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# 15. Priority places and the best conservation projects

Conservation managers at Levels I to III have to decide which places most need conservation action, and then which projects deliver most conservation for their cost. At one scale managers must identify which environments are most in need of conservation and then, at higher resolution, they must identify which places within those priority environments will supply most benefit from conservation investment. At some sites, this will require the protection of existing benefits. At others it will involve restoration of lost benefits. Managers then need to know which projects will achieve most conservation for the budget available.

At management levels IV and V, decisions have to be taken about levels of conservation investment between conservancies and regions. This is essentially an expansion of the last step: identifying the suite of projects that deliver most conservation for the regional or national budget. Beyond DOC management, Government is interested in knowing what benefits can be gained (or lost) with an incremental change in conservation investment. It is also useful to know how much it is likely to cost to achieve a high-level goal such as ‘reversing the decline’ in New Zealand’s biodiversity.

Priority places are not to be confused with high-value places. High-value sites (Tables 5 and 6) may not be threatened. There is no benefit in putting conservation effort in high-value places that are not threatened. High-value places will only be priorities if they are at risk of degradation. Priority places for conservation action are those where the greatest loss of natural heritage-derived benefit is expected in absence of management. This means that badly degraded places will not usually be priority sites (because being already degraded they are not easily threatened by additional degradation). Exceptions will be places that are highly distinctive and among the best of what remains of their type, severely degraded though they may be.

*De novo* priority sites can be identified by estimating site value now and without management and then sorting the list by magnitude of loss. Since conservation is ongoing, 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 effort. They can be identified by the difference in site value now and with current management. The magnitude of predicted loss puts priority sites at the top of the list.

## 15.1 IDENTIFYING PRIORITY ENVIRONMENTS FOR CONSERVATION ACTION

Priority environments for *de novo* conservation effort are where most pressure increase is predicted without management (Table 18). Thus environments 71, 15, 45, 12 and 5 are priority environments for management. Environments 5, 35, 31, 33 and 81 are priorities for additional effort. Note that the correlation

TABLE 18. PRIORITY ENVIRONMENTS FOR CONSERVATION. PRIORITY ENVIRONMENTS ARE THOSE AT RISK OF MOST DEGRADATION WITHOUT MANAGEMENT. THE PERCENTAGE AREA PROTECTED IS A POOR PREDICTOR OF PRIORITY RANK.

| ENVIRONMENT | | | PRESSURE | | | VULNERABILITY | | PRIORITY RANK | |
|---|---|---|---|---|---|---|---|---|---|
| NO. | AREA ($KM^2$) | % PROTECTED | NOW | WITH MGMT | WITHOUT MGMT | WITHOUT MGMT | WITH MGMT | *DE NOVO* EFFORT | FOR MORE EFFORT |
| 5 | 1216.6 | 27.8 | 0.669 | 0.796 | 0.923 | 0.254 | 0.127 | 5 | 1 |
| 35 | 3445.6 | 3.8 | 0.858 | 0.964 | 0.987 | 0.129 | 0.106 | 6 | 2 |
| 31 | 34.8 | 60.2 | 0.818 | 0.921 | 0.945 | 0.127 | 0.103 | 7 | 3 |
| 33 | 535.3 | 2.9 | 0.886 | 0.986 | 0.994 | 0.108 | 0.1 | 9 | 4 |
| 81 | 52.2 | 3.8 | 0.895 | 0.989 | 0.995 | 0.1 | 0.094 | 10 | 5 |
| 10 | 1.7 | 1.5 | 0.906 | 0.998 | 0.998 | 0.092 | 0.092 | 11 | 6 |
| 1 | 0.1 | 0 | 0.913 | 0.998 | 0.999 | 0.086 | 0.085 | 12 | 7 |
| 87 | 329.1 | 0.033 | 0.915 | 0.998 | 0.999 | 0.084 | 0.083 | 14 | 8 |
| 41 | 160.6 | 5 | 0.895 | 0.975 | 0.975 | 0.08 | 0.08 | 15 | 9 |
| 37 | 217.4 | 12.8 | 0.899 | 0.973 | 0.984 | 0.085 | 0.074 | 13 | 10 |
| 15 | 57.9 | 96.7 | 0.54 | 0.609 | 0.882 | 0.342 | 0.069 | 2 | 11 |
| 82 | 1524.8 | 4.5 | 0.927 | 0.993 | 0.994 | 0.067 | 0.066 | 16 | 12 |
| 12 | 1237.3 | 34 | 0.26 | 0.324 | 0.535 | 0.275 | 0.064 | 4 | 13 |
| 54 | 40 | 1.03 | 0.942 | 0.998 | 0.998 | 0.056 | 0.056 | 17 | 14 |
| 42 | 389.8 | 81.5 | 0.489 | 0.513 | 0.516 | 0.027 | 0.024 | 18 | 15 |
| 83 | 306.1 | 0.25 | 0.975 | 0.996 | 0.996 | 0.021 | 0.021 | 19 | 16 |
| 88 | 304.2 | 35.4 | 0.973 | 0.987 | 0.994 | 0.021 | 0.014 | 20 | 17 |
| 76 | 122.6 | 58.9 | 0.623 | 0.634 | 0.733 | 0.11 | 0.011 | 8 | 18 |
| 62 | 9.8 | 1.2 | 0.994 | 0.998 | 0.998 | 0.004 | 0.004 | 22 | 19 |
| 71 | 60.6 | 100 | 0.435 | 0.437 | 0.94 | 0.505 | 0.002 | 1 | 20 |
| 90 | 38.2 | 0.79 | 0.999 | 1 | 1 | 0.001 | 0.001 | 23 | 21 |
| 84 | 2.3 | 23.8 | 0.992 | 0.992 | 0.992 | 0 | 0 | 24 | 22 |
| 74 | 110.1 | 100 | 0.012 | 0.003 | 0.026 | 0.014 | -0.009 | 21 | 23 |
| 45 | 523.2 | 78.3 | 0.076 | 0.062 | 0.387 | 0.311 | -0.014 | 3 | 24 |
| Correlation (r) with % protected: | | | –0.803 | –0.818 | –0.673 | 0.536 | –0.423 | –0.362 | 0.413 |

between percentage area protected and priority rank is negative for *de novo* priorities and positive for additional effort priority environments (see bottom row of Table 18). This demonstrates that percentage representation in places managed for conservation purposes is a poor indicator of priority rank.

## 15.2 IDENTIFYING PRIORITY SITES FOR CONSERVATION ACTION

Two competing frameworks for identifying priority sites were identified. One maximises the volume of benefits supplied by natural heritage by avoiding most site value loss. The other maximises the diversity and quality of benefits supplied by identifying the most vulnerable and irreplaceable sites as priorities (Margules & Pressey 2000).

### 15.2.1 Priority sites identified by magnitude of value loss

*De novo* priority sites are shown in Table 19 and priority sites for additional (or alternative) effort are given in Table 20. The *de novo* priority sites are mostly large. However, current management is addressing the threats in these large sites. Consequently they do not appear among the top priority sites for additional conservation action, which are dominated by small areas (< 10 km$^2$) in lowland environments.

### 15.2.2 Priority sites identified by irreplaceability and vulnerability

Another approach to priority site identification is based around minimisation of option-value-loss. This requires identification of sites that are *both* most irreplaceable and most vulnerable. The product of distinctivess and importance is an index of irreplaceability. If a site is highly distinctive, then there are no others like it and so the site is highly irreplaceable. Similarly, if a site is the best of its environment type, it is also highly irreplaceable. The difference in pressure now and in the future is an index of vulnerability. A highly vulnerable site is one where much pressure increase (or condition loss) is expected. Thus vulnerable sites initially have low pressure. Degraded sites under high pressure cannot be highly vulnerable but they can be highly irreplaceable. Priority sites are those that are both irreplaceable and vulnerable.

TABLE 19. PRIORITY SITES FOR CONSERVATION. Sites are ranked by loss in value expected without management. These are the sites expected to lose most value in absence of any management effort.

| PLACE | AREA (km$^2$) | SITE VALUE NOW | SITE VALUE NO MGMT | CHANGE |
|---|---|---|---|---|
| Mt Cook National Park | 725.5 | 1.948 | 1.0830 | –0.865 |
| St Marys Range (South) | 90.0 | 0.338 | 0.0856 | –0.253 |
| Lower Waitaki Riverbed Cons A | 0.6 | 0.215 | 0.0001 | –0.214 |
| St Marys Range (North) | 44.7 | 0.253 | 0.0572 | –0.196 |
| Waitaki River Bed Crown Land | 0.5 | 0.173 | 0.0003 | –0.172 |
| Godley Macauley Cons Area | 248.8 | 0.282 | 0.1182 | –0.164 |
| Ohau Cons Area Hopkins/Huxley | 187.0 | 0.235 | 0.0783 | –0.157 |
| Plantation | 3.2 | 0.138 | 0.0001 | –0.138 |
| Mt Ida Conservation Area | 59.1 | 0.135 | 0.0052 | –0.130 |
| Lake Tekapo Scientific Reserve | 10.3 | 0.127 | 0.0001 | –0.127 |
| Soil Conservation | 1.1 | 0.122 | 0.0020 | –0.120 |
| Godley Peaks Retirement Area | 90.7 | 0.159 | 0.0577 | –0.102 |
| Ahuriri River M.Strip | 0.4 | 0.098 | 0.0001 | –0.098 |
| Cass River Delta Cons Area | 0.5 | 0.092 | 0.0005 | –0.091 |
| Fishing Purposes | 15.9 | 0.078 | 0.0005 | –0.077 |
| Pt Ahuriri R M.Strip | 0.5 | 0.062 | 0.0022 | –0.060 |
| Lake Tekapo Recreation Reserve | 0.3 | 0.049 | 0.0008 | –0.048 |
| Ferintosh Retirement Area | 53.2 | 0.068 | 0.0277 | –0.041 |
| Ohau Cons Area (Freehold Creek) | 105.4 | 0.050 | 0.0161 | –0.034 |
| Mt Cook Stn Retirement Area | 71.9 | 0.061 | 0.0285 | –0.032 |
| Kirkliston Range Cons Area | 76.0 | 0.035 | 0.0070 | –0.028 |

TABLE 20. PRIORITY SITES FOR CONSERVATION. Sites are ranked by loss in value under current management. These are the sites expected to lose most value despite current management effort.

| PLACE | AREA ($km^2$) | SITE VALUE NOW | SITE VALUE WITH MGMT | CHANGE |
|---|---|---|---|---|
| Lower Waitaki Riverbed Cons A | 0.6 | 0.215 | 0.0800 | –0.135 |
| Waitaki River Bed Crown Land | 0.5 | 0.173 | 0.0418 | –0.131 |
| Soil Conservation | 1.1 | 0.122 | 0.0030 | –0.119 |
| Plantation | 3.2 | 0.138 | 0.0539 | –0.084 |
| Lake Tekapo Recreation Reserve | 0.3 | 0.049 | 0.0009 | –0.048 |
| Plantation | 0.6 | 0.021 | 0.0002 | –0.021 |
| Pt Ahuriri R M.Strip | 0.5 | 0.062 | 0.0455 | –0.017 |
| Lake Alexandrina, Tekapo Dom. | 6.2 | 1.020 | 1.0088 | –0.011 |
| St Mary's Range (North) | 44.7 | 0.253 | 0.2439 | –0.009 |
| Mt Ida Conservation Area | 59.1 | 0.135 | 0.1285 | –0.007 |
| St Marys Range (South) | 90.0 | 0.338 | 0.3319 | –0.006 |
| Dobson Forest | 41.2 | 0.024 | 0.0220 | –0.002 |
| Ohau Terminal Moraine Scen Res | 0.8 | 0.027 | 0.0260 | –0.001 |
| Hopkins Forest (Pt) | 26.5 | 0.008 | 0.0080 | –0.0003 |

TABLE 21. PRIORITY SITES FOR MANAGEMENT EFFORT TO AVOID LOSS OF OPTION VALUE. Priority sites are those with both irreplaceability and vulnerability > 0.1 (shaded area in Figures 60 and 61). *De novo* priorities are those listed under 'no Mgmt'. Priority sites for additional or redirected effort are listed under 'Current Mgmt'.

| PLACE | VULNERABILITY NO MMT | VULNERABILITY CURRENT MGMT | IRREPLACE-ABILITY | PRIORITY SITES NO MGMT | PRIORITY SITES CURRENT MGMT |
|---|---|---|---|---|---|
| Lower Waitaki Riverbed | 0.566 | 0.388 | 0.462 | X | X |
| Waitaki River Bed Crown Land | 0.562 | 0.388 | 0.411 | X | X |
| Lake Tekapo Recreation Res | 0.198 | 0.196 | 0.403 | X | X |
| Soil Conservation | 0.198 | 0.191 | 0.589 | X | X |
| Plantation | 0.137 | 0.133 | 0.188 | X | X |
| Rabbit Board Buildings | 0.230 | 0.108 | 0.314 | X | X |
| Plantation | 0.138 | 0.093 | 0.619 | X | X |
| Ohau Terminal Moraine S. Res | 0.138 | 0.093 | 0.209 | X | X |
| Fishing Purposes | 0.143 | 0.090 | 0.178 | X | X |
| Ahuriri River M.Strip | 0.303 | 0.054 | 0.467 | X | |
| Ahuriri River M.Strip | 0.303 | 0.054 | 0.449 | X | |
| Lake Tekapo Scientific Res | 0.138 | 0.050 | 0.359 | X | |
| Crown Land | 0.420 | 0.040 | 0.541 | X | |
| St Marys Range (North) | 0.347 | 0.030 | 0.124 | X | |
| St Marys Range (South) | 0.402 | 0.022 | 0.104 | X | |
| Mt Cook National Park | 0.330 | 0.007 | 0.186 | X | |
| Lower Ahuriri Riverbed | 0.276 | -0.261 | 0.477 | X | |
| Pt Ahuriri R M.Strip | 0.329 | -0.263 | 0.247 | X | |
| Cass River Delta Cons Area | 0.337 | -0.326 | 0.369 | X | |

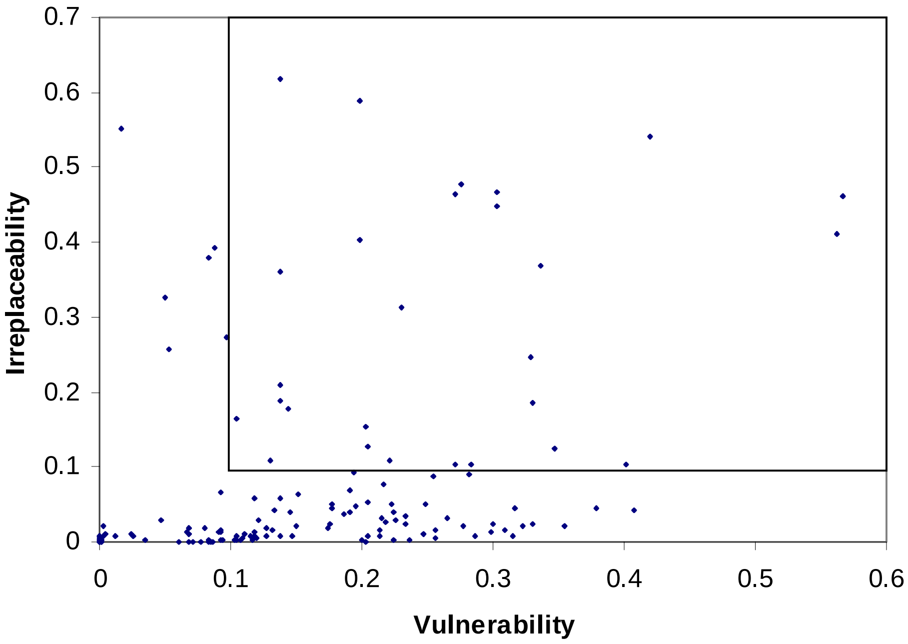



Figure 60. Priority sites (without management). Sites were identified by their irreplaceability and vulnerability to degradation. Each point represents a conservation land unit; points inside the shaded area represent priority sites for conservation management effort.

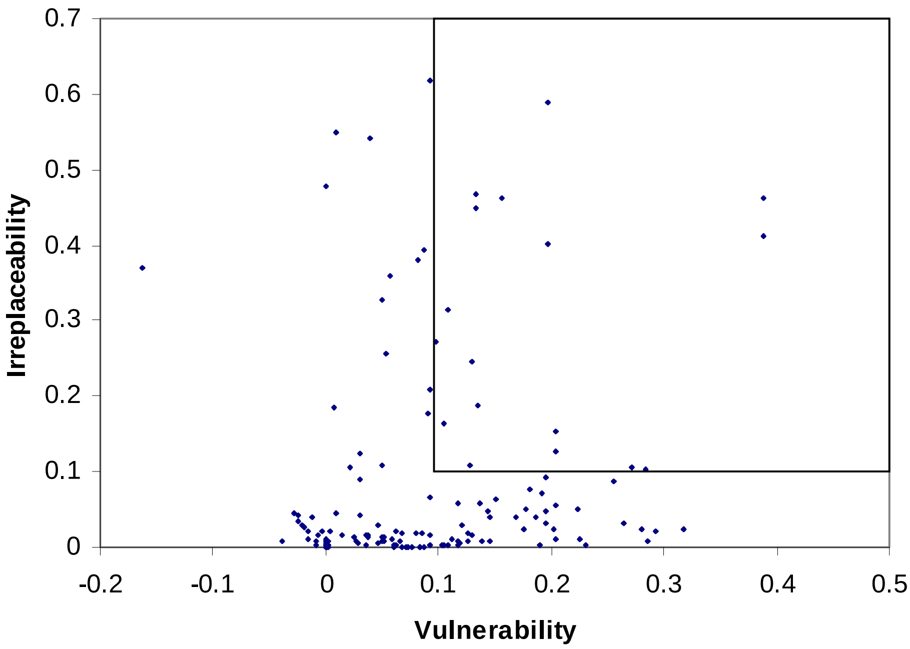



Figure 61. Priority sites (with management). Sites were identified by their irreplaceability and vulnerability to degradation. Each point represents a conservation land unit; points inside the shaded area represent priority sites for additional or redirected conservation effort. Sites with negative vulnerability have reduced pressure and are recovering.

Site irreplaceability and vulnerability were calculated (Table 21) and plotted in a scattergram (Fig. 60 and 61). Sites located in the top-right shaded area (i.e. both irreplaceability and vulnerability > 0.1) are priority sites for conservation effort aimed at minimising loss of natural heritage diversity and quality. Several of the priority sites are too small to be easily seen on a map of the whole study area. Thus maps showing the location of priority sites are not provided.

A number of conservation performance statistics can be derived from these scattergrams. One performance statistic could be based on change over time (e.g. the term of a Conservation Management Strategy) in the combined area of sites falling inside a specified 'priority' zone (e.g. the shaded zone where both irreplaceability and vulnerability exceed 0.1).

## 15.3 IDENTIFYING THE BEST CONSERVATION PROJECTS

We define the best projects as those that deliver most conservation output for their cost. Project merit is outcome size discounted for time until the outcome will be achieved and weighted for the feasibility of the project. Project merit scores (Table 22) ranged over four orders of magnitude from 0.398 (wilding pines included in the RPMS and controlled on conservation land in 7 years) to 0.00005 (gorse control achieved in 50 years). The merit value for the PRR weed control project is very low because it will take so long (50 years) causing its outcome to be heavily discounted.

Project cost-effectiveness (Table 23) ranged over three orders of magnitude, from wilding pine control plus inclusion in the RPMS (0.384) to the Russell lupin control component of Project River Recovery (0.00015). Yellow lupin eradication is a very low-cost project with a prompt outcome. This more than compensates its small outcome size (Table 22) so that this project is particularly cost-effective. The wilding pine control projects produce by far the largest outcomes but are only cost-effective if outcomes are delivered in a reasonably short time. The current design for wilding pine control will not deliver the

TABLE 22. MERIT VALUES FOR A RANGE OF CONSERVATION PROJECTS DESIGNED FOR IMPLEMENTATION OVER DIFFERENT TIMEFRAMES.
NPV Outcome size is based on a 10% discount rate. Codes refer to the project descriptions and scenario compositions described in Table 3. The numeric suffix identifies the number of years until the outcome of the project will be achieved.

| CODE | OUTCOME SIZE | NPV OUTCOME SIZE | FEASIBILITY | MERIT |
|---|---|---|---|---|
| PineRPMS7 | 1.250 | 0.621 | 0.641 | 0.398 |
| PineDOC7 | 0.630 | 0.313 | 0.976 | 0.305 |
| Thar | 0.126 | 0.114 | 0.889 | 0.101 |
| BStilt1 | 0.095 | 0.086 | 0.877 | 0.075 |
| StockTR | 0.098 | 0.059 | 0.795 | 0.047 |
| StockCL | 0.089 | 0.054 | 0.758 | 0.041 |
| StockSQ | 0.052 | 0.047 | 0.790 | 0.037 |
| PRR10 | 0.080 | 0.031 | 0.755 | 0.023 |
| Bennetts | 0.015 | 0.014 | 0.622 | 0.0084 |
| PineRPMS50 | 1.250 | 0.008 | 0.838 | 0.0071 |
| Willow10 | 0.022 | 0.008 | 0.814 | 0.0067 |
| PineDOC50 | 0.630 | 0.004 | 0.981 | 0.0042 |
| Broom10 | 0.013 | 0.005 | 0.796 | 0.0039 |
| Rlupin10 | 0.016 | 0.006 | 0.554 | 0.0033 |
| Gorse10 | 0.007 | 0.003 | 0.900 | 0.0023 |
| Ylupin | 0.002 | 0.0016 | 0.852 | 0.0013 |
| Pig | 0.001 | 0.0013 | 0.992 | 0.0013 |
| PRR | 0.080 | 0.0007 | 0.868 | 0.00064 |
| Rabbit | 0.001 | 0.0006 | 0.895 | 0.00056 |
| Willow50 | 0.022 | 0.0002 | 0.865 | 0.00013 |
| Rlupin50 | 0.016 | 0.00011 | 0.792 | 0.00009 |
| Broom50 | 0.013 | 0.00009 | 0.926 | 0.00008 |
| Gorse50 | 0.007 | 0.00005 | 0.950 | 0.00005 |

outcome (i.e. < 0.1% cover on all conservation lands) for about 50 years. Consequently, outcome size is heavily discounted and high annual costs continue throughout the 50-year period. Intensive control over the next 7 years will both bring the outcome forward and confine costs in future years to those required for maintenance.

The set of projects currently being implemented are not the most cost-efficient, largely because the value of quick outcomes is not fully recognised and also because of excessive risk aversion. But if:

- wilding pines were included in the RPMS with control designed to achieve the outcome after seven years, and
- Project River Recovery were accelerated to achieve its outcome in 10 years,

the total conservation output could be increased three-fold for a very similar cost (Table 24). Current Departmental funding arrangements mean that an injection of new money would be necessary to accelerate wilding pine control but PRR may be accelerated just by reducing allocations to research and advocacy. However, this would impact the risk profile of the project by reducing the portions of outcome and social risk that could be effectively managed.

TABLE 23. CONSERVATION PROJECTS AND SCENARIOS RANKED BY COST-EFFECTIVENESS. Projects currently being implemented are shown in bold. Scenario codes refer to the scenario and project descriptions described in Table 3. The numeric suffix identifies the number of years for the outcome to be achieved.

| SCENARIO CODE | SCENARIO DESCRIPTION | YEARS TO OUTCOME | MERIT | $NPV_{50}$ ($k) | COST-EFFECTIVENESS |
|---|---|---|---|---|---|
| PineRPMS7 | Wilding pines in RPMS; control on cons. land | 7.0 | 0.3979 | 1037.5 | 0.384 |
| PineDOC7 | Wilding pine control on conservation land | 7.0 | 0.3053 | 997.1 | 0.306 |
| **Thar** | **Thar control only** | 1.0 | 0.1015 | 711.8 | 0.143 |
| Broom10 | Broom control component of PRR10 | 10.0 | 0.0039 | 49.8 | 0.079 |
| **Ylupin** | **Yellow tree lupin control component of PRR** | 2.0 | 0.0013 | 21.0 | 0.063 |
| **Bennetts** | **Bennetts wallaby control only** | 1.0 | 0.0084 | 156.7 | 0.054 |
| Gorse10 | Gorse control component of PRR10 | 10.0 | 0.0023 | 49.8 | 0.047 |
| **Bstilt** | **Current predator control** | 1.0 | 0.0188 | 414.1 | 0.045 |
| BStilt1 | Extended predator control | 1.0 | 0.0751 | 1983.0 | 0.038 |
| **StockSQ** | **Existing stock fences maintained** | 1.0 | 0.0370 | 1115.4 | 0.033 |
| **Pig** | **Pig control only** | 1.0 | 0.0013 | 51.1 | 0.025 |
| PRR10 | PRR done in 10 years | 9.5 | 0.0235 | 1521.5 | 0.015 |
| Willow10 | Willow control component of PRR10 | 10.0 | 0.0067 | 797.6 | 0.0084 |
| PineRPMS50 | Wilding pines in RPMS; control on cons. land | 50.0 | 0.0071 | 914.1 | 0.0077 |
| StockCL | Stock fencing around all conservation land | 5.0 | 0.0407 | 7138.7 | 0.0057 |
| Rlupin10 | Russell lupin control component of PRR10 | 10.0 | 0.0033 | 603.2 | 0.0055 |
| **PineDOC50** | **Wilding pine control on conservation land** | 50.0 | 0.0042 | 851.6 | 0.0049 |
| StockTR | Stock fencing around all Crown Land | 5.0 | 0.0471 | 10261.8 | 0.0046 |
| **Broom50** | **Broom control component of PRR50** | 50.0 | 0.00008 | 49.6 | 0.0016 |
| **Gorse50** | **Gorse control component of PRR50** | 50.0 | 0.00005 | 49.6 | 0.0010 |
| **Rabbit** | **Rabbit control only** | 1.0 | 0.00056 | 625.1 | 0.00090 |
| **PRR50** | **PRR done in 50 years** | 46.8 | 0.00064 | 1587.5 | 0.00040 |
| **Willow50** | **Willow control component of PRR50** | 50.0 | 0.00013 | 872.5 | 0.00015 |
| **Rlupin50** | **Russell lupin control component of PRR50** | 50.0 | 0.00009 | 594.9 | 0.00015 |

The link between project cost information and the project site means that cost and cost-effectiveness data can be displayed spatially to reveal patterns over the landscape (Fig. 62). Current management makes most difference in the high country but the greatest expenditure per km$^2$ is in lowland areas, particularly in the river beds. Consequently, expenditure is most cost-efficient in the high country and least cost-efficient in the river valleys and foothills. However, if the more cost-efficient conservation programme in Table 24 were implemented, conservation efficiency would be much improved, particularly in the foothill country. This implies that there is significant under-investment in conservation of the foothill and basin areas.

### 15.3.1 The most cost-efficient suite of projects for a given budget

The most cost-efficient programme of projects is that which maximises the total merit score for a given budget. This is not necessarily the same as selecting the most cost-efficient projects from the top of a ranked list until the budget is spent. Some very cost-effective projects may be too costly for the budget, or for the remaining budget after more cost-effective projects have been included. The most cost-efficient programme can be identified using an optimisation process (available in MS Excel: Tools/solver) to construct an optimisation model (Appendix 2) that identifies the set of projects that maximises summed project merit for a specified budget (Table 25).

TABLE 24. COST-EFFECTIVENESS OF THE CURRENT CONSERVATION WORK PROGRAMME (ABOVE) AND A MORE COST-EFFICIENT CONSERVATION PROGRAMME (BELOW). The more cost-efficient projects in the restructured programme are italicised.

| PROJECT DESCRIPTION | NPV OUTCOME | FEASIBILITY | MERIT | $NPV_{50}$ COST ($k) | COST-EFFECTIVENESS |
|---|---|---|---|---|---|
| CURRENT PROJECTS | | | | | |
| Thar control only | 0.1141 | 0.889 | 0.1015 | 711.8 | 1.426 |
| Bennetts wallaby control | 0.0135 | 0.622 | 0.0084 | 156.7 | 0.537 |
| BStilt: Current predator control | 0.0212 | 0.888 | 0.0188 | 414.1 | 0.455 |
| Existing stock fences maintained | 0.0469 | 0.790 | 0.0371 | 1115.4 | 0.332 |
| Pig control | 0.0012 | 0.992 | 0.0012 | 51.1 | 0.241 |
| Wilding pine control on cons. land (50 years) | 0.0043 | 0.981 | 0.0042 | 851.6 | 0.049 |
| Rabbit control only | 0.0006 | 0.895 | 0.0005 | 625.1 | 0.009 |
| PRR done in 50 years | 0.0006 | 0.857 | 0.0005 | 1587.5 | 0.003 |
| **Total** | | | **0.1722** | **5513.3** | |
| MORE COST-EFFECTIVE SET OF PROJECTS FOR SIMILAR COST | | | | | |
| *Wilding pines in RPMS; control on cons. land (7 yr.)* | 0.6208 | 0.641 | 0.3979 | 1037.5 | 3.836 |
| Thar control only | 0.1141 | 0.889 | 0.1015 | 711.8 | 1.426 |
| Bennetts wallaby control | 0.0135 | 0.622 | 0.0084 | 156.7 | 0.537 |
| BStilt: Current predator control | 0.0212 | 0.888 | 0.0188 | 414.1 | 0.455 |
| Existing stock fences maintained | 0.0469 | 0.790 | 0.0371 | 1115.4 | 0.332 |
| Pig control | 0.0012 | 0.992 | 0.0012 | 51.1 | 0.241 |
| *PRR done in 10 years* | 0.0303 | 0.554 | 0.0168 | 1421.8 | 0.118 |
| Rabbit control only | 0.0006 | 0.895 | 0.0005 | 625.1 | 0.009 |
| **Total** | | | **0.5822** | **5533.5** | |

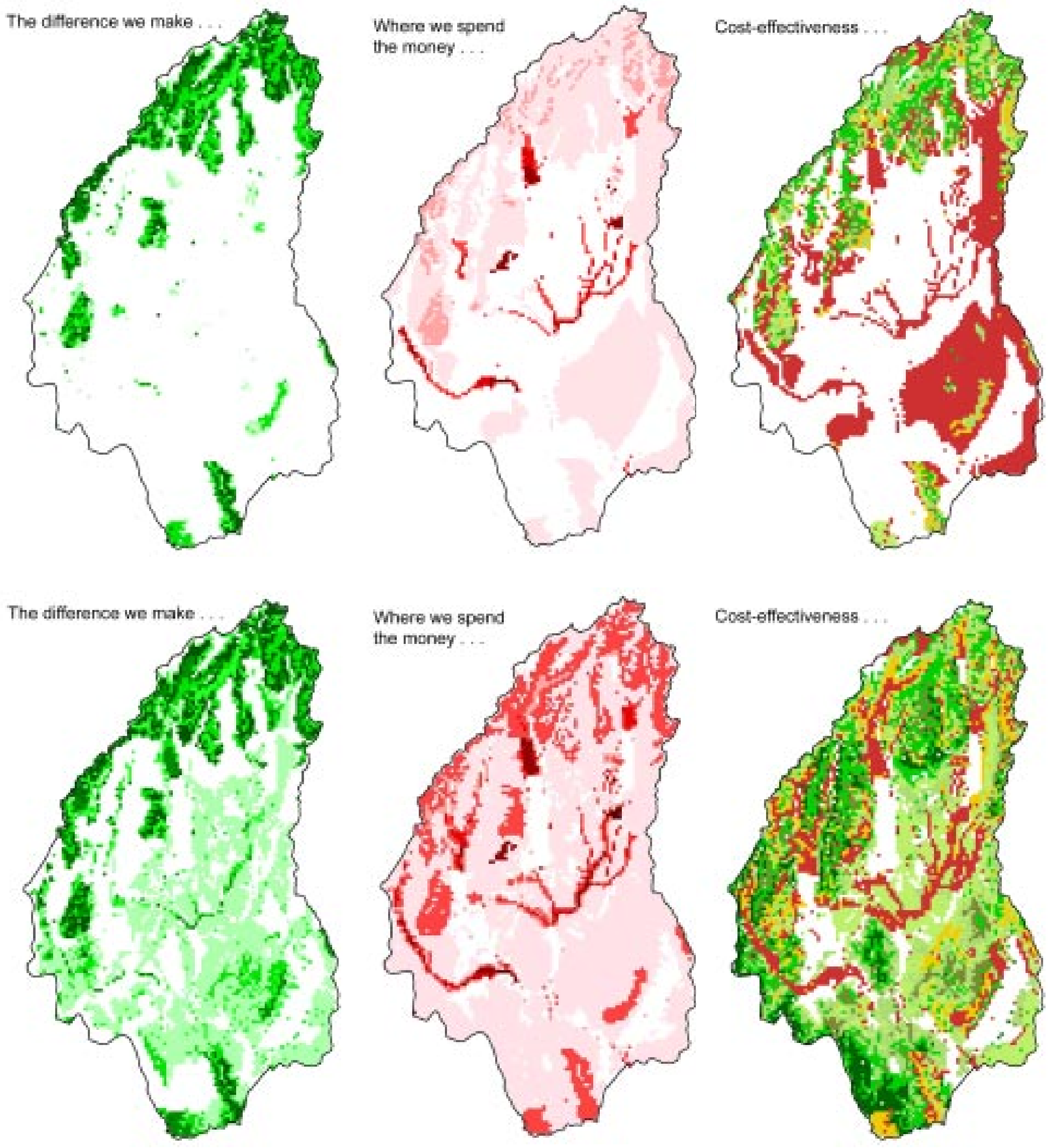



Figure 62. Mapping the difference made, cost and cost-effectiveness. The difference made (left), cost (centre) and cost-effectiveness (right) of the current work programme (above) and of the restructured programme (below) as defined in Table 21. Dark green indicates most difference made (left-hand maps), dark red shows greatest expenditure per-unit area (centre maps); dark green (right-hand maps) shows greatest cost-effectiveness.

Once the most cost-efficient programme of projects for a given budget can be identified, conservation cost-supply relationships can be estimated by plotting the summed pressure gains and losses achieved by a programme (i.e. conservation supply) against its cost (Figs 63 and 64). Cost-supply curves rise initially with thar control then rise sharply at about $900k with inclusion of pine control. The increase reflects the substantial gains associated with this project. A third ‘bump’ in the curve is associated with fence maintenance and further rises occur as all conservation land and finally all Crown land is fenced. The horizontal line at zero indicates the point at which ‘the decline is halted’.

Estimates of conservation supply should be discounted for feasibility to account for the outstanding risk not accommodated within project designs. This lowers the curves and adds to variability associated with small projects of varying feasibility (Fig. 64). On the basis of the suite of projects examined, it seems that the minimum $NPV_{50}$ of the cost of ‘halting the decline’ on land managed for conservation is about \$8m (approx. \$800k annually) and twice this figure to halt the decline over the whole Twizel Area.

### 15.3.2 Priorities for additional conservation effort

Cost-effectiveness analysis and the associated cost-supply curves can only be based on the suite of projects put up for analysis. This does not consider questions about identification of priorities for additional or re-deployed conservation effort. Priority areas for additional conservation effort are those which are most irreplaceable and vulnerable (Fig. 65). Pixels with negative vulnerability are recovering and need no additional conservation effort. Pixels

TABLE 25. THE MOST COST-EFFICIENT WORK PROGRAMME FOR A GIVEN BUDGET. 1 indicates project inclusion as determined by the optimisation process described in Appendix 2. The sum of pressure changes are given for three land tenure classes as well as for the whole Twizel Area.

| PROJECT CODE | PROJECTS SELECTED FOR PROGRAMME | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PineRPMS | | | | | | | | 1 | 1 | 1 | 1 |
| PineDOC | | | | | | | 1 | | | | |
| Thar | | | | | | 1 | | | 1 | 1 | 1 |
| Broom | | 1 | 1 | 1 | | 1 | | | 1 | 1 | 1 |
| Ylupin | 1 | | | 1 | 1 | 1 | | | 1 | 1 | 1 |
| Bennetts | | | | 1 | | | | | 1 | 1 | 1 |
| Gorse | | | 1 | | | | | | 1 | 1 | 1 |
| Bstilt | | | | | 1 | | | | | | |
| BStilt1 | | | | | | | | | 1 | 1 | 1 |
| StockSQ | | | | | | | | | 1 | | |
| Pig | | | | | | | | | 1 | 1 | 1 |
| Willow | | | | | | | | | | 1 | 1 |
| StockCL | | | | | | | | | | 1 | |
| Rlupin | | | | | | | | | | 1 | 1 |
| StockTR | | | | | | | | | | | 1 |
| Rabbit | | | | | | | | | | 1 | 1 |
| Sum of merit | 0.001 | 0.004 | 0.006 | 0.014 | 0.020 | 0.107 | 0.305 | 0.520 | 0.751 | 0.765 | 0.772 |
| $NPV_{50}$ cost (\$k) | 21.0 | 49.8 | 99.7 | 227.5 | 435.1 | 782.6 | 997.1 | 1037.5 | 5176.1 | 13225 | 16348 |
| $NPV_{50}$ budget (\$k) | 25 | 50 | 100 | 250 | 450 | 800 | 1000 | 1200 | 5500 | 15000 | 20000 |
| | CHANGE IN PRESSURE | | | | | | | | | | |
| Conservation land | −709.4 | −709.1 | −709.1 | −707.0 | −709.4 | −633.6 | −282.9 | −282.4 | −8.1 | 82.5 | 82.5 |
| Other Crown land | −509.8 | −509.8 | −509.8 | −508.7 | −509.3 | −479.1 | −509.1 | −123.4 | −57.2 | −49.0 | 151.0 |
| Private land | −481.5 | −480.9 | −480.8 | −479.9 | −480.9 | −480.4 | −480.8 | −269.9 | −235.7 | −187.7 | −187.7 |
| Whole area | −1700.7 | −1699.8 | −1699.7 | −1695.6 | −1699.6 | −1593.1 | −1272.7 | −675.7 | −301.0 | −154.2 | 45.8 |

Figure 63. Cost of supplying conservation—not discounted. The horizontal line at zero indicates the point at which pressure increase has been halted. These curves have not been discounted for feasibility and so represent an unrealistically optimistic view of the cost of conservation supply.

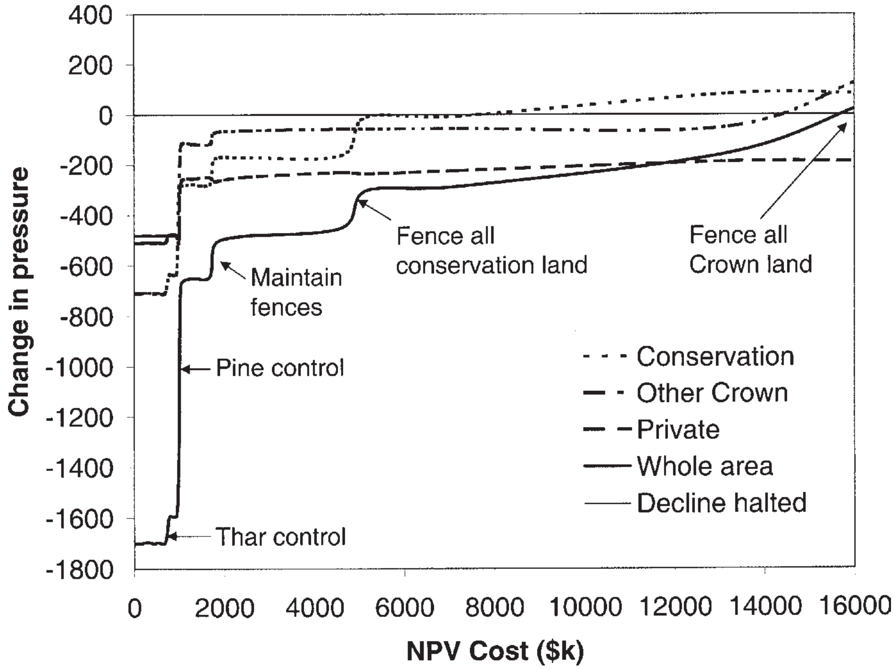
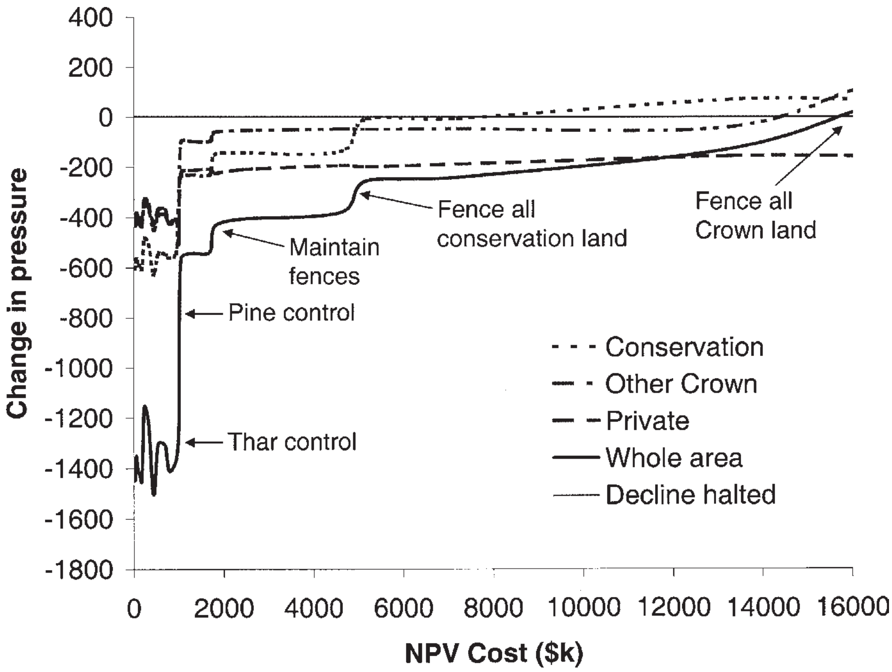



Figure 64. Cost of supplying conservation—discounted. The horizontal line at zero indicates the point at which pressure increase has been halted. These curves have been discounted for feasibility.




with positive vulnerability have increased pressure. Priority pixels for additional conservation effort are located in the right quadrant where both irreplaceability and vulnerability exceed the arbitrary 0.1 threshold. These 'priority pixels' can then be mapped to identify their locations and ecosystem type (Fig. 66). The majority of priority areas are river beds, terraces, tarns and palustrine wetlands. It seems that current investment in the conservation of freshwater ecosystems is low, relative to their irreplaceability and vulnerability.

The tenure review process provides an opportunity to formally protect some of these priority places by allocating some Crown land pastoral lease land units to conservation use and other units to private freehold use. The represent-

Figure 65. Priority places defined by the irreplaceability and vulnerability of individual pixels. The highest priority places are located in the upper right of the scattergram (shaded area) and these are identified spatially in Fig. 66. Places where pressure is being reduced have negative vulnerability and these are not priorites for additional or re-directed management effort.

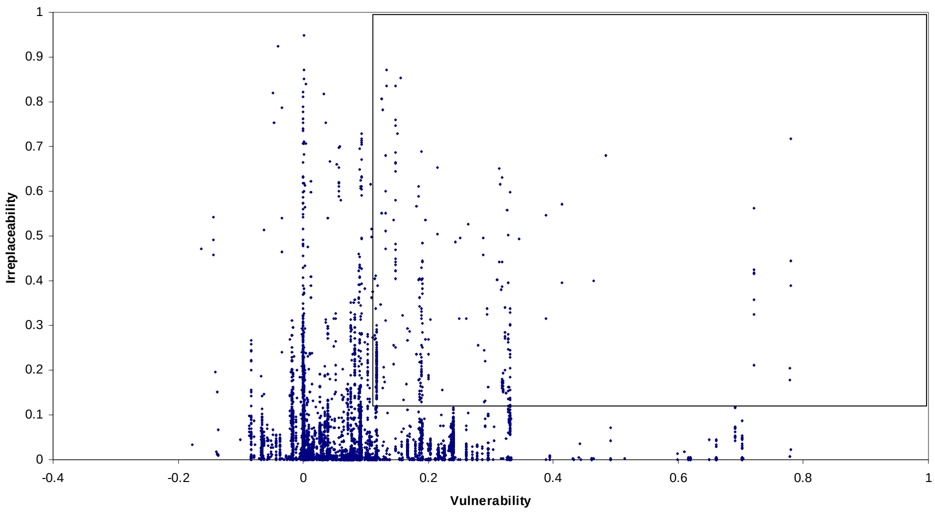



Figure 66. Priority places for additional or re-deployed conservation action. Each point on the scattergram (Fig. 65) represents a pixel. Secure and recovering pixels have negative vulnerability. Pixels with high irreplaceability and vulnerability mapped here represent places that should be high priorities for redirected or additional conservation investment. Many of the priority areas are freshwater systems.

ativeness analysis (Table 18) identifies under-protected environments and opportunities for protection. Of the 24 environments recognised in the Twizel Area, 10 are seriously unprotected (5% or less protected) and two are underrepresented in protected areas. Six environments have very high mean pressure (>0.93) suggesting that most of the native biota associated with these

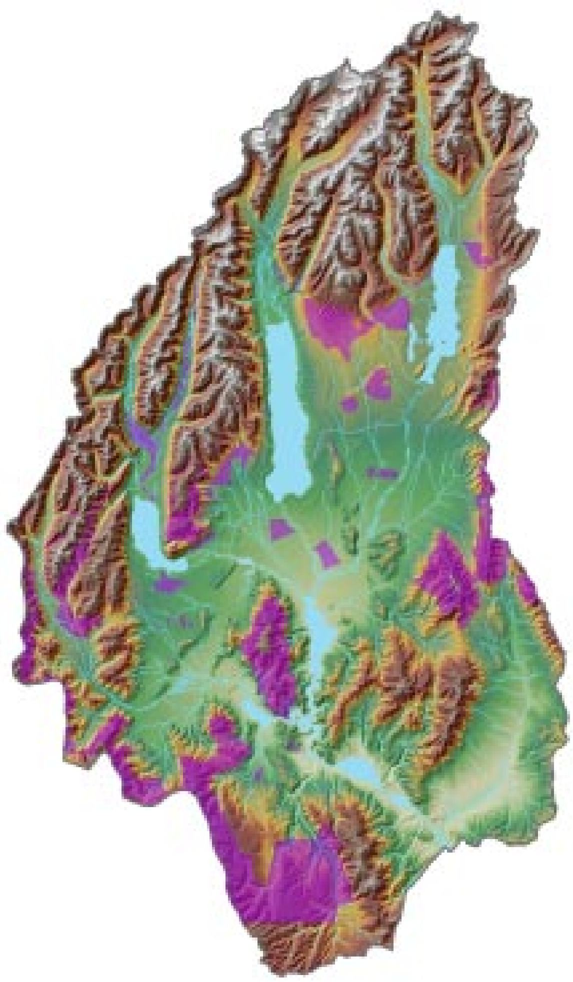


Figure 67. Increasing the representativeness of protected areas. The best sites for protection are in unprotected environments and under least pressure (purple areas).

environments may already have been lost. Protection of what vestiges remain will involve considerable restoration effort on private land which requires resolution of some difficult property rights issues or novel biodiversity protection schemes that include monetary advantage to the landowner. Some of the pixels identified as priority places for additional conservation effort (Fig. 66) were also identified as key places for improving the representativeness of protected areas (Fig. 67). Thus the tenure review process provides an important opportunity to both improve the representativeness of the heritage portfolio and to reduce losses at the most vulnerable and irreplaceable sites. However, this still leaves unresolved the issue of conserving something of what remains in the three environments with more than 90% in private ownership.

# 16. Discussion

New Zealand society invests in conservation, to sustain benefits supplied by natural heritage; it does so in order to achieve multiple social outcomes, that is, to maintain or improve our quality of life and that of future generations. The investment will be successful if it supplies desired benefits cost-effectively and these lead to positive social outcomes. Thus to manage the business of conservation efficiently, it is necessary to:

- specify the particular benefits sought by society in order to identify the work required to sustain them
- measure the state of natural heritage in a manner that reflects the flow of benefits it supplies in order to identify priorities for conservation effort
- quantify the effect of conservation action on the flow of benefits supplied in order to identify the best conservation actions.

The conservation measurement process provides a framework for managing conservation as a value-driven asset management business in which the primary goal is to maximise the flow of benefits to society from natural heritage while providing the particular outcomes sought by society. It does this via a structured inventory of natural heritage in which the smallest map unit is the pixel with properties defined by environmental, land cover and human disturbance pressure attributes. The volume, variety and quality of benefits associated with a particular outcome is estimated by the degree to which the area affected (by achieving the outcome) contributes to the size, diversity, representativeness and pressure on natural heritage. Together, these four heritage attributes are thought to determine the volume, variety and quality of the many (largely unrecognised) benefits natural heritage supplies to society. Our project demonstrates a quantitative application of these concepts using a real New Zealand conservation management setting. We demonstrate that it is possible to construct a comprehensive natural heritage inventory and use this for quantitative performance reporting and decision support.

Systematic conservation decision-making is dependent on specification of place-based outcomes that define the place, key valued attributes, their desired state and how people will interact with them. These are the particular outcomes sought by local communities and wider society. Ideally the outcome specification process is democratic, participatory and well informed (Fig. 46, p. 74). If conservation experts choose desired outcomes with insufficient social mandate, there will be insufficient community buy-in to the outcomes sought and the methods used to achieve them to sustain the level of societal support needed for success. Support for conservation will ebb and the social risk associated with conservation projects will increase. But without expert input, investment will be less efficient and there is greater risk of bad choices leading to undesirable social outcomes. There is therefore a need for a robust democratic and well informed participatory process for place-based outcome specification that will both lead to outcome choices that maximise benefits, and deliver the strong social mandate for the conservation work programme needed to deliver the outcome. The process for Conservation Management Strategy (CMS) development could be designed to fill this need.

We measure outcomes as change to the flow of benefits supplied by heritage. This is expressed as change in site value. Outcome measurement in terms of change in site value is appropriate for *in situ* conservation. But some important and valued conservation work may make very little difference to site value. Some examples are:

- intensive management of individual animals required to sustain some threatened species (e.g. kakapo conservation)
- action to benefit one threatened species at the cost of maintaining other native biota (e.g. Mahoenui weta)
- actions that limit the effects of predators without altering predator abundance and consumption pressure (e.g. captive breeding to compensate for mortality; rata banding).

Indeed, the outcomes supplied by conservation focused on single species are likely to be small unless based on reduction of sufficient pressure to sustain species in places within their natural range. This suggests that species-focused work should be planned, costed and evaluated as parts of much larger work programmes. So, for example, the outcome of the kakapo programme should not be limited to increasing the number of birds in the population, but should include the protection, restoration and elimination of human-induced disturbance pressure in sufficiently large areas to sustain kakapo within their natural range. Intensive kakapo management is just one of several critical steps toward returning kakapo to suitably protected and restored ecosystems. Others would include identification of appropriate places for their re-establishment (e.g. Stewart Island), achieving appropriate levels of statutory protection (e.g. National Park status), eradicating introduced predators and defending these places from pest incursions. Similarly, the maintenance of a gorse, pasture, goat and cattle system to sustain Mahoenui tusked weta should be seen as the first of several critical steps towards returning this giant weta to native ecosystems that currently have too much human-induced disturbance pressure to sustain them.

Most known threatened species should be effectively secured within this *in situ* conservation framework. Unknown threatened species can only be protected by *in situ* conservation. However for some known threatened species, sufficient pressure reduction may not be cost-effective compared with other conservation work. Indeed, it may be impossible. For such known species, *ex situ* conservation is the only remaining conservation option. But because *ex situ* conservation does not alter the state of the natural heritage portfolio (as here defined), the outcomes supplied by the two forms of conservation are not comparable. Therefore *ex situ* conservation work should be funded and prioritised separately from *in situ* conservation. Nevertheless, much of the framework described here could still be used for identifying priorities and for cost-effectiveness comparison.

## 16.1 IMPROVEMENTS AND REFINEMENTS

Conservation measurement is information-hungry and reliant on mechanistic models that would benefit from stronger empirical foundation, testing and validation. Three key strands for research activity needed to support general implementation are:

- improving component models
- survey co-ordination and data curation aimed at supplying national coverage for key pressure data layers so that conservancy capacity constraints do not preclude implementation
- developing tools to enable standard construction of pressure themes that cannot be constructed nationally.

Spatial resolution could be improved by reducing pixel size. This is important if the small-scale landscapes of the North Island are to be adequately represented and to capture small ecosystem types such as geothermal vents, remnant and marginal wetlands and linear features such as rivers and streams. However, smaller pixel size adds much to cost and logistic issues associated with managing large databases. Based on 1 $km^2$ pixels, the Twizel Area required a database of 10 668 primary records. If 4 ha (400 $m^2$) pixels had been used, then 266 700 primary records would be needed. This is well beyond the limits of Microsoft Access software in which this project was developed.

Greater project differentiation would enable improved targeting of pest control projects. For example, wilding pine control could be broken down into a set of place-based pine control projects. This would enable control work to focus on the places where the greatest difference can be made for the cost.

## 16.2 ENVIRONMENTAL CLASSIFICATION AND MAPPING

The natural heritage inventory used for conservation measurement is founded on objective classification and mapping of environments. The environmental units indicate the location and extent of natural ecosystems in the absence of human disturbance. This assumes that the composition of the biota, the rates of bio-physical processes and internal recycling are more similar within environment units than between them. If this is the case, then these environmental units delineate natural, undisturbed ecosystems and provide an objective framework for assessment of the current state of natural environments. However, they do not necessarily indicate the location of extant ecosystems because human disturbance has created a subset of entirely different ecosystems (e.g. urban-residential ecosystems, agricultural ecosystems) with distinctive species compositions and bio-physical process rates. Extant ecosystems can be mapped by intersecting land cover classes with environmental units (Fig. 11, p. 30) in order to identify areas where biotic composition and process rates are likely to be more similar within, than between units. These units are useful aids in describing bio-physical pattern in the landscape; but because many ecosystems are now anthropogenic, environmental units offer a more powerful spatial framework for conservation management and assessment purposes.

Our conservation measurement demonstration used a second-generation prototype environmental classification (Leathwick 1998). Distinctiveness was derived from the preliminary set of environmental data based on a rudimentary 1 $km^2$ digital elevation model assembled for New Zealand's first prototype classification of environments (Overton & Leathwick 2001). A high-resolution, national classification of terrestrial environments is underway using a much improved set of environmental data and a considerably refined 20 m digital elevation model. Classification of aquatic environments (freshwater and marine) is also underway (Snelder et al. 1998; Snelder & Guest 2000) and thought is currently being given to integration of terrestrial and aquatic classifications. At present, two issues preclude use of the river environment classification in conservation measurement processes. First, the rule-based approach adopted for rivers and streams prevents estimation of environmental distinctiveness. Second, inclusion of disturbance pressure attributes in the classification precludes meaningful estimation of site importance. These issues are currently being addressed.

Environmental distinctiveness is a key derivative of environmental information. There are at least two ways to estimate distinctiveness:

- mean distance to the nearest set of protected pixels in environmental space
- mean distance (in environmental space) to all protected pixels.

The latter approach was used here because it avoids the untenable assumptions that species are distributed around their environmental optima (e.g. NZ beech forest is not: Leathwick 1998) and pressure on protected areas is independent of environment (protected area degradation is strongly correlated with environment). Nevertheless, complementarity (*sensu* Pressey et al. 1994) is more effectively addressed by the former approach (Faith & Walker 1996), particularly if the environmentally systematic pattern of pressure increase within protected areas can be adequately addressed. The challenge is to find a computationally feasible method for calculating the contribution of a site or project to the representativeness of heritage, in a manner that appropriately takes into account the continuous nature of both condition and environmental variety.

## 16.3 LAND COVER

The Land Cover Database is due to be updated in 2003 but a number of improvements are needed for future classifications. First, classification should be based on actual measured vegetation composition, not on a subjective, issue-based *a priori* classification. The classification should be hierarchical so that different levels of classification can be chosen for particular tasks. The maximum classification resolution would be determined by an error limit on achievable cover class resolution. Resolution should be probabilistic, based on integration of statistical associations between spectral, environmental and plot data. The process for spatial extrapolation of plot-based data using Generalised Regression Analysis and Spatial Prediction (GRASP) developed by Lehmann et al. (1998) provides a powerful automatic method for such integration. The GRASP process standardises spatial extrapolation of any variable of interest, making it a transparent, reproducible and objective process.

There is no aquatic equivalent of the Land Cover Database that classifies and maps biota in freshwater and marine environments. The three-dimensional nature of aquatic environment creates challenges that have not been addressed in terrestrial environments.

## 16.4 DISTURBANCE PRESSURE

Conservation measurement and associated tools depend on estimation of the intensity of human-induced disturbance, scaled according to the effect of each disturbance on biotic composition. Effect is defined as compositional distance from that expected without disturbance. Methods for measurement of both condition and human disturbance are in their infancy and are therefore a key area for research effort. Perhaps the greatest gap is absence of robust empirical methods for relating animal pest abundance to change in the composition of native biota. Since all pest control is based on the premise that there is a relationship between pest abundance and impact on benefits, it is significant that these relationships have not been defined, particularly given the level of spending on animal pest control. Another key gap is the lack of methods to quantify edge and connectivity effects on native biota. Some basis for scaling these effects is needed for comprehensive pressure assessment that includes the impact of fragmentation.

Robust pressure and condition assessment ultimately depend on plot- and transect-based measurement within an efficient sampling framework, designed to sample the full range of environment combinations and human disturbance—glaciers, wetlands, forests, geothermal vents, coastal sand bars and offshore reef systems to dairy pasture, residential subdivisions, urban buildings, motorways and car parks. There are several major central and regional government stakeholders for this kind of information, but there is no driver for any one agency to take the lead and responsibility for designing and implementing such a major task and becoming custodian for resulting data. Indeed, there is a policy culture that perceives rigorous inventory, monitoring and information management as an impediment to efficient conservation management and an unacceptable drain on conservation resources. In addition, there are a number of technical field protocol development challenges:

- vegetation measurement is usually possible within one visit whereas animal pests usually require repeated visits (e.g. residual trap catch (RTC) monitoring for possums; tracking tunnel monitoring for rodents)
- appropriate reproducible methods to characterise the invertebrate fauna await development
- consent and privacy issues may confound effective sampling on private land.

If robust environmental and conservation reporting is to be comprehensive and sustained, then there has to be a major inter-agency commitment to a well designed, co-ordinated and managed environmental information collection and management programme. This was done in New Zealand until the mid 1980s and much of the data that made the present demonstration possible came from these now rapidly ageing databases. Specific examples are the National Indigenous Vegetation Survey (NIVS) database, the Meteorological Service climate data and the Land Resources Inventory (LRI) data from which the environmental classification was derived. The development of integrated data sets that combine economic, production, physical and biological data sets at similar scales is essential if the potential of geographic information systems for strategic policy analysis is to be realised (Walker & Young 1997).

The conservation measurement process depends upon prediction of change in the intensity of human-induced disturbances. This could be made more consistent and transparent with standardised pest and weed spread models that use location, rate of dispersal, environmental and habitat correlates in the context of environment, land cover and control information to estimate future abundance at a specified point in time. In this way, much of the input information could be standardised and automated so that conservation managers only have to define operational boundaries, project cost and risk profiles in order to implement the conservation measurement process. Standardised pest and weed spread models will be key tools needed to close the gap between conservancy capacity and the data demands of conservation measurement procedures.

The temporally explicit modelling described above is also needed to examine the time-paths of pressure change (cf. the static snapshot results presented here). This is a key pre-requisite to discerning benefit flow patterns over time so that the effect of different assumptions, project designs and management scenarios on the temporal pattern of benefit flows can be quantified. This is what conservation achievement measurement will have to do if conservation and environmental management is to maximise the flow of benefits supplied by heritage over time.

## 16.5 IMPLEMENTATION

We have addressed the conceptual and technical issues that must be resolved to make the measurement of conservation achievement technically feasible. These issues were challenging but not nearly as difficult as the cultural and systems issues that conservation agencies must address if they are to successfully use these decision support and reporting tools to manage their conservation business.

Perhaps the most formidable issue is weak accountability. All government conservation agencies have a culture of weak accountability for conservation output because there has been no basis for measuring it. Beleaguered managers have little interest in taking on additional responsibility; without real accountability for conservation output, they have little incentive to invest scarce funds in the data collection, training, systems and processes needed to support performance monitoring and output measurement. Consequently, there will be resistance, particularly at high management levels where demands and accountabilities are greatest, to the use of conservation funds to set up and service such systems—even if the cost-benefit ratios for doing so are very large indeed. Thus there is potential for agencies to be paralysed by an inability to implement meaningful achievement measurement. Weak accountability for conservation output leaves agencies exposed to ongoing funding cuts, because governments and control agencies have little means of knowing what the costs and benefits are of different conservation funding levels except by reducing funding levels and monitoring society's reaction to the consequences. Breaking out of this pernicious cycle will require outstanding leadership.

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# Appendix 1

## CALCULATION OF NPV OUTCOME, WEIGHTED AVERAGE FEASIBILITY AND MERIT FOR A MULTI-PROJECT SCENARIO (CMan)

| Code | C<br>Yrs man | D<br>Efficacy | E<br>D×D/ΣD<br>Adjusted efficacy | F<br>E×EXP(-0.1×C)<br>Adjusted NPVOutcome | G<br>F/ΣF<br>NPVEff weighting | H<br>Feasibility | I<br>G×H<br>Feasibility contribution | D×H×EXP(-0.1×C)<br>Project merit | F×H<br>Adjusted merit |
|---|---|---|---|---|---|---|---|---|---|
| Bennett's | 1 | 0.0150 | 0.0164 | 0.01483 | 0.0685 | 0.6218 | 0.0426 | 0.00844 | 0.00922 |
| Broom | 50 | 0.0134 | 0.0146 | 0.00010 | 0.0005 | 0.9263 | 0.0004 | 0.00008 | 0.00009 |
| Cat | 1 | 0.0072 | 0.0079 | 0.00712 | 0.0329 | 0.8883 | 0.0292 | 0.00579 | 0.00632 |
| Ferret | 1 | 0.0083 | 0.0091 | 0.00820 | 0.0379 | 0.8883 | 0.0337 | 0.00667 | 0.00729 |
| Pig | 1 | 0.0014 | 0.0015 | 0.00138 | 0.0064 | 0.9920 | 0.0063 | 0.00126 | 0.00137 |
| PineDOC | 50 | 0.6298 | 0.6880 | 0.00464 | 0.0214 | 0.9811 | 0.0210 | 0.00416 | 0.00455 |
| Rabbit | 1 | 0.0007 | 0.0008 | 0.00069 | 0.0032 | 0.8946 | 0.0029 | 0.00057 | 0.00062 |
| Stoat | 1 | 0.0016 | 0.0017 | 0.00158 | 0.0073 | 0.8883 | 0.0065 | 0.00129 | 0.00141 |
| StockSQ | 1 | 0.0518 | 0.0566 | 0.05121 | 0.2365 | 0.7900 | 0.1868 | 0.03703 | 0.04045 |
| Thar | 1 | 0.1261 | 0.1378 | 0.12465 | 0.5757 | 0.8891 | 0.5118 | 0.10145 | 0.11083 |
| Willow | 50 | 0.0223 | 0.0244 | 0.00016 | 0.0008 | 0.8648 | 0.0007 | 0.00013 | 0.00014 |
| Ylupin | 2 | 0.0019 | 0.0021 | 0.00170 | 0.0078 | 0.8516 | 0.0067 | 0.00132 | 0.00145 |
| Rlupin | 50 | 0.0163 | 0.0178 | 0.00012 | 0.0006 | 0.7920 | 0.0004 | 0.00009 | 0.00010 |
| Hedge | 1 | 0.0001 | 0.0001 | 0.00010 | 0.0005 | 0.8883 | 0.0004 | 0.00008 | 0.00009 |
| Gorse | 50 | 0.0070 | 0.0076 | 0.00005 | 0.0002 | 0.9500 | 0.0002 | 0.00004 | 0.00005 |
| **TOTAL** | | 0.9029 | 0.9864 | 0.21653 | | | 0.8496 | 0.16840 | **0.1840** |
| **CMan** | **Null** | **0.9864** | | **0.2165** | | **0.8496** | | **0.1840** | |

Multi-project scenarios will have null values for both YearsToOutcome_Man and Years To Outcome_Pot

Efficacy is the sum of adjusted component project efficacy values

NPVOutcome is the sum of component project NPVOutcome values

Feasibility is the sum of weighted contributions from component projects

Merit remains the product NPVOutcome × Feasibility

The sum of the 'synergy' adjusted merit equals Merit

# Appendix 2

## WORK PROGRAMME OPTIMISATION

An optimisation model to identify the most cost effective programme of projects for a given budget. This example demonstrates identification of the most cost-effective choice of projects for a budget of $2.5m from a suite of projects costing c. $25m (= total NPV cost).

| A<br>Project | B<br>Project done? | C<br>NPVcost $k | D<br>Project Merit | E<br>In or Out (1 or 0) | D × E<br>Total Merit | C × E<br>Total Cost ($k) |
|---|---|---|---|---|---|---|
| PineRPMS7 | **1** | 1037.5 | 0.5204 | 1 | 0.5204 | 1037.5 |
| PineDOC7 | 0 | 997.1 | 0.3053 | 0 | 0.0000 | 0.0 |
| Thar | **1** | 711.8 | 0.1015 | 1 | 0.1015 | 711.8 |
| Broom10 | **1** | 49.8 | 0.0039 | 1 | 0.0039 | 49.8 |
| Ylupin | 1 | 21.0 | 0.0013 | 1 | 0.0013 | 21.0 |
| Bennetts | 1 | 156.7 | 0.0084 | 1 | 0.0084 | 156.7 |
| Gorse10 | 1 | 49.8 | 0.0023 | 1 | 0.0023 | 49.8 |
| Bstilt | **1** | 414.1 | 0.0188 | 1 | 0.0188 | 414.1 |
| BStilt1 | 1 | 1983.0 | 0.0751 | 0 | 0.0000 | 0.0 |
| StockSQ | 1 | 1115.4 | 0.0370 | 0 | 0.0000 | 0.0 |
| Pig | **1** | 51.1 | 0.0013 | 1 | 0.0013 | 51.1 |
| Willow10 | 1 | 797.6 | 0.0067 | 0 | 0.0000 | 0.0 |
| StockCL | 1 | 7138.7 | 0.0407 | 0 | 0.0000 | 0.0 |
| Rlupin10 | 1 | 603.2 | 0.0033 | 0 | 0.0000 | 0.0 |
| StockTR | 1 | 10261.8 | 0.0471 | 0 | 0.0000 | 0.0 |
| Rabbit | 1 | 625.1 | 0.0006 | 0 | 0.0000 | 0.0 |
| | **Budget ($k) = 2500** | | | **Sum of Merit = 0.6579** | | **2491.8** |

**Maximise Sum of Merit by setting cells in column E to 0 or 1, Subject to the constraint that Programme Cost ≤ Budget**

**Programme Cost ($k)**

# Glossary of terms, indices, and assumptions made in their calculation

**Condition** the similarity of contemporary biota to biota expected in the absence of human-induced disturbances. Condition is measured by an additive combination of several components, such as taxonomic composition, phylogenetic diversity, functional diversity, structural diversity and age diversity.

**Conservation achievement** measures 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; it is an essential part of ensuring defensible and accountable stewardship of natural heritage.

**Conservation performance** measures how fully particular conservation project outputs are delivered. It can be useful for monitoring progress towards chosen outcomes and is an essential part of ensuring management accountability for delivery of agreed outputs and outcomes.

**Feasibility** the consequence to a specified output (or outcome) of risks modified by management to mitigate them. For each risk factor it, its effect on the output and how much of this effect will effectively managed must be estimated. Five risk factors must be considered to total feasibility.

**Importance** a measure of the representativeness of a site. The index measures how close a site is to being the best of what remains of its type. It is a context-dependent measure that requires an environmental classification and pressure (or condition) input information.

**Irreplaceability** an index based on the product of site distinctiveness and importance measures.

**LCDB (Land Cover Database)** The first national digital map of New Zealand's land cover.

**Nett present value (NPV)** the time discounted value of an outcome or stream of annual project costs. The discount rate (d) determined the rate of value loss over time. In this study, the discount rate was based on the DOC capital charge rate (10%).

**Pressure** the intensity of human induced disturbances. Pressure is made of five types of human-induced disturbance: biota removal; physico-chemical resource alteration; infestation pressure; consumption pressure; and fragmentation. Pressure is defined by the product of fractional indices for four components and a smoothing function to account for fragmentation. In our study, fragmentation was not accounted for in the pressure index.

**Project merit** the measure of conservation output associated with a conservation project. The sum of project merit values for a set of projects comprising a work programme is the conservation output delivered by that work programme. Project cost-effectiveness is project merit divided by the NPV of the costs of delivering the project outcome.

**Project outcome** the benefit (e.g. security of a previously threatened species; maintenance of predominantly native vegetation cover) gained or benefit loss avoided by successful implementation of the project. Outcomes occur from project objective to national programme scales, over short and long timescales.

**Project outcome size** the change in benefit flow indexed by the difference in project site value between 'with project' and 'without project' scenarios.

**Project output** a clearly identifiable milestone in the implementation of a conservation project. This will often be the change in threat level (e.g. pest abundance) delivered (or avoided) by successful implementation of the project. For example, a possum control output could be the reduction of a possum abundance index to <5% residual trap catch over a specified area; an output of a wetland restoration project could be construction of a weir to raise the mean annual water level by 1.5 m. Project outputs generally cannot be aggregated to indicate the value added by conservation effort.

**PRR (Project River Recovery)** the name of a large conservation programme aimed at restoring the condition of the rivers impacted by the upper Waitaki hydro-electric power scheme.

**Project site** the area over which the project causes a reduction in pressure.

**RHD (Rabbit Haemorrhagic Disease)** a virulent viral disease of rabbits illegally introduced just prior to this study, that resulted in the decimation of central South Island rabbit populations.

**RMA Resource Management Act 1991**

**RPMS (Regional Pest Management Strategy)** describes the pests, policies and control tactics to be implemented by regional and local government.

**Site** any spatially defined area. Conservation land units are surveyed cadastral units of Crown land managed for conservation purposes. The 'project site' is the area where a project reduces pressure on natural heritage.

**Site priority** identified by one of two possible methods. Magnitude of site value loss or the combination of site irreplaceability and vulnerability. The former gives more weight to benefit volume loss. The latter gives more weight to benefit quality and diversity loss.

**Site size** the area of a site scaled according to the rate at which benefits supplied by natural heritage increase with site area. We assumed that the most valued benefits (i.e. charismatic megafauna and flora) increase with $area^{0.4}$.

**Site value** an index that measures a site's contribution to the state of natural heritage, defined by the product of its size, importance, pressure and distinctiveness. The volume, diversity and quality of benefits supplied by natural heritage to society are assumed to be positively correlated with site value.

**Site vulnerability** an index based on the magnitude of predicted change in pressure. Positive values indicate sites expected to be degraded; negative values indicate predicted improvement or restoration.

**State of Natural Heritage** defined by its size, representativeness, condition and the diversity it contains. The flow of heritage-derived benefits to society are assumed to be positively associated with these four attributes of heritage.