A REVIEW OF OPTIONS TO MANAGE

WHITE-TAILED DEER (*Odocoileus virginianus*)

ON STEWART ISLAND

INVESTIGATION NO : S7010/533
CORPORATE OBJECTIVE NO: 2.15

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EXECUTIVE SUMMARY (FINAL)

INVESTIGATION NO: S7010/533
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INVESTIGATION TITLE:	A review of options to manage white-tailed deer *Odocoileus virginianus* on Stewart Island.
STUDY VENUE:	Southland
INVESTIGATION LEADER:	G. Nugent
INVESTIGATION STATUS:	Completed
CLIENT:	Department of Conservation

INVESTIGATION SUMMARY:

The legal status, history, biology, and management of white-tailed deer (*Odocoileus virginianus*) on Stewart Island were reviewed by the Forest Animal Ecology section, Forest Research Institute, Christchurch. Management options are evaluated for the Department of Conservation.

OBJECTIVES:

1. To describe the legal status, history, and management of white-tailed deer on Stewart Island.
2. To review the herd's biology, impact, and value in relation to the range of options for its management.

RESULTS:

1. The Department of Conservation has a legal obligation to attempt to eradicate white-tailed deer from Reserves (60% of Stewart Island). Management goals are not specified in law for Stewardship land (33%) or private land (7%).
2. White-tailed deer remain at high densities in some coastal forest despite State-funded control from 1927 to 1958, commercial hunting during the 1970s and early 1980s, and continued recreational hunting. About 1500 are now harvested annually, (two-thirds from the DOC estate), and population size is about 10 000 deer.
3. White-tailed deer have a high reproductive potential, juvenile dispersal is extensive, and these deer are hard to hunt, all of which make the species difficult to control.
4. The herd has little realizable commercial value at present, but its recreational value is c. $830 000 p.a.
5. White-tailed deer have modified the understorey composition of the coastal forests, but the forest canopy has been less affected. However, many canopy species are not regenerating adequately, and canopy composition may change toward less palatable species (which will reduce deer carrying capacity). Deer inhibit reafforestation of areas of coastal dieback.
6. Of the suitable control techniques (ground-based hunting, airborne hunting, foliage bait poisoning, and fencing), foliage bait poisoning is probably the most cost-effective, but is likely to meet public opposition.

7. There are three management options: eradication, State-funded control (management to protect the vegetation), or management for hunting or revenue. Eradication may be technically possible, but would be costly (>$3 million) and would be opposed by hunters and private landowners. State-funded control appears worthwhile only if near-zero densities can be sustained in perpetuity to achieve a least-modified flora, or at least long enough to allow palatable species to grow through the browse tier to maintain a diverse canopy. Harvesting by private hunters alone is unlikely to yield major conservation benefits whether management is for minimum deer density (control), maximum sustained yield, or maximum revenue.

CONCLUSIONS AND RECOMMENDATIONS:

1. The Department must subjectively decide whether the impact of white-tailed deer on Stewart Island vegetation outweighs the herd's recreational value, and whether expenditure on control is warranted. Techniques for more objectively quantifying conservation and other values should be investigated.
2. To reduce deer impact, the choice is between eradication or control. Sustained control could cost less annually than the hypothetical return that would be obtained by investing the sum needed for an eradication attempt, and is more likely to be politically acceptable. Temporary control seems to offer a compromise between vegetation protection and conservation of the hunting resource.
3. If eradication is chosen, but delayed, no interim control should be done.
4. If DOC decides not to kill deer itself, it must choose between minimising net hunting administration costs and generating revenue from the herd.

2. INTRODUCTION

White-tailed deer (*Odocoileus virginianus borealis*) have drastically modified the understorey composition and regeneration patterns of the forest on Stewart Island (Veblen & Stewart 1980; Stewart & Burrows 1989). The Department of Conservation (DOC), which administers 93% of the Island, aims to protect the indigenous biota (Holloway 1989). However, the population also provides the main opportunity to hunt white-tailed deer in New Zealand, and has become one of our most important recreational hunting resources (Holden 1987; G. Nugent 1989, unpubl. FRI contract report). As hunters' aspirations for the herd conflict with conservation objectives, the management of the species will continue to be controversial. Before deciding how to manage white-tailed deer, DOC commissioned this review from the Forest Animal Ecology section, Forest Research Institute, Christchurch.

Information for the review was obtained from published material, unpublished reports, departmental files, and discussions with individuals involved with white-tailed deer management or hunting, or in assessing their impact. Unpublished reports are listed in Appendix 14.1. For this review "control" is defined as management intended to minimise the impact of deer on the vegetation, and "management for hunting" means management for some non-vegetation value such as total harvest, hunting success, or revenue.

3. OBJECTIVES

- To describe the legal status, history, and management of white-tailed deer on Stewart Island.
- To review the herd's biology, impact, and value in relation to the range of options for its management.

4. LEGAL STATUS

The Wild Animal Control Act provides DOC with the power to control (and where necessary eradicate) white-tailed deer as dictated by "proper land use". For the 160 700 ha of Stewart Island administered by DOC (93% of the Island; Fig. 1) proper land use is determined by the Conservation Act and the Reserves Act. Most of the DOC land consists either of Nature or Scenic Reserve (49%, and 11% of Stewart Island, respectively; Fig. 1). Under the Reserves Act these reserves must be managed to ensure that the indigenous flora and fauna are, as far as possible, preserved, and exotic flora and fauna are exterminated, except where the Minister determines otherwise. Introduced deer in these Reserves will therefore generally be controlled at "the lowest level that can be practically achieved and maintained given the management tools and financial resources available" (Holloway 1989). The remaining DOC land consists of Stewardship land (33% of Stewart Island; Fig. 1). Land use is determined solely by the Conservation Act, which stresses the protection of natural, though not specifically indigenous, resources. Some hunters have argued that deer are a natural resource to be conserved (Hodder 1990), but departmental policy has been to apply the policy of 'extermination as far as possible' to most of its estate, including Stewardship land (Holloway 1989). Outside the DOC estate, the ability of the Department to manage white-tailed deer is not clear. Although DOC has the power to control and even eradicate deer on private and other land (under the Wild Animal Control Act) it must do so within the dictates of "proper land use", criteria which have not been clearly specified in law for non-DOC land. However, it can be argued that the Wild Animal Control Act permits DOC to control and even eradicate animals on adjoining lands where the animals, by providing a source for reinfestation, threaten conservation values on the DOC estate.

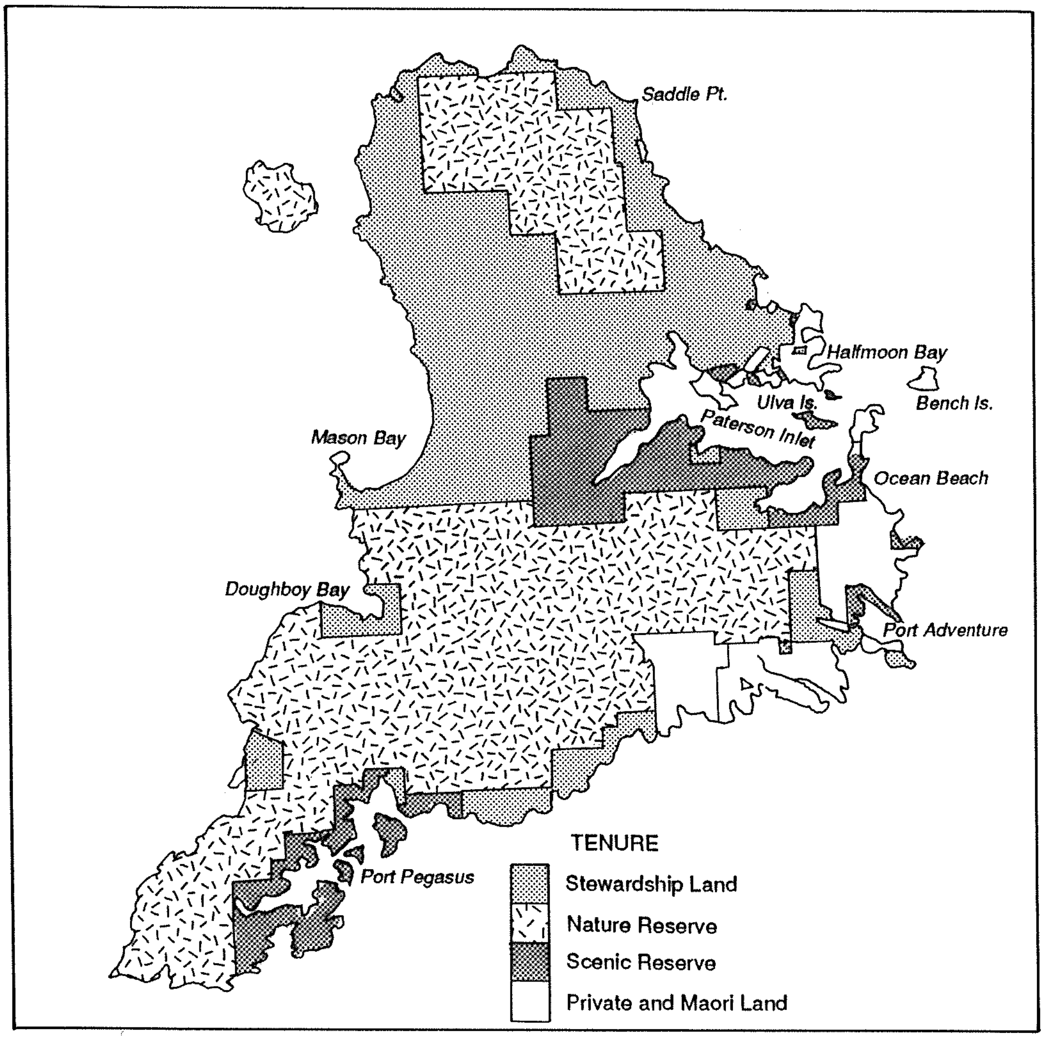

Fig. 1. Stewart Island, showing land tenures.

5. HISTORY OF INTRODUCTION AND MANAGEMENT

5.1 Introduction of deer and other herbivores

In 1905, nine "Virginian" deer (7 does, 2 bucks) were liberated at Port Pegasus where they successfully acclimatised (McKinnon & Coughlan 1960). Hunting was first permitted in 1919 when two licences were issued for white-tailed deer. Licensed hunting continued till 1926 when all protection was removed from white-tailed deer (Harris 1981).

Within 20 years white-tailed deer had spread over the whole island (Harris 1981). It is likely that food was initially plentiful, and the herd increased rapidly to a peak and then declined.

Red deer (*Cervus elaphus scoticus*) were liberated on Stewart Island in the Paterson Inlet area in 1901 and 1902 (Donne 1924). They were also first hunted in 1919, when the animals were reported to be in particularly good condition and in reasonable numbers in the Mason Bay area (Southland Times, 2 May 1919). Red deer comprised most of the deer killed during initial culling operations, and it was noted in 1938 that they had not recovered from the "large" cull in 1931 (McKinnon & Coughlan 1960). The red deer herd has persisted in areas not favoured by white-tailed deer, but densities have remained very low since commercial harvesting in the 1970s (M.J. Slater 1982, unpubl. NZFS report).

Possums (*Trichosurus vulpecula*) were liberated on the Island in 1890, and were common by 1922 (Thomson 1922). The species remains common today.

Pigs (*Sus scrofa*) were once present (Wodzicki 1950) but are now absent. Feral cattle (*Bos taurus*) and sheep (*Ovis ovis*) have now been eliminated, apart from a few sheep at Mason Bay.

5.2 State-funded hunting

Concern about the damage caused by deer on the Island prompted the Government to offer a bounty for each deer killed in 1927, and to employ hunters to reduce the deer population in 1927-28, 1928-29, and 1930-31 (Harris 1981). State-funded hunters were also employed continuously from 1937-38 till 1952-53 (Appendix 14.2), and killed an average of 425 deer per year (range 151-971), two-thirds of which were probably red deer (the species composition of the kill was only reported for 4 of the 15 years). These operations would have had little impact on the white-tailed deer population, unless the unrecorded harvest by private hunters was substantial. A bounty scheme between 1953 and 1958 accounted for only 1797 deer, of which 1006 were white-tailed deer (Appendix 14.2).

Since 1958 government employees involved in other work have routinely shot small numbers of deer. In other State-funded attempts at control, about 400 deer were killed during a foliage-bait poisoning trial in 1981 (G. Nugent 1990, unpubl. FRI contract report FWE 90/4), the New Zealand Forest Service killed about 200 during airborne hunting trials in the 1980s (Appendix 14.3), and some deer have been shot by DOC staff since 1987 (K. Timpson, pers. comm.). Some deer were also killed during aerial 1080 poison operations against possums on the north coast between 1970 and 1976 (unpubl. NZFS file note).

5.3 Private hunting

5.3.1 Ground-based

Data on private hunting are fragmentary (Appendix 14.2). In 1960, private hunters reported 686 deer kills (number of permits, effort, and return rate unknown; unpubl. NZFS file note), indicating a high level of recreational interest at that time.

A commercial freezer for carcasses was operated at Halfmoon Bay from early 1967, and processed about 1500-2000 carcasses per year in the first years of operation (M. Gooms, depot operator, pers. comm.).

For the 1970-71 financial years, 475 permits were issued, of which 235 were returned (unpubl. NZFS file note). These reported 892 deer kills which, by extrapolation, indicates a permitted kill of about 1800 deer. In addition, many deer were taken without a permit (M. Gooms, B. Crookshanks, pers. comm.). Some deer were undoubtedly kept for private consumption, or shot but not recovered. This combined information suggests that about 3000 deer were shot annually in the late 1960s.

The freezer at Halfmoon Bay continued to operate up till about 1978 (B. Crookshanks, depot operator, pers. comm.). An additional freezer was operated at Mason Bay between 1970 and 1976, 30-200 carcasses being flown out annually by plane (T. Te Aika, pers. comm.).

During the 1970s, interest in the recreational hunting of white-tailed deer appeared to increase steadily, judging by the number of permits issued annually (Appendix 14.2; from 1981 a permit was issued to each hunter, not to each party as previously). Since 1980 about 1000 hunters have been issued permits annually for State-administered land (Appendix 14.2). In addition about 110 parties (with an average of 6-7 hunters in each) hunt land administered by the Rakiura Maori Incorporation (H. Ashwell, pers. comm.). Nationwide, an estimated 1500 white-tailed deer were taken by about 2000 ground-based hunters in 1988 (G. Nugent 1989, unpubl. FRI contract report).

5.3.2 Airborne hunting

Commercial airborne hunting began in 1967, but most hunting took place during the 1970s, with a peak about 1974-75 (T. Te Aika, B. Crookshanks, pers. comm.). Airborne hunting was mainly restricted to the more open northern and western parts of the Island, where the deer were most vulnerable to helicopter-based hunters (Appendix 14.3). The large-bodied red deer were the primary target, at least initially.

By the late 1970s, red deer had been reduced to very low densities, and incomplete returns indicate that some hundreds (rather than thousands) of mainly white-tailed deer were taken annually during the late 1970s and early 1980s (Appendix 14.2). The commercial harvest is now negligible.

5.3.3 Live capture

Some white-tailed deer were captured alive from helicopters, in nets, or in traps during the late 1970s and early 1980s (B. Crookshanks, R. Dennis, T. Te Aika, pers. comm.), but the market for live white-tailed deer was limited by their inability to adapt to pastoral farming.

5.4 Recreational Hunting Area proposal

Establishment of a Recreational Hunting Area for white-tailed deer in the State Forests north and west of the Rakeahua river was formally proposed in 1982 (M.J. Cuddihy & M.J. Slater 1982, unpubl. NZFS report). Difficulties arising from the perceived conflict between Recreational Hunting Area status and deer management objectives on adjacent Reserves were not resolved, and the proposal was abandoned after DOC was established.

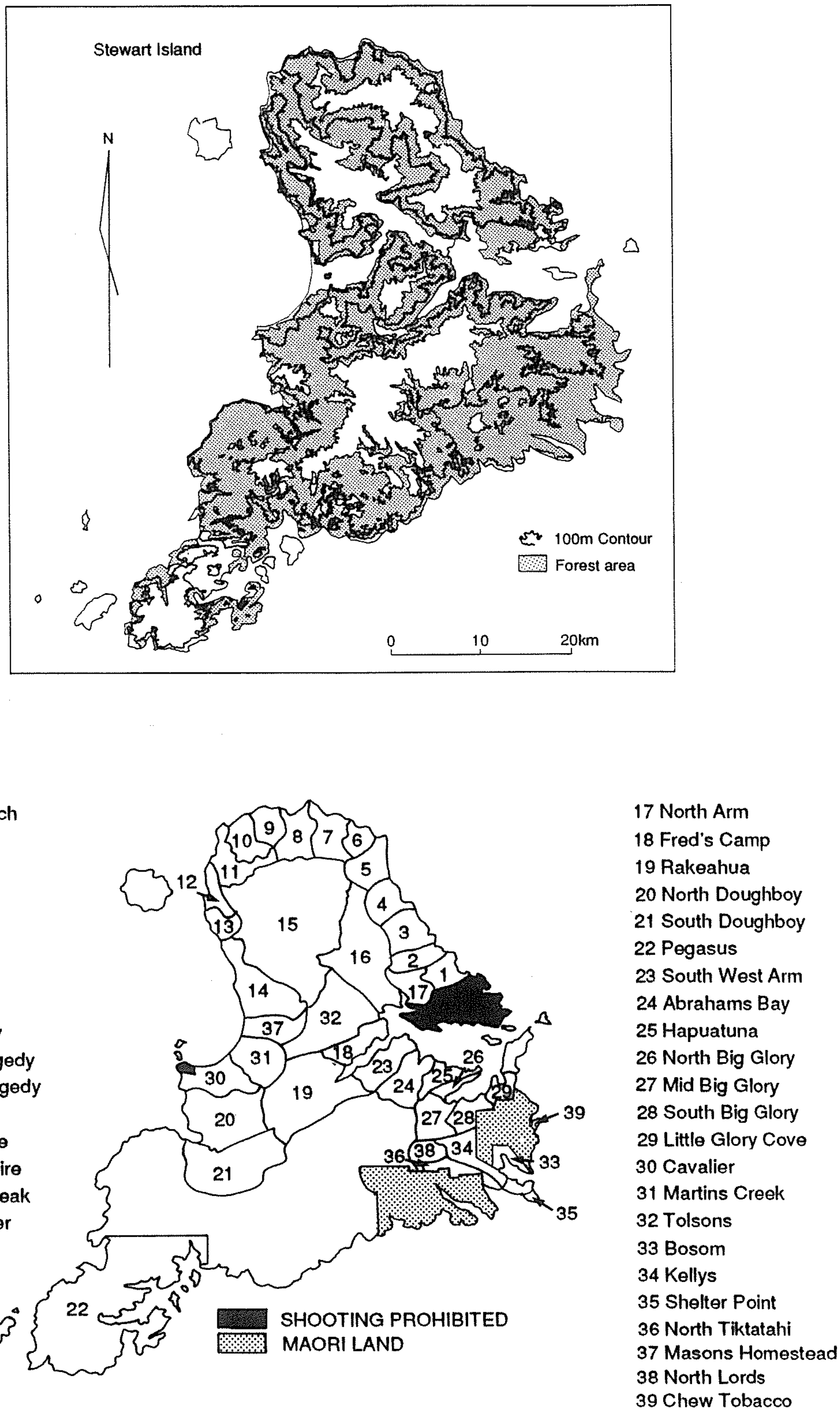

Fig. 2. Stewart Island, showing (a) the extent of forest and 100 m a.s.l. contour, and (b) the hunting blocks on DOC land.

5.5 Current recreational hunting management and practices

At present, recreational hunting on both DOC and Maori land is administered under an exclusive block system, with one party of hunters having exclusive hunting rights to one of 39 DOC (Fig. 2) or 16 private blocks for up to 14 days. For DOC land, blocks may be booked up to 12 months in advance, but must be confirmed 3 months before the hunting date. Permits are posted to hunters, who are required to sign and return them. Administration of the hunting system has been streamlined recently, but is conservatively estimated to still cost DOC $8000 annually.

In the early 1980s most hunters travelled to their block by boat (84%), either from Oban, or direct from Bluff (Burton & Howden 1982). In recent years, many hunters have flown to their blocks by helicopter, which costs $200-300 per hunter (R. Mills, pers. comm.).

Hunters stay for 1-2 weeks, mostly seeking male trophies. Typically, hunters at first shoot as many as possible of the deer they see (for meat), but later no other females are shot until near the end of the trip as the meat cannot be stored. Some hunters do shoot all the animals they can.

The blocks vary in popularity, depending on ease of access and perceived number of animals (Appendix 14.4). Although most hunters come from Southland or Otago, significant numbers come from as far away as Auckland and even Australia (Appendix 14.5).

Hunters are requested to report the number of animals killed and the number of days spent hunting. Those not submitting a return are sent a reminder, resulting in a high return rate (>90% in 1988 and 1989).

6. BIOLOGY AND HERD STATUS

6.1 Biology

White-tailed deer are a medium-sized species native to North and Central America. They have a grey-brown winter coat on back and sides (light-brown in summer), with white markings under the chin, on the rump patch, and beneath the characteristic long tail. Newborn fawns have white spots on back and sides.

The species varies greatly in size, partly as a result of genetic differences and partly because of habitat quality (Teer *et al.* 1965). Whole weights of adult deer (>36 months) killed in a poison trial on the east coast of Stewart Island in 1981 were 41 kg for females, and 58 kg for males (FRI unpubl. data). A small sample of deer taken from the far south of the Island in early 1987 were 15% lighter than this (Davidson & Challies, in press). In comparison, Banasiak (1961; cited in Teer *et al.* 1965) reported an average field dressed weight of more than 76 kg for adult males from New Hampshire, the area from which the Stewart Island deer originate. The small size of Stewart Island white-tailed deer indicates that the Island is currently not good deer habitat.

Breeding patterns of white-tailed deer in America can be either closely synchronised seasonally or nearly completely asynchronous, depending on latitude. On Stewart Island (47°S), the rut extends from late April to the end of May, and most fawns are born in December. Males do not vocalise during the rut, and do not maintain a harem. Instead they search out individual oestrus females.

White-tailed deer have a greater reproductive potential than any other deer species present in New Zealand. In America well-nourished fawns can reach sexual maturity at 6-7 months of age, and up to 74% of females may breed in their first year (Teer *et al.* 1965). Well-nourished older females often produce twins or even triplets. In the George Reserve in Michigan, USA, an initial herd of 10 deer increased to 212 animals within 6 years (McCullough 1984), more than doubling in each of the first 2 years, and maintaining an average finite rate of increase of 1.66 per annum over the 6 years. However, the reproductive rate decreased almost linearly as the population increased in size toward carrying capacity (Fig. 3a).

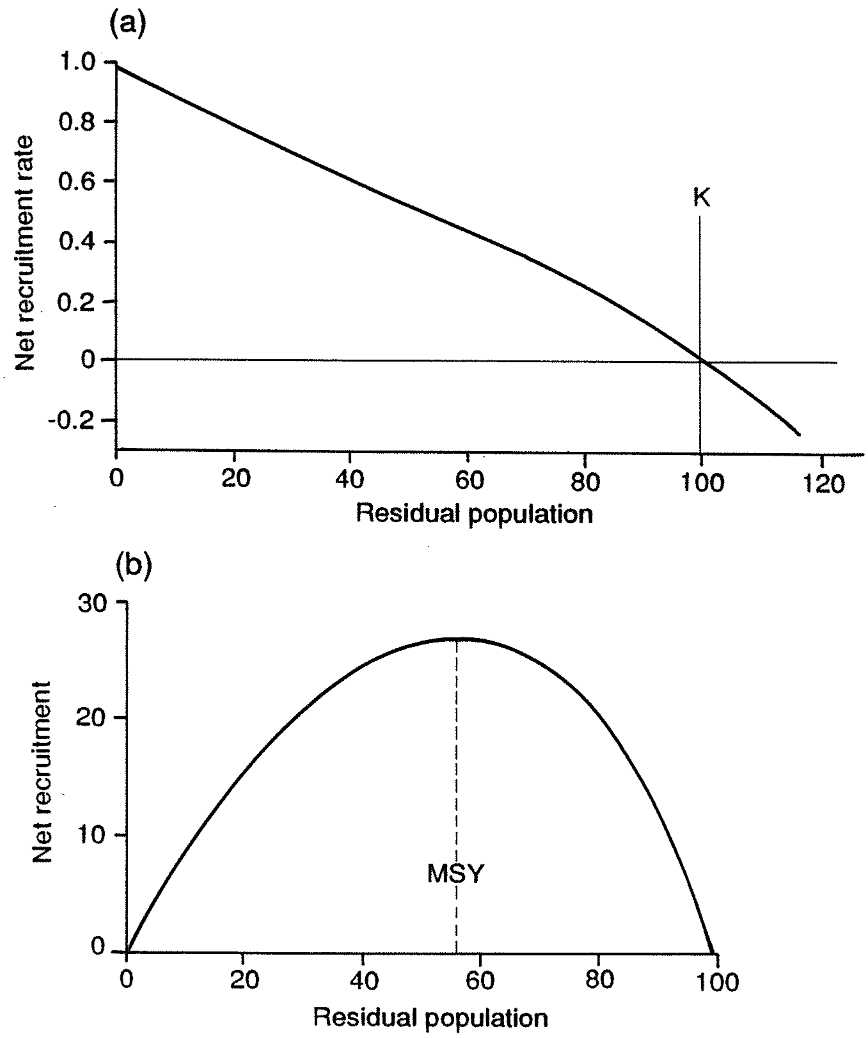

Fig. 3. The relationship between recruitment rate, net recruitment (yield), and nearness to carrying capacity density (K). msy = maximum sustained yield. The x axis may be read as % of carrying capacity: (a) shows the size of the fawn crop in relation to population size. (b) shows the fawn crop as a percentage of the carrying capacity density. Reproduced from McCullough (1984).

On Stewart Island white-tailed deer do not achieve their reproductive potential, particularly in the far south. Of nine adult female deer shot there in winter 1985 only four were pregnant, and only one contained twins, the low pregnancy rate reflecting the poor condition of the animals (Davidson & Challies, in press). Only seven of 11 females shot there in summer 1987 were lactating (Appendix 14.3). About 82% of 38 adult females killed during the 1981 poison trial were lactating (G. Nugent 1990, unpubl. FRI contract report FWE 90/4).

American studies suggest young white-tailed deer probably disperse further from their natal range than those of other deer species present in New Zealand (Dusek *et al.* 1989). Both male and female young disperse, and dispersal distances greater than 100 km have been recorded.

Following their release at Port Pegasus, deer were reported near the island's northern tip as early as 1926, a dispersal rate of 2.9 km/yr (Harris 1981). After the 1981 poisoning trial there was a rapid influx of deer to the poisoned areas which, given the subsequent rapid increase, must have included many females (G. Nugent 1990, unpubl. FRI contract report FWE 90/4).

White-tailed deer appear at ease in the water, and have been frequently reported swimming to islands in Paterson Inlet and even up to 4 km from the shore (Harris 1981).

The short curved antlers of white-tail deer are attractive as trophies. Antler size on Stewart Island is generally smaller than in America, probably a consequence of the poor environment. The genetic potential of the herd is illustrated by the large trophy (Douglas score 216) taken in 1988 from the Wakatipu herd (which has the same origins as the Stewart Island population). The largest recorded trophy from Stewart Island was taken in 1974 (Douglas score 179.25; Holden 1987).

6.2 Distribution and density

There have been five major surveys of deer density and distribution on Stewart Island, the north-west being surveyed in 1975-76 (M.J. Williamson 1976, unpubl. NZFS report), 1980-81 (M.J. Slater 1982, unpubl. NZFS report), and 1985-86 (Lovelock 1987), and the south-east in late 1976 (A.D. Ross 1977, unpubl. NZFS report) and late 1979 (M.J. Cuddihy 1983, unpubl. NZFS report). In addition, deer densities in the Ocean Beach-Port Adventure area were monitored between 1980 and 1986 to assess the impact of the 1981 poison trial (G. Nugent 1990, unpubl. FRI contract report FWE 90/4).

6.2.1 North-west Stewart Island

The 1975-76 and 1980-81 surveys distinguished between red and white-tailed deer faecal pellets, whereas the 1985-86 survey did not.

In 1976, white-tailed deer were concentrated around the north and western coasts, with significantly lower densities in the inland catchments (Freshwater and Rakeahua). Within coastal catchments white-tailed deer density decreased markedly away from the coast. Red deer were relatively scarce, with the highest density in the Freshwater catchment.

By 1981, deer pellet density had decreased by about 68% (66% for white-tailed deer and 77% for red deer). The percentage decrease was greatest on the west coast, reflecting the greater vulnerability of deer to helicopter-based hunters in that area.

By 1986, deer pellet density had climbed to about 67% of the 1976 level for the whole of the northwest, and 74% along the north coast. Although differences in the disappearance rate of faecal pellets between years might have affected the estimates (Lovelock 1987), this increase is supported by an increase in hunter success rates during this period (Fig. 4a,b,c).

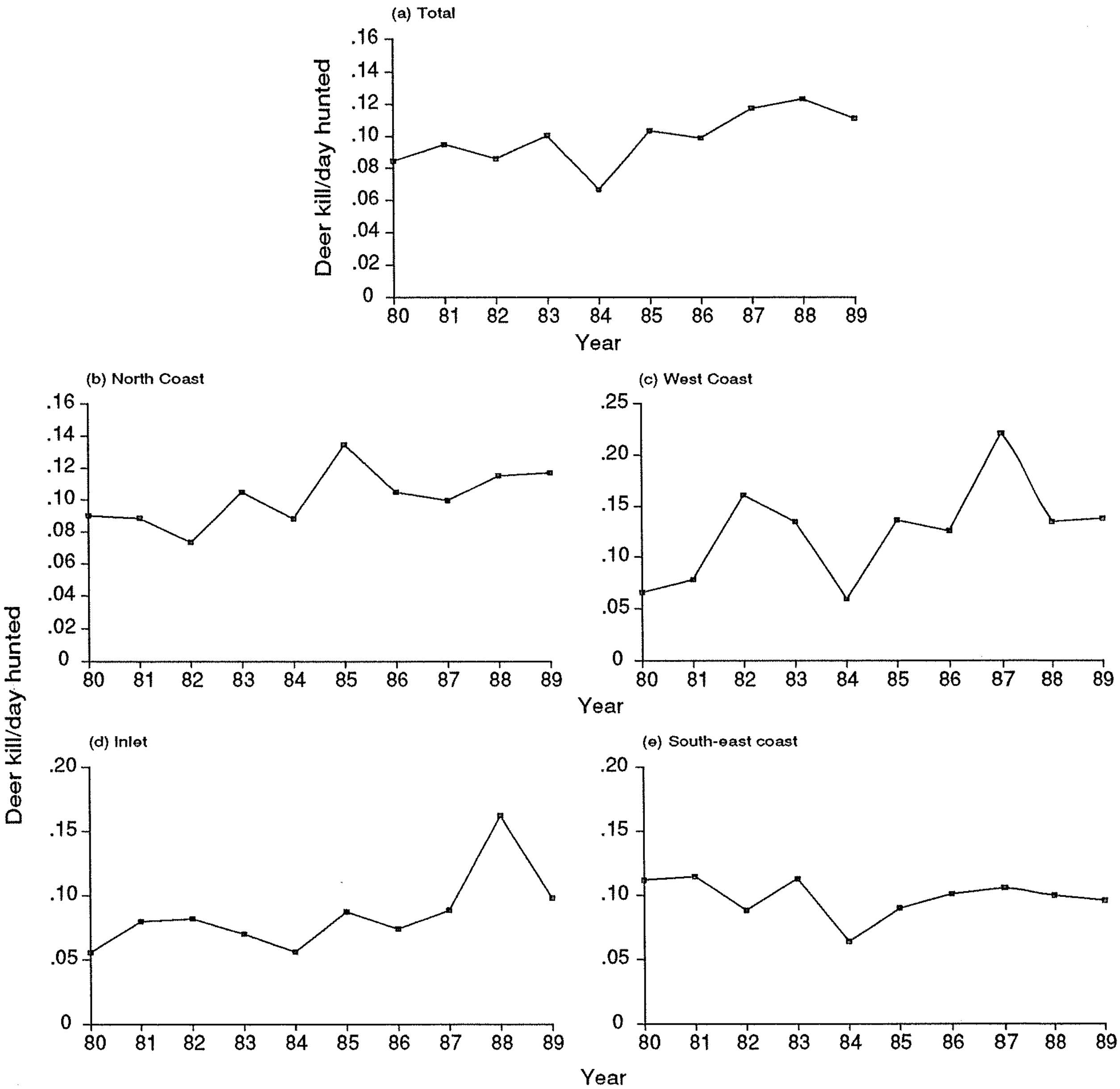

Fig. 4. Patterns of hunter success 1980-1988 for State-administered hunting blocks. (a) all Stewart Island, (b-e) north coast, west coast, Paterson Inlet, and south-east coast respectively (see Appendix 14.4 for the blocks in each of these sub-areas).

These three surveys suggest that airborne hunting in the late 1970s had a significant impact on white-tailed and red deer populations, but once airborne hunting activity declined, recreational hunting alone was unable to prevent a population increase.

In 1986, average deer density in the coastal strip (0-800 m from the sea) were, on average, 3.4 times that in the forests further inland (18.2 and 5.4 deer/km^2, respectively; Lovelock 1987). The deer population was estimated at about 5600 ± 1300 animals, of which about 4500 were thought to be white-tailed deer. Although the inland area had a much lower deer density, it comprised 84% of the surveyed area and so contained 61% of the deer population.

6.2.2 South-east Stewart Island

The 1976 survey recorded white-tailed deer pellet frequencies 4 times higher than those for north-west Stewart Island. However this at least partly reflected a deliberate sampling bias toward the coastal areas where deer densities were highest.

By late 1979, pellet frequencies had declined by 18%, much smaller than the 67% recorded over 5 years in the northwest. Airborne hunting clearly had little impact in this area, reflecting the lack of open country.

Generally, deer density was highest in the northernmost part of the region and declined in the south, and populations were again highest near the coast, particularly in the south. The coastal concentration was less marked near the Heron River where suitable forest habitat extends much further inland.

The FRI poison trial in early 1981 reduced deer densities in the Ocean Beach-Port Adventure area to low levels for 1-2 years, but by 1985 densities had increased to near pre-poison levels. Densities as high as 45 deer/km^2 were recorded in some of the most favoured coastal areas (New Zealand Forest Service 1984).

Hunting success rates in the blocks adjacent to Paterson Inlet were generally low, but increased gradually during the 1980s (Fig. 4d; the high value for 1988 is an artefact of the incorporation of previously "underhunted" areas). In contrast, the success rate for the south-east coast in the early 1980s was higher than for any other part of the Island. However, this success rate appeared to decline rather than increase (Fig. 4e), suggesting deer density there may have declined slightly in recent years, which is consistent with hunter reports (R. Thomas, K. Schashing, H. Ashwell pers. comm.).

6.2.3 The far south

The far south and south-west of Stewart Island has never been systematically surveyed. Much of the interior is covered by low damp shrubland that is almost completely devoid of deer (or possums). The sheltered bays of Port Pegasus contain the highest number of deer, but they are confined to the small pockets of tall forest (Appendix 14.3, A.D. Ross 1977, unpubl. NZFS report).

6.3 Population size and carrying capacity

Population size has not been estimated for the south-east or far south of Stewart Island. However, more than half the total 1986 harvest (about 40% of the total harvest from DOC land plus c. 400 deer taken from Maori land) was taken there, which indicates this area probably had a slightly larger population than the 4500 estimated to inhabit the north-west by Lovelock (1987). This suggests a total population of about 10 000 white-tailed deer.

A crude indication of carrying capacity can be obtained by combining this guess at present population size with data on the herd's reproductive state. Of the 243 deer carcasses found after the 1981 poison trial, 48 were fawns (G. Nugent 1990, unpubl. FRI contract report FWE 90/4), a recruitment rate of 25%.

Assuming that the relationship between recruitment rate and carrying capacity on Stewart Island is similar to that found in an American study (the George Reserve; Fig. 3a), this recruitment rate suggests the population was at about 75-80% of the carrying capacity. Using my guess at population size, this suggests the carrying capacity is about 12 500 white-tailed deer. From the yield curve for George Reserve deer (Fig. 3b) a population in an area with a carrying capacity of 12 500 would have a maximum sustained yield of 3200 deer annually, and this would be produced when the population was held at about 7000 animals (56% of carrying capacity). Although only a guess, this estimate of MSY is substantially larger than the estimated annual harvest (1500), even allowing for a further 200-300 mortally wounded animals not recovered by hunters. To reduce the population below MSY size would therefore seem to require a substantial increase in annual harvest, at least in the short-term.

Longer-term, however, Nugent & Challies (1988) predicted the carrying capacity will decline because deer are preventing adequate re-establishment of some of their most important food species. If so, the MSY density will also decline, as will the annual harvest required to reduce to densities below this.

6.4 Deer habitat

The forests of Stewart Island were first described in detail by Cockayne (1906). Later writers recognised 12 forest associations (4 scrub, 7 podocarp, and 1 shrub-hardwood association), 2 alpine associations, and a coastal waterfern (*Histiopteris incisa*) association arising from die-back of coastal forests (Evan & Fine 1976; M.J. Williamson 1976 and M.J. Slater & M.J.Cuddihy 1982 (unpubl. NZFS reports)). About 28 of the 580 vascular species native to Stewart Island are endemic (Wilson 1982).

Deer make little use of the higher altitude forests, subalpine shrub, or alpine associations, and the vegetation on many of these typically less fertile sites is essentially unmodified (H. Wilson pers. comm.).

In the lowland areas, podocarp-hardwood forest dominates. Inland from Oban, a line joining North Arm and Port William forms the western edge of the main area (2000 ha) of cutover forest, in which podocarps and many other species are regenerating profusely (M.J. Cuddihy 1983, unpubl. NZFS report). Manuka (*Leptospermum ericoides*) scrub occupies land that was cleared by fire, mainly in the Freshwater valley, and in some areas along the south coast.

Around Island Hill an area of swamp is separated from Mason Bay by a line of sand dunes up to 120 m high. Until 1986 this area was a sheep-grazing run, and deer in this area were partially protected but the sheep have since been removed, and the deer have been substantially reduced (K. Timpson, pers. comm.).

White-tailed deer concentrate in the coastal forests, which have a mixed podocarp-hardwood canopy consisting mainly of rimu (*Dacrydium cupressinum*) and miro (*Prumnopitys ferrugineus*), which are often emergent, southern rata (*Metrosideros umbellata*), and kamahi (*Weinmannia racemosa*) (Wilson 1982). The extensive subcanopy includes hardwood trees such as broadleaf (*Griselinia littoralis*), *Pseudopanax simplex, P. crassifolius*, marbleleaf (*Carpodetus serratus*), and *Coprosma lucida*, and the tree-fern (*Dicksonia squarrosa*). These sometimes form the canopy on wet sites where the liane supplejack (*Ripogonum scandens*) is also common. The ground and shrub tiers are sparse, with few young hardwood trees. The only unforested coastal areas are small patches of dune and swamp vegetation, and places where forest dieback has occurred. In dieback areas the invading species are usually waterfern and sedges such as *Carex solandri.*

On the south coast tall forest is found only in pockets surrounded by sub-alpine scrub or swamps (some fire-induced).

6.5 Feeding and diet

White-tailed deer are "concentrate selectors", and have a poor ability to digest fibre (Hofmann 1985). They feed more selectively and require diet higher in energy than red or fallow deer (*Dama dama*), which Hofmann classes as "grass/roughage feeders". This need for a high-energy diet probably explains the failure of attempts to pastorally farm white-tailed deer.

On Stewart Island white-tailed deer have clear food preferences, particularly favouring the subcanopy hardwood trees, and they tend to avoid most shrubs, ferns, and podocarps (Nugent & Challies 1988). On the northern and eastern coasts, woody plants comprise 85.1% (dry weight) of annual diet, with broadleaf (34.6%) and supplejack (18.6%) the two most important food species (Nugent & Challies 1988). In the Port Pegasus area the highly preferred supplejack is absent from the diet, and the deer there eat more of the less preferred shrub, fern and grass species (FRI, unpubl. data). This apparently poorer diet is consistent with the smaller size of deer in that area (section 6.1).

The most important finding of these diet studies was that deer were relying on litterfall (mainly broadleaf leaves and supplejack fruit). The use of supplejack fruit parallels the use of acorns and other fruit by deer in American forests, and is consistent with concentrate feeding. On Stewart Island edible litterfall is probably scarcest in summer, the time of greatest metabolic demand for deer. The apparent mismatch between food supply and deer requirements may explain the small size and low reproductive rates of white-tailed deer on the Island.

7. IMPACT AND VALUE

7.1 Conservation values

White-tailed deer are seen to have a negative impact on conservation values in New Zealand because they alter the structure and regeneration patterns of the indigenous vegetation, and presumably also adversely affect the indigenous fauna.

7.1.1 Impact on the vegetation

The changes in Stewart Island vegetation that followed colonisation by deer have been described qualitatively by Traill (1965). Deer initially focused on sub-canopy hardwood trees such as *Coprosma lucida* and *Pseudopanax colensoi*, and the fern *Asplenium bulbiferum*. As deer numbers increased, the understorey became eaten out, particularly along gentle ridge tops within the forest. Deer also stripped bark from the above tree species (and *Schefflera digitata*). *Coprosma foetidissma* apparently survived longer, and broadleaf did not appear as palatable as these species. This account documents the demise of the most preferred foods - by the time of more quantitative studies in the 1970s some of these species had all but disappeared.

The impact of deer on the vegetation is best illustrated by two studies comparing the vegetation of deer-free Bench Island (6 km north-east of Stewart Island; Fig. 1) with the forest on the south-east coast (Veblen & Stewart 1980; Stewart & Burrows 1989). Canopy composition on Stewart Island had changed little 60 years after deer colonisation, but tall seedlings and saplings of the preferred sub-canopy hardwoods were almost completely absent. In contrast, such seedlings and saplings were abundant on Bench Island. When deer were excluded from areas of coastal forest on Stewart Island, the number of preferred species in the browse tier increased rapidly (Stewart & Burrows 1989), indicating that the coastal forest retains the potential to recover.

Although small seedlings (<15 cm) of the preferred hardwood food trees are still common (Stewart & Burrows 1989), they are rapidly removed by deer as they grow into the browse tier. Although these seedlings contribute little substance to the present diet of deer, they are generally preferred to the staple food, litterfall, so that deer are likely to continue to impede their widespread establishment unless deer densities are reduced to near zero (Nugent 1990). G.H. Stewart & L.E. Burrows (1988, unpubl. FRI contract report) also concluded that "Numbers of white-tailed deer need to be drastically reduced if shrub hardwoods are to be retained as a component of the forest".

It is the presence or absence of shrub-hardwood tree species that has the greatest impact on the visual appearance of the forest and its ability to support birdlife (and deer). Therefore, the threshold deer density below which the sub-canopy trees regenerate freely provides one clear goal for control. Above this threshold density regeneration of subcanopy trees would be restricted to inaccessible or protected sites (Appendix 14.5), and only the abundance of less preferred browse tier species (shrubs, ferns, and grasses) would tend to vary in response to varying deer density.

Studies conducted in the early 1980s suggest that the dieback of coastal forest, although linked to periodic climatic events, is aggravated by introduced mammals. Possums in particular are thought to open up the canopy of gully head associations comprised mainly of *Fuschia excorticata*, predisposing them to dieback (J.D. Coleman & C.J. Pekelharing 1989, unpubl. FRI contract report). Deer then prevent the reafforestation of these areas, by removing woody seedlings. Some recovery of woody species (including palatable species) can occur in the tangle of debris on the margins of dieback areas despite deer being present (G.H. Stewart & L.E. Burrows 1988, unpubl. FRI contract report; Appendix 14.6). On Bench Island areas of dieback are freely and rapidly recolonised by woody species.

After the commercial reduction in deer densities in the 1970s, the abundance of some less preferred species such as *Coprosma foetidissima* increased (M.J. Slater 1983 and M.J. Cuddihy 1983, unpubl. NZFS reports).

Most research has focused on the coastal forest, where deer impact is greatest. Away from the coast the continued uncontrolled presence of deer is unlikely to result in deforestation, as these areas contain relatively few deer-preferred species, and densities of deer are low. The prolific podocarp and kamahi regeneration in many of the previously logged areas (Wilson 1982; M.J. Slater 1983 and M.J. Cuddihy 1983, unpubl. NZFS reports) suggests that deer have a lesser impact in much of this inland podocarp-hardwood forest.

Four plant species found on Stewart Island (*Euphorbia glauca, Gunnera hamiltonii, Stilbocarpa lyalli*, and *Lepidum oleracum*) are listed as threatened species (Wilson & Given 1989). All four are herbaceous, and the first two are mainly dune species and therefore probably readily accessible to deer. I have no idea of the deer density required to protect these species.

It therefore appears likely that the impact of white-tailed deer on the vegetation will be localised, but they will continue to have a major effect on the composition of coastal forest, particularly those associations with a high component of sub-canopy hardwoods. Near the coast deer may contribute to further dieback, but the area involved will probably be small. Large-scale deforestation by deer appears unlikely and it is possible that some dieback areas may be gradually recolonised by mostly unpalatable woody species, with a few palatable species on sites inaccessible to deer.

7.1.2 Impact on indigenous fauna

The impact of deer on the indigenous fauna has not been investigated. What little is known about the invertebrate fauna indicates a high endemicity in the coastal and alpine zones (Purey-Cust & McClymont 1978). It is likely that the changes in the understorey have affected the composition of this fauna, which in turn may have affected some bird species. It should be noted that the impact of deer need not always adversely affect the fauna. For example, the numbers of kiwi on Stewart Island have apparently increased this century (R. Traill, unpubl. Department of Internal Affairs file notes) coincident with the increase in deer numbers, and it is not inconceivable that the two events are linked.

Deer may also affect frugivorous or nectar-feeding birds by competing directly for food or by gradually eliminating many of the sub-canopy trees that form an important food source for these species. However, other introduced animals such as rats and cats have probably had a greater and more immediate impact than deer on bird populations.

7.1.3 Impact on scenic values

The "forested-to-waterline" appearance of most of the coastline is an important part of Stewart Island's scenic value (Purey-Cust & McClymont 1978). Deer, therefore, have some impact on scenic values by preventing reafforestation of the areas of coastal forest dieback.

7.2 Commercial value

White-tailed deer are not sought as livestock, but there has been a tiny niche market for zoological specimens and "curiosities" (R. Dennis, pers. comm.).

The animals are worth an average of about $80 each as venison (assuming an average market carcass weight of about 25 kg, and a price of $3.30 per kg). The estimated annual harvest of 1500 deer is therefore worth about $120,000 as venison, but it is unlikely that this could ever be economically recovered, given the remoteness of the Island, the retention of venison by recreational hunters, and the low densities of deer in the areas most easily hunted by helicopter. Potential revenue from the sale of commercial hunting rights for venison would, therefore, be small or non-existent.

Commercial guiding of recreational hunters is receiving some interest (P. Wilson pers. comm.). The present and potential scale of this is unknown, but it is probably small. It would be difficult to ensure that high-quality trophies were consistently available.

Revenue could be generated from recreational hunters. At present, hunters using Maori land pay a land-access fee (essentially a de facto hunting fee) of $15 per person per week. About 110 parties of an average of 6-7 hunters use the area for 1-2 weeks per year, suggesting an income in excess of $10,000.

At present DOC does not charge for entry onto its land or its administration of the block system, but potential revenue can be estimated using the travel-cost method (Appendix 14.5). This analysis suggests a maximum potential revenue of about $50,000 annually could be obtained from hunters using DOC land. This maximum revenue would be generated by charging each hunter about $125, but doing so would probably reduce hunting pressure by 70% (Fig. 5).

7.3 Recreational value

7.3.1 Hunting

In 1988, an estimated 2000 hunters nationwide hunted white-tailed deer on about 15 000 days, spending an average of $47 for each day hunted (G. Nugent 1989, unpubl. FRI contract report). This suggests a total national expenditure of $731,000, or $438 per white-tailed deer killed. Nearly all of this hunting was done on Stewart Island.

The amount extra that hunters would be prepared to pay (if required to do so) can be calculated and added to the estimate of actual present national expenditure. Travel cost analysis (Appendix 14.5) puts this additional amount at about $66 per hunter, a total of about $100,000, only part of which would be recoverable as revenue (see section 7.2). These calculations suggest the recreational value of the herd is, in economic terms, about $830,000 annually.

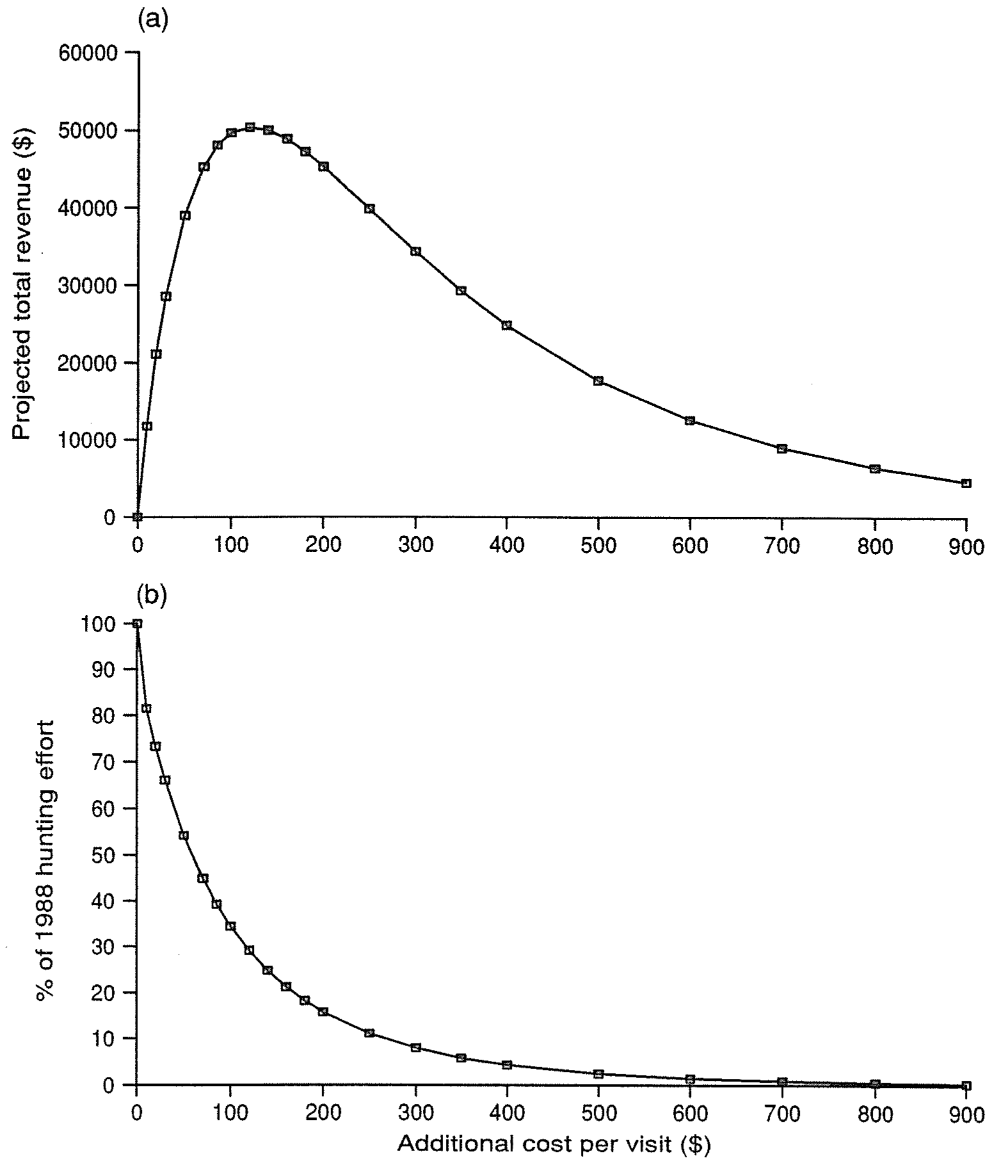

Fig. 5. Estimated potential revenue from recreational hunting on DOC land. Projected revenue (a) and hunting effort (b) are shown in relation to charge per hunter visit (= permit).

7.3.2 Non-hunting

For some visitors to the Island, particularly those not botanically inclined, the sighting of wild deer adds to their enjoyment of the scenery and their wildland experience.

7.4 Contribution to the Island's economy

In 1980-81 hunters made an important contribution to the economy of Stewart Island, spending about $150,000 (1990 dollars) on accommodation, boat and aircraft hire, and supplies (Burton & Howden 1982). Since then, an increasing number of hunters travel direct to their hunting blocks from Bluff or Invercargill, so the contribution may now be smaller.

7.5 Assessing an overall value

It is difficult to reconcile the positive recreational value of the white-tailed deer herd with its negative impact on conservation values. A quantitative estimate of the recreational value of deer hunting has been made (section 7.3.1), but there is no equivalent assessment of the conservation and recreational value of Stewart Island forest not modified by deer. Such an assessment is possible using the contingent valuation method (widely accepted for valuing environmental resources in North America; Loomis 1989), but is beyond the scope of this review.

Removal of all deer from Stewart Island would obviously mean a complete cessation of hunting. In my opinion, the number of additional visitors attracted to the Island by the return of the vegetation toward its deer-free state is unlikely to balance the loss of the number attracted by hunting, particularly if other introduced mammals remain present. If so, the conservation value of unmodified forest is either largely non-consumptive (i.e., the community values unmodified forest even though people are unlikely to visit the island specifically to see that vegetation) or the conservation value is lower than the value of recreational hunting.

8. CONTROL METHODS

8.1 Ground-based hunting

White-tailed deer have long been regarded as difficult-to-hunt, this characteristic being noted by government hunters as early as 1938 (McKinnon & Coughlan 1960). Although white-tailed deer densities on Stewart Island are probably as high as those for any deer species in New Zealand, the daily kill rate of private ground-based hunters is lower than that for any of the other common species (G. Nugent 1989, unpubl. FRI contract report).

State-funded ground-based hunting up to 1958 failed to eliminate white-tailed deer on Stewart Island. It is unlikely that these harvests were sufficient to reduce the deer population to the near-zero densities required for adequate regeneration of the most-preferred deer foods (section 7.1.1), except on the islands in Paterson Inlet. Any improvement in the understorey was probably lost when the control effort was abandoned, so that the expenditure was largely wasted.

The commercialisation of hunting in the late 1960s seemed to have some impact on densities as carcass weights increased after 2-3 years in which mainly ground-based commercial hunters took up to 2000 deer annually (M. Gooms, pers. comm). These reduced densities were maintained through the 1970s by the combined influence of ground-based and airborne hunting. However, interest in airborne hunting declined in the early 1980s, and private ground-based hunting alone did not prevent an increase in deer density (Lovelock 1987, Fig. 4a).

The ground-based hunting effort required to reduce the total population to near zero cannot be estimated. Any major State-funded harvest would tend to replace rather than add to the present recreational harvest. Recreational hunters currently spend 15 000 days hunting to harvest 1500 deer. An equivalent State-funded harvest would therefore be expensive even if State-funded hunters were 10-20 times more effective than recreational hunters.

8.2 Trapping and snaring

Snares were successfully used to kill white-tailed deer during the 1930s and 1940s, with up to 500 snares being used at one time (unpubl. Internal Affairs file notes). Small box traps baited with broadleaf were used to catch deer alive at Mason Bay during the 1970s and 1980s (T. Te Aika, pers. comm.). White-tailed deer were also caught alive on Stewart Island by using dogs to drive them into nets strung through the forest, the nets being positioned to effectively isolate areas such as peninsulas ((R. Dennis, pers. comm.). Dogs were also used to clear deer off islands in Paterson Inlet (M. Schofield, Internal Affairs Department file note).

The relative effectiveness of these methods can only be guessed at, but would probably not differ greatly from ground-based shooting.

8.3 Airborne hunting

Commercial hunting of white-tailed deer using helicopters is not economic at present. Four State-funded trials (in 1980, 1984, 1985, and 1987) have been used to assess the effectiveness of non-commercial airborne hunting (Appendix 14.3). The 1980 trial on the northern and eastern coasts indicated the north-west was the most suited to airborne hunting, consistent with the reports of commercial operators. Results of operations in 1984, 1985, and 1987 in the far south, an area seldom visited by recreational hunters, indicated that the technique could be used to intensively control deer over much of that area.

8.4 Foliage-bait poisoning

Foliage-bait poisoning using gel containing 10% Compound 1080 (sodium monofluoroacetate) has proven highly effective against white-tailed deer when the population is near carrying capacity (New Zealand Forest Service 1983, 1984; G. Nugent 1990, unpubl. FRI contract report FWE 90/4).

In the main field trial in 1981 deer faecal pellet group recruitment rate declined by 96% in the high-bait-density block (5/ha), and by 85% in the low-bait-density block (2.5/ha). It is possible that all deer present in the high-bait-density block were killed and that the few signs of deer presence found after the operation were the result of immigration as deer rapidly recolonised the poisoned areas. Population densities increased to near original densities within 3-4 years, despite continued (although reduced) hunting pressure.

Monitoring the take of non-toxic baits showed that bait acceptance was highest in summer, possibly because edible litterfall may be relatively scarce then (Nugent & Challies 1988). This suggests that, ideally, poison operations on Stewart Island should be done in summer.

Some deer were able to detect and reject the poison carrier during non-toxic foliage baiting trials on Stewart Island (C.N. Challies 1988, unpubl. FRI contract report). In the poison trial, the high (possibly total) kill suggests that scarcity of food forced deer to overcome any aversion. It is not known whether the same would occur if food was plentiful.

Foliage-bait poisoning provides the ability to reduce a population near carrying capacity to near zero, and offers a realistic prospect of "one-hit" elimination of deer from an area. Eradication (the total permanent removal of deer) is possible only if all deer on the Island can be put at risk.

Foliage-bait poisoning may be less useful at maintaining deer densities at near-zero densities. At such densities, an abundant food supply would probably decrease bait acceptance, and increase deer reproductive rates. My guess is that repeated poisonings of a quarter of the Island (to minimise the effect of reinvasion) every 3-4 years would hold deer densities near the threshold density at which preferred sub-canopy trees begin to regenerate freely.

8.5 Fencing

The fencing of small areas of the habitats most damaged by deer has long been mooted as a form of partial control (R. Traill, unpubl. Dept. Internal Affairs file notes). Deer have been excluded from a few very small areas as part of vegetation studies, and these exclosures have generally been successful in allowing the vegetation to recover (Stewart & Burrows 1989). Although fences need to be constantly maintained, this may be cheaper than trying to maintain a near-zero density in small areas using other control methods.

9. MANAGEMENT OPTIONS

In similar reviews of the management options for thar, goats, and chamois, J.P. Parkes (1988, 1989, 1990, unpubl. FRI contract reports) has dealt at length with the philosophy and practice of managing wild animals. This will not be repeated in detail here. Instead, three broad options will be evaluated: eradication, control at specified densities, and management for hunting or revenue. These differ slightly from the three broad options outlined by J.P. Parkes (1988, unpubl. FRI contract report), as "control" is defined for this report as management of the herd to minimise their impact on the flora. The control option is further subdivided according to the scale of State input required.

9.1 Eradication

It is unlikely that any control method other than foliage-bait poisoning would successfully eradicate all deer (white-tailed and red).

The 1981 foliage-bait poisoning trial indicated that eradication might be achievable (but not guaranteed) in a single operation where baits were laid over the entire Island at densities of about 5 baits/ha. Success would depend on whether deer in habitats other than those in which the trial was conducted could be poisoned as successfully.

A team of two people can lay about 100 baits per day at a density of 2.5 baits /ha (Parkes 1983). At $160 per day (J.P. Parkes 1989 unpubl. FRI contract report), poisoning all of Stewart Island with 5 baits/ha would require about 865 000 baits and would cost about $2.8 million. The bait application cost could be reduced by reducing bait density, and by not poisoning areas thought to be devoid of deer, but this would increase the risk of failure.

An eradication attempt should therefore be preceded by further research to determine the minimum bait densities required to ensure all deer in all habitats would take a bait, or whether all deer using unforested high-altitude areas would be poisoned by baits laid in the forest zone, or whether all of these deer could be removed by airborne hunting at the time poison is laid in the forest. The cost of this research, and of the additional administrative and public relations work needed to carry out eradication, would probably exceed any savings in bait application cost. I believe that eradication is technically feasible but that it would cost in excess of $3 million. Most of this would have to be spent within a single year, and there is no guarantee the operation would be successful. It is impossible to guess what mopping-up operations would cost, should the poison operation fail.

Eradication would be legally and politically difficult. To be successful, DOC would need to kill all deer, including those on the 7% of the Island in private ownership (Fig. 2a). Some owners object to eradication, and would dispute DOC's right to eliminate deer in court (H. Ashwell, Secretary, Rakiura Maori Incorporation, pers. comm.). Because "proper land use" for privately owned land does not preclude the presence of deer, DOC would have to argue that these deer threatened conservation goals on the adjacent DOC land. Some of the adjacent areas are Stewardship land, for which there is no legal obligation to eradicate deer.

Public opposition to large-scale poisoning of deer is strong. In 1959 the New Zealand Deerstalkers Association petitioned Parliament to prevent the use of 1080 against deer, the petition being the largest of those presented to that time (80,000 signatures; Holden 1987)). This opposition persists, and is particularly strong in Southland and Otago.

In summary, by eradicating white-tailed (and red) deer, DOC would be complying with its legislative obligation to exterminate introduced biota in Scenic and Nature Reserves. Vegetation composition and structure would revert toward that prevailing before deer were introduced, but unless possums and rats were also removed (a far more difficult task) recovery would not be complete.

Against these benefits, an attempt at eradication would be costly and might not succeed. Recreational hunters would lose an important resource, and the Island would suffer some economic loss. The Department would lose considerable goodwill, and the eradication programme might be thwarted by intentional re-liberation of deer or other pests by discontented hunters.

9.2 Control at specified densities

Although an initial reduction in deer density to below carrying capacity might allow many of the least palatable species in New Zealand forests to regenerate, the most palatable species are unlikely to regenerate adequately unless densities are reduced to near zero (Nugent & Challies 1988; Nugent 1990). The deer densities maintained by recreational hunters at present probably already allow much of the easily attainable vegetation response, so that substantial further reductions in deer density would be needed to gain any major additional improvement. There are three ways DOC might attempt to make such reductions in deer density.

9.2.1 Large-scale State-funded control

The Department of Conservation could attempt to control deer on all DOC land at very low densities in perpetuity. Of the three techniques that could be used for such an attempt (ground-based hunting, airborne hunting, and foliage bait poisoning), foliage-bait poisoning would almost certainly be the most cost-effective, although airborne hunting might be better in open areas. Some of the cost of such airborne hunting could be offset by selling the deer killed. Conversely, the operation could be partly conducted by subsidising private commercial hunting.

Maintaining near-zero densities would require killing, on average, the equivalent at least 50% of the breeding population per year (see Fig. 3a). To achieve this would require either a consistent major input into hunting, or repeated poisonings at regular intervals. The rapid increase to near carrying capacity of the George Reserve (Michigan, USA) herd in just 6 years (McCullough 1984) and the similarly rapid increase after the 1981 poison trial on Stewart Island suggest the interval should be no more than 3-4 years.

The cost of such operations would be high. Poisoning the 11 300 ha of forest below 100 m a.s.l. at 5 baits/ha every 3 years would cost $56,500 annually, while poisoning the 30 000 ha of forest within 1 km of the coast would cost nearly three times this. Whether sufficiently low densities would be maintained by regularly poisoning only the preferred habitat in this manner is unclear, as although this area contains the highest deer densities, most deer live more than 800 m inland (Lovelock 1987).

The benefits of large-scale control in perpetuity would be the attainment of most of the conservation goals achievable by eradication, without the need to gain access to private land. Although the cumulative cost of sustained control would eventually exceed the eradication cost, the annual cost could be less than the hypothetical return that would be obtained by investing the sum needed for an eradication attempt.

The chief disadvantage of control in perpetuity is the instability of the plant/herbivore system that such control establishes (J.P. Parkes 1990, unpubl. FRI contract report FWE 90/19). None of the main control techniques appear to work well at low deer densities, so the annual cost of control would be large. The Department would probably have difficulty in guaranteeing the necessary continuity of funding in perpetuity to sustain the level of control required.

Control in perpetuity would almost destroy the recreational hunting resource, as deer densities would probably be too low to sustain hunter interest. However, the few remaining animals would be in particularly good condition, and trophy quality would be higher than at present.

9.2.2 Small-scale or temporary State-funded control

Rather than attempt simultaneous control over all DOC land on Stewart Island, DOC could attempt control in perpetuity in parts of the Island, or temporarily reduce deer densities, with reductions at different times in different places. It is presumed that private hunting would continue on the remainder of the Island.

The choice of control technique would depend on the area targeted for protection, as the effectiveness of each method varies between areas. Any or all of the following three strategies could be used.

(a) Localised control in perpetuity: The far south of Stewart Island could be regularly hunted using helicopters, with spot poisoning of the pockets of tall forest along the coast. This area is seldom visited by recreational hunters, and the low vegetation of much of the interior lends itself to easy (cheap) control. However, this vegetation is not greatly threatened by deer, so the conservation gains would be small.

Islands and other small areas easily hunted from the ground could be regularly hunted by DOC staff, as has been done in recent years. The importance of the conservation gains in these areas would need to be weighed against the cost of keeping them largely deer-free in the face of constant reinvasion.

For local control in any of the remaining areas of Stewart Island, foliage-bait poisoning at regular (3-4 years) intervals is likely to be the most cost effective technique.

(b) Fencing: Small areas (<100 ha) of the habitat types most vulnerable to deer could be fenced, and deer eliminated from within. Adjacent areas could then be fenced to progressively expand the deer-free area. Maintaining the initial fences would help ensure that accidental breakdown of a fence would not put the whole of the "reclaimed" area at risk. The deliberate breakdown of fences by hunters could be a potential problem, but seems unlikely if the area enclosed remains a small proportion of the overall deer habitat. Such fences could be maintained in perpetuity or just long enough for a cohort of palatable species to re-establish and grow to rejuvenate the canopy. Although the cost of of this progressive fencing of small areas would undoubtedly be high, it could be acheived over a long period. Progressive exclusion by fencing would seem less vulnerable to short-term funding failure than hunting.

(c) Periodic intensive control: Rather than constant sustained control in perpetuity, an alternative strategy would be to reduce deer densities to near-zero densities periodically (over all or part of the Island). Densities should then be held low long enough for a cohort of trees and lianes to grow through the browse tier. The period required for this is unknown but is probably 10-20 years. Subsequently, deer densities could be allowed to increase to the level determined by private hunting alone. The aim of such a strategy would be to rejuvenate the canopy periodically, and perhaps allow reafforestation of any dieback areas. It is clearly feasible to obtain the initial reduction by poisoning, but the ability to maintain the near-zero densities by poisoning is less clear. The cost will depend on the size of the area being controlled, but it must be large enough to minimise the effect of deer reinvasion.

The benefits of this approach are that it would reduce the long term cost of control, and could maintain a canopy not greatly different from that of deer-free forest. The approach also has some benefits for hunters. Although there is a short-term loss of hunting opportunities the replenishment of the sub-canopy tree component (their main food supply) would maintain a higher carrying capacity. This should mean more deer in better condition being available in the long-term. Unlike other control options which aim for long-term stability, this option would attempt to use instability to advantage. The chief disadvantage would be that the forest understorey receives a relatively short respite, and for most of the time would be depleted.

9.2.3 Control by private hunters

Should DOC not have the resources to kill deer itself, it could attempt to encourage private hunters. This is effectively the status quo.

Recreational hunting maintains deer density somewhat below carrying capacity, the level being determined the balance between the attractiveness of hunting white-tailed deer on Stewart Island and the cost of getting there. These factors seem inherently less likely to change suddenly than the level of State funding. Thus, although the conservation gains may not be great, this option has greater stability than the other control options.

Deer density could be reduced by private hunting if the attractiveness of white-tailed deer hunting could be increased or the cost decreased. Any increase in hunting pressure would tend to be self-limiting as it would decrease deer density and hunter interest. Conservation gains would then be small unless the inducements were large, in which case it would probably be more cost-efficient for DOC to kill the deer itself.

Some potential methods for this control option are subsidising commercial recovery, advertising the hunting opportunities on the Island more widely, improving tracks and camping facilities in areas not already well served, or by running hunting competitions. It could be possible to increase hunter impact by encouraging recreational hunters (using an education programme) to shoot all the female deer they see.

Administering hunting on DOC land on Stewart Island at present costs at least $8000 annually. This is classed as a wild animal control cost, but I would argue that administering hunting provides little benefit for DOC in the control context. Although hunters prefer to have exclusive use of their hunting blocks (which is the privilege provided by the present system), most would still hunt on the Island (i.e., current deer densities would be maintained) whether or not DOC issued permits. The cost of hunting administration should therefore either be viewed as expenditure to enhance recreation (rather than to control deer), or be recovered from the hunters. Alternatively, DOC could cease administering hunting.

To summarise, management for the lowest densities attainable by private hunters would not gain any major vegetation recovery beyond the status quo. The abundance of many subcanopy tree species would continue to decline. The quality of the forest as deer habitat would also diminish, so that the hunting resource would be adversely affected in the long-term. In the short-term, however, the system is stable and requires little DOC input. There is potential for improvement, either by somehow manipulating the private hunting effort or by reducing the net cost of DOC inputs into administration.

9.3 Management for hunting or revenue

For the Scenic and Nature Reserves DOC is legally obliged to attempt eradication. However, the Minister may grant an exception, and the legal obligation does not extend to Stewardship land, so DOC can legitimately consider management for hunting, particularly as it also has an obligation to encourage recreation. There are two ways the herd might be managed for hunting; management for maximum sustained yield or management for maximum revenue.

(a) Management for maximum sustained yield: Somewhat paradoxically, achieving the maximum deer harvest sustainable in the short- to medium-term would require reducing the population. The herd is at present sufficiently near carrying capacity for its reproductive rate (and probably the survival of fawns) to be impaired by the scarcity of high-quality foods. Reducing deer density would immediately increase the per capita food availability, and this would be reflected in deer of better condition which would survive and reproduce better. The condition of deer in the Chew Tobacco area apparently improved substantially after the 1981 poison trial lowered densities there (R. Thomas, pers. comm.).

Management for maximum sustained yield would therefore aim to lower deer density, resulting in a slight improvement in the vegetation, in line with DOC legal obligations and policy. Although the daily success rate of hunters would be lower, the deer shot would be in better condition, and such management would probably find favour with hunters. In the Blue Mountains Recreational Hunting Area, the introduction of restrictions designed to benefit hunters resulted in an immediate upsurge in hunter interest, even though the restrictions produced an initial decrease in success rate (G. Nugent, unpubl. data). It would probably be easier to convince recreational hunters to kill more female deer to improve total deer harvest and condition (at the cost of daily success rate) than to improve the vegetation.

(b) Management for maximum revenue: Using the travel cost method, I estimate the department could earn $50,000 or more annually by charging for hunting on DOC land on Stewart Island (Fig. 5a). Such revenue could fund localised or temporary deer control (Section 9.3) or other conservation work.

The main consequence of such management would be a decline in hunting pressure, as an increase in the cost per visit would result in a decline in the number of visits (Fig. 5b). Deer densities would therefore increase and the vegetation would deteriorate, as would the condition of the animals. Daily kill rates would probably increase with the increased numbers of deer, but overall hunter satisfaction would probably decrease as the better hunting would be experienced by fewer hunters.

9.4 Choosing an option

The eradication or large-scale State-funded control options would reduce the influence of deer dramatically. Both appear technically feasible but costly. Control by private hunters or management for hunting need not cost anything, but would not prevent significant further degradation of the forest. Small-scale or temporary control would be intermediate both in what it can achieve and in what it would cost.

The first step in choosing an option is therefore to decide how badly the Department wishes to reduce the impact of deer on the vegetation. Although legally obliged to do so for some parts of the Island, the Department has the discretionary power to decide where its limited resources should be spent.

Any assessment of the acceptability or otherwise of vegetation modification involves not only assessing the impact of deer, but also evaluating it in relation to the impact of rats, cats, possums, and any other introduced animals or plants. Any assessment also means comparing the conservation value of deer-free (but not unmodified) forest with the recreational value of the deer herd. Finally, the impact of deer has to be evaluated against other conservation objectives. As most of these impacts or values are poorly understood or quantified, the decision will be largely subjective.

If the modification of indigenous forest under the present regime is unacceptable, the degree of unacceptability must be measured against the funding available. Vegetation regeneration patterns are thought to remain largely unchanged over a wide range of intermediate deer densities, so that low-intensity control by State or private hunting appears unlikely to produce worthwhile gains. This effectively narrows the choice to major expenditure (eradication or large-scale intense control) or lesser expenditure (small-scale or temporary) intense control.

If modification of the forest is acceptable, no control is needed (the choice is then simply how to manage the hunting system).

Pragmatically, then, there are three possibilities for State expenditure: a lot, a little, or none.

9.4.1 Major State expenditure

The choice is between eradication or extensive sustained control. To resolve this requires two decisions. Would the Department be permitted to kill deer on private land? Would the large-scale use of poison be permitted? A negative answer to either question would rule out the eradication option, but would merely increase the cost of the control option.

If eradication is politically and legally possible, the next question is whether DOC can afford it. The large short-term cost must be compared to the lesser but ongoing cost of control in perpetuity, taking into account the instability inherent in the latter. If eradication appears affordable, some preliminary research would be necessary to determine optimal bait densities.

If eradication is not affordable, a range of questions on choice of control technique and specification of target density need to be answered. The latter in particular would require further research.

Control at low density should not be used as a precursor to an eradication attempt. The low densities would make eradication more difficult, and the money spent achieving them would be wasted. It is, therefore, important that the goals of management reflect management practices, i.e., the stated goal should not be eradication, if the intent and practice is control in perpetuity. Even if DOC decides that eradication is the goal, but because of lack of funds postpones action for the foreseeable future, any money spent on control in the interim would be wasted.

9.4.2 Moderate State expenditure

If deer impact is not sufficiently important to warrant large-scale control, but too important to ignore, some attempt could be made to protect those habitats where the deer influence is least acceptable (the coastal forest, or the vicinity of threatened plant species, for example). The choice of the area(s) to be protected should be based primarily on the conservation gains possible, rather than simply on the ease of control. The choice of control technique would depend on the area targeted for protection.

The other important choice is between permanent or temporary control. Although control in perpetuity of an area would protect the forest as a whole, temporary control of the correct periodicity would reduce canopy modification, but would offer less protection to the understorey. If preservation of an unmodified canopy is the primary goal, temporary control could suffice. Temporary control is obviously cheaper long term, and has an additional advantage in that it should be acceptable to hunters, as in the long-term, it is likely to ensure better deer habitat and higher deer numbers on average. It is not inconceivable that hunters might be convinced to fund temporary control as being in their own best interests.

9.4.3 Minimal State expenditure

In my opinion, the management practices and conservation outcome are likely to be the same whether DOC attempts to manipulate private hunters for minimum deer density or manages for maximum sustained yield. However, although the choice between the management intentions is somewhat irrelevant in terms of outcome, it is important philosophically, and in how it affects the way hunters perceive the Department's management.

Regardless of which of these two management policies are adopted, DOC must decide how to fund hunting administration. The current system produces no benefits for DOC (apart from hunter goodwill) that they would not obtain anyway. The Department could therefore reduce costs by abandoning hunting administration, recover the costs of administration from hunters, or recognise the hunting administration as a free recreational service. Although there is also a potential to generate a significant profit from hunting administration, this would reduce hunting pressure.

10. CONCLUSIONS

- The Department of Conservation has a legal obligation to attempt to exterminate deer from the Nature and Scenic Reserves which comprise 60% of Stewart Island, within the resources available, and unless the Minister decrees otherwise. It is not so obliged on Stewardship land (33%).
- White-tailed deer have a higher reproductive potential, have greater dispersal distances, and are more difficult to hunt than most other deer species in New Zealand. This, their small size, and their forested habitat makes them the most difficult ungulate to control.
- White-tailed deer have substantially modified the forest understorey in Stewart Island's coastal forest, but have had less impact inland. Although still common, many subcanopy tree species will become rare unless deer densities are reduced to low levels. These low densities are not achievable by private hunting.
- The herd provides a significant hunting resource, on which hunters at present spend about $731,000 annually, and from which revenue of up to $50,000 p.a. could be derived.
- Eradication of deer by poisoning appears to be technically feasible, but would probably cost more than $3 million, might not succeed, and might not be legally or politically possible.
- Large-scale control in perpetuity at the low densities required is also feasible but expensive. It is inherently unstable. However, some reduction in deer impact is possible with less expensive localised or temporary control. Temporary control could permit canopy rejuvenation and simultaneously improve long-term hunting prospects.
- Although the present hunting system does reduce deer impact this level of reduction would probably occur whether or not DOC continued to administer the system.

11. RECOMMENDATIONS

- The Department must decide the acceptability of the present and predicted impact of deer, based on an assessment of the human values involved. However, present information is inadequate to allow an objective evaluation of these values, so the Department will have to resolve this issue subjectively. Because such assessments of acceptability are fundamental to the Department's management of any hunted game, not just white-tailed deer, DOC should investigate ways of quantifying the various values more objectively than at present.
- If DOC decides to reduce deer impact, it should be to attain zero or near-zero deer densities over some or all of the Island. Moderate reductions to half or quarter of carrying capacity appear not worthwhile. If DOC resources are inadequate for its objectives, DOC should explore the option of temporary control funded in part by private hunters.
- If DOC decides not to attempt control, it should at least act to reduce the net cost of administering hunting.

12. ACKNOWLEDGEMENTS

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14. APPENDICES

Appendix 14.1 List of unpublished reports

Challies, C.N. 1988: Foliage bait poisoning of ungulates. 1: Palatability of petrolatum and carbopol gel to white-tailed deer. Forest Research Institute contract report. 9 p.

Coleman, J.D.; Pekelharing, C.J. 1989: The role of possums in dying coastal forest of Stewart Island. Forest Research Institute contract report. 14 p.

Cuddihy, M.J. 1982: Changes in the density and distribution of wild animals in southern Stewart Island. New Zealand Forest Service report. 22 p.

Cuddihy, M.J. 1983: Trends in the forests of Northern Stewart Island. New Zealand Forest Service report. 19 p.

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Evans, G.R.; Fine, N.M. 1976: Resource survey of northern Stewart Island. Part One: Indigenous grasslands. *Forest Research Institute Protection Forestry Report No. 143.* 18 p.

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Nugent, G. 1990: A white-tailed deer poisoning trial on Stewart Island. Forest Research Institute contract report. 14 p.

Parkes, J.P. 1988: A review of options to manage Himalayan thar *Hemitragus jemlahicus* in New Zealand. Forest research Institute contract report. 43 p.

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Stewart, G.H.; Burrows, L.E. 1988: Assessment of animal effects on forest regeneration in Stewart Island. Forest Research Institute contract report. 40 p.

Williamson, M.J. 1976: Resource survey of Northern Stewart Island. Part Two: Forests & introduced animals. New Zealand Forest Service report. 31 p.

Appendix 14.2 History and known harvest of white-tailed deer on Stewart Island. Data are for years ending 31 March up to 1979, and for calender years from 1980. The letter following the number of kills indicates the hunter type (g = government, r = private ground-based, h = helicopter).

Year	Kills	Notes
1905		7 does, 2 bucks released at Port Pegasus on 26 March.
1909		Reported as "successfully acclimatised".
1919		2 licences issued for up to a total of 4 trophies.
1927		Protection lifted (1926) Bounty of 2/- per tail offered.
1928	73g	Two hunters
1929	80g	Two hunters
1931	463g	Government stalkers. From July bounty for white-tailed deer raised to 4/- (but not red)
1938	406g	(60 white-tailed)
1939	356g	(56 white-tailed)
1940	399g	(189 white-tailed)
1941	426g	
1942	416g	
1943	365g	
1944	632g	
1945	346g	
1946	351g	(106 white-tailed)
1947	151g	
1948	340g	
1949	415g	
1950	971g	
1951	644g	
1952	162g	
1953-58		Bounty of 10/- per tail offered. Total of 1747 bounties paid, 1006 for white-tailed
1961	311r	Kills reported for April and May
1971	892r	471 permits,1021 hunters, 235 returns
1972	264r	214 permits, 527 hunters, 68 returns,
1973	241r	permits, 421 hunters
1974	213r	190 permits, 673 hunters
1975	381r	300 permits, 852 hunters
1976	314r	308 permits, 967 hunters
1977	503r	363 permits, 958 hunters
1978	730r	413 permits, 1128 hunters, 289 returns,
1979		data incomplete
1980	753r 170h	483 permits
1981	585r 285h	868 permits
1982	554r 64h	1065 permits
1983	573r 99h	902 permits
1984	581r 63h	956 permits
1985	570r	810 permits
1986	578r	998 permits
1987	715r	1092 permits
1988	681r	1063 permits
1989	674r	997 permits

Appendix 14.3 Summary of State-funded airborne hunting trials. Based on unpublished New Zealand Forest Services file notes, file 6/7/35, by C. Main. Trials were conducted in 1980, 1984, 1985 and 1987.

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a) **Trial 1 March 1980**
A total of 13 h 15 min were flown, 84 were animals seen (71 white-tailed deer, 7 red deer, and 6 sheep), and 53 killed (42, 5, and 6, respectively). A Hiller 12E helicopter was used. Both the north-west and south-east coasts were hunted, but the far south was not. Main concluded the method was successful for the coastal 1 km strip in the north-west (Mason Bay to Saddle Point), because the area had many clearings, but of far less worth for the south-east coast.

b) **Trial 2 February 1984**
A total of 13 h 5 min were flown, and 63 white-tailed deer killed. Only the far south was hunted. The deer were easily seen at this time of year because of their light brown colour. Most deer were in coastal areas, mainly in the pockets of taller forest.

c) **Trial 3 July 1985**
Only the far south was hunted. About 15 h 45 min were flown, and 41 deer were killed. A third of the flying time was used to recover 27 animals for autopsy (eight were fawns (6 M, 2 F), three were yearlings (1 M, 2 F), and 16 were adults (7 M, 9 F) - of the nine adult females, four were pregnant, one with twins). The deer were not as visible as in summer, the grey winter coats blending into the vegetation. About 80% of the deer seen were shot, and the deer were found in much the same areas as the previous year.

d) **Trial 4 February 1987**
No hunting effort and kills were recorded, but 31 deer were recovered for autopsy from the far south. No yearling or 2-year-females were lactating and only seven of 11 adult females.

Appendix 14.4 Hunter usage and success rates on DOC-administered land in 1988. Note the high use of blocks on the south-east coast (SE) and relatively low use in the inland areas adjacent to Paterson Inlet (IN). Blocks on the north and west coast are designated NC and WC respectively (see Fig. 2b for block locations).

Block No./Name		Permits Issued	Days hunted	White-tail killed	Kills/ Day	Subarea
1	Maori Beach	33	125	24	.192	NC
2	Bungaree	40	205	18	.088	NC
3	Murray	22	160	12	.075	NC
4	Rollers	13	87	8	.092	NC
5	Christmas	27	133	10	.075	NC
6	Lucky	27	159	18	.113	NC
7	Yankee	26	181	19	.105	NC
8	Smokey	10	69	9	.130	NC
9	Long Harry	18	121	23	.190	NC
10	E Ruggedy	32	147	19	.129	WC
11	W Ruggedy	25	108	12	.111	WC
12	Waituna	7	40	5	.125	WC
14	Big Hellfire	6	16	3	.188	WC
14	Little Hellfire	38	239	27	.113	WC
15	Bensons	7	27	4	.148	IN
16	Freshwater	6	16	5	.313	IN
17	North Arm	10	34	0	.000	IN
18	Freds Camp	24	92	6	.065	IN
19	Rakeahua	13	44	15	.341	IN
20	N Doughboy	30	184	10	.054	WC
21	S Doughboy	11	72	1	.014	WC
22	Pegasus	19	83	15	.181	SE
23	SW Arm	25	76	14	.184	IN
24	Abrahams	27	133	18	.135	IN
25	Hapuatuna	20	83	8	.096	IN
26	N Big Glory	13	34	2	.059	IN
27	M Big Glory	13	59	5	.085	IN
28	S Big Glory	28	175	17	.097	IN
29	Little Glory	52	124	19	.153	IN
30	Cavalier	61	364	91	.250	IN
31	Martins	48	206	50	.243	WC
32	Tolsons	11	77	16	.208	IN
33	Bosom	116	670	47	.070	SE
34	Kellys	61	272	23	.085	SE
35	Shelter Point	42	276	21	.076	SE
36	N Tikotahi	47	270	32	.119	SE
38	N Lords	24	208	36	.173	SE
39	Chew Tobacco	31	153	19	.124	SE
Total		1063	5522	681	.123	

Appendix 14.5 Estimation of potential revenue from recreational hunting.

This analysis uses the Travel Cost method (Kerr & Sharp 1987). Using hunting returns for the 1988 calender year, hunters who reported hunting on at least one day were classified by region. The likely travel cost of getting from each region to Stewart Island was estimated from the cheapest options. These costs are travel costs only, and do not include the cost of getting to the hunting areas from Oban (or the equivalent additional cost of going direct from the South Island). As travel costs increase the visits per head of population decreases ($R^2 = 0.89$, $p<0.001$):

Visits per 1000 of population = exp (-0.303 (sqrt (travel cost) +4.2))

This equation was used to estimate the potential revenue from recreational hunters by simulating the effect of an increase in cost resulting from a charge for hunting permits (Fig. 5). These calculations are conservative as they do not allow for an increased time cost with increasing distance travelled.

Region	No. of visits	No. of visits per 1000 of population	Distance (km)	Cost ($)	Total Expenditure ($)
Australia	15	.002	>3000	905	16177
Northland	16	.150	1746	584	11135
Auckland	67	.086	1575	544	43435
Waikato/B. Plenty	18	.050	1449	530	11369
Central North Is.	11	.120	1388	528	6921
Hawkes Bay	27	.231	1247	494	15895
Horowhenua	5	.124	1077	443	2640
Wellington	44	.105	1008	428	22442
Taranaki	25	.191	1121	458	13645
Nelson	17	.291	1016	416	8428
Marlborough	13	.405	899	324	5019
West Coast	26	.838	650	288	8923
N. Canterbury	130	.444	578	233	36097
S. Canterbury	93	1.078	416	212	23496
Otago	232	1.818	217	149	41195
Southland	115	1.115	97	111	15212
Stewart Island	38	83.551	0	0	0
TOTAL	892				282030

Appendix 14.6 Forest development at the dieback ecotone.

The following unpublished data and summary were provided by Dr. R.B. Allen. Changes along the ecotone between comparatively intact southern rata-kamahi forest and more seaward open-canopied forest on the edge of dieback areas were assessed using transects established in 1982 and remeasured in 1989.

Basal area loss and tree death from 1982 to 1989 was greater in open forest than in intact forest, because of high mortality of southern rata in open forest. Sub-canopy broadleaf and *Coprosma foetidissima* increased over this time. About 20% of all trees in open and intact forest had a decrease in crown condition from 1982 to 1989. Southern rata trees declined more (40% and 42% in open and intact forest respectively) than kamahi (38.7% and 13.3%).

Numbers of kamahi, broadleaf, and *Coprosma lucida* saplings (>1.35 m) increased on intact and open dieback transects from 1982 to 1989, although densities were higher on the intact transects (Table 14.6). *Pseudopanax simplex, Carpodetus serratus, Senecio reinoldii*, and *Coprosma foetidissima* also increased on intact and open transects, but densities were higher in areas of open canopy. Southern rata saplings and *Cyathea smithii* increased only on intact transects, and *Dicksonia squarrosa* increased only on open transects.

Apparently, the tangle of debris at the dieback ecotone on Stewart Island allowed saplings of many palatable species to grow on raised surfaces and protected sites out of the reach of deer. These were the only conditions where kamahi saplings were common. Kamahi saplings were more abundant in intact than open forest, although kamahi increased markedly in open forest (Table 14.6). The continuing southern rata mortality on transects and the absence of saplings after canopy collapse suggests kamahi will become more prominent in these forests, at least in the short term.

Table 14.6. Density of saplings and treeferns on open canopied and intact transects on Stewart Island in 1982 and 1989. Not all species are included.

	Sapling density (#/ha)			
	open		intact	
Species	1982	1989	1982	1989
Trees				
Metrosideros umbellata		4.2	6.2	
Weinmannia racemosa	16.7	116.6	7.3	81.2
Griselinia littoralis	5.2	62.5	3.1	19.8
Pseudopanax simplex		6.2	3.1	9.4
Carpodetus serratus	2.1	8.3		22.9
Shrubs and treeferns				
Senecio reinoldii		606.0	75.0	1657.1
Dicksonia squarrosa	337.4	323.8	146.8	251.0
Cyathea smithii	45.8	61.4	48.9	45.8
Coprosma foetidissima	8.3	206.2	51.0	263.5
Coprosma lucida	4.2	22.9		6.2