Vegetation Protection: Some Economic Analysis

Ross Cullen
Economics and Marketing Department
Lincoln University

New Zealand Association of Economists,
Australian Agricultural Economics Society
Conference
Hamilton, August 1992.

Vegetation Protection: Some Economic Analysis

Ross Cullen
Economics and Marketing Department
Lincoln University

Possums, a native of Australia, were first liberated in New Zealand in 1858 to provide a source of fur. Today they number about 70 million and few parts of the country have not been invaded by possums. Possums have well developed appetites and their browsing habits cause many problems. National Parks, and other areas of conservation land which are bush covered are major habitats for possums. Some conservation forest areas in New Zealand are being severely modified by browsing possums, and many trees become so stressed by continual possum browsing that death occurs. Efforts to prevent damage by possums can be appraised to determine whether the policies pursued are economically defensible. This paper examines the rationale for protecting conservation areas from damage by possums, attempts to illustrate how efficient levels of control can be determined, provides some empirical evidence on costs of protection, indicates how the benefits of protection actions might be measured, and comments on the delivery of vegetation protection.

Many vertebrate species have been introduced into New Zealand during approximately 1000 years of human habitation. The introduction and presence of these species is typically a mixed blessing as they are valued for some characteristics, such as fur, or meat production, but their presence also often causes many problems. These problems include competition with domestic animals for food, browsing on and destruction of vegetation, destruction of habitat for indigenous species, competition for food with indigenous species, and transmission of diseases. The prevalence and severity of these problems can in some cases lead to vertebrate species becoming labelled pests. Some pests in some situations become of sufficient importance to provoke expenditures to control their population numbers. Attempts to control population numbers of introduced vertebrates is a means to an end such as protecting indigenous species from predation, browse or destruction, or protecting ecosystems, crops, or domestic species from damage and potential destruction.

The problems posed by vertebrate pests in New Zealand have been recognised for many decades and considerable expenditures are made to control populations, protect crops, species and ecosystems. Some of the effort applied to control vertebrate species is intended to protect indigenous flora and fauna from competition, browse and destruction. These expenditures typically occur on lands managed by the Department of Conservation, who are responsible for the management of approximately 5m hectares of land in New Zealand.

A recent paper presented to the New Zealand Conservation Authority, reported in (Hobbs 1991), argued that expenditures to control possums on conservation lands could amount to $56m per year to maintain possum populations at a low level, and total $1 billion over the next twenty years. At present annual expenditures by the Department of Conservation total $131.7m (Department of Statistics 1992). The implication is obvious - protection of indigenous species from damage by vertebrate pests such as possums could absorb a major chunk of all conservation expenditures in future. Given the potential magnitude of these forest protection expenditures, some economic analysis of these activities seems appropriate.

This paper asks some simple questions about programmes designed to protect flora and fauna on conservation lands, by focusing on the case of possums in New Zealand. Some questions which land managers must grapple with include: Should control of exotics species be attempted? What are the objectives sought in exotic species control programmes? Where should exotics species be controlled? How much expenditure should be made on exotics species control? Which control techniques should be used? How should control be organised? This paper attempts to provide some analysis and some answers to those questions.

Invasion and Equilibria in Ecosystems.

Introduction of exotic species can lead to several outcomes ranging from failure to establish viable populations, to causing major disruption to existing communities. Ecologists suggest that our understanding of invasion processes is rudimentary (Crawley, 1986), but it is clear that the flood of introduced species into New Zealand has in many cases caused major changes to ecosystems and communities. These invasions might be expected in time to lead to new relatively stable equilibria but at the expense of significant changes in the balance of species in an area. This process of successive invasions by exotic species does portend a possibility of homogenization of ecological communities by the world-wide spread of exotics. This possibility can be combated by efforts to prevent the introduction of further exotics, and efforts to control the spread and influence of existing, aggressive exotics (Townsend 1991).

These efforts to prevent introduction or control the spread of exotics require expenditures and it is an open question whether the benefits from such activities exceed the costs of those activities. Where the costs of preventing the introduction, or controlling the spread of exotics, are high relative to the benefits obtained, taking no action may be an economically defensible strategy. In practice the costs of controlling vertebrate exotic species vary greatly. Parkes (1991) suggests annual cost to maintain low mammal densities range from $1.30 / ha for red deer to $115 / ha for ship rats. These cost differences may be matched by wide variations in benefits obtained from control of various vertebrate exotics. Case by case analysis seems essential to determine whether control of exotics is economically defensible.

Possums: Economic Resource or Public Bad?

Brush - tailed possums (*Trichosurus vulpecula*), a native of Australia, were first successfully liberated in New Zealand in 1858 (Department of Statistics, 1990). Liberations at various points have continued until as recently as the mid 1980's as people have sought to create new possum populations to provide a source of fur for harvest. Today possums number about 70 million and few parts of the country have not been invaded by the species (Seitzer, 1992). Possums have well developed appetites and their browsing habits cause many problems. It has been estimated that possums eat 21 000 tonnes of vegetation each night, mostly the leaves and shoots, of a wide range of plant species (Seitzer, 1992). National Parks, and other areas of conservation land which are bush covered are major habitats for possums. Some conservation forest areas in New Zealand are being severely modified by browsing possums, and many trees become so stressed by continual possum browsing that death occurs. Pohutakawa, Rata, Kamahi, Mistletoe and Fuchsia are some of the species most prone to attack by possums.

Possums have also become a serious problem for many farmers as possums transmit bovine tuberculosis (TB) to cattle and deer. Farm animals which are found to be infected with TB have to be slaughtered. Farmers and New Zealand suffer a significant financial loss because of this problem. The current bovine tuberculosis scheme is estimated to have cost approximately $10m in 1989 and $13m in 1990 (Cowan,1991). The presence and spread of bovine TB is also a threat to New Zealand's continued access to overseas beef markets.

Harvesting possums for fur production has at times been a significant activity in New Zealand and the value of possum skin exports peaked at $23 m in 1980. However the world-wide downturn in demand for pelt and fur products during the 1980's has dramatically reduced the prices received for possum skins. Exports of possum skins in 1990 were worth only $1.5m. However the positive prices received for possum skins does mean that possums can potentially be viewed as economic resources in some circumstances and as public bads in other circumstances. Judgment about their economic status is dependent upon whether their harvest costs exceeds the returns from their harvest.

Harvest costs for possums are likely to be lowest on regions where possum population densities are high, and where accessibility by groundhunters is high. Where these conditions exist then possums can potentially be economic resources.

But in many instances where population densities are low, and the regions possums inhabit are relatively isolated, possums are likely to be public bads. In practice the status of possums is likely to switch from economic resource to public bad during population control programmes, as successful control programmes reduce possum densities so greatly that their harvest becomes uneconomic. This phenomenon can be illustrated by using two prices for possum skins of $6 and $16, and assuming an 80% kill rate for control programme at high possum population density, and a 42% kill rate at low possum population density.

Table 1. Illustrative Revenues and Costs for Harvest of Possums

Density/ha	Price	Revenue/ha	Cost/ha
6.0	$6.0	4.8 x 6 = $28.8	$28.0
1.2	$6.0	0.5 x 6 = $3.0	$15.0
6.0	$16.0	4.8 x 16 = $76.8	$28.0
1.2	$16.0	0.5 x 16 = $8.0	$15.0

This switch from economic to sub-economic status, will vary with price levels for possum skins, but it seems clear that once possum control operations have reduced possum population densities to low levels, harvesting them for their skins is not a profitable activity and possums are no longer economic resources.

Private or Public Bads (Goods)?

Many harvested species can be described as fugitive resources. There are not well defined property rights for vertebrate pests such as possums, and they are able to readily move from one area to another. Research suggests that possum populations can extend their range at a rate of about 1 kilometre per year. This migratory ability does mean that possums are unlikely to be classified as private bads (goods). However this migratory potential varies between sites. Possums are unwilling swimmers and populations on some offshore islands may be strictly private bads (goods) if there is a sole owner of the island. Populations on some onshore islands can also be considered private bads (goods) as topographical features - rivers, seas, mountains and distance - can effectively reduce migration rates to close to zero. Equally it is possible in some circumstances to control migration by use of electric fences. In New Zealand electric fences have been erected across an isthmus on the Coromandel Peninsula to prevent the migration of possums into an area and allow the extermination of the possums already present (Seitzer, 1992).

Access to possums for harvesting is almost invariably controlled by land owners, and hence rights to harvest are private goods. But in the majority of cases in New Zealand possums are uncontrolled in their range and do not fit neatly into the category of private bads (goods). Possum populations per se appear to be best described as having some public bad aspects - reduction in a population on one area also confers some benefit on a neighbouring region. This public bad aspect does suggest collective or joint funding of possum control rather than individual funding may be appropriate as individual actions on control are likely to fall short of efficient levels. Possums live on conservation lands which vary greatly in area. The smaller are the areas in question, and the easier the migration of the possums, the stronger is the case the case for collective or joint action. Possums in other areas such as on large national parks which are distant from farms, have few public bad characteristics.

Objectives of Exotic Species Management

Control of exotic species on conservation lands can be directed at more than one objective, but the underlying motive for control actions should be recognised, typically they are designed to protect indigenous vegetation from browse damage, to protect indigenous fauna from predation, or to prevent loss of food supply for an indigenous species. The objective is not control of the exotic species per se (Parkes, 1991). Control of exotic species does involve costs and the payoff can theoretically be measured as the welfare gains which occur because of the protection of the indigenous flora and / or fauna. Control of exotic species will only pass an economic efficiency test if the benefits of control activities equal or exceed the costs of the control activities. Several strategies exist for management of exotic species including: limitation of introduction or dispersal; eradication; one-off control; sustained harvesting; recreational harvesting; periodic harvesting; no harvesting.

Choice amongst these management strategies may be based on several criteria, including: contribution to conservation goals; effects on ecosystem stability; cost effectiveness; and economic efficiency. In practice the relative importance attached to each of the criteria may significantly alter the choice of management strategy. Periodic harvest may provide the most cost effective management of an exotic species such as possums, but may also result in the most unstable possum population size and the least ecosystem stability. Determination of the relative importance of the various criteria is likely to have a major influence on choice of management strategy for exotic species.

Several options exist for controlling possum populations and protecting indigenous species from possum damage. Groundhunters employ combinations of traps and cyanide poisoned baits to control possums. An alternative is aerial application of cereal baits containing a poison, sodium monofluoroacetate (1080). Localised control is attempted in some areas by use of bait stations. In some regions protection of particular tree specimens can be achieved by placing metal bands on trees and thus preventing possums climbing up onto the trees to reach their branches and leaves.

Allocation of Forest Protection Expenditures in New Zealand

Taxpayers fund most of the expenditure on possum control in New Zealand and there is only a limited amount of money available to control possums. At present expenditures on possum control total approximately $3 million (Seitzer, 1992), far short of the amount required to provide protection of all conservation lands (5.35m ha), or even all 'at risk' conservation areas. The result is that only some areas can be protected from damage by possums and prioritisation of areas for protection is necessary to ensure best use is made of the limited resources available. Methods of prioritising areas for protection currently employed in New Zealand emphasise the botanical and wildlife characteristics of different areas. The system currently employed scores each potential area for wildlife (mostly birds) based on a system developed by Elliot and Ogle (1985) and botanical 'values' based on a system developed by Shaw (1988). The approach used gives highest weight to rarity of species present in a conservation area, and their vulnerability to damage. Conservation areas are given scores on a scale from 6 (national importance) to 1 (potential), for both botanical and wildlife values, and the highest of these two primary scores is weighted by a vulnerability score ranging from 0.5 (no apparent risk to any value) to 1.5 (direct risk). Conservation areas are then ranked for protection based on these 'rarity x vulnerability' scores. Other secondary characteristics such as: past history of control; land tenure; risk of reinvasion, are used only to separate areas which are tied on primary scores.

Parkes (1991) has noted that the presence of a valued resource does not in itself justify action against an exotic vertebrate pest. Justification he suggests relies upon how much the resource is affected by the pest and this impact is a function of population dynamics, directness of the impact and ecosystem resilience Parkes (1991). Parkes advocates basing weightings of scores on the population dynamics (rates of increase, proximity to carrying capacity) of the pest-resource system. The system currently employed does not include weightings for population dynamics, and is notable also for the absence of any weightings for location, or the additional benefits obtained by visitors to sites, or the general population, from protection of the forests. The thrust of the 'biological' scoring system appears to be to emphasise existence and option values associated with each conservation area. Use values appear not to be considered. An alternative scoring system can be proposed which includes some recognition of location factors and the 'use benefits' which will be obtained from protecting various areas. However research is required to determine what weights should be given to location and use values in an expanded weighting system.

Efficient Levels of Protection

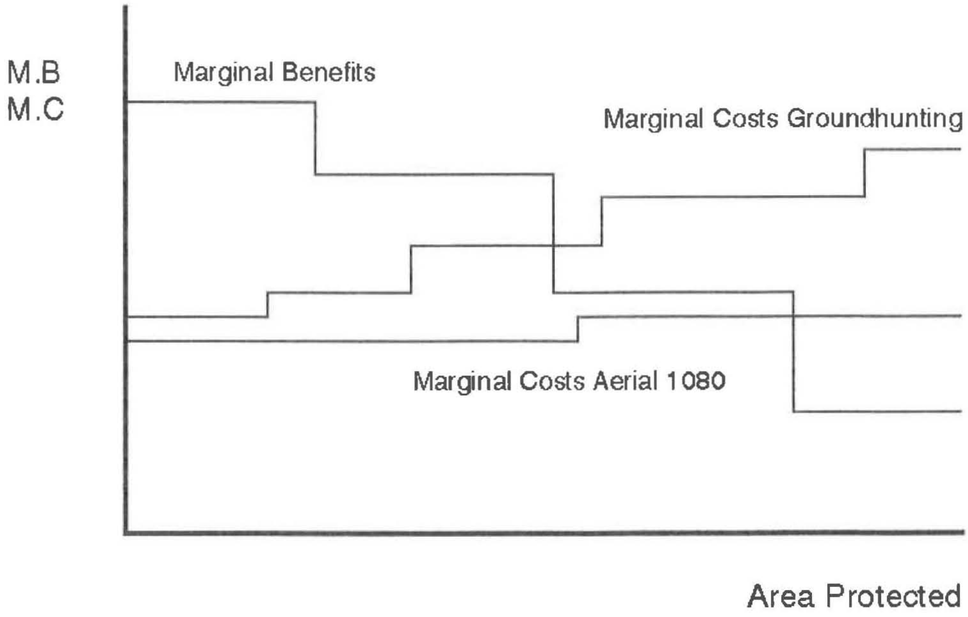
To be really useful protection efforts must either aim for eradication of exotic pests, or for sustained protection by holding pest numbers to low levels. In practice resources available for exotic species management are limited and decisions are required on how much to spend on management and where to apply those efforts.

In a static framework, protection activities should be extended so long as the marginal benefits from protection exceed the marginal costs of that additional protection. On conservation lands, protection strategies typically focus on blocks of land containing hundreds or thousands of hectares. The marginal costs of protecting additional blocks of land can be calculated and compared to the additional benefits obtained from protecting further blocks. Marginal analysis suggests that additions to net benefits will be attained so long as extending protection onto further blocks results in additions to marginal benefits which are greater than marginal costs.

Analysis of the production functions and cost data for protection activities indicates that the marginal costs per hectare of extending control to additional blocks varies greatly, and depends upon the choice of control technique. Location and terrain exert major influences on costs of control, particularly if groundhunting techniques are employed. For groundhunting, marginal costs per hectare of protecting additional areas will increase strongly as the number of blocks protected is increased, and more distant and more rugged areas are included. In contrast, extending protection by increased use of aerial application of 1080 baits may lead to only modest increases in marginal costs per hectare protected, as location and terrain play a much smaller role in determining costs per hectare.

Extending protection to additional areas can be expected to provide additional benefits, however these marginal benefits will vary with the characteristics of the areas protected. If areas of greatest benefit are protected first then marginal benefits will follow a pattern of lumpily declining marginal benefits. Figure 1 below illustrates hypothetical marginal benefit and marginal cost curves for protection of conservation lands.

Figure 1. Illustrative Marginal Benefits and Marginal Costs of Forest Protection Programmes



The efficient level of protection occurs where the marginal benefits of extending protection equal the marginal costs of extending protection to a further block. Judging when this point is reached does require information on the magnitudes of marginal benefits and marginal costs as the area protected is increased. Obtaining this information to allow accurate judgment of the efficient level of protection is an obvious management task.

Costs of various protection techniques

Protection against damage by possums can be achieved by several techniques including trapping and hunting, poisoning by ground hunters, and poisoning with a toxin 1080 delivered by air in cereal baits. Despite the fact that forests have been protected from damage by possums for several decades in New Zealand, obtaining accurate comparative data on protection costs is a difficult task. Prior to the establishment of the Department of Conservation in New Zealand in 1987, little useful information on costs of control were recorded by the responsible Government departments. More recently the major problem appears to be how to cost and include non-operational items such as planning and administration of protection activities (Warburton, Cullen, McKenzie, 1991). However some cost data which is believed to be comparable for the various control techniques is available and is displayed in Table 2.

There are two protection situations which can be considered: knockdown and maintenance. Knockdown situations are circumstances where possum densities are high, eg 6 / ha and the initial requirement is to reduce this to below a chosen level. A target figure of 1 / ha might be chosen to ensure that vegetation damage is minimal. Possums numbers can increase rapidly following an initial knockdown, and ongoing efforts are required to ensure that damage to vegetation does not rapidly re-occur. Hence ongoing maintenance efforts are required to ensure that damage to vegetation is kept below some acceptable threshold level. While vegetation protection is only likely to be valuable if it provides long term benefits, a two part approach to protection is defensible and costs for the two components can be considered separately.

Table 2 illustrates that for the areas listed, costs per hectare protected are lower using aerial 1080 than are groundhunting techniques. This cost advantage to aerial 1080 is likely to be reduced or even reversed where the area protected is relatively small, and where helicopters are required instead of fixed wing aircraft.

Table 2. Possum Control Costs for High Population Density Areas

Year	Location	Area (ha)	Method	Kill%	Cost $/ha
1991	Whitecliffs	1500	aerial 5kg/ha	91	21.80
1990	Waipoua	18000	aerial 5kg/ha	86	19.22
1990	Waipoua	18000	aerial 10kg/ha	86	31.96
1989	Otira	6800	aerial 10kg/ha	80	26.12*
1989	Otira	2230	groundhunting	84	29.82
1990/2	Copland	3500	ground x2	84	48.54

* Shadow cost estimate
Source: Warburton,Cullen, McKenzie, 1991

Periodic application of aerial 1080 may provide the least-cost method of providing long term protection of vegetation on large blocks where possum population densities are low. Possum numbers have been found to increase at annual growth rates between 20 -30 % in areas where food supply is not a limiting factor. If an 80% kill of possums is obtained on an area then at a 22 percent annual growth rate possum numbers will take about 6 years to rebound to equal those present before the control operation commenced (Warburton, Cullen, McKenzie, 1991). Control operations every six years appear to be a possible strategy for protecting forests. This six yearly control could be attempted by aerial 1080 operations or by groundhunting operations. Because aerial 1080 has a cost advantage over groundhunting on large blocks, aerial 1080 appears to provide the least cost way of protecting forests from damage by possums when densities are low. Table 3 below, illustrates present values of possible control costs for low possum population density areas using various control methods over a 23 year period of control. A 10% discount rate is used in these calculations.

These costings are sensitive to assumptions about bait application rates, length of the control programme, areas protected, probability of failure, choice of discount rate and other influences. Some simple selective sensitivity tests can be conducted to determine the robustness of the figures. One obvious test is whether a probability of failure of aerial 1080 operations because of rain or other factors, can overturn the apparent cost advantage in favour of aerial 1080. Warburton, Cullen and McKenzie

(1991) report that an, assumed, twenty percent probability of failure for aerial 1080 operations does not increase costs sufficiently to overturn the result that aerial 1080 appears to provide the least cost way of both achieving knockdowns of high possum population densities, and providing ongoing protection against damage by possums at low population densities.

Table 3. Present Values of control costs to maintain possum populations below a given density

Method	Present Value of Costs $/ha
6 year aerial control (5kg/ha)	39.65
6-year aerial control (10kg/ha)	66.01
Annual ground control	85.79
Biennial ground control	67.30

Source: Warburton, Cullen, McKenzie, 1991

Recent technological advances in aerial 1080 control programmes have significantly reduced control costs per hectare. Use of only 5kg per hectare of cereal bait instead of 10 kg per hectare, allows a 60 percent reduction in costs per hectare, and refinements in application techniques may further reduce costs per hectare in future. These advances do mean that the cost of protecting conservation areas against possum damage over the next twenty years should be significantly less than $1 billion.

Some Influences on Groundhunting Costs

Econometric analysis can be employed to determine which factors influence effectiveness of possum control operations and their cost effectiveness. Econometric analysis is dependent on the quality of the data employed if reliable results are to be generated. The GIGO principle does hold here, but some insight can be obtained from analysis of possum control data,.despite some worries about the comparability of the data . Data from twelve groundcontrol possum operations is employed to test the determinants of kill percentages, cost/ha, and cost/possum. Ten of the regions are on the West Coast, and two are in Otago and the management areas range from 195 ha to 2806 ha. The numbers used in the analysis were extracted from data provided by the Department of Conservation. Unfortunately there is insufficient data available at present to complete a similar analysis of aerial control costs.

OLS multiple regression analysis was used to determine the role of four factors in determining costs and effectiveness of groundhunting. A summary of the results from regressions to 'explain' cost / ha, cost / possum, and kill % are listed below, and some of the results are shown in the appendix tables and plots.

1. Cost/ha for groundhunting can be explained by in order of importance: Kill% attained; start possum density; and management area. The signs of the independent variables are all as expected. Cost/ha does vary directly with kill% attained and with start density, but has a strong inverse relationship with management area.
2. Cost / possum for groundhunting can be partly explained by start possum density

and this variable has the expected negative sign. The two other independent variables, area, and Kill% attained, are not statistically significant.
3. Kill% attained by groundhunting can be explained by in order of importance: cost/ha; start possum density; and management area. The signs of the independent variables are all as expected. Kill% does vary directly with cost/ha and inversely with start density, but has no statistically significant relationship with management area.

These results can be considered when designing forest protection strategies. Two important points to note from this analysis of groundhunting are the strongly inverse relationship between cost/ha and management area, and the strong direct relationship between kill% and cost/ha.

Aerial control of possums is likely to generate rather different results. A breakdown of costings for one well documented aerial control of possums reveals that the major components are: Bait 50 %, aircraft 14.5 %, monitoring 16.8%, planning and administration 10% (Warburton,Cullen, McKenzie, 1991). Aerial control seems likely to provide control of possums at near constant direct cost/ha irrespective of number of hectares treated for blocks greater than say 200ha. Steepness of terrain and distance from airstrips will cause only minor increases in costs per hectare as aircraft costs are a minor part of total costs. Aerial control may provide a near constant kill% irrespective of expenditures per hectare so long as a minimum amount of bait such as 5kg per hectare is applied. But aerial control costs per hectare are certain to increase significantly for smaller areas, and where helicopters are required rather than fixed wing aircraft.

Benefits from Forest Protection

For planners to make informed judgments about the merit of using resources for a particular task, information is required about both the costs and the benefits obtained from use of resources. Because resource constraints mean only some areas can be protected from damage by possums, it is important to know where forest protection efforts will provide the greatest benefits. While only some information is known about the costs of protecting vegetation from damage by possums, almost nothing is known about the benefits obtained from vegetation protection activities. At present areas are ranked for protection by reference to an index of biological characteristics. While this device may serve to rank areas for protection it does not provide any direct information on benefits obtained from protection.

Our focus is on protection of conservation lands, and no market-generated data is available to provide estimates of benefits from vegetation protection on these lands. Non-market valuation techniques appear to provide the obvious means to generate some information to help make judgments on the benefits of vegetation protection programmes. These techniques are quite widely used to generate information to aid decision-making when there are no markets present providing information on prices and quantities. The most obvious technique to use in this case is Contingent Valuation Method (CVM) which use surveys to determine 'willingness to pay' for goods or services. Willingness to pay studies have been completed in New Zealand for many 'environmental goods' including the value of National Parks, the value of clean air and water, the value of road safety and many other items (Fahy and Kerr, 1991).

Two New Zealand studies have used Contingent Valuation Method to generate data on willingness to pay for vegetation protection activities. Greer and Sheppard (1990) employed a nationwide postal survey to obtain information on benefits of research into biological control of *Clematis Vitalba*. Results from this study indicate that New Zealanders were willing to pay between $44m and $111m for research into biological control of *Clematis Vitalba*. Lock (1992) employs contingent valuation method to generate data on willingness to pay for possum control activities. This study asks respondents willingness to pay for possum control in the Whanganui-Manawatu region, and willingness to pay for national control of possums.

These studies suggest that data might be generated on willingness to pay for forest protection programmes. But some difficult issues have to be dealt with if CVM is to be used to generate WTP for forest protection at several sites, to allow decisions to be made on allocation of a forest protection budget. One problem to be solved is how to convey to respondents the nature of the outcomes likely to be obtained from forest protection activities.

Visual aids have been used in some studies to indicate before and after effects, and similar devices can be used for 'protection from possum damage' studies. A 'Forest Quality Ladder 'can be constructed which is similar to the Water Quality Ladder used in some CVM studies, to convey to respondents the status of the vegetation in an area. Figure 2 illustrates the Forest Quality Ladder used in a recent Contingent Valuation study Cullen and Kerr (1992).

Figure 2. Forest Quality Ladder

A	No damage by possums
B	Possums graze on some palatable trees and shrubs causing minor damage to the forest
C	Possums intensively graze on palatable trees and shrubs causing major damage to the forest
D	Death of many trees and shrubs, major change occurs in the forest composition

As well as this relatively standard application of CVM, studies can be attempted to determine what it is that people express WTP for. Cullen and Kerr (1992) investigate peoples' willingness to pay for possum control programmes, but also attempt to dig a little deeper to find out what it is that determines peoples' willingness to pay. The focus is on the importance people attach to various factors in determining whether regions of indigenous vegetation should be protected from damage by possums. The motivation for this line of research is the desire to discover whether the general population attach significant weights to changes in use values for forests protected from damage by possums. The relevant survey question took the form shown below.

5. There are approximately 70 million possums in New Zealand and most parts of the country are inhabited by them. There is a limited amount of money available to spend protecting forests from damage by possums so only some areas can be protected. We wish to know how you would rank conservation areas for protection from damage by possums.

Please indicate how important are the following factors in determining which conservation areas should be protected from damage by possums.

(1 = no importance, 2 = slight importance, 3 = moderate importance, 4 = high importance, 5 = most importance). Please circle the appropriate numbers.

Distance from the conservation area to large centres of population	1 2 3 4 5
Ease of access to the conservation area for viewing and recreation	1 2 3 4 5
Rarity of the plant and animal species which will be protected from damage	1 2 3 4 5
Scenic attractiveness of the species which will be protected from damage	1 2 3 4 5
Vulnerability of the species which will be protected from damage	1 2 3 4 5
Distance from the conservation area to farms	1 2 3 4 5
Recreation opportunities in the conservation area	1 2 3 4 5

Some initial results from this study are reported in Kerr and Cullen (1992).

Delivery of Forest Protection Programmes

Forest protection programmes on conservation lands can be supplied in several ways including, State supply, private contractors, and mixed contract and State supply. Choice of supply arrangements can be important in influencing the incentive structures, the costs, and effectiveness of vegetation protection programmes

At least one author has argued that delivery of forest protection programmes has been ineffective in the past because of the inappropriate incentive structures associated with bounties on possums, and possum hunting programmes (Ericksen 1991). Ericksen asks, do bounties and groundhunting programmes lead to a focus on the correct target, and ensure that resources are used in the most efficient manner? He concludes that bounties, and payments for controlling possums provide some misleading signals and do not lead to efficient uses of resources.

Bounties he argues are blunt instruments which do not recognise the differing marginal benefits attained from control of possums on different regions. Hence a uniform bounty payment system is likely to lead to harvest of possums on highly accessible regions such as roadsides which may have low ecological value, and little harvesting on inaccessible but possibly ecologically important regions. Efforts have to be concentrated on the most important conservation areas to ensure the most effective use is made of forest protection dollars. This appears to be a reasonable criticism of bounty systems.

A second problem Ericksen detects is the inappropriate incentive structure which motivates groundhunters. Groundhunters he argues have an incentive to ... 'ensure that breeding populations remain or exist in all areas to supply future income.' He advocates an alternative approach which transforms the situation from a harvest problem into a requirement to deliver 'absence of possums'. The second part to this argument is the suggestion that a focus on possums is inappropriate, for the real objective should be the absence of possums.

Taking the first part of the argument first, this line of reasoning is dependent on the monitoring agency or the employer failing to correctly determine the true level to which the possum population is reduced by control activities. Secondly the argument is dependent on the returns from possum hunting being sufficient to make possum hunting profitable. As was demonstrated in an earlier section possum hunting is unlikely to be a profitable activity wherever there are low population levels and low prices for skins. Hence for possum hunters to be motivated to leave a residual possum population to breed and provide future employment, they must anticipate that possum populations will be allowed to increase several fold in future. A commitment to continued control on 'at risk' areas is required to combat that notion.

The second part to the argument also appears only partly correct, the focus on possums killed is inappropriate, but the ultimate objective is forest, or forest habitat status, not absence of possums per se. Forest protection programmes might be delivered in a cost effective manner if contracts were let for the delivery of forest of a certain status. Contractors would be able to deliver this by controlling possums using least cost technologies, subject to certain restrictions to protect public safety, to control effects on non-target species and other requirements. This approach while theoretically appealing, does encounter the widely noted problem of difficulty in monitoring outcomes. While forest status can be monitored over time, the indices which could possibly be used for this purpose are not yet well tested, and improvements in forest status are difficult to measure over short time periods. Numbers of dead possums, and changes in possum densities in an area, are both easier to measure over short time periods than are changes in vegetation status.

Ericksen's (1991) advocacy for the introduction of a system of contestable or tradable property rights for the absence of possums is useful for forcing consideration of the way in which forest protection programmes are organised in New Zealand. However the objectives he seeks, namely cost effective use of resources on forest protection, can be achieved without the need to create new property rights. The Department of Conservation can continue to prioritise areas for protection, and can call tenders for the achievement of designated possum population densities, subject to public safety regulations, and effects on non-target species. Final payment can be dependent on achievement of the target population density as verified by results from trapcatch surveys (Warburton, Cullen, Mckenzie 1991). This approach appears to have the virtues of simplicity, flexibility, and low administration costs compared to a new property rights system, whilst ensuring that least cost techniques can be found for the control of possums, subject to some necessary safety constraints. A further virtue of this approach is the transparency of data on operational costs of control operations.

Summary

Protecting indigenous forests and other indigenous species against invasion and damage by exotic species such as possums is a continuing task in New Zealand. Several strategies can be pursued in the management of these exotic species, and there are multiple objectives which can be considered when determining which strategy to pursue. Because the resources available to manage these exotics species are limited, efficiency considerations are important and should be considered when designing forest protection policies. Marginal analysis suggests that protection should be extended until MB equal MC. There is some data available on the costs of various possum population control programmes. These costs are influenced by the size of the areas controlled, the control technique employed, the nature of the terrain, and practicality of using fixed wing aircraft. Ranking areas for protection is accomplished at present by use of a 'biological' scoring system which attaches no weight to use values of sites. Few attempts have been made to obtain data on the benefits obtained from forest protection programmes, but contingent valuation method shows some promise on this front.

Continued protection of indigenous forests from damage by possums is likely to be achieved after possum densities have been reduced to low levels. Possum population densities can be reduced to low levels by two aerial 1080 operations, for a total cost of less than $40 per hectare. Periodic control operations using aerial 1080 may provide the lowest cost method of maintaining densities at low levels. 'Once every six year' control operations may provide population control at an annualised cost of approximately $4.50 per hectare. Adoption, and successful application, of least cost control techniques, should ensure that protection of indigenous vegetation on conservation lands costs less than $1 billion over the next twenty years .

Transparency of all costs involved in forest protection activities is desirable and might be achieved by calling tenders for possum population control programmes, together with the use of explicit guidelines on procedures for the reporting of data on non-operational costs. These steps should ensure that better information is available than currently exists for forest protection programmes. Continued advances in the technology of aerial 1080 control programmes provide hope that control costs can be further reduced allowing more 'at risk' forest to be protected per million dollars of taxpayers funds.

References

Cowan,T.P. 199, The ecological costs of possums in the New Zealand Environment. in, Proceedings of a Symposium on Tuberculososis, Veterinary Continuing Education Publication No. 132, Massey University, 73-88.
Crawley, M.J. 1986, The population biology of invaders. Philosophical Transactions of the Royal Society., London,Series B, 314: 711-731.
Cullen,R. and Kerr, G.N. 1992, Forest Protection Benefits. Unpublished research report, Lincoln University.
Elliot,G.P. and Ogle,C.C. 1985, Wildlife and wildlife habitat values of Waitutu Forest, Western Southland. Fauna Survey Unit Report No.39.
Ericksen, K. 191 A new approach to possum control. NZAE /AAg EA. Conference paper , August 1991
Fahy, A.E.C. and Kerr, G.N. 1991, Valuing non-market goods. Unublished report for the Ministry for the Environment, Centre for Resource Management, Lincoln University.
Greer,G. and Sheppard, R.L. 1990, Economic evaluations of the benefits of research into biological control of Cematis Vitalba. Agribusiness and Economics Research Unit Report No. 203.
Hobbs,W, . 1991. Possums may cost $1000m. The Press, 28/6/91.
Lock, G.M. 1992 , The possum problem in the Manawatu-Wanganui Region. MAgSci Thesis, Massey University.
Kerr,G.N. and Cullen,R. 1992, Insights from three recent non-market valuation studies. NZAE Confernce paper .
Seitzer,S., 1992, Possums: an ecological disaster. New Zealand Geographic, 13, 42-70
Department of Statistics, New Zealand Official Yearbook, Department of Statistics, Wellington,1990.
Department of Statistics, New Zealand Official Yearbook, Department of Statistics, Wellington,1992.
Shaw ,W.B.1988, Botanical conservation assessment of crown lands in the Urewera/Raukamara planning study area. Forest Research Institute Contract Report
Parkes,J. Pest management for conservation in New Zealand. Forest Research Institute,1991
Warburton,B. , Cullen, R. and McKenzie, 1991, D. Review of Department of Conservation possum control operations in West Coast Conservancy. Forest Research Institute.
Townsend ,C.R. ,1991, Exotic species management and the need for a theory of invasion ecology. New Zealand Journal of Ecology, 15(1) 1-3.

Multiple Regression Y_1:COST/HA 3 X variables

DF:	R:	R-squared:	Adj. R-squared:	Std. Error:
11	.97	.941	.919	2.657

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
REGRESSION	3	901.344	300.448	42.55
RESIDUAL	8	56.488	7.061	p = .0001
TOTAL	11	957.832		

Beta Coefficient Table

Parameter:	Value:	Std. Err.:	Std. Value:	t-Value:	Probability:
INTERCEPT	-2.232				
AREA	-.003	.001	-.253	2.4	.0432
START DENS	2.45	.701	.353	3.495	.0081
KILL%	.241	.048	.565	5.067	.001

Multiple Regression Y_1:COST/POSSUM 3 X variables

DF:	R:	R-squared:	Adj. R-squared:	Std. Error:
11	.762	.581	.424	4.871

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
REGRESSION	3	263.636	87.879	3.703
RESIDUAL	8	189.85	23.731	p = .0616
TOTAL	11	453.486		

Beta Coefficient Table

Parameter:	Value:	Std. Err.:	Std. Value:	t-Value:	Probability:
INTERCEPT	21.944				
AREA	-.003	.002	-.308	1.098	.3041
START DENS	-4.184	1.285	-.875	3.257	.0116
KILL%	.048	.087	.164	.554	.5949

Multiple Regression Y_1:KILL% 3 X variables

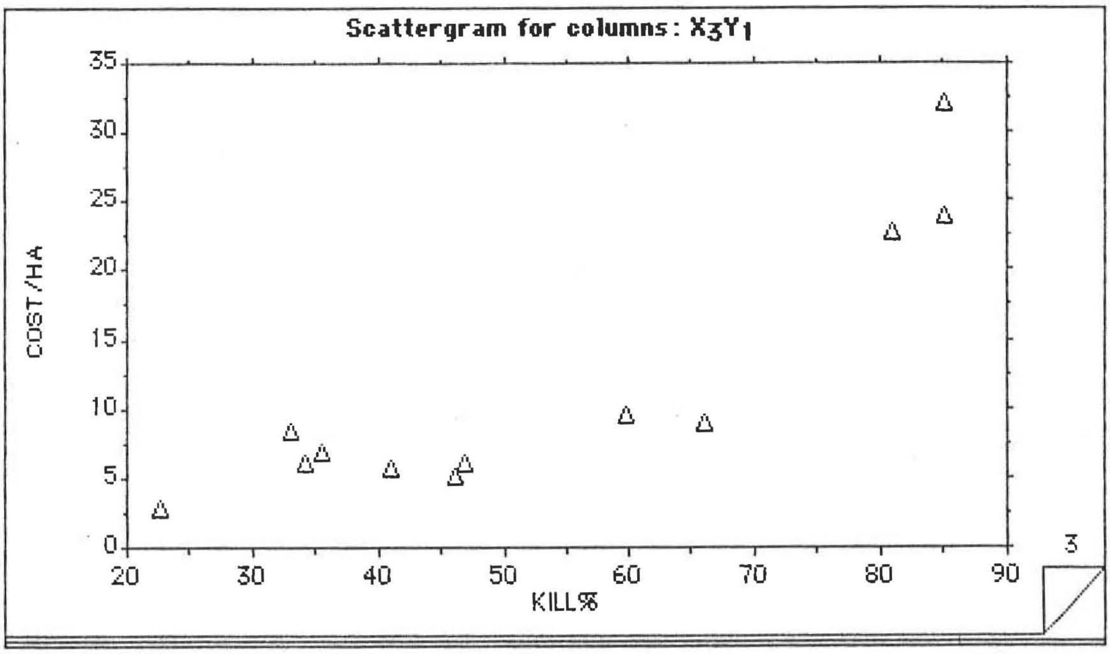
DF:	R:	R-squared:	Adj. R-squared:	Std. Error:
11	.927	.859	.806	9.615

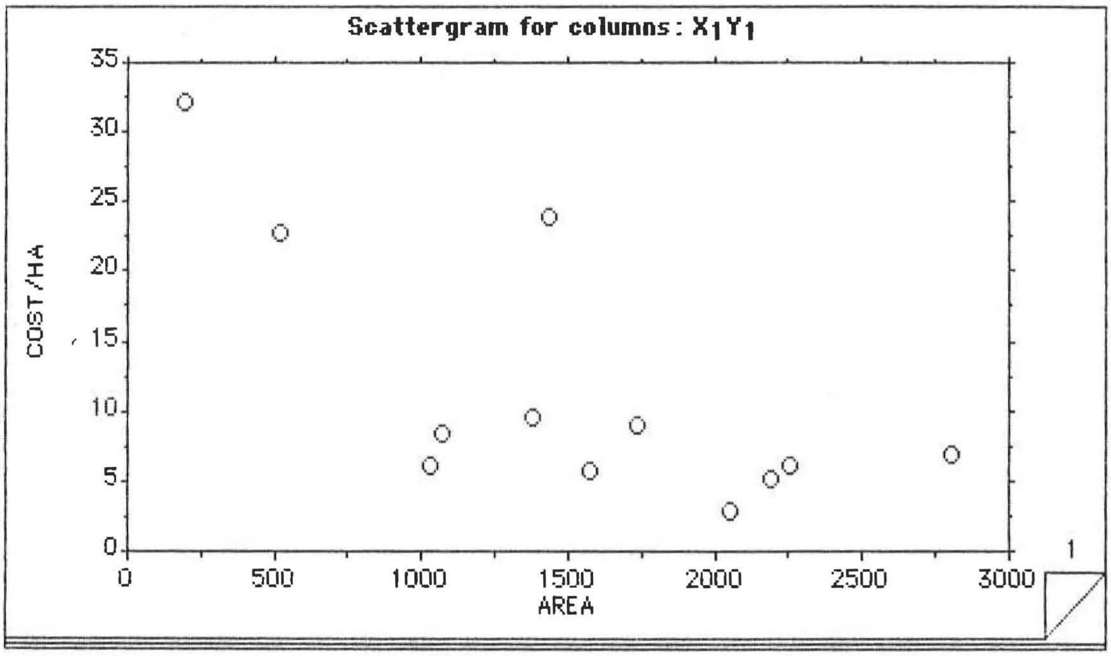
Analysis of Variance Table

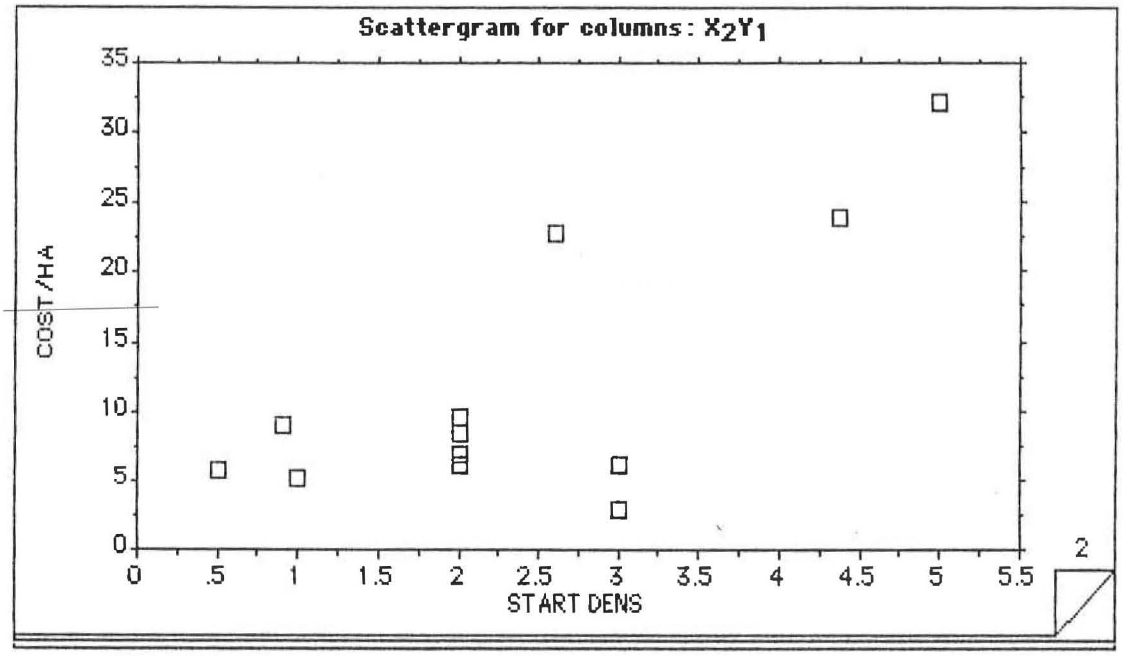
Source	DF:	Sum Squares:	Mean Square:	F-test:
REGRESSION	3	4510.41	1503.47	16.262
RESIDUAL	8	739.626	92.453	p = .0009
TOTAL	11	5250.036		

Beta Coefficient Table

Parameter:	Value:	Std. Err.:	Std. Value:	t-Value:	Probability:
INTERCEPT	21.131				
AREA	.007	.006	.24	1.222	.2567
START DENS	-6.465	3.321	-.397	1.947	.0874
COST/HA	3.16	.624	1.35	5.067	.001


Scattergram for columns: X3Y1
COST/HA
KILL%
35
30
25
20
15
10
5
0
20
30
40
50
60
70
80
90
3


Scattergram for columns: X1Y1
COST/HA
AREA
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
1


Scattergram for columns: X2Y1
COST/HA
START DENS
35
30
25
20
15
10
5
0
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
2