9 deer/km^2 (Handford 1991 unpubl. DOC report). Deer density was apparently dramatically reduced in part of the area by a possum poisoning operation in 1979, because pellet frequencies there subsequently increased from 0.4% in 1980 to 5.4% in 1987, despite continuous recreational hunting pressure (there was no pre-poison estimate of deer density).

   In the 1950s, much of the understorey was bare. By 1971, some species of low palatability had begun to establish, but none of high palatability, yet most of the latter were abundant within two deer exclosures (Jane & Pracy, 1974). Since then, the recovery of less palatable species has continued, most notably the tree fern (*Cyathea dealbata*), hook grass (*Uncinia* spp.), and the beeches, and these species form a dense understorey in some places, but the highly palatable species remain absent or rare (J.D. Coleman, pers. comm.).

7. **Tararua.** This 1200-km^2 range is 14% unforested, and its forests are mainly beech or kamahi associations. Deer and possums are present and goats and cattle were once common. State-funded hunting began in 1938, with recent emphasis on goats. The first legal helicopter hunts were in the mid-1970s, but commercial helicopter-based hunting did not begin until 1979.

   Pellet frequencies declined from 27% in 1958/59 to about 3% in 1982/83 (Fig. 8b), but the bulk of this reduction occurred before legal aerial hunting began. By 1988/89, pellet frequencies in the Waiohine had doubled from 2% in 1982/83 to 4% (Handford 1989 unpubl. DOC report). Deer use of the grassland was minimal.

   The annual State-funded kills declined from 2568 in 1938/39 to about 1200 in 1961, 300-700 in the mid 1970s, and less than 200 since 1984. In the late 1980s, helicopter operators took an annual harvest of 300-400, and recreational hunters about 1200. At present, deer densities are about 5/km^2.

   By the late 1950s, much of the subalpine scrub belt had been destroyed (Holloway *et al.* 1963), but this was recovering by the mid 1970s (Moore 1976 unpubl. FRI report). Davidson & Kean (1960) noted the disappearance of flowering herbs in grassland, and a general increase in tussocks relative to other species. In the forest deer initially prevented regeneration of beeches, but by 1973/74 only the high-altitude beech forest was being severely affected (Griffith 1976 unpubl. FRI report), and by 1982/83 even that was improving (Brady 1987 unpubl. DOC report). However, most highly palatable species still appeared to be in decline.

8. **Ruahine.** This 1140-km^2 area contains many vegetation types, with about half in beech-dominated associations, much of the remainder in hardwood-dominated associations, and a limited area of grassland (Oaks 1983 unpubl. NZFS report). Deer and possums are present, as are goats. Sheep and cattle once grazed much of the north and west. Pigs are now rare. State-funded hunting began in 1938

and helicopter-based hunting in 1972, with commercial use of helicopters since 1975.

Cunningham (1966, unpubl. FRI report) reported pellet frequencies of 65% for deer, 55% for possums, 10% for sheep and 2.5% for pigs from the Tararau catchment. In the southern Ruahines, deer pellet frequencies in 1969/70 varied between 18% and 43% (James & Beaumont 1971 unpubl. FRI report), had halved by 1975/76, and were down to 2-3% by 1982/83 (Oaks 1983 unpubl. NZFS report; Fig. 10c). Deer use of the grassland was minimal. In the north-east frequencies declined from 17-19% in 1974/75 to 5-6% by 1981 (Jenkins 1981, unpubl. NZFS report).

Nearly 5000 deer were shot in 1938/39 (Elder 1965) and the annual State-funded government kill in the 1950s and 1960s was about 2000 deer. The known kill (government + commercial) was slightly higher than this in the early 1970s, but since 1978 annual commercial harvests have been less than 525 deer. An estimated 1500 deer were taken by ground-based hunters in 1988 (Nugent 1989b, unpubl. FRI contract report), and pellet-group recruitment rate data in Oaks (1983 unpubl. NZFS report) suggest a deer density of 5 deer/km^2.

Animal impacts have been more severe in the Ruahine Range than elsewhere because the original forest contained a high proportion of hardwood tree species favoured by possums, and because deer, possum, and goats all reached high numbers at the same time in the 1950s (Batcheler 1983). By 1978, the canopy had collapsed over some thousands of hectares, and was largely replaced by a short scrub of pepperwood and mahoe interspersed with grasses and ferns. There is no recent information on vegetation condition.

9. **Kaimanawa.** This 765-km^2 Forest Park contains mainly beech forest, but about 16% is unforested. Red deer have been largely replaced by sika, and possums and a few pigs are also present. Some commercial hunting took place in the 1970s, and continued (illegally) through the 1980s, but for most of the 1980s recreational hunting was the main form of deer control.

Pellet frequencies in the 240-km^2 Kaimanawa RHA have apparently increased from 29% in 1979 to 30% in 1985, 37% in 1986, and 35% in 1988 (Brabyn 1988 unpubl. DOC report). Pellet-group recruitment rates suggest deer densities as high as 30 deer/km^2, but 1988 harvest rates and encounter rates suggest deer densities of 12-15 deer/km^2 (C. Speedy, pers. comm.).

Elder (1962) reported 7200 deer were killed in 1938/39, and an average of 1500 deer were killed annually during the late 1940s. In recent years 5000-6000 permits have been issued each year, and returns suggest a ground-based kill of about 2500 deer.

By 1931 Elder (1962) reported red deer had eaten out the understorey, and were threatening the regeneration of the canopy. However "deer numbers fell away", permitting some recovery, although not as much as in the nearby Kaweka Ranges, possibly because sika browsed more heavily than red deer. Possum impacts have been limited, but fire and domestic stock have been important influences in the tussockland to the south.

A 1988 survey (Brabyn 1988 unpubl. DOC report) reports little change in basal area of stems over the preceding decade, but an increase in overstorey stem and sapling density attributable mainly to an increasing number of the least palatable species. There were no significant changes in seedling densities, but highly palatable species remained rare. Beech regeneration appeared adequate to maintain canopy composition, but overall composition was still changing. Speedy (1991 unpubl. DOC report) described prolific regeneration within a 7-year-old exclosure, but a sparse understorey outside.

10. **Urewera.** The 4400-km^2 Urewera land tract is almost completely forested with various combinations of podocarps, beeches, and tawa (*Beilschmiedia tawa*). The area contains mainly red deer with a few rusa, sambar, and sika. Pigs and possums are common, but the goats and cattle once present are now much reduced or absent. Deer control began in 1938, lapsed in 1955, and resumed in 1960. Over 3000 deer were culled annually in the late 1960s, the kill dropping somewhat in the ensuing decade and effectively ceasing in the 1980s. Legal commercial use of helicopters began in the late 1970s, and commercial harvest has averaged about 3000 deer per year since (Beadel 1988).

Pellet group densities equivalent to frequencies of about 40% were recorded in 1969 in the northern half of the area (Wallis & James 1969 unpubl. FRI report). A series of transects regularly assessed between 1969 and 1985 show initial frequencies of 37% declining to 7% by 1980, but then more than doubling over the next 6 years (Fig. 8d). A similar increase in pellet frequency during the early 1980s was recorded in overall surveys of the whole area, with frequencies in 1985-1987 averaging about 18%. Pellet group recruitment rates suggest deer densities of about 12 deer/km^2 (Beadel 1988).

Wallis & James (1969 unpubl. FRI report) stressed the role of possums in the collapse of forests on many seral sites. Jane (1979 unpubl. NZFS report) reported that where deer numbers were low at the time of possum depletion, the resulting clearings revegetated rapidly, but that where deer pellet frequencies remained above 5% (roughly equivalent to 3 deer/km^2) any recovery was unlikely. Allen *et al.* (1984) reported a much greater species richness and stem density inside exclosures, and note that the ability of certain species to regenerate was still being inhibited despite a substantial reduction in deer density. These included some canopy species, though these were less affected than most of the sub-canopy hardwoods.