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Measuring conservation achievement

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ABSTRACT

The absence of methods and systems to measure the state of the nation's natural heritage assets prevents specification of measurable conservation goals, measurement of conservation achievement and recognition of the most cost-effective conservation projects. This contributes to the poor visibility of returns on society's investment in conservation and also to doubt about the quality of expenditure. Together, these factors probably penalise conservation in trade-offs against society's other quality-of-life objectives. Here, a framework for a catalogued inventory of natural heritage assets is proposed and used first to define measurable conservation goals and then to develop models for reporting on the status of natural heritage, for measuring conservation achievement and finally, for cost-utility evaluation of conservation projects. The natural heritage asset inventory is based on environments subdivided by land cover and then by levels of human induced processes causing biodiversity loss (biomass removal, introduced predators and competitors, resource modification, fragmentation and artificial ecological connection). The status of natural heritage is conceived in terms of spatial extent, the intensity and the number of human induced processes responsible for biodiversity loss. Conservation achievement is the natural heritage restored plus loss avoided as a result of conservation. The worth of a conservation project outcome is measured by a utility index based on the product of three primary components: project return, urgency and feasibility. Their various sub-components are defined and their measurement is discussed.

1. INTRODUCTION

How much would you spend on painting your house if you only had the vaguest idea of its value, cash was tight, and you didn't know:

- What condition the house was in and how much its condition would be protected by painting it?
- How much painting was needed and which bits needed painting most?
- How much painting got done for your money?

But you do know that the family will be inconvenienced while the job is underway and the cost will force you to cancel a very desirable week at the beach.

You would be most unlikely to forgo the beach holiday. You might ask a house painter what needed painting most, but vested interest demands scepticism in the advice given, so you might even take a punt that painting the house is not really necessary, particularly if it will be someone else's problem by the time it really matters.

How do you think the house painting business might fare if this scenario were typical? House painters would not be wealthy! They probably couldn't even afford the right tools for the job and in the absence of outcome measurement (i.e. how much loss is avoided per dollar spent), how could they be efficient? There would also be some 'downstream' effects: not a lot of development and improvement of painting equipment for instance.

Would you spend more on painting the house if you had good information about its condition, the parts most in need of attention, the losses avoided by painting it and a good breakdown of costs? And if all house owners had this information, what would be the consequences for the condition of houses and the house painting industry? My guess is there would be lots of very tidy homes and plenty of increasingly efficient house painters set up with the very best equipment for the job. Decaying and derelict houses would be rare and the cost of getting your house painted would steadily fall.

This is just an analogy for natural heritage conservation. The taxpayer is the house owner, natural heritage is the home, the holiday represents other objectives (e.g. health, welfare, education, economic growth, etc.) and conservation is the house painting business. The question faced by the house owner is analogous to that of the taxpayer: how much of other benefits is it worthwhile to forgo in order to secure natural heritage? However, there is no inventory of our natural heritage asset portfolio and this prevents:

- Measurement of natural heritage status
- Measurement of conservation achieved
- Identification of the most cost-effective conservation projects.

In this information vacuum, there is no basis for identifying the optimum investment in conservation and the immediate, tangible and valued returns from investments in other objectives are a compelling incentive to penalise conservation. This may be why biodiversity decline is our most pervasive environmental issue (Ministry for the Environment 1997). Our inability to measure achievement and identify the most cost efficient projects generates doubt about efficiency and agency accountability and this has provoked strident criticism of conservation in New Zealand (Hartley 1997; Kerr 1998), even though the problem is common to all nations concerned with natural heritage conservation (UNEP 1995). Doubt about conservation efficiency, quality of expenditure and agency accountability must be expected to further penalise natural heritage conservation in trade-offs with other quality-of-life objectives.

Halting the decline of natural heritage requires a major increase in conservation investment. One way to achieve this is to adopt a strategy aimed at altering the trade-off between quality-of-life objectives in favour of conservation. If society's trade-off decisions reflect the visibility, value and efficiency of the return on investments, then allocation to conservation should grow in response to a more visible, valued and efficient return. Fundamental and critical to this strategy are systems to measure conservation achievement and evaluate the cost-effectiveness, and value to society, of different courses of conservation action.

New Zealand's natural heritage is its portfolio of natural assets. Conservation is the business of maintaining that asset portfolio, enabling society to enjoy the products and services derived from it. Conservation achievement is the sum of gains made and losses avoided, summarised by the difference between the status of the asset portfolio with and without conservation investment. The value to society of that return is the net worth of all products and services gained, and losses avoided, by conservation investment. A conservation goal specifying how much and which bits of the natural heritage asset portfolio society wishes to maintain can express society's perception of the optimum trade-off for investment in conservation relative to other objectives. The New Zealand Biodiversity Strategy presents a spectrum of goals to help New Zealanders decide how much natural heritage they wish to retain. Inventory of the asset portfolio is fundamental to goal definition and measurement of the return on conservation investment.

This paper proposes an approach to measurement of conservation achievement in order to improve the visibility of the return on society's conservation investment and to demonstrate the efficiency of conservation expenditure. It proposes a framework for a natural heritage asset inventory as a platform for measurable definition of a conservation goal and then develops methods for measurement of natural heritage status, conservation achievement and the cost-effectiveness of diverse conservation outcomes.

2. DEFINING A GOAL FOR NATURAL HERITAGE CONSERVATION IN NEW ZEALAND

Natural heritage is New Zealand's physical and biological wealth, supporting our economy through use of natural resources and the benefits from services provided by healthy ecosystems. Much of our natural heritage occurs only in New Zealand and so provides the inspiration for our national identity, symbols, logos and trademarks: the kiwi, silver fern and koru, Aorangi and Rangitoto. The objective of conservation is to maintain our natural assets. But how can this be expressed in measurable ways to enable quantifiable expression of conservation goal options? Measurable goal options are needed because:

- They express different levels of conservation enabling society to make informed choices about the desirability of different levels of conservation. This promotes efficient trade-off decisions between society's objectives.
- A goal provides a basis for measurement of the contribution of individual conservation projects to the maintenance of our natural asset portfolio. This contributes to efficient trade-off decisions between conservation options.

Because conservation is an asset management business, a conservation goal is most usefully expressed in terms of the wellbeing of the asset portfolio and this requires a catalogued inventory in order to make transparent trade-offs and monitor progress in relation to the goal. Biological assets are catalogued in two ways: taxonomic and ecological. The Linnaean system of taxonomy groups asset types into phylogenetic levels (i.e. species, genera, families, orders, classes, phyla and kingdoms). Ecological classification recognises associations of biota, biological processes and their environment as ecosystem units.

2.1 The taxonomic catalogue

The Linnaean system is robust and universally accepted but much of the variety of life awaits taxonomic description and recognition. We have good, though incomplete, taxonomy for terrestrial vertebrates and vascular plants but distribution data for only a portion of these. Much biodiversity (small invertebrates, fungi, unicellular life forms and deep-sea fauna) awaits taxonomic recognition. Consequently, we are not in a position to even recognise much of the phylogenetic variety of life in New Zealand, much less its distribution and conservation status. This means that a taxonomic catalogue of biodiversity offers very little basis for making efficient choices and measuring progress towards the conservation objective: progress and efficiency cannot be measured if we have no means of comprehensively knowing which assets are being lost and where loss is happening. Goals and project outcomes based on numbers of species conserved or lost would be unmeasurable because the contributions of projects to the goal cannot be measured in terms of species maintenance if most losses cannot be recognised. It is therefore unhelpful to define biodiversity conservation goals primarily in terms of species loss, even though a fundamental objective of biodiversity conservation is prevention of human induced species loss.

2.2 The ecological catalogue

Ecological classification is undeveloped compared with the Linnaean system of taxonomy. There is no single generally accepted system of classification and the choice of approach is purpose and context driven. Approaches can be divided into two groups: community based and environment based.

2.2.1 Community based classification

Community based approaches recognise ecological units from characteristic species assemblages. These assemblages are confined to the taxonomically recognisable and most readily observed portion of a community that, on land, is typically the structurally dominant vascular plants (e.g. Newsome 1986). For the purpose of cataloguing biodiversity assets, this approach has one major advantage: it is a spatially comprehensive inventory for terrestrial life. However, there are several limitations. First, it does not provide for the marine environment, nor the physical landform elements of natural heritage. Second, it is based on a tiny portion of total biodiversity and requires the assumption that the distribution and wellbeing of all other biodiversity is well correlated with the vegetation classification. Third, while the approach offers a reasonable inventory of remaining vegetation, it provides little basis for recognising what has already been lost and so confounds assessment of the significance of what remains and evaluation of trade-offs.

2.2.2 *Environment-based classification*

Environment-based classification relies on the premise that the distribution of all biota, biological processes and landform features is determined by environmental pattern, previous disturbance, and geological and biogeographic history. The Ecological Regions and Districts of New Zealand (McEwen 1987) identify units of recurrent ecological pattern and so offer an ecological catalogue of terrestrial natural heritage assets. However, being contiguous units, they contain considerable environmental and biological variation. Environments can be defined in terrestrial, freshwater, and marine environments on the basis of similarity in a suite of environmental attributes (Bailey 1996). Environmental attributes are selected on the basis of both functional linkage to the major life-processes of biota and correlation between species distributions and environmental attributes. Consequently, environments are characterised not just by environmental and landform similarity, but also by biotic assemblages, ecological and physical processes. They are the most effective stratification of natural heritage because they account for more variation in species composition and landform features than other options such as Ecological Regions, Newsome's (1986) vegetation cover, or a purely spatial classification (J. Overton, pers. comm.)[1]. Furthermore, environments can be recognised at any scale.

Environment based classification does not inventory natural heritage; it provides a catalogue system, or framework, for the inventory. Information about content is required to turn the catalogue into a natural heritage inventory. In this sense, environment-based classification is analogous to a library with its shelves and Dewey catalogue system. It is the framework for a structured inventory.

2.3 Biodiversity inventory

Since the environmental classification accounts for broad scale variation in biotic and landscape pattern, high-resolution differentiation of land cover type is not necessary because it can be assumed that the same type in different environments represents different associations of biota. For example, the biodiversity of 'native forest' or of 'wetland' land cover would be somewhat different in each environment. This means that land cover information classified into relatively few predominantly natural types could form the basis for a biodiversity inventory if catalogued by environment. Suitable cover classes for mainly natural areas would include primary forest, secondary forest, shrub land, wetland, tussock grassland, bare ground, duneland, rivers and streams. In mainly modified areas, cover classes would include cropland, horticulture, exotic grassland, exotic forest, exotic shrub land, residential and urban areas.

A complete inventory of biodiversity must include the content of all types of land cover because both indigenous and exotic biodiversity are present in all types. However, the wellbeing of indigenous biodiversity varies with the type of land cover: there is far more indigenous biodiversity associated with forest or wetland cover than with crop or urban cover because of the type and intensity

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[1] Overton, J.: 'Measuring the ability of four spatial classifications of New Zealand (ecological districts and regions; environmental domains; Newsome's (1986) vegetation cover; an arbitrary spatial classification based on northing and easting) to account for vegetation pattern in National Indigenous Vegetation Survey (NIVS) plots.' Unpublished report)

of human modification which is inimical to indigenous biodiversity. Thus land cover data provide a first-order stratification of biodiversity within an environmental framework. However, this level of differentiation is not sufficiently sensitive to changes in the condition of biodiversity within land cover types to define a conservation goal, measure conservation achievement and evaluate project outcomes. For example, there is no distinction between a native forest community depleted by introduced predators and browsers and another forest which sustains species that are vulnerable to introduced mammals (e.g. *Dactylanthus taylori*, kokako, kiwi, giant weta, etc.). It is therefore necessary to further differentiate the status of biodiversity if the inventory is to be sensitive to conservation project outcomes and so provide a basis for measurement of the return on investment in conservation.

Two possible approaches are discussed here: (1) direct assessment of biodiversity condition and (2) assessment of natural character, or its converse, human modification as a surrogate for biodiversity condition.

2.3.1 Direct assessment of biodiversity condition

Direct assessment of biodiversity condition is based on a comparison of the present biota with that thought to be present at some historic reference point, such as c. 1100 AD when Polynesian colonisation began. The strength of this approach is that similarity is a direct measure of biodiversity condition and so is a direct measure of conservation outcome. The disadvantages are that:

- The comparison could only be based on the taxonomically recognised and surveyed subset of biodiversity for which the pre-human distribution can be estimated. This is a very small subset of total biodiversity;
- The cost of survey precludes general application;
- A similarity measure implies an objective aimed at the pre-human state which may inappropriately influence goal formulation towards a static view of 'naturalness', which unnecessarily constrains restoration efforts and potentially leads to the setting of unattainable goals (Hobbs & Norton 1996).

2.3.2 Natural character

Assessment of natural character as a surrogate for natural heritage condition is based on the premise that the condition of natural heritage is strongly correlated with human modification of ecosystems. Natural heritage in general and indigenous biodiversity in particular, is depleted most where human modification is intense and least where human modification is negligible or benign. Conservation aims to protect or restore natural character by preventing or undoing human damage in order to sustain natural heritage and natural processes associated with particular sites. Therefore, differentiation of natural heritage within environments based on natural character can, in principle, be designed to be sensitive to conservation outcomes.

Human modification and its converse, natural character, may at first seem unquantifiable. However, if one considers the activities by which humans deplete natural heritage, then the attributes of natural character important in a conservation context become clear and their quantification becomes feasible.

Upon arrival in an unoccupied land, humans typically start the modification of natural ecosystems by removing biomass, at first selectively (hunting, fishing, logging) causing extinctions of large and vulnerable prey (Flannery 1994) and then wholesale (vegetation clearance) as agriculture and urbanisation develop. Associated with human colonisation, and agriculture in particular, is the introduction of alien animals and plants (Diamond 1997). Introduced animals alter the consumption (i.e. predation and herbivory) regime, leading to extinctions of species unable to cope with novel forms of predation and loss of their functional roles (e.g. pollination, seed dispersal, litter decomposition, nutrient and energy cycling) which may in turn lead to further biodiversity loss. Introduced plants alter the competitive pressures for space and resources, leading to displacement, community restructuring and more extinctions. As the agricultural economy grows, land use becomes both extensive and intensive, modifying resource availability through alteration of soils, hydrology, nutrients and toxic substances, causing habitat loss and landform damage with associated consequences for natural heritage. Extensive land use alters spatial relationships between ecosystems, fragmenting large ecosystems and isolating fragments. Transport networks create ecological connections between naturally isolated ecosystems. Both cause biodiversity loss.

In marine environments, the process is similar. Fishing removes much of the biomass present in large bodied animals and also the functional roles they provide. Pollution and reclamation alter the resource base and mechanical fishing methods impose novel disturbance regimes on the marine benthos, restructuring benthic communities and further depleting biodiversity. There have also been introductions of alien species that have altered the competition regime, though not on the same scale as has occurred in terrestrial environments.

The human activities causing natural heritage loss can be summarised by considering change to five attributes of natural character (Table 1).

None of these five attributes of natural character are amenable to direct measurement. Furthermore, widespread assessment is only logistically possible using extremely rapid methods because there are so many sites to assess. A pragmatic approach is to differentiate land cover classes within environments on the basis of natural character as defined by information about the distributions of plant and animal pests, land use and fragmentation. The land cover classes are in part distinguished by the extent of human modification. For

TABLE 1. HUMAN ACTIVITIES AND HUMAN-INDUCED PROCESSES THAT DEPLETE NATURAL HERITAGE AND ASSOCIATED ATTRIBUTES OF NATURAL CHARACTER.

HUMAN ACTIVITY	ATTRIBUTE OF NATURAL CHARACTER AFFECTED
Hunting, fishing, logging, fire & clearance	Plant and animal biomass and richness
Introduced animal pests	Predation and herbivory regime
Introduced plant pests	Competition
Land management and use	Light, nutrient, water, physical disturbance
Fragmentation and transport	Connection and isolation

example, the level of biomass and species removal can be deduced from vegetation type (e.g. crops, pasture, induced shrub land, secondary forest and primary forest). However, further differentiation of the predominantly natural vegetation cover classes is needed to achieve adequate sensitivity to conservation outcomes. To this end, indices and normative descriptors can be designed to differentiate the intensity of human modification and these might be calibrated to quantify the proportion of pre-human biodiversity associated with these levels of natural character (Tables 2 and 3).

TABLE 2. SOME LAND COVER CLASSES THAT MIGHT BE INFERRED FROM A COMBINATION OF REMOTE-SENSING DATA AND ENVIRONMENTAL INFORMATION. THE CLASSES ARE ASSOCIATED WITH PUTATIVE PERCENTAGES OF PRE-HUMAN BIODIVERSITY REMAINING, TO ILLUSTRATE THE USE OF LAND COVER DATA AS A FIRST-ORDER BIODIVERSITY INVENTORY.

VEGETATION COVER	% BIODIVERSITY REMAINING
Primary Forest	95
Natural scrubland	95
Natural grassland	95
Secondary Forest	55
Induced native scrubland	50
Induced native grassland	50
Exotic Forest	30
Exotic scrubland	20
Exotic grassland	1
Horticulture & orchard	2
Crops and market gardens	0.1
Residential	2
Urban	0.1

Calibration can be based on measurement of natural character (using indices and descriptors) and correlation with estimates of biodiversity loss. For example, the isolated secondary conifer forest remnant Claudlands Bush (Hamilton) contained 128 native plant species in 1933 (probably its total pre-human content) but only 83 plant species in 1994 (Whaley et al. 1997). Thus, present vascular plant biodiversity represents about 65% of its pre-human content. The site was probably used by up to 46 species of native birds (Atkinson and Millener 1990) but is now used by about 9 native bird species, suggesting the site sustains only about 20% of its former avian biodiversity. Surveys of 116 of 121 remnant kahikatea dominated forest stands in the Waikato originally identified in 1977 suggests species richness of indigenous plants, beetles, and snails is moderate in comparison to nearby large forest tracts, but indigenous bird diversity is low (Burns 1997). It therefore seems that secondary forest remnants of the Waikato sustain some 50% to 60% of their former native biodiversity.

Conversion of forest to pasture removes all the native vegetation, although some invertebrates (e.g. *Porina* spp.) and birds (harrier, pukeko) may remain, representing in the order of perhaps 1% of prehuman biodiversity. Conversion to intensive cropping further reduces the native fauna, perhaps by another order-of-magnitude. Continued disturbance in the form of grazing, fertiliser, tilling and pesticide prevent the recovery of native biodiversity.

TABLE 3. A FEW COMMON ALIEN CONSUMERS PRESENT IN INDIGENOUS ECOSYSTEMS AND THE MAJOR ORGANISM GROUPS (GUILDS) THEY FEED ON. THE NUMBER OF ALIEN CONSUMER SPECIES FEEDING IN EACH GUILD IS A MEASURE OF ALIEN CONSUMPTION PRESSURE.*

	GUILD		
SPECIES	PLANTS	INVERTEBRATES	VERTEBRATES
Human hunting/gathering	X	X	X
Possum	X	X	X
Wallaby	X		
Red deer	X		
Sika deer	X		
Pig	X	X	
Goat	X		
Thar	X		
Rabbit	X		
Hare	X		
Cat		X	X
Ferret		X	X
Stoat		X	X
Weasel		X	X
Norway Rat	X	X	X
Ship Rat	X	X	X

* For example, if red deer, possums and ship rats were present at a site, then the consumption pressure index would be 7 (i.e. the sum of crosses in the relevant table rows). The index could be refined by expressing presence (X) as an index (range 0 to 1) of guild vulnerability to each alien consumer according to the type of environment represented by the site and the level of control of each animal pest.

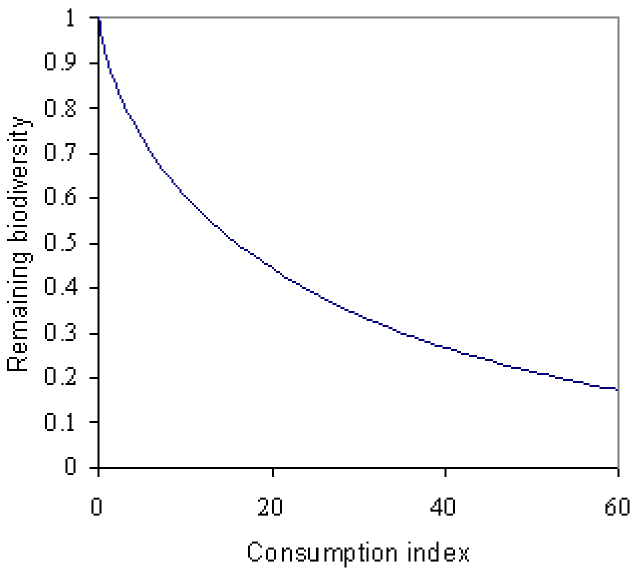

Figure 1. A hypothetical relationship between remaining biodiversity and a consumption index (Table 2) based on the number of alien predators and herbivores present in each of three guilds.

Animal pest distribution data could be used to construct an index of alien consumption pressure based on the number of alien consumers present, the major organism groups eaten, their vulnerability to particular pests in particular environments and the level of control for each pest (Table 3). A calibration of consumption pressure and remaining biodiversity would be an inverse relationship, perhaps a continuing decline, as in Figure 1. Remaining biodiversity (i.e. the portion below the line) being that which is not in the diet, or can sustain the level of alien consumption, and is not dependent on other species lost to alien consumption.

Plant pest distribution data could be used to index change to the natural competition regime with the intensity of alien competition being indicated by the extent of occupation of each vegetation tier (an infestation index). Land use information could be used to assess physical and chemical disturbance and consequent change to the resource base. A fragmentation index could be derived from land cover data using a combination of ecologically relevant spatial measures such as size, number of fragments, distance to nearest neighbour and edge to core area ratio. These indices should each be calibrated against biodiversity loss to maximise their value as surrogate measures of biodiversity.

In summary, environments, subdivided by land cover type and natural character, calibrated against native biodiversity loss, can account for much of the location, type and condition of natural heritage, on all land and water, in natural as well as intensively used, urban, residential and agricultural parts of the landscape. Measurement of natural character should be achievable without the need for expensive site surveys and targeted research should provide the necessary calibration against biodiversity loss. This information offers a spatially comprehensive and catalogued ecological inventory of New Zealand's portfolio of natural heritage assets, enabling:

- Informed definition and selection of an appropriate and measurable natural heritage conservation goal
- Measurement of conservation achievement based on quantifiable losses and gains
- Measurement of the contribution of conservation projects to the conservation goal.

2.4 Defining a natural heritage conservation goal

The fundamental objective of natural heritage conservation is maintenance and restoration of the nation's portfolio of natural heritage assets. The full variety of indigenous species is a fundamental feature of the asset portfolio which conservation aims to maintain. But paradoxically, because so many species are unrecognisable and the distributions of many more are unknown, the asset portfolio can only be defined in terms of an ecological classification of surrogate information. It is therefore necessary, in formulating a goal statement, to identify the species and landform maintenance purpose behind conservation activities, performance standards and performance measurement (Table 4).

This goal spectrum specifies the framework for performance measurement (e.g. *enough of the natural character of … environments to sustain populations of characteristic taxa and landform features*) and sets measurable performance targets. The concept *enough of the natural character* indicates that naturalness in not a target in itself but simply a means to achieving the species conservation objective. The specification *populations of … living taxa and landform features known to be characteristic* avoids the problem of incomplete taxonomy and inadequate species distribution data which confound the utility of a species based biodiversity goal, yet provides for species-focused conservation.

The goal level selected indicates how much natural heritage, and which bits, society wants conserved. The choice of goal level should reflect the trade-off between natural heritage conservation and society's other objectives. Goal specification should articulate society's preferences for the conservation of particular components of natural heritage (e.g. nominated taxa, environments, places, landforms and habitat types) and levels of natural ecosystem character

TABLE 4. A RANGE OF NATURAL HERITAGE CONSERVATION GOAL LEVELS.

1. There is enough of the natural character of all environments to sustain populations of all living taxa and landform features known to be characteristic of each environment. Requires complete and comprehensive representation of all environments in the natural area network. Natural areas will need to be large enough, and maintained to a sufficiently high standard, to sustain the most vulnerable species in each environment. Populations of all characteristic species missing from environments would be restored. This goal level is not achievable within the foreseeable future.
2. There is enough of the natural character of all environments to sustain populations of all remaining taxa and landform features still present in each environment. Requires representation of all environments but at variable levels. No taxa would be lost from any environment where they still occur. This goal would maintain the present level of representation with improvement where needed to sustain remaining taxa or to represent environments which no longer have any natural areas. The level of management is typically only enough to stop further losses. Species transfers would occur if needed to ensure species survival and if species can be returned without adding to the level of management required. Restoration is done to rehabilitate processes such as pollination or seed dispersal needed to ensure ecosystem sustainability. This is an ambitious but achievable goal.
3. There is enough natural character to sustain populations of all living taxa and remaining landform features. Requires considerable but variable representation to ensure that all remaining taxa are adequately provided for somewhere. Some environments would not be represented in the natural area network and some vulnerable species would not be sustained in all the environments where they presently occur. Species transfer and restoration would be done mainly for species survival reasons or for critical process maintenance purposes.
4. There is enough natural character to sustain populations of the most valued remaining taxa and landform features. This targets conservation effort at the most valued taxa and landform features. Levels of representation and management would be determined by what is required to sustain the most valued remaining taxa and landform features. This goal approximates the present level of conservation achieved by the Department of Conservation.
5. No loss of natural character that exacerbates threats to the most valued remaining taxa and landform features. This attempts to avoid accelerating the rate at which we are losing our most valued natural heritage assets. Conservation activity would focus on avoiding and mitigating the adverse effects of present and future human activities. This approximates the level of conservation achieved by regional and district councils.
6. Do nothing: no public investment in conservation effort. The level of conservation achievement would be determined by market forces and so would be determined primarily by market incentives, including the effects of subsidies on particular activities.

(e.g. fire induced tussock grasslands for inland Canterbury versus the pre-human totara-matai forest). Priority species and places can be identified from their contribution to the variety and status of the whole asset base. For species, this would require recognition of functional roles and phylogenetic distinctiveness (Vane-Wright et al. 1991) as well as their vulnerability to loss.

3. CONSERVATION PERFORMANCE MEASUREMENT

Since the fundamental conservation objective is to maintain our natural heritage assets, the proximate measure of conservation performance is the status of that asset portfolio, defined in terms of natural character, spatial extent and asset diversity. Natural character and spatial extent are required to sustain landforms and populations of characteristic species and their representation by environment ensures maintenance of asset diversity. The ultimate conservation performance measure is the status of species populations and landforms characteristic of each environment. Declining populations and damaged landforms indicate insufficient area with adequate natural character to achieve the conservation goal, often because there are too many alien pests or excessive modification of the physical environment.

On this basis, the status of a site can be defined in terms of its size and natural character:

$$Site\ Status = Site\ Area \times Natural\ Character$$

where *Natural Character* is a combination of its five components (see Table 1). The most appropriate form of combination (e.g. mean, product, etc.) will be indicated by the form of the relationship between biodiversity and the five components of natural character. The status of any larger area is the average status of all sites comprising that area:

$$Biodiversity\ status = \frac{\sum_{All\ Sites} Site\ \ Status}{A}$$

where *A* is the combined area of the sites. However, the status index is deficient in that it takes no account of the loss of variety caused by loss of distinctive elements and it is not clear how this should be remedied.

This index captures the status of natural heritage as a single number ranging between 0 and 1, representing what remains as a fraction of its pristine, pre-human state. This single-number index is probably most useful for monitoring overall progress but it excessively summarises status for many other reporting purposes. Much more detailed information could be presented in map form, showing:

- The natural character of environments
- The extent of areas with different levels of natural character
- The difference between current natural character and that needed to achieve the natural heritage conservation goal
- The difference between two points in time, to highlight places where most change has occurred
- The geographic distribution of each component of natural character.

The information could also be summarised graphically with histograms showing the area (hectares) that lies between natural character levels or, possibly more usefully, as exceedence curves showing the area (hectares) over which a given level of natural character is equalled or exceeded (see Figure 2 and below).

There are a number of ultimate measures of status. In particular, the number of environments sustaining all the species and landform features identified *a priori* as '*characteristic of each environment*'. This information could be presented as maps in which environments are coloured according to the percentage of characteristic elements sustained, or as summary histograms (or exceedence curves) showing the number of environments in which percentages of characteristic species and landform features are sustained, threatened or lost.

3.1 Measurement of conservation achievement

The status of the natural heritage asset portfolio does not tell us what is being achieved for the money spent on conservation because much natural heritage would remain without targeted conservation expenditure. Conservation expenditure maintains assets that would have been lost or degraded without it. So, to measure the return on conservation expenditure, a projection is needed of the status of natural heritage *without* the funded activities and this must be compared with status actually achieved *with* conservation expenditure:

$$Natural\ Heritage\ Conserved = Status_{With\ Management} - Status_{Without\ Management}$$

The difference is natural heritage restored, or loss avoided, as a consequence of conservation.

Just as natural heritage status information can be presented as maps, histograms and exceedence curves, so can the conservation achieved for a given expenditure (Figure 2). Here, the area (y-axis) over which natural character is equalled or exceeded (x-axis) is projected for three levels of expenditure (none to $2m). The difference achieved by a given level of expenditure can also be illustrated in terms of the viability and distribution of species and landform features that benefit from the management delivered. However, this species response information will tend to underestimate the total biodiversity gain, because not all beneficiaries can be identified and monitored. The species information is probably best used to give 'life' and appeal to the rather abstract natural character data.

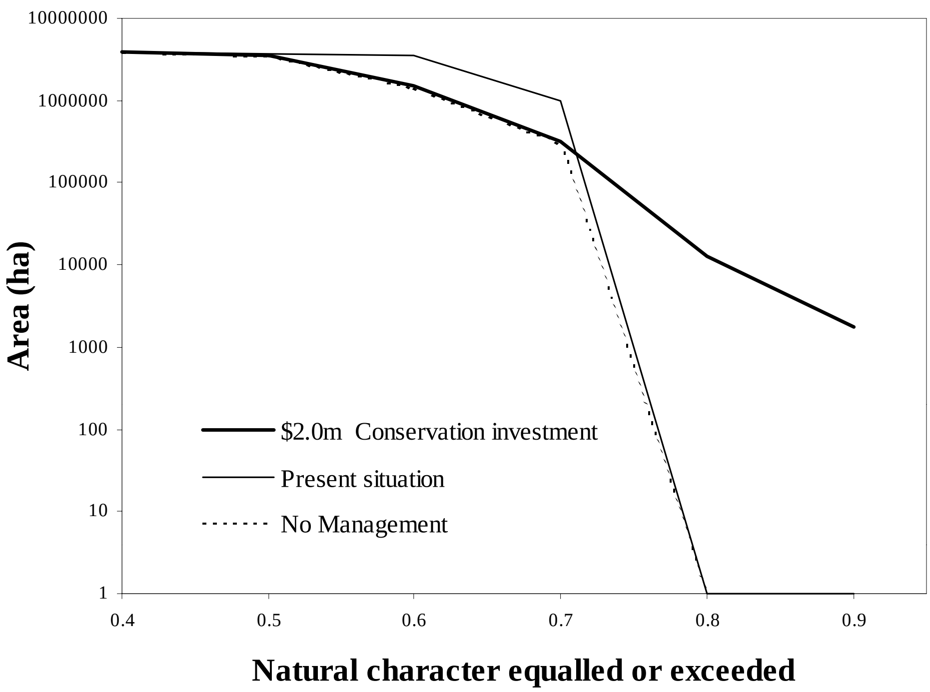

Figure 2. An exceedence curve showing the status of natural heritage (area over which natural character is equalled or exceeded) under three scenarios: present investment situation; without management and with major ($2m) expenditure on conservation (from Stephens, R.T.T. and Lawless, P. Cost-utility evaluation of conservation projects. in prep). The area below the curves represents the magnitude of outcome achieved. The area between the lower 'No Management' curve and higher curve associated with some investment in conservation is a measure of the size of outcome achieved from that investment.

4. CONSERVATION PROJECT EVALUATION

The most efficient trade-off decisions result in a project mix which contributes most to the goal for the funds available (Keeney 1992). Conservation efficiency, therefore, requires definition of conservation project outcomes so that their contributions to the natural heritage conservation goal can be measured and their cost-effectiveness compared. Recent developments (Cullen 1995; Fairburn 1998) are based on the cost–utility approach but the utilities (i.e. measures of outcome worth) proposed were developed without the benefit of goals defined in terms of the nation's natural heritage asset portfolio. Consequently, these utilities index only a small part of a project's contribution to the goal and the utilities cannot be applied to all types of natural heritage conservation project.

Just as the conservation goal provides a basis for performance measurement, it also provides some insights into attributes of conservation project outcomes contributing to goal achievement. To maintain and restore *enough of the natural character to sustain populations of remaining taxa* requires that additional human modification is to be avoided if it would threaten remaining species and existing damage should be repaired if it compromises the sustainability of remaining species and landform features. On this basis, projects that prevent seriously damaging modification, or recover serious damage, contribute more to the conservation goal than projects that prevent or recover minor damage or benign human modification. Specification of *... every environment* reflects the need to maintain diversity and distinctiveness that comprise the total variety of natural heritage. Thus projects which maintain or restore highly distinctive assets contribute more to the goal than projects which conserve less distinctive assets. The qualifier *... enough of the natural character* implies that it is more important to conserve sites representing much of what remains than other sites representing little of what remains. The purpose statement *... to sustain populations* identifies the needs (i.e. life-support systems) of threatened species as the basis for choosing the level of natural character to be maintained or restored. It also implies that the size or spatial extent of natural areas is important because sustainable populations have minimum spatial requirements. Thus society's preference for some species over others influences the spatial extent of natural areas to be conserved, the selection of sites for conservation action and the level of natural character to be maintained or restored. The constraint *... known to be characteristic of each environment* or *... remaining taxa and landform features* discourages management for species not characteristic of environments while not precluding their use in intermediate steps towards eventual return to their native environments. It also puts focus on the species we know about while providing for response to new information.

4.1 Defining the return on a conservation project

In general, the outcome of natural heritage conservation projects is alteration of the natural character and spatial extent of natural areas in ways that enhance the sustainability of natural heritage. This may be achieved by maintenance, which avoids or reduces degradation that would occur in absence of the project, and by restoration, which repairs damage already done. The magnitude of loss avoided and restoration achieved is project efficacy. The contribution of the outcome to the conservation goal depends on the value of the asset affected: an outcome for a particularly valuable asset contributes more to the conservation goal than the same outcome for a less valuable asset.

If the site has value and the project has efficacy, then the project contributes to the conservation goal. If the site has value but efficacy is negligible, then the project contribution to the goal is also negligible. However, the converse is not necessarily true. If the asset has no attributes of value but a restoration project has some efficacy, so that the site becomes valuable, (e.g. restoration of a sterile, toxic waste dump) then there is a positive contribution from the project. The nature of this relationship suggests that outcome size may be best defined by an interaction of site value and project efficacy akin to:

$$Project\ Outcome = Final\ Site\ Value \times Project\ Efficacy$$

where *Final Site Value* is that associated with the project's outcome, as opposed to the initial or present value of the site.

4.1.1 Efficacy

The efficacy of a conservation project can be defined as the change in site size and natural character (*NC*):

$$Project\ Efficacy = \Delta(Size \times NC)$$

where *NC* is a surrogate for the proportion of pre-human natural heritage remaining at a site. *NC* is composed of the five components of natural character, each calibrated to index the proportion of pre-human biodiversity remaining. As an index of biodiversity, *Size* is probably best expressed as the logarithm of site area because species-area curves are characterised by rising curves of diminishing slope typically straightened by logarithmic transformation of area data.

In its simplest form, project efficacy is the difference between projected outcomes for site size and natural character with (*w*) and without (*w/o*) project implementation:

$$Efficacy = (Size_w \times NC_w) - (Size_{w/o} \times NC_{w/o})$$

This applies to threats from which there will be no recovery (e.g. alien pests). However, natural ecosystems are more resilient to some threats (e.g. pollution; nutrient enrichment; vegetation removal; fire) and recovery will occur over time if the damage is just a single event and not chronic. It is therefore appropriate to recognise the temporary nature of such losses by reducing efficacy according to this recovery (*R*):

$$Efficacy = R \times ((Size_w \times NC_w) - (Size_{w/o} \times NC_{w/o}))$$

Recovery (*R*) is probably best indexed by a decay function:

$$R = exp(-ln(1 + \beta t))^P$$

where β is a scaling term to reflect society's concern about the duration of damage and t is the projected time in years until the expected degree of recovery (*P*) has occurred (Figure 3). The recovery index ranges from 1 (immediate and full recovery) to zero (no recovery).

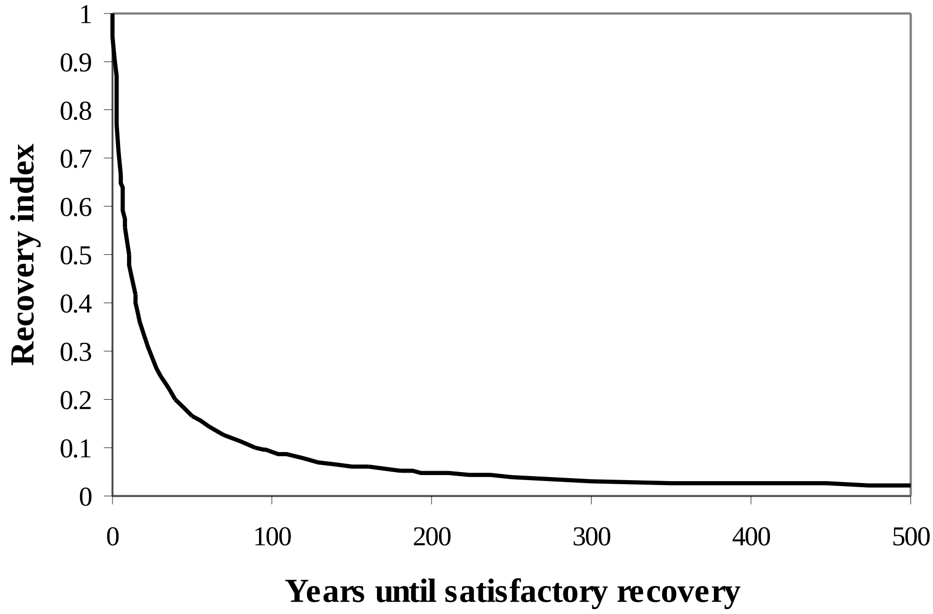

Figure 3. A recovery index to reflect concern about the duration of temporary damage to natural heritage. ($\beta = 0.1$; $P = 1$)

4.1.2 *The components of site value*

The contribution to the conservation goal of a given magnitude of efficacy depends on the value of the asset affected. A project outcome for a valuable asset contributes more to the conservation goal than the same outcome for a less valuable asset. If the site contributes much to the variety, quantity or sustainability of New Zealand's natural heritage, then the site is a particularly valuable natural heritage asset. Site value is composed of four substantially independent attributes:

- Distinctiveness
- Importance
- Size
- Natural character

A distinctive site contributes much to the total variation within the asset portfolio. An important site represents much of the remaining natural character of an environment. Other things being equal, a large site sustains more biodiversity and landform features than a small site and a pristine site is likely to sustain more biodiversity than a highly modified site, and so is also more valuable. Site value is determined independently by each of the four attributes and so is probably best defined by an additive function:

Site Value = Distinctiveness + Importance + Size + Natural Character

The distinctiveness of a site could be differentiated by:

- The endemism of its biota (i.e. whether species present at the site are endemic to the site, environment, North or South Island, country) and distinctiveness of its landform features.
- The distinctiveness of its environment and biogeographic history (the major determinants of endemism and landform distinctiveness associated with particular sites).

Environmental distinctiveness might be defined as the mean environmental distance (in ordination space) of the site to all other sites. This raises some difficult scale issues concerning site identity, size and choice of environmental parameters to assess distinctiveness in very different environments (e.g. deep sea marine, montane forest, intertidal, geothermal, glacial). These practical considerations dictate that distinctiveness is best differentiated by an index of endemism until measures of environmental distinctiveness and landform distinctiveness can be developed.

Site importance could be defined by the proportion of what remains within the environment represented by the site. However, the magnitude of total loss is also pertinent because if most of a particular type of ecosystem type has been lost, then all that remains is important, even if the site is only a small portion of what remains. On this basis an index of importance could be defined by:

$$Importance = \left(\frac{Site\ \ Area}{Area\ \ Remaining}\right)^{\beta\left(\frac{Area\ \ Remaining}{Pre\text{-}human\ \ Area}\right)}$$

where β is a scaling term reflecting the concern society has for what has already been lost, *Area Remaining* is the total area within an environment with natural character equal to, or exceeding, that of the site and *Pre-human Area* is the entire area of the environment. The importance index ranges from zero to one with high values if the site is a large proportion of what remains or if the area remaining is a tiny portion of its pre-human extent (Figure 4).

Size and *Natural Character* are as defined in paragraph 4.1.1 above.

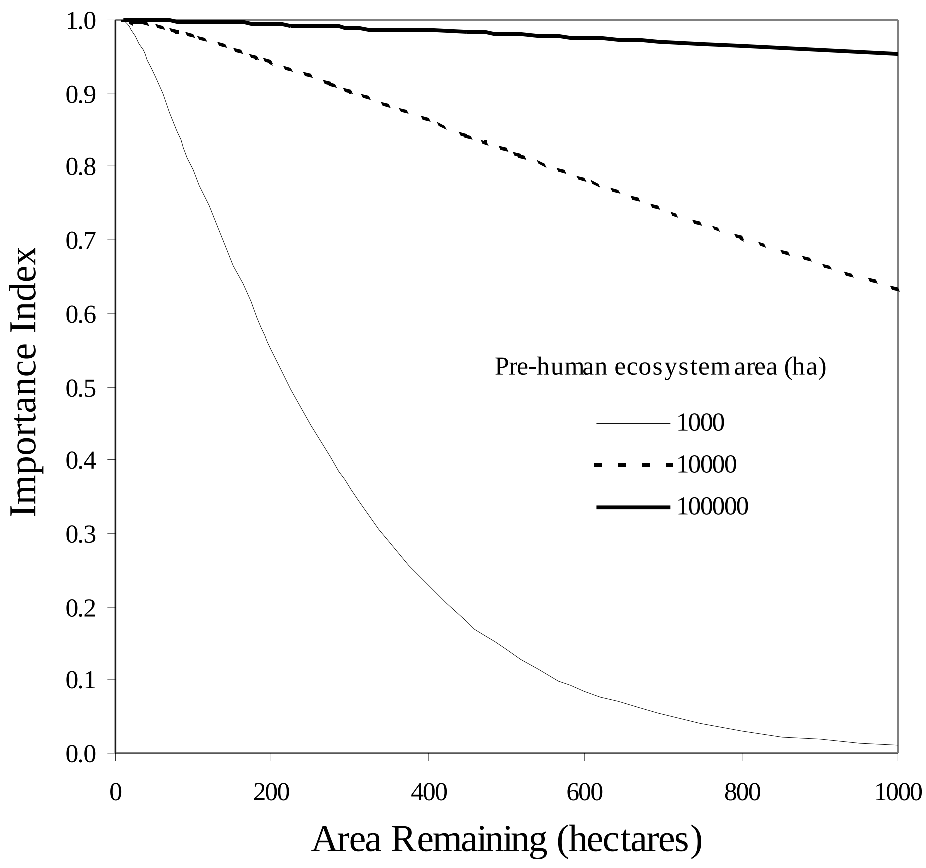

Figure 4. Variation in the importance of a 10 ha site in relation to both the area remaining of the ecosystem type(s) represented by the site and the pre-human extent (three levels, 1000, 10,000 and 100,000 hectares) of the type(s) present. The scaling term (β) is 2.

4.2 Project merit

The outcome of a conservation project, measured in terms of its contribution towards the conservation goal, accounts for much of what needs to be considered in evaluating a project's merit. However, there are two more project attributes which should be considered in the evaluation of projects: urgency and feasibility. Urgency expresses the time for loss and recovery to occur and feasibility reflects the potential for failure to achieve the outcome sought. Both factors reduce and may nullify an outcome if it is not urgent or if some key aspect of a project is not feasible so that its outcome is not achieved. These relationships suggest that project worth is best indexed by a multiplicative function of its three components: outcome size, urgency and feasibility,

$$Project\ Merit = Outcome \times Urgency \times Feasibility$$

where *Project Merit* is the index of project worth.

4.2.1 *Project urgency*

If a threat is fast acting (e.g. fire, wetland drainage) and a project is designed to counter the threat and so maintain the status quo, then urgency has a large threat component but no recovery component. Similarly, if the damage has already been done and a restoration project is designed to recover the damage, then there is a recovery component but no threat component. The absence of either component does not nullify project merit. However, if there is no threat component and recovery is inexorably slow, then merit is negligible. This suggests that the two components of urgency interact in an additive manner but their combined interaction with project return is multiplicative. An index of urgency seems best based on a decay function:

$$Urgency = exp(-1n(1 + \beta t_T)) + exp(-1n(1 + \beta t_R))$$

where t_T is the time in years for the projected outcome of the threat to happen, t_R is the time in years for the projected recovery to eventuate and β is a scaling term reflecting the value society places on quick results. The index ranges from zero to one and if β is set to 0.01, it generates high values (>0.5) for outcomes expected within 10 years and low values (<0.01) for outcomes expected to take millennia.

4.2.2 *Project feasibility*

Project feasibility is a key factor in trade-off decisions because any one of the various risk factors contributing to project feasibility has the potential, if inadequately managed, to prevent achievement of the outcome and so nullify its contribution to the conservation goal. At least five risk factors can contribute to the failure of conservation projects:

Outcome risk — the risk that the project cannot achieve the outcome sought because the actions are inappropriate, probably because the conservation problem is inadequately understood. Research or an experimental approach to management (e.g. Walters 1986; Lancia et al. 1996) is required to manage outcome risk. Outcome risk is indicated by inexperience with the problem, difficulty with selection of appropriate objectives to achieve the outcome sought or with design of methods to achieve project objectives.

Operational risk — the risk that unforeseen events cause insufficient project implementation to achieve the intended outcome. A complex work environment, difficult weather, poor planning, resourcing or weak commitment are major sources of operational risk, leading to inadequate staff capability, equipment and support infrastructure, resulting in various failures, including delays and accidents.

Legal risk — occurs when other stakeholders can determine whether or not a project will be implemented perhaps because of dependence on access through private property or on consents issued by third parties. Legal risk also occurs if conflicting mandates under different legislation cause uncertainty as to whether the proposed action can be implemented, or if the action is dependent on precedent setting case law or passage of special enabling legislation.

Collateral damage risk — occurs when an action has adverse effects on other biodiversity values, as may occur in a pest control operation that may cause some by-kill of native species or leave toxin residues in the environment.

Socio-political risk — occurs when public and hence political concerns about the management problem impinge upon capability to implement the action proposed. It has two components, support and opposition. Risk increases with the level of public opposition to a project but diminishes with public support. Socio-political risk is managed through various community relations activities to gain a common understanding of values and a general acceptance of a particular management response. Effective public consultation, communication, public participation and involvement, as well as public education are input activities that contribute to reducing socio-political risk.

Project feasibility, design and associated cost are inter-related because all project expenditure is ultimately intended to reduce the risk of failure. Project cost represents the design trade-off between project feasibility and cost. Both project feasibility and cost increase with more comprehensive risk management. Value-for-money increases while feasibility increases at a faster rate than cost but declines as the project becomes 'over designed' so that the additional cost is not fully compensated by increased feasibility. Project design is optimised when project value-for-money is maximal. Characterisation of the relationship between project feasibility and cost can aid recognition of optimal project design.

Project risk is the difference between the consequences for the outcome sought of the risk and the portion of this risk that is managed and accounted for by the design of the project. Both can be explicitly quantified using normative descriptors (Table 5). Thus, for example, a project may have high outcome risk with disastrous potential for the outcome sought, but the planned provision for research, monitoring, review of project objectives and testing of methods may be sufficient to eliminate most of this risk so that the residual risk is negligible. The residual risk is the actual risk associated with outcome achievement:

$$\textit{Residual Risk} = \textit{Consequence of risk} - (\textit{Consequence of risk} \times \textit{Proportion managed})$$

and feasibility is:

$$\textit{Feasibility} = 1 - \textit{Residual Risk}$$

TABLE 5. SOME RISK DESCRIPTORS AND INDICES THAT MIGHT BE USED TO DIFFERENTIATE THE CONSEQUENCES OF RISK FACTORS (SCORE A) AND THE DEGREE TO WHICH PROJECT DESIGN ADDRESSES THE MANAGEMENT OF RISK FACTORS (SCORE B). FEASIBILITY ASSOCIATED WITH ANY ONE RISK FACTOR IS INDICATED BY:

$$Feasibility = 1 - (A - (A \times B))$$

PROJECT FEASIBILITY IS THE PRODUCT OF THE FEASIBILITIES ASSOCIATED WITH EACH RISK FACTOR.

SCORE A	CONSEQUENCE OF RISK FOR OUTCOME SOUGHT	SCORE B	LEVEL OF RISK MANAGEMENT (PROPORTION MANAGED)
1	No useful outcome.	1	Contingencies planned for all possibilities.
0.8	A small (20%) portion achieved.	0.85	Risk well understood, most possibilities provided for.
0.5	About half achieved or doubles project duration.	0.6	Risk well understood, some key possibilities not provided for.
0.2	Most (80%) achieved or moderate completion delay.	0.3	Risk poorly understood, skeletal provision for its management.
0.1	Nearly all achieved or minor delay.	0.1	Risk identified but inadequately assessed and provided for.
0	Negligible consequence	0	Risk not identified.

Thus when the consequence of risk is recognised and fully managed, feasibility is high. Project feasibility is the product of the feasibilities for each of the various risk factors:

$$Project\ Feasibility = Feasibility_1 \times Feasibility_2 \times Feasibility_3 ....$$

The relationship must be multiplicative because negligible feasibility with respect to any one risk factor fatally flaws the project. A complex project has many risk factors that, in combination, lower its feasibility.

In summary, the attributes (i.e. *return, urgency,* and *feasibility*) of the intrinsic worth of a project to a biodiversity conservation goal have been characterised and an approach to their measurement and combination into an index of outcome worth (i.e. *Project Merit*) has been proposed.

5. IDENTIFICATION OF THE MOST COST-EFFICIENT SUBSET OF PROJECTS WITHIN A BUDGET

Project Merit is the utility measure of a project's worth (Figure 5). If *Project Merit* is divided by the cost of the project, a measure of project cost-effectiveness is provided. An optimisation process could then be used to identify the set of projects which maximises their combined merit scores for the budget available. However, there are some complicating issues:

- Project cost must be standardised to enable comparison of projects with different cost structures.
- There are at least two extrinsic, context dependent factors that can have a major influence on the worth of an outcome: asset complementarity and the value of new capability generated by doing the project.

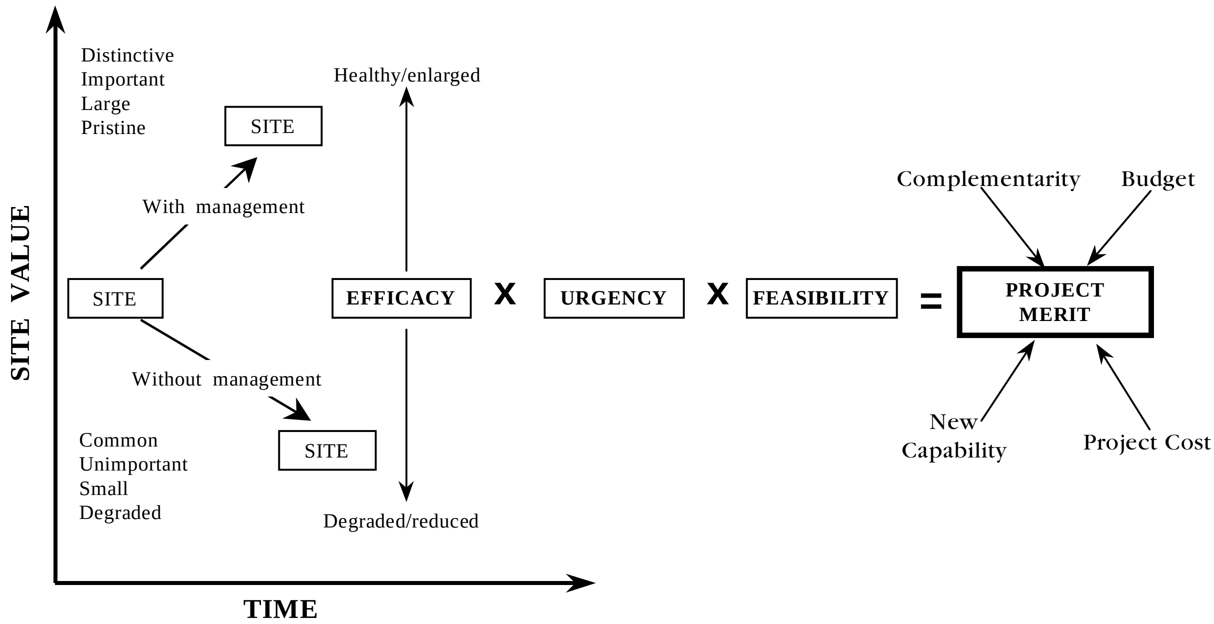

Figure 5. A schematic summary of a cost utility index to measure the relative worth of natural heritage conservation projects showing the relationship between the four intrinsic factors contributing to project worth (site value; project efficacy, urgency and feasibility) and the four extrinsic factors which determine the composition of the work programme.

5.1 Project cost

Project costs are made up of one-off purchase costs, expenditure over finite periods and long term ongoing costs (e.g. maintenance and monitoring). Some projects are a one-off cost while others include ongoing, long-term commitments. One way to standardise cost measurement for projects with different cost structures is to convert actual costs to long run cost by adding one-off costs to capitalised ongoing costs:

$$\textit{Long-run cost} = \textit{One-off cost} + \left(\frac{\textit{On-going costs}}{d}\right)$$

where *d* is the long term interest or discount rate. Thus, given a discount rate of 0.1 (equivalent to an interest rate of 10%), a project costing $5000 annually would have a long run cost of $50,000. The discount rate also affects the purchasing power of the annual budget, defined by:

$$Budget\ \ Purchasing\ \ Power\ \ =\ \frac{Annual\ \ Budget}{d}$$

A low discount rate both increases the long run cost of a project and increases the purchasing power of an annual budget. However, because projects vary in their cost structures, the relative cost of projects (i.e. cost in relation to the purchasing power of the annual budget) is discount rate dependent.

5.2 Complementarity

The complementarity (*sensu* Pressey et al. 1994) of an asset is the degree to which, if conserved, it would add to the diversity of assets which are secure or under management. Complementarity is an important factor influencing project selection if the value of the total asset base is dependent on the diversity of its elements, as is the case with biodiversity. More biodiversity conservation is achieved by spreading attention across a diverse range of equally deserving assets than by concentrating effort within a group of similar asset types. Therefore, other things being equal, projects should be selected if they protect assets which are most dissimilar (i.e. complementary) to those which are secure or under management. This will give preference to assets that contribute so-far unrepresented variation. Asset complementarity is not a constant attribute. It is context dependent, varying with the content of the programme because, as one project to benefit a particular asset type is selected for the programme, other projects benefitting similar asset types decline in worth relative to complementary projects for other, different types of biodiversity asset. However, the nature of the trade-off between complementarity and merit for optimal selection of conservation projects is unclear. For example, when is it appropriate to select a high-merit project that conserves a duplicate asset ahead of a lower-merit project that conserves a complementary asset? To what extent should complementarity override merit in the project selection process?

5.3 Worth of new capability

A project with negligible intrinsic merit (perhaps because its outcome is small due to low asset value) could be of considerable worth because of capability generated which can be applied to many other worthy projects, increasing their feasibility and reducing their cost. New capability can be in the form of understanding, skills, technology, equipment, legislation and community support and its worth is determined by what it can be usefully applied to. The worth of a new capability is the sum of additional project merit that the capability would give to all projects needed to achieve the natural heritage conservation goal. It is important in the context of project selection because, other things being equal, a project that makes other worthy projects more achievable, should be preferred over projects contributing little to their implementation. Estimation of the worth of a new capability requires a comprehensive asset inventory and associated compilation of projects needed to maintain them.

Project merit increases if new capability is added but is not reduced if project implementation creates no new capability. This behaviour indicates an additive relationship, suggesting that the worth of new capability is probably best added to intrinsic project merit in order to capture the full worth of a project's outcome.

5.4 Programme selection

A linear optimisation process found on most computer spreadsheet applications can be used to identify, from the set of potential projects, the mix of project outcomes that together provide the most cost-effective conservation for the budget available. However, since it is not clear how asset complementarity should interact with project merit, a significant component of effectiveness is not accounted for. Also, the full compilation of projects needed to maintain natural heritage is not knowable, so the value of new capability must be an incomplete estimate. Furthermore the relationship between project outcome and its worth to society in terms of the products and services maintained or restored is generally unclear. Therefore, the optimisation process can only provide an indicative selection of the most cost-efficient subset of projects that can be implemented for the budget available. Sound judgement is still required to finish the selection task. The optimisation process is therefore only useful to inform the decision making process. It is not a substitute for it.

6. DISCUSSION

Natural heritage conservation is an asset management business. Therefore a natural heritage conservation goal must concern the wellbeing or status of the total asset portfolio. The assets of natural heritage are dominated by biodiversity, yet much of the biota is undescribed and the distribution and wellbeing of many that are described is unknown. Such incomplete information precludes formulation of a comprehensive biodiversity inventory based on species. However, species form ecological associations determined by environment, dispersal and history. Recognition of these associations as the asset portfolio's units offers an way to inventory biodiversity comprehensively, enabling the status of the portfolio to be measured and so provide the basis for a measurable conservation goal. With a comprehensive asset inventory and a conservation goal, the total magnitude of the conservation task becomes knowable and the resources needed to achieve the goal can be estimated. Given this information, society would be in a much better position to make explicit choices about how much and which bits of natural heritage should be maintained and so make better informed trade-offs between natural heritage conservation and other objectives. The consequences of these trade-offs can then be demonstrated by monitoring the status of the natural heritage asset portfolio, providing the opportunity for society to further improve the quality of its choices. Monitoring should also introduce a new level of accountability for actions taken, or not taken, by the various agencies responsible for natural heritage management.

Much of the information needed to construct a national natural heritage inventory is available for terrestrial environments. We have the ecological district and region framework and the research and development behind the next advance, environmental classification, is progressing well. There is a recently developed national land cover database (LCDB) derived from remote sensing data. The distributions of many pests and weeds are reasonably well known and the potential distributions of many more should be predictable using environmental correlates. Land use information is the most problematic, being of variable quality and organised by property title. This presents problems for the assessment of natural heritage assets affected by off-site activities in intensively used areas. Of greater concern is the lack of comparable information for the marine environment. An ecological classification of New Zealand's coastal-marine area has been attempted but this has yet to be developed sufficiently for application in the management of marine biodiversity. Classification of marine environments based on functional linkage to major life-processes of marine biota and correlation with the distributions of diverse species groups has yet to be attempted.

Since capability and expense preclude direct assessment species and landform loss, there is little option but to use surrogate information to measure natural heritage status. Consequently, development of indices of natural character and their calibration against biodiversity loss is critical to the utility of natural character information as a surrogate for natural heritage status. Relationships between the attributes of natural character and natural heritage loss are unlikely to be linear, they probably vary across environments and there may be important interaction among the attributes in their effects on natural heritage. There is therefore much precision to be gained from research aimed at characterising relationships between natural character and natural heritage loss.

Natural heritage has suffered because human trade-off decisions favour maintenance of the tiny portion of biodiversity assets that is both fast-growing and has tradeable value at the expense of the vast remainder which is slow-growing, lacks tradeable value or can be converted into something faster-growing and tradeable. The increasing scarcity value of both natural heritage and the ecosystem products and services it supplies, provides an incentive for better recognition of the trade-offs involved and more careful evaluation of trade-off decisions. However, without an understanding of how much natural heritage conservation provides the maximum benefit to society, there is no analytical basis to evaluate the efficiency of trade-offs. A measurable natural heritage conservation goal defined by society is one expression of the appropriate trade-off, but it is a crude estimate that cannot help with assessment of the benefit gained from incremental change to investment in conservation. Evaluation of the benefits of increased or reduced spending is fundamental to decisions about adjustment to the level of investment in different objectives. For this, it is necessary to measure the net benefit of an incremental change, this being the benefit gained after the costs of delivering it have been deducted.

The index of project outcome (Section 4.1) provides a measure of gross benefit. Society's willingness to pay for it expresses the perceived value, net of costs, of gaining that benefit. This includes the cost of the opportunity lost to invest elsewhere because the resources are tied up in conservation. When project costs are less than society's willingness to pay, society perceives a positive net benefit. If society's willingness to pay is less than the cost of delivering the outcome, society judges that greater returns are available from investment in another quality-of-life objective. Thus to improve upon the preferred investment in conservation indicated by society's selection of a natural heritage goal, it is necessary to measure society's willingness to pay for different conservation outcomes. Clearly this would require expression of the outcome measure in a way that is comprehensible to the public. This could be achieved by establishing the public's willingness to pay for different levels of loss avoidance and restoration at places of varying site value. These levels could be defined by the capacity of the site to sustain well known species of differing sensitivity to human modification (e.g., broadly in ascending order of sensitivity: pukeko, fantail, tui, bellbird, kereru, Northern rata, robin, kokako, mistletoe, *Dactylanthus*, kiwi, kaka, mohua, saddleback, tuatara, hihi, kakapo). A complementary approach would be to define conservation outcomes in terms of different levels of the five attributes of natural character, communicated with illustrations and photographs.

If society can become well informed about the state of natural heritage, and the benefits derived from it, then society's investment in conservation can be sensibly based on society's demand for conservation and the cost of its delivery. Cost-utility evaluation of conservation projects should be used to ensure the efficiency of expenditure and so minimise the cost of delivery. In combination, these processes provide a sound basis for confidence in the quality of conservation expenditure and this should favourably influence trade-offs between natural heritage conservation and other quality-of-life objectives. In the meantime, the New Zealand Biodiversity Strategy is providing a process for choosing measurable natural heritage conservation goals that will specify how much and which bits of natural heritage New Zealand wishes to conserve. The data needed for reporting on the status of natural heritage, for measuring and monitoring conservation achievement and for measuring the return on conservation projects is largely available and the remainder is not unobtainable. The information systems needed to support these processes await development but the necessary technical capability exists, as do the research skills needed to refine measurement and assessment. If we have both the technical capability and a compatible institutional structure to solve the natural heritage management puzzle, then the decline of our precious and unique natural heritage need not remain New Zealand's most pervasive environmental issue.

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