Measuring Conservation Achievement: concepts and their application over the Twizel Area

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ABSTRACT

Effective management of conservation has been constrained by the absence of methods for measuring conservation achievement because the worth of diverse conservation outcomes cannot be objectively compared. This means:

- conservation agencies cannot demonstrate what difference their efforts make
- there can be no objective basis for deployment of their resources to supply conservation.

These issues are addressed on the premises: (1) that conservation is a value-driven asset management business; (2) that the asset portfolio is the nation's natural heritage; and (3) that conservation is the business of maintaining the natural heritage asset portfolio in a state which maximises the flow of benefits it provides to society. The state of the heritage portfolio is defined in terms of the four key attributes that control the flow of benefits it supplies: its size, representativeness, condition, and the variety contained within it. The underlying assumption is that *the volume, range, diversity and quality of benefits provided by natural heritage to society increase with the state of the heritage asset portfolio*; and that specific benefits (e.g. viable kiwi populations) are associated with particular states (i.e. sufficient size and condition with low consumption pressure from mammal predators).

This report describes an objective method to measure conservation achievement and then reports its application over the Twizel Area (central South Island, New Zealand) to demonstrate:

- capture of the information required
- a framework for reporting on the state of natural heritage and the difference made by conservation at a range of scales
- several decision support tools to identify priority places for conservation work and the most cost-effective conservation work programme.

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Part 1. Concepts and model development

New Zealand is home to such a diverse range of native plants, animals and environments that the challenge of conservation is often boiled down to 'caring for our natural heritage'. Precisely because our natural world is so diverse and dynamic, it is very difficult to measure and articulate just what difference our conservation efforts make. Yet, this is what accountable conservation managers must do to secure society's confidence in the value of conservation expenditure. Such confidence is critical to growing the conservation investment sufficiently, in order to halt the decline of our native biodiversity.

Part 1 describes the problem and its consequences, then defines the conservation business model from which the conceptual basis for measuring conservation achievement is derived. Part 2 applies these concepts over the Twizel Area to demonstrate the capture and integration of the information required. Part 3 describes the state of natural heritage and then demonstrates a framework for conservation reporting and decision support. A glossary on p. 113 explains the terms and indices used, as well as the assumptions made in their calculation.

1. Introduction

What difference does the Crown's expenditure on conservation (NZ$170.9 million in 2000/01) make to the state of New Zealand's natural heritage and the benefits it supplies to society? Given that society undertakes conservation to achieve positive social outcomes, information about the state of the nation's heritage portfolio—and some framework for measuring how conservation investment affects the flow of heritage derived-benefits—seem fundamental to sound management of conservation business.

The Department of Conservation (DOC) Annual Reports describe and count the actions undertaken and specific outputs completed. Achievement is indicated by anecdotes describing successes at particular places and with particular species. There is no reporting on what difference conservation activities make to the representativeness or condition or overall state of natural heritage; or to the benefits derived from lands and water managed for conservation purposes. For example, in the 1999/2000 Annual Report (Output 2.01: Legal, Protection and Status Changes), there is a clear statement about the output's purpose:

> 'The aim of work under this output is therefore the formal protection of priority sites to complete this network of protected areas that best reflects the full range of conservation and community values.'

Despite this clear intention, there is no description of what difference these acquisitions have made to the representativeness of lands managed for conservation purposes, nor any indication of progress toward priorities. Instead, four pages are dedicated to reporting on the number of Protected Natural Area surveys completed and reported; the number of sites under negotiation for protection; the number of National Park investigations; Ramsar wetland designations, and other new reserve classifications. This activity-based reporting pattern is consistent throughout the annual reports since 1998/99. The sections on animal pest control (Outputs 4.02, 4.03 and 4.04) report achievement in terms of the area treated, under sustained management and total benefit area. There is no indication of what difference this pest control effort has made to predator and browser pressure on the native biota, nor any indication of change in the condition of native biota. Furthermore, each animal pest is reported on separately so there is no way to identify if (or where) there may be synergistic benefits from multiple pest control in the same area. In short, there is no reporting against the fundamental purposes (e.g. defending and improving the condition of our natural heritage) for undertaking these activities.

While it is easy to be critical of such reporting, in reality, there are few quantitative tools for measuring conservation achievement. There are no methods for measuring the state of heritage or even to satisfactorily estimate change in the representativeness of the protected area network. Furthermore, there is insufficient knowledge of the benefits supplied by heritage to realistically contemplate reporting on variation in the flow of heritage-derived benefits to society. Yet ultimately, this is what we must do in order to identify which conservation investments will provide the best outcomes for society.

The present study aims to fill these gaps by developing and illustrating a method for systematic conservation measurement, reporting and decision support.

1.1 WHY MEASURE CONSERVATION ACHIEVEMENT?

Weitzman (1998) identified that:

> 'Current approaches to endangered species protection seem almost completely lacking in theoretical underpinnings that might reasonably guide policy. As a result, we do not have rigorously grounded criteria for choosing among biodiversity-preserving alternatives, and it is difficult to evaluate performance.'

The absence of a framework to quantitatively describe the difference made by conservation effort (i.e. conservation output) confounds both credible reporting and objective allocation of resources for conservation action. The value-for-money of different conservation actions producing different outputs cannot be compared objectively without a common measure of conservation output (Metrick & Weitzman 1998) because there is no logical basis to support choices between competing actions. For example, without a common, generic measure of conservation output, it is impossible to compare the cost-effectiveness of a pest control operation, with the recovery of a threatened species or a wetland restoration project.

Several conservation output measures and performance indicators have been proposed for specific components of conservation business. Hockings *et al.* (2000) developed a framework for evaluating the effectiveness of protected area management based on a series of qualitatively assessed performance indicators. Pressey *et al.* (1994) use complementarity for reserve selection. Woinarski & Price (1996) used phylogenetic distinctiveness and Barker (in press) has devised some phylogenetic diversity measures of conservation output. Weitzman (1998) used a measure of 'marginal distinctiveness plus utility per dollar' for species conservation. Fairburn *et al.* (2000), Fairburn (1998) and Cullen *et al.* (1999) demonstrate the use of Conservation Output Production Years (COPY) to measure the productivity of threatened species conservation projects. These are all valuable contributions to conservation performance assessment and cost-utility analysis, yet the scope of conservation output captured by these measures (reserve selection and threatened species management) is insufficient to be useful for comprehensive reporting and decision support purposes. Reserve selection and threatened species conservation are just two of many facets of natural heritage conservation. In New Zealand, animal pest and weed control are much larger components of the conservation effort. Consequently, measures of output for reserve selection and species protection do not enable comparisons among the full range of competing conservation projects; nor do they contain information suitable for comprehensive reporting on the difference conservation effort has made to the state of natural heritage. Furthermore, species-based measures (e.g. COPY) can only apply to the small portion of biodiversity for which there is adequate taxonomic and survey information and they do not take into account the benefits to many species of actions undertaken to secure a few threatened species (e.g. island rat eradications to protect tuatara populations). While these are significant issues, an even greater problem is that these measures of conservation output (with the possible exception of Weitzman's (1998) measure) are unrelated to the value of natural heritage to society. Given that society undertakes conservation in order to protect the flow of benefits supplied by heritage to society, the most useful measures of conservation output will be related to benefit flow, and will be applicable across the full scope of natural heritage conservation activity.

In summary, effective management of conservation is constrained by the absence of credible methods for measuring conservation output because the worth of diverse conservation outcomes cannot be objectively compared. For example, we cannot compare the worth of a new marine reserve with that of a possum control operation. This means:

- DOC cannot demonstrate what difference its efforts make
- there can be no objective basis for deployment of its resources to supply conservation outcomes.

Consequently, there is doubt about quality of conservation expenditure and agency accountability (Hartley 1997; Kerr 1998), causing heritage conservation to be penalised in trade-offs with other government objectives (Fig. 1).

The vision behind our project is the development of comprehensive and objective conservation measurement as standard practice to secure confidence in the efficiency of conservation expenditure and so encourage additional conservation investment. We describe a conceptual framework and method for conservation measurement and its use over the Twizel Area to demonstrate:

- capture of the information required to apply the method
- ways to report on the state of natural heritage and the difference made by conservation
- decision support tools to identify priority places for conservation and the most cost efficient work programme for a given budget.

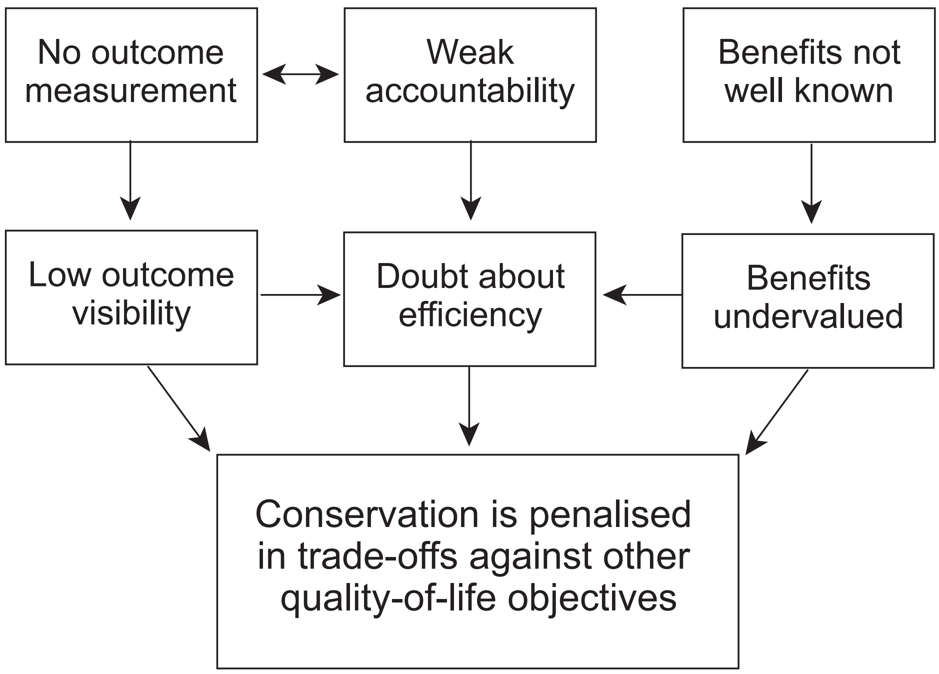


Figure 1. Conservation funding bind. The absence of conservation outcome measurement, combined with paucity of knowledge of the benefits supplied by heritage, results in conservation being penalised in trade-offs against other social outcomes (e.g. health, education, social welfare).

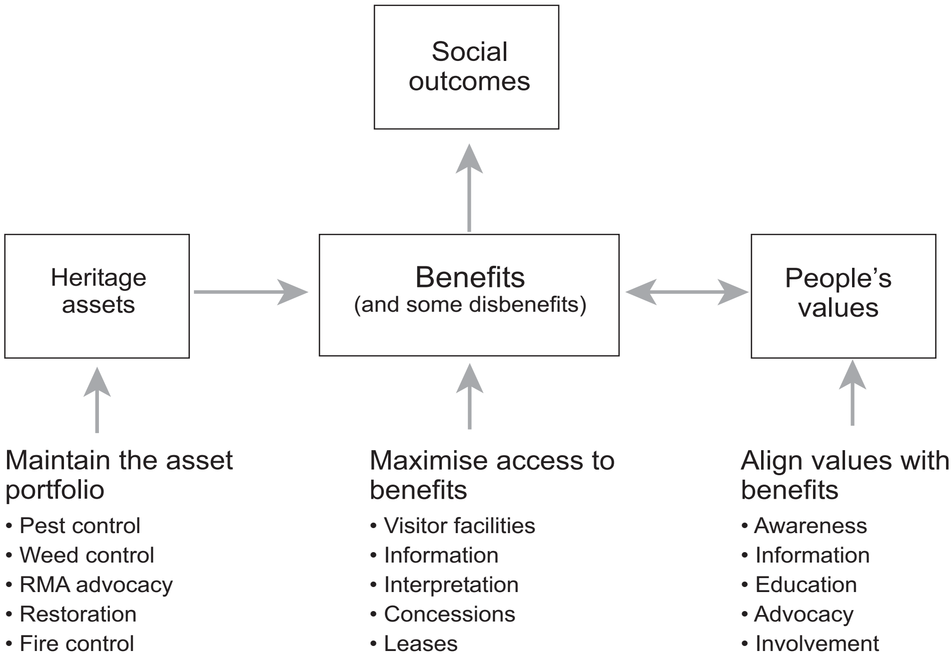


Figure 2. Conservation business model. Heritage supplies diverse benefits (and some detriment) that sustain social outcomes. People value these benefits in different ways, depending on their cultural background and personal experiences. This gives rise to three conservation business streams. The first aims to maintain the heritage asset portfolio in whatever state maximises benefit flow. The second aims to provide equitable physical, intellectual and commercial access to the stream of benefits. The third aims to better align the value that people accord particular benefits with expert knowledge of value, so as to sustain the mandate for controversial conservation activities in the other two business streams.

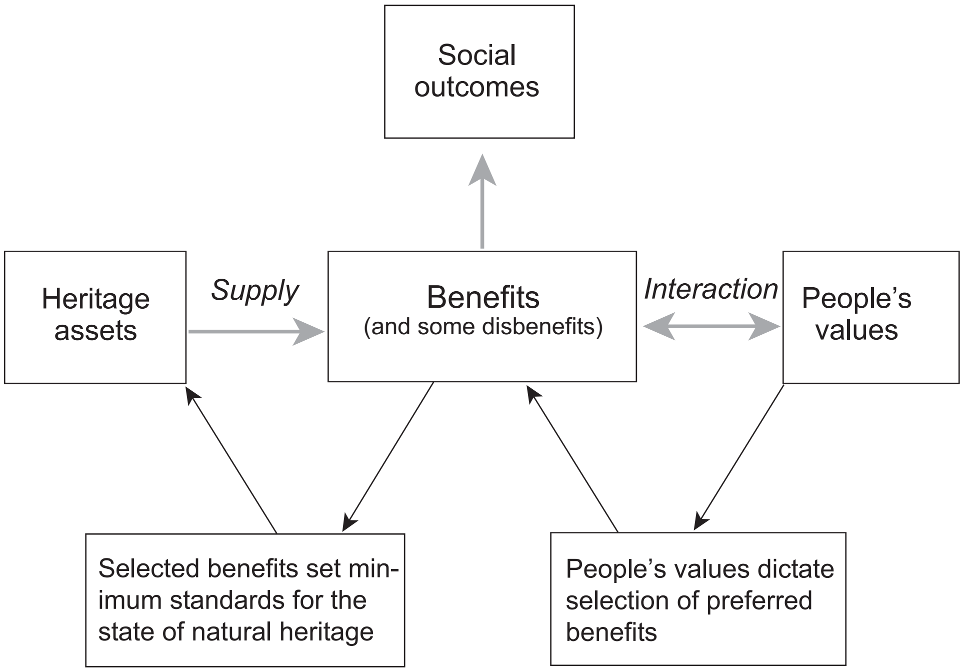
1.2 THE CONSERVATION BUSINESS MODEL

Our process for measuring conservation achievement is based on the premise that conservation is a value-driven asset management business (Fig. 2). The asset portfolio is New Zealand's natural and historic heritage. Conservation is the business of maintaining the natural heritage portfolio to maximise the flow of benefits it provides to society. It has three business streams:

- heritage maintenance to maximise the volume, diversity and quality of benefits it provides
- management of the public use and enjoyment of heritage to maximise fair physical and intellectual access to benefits and minimise unwanted exposure to harm (e.g. from natural hazards)
- improving society's understanding of the nature and value of heritage in order to sustain support for goals within the other two business streams and the actions required to achieve them.

Conservation is a value-driven business. The value that people accord particular benefits (e.g. wilderness; recreation; distinctive or charismatic fauna and flora) drives selection of what people want from heritage (i.e. the desired outcome). The specific benefits selected dictate minimum standards for the state of natural heritage at particular places necessary to sustain the desired outcomes (Fig. 3). Thus, if abundant kiwi and natural kauri vegetation are benefits sought by society at Trounson Reserve, then selection of these particular benefits effectively specify minimum standards for the abundance of introduced predators and weeds. This relationship means that the size of an outcome can be measured by change in the state of heritage caused by achieving that outcome. This is the key principle upon which the conservation measurement

Figure 3. Conservation business dynamics. The particular benefits that the public wants (i.e. the site-specific outcome specification) indirectly set minimum standards for the state of heritage at the site. This relationship means that the size of an outcome can be measured as change in the site's contribution to the state of the heritage portfolio.



process is founded: the size of unlike outcomes derived from very different conservation actions (e.g. creation of a marine reserve vs. possum control) can be compared by measuring the effect of these activities on the state of natural heritage and the benefits it provides.

Local, place-based outcome specification is the start to the process. There are many democratic structures and participatory processes available for outcome specification (e.g. legislation, national, regional and local strategies, conservation boards, consultation processes and lobbying). None of these are clearly focused on achieving place-based outcome specification for the purpose of driving conservation business, though conservancy Conservation Management Strategies could potentially fulfil this role. The process for place-based outcome specification must be participatory, democratic and informed to sustain public support for the both the chosen outcomes and the actions needed to achieve them. Outcome specifications should define at least four components of the outcome:

- the key valued attributes (benefits) to be the focus of conservation effort
- the desired state for these attributes
- where (i.e. the place) this should happen
- the sort of interaction people want with key valued attributes.

This information defines the scope for projects (i.e. the work programme) designed to deliver the outcome. A range of project designs is desirable as they provide the opportunity to optimise cost, risk and delivery time tradeoffs. The conservation measurement process then uses the outcome and project design specifications to measure the conservation achieved. This information can then be used in a variety of ways to inform conservation management decisions.

1.3 CONSERVATION ACHIEVEMENT MEASUREMENT AND PROJECT PERFORMANCE MONITORING

Conservation achievement measures the difference made to the state of natural heritage; it is separate and distinct from project performance monitoring which measures the delivery of specific outputs and progress towards particular outcomes. Project performance monitoring is central to management accountability for the delivery of project outputs. It is needed to determine whether accountable managers are reaching key project milestones and are delivering the outputs needed to achieve chosen outcomes. It provides the information needed to review and improve the way a project is implemented and so is of most value to the accountable project manager. Taking the Trounson kiwi and kauri forest example (Section 1.2), pest control performance monitoring is required to determine whether pest control staff are delivering the specified level of pest control expected to ensure juvenile kiwi survival; weed monitoring is needed to ensure that weed control is adequate to maintain the natural kauri forest community; juvenile kiwi must be monitored to ensure that adequate survival is occurring; and visitor satisfaction monitoring is necessary to ensure that facilities and information meet visitor expectations. Note that the particular parameters measured are highly project-specific and so offer no basis for comparing the achievements of unlike projects; nor can they be aggregated to measure the achievement associated with a suite of projects. For example, if the Trounson manager was also managing a wetland restoration project, then one output measure might be the complete blocking of three drains; another might be an increase of 1.5 m in the mean annual water level and an outcome measure might be the recovery of some named wetland plant and animal populations at the site. Clearly these wetland restoration performance measures cannot be compared or combined with the Trounson performance measures. They are therefore of no value for measuring the total conservation output delivered by these two projects.

Performance monitoring information is of little value to management levels above that of the accountable project manager. It is of most value to the project manager for the purpose of managing and improving project implementation—but only if that manager is truly accountable for output delivery. If institutional culture and systems do not demand accountability for outputs then there is no incentive to monitor output delivery, improvements and progress towards chosen outcomes. Higher-level managers need to know more about what difference projects are making and progress toward high-level outcomes (i.e. the value added by the project), than how to improve the implementation of individual projects (this being the business of the accountable project manager). Project performance measures cannot provide this information and it is simply not possible to estimate what value conservation effort adds by collating these measures. Nevertheless, this has been the approach used for national reporting in DOC annual reports. That is why these reports fail to indicate what difference conservation has made to the state of New Zealand's natural heritage.

Thus conservation project performance measurement informs decisions about *how* to achieve the desired outcome and promotes line accountability for output delivery at the scale of individual projects. In contrast, conservation achievement measures the outcome of conservation effort: the difference made to the state of natural heritage. It also promotes line accountability for delivery of both outputs and outcomes, but in addition, it informs decisions about where to do what and it enables reporting on the difference made at each level of management. Measures at the project scale can be aggregated to measure achievement at all management levels and so can promote accountability for conservation output at all levels of management. Defensible and accountable conservation management requires both project performance monitoring to support delivery work 'in' the business and achievement measurement to support management work 'on' the business.

1.4 THE CONCEPTUAL BASIS FOR MEASURING CONSERVATION ACHIEVEMENT

Conservation achievement measurement is based on change in the state of natural heritage. Taxonomic and survey capacity constraints mean that the state of natural heritage cannot be assessed directly. Taxonomy is reasonably complete only for vascular plants, vertebrates and the larger terrestrial molluscs and arthropods. Together, these comprise a very small portion of the total biota. Our capacity to survey the biota and the physical processes comprising natural heritage is minute relative to the portion that we do know about. This means we can quantify only a tiny fraction of the elements comprising natural heritage. The state of natural heritage, and the difference conservation makes, must therefore be based upon integrative surrogates chosen for their ability to account for biotic pattern in time and space (Margules & Pressey 2000).

Stephens (1999) developed a conceptual model for measuring the 'state' of natural heritage. *State* is defined in terms of the four key attributes that control the flow of benefits supplied by natural heritage: the size of the heritage asset portfolio, its representativeness, its condition and the variety of heritage contained within it.

Size is a major determinant of the volume of many direct benefits (e.g. water yield; carbon fixation; species richness) whereas other benefits (e.g. whales and wilderness) are dependent on the existence of large natural areas.

Representativeness determines how much of the full range of benefits potentially available are actually supplied. If the full range of benefits supplied by New Zealand's heritage is to be provided, then the heritage portfolio must contain some representation of every type of heritage. For example, people cannot enjoy the naturally abundant large fish in our inshore reefs if these environments are insufficiently represented and protected in the reserve network.

Condition determines quality and presence of sensitive and vulnerable benefits. Vulnerable taxa cannot be sustained in degraded environments and the awe inspired by the grandeur of our podocarp and kauri forests is dependent on their good ecological condition.

Variety within the heritage portfolio determines the diversity of benefits it supplies. Special and distinctive features can only be sustained in a diverse heritage portfolio. Thus a uniformly montane and alpine reserve network cannot supply the benefits (e.g. endemic species) associated with lowland forests, islands or coastal reef systems.

This approach to measuring the state of natural heritage provides a way to measure conservation achievement and project outcomes in terms of the difference made to the state of natural heritage and hence to the flow of heritage-derived benefits. The underlying assumption is that *the volume, range, diversity and quality of benefits provided by natural heritage to society increase with the state of natural heritage* and that specific benefits (e.g. viable kiwi populations) are associated with particular states (i.e. sufficient size and condition with low consumption pressure from mammal predators). Conversely, benefits provided from non-natural (alien or introduced) heritage decrease with the state of natural heritage. Thus benefits derived from deer (e.g. via farming and hunting) increase with deer abundance but are associated with a reduction in the condition of natural heritage.

2. The components of site value

A site may be a single, spatially contiguous area or a collection of separate places. At maximum resolution, the smallest unit is represented by a single pixel on a digital map. The 'value' of a site is a measure of its contribution to the overall state of natural heritage. Thus 'site value' is a composite, context-dependent measure that captures a site's contribution to the value of the whole natural heritage portfolio, which is in turn determined by its size, the variety of heritage within it, its representativeness and its condition. The corresponding attributes of site value are:

- *Size*: a large site contributes more to the size of the portfolio and so to the volume of benefits supplied than a small one.
- *Distinctiveness*: a distinctive site adds more to the variety within the portfolio and diversity of benefits supplied than a similar, commonplace one.
- *Importance*: an important site is a better example of what remains of its ecological type and so contributes more to representation of the range of benefits available than an unimportant site.
- *Condition*: a site in good condition contributes more to the state of the portfolio and supplies sensitive benefits not available from degraded sites.

A site adversely affected by human-induced disturbances will lose condition, will become less representative of its natural ecosystem type, may lose distinctive features and may be reduced in size (Fig. 4). Any of these changes diminish a site's value because they reduce its contribution to the state of natural heritage and so reduce the flow of benefits it supplies. With conservation management, the loss will be reduced or prevented, or there may be some restorative improvement that increases its value. The difference between the value of a site with and without conservation management is a measure of the size of the outcome brought about by that management.

Outcome size could be used to differentiate the worth of different conservation management programmes, but this would ignore preference for immediate and

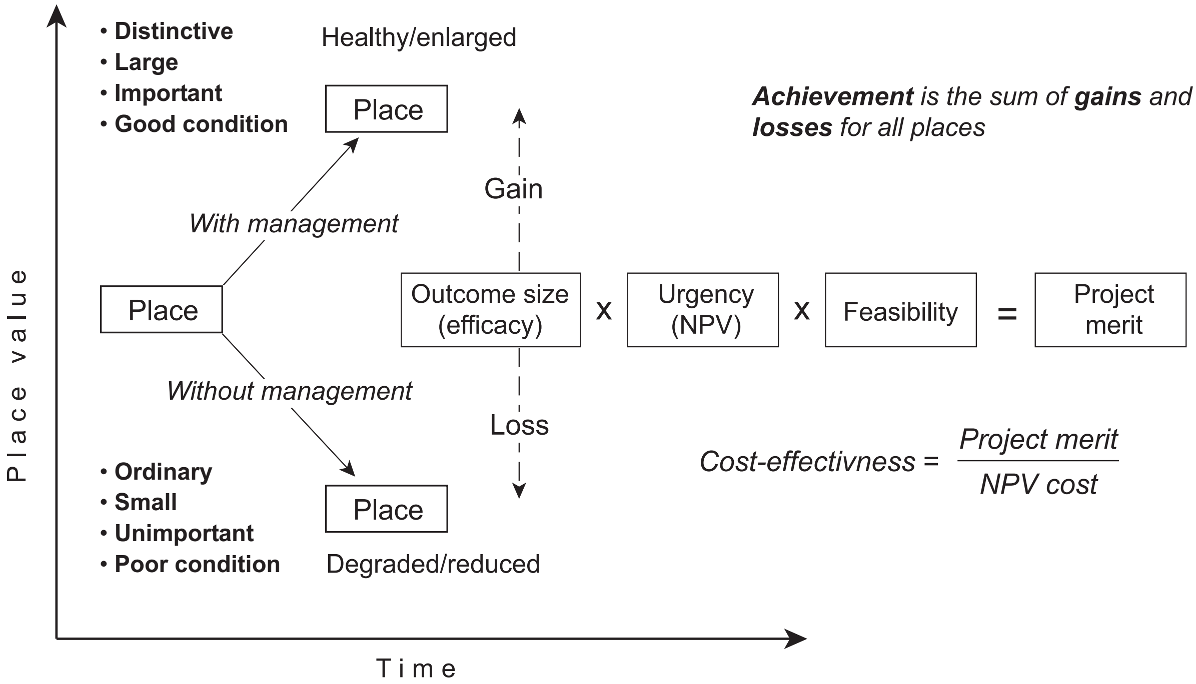


Figure 4. Modelling project merit. Project merit is outcome size discounted for time and feasibility. It measures the value added by a conservation project to the flow of benefits supplied by the heritage portfolio.

highly feasible outcomes over those that will take longer or are less feasible. It is therefore necessary to discount outcome size twice. First, according to how long it will take to provide the outcome (and the relevant discount rate) in order to estimate the nett present value (NPV) of the outcome. Second, the outcome must be further reduced according to the risk of not achieving it (i.e. feasibility). The fully weighted project outcome (i.e. project merit) measures how much value a project will add to the state of natural heritage and, by implication, is an index of the added benefit flow from natural heritage. It is therefore a measure of conservation output. This measure can be divided by the cost of achieving it to measure project cost-effectiveness relative to other conservation projects (Fig. 4).

2.1 HOW DOES SITE SIZE CONTRIBUTE TO SITE VALUE?

The quantity of natural heritage present in a site is related to its size. Other things being equal, a large site contains more natural heritage than a small one. It will contain more species, greater structural and functional diversity, and will sustain a greater volume of ecosystem products and services. Thus the size of a site contributes to the quantity of benefits provided (e.g. species richness, population sizes, water flows and carbon storage) and to key qualitative attributes of the portfolio (e.g. resilience, wilderness, water quality). Since species richness and other benefits provided by natural heritage are proportional to a root function of site area, a fractional exponent of site area was chosen as the most appropriate index of the contribution of site size to the heritage portfolio. This exponent expresses the rate at which natural heritage (and benefit flows) increase with site size or, conversely, the rate of loss associated with diminishing area.

2.1.1 Indexing the contribution of site size to site value

Species richness–area relationships indicate that the number of very small-bodied, low-mobility species that do not depend on environmental heterogeneity to complete their life cycles (e.g. many unicellular and colonial soil micro-organisms) increase in proportion to area with an exponent of c. 0.15. Large-bodied species (particularly vertebrates) that require a range of environments (e.g. migratory native fish; much of our charismatic megaflora and fauna) or use ephemeral habitats (e.g. forest gaps) are more dependent on large areas, increasing in number in proportion to area with a larger exponent, up to c. 0.4 (Connor & McCoy 2001). Ecosystem products and services (e.g. carbon fixation; water supply; waste recycling) increase in proportion to area with an exponent approaching 1.0. The appropriate exponent to use for the purposes of natural heritage conservation depends upon which particular benefits conservation is required to sustain. If the business is to ensure the supply of ecosystem products and services, then an exponent of c. 0.95 is appropriate. If the business is to retain a minimum set of examples of each ecosystem type, then a small exponent between 0.15 and 0.25 would be appropriate. If the business is biodiversity conservation with particular regard to the charismatic megaflora and fauna and ecosystem resilience, then the exponent should be larger, probably c. 0.4. For the purposes of this trial, it is assumed that the core business of conservation is biodiversity conservation and that society particularly wants our familiar and charismatic mega biota to be sustained. Hence the chosen exponent was 0.4. If the core business of Regional Councils is protection of environmental goods and services (one interpretation of 'life supporting capacity') then it would be appropriate for these agencies to adopt an exponent of c. 0.9–0.95.

The key consequence of a size exponent less than 1 is that the value of an additional hectare is greater for a small site than for a large site. Similarly, the incremental benefit of an additional hectare of pest control declines with the size of the area over which the pest is already controlled. Thus the benefits of pest and weed control are not proportional to the area of control.

2.2 HOW DOES DISTINCTIVENESS CONTRIBUTE TO SITE VALUE?

The variety of benefits supplied by the natural heritage asset portfolio is related to the diversity of assets comprising the portfolio. It is the distinctiveness of heritage assets that collectively make up the diversity contained within the whole portfolio. Thus asset distinctiveness is a key attribute of asset value.

There are two candidates for estimation of heritage distinctiveness: environmental distinctiveness and biotic distinctiveness. The former was chosen because it is:

- a key driver of biological distinctiveness and diversity
- much more easily quantified in a spatially comprehensive manner than biotic distinctiveness.

Incomplete taxonomy and limited survey capacity mean that biotic distinctiveness could only be based on the minute portion of biota that is both taxonomically described and surveyed. Estimates of biotic distinctiveness will inevitably be biased towards the small portion of the biota that we can know about. The primary problem with environmental distinctiveness as a surrogate for biotic distinctiveness is that biogeographic history, the other major driver of biotic pattern, may not be adequately described by the environmental variables used to measure distinctiveness. This may be remedied by including variables such as age of surface in order to capture biogeographic patterns. Also, small-scale environments and habitats (e.g. geothermal vents) that exist at smaller scales than the resolution of the underlying data will generally not be recognised. These small-scale environments could be major contributors to regional biotic distinctiveness, especially for plants and invertebrates.

2.2.1 Indexing the contribution of distinctiveness to site value

Environmental distinctiveness was measured (Overton 2001) using six climate variables and three landform variables (see Section 5.1) selected for their significance for plant growth and ecological processes.

Distinctiveness was measured as the mean distance in ordination space from each pixel to other pixels across New Zealand. The concept behind the measure can be illustrated in two dimensions by plotting one environmental variable against another (Fig. 5). The resulting scattergram might form a group with a few outliers. The mean distance from one point within the group (X) to all other points is less than the mean distance from an outlier (O) to all other points. The mean distance measures the distinctiveness of each point in relation to all others. The mean distance in multi-variable space (as opposed to two-variable space) is a similar calculation. For the purposes of conservation assessment, the preferred measure of distinctiveness is the (range standardised) mean distance in ordination space to pixels lying within areas managed for conservation purposes. This measure identifies places that would add to the diversity of environments present within areas managed for conservation.

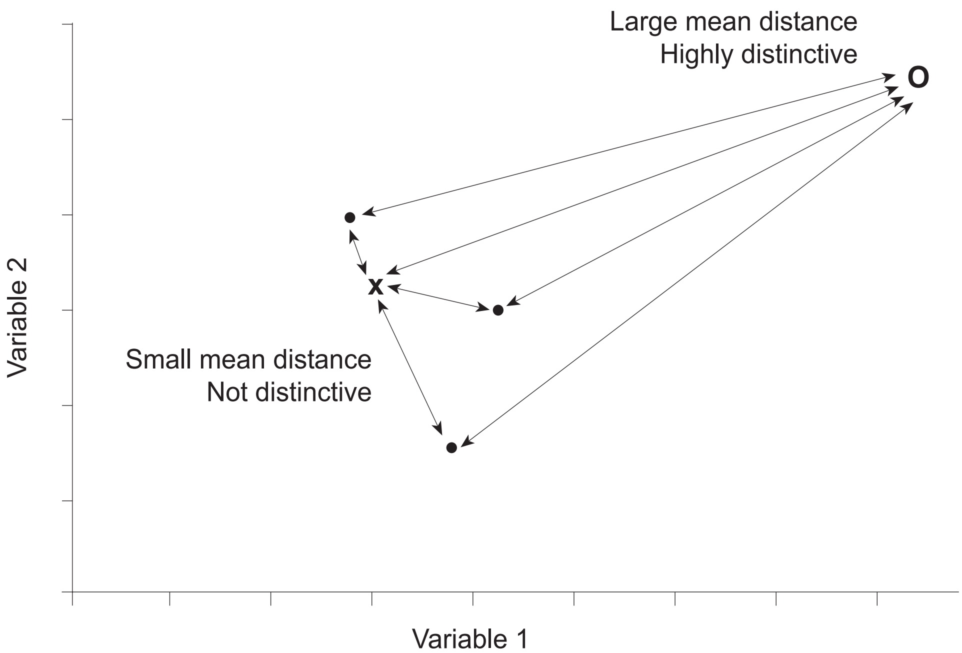
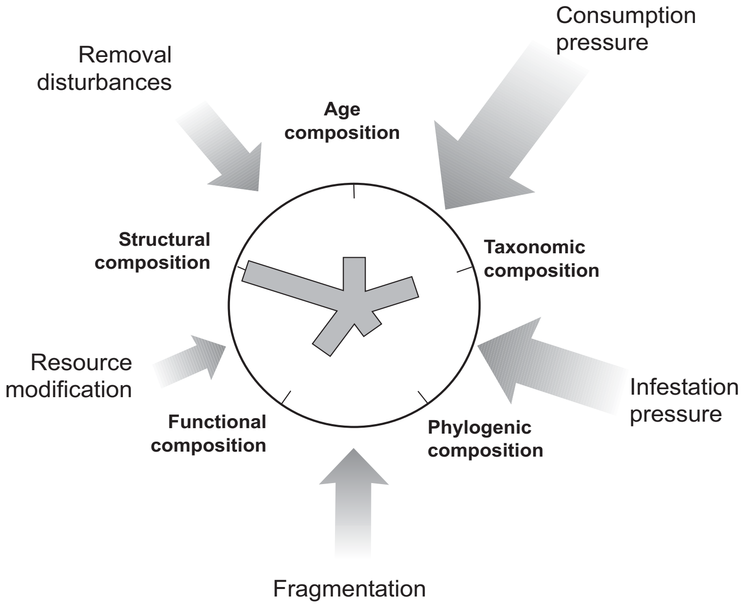


Figure 5. Measuring environmental distinctiveness. Environmental distinctiveness is the mean distance in ordination space to a set of reference points. These might be all of New Zealand (Fig. 14) or all pixels within Crown land managed for conservation (Figs 15 and 16).

Figure 6. Pressure and condition. Condition is defined as compositional similarity to undisturbed biota. Pressure reflects the intensity of human-induced disturbance. Both have several dimensions. The condition of a site is some additive combination of compositional similarity in each dimension.



2.3 WHAT IS PRESSURE AND CONDITION?

Pressure on natural heritage is a measure of the various human-induced disturbances affecting the condition of native biota. Condition measures the difference in the biota caused by pressure (Fig. 6). Because of the cause-effect relationship between them, pressure can be a surrogate measure of condition. Condition is a relative property —not an intrinsic heritage property. It measures the similarity of contemporary biota to biota expected in absence of human-induced disturbances. It is the inverse of compositional distance to undisturbed biota:

$$\text{Condition} = \frac{1}{1 + \text{Compositional distance}}$$

Condition is an additive combination of several components, such as taxonomic composition, phylogenetic diversity, functional diversity, structural diversity and age diversity. Biota loss is conceived as the complement of condition (i.e. Biota Loss = 1 – Condition). Thus condition is a measure of biodiversity persistence. It measures what remains of its physical structure and biotic content.

Pressure is the proximate target of conservation and is directly altered by management whereas condition is the ultimate target but is only indirectly or partly affected by management. For example, weed cover (a pressure component) might be the proximate management target whereas natural vegetation composition (i.e. condition) is the ultimate target. Clearly weed control is only one of many factors that will determine future vegetation composition. Causal links between condition and conservation management are often unclear and there can be significant time lags between management action and changed condition. Ideally, conservation achievement would be measured in terms of condition gained and losses avoided. However, because of the time lags, poorly understood causal links and lack of condition data, it is difficult and expensive to ascribe incremental condition change directly to conservation action. In part, this is why so little management effort (cf. research effort) goes into demonstrating causal links and hence the difference made by management. Our approach to conservation measurement is to estimate the effects of management on the immediate, proximate targets of conservation action (e.g. pests) and to assess conservation achievement via explicit relationships between pressure targets and condition. Research is needed to improve our understanding of these relationships; meanwhile we make explicit the assumed relationships between pressures (e.g. possum abundance) and condition in order to use pressure as a surrogate measure of condition.

Thus the conservation measurement process uses pressure as a temporally disconnected, surrogate measure of condition. It is temporally disconnected because of time lags between the start of human disturbance and condition loss. Similarly, condition recovery may lag some years behind effective conservation management.

Pressure is based on measurement of five types of human-induced disturbance:

- *Biota removal*: the intensity of disturbances that reset succession trajectories, as indicated by the amount of biota removed through hunting, fishing, logging, fire, land clearance and pesticide use.
- *Physico-chemical resource modification*: the intensity of disturbances that tend to divert succession trajectories, as indicated by change to natural hydrology, nutrient, substrate, light and temperature regimes from land use activities (e.g. drainage, inundation, road and urban development).
- *Consumption pressure*: the pressure on native plants, animals and invertebrates as indicated by the variety and abundance of introduced animal pests.
- *Infestation pressure*: the pressure on native plants, animals and invertebrates as indicated by the cover of introduced plants.
- *Fragmentation*: altered spatial relationships as indicated by pressure on the surrounding landscape.

Human-induced disturbance pressures were measured by indices scaled according to condition loss (expressed as a fraction) thought to be associated with the intensity of each type of disturbance. Where possible, indices were derived from process-based models of impacts on native biota.

2.4 THE CONTRIBUTION OF IMPORTANCE TO SITE VALUE

The capacity of the natural heritage portfolio to supply the full range of benefits available in New Zealand depends upon how well the nation's heritage is represented in the portfolio. Importance is a measure of how much a site contributes to the representativeness of natural heritage. A site may be important for two reasons:

- it contains the best of what remains of those environments represented within the site
- there is very little left of the environments represented at the site in a near-natural state.

An important site contains the best of what remains of its type. A site may be important even if condition is degraded because other parts of those environments are even more degraded. Thus importance is a context-dependent measure that varies not only with the condition of the site but also with the condition of the same environments in areas outside the site.

This relationship was captured in an index by expressing the 'site area remaining' as a proportion of 'remaining environments' adjusted according to what remains of the potential extent of natural environments. The importance index was defined by a power function (one fraction raised to the power of another fraction) based on a site's contribution to what remains and adjusted for past losses:

$$\text{Importance} = \left\{\frac{\text{Site area remaining}}{\text{Remaining area}}\right\}^{\left(\frac{\text{Remaining area}}{\text{Environment area}}\right)}$$

Where:

Site area remaining is the area of the site with Pressure ≤ the Mean pressure for the site. If a site is a single pixel, then 'Site area remaining' is pixel area.

Remaining area is the area of those environments that occur at the site with Pressure ≤ the Mean pressure for the site.

Environment area is the total area of environments represented at the site.

The importance of an area provides a measure of how well that area represents what remains of its environment type and so offers a way to identify the best of what remains over the whole landscape. However, this method requires the simplifying assumption that all environments are equally different, which clearly they are not. A method of measuring importance that properly accounts for the continuous nature of environmental variation has yet to be devised.

3. Site value, vulnerability, irreplaceability, and priority for management

Site value measures how much a site contributes to benefits supplied by the natural heritage portfolio. The site value measure integrates the contribution of a site's area, distinctiveness, importance and pressure to portfolio size, diversity, representativeness and condition. We define site value as the product of its four components:

$$\text{Site value} = \text{Site area}^{0.4} \times \text{Distinctiveness} \times \text{Importance} \times (1-\text{Pressure})$$

Site value was defined by a multiplicative function because if any one of the four attributes is zero, then site value should be negligible. This would not be expressed by an additive function. A key issue with the multiplicative function is the large variance it creates. The model differentiates site value very effectively and this is useful when dealing with large numbers of sites. However, it is not clear whether the magnitude of differentiation is appropriate and we have been unable to conceive of an objective basis for testing the validity of this degree of differentiation.

Inclusion of the context-dependent importance measure means that site value is also a context-dependent measure. Consequently, even if conservation work decreases site pressure, it may not increase site value if that work causes a greater reduction in pressure outside the site in environments represented within the site.

3.1 IDENTIFYING PRIORITY SITES FOR MANAGEMENT

Sites can be ranked according to their value but high-value sites that contribute most to the heritage portfolio are not necessarily those most in need of conservation effort. Since the goal of conservation is to maximise the flow of benefits from the portfolio, then priority sites are those from which most benefit will be lost. This then raises the question as to whether benefit volume, or the diversity and quality of benefit should drive priorities.

De novo priorities can be identified by the difference between site value now and that predicted without management. However, there is little management need to identify *de novo* priorities. In reality, conservation effort is ongoing and the more pertinent problem is identification of priority sites for additional (or alternative) effort. These are the sites that are losing most value despite current management. They can be identified by the difference in site value now and with current management.

3.2 MEASURING PROJECT OUTCOMES

Measuring project outcomes requires definition of the 'project site'. We define the project site as all places (pixels) where pressure reduction is expected as a consequence of project implementation. Project outcome size is the difference in value of the project site caused by project implementation. This difference is driven by change in both pressure and importance at the project site. Importance is in part determined by pressure. The other two attributes of site value (i.e. environmental distinctiveness and site size) are independent of management (i.e. constant for the project site whether or not the project is implemented). Thus change in pressure is the key driver of project outcome size.

Project outcome size can be weighted according to how long it will take and the risks of non-achievement to index project merit. This measures conservation output. Project merit can then be divided by project cost to quantify project cost-effectiveness.

4. Summary of concepts and terms

1. Conservation achievement measurement quantifies the difference made to the state of natural heritage. It is useful for informing decisions about where to do what, and to enable reporting on the difference made and is an essential part of ensuring defensible and accountable stewardship of natural heritage.
2. Conservation project performance measurement measures how fully particular conservation outputs are delivered. It is essential for ensuring management accountability for delivery of agreed outputs and is useful for monitoring progress towards chosen outcomes.
3. The volume, range, quality and variety of benefits from natural heritage ('state') increase with its size, representativeness, condition and variety.
4. Site value is related to the benefits it supplies to society and so is a function of its size, distinctiveness, importance and condition.
5. Site size contributes to the quantity of benefits provided (e.g. species richness, population sizes, water flows and carbon storage) and to key qualitative attributes of the portfolio (e.g. resilience, wilderness, water quality). Benefits increase with site size but at a diminishing rate.
6. Pressure is a measure of human-induced disturbances to natural heritage that cause condition loss. It comprises five types of pressure: biota removal; physico-chemical resource modification; consumption pressure; infestation pressure; and fragmentation.
7. Importance is an index of representativeness. It measures how close a site is to being the best (defined by pressure) of what remains of its type (defined by environments present within the site).
8. Distinctiveness is a measure of similarity to the environments (and by proxy, potential biota) of areas managed for conservation purposes. Distinctive places add to the diversity of natural heritage.
9. Vulnerable sites are those at risk of increasing pressure and hence condition loss.
10. Irreplaceable sites are distinctive and/or important sites.
11. Priority sites for management are at risk of value loss or are both irreplaceable and vulnerable.
12. Conservation outcome size is measured by change in the value of the area affected by management.
13. Conservation output is measured by outcome size weighted for delivery time and feasibility.

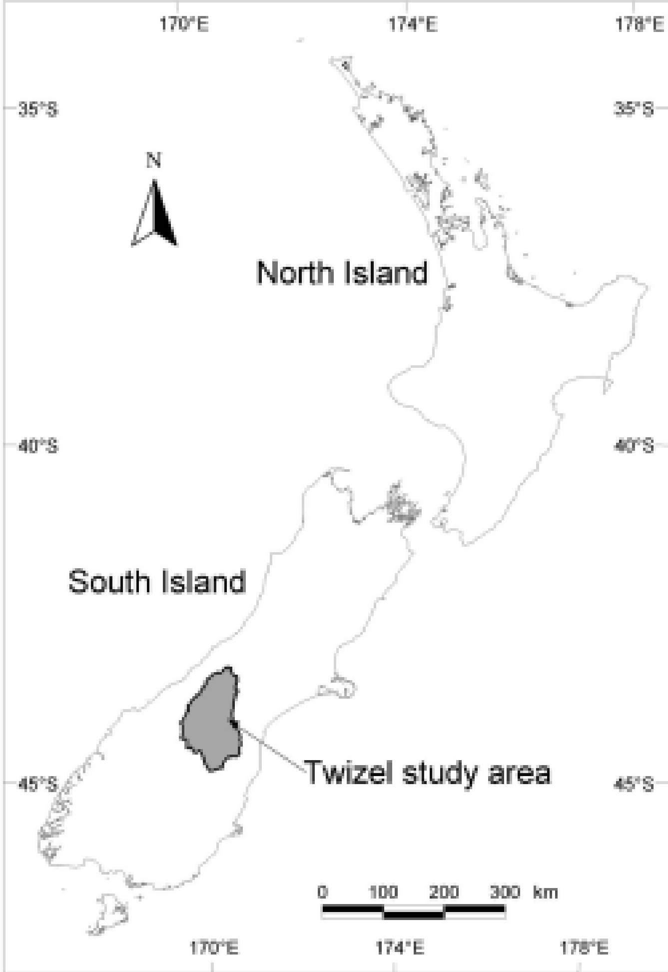
Part 2. Capturing the data and deriving the components of site value and project merit

The conservation measurement model described in Part 1 was applied over the administrative areas of the Twizel and Aoraki Area Offices of the Department of Conservation to demonstrate:

- how the necessary data can be captured
- reporting—the state of natural heritage and the difference made by conservation
- decision support—identifying priority and places and cost-effective work programmes.

Part 2 first demonstrates how the data needed for measuring conservation achievement can be assembled; it then develops the models needed to define project outcomes and project merit. It concludes with a discussion of sensitivity issues.

Figure 7. Location of the Twizel Area in the central South Island of New Zealand.



5. The Twizel Area

The Twizel-Aoraki administrative area is in the central South Island of New Zealand (Fig. 7). The area comprises 10 668 km^2 of mountain ranges, glaciers, glacial lakes, tarns, wetlands, braided rivers and inter-montane basins (Fig. 8). The Canterbury Conservation Management Strategy indicates that highly valued benefits supplied by natural heritage in the Twizel Area are its:

- high mountains, snowfields and glaciers
- alpine landscapes set in native vegetation
- freshwater resources and
- wading birds, particularly the black stilt.

The conservation outcomes sought are:

- a mainly natural native vegetation setting for the alpine landscapes of the area
- no further loss of native species, with particular focus on recovering the black stilt.

Pest and weed control projects are the principal activities intended to deliver these outcomes.

The conservation measurement process requires four spatially explicit levels of environmental information to define the natural heritage portfolio:

- classification of the physical environment (e.g. Land Environments of New Zealand)
- classification of biotic cover (e.g. Land Cover Database)
- human-induced disturbance pressure on natural heritage (derived from topographic and land cover data, animal pest abundance, weed cover and fragmentation measures)
- distinctiveness (ideally biological distinctiveness derived from attributes of the biota but more realistically, environmental distinctiveness derived from the environmental variables behind the classification of the physical environment).

It utilises contextual information:

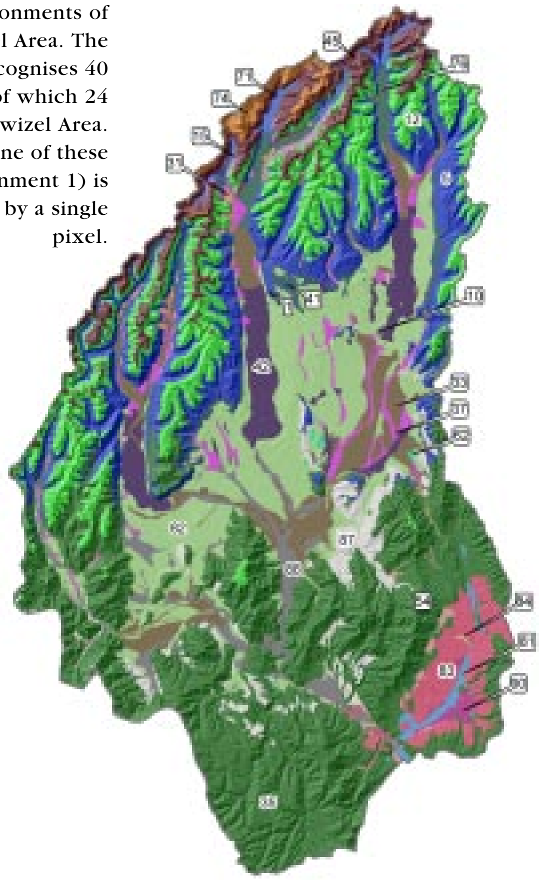
- land tenure (cadastral) data
- topographic data

and project-specific information describing:

- control area boundaries
- animal pest abundance and weed cover scenarios now, in the future (10 to 50 years), with and without control
- years until scenarios with and without conservation management will happen
- effects of risk factors on achievement of the desired project outcome and an assessment of how much of each risk factor is managed
- annual project cost estimates.

Figure 8. Twizel Area topography.

Figure 9. Environments of the Twizel Area. The classification recognises 40 environments of which 24 occur in the Twizel Area. One of these (Environment 1) is represented by a single pixel.



5.1 CLASSIFICATION OF ENVIRONMENTS

Leathwick (1998b) developed a classification of the physical environment based on environmental variables shown to account for much of the distribution pattern of native canopy trees, shrubs and ferns (Lehmann et al. 1998). The classification is hierarchical and so can be applied at a range of classification and spatial scales.

The classification was based on six climate variables selected for their significance for plant growth and ecological processes:

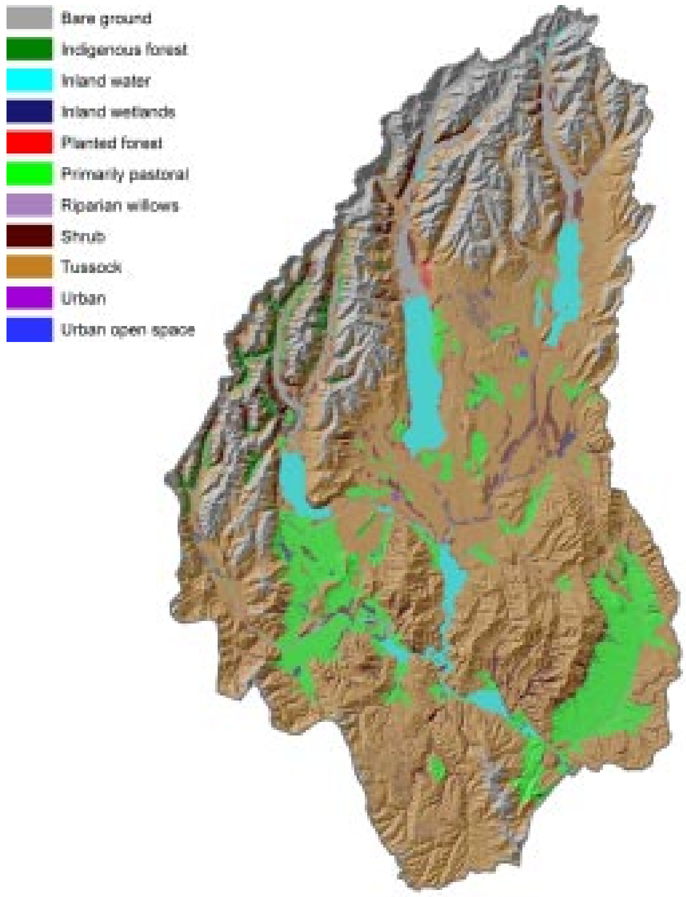
- Mean annual temperature
- Minimum annual temperature
- Mean annual solar radiation
- Minimum solar radiation
- Ratio of rainfall to potential evapotranspiration (PET)
- October vapour pressure deficit

and three landform variables:

- Parent material
- Drainage
- Slope

The Ministry for the Environment (MfE) commissioned Landcare Research (Leathwick et al. 2001) to classify environments present in the Canterbury Region. In our study we used their classification, at the 40 group level with a minimum map

Figure 10. Land cover in the Twizel Area. Derived from the Land Cover Database (LCDB). It is a 12-group classification mapped at 1: 50 000 from satellite images and aerial photographs (cover class Mangroves is not represented in this area).



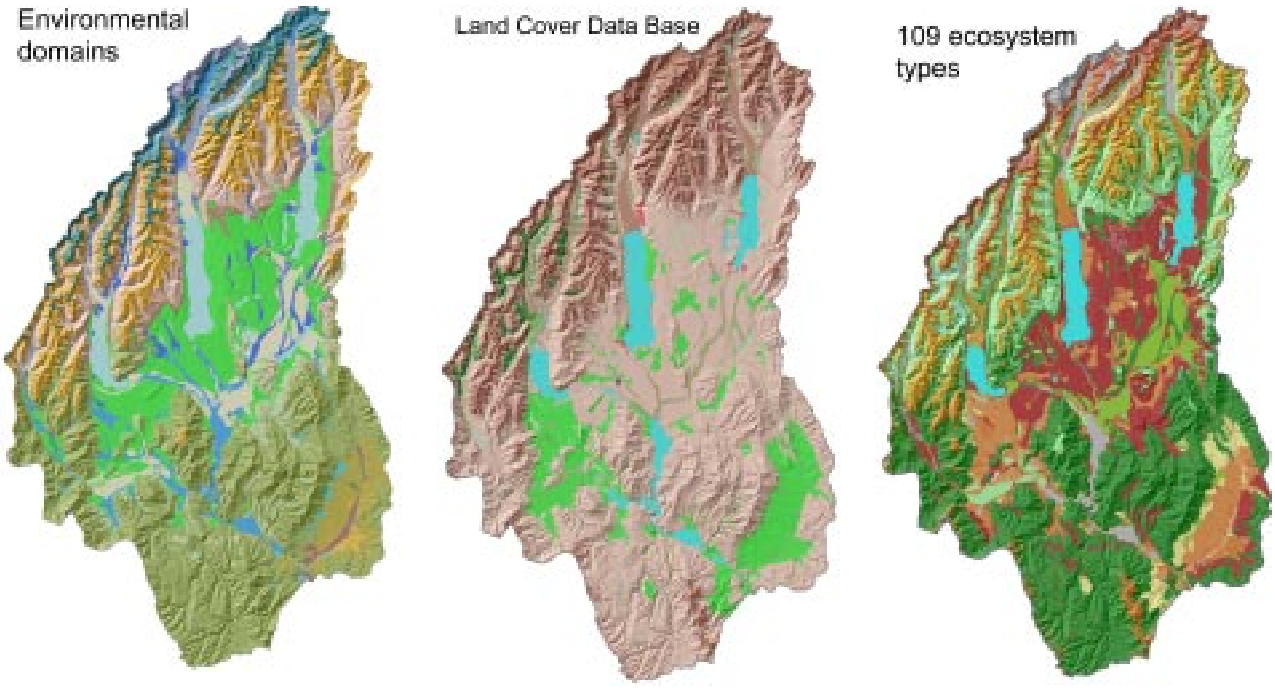
unit (pixel) of 4 ha (400 m^2), which groups those places whose combination of environmental variables is similar. Twenty-four of the 40 environments present in the Canterbury Region are represented in the Twizel Area (Fig. 9), albeit that one environment (No.1) is represented by a single pixel.

An updated national classification at 1 ha (100 m^2) pixels based on seven (not six) climate variables and eight (not three) land surface variables, including age of surface as a surrogate measure of biogeographic history, is intended to be available during 2002.

5.2 BIOTIC COVER

The Land Cover Database (LCDB) provided a coarse classification of biotic cover (Fig. 10). Twelve cover classes are recognised, although some classes would more accurately be described as land uses (e.g. plantation forest) and others as landforms (e.g. inland water). The classification is based largely on spectral information from the SPOT satellite, aerial photography and ground checks. There is significant mis-classification error, particularly for wetlands. An improved land cover database (LCDB2) with 64 cover classes is planned to be produced in 2003.

The merged combination of biotic cover (i.e. LCDB) and environments provides a spatially explicit classification of ecosystems (Fig. 11). Spatial intersection of the 12 cover classes with the 24 environments from Leathwick's (2001)



Environment + Land Cover = Ecosystem

Figure 11. Ecosystems in the Twizel Area. The unique combination of environments and land cover delineates 109 ecosystem types.

classification generates 109 unique combinations. If these units are a reasonable spatial definition of ecosystems, then the biotic composition and rates of both physical and biological processes should be more similar within units than between units. These ecosystem units were used to provide the basis for spatial extrapolation of some pest and weed data. However, they do not offer a useful framework for conservation assessment because they are products of different levels of human modification of the landscape and the most modified are of no conservation interest. Environment units provide a much more satisfactory framework for conservation assessment, with predominantly natural areas in each environment being of most conservation interest.

6. Site size

Site size is determined by survey data of parcel boundaries defined in the Crown record system linked to the land register. The Crown record system is the official Crown cadastral record of parcel boundaries; by linking it to the Department's land register, land managed by DOC for conservation purposes (conservation land) can be determined. Linking the Crown Pastoral Lease data to the Crown record system gives the balance of land displayed. Many of the Crown Pastoral leases are currently being reviewed with the intention of transferring ownership of some of the more productive and more modified land parcels into private ownership (freehold), while retaining public access

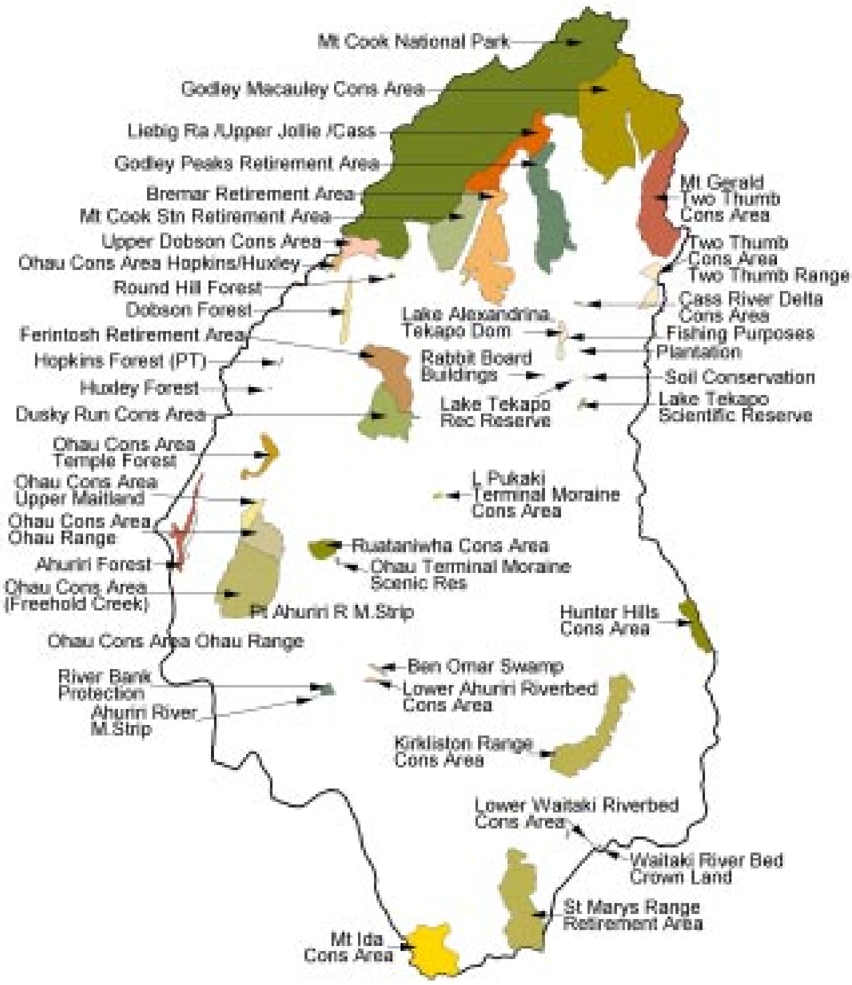


Figure 12. Crown land managed for conservation purposes. Places named in the text and tables are given.

easements over the freehold. The balance will transfer to DOC to be managed as public conservation land.

The land register is a vector database of Crown land units describing many attributes for each land unit, including legal status and area (Figs 12 and 13). There is no ecological basis for boundary locations or the subdivision of conservation areas into separate land units. Names of places referred to in the text (including tables) are given in Figs 12 and 13.

Project sites are *areas where a specified conservation project makes a difference*; they were identified by the set of pixels where there will be a difference in pressure with and without the project. The project site is not necessarily the same as the area over which the outcome is sought and it can cover a range of environments, land tenures and land cover classes. The area of the project site was estimated by summing the areas of all the pixels affected by the project.

Figure 13. Crown pastoral lease land. Places named in the text and tables are given.

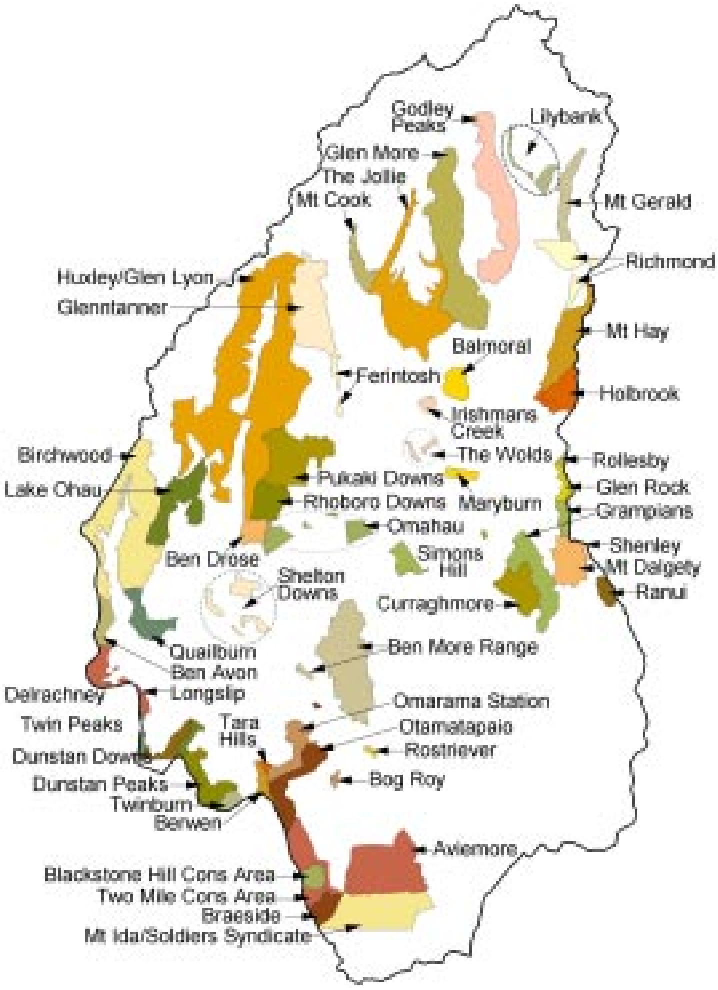


Figure 14. Environmental distinctiveness relative to the nation's environments. Here, environmental distinctiveness was calculated as the mean distance in ordination space to (a random sample of) all pixels. Red identifies highly distinctive environments, grey moderately distinctive environments and blue undistinctive environments.

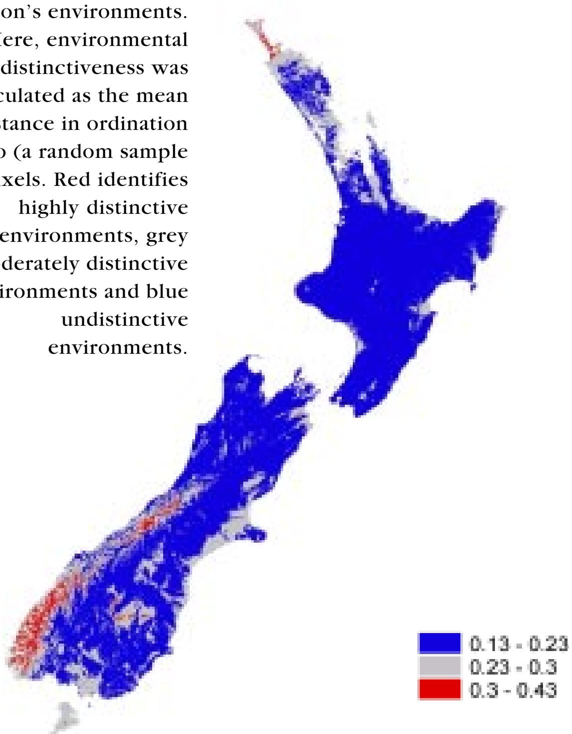
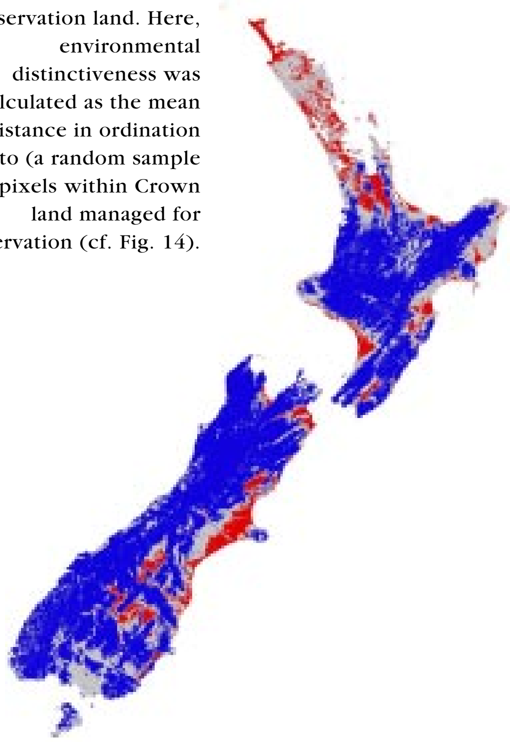


Figure 15. Environmental distinctiveness relative to conservation land. Here, environmental distinctiveness was calculated as the mean distance in ordination space to (a random sample of) pixels within Crown land managed for conservation (cf. Fig. 14).



7. Environmental distinctiveness

New Zealand's most distinctive environments occur at North Cape, Mount Cook and Fiordland (Fig. 14). Moderately distinctive environments occur in the greater Auckland area, Waikato, Canterbury, McKenzie Basin, Central Otago, Southland and Stewart Island (Overton & Leathwick 2001).

New Zealand's environments are not equally represented in lands managed for conservation. Thus the pattern of environmental distinctiveness for the nation does not reflect distinctiveness in relation to the nation's conserved natural heritage. The latter was measured by the mean environmental distance from each pixel to pixels *located within lands managed for conservation* (Fig. 15). The most distinctive environments relative to those represented in conservation land occur in Northland, Auckland, Waikato, Bay of Plenty, Gisborne, Hawke's Bay, Wairau Plains, Canterbury Plains, McKenzie Basin and Central Otago. The warm, dry, flat and fertile environments in these places are poorly represented in conservation lands and so are distinctive relative to those present in land managed for natural heritage conservation. Steep, wet and cool environments are very well represented. Consequently the distinctiveness of Mt Cook and Fiordland environments is lower relative to conservation land than it is relative to the nation. This implies that land acquisition policy should discourage further acquisition of low distinctiveness environments. Instead, it should focus resources on purchase, defence and restoration of the best natural areas remaining in distinctive environments. The biota in these areas will be more likely to add to the range of conserved biodiversity than will biotas from natural areas in less distinctive environments. Thus the Tenure Review process in the Twizel Area should aim to add places that are distinctive (relative to protected areas) to lands managed for conservation purposes.

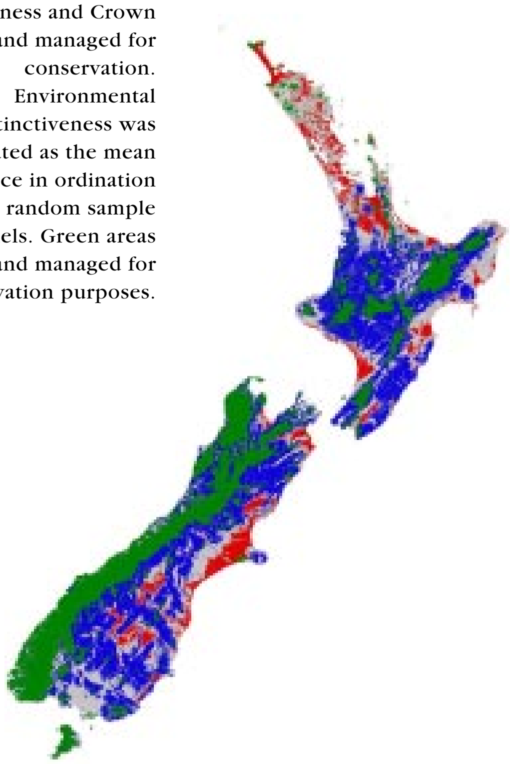


Figure 16. Environmental distinctiveness and Crown land managed for conservation. Environmental distinctiveness was calculated as the mean distance in ordination space to (a random sample of) all pixels. Green areas indicate land managed for conservation purposes.

The poor representation of fertile lowland environments in the lands managed for conservation is obvious when land managed for conservation is overlain on distinctiveness data (Fig. 16). Very little conservation land lies over the most distinctive environments.

The Twizel Area contains the full range of environmental distinctiveness relative to lands managed for conservation (Fig. 17). The central McKenzie Basin and Ahuriri Valley contain environments that are highly distinctive relative to conservation lands. The Mt Cook area is only moderately distinctive, despite being the most extreme alpine environment of New Zealand. This is because alpine environments are very well represented within lands managed for conservation.

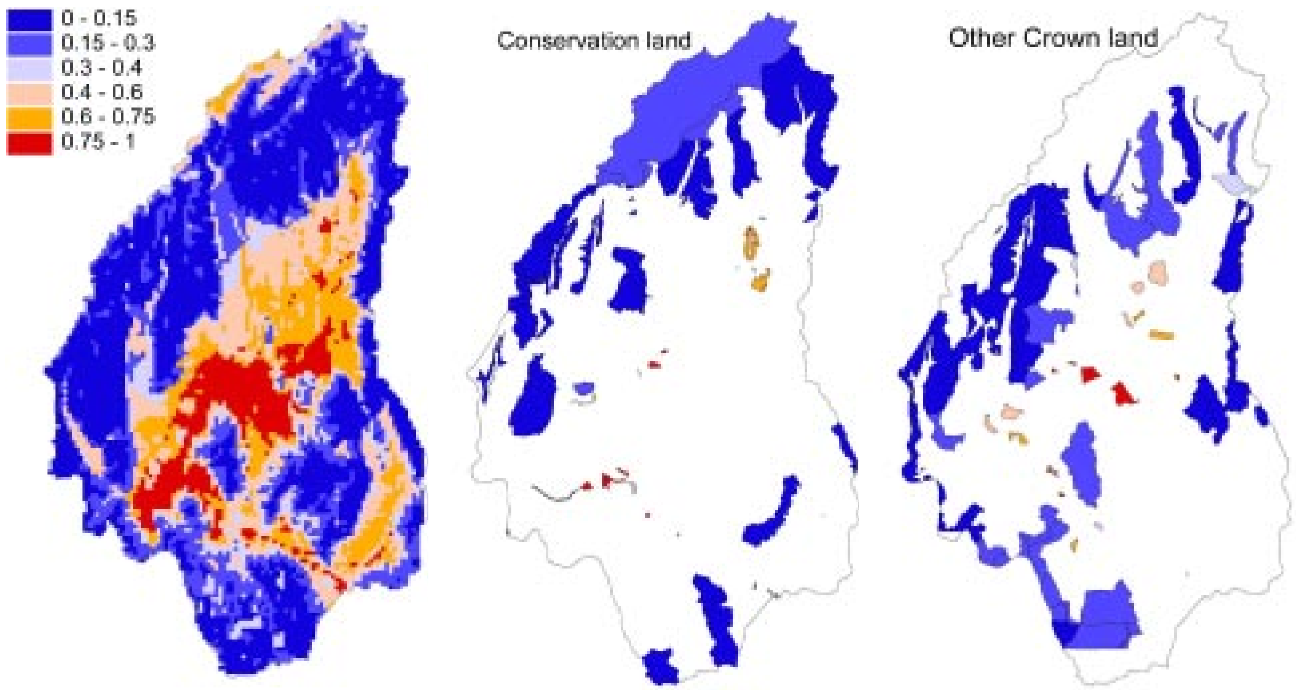


Figure 17. Environmental distinctiveness index in the Twizel area. Distinctiveness data for the Twizel Area were clipped from the national data set and then range-standardised. Mean distinctiveness for Crown land units was then calculated.

8. Mapping the components of pressure

Four of the five components of pressure were mapped. These were:

- biota removal
- physico-chemical resource modification
- consumption pressure
- infestation pressure.

Fragmentation was not mapped because we were unable to devise a satisfactory method for depicting fragmentation that would enable all the conservation management scenarios to be satisfactorily modelled. This is discussed further in Section 8.5.1.

In order to assess the difference made by conservation effort, it is necessary to map each component of pressure as it is now, and how it would be in future with and without management. Since most conservation effort goes into plant and animal pest control, most attention has been given to estimating change in consumption and infestation pressure.

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