New Zealand Agricultural and Resource Economics Society (Inc.)

Valuing indigenous biodiversity in the freshwater environment

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Summary:

Biosecurity incursion response decisions require timely, high quality information involving science and economics. The value of the impact on indigenous biodiversity is a key aspect of the economics typically involving cost-benefit analysis. The hypothetical incursion of Biosecurity New Zealand's top priority weed hydrilla (*Hydrilla verticillata)* in a typical New Zealand lake (Lake Rotoroa otherwise known as Hamilton Lake) elicits dollar values of impacts on indigenous biodiversity in a freshwater environment. Using the stated preference tool, Choice Modelling, the experimental design was maximised for efficiency of Willingness to Pay (WTP) estimation. The survey method of community meetings of four population samples at varying distances to the incursion site is a cross between a mail survey and an individual interview survey. Results show an efficient design with minimal sample size and biodiversity attributes that have values statistically different from zero but not statistically different between locations.

Key words:

Non-market valuation, biosecurity, biodiversity

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Valuing indigenous biodiversity in the freshwater environment

Background

Biosecurity New Zealand (BNZ) has primary responsibility for weed and pest management in New Zealand including the detection and prevention of incursions, and surveillance and responses to incursions (Biosecurity Council, 2003). As funding is limited, a framework is needed to allocate available resources to maximise net national benefit of biosecurity programmes. Cost benefit analysis (CBA) has long been the tool used to quantify these net benefits where market prices are available to assess the impacts on industry and assist in making these resource allocation decisions (Treasury, 2008). But where there are no market prices, such as where pests impact on indigenous biodiversity, special tools are needed to estimate values in dollar terms that will allow its inclusion in the CBA alongside impacts on the market economy.

This project is one of four case studies aimed at establishing a database of non-market values of high priority ecosystems (i.e. those that have a high vulnerability to incursions and high biodiversity values) to be used by BNZ in CBA studies during pest incursions when time and money are constrained. This will lead to the development of a decision support system for invasive species impacting on indigenous biodiversity. The four case studies include high country, coastal marine, beech forest and freshwater systems.

The aim of the freshwater case study is to elicit dollar values of impacts on indigenous biodiversity due to a hypothetical incursion of the exotic weed hydrilla in Lake Rotoroa. It applies a choice experiment to estimate dollar values of four population samples located at varying distances from Lake Rotoroa.

Freshwater system: Hypothetical weed incursion

Hydrilla was chosen as the case study invasive as it is BNZ's top priority weed. Although currently restricted to only three lakes in the Hawkes Bay area, it has the greatest potential for negative impacts on New Zealand's freshwater systems.

Hydrilla is a submerged freshwater perennial plant that is characterised by prolific growth and tolerance of a wide range of freshwater habitats including clear or murky, still or flowing water; temperature between 0 and 35^{o}C; water depths from a few centimetres to 9 meters; low light to full sun; and a wide range of acidity and nutrient levels.

In conjunction with BNZ, Lake Rotoroa (also known as Hamilton Lake) was chosen as the freshwater system under threat as it has a high risk of hydrilla invasion, has a long history of management, has a high profile due to shoreline housing and recreational use and has some indigenous biodiversity similar to other New Zealand lakes (Harrison pers. comm., 2008).

The threat of hydrilla to the lake ecosystem is far greater than that of the current exotic incursions of oxygen weeds. Hydrilla would likely develop into extensive weed beds at all depths and smother the native charophytes in particular. While eels are likely to be unaffected, the remaining species of native fish and mussels would be severely impacted through a reduction in available space and change to the habitat. It is also likely that the shags would stop frequenting the lake as the areas of clear water reduced. Swans would be attracted and this would help clear water to a depth of around 1m, but their aggressive behaviour particularly towards children has a down side. Boating would be severely hindered.

If hydrilla was ever introduced to Lake Rotoroa and became well established, there would be no realistic prospect of elimination without the long term use of grass carp. A small incursion detected early could be controlled with the herbicide endothall, or other methods, such as weed matting, but use of these techniques would depend very much on where the specific incursion was, and how established it had become. As hydrilla would eliminate all native vegetation anyway, especially charophytes and the underlying seed beds, the use of grass carp would be justified to prevent irreversible damage to the lake ecosystem. Hence the best management strategy is to target effort towards investing in preventing the introduction of hydrilla, or eradicating hydrilla before it became established (de Winton et al 2005; Clayton 2008a pers comm.; Hofstra 2008 pers. comm.).

Economic problem

The introduction of hydrilla into Lake Rotoroa would result in very serious impacts on indigenous biodiversity as well as on how humans would interact with the lake. Thus, the benefits of eradication or control of hydrilla are the negative impacts avoided. The negative impacts include loss to the lake of native species particularly charophytes, fish, mussels and birds. As the clarity and quality of the water progressively became reduced, there would be increasing negative impacts on humans through a reduction in the quality of the experience of visiting the lake for boating, a gross deterioration in the view presented and eventually odour issues.

The ability to eradicate or control an infestation is dependent on prevention and early detection. Depending on the management strategy adopted, different states of the ecosystem are possible. The attributes associated with the different states of the ecosystem become the basis for framing the choices put to survey participants. Through carefully constructed questionnaires which present participants with alternative choices of the attributes of the ecosystem along with a money cost to their household, it is possible to elicit their willingness to pay (WTP) for a particular state of the environment. This forms a proxy for the value of a change to the ecosystem allowing environmental values to be included in the CBA.

Choice modelling

Choice modelling (CM) is the stated preference tool used to elicit marginal dollar values for the key attributes of the lake. CM is the tool that has gained most credence in performing non-market valuation of environmental goods and services (Rolfe and Bennett, 2006). CM has emerged from utility theory and belongs to the suite of tools referred to as stated preference techniques as they rely on people stating their preference when faced with a number of choices about changes to key attributes given some cost to them. Different levels of the key attributes (e.g. levels of the lake's native species, particularly charophytes, fish, mussels and birds) along with a money attribute (e.g. cost to the household) describe options on future states of the lake. Respondents are presented with a limited number of options (a choice set typically comprised of a status quo alternative plus two other alternatives) and are asked to indicate their most preferred state from the choice set. This process is repeated a number of times (i.e. answering a number of choice sets) to go through a relevant subset of the range of options. Statistical experimental design allows the selection of a relevant subset of options that provides the best information to mathematically infer values from the choices of respondents.

The hypothetical question is the willingness to pay for maintaining or limiting deterioration of key environmental aspects of Lake Rotoroa due to the weed hydrilla (*Hydrilla verticillata)* with the focus on impacts on indigenous biodiversity. The payment vehicle for eliciting willingness to pay is a special tax on rate payers assessed annually for five years.

The generic utility of policy alternative *j* for respondent *n* in choice task *t* is defined as:

$$U_{jnt} = V(\beta_{kn}x) + \varepsilon_{jnt} = \beta_{1n}HYD_{jnt} + \beta_{2n}WQ1_{jnt} + \beta_{3n}WQ2_{jnt} + \beta_{4n}WQ3_{jnt} + \beta_{5n}CHA_{jnt} + \beta_{6n}BIR_{jnt} + \beta_{7n}FISHMUS_{jnt} + \beta_{\$}PRICE_{jnt} + 1(1\text{-}SQ)\eta_n + \varepsilon_{jnt} \quad (1)$$

Where β_{kn} denotes random (across people, or *n*) taste intensities for attribute *k*, η_n is a random normal error component with zero mean entering the utility of the experimentally designed policy scenarios (the non-SQ alternatives), and ε_{jnt} is the Gumbel distributed error component. The attributes considered were:

HYD	Percentage of success in preventing hydrilla cover (0%, 35%, 70% and 100% success levels)
CHA	Percentage of success in preserving charophytes cover (0%, 7%, 14% and 21% success levels)
BIR	Number of shags species visiting the lake (0,1, 2 and 4 species)
FISHMUS	Number of fish species and mussels retained (0, 1, 2 and 3 species)
WQ1, WQ2, WQ3	Effects coding for 4 levels of water quality (significant, moderate or slight deterioration, or same condition from current quality and clarity of water)
PRICE	The money attribute was set at 6 levels: \$0, \$10, \$20, \$40, \$80, \$160 and presented as the cost to the respondent's household each year for the next 5 years.

Given $\boldsymbol{\beta}_n$ and η_n the probability of observing alternative i to be selected from the J alternative in the choice task is logit and the sequence of t choices made by a respondent is a joint logit or:

$$\Pr(i_1, i_2, i_3, \ldots, i_t | \beta_n, \eta_n) = \prod_t \Pr(i_t \mid \beta_n, \eta_n) = \prod_t \frac{\exp(\beta_n' x_{jnt} + \eta_n)}{\sum_{j=1}^{J} \exp(\beta_n' x_{jnt} + \eta_n)} \qquad (2)$$

To obtain the unconditional probability, the random components need to be integrated out over their respective ranges:

$$\Pr(i_1, i_2, i_3, \ldots, i_t) = \int_{\beta_n} \int_{\eta_n} \prod_t \frac{\exp(\beta_n' x_{jnt} + \eta_n)}{\sum_{j=1}^{J} \exp(\beta_n' x_{jnt} + \eta_n)} f(\beta_n, \eta_n \mid \boldsymbol{\mu}, \boldsymbol{\Omega}) d\beta_n d\eta_n \qquad (3)$$

The assumed distributions are normal with mean vector $\boldsymbol{\mu}$ and variance covariance $\boldsymbol{\Omega}$, only the mean of η_n is restricted to zero.

In the maximum simulated likelihood estimation these integrals were approximated by weighted probability averages based on quasi-random draws from prime numbers i.e. Halton draws (Train 2003) to take advantage of their good coverage properties and reduce the number of necessary draws to achieve high precision.

Design

Having defined the economic problem and hypothetical question, the first step in the survey design is to determine the important attributes of Rotoroa Lake and the relevant levels of those attributes. This was done using focus groups arranged by a professional market research agency. Groups were convened in Wellington and Hamilton in April 2008. Participants did not know the purpose of the study until they arrived at the meeting. Prior to this the focus group presentation was tested with a group from Biosecurity New Zealand to ensure the technical aspects were accurate.

The first part of the focus group session was a presentation to introduce the concepts of freshwater biodiversity, the threats to lake biodiversity and biodiversity protection and control measures. Next, we introduced the case study lake and described its features using slides to depict the various attributes of the lake including natural and man-made aspects. We then asked participants to make a choice between two different states of various aspects of the lake. The idea here was to determine which features of the lake people valued most highly. Aspects of the lake that were tested included water with and without surface plants, board walk versus natural lake edge, ducks versus pukeko (exotic vs. native), oxygen weed versus charophytes (exotic vs. native), a scene with boats on the lake versus birds on the lake, and a scene of the lake side with introduced trees versus native trees.

The next stage introduced hydrilla, the potential invasive weed, its characteristics and likely impacts. We then asked participants to indicate how acceptable different states of the environment would be to them. We tested water quality and clarity, presence of hydrilla, presence of native water plants (charophytes), presence of native fish and mussels, native birds, water sports and lake side recreation. Finally, we asked participants to consider various increases in their annual rates bill for different control mechanisms resulting in different outcomes.

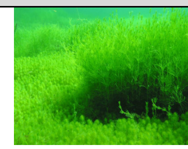
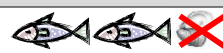
On the basis of the information collected from the three focus group meetings, the key attributes and attribute levels were selected for the choice experiment. This was tested on a convenience sample of 12 people in June 2008. The results were analysed and used as the priors to assist in the experimental design of the survey (discussed later in this section). Figure 1 shows an example choice set. The rows represent the attributes, for example, water quality and clarity, coverage of native submerged plants etc. and the columns represent the options or scenarios, which are described by a set of attribute levels including the cost to the participant's household.

The money attribute was "the cost to your household each year for 5 years." The payment vehicle was a household rate levied to fund hydrilla control, as provided for under the Biosecurity Act (1993). Money values were chosen to cover the range of payments likely to be acceptable based on the focus group results being $0, $10, $20, $40, $80 or $160.

Figure 1: Example of a Choice Set

Question 1:

Options A, B and C
Please choose the option you prefer
By ticking ONE box

	Option A	**Option B**	**Option C**
Extent of hydrilla	 100% coverage	 30% coverage	No hydrilla
Water quality and clarity	Significant deterioration	OK Same as now	OK Same as now
Coverage of native submerged plants	Eliminated from lake	Eliminated from lake	 Same as now at 21% cover
Number of native bird species	 All 4 shag species do not visit the lake anymore	 3 shag species do not visit the lake anymore	 3 shag species do not visit the lake anymore
Fish and mussels	 2 fish species and mussels disappear from the lake	 Mussels disappear from the lake	 1 species of fish and mussels disappear from the lake
Cost to your household each year for 5 years	$0	$160	$20
I would choose ☑	☐ A	☐ B	☐ C

The status quo is the do nothing option with a payment of zero dollars and with all environmental attributes at the worst level. The status quo is presented as Option A in all choice situations. Two alternatives to the status quo (Alt1 and Alt2) are presented as Option B and C, respectively, in the survey questionnaire.

Efficient design of surveys results in reliable parameter estimates characterised by small standard errors. The experimental design is Bayesian in nature using the normal distribution for the coefficients of all environmental attributes and the money attribute. As discussed in Ferrini and Scarpa (2007), a Bayesian efficient design is less sensitive to misspecifications of the priors than a point efficient design. The MNL estimates of the parameters from the convenience sample (see Table 1) were used as priors (where significant at 95% confidence level, otherwise a theoretical prior was used) for the experimental design, which were assumed to be normally distributed with standard deviation equal to the estimated standard errors. For example, the design ignored the negative BIRDS1 coefficient and this was set close to zero with large variance in the Bayesian prior. The variables are dummy-coded with respect to status quo (level 0). The criterion to be minimized was the sum of the variances of the marginal WTP of each attribute, as suggested in Scarpa and Rose (2008).

Table 1: MNL estimate convenience survey

Variable	Coefficient	Standard Error	P[|Z|>z]
HYDR1	0.8814*	0.5047	0.0807
HYDR2	1.1512**	0.5371	0.0321
HYDR3	2.1230***	0.5621	0.0002
WQUAL1	0.7167	0.5082	0.1584
WQUAL2	0.5628	0.5283	0.2867
WQUAL3	0.2473	0.4903	0.6140
CHAR1	1.3297**	0.5441	0.0145
CHAR2	2.3927***	0.6032	0.0001
CHAR3	3.1035***	0.5812	0.0000
BIRDS1	-0.1871	0.5544	0.7358
BIRDS2	0 .2586	0.4947	0.6011
BIRDS3	1.5754***	0.5149	0.0022
FISH1	0.3807	0.5470	0.4864
FISH2	1.3063**	0.5114	0.0106
FISH3	1.7579***	0.4870	0.0003
PRICE	-0.0206***	.0044	0.0000
LL			-64.545
Pseudo-R^2			0.382
AIC (Akaike information criterion)			1.134
BIC (Bayesian information criterion)			1.467

*** Significant at 99% confidence level
** Significant at 95% confidence level
* Significant at 90% confidence level

The algorithm for the experimental design minimises the sum of the variances of the WTP for the various policy attributes. As a result, the design is specific to WTP estimation (*C*-efficiency), rather than to estimation of parameter estimates (*D*-efficiency). See Scarpa and Rose *op cit* for review of these efficiency criteria.

The recent release of Ngene[1], an experimental design software for stated choice experiments, allowed the evaluation of the survey design for efficiency. The evaluation result showed that the design is efficient with an S estimate 4.156 and D-error of 0.022. While the S estimate implies that the minimum sample size required is 5 respondents for the most difficult attribute to estimate, bias errors necessitate higher sample sizes. Bias arises from random choice behaviour and the assumption that all random components are independent (the IID assumption in MNL). However, the low S estimate achieved indicates an efficient design (ChoiceMetrics, 2009).

The optimal design comprised 60 choice sets. These were randomly divided into five groups resulting in a manageable grouping of 12 choice sets per respondent. The five groups of choice sets are uniformly distributed in each survey sample resulting in each group of choice situations being (more or less) uniformly represented. Please refer to Appendix 1 for the complete experimental design and coding of levels for the environmental attributes.

Data collection

Typical methods for data collection include paper mail-out surveys, telephone surveys, internet surveys and personal paper or computer-aided design interviews. Telephone surveys involve huge cognitive burden as each questionnaire involves 12 choice sets with three options across six attributes per choice set. Impersonal mail-out surveys are unable to convey richness of information to a similar level achieved in a personal interview (Kerr and Sharp, 2003). Personal interview ensures respondent understanding of the survey and allow the use of visual aids to convey information but is the most expensive form of data collection particularly in multiple locations.

This study implemented a hybrid community meeting approach that involved a 40 minute presentation of freshwater biodiversity, biodiversity protection, the case study lake, the hypothetical hydrilla incursion and the range of impacts that hydrilla could have on the ecosystem. This was followed by 20 minutes for answering 12 choice questions. The hybrid approach has the advantage of bringing the assembled group of respondents to a uniform level of understanding of the issue and administering choice questionnaires to multiple respondents in one sitting.

Community service groups (e.g. school, dragon boating association, Lions or Rotary) were tapped to organise the community meetings with a target of 50-60 participants using a promotional flyer, a $50 donation per person recruited and $20 petrol voucher to the participant. The community service groups were requested that a cross-section of adults in the community be invited with a gender balance, and a range of ages, educational qualifications, incomes and ethnicity.

[1] Version 1.0.0 © 2009 Rose, Collins, Bliemer and Hensher.

The survey samples were drawn from four locations with varying proximity to Lake Rotoroa. The four samples are Rotoroa (sample beside or near the lake), Rototuna (sample in Hamilton - same city as the lake), Morrinsville (sample in Waikato – same region as the lake) and Karori (sample in Wellington – a distant urban location). The four locations were chosen to observe the effect of distance-decay for any of the attributes.

Modelling and results

The survey gathered a total of 225 respondents but twelve under-age participants in the Rotoroa sample (under 18 years old) were excluded as they would be unlikely to be a party to household budget decisions. This resulted in a total of 213 respondents distributed among Rotoroa (44), Rototuna (40), Morrinsville (65) and Karori (64). Overall, the analysis consisted of 2,556 observations.

The community meeting approach is not intended to generate a representative sample of each community. However, it is a good representation of an informed community such as the scenario that will exist following a community awareness campaign and debate about management options for a hydrilla incursion.

Population samples are generally representative of the relevant population (refer to Table 2 below) for some aspects (e.g. gender in Rototuna and Karori; young and mid-age in Morrinsville and Karori; low income in Rotoroa and high income in Rototuna, European/Asian ethnicity and high/low skills in Rototuna). In terms of gender, male is over-represented in Morrinsville. Polytech and degree qualifications are generally over-represented in all samples. The old and young age groups are generally under-represented except in Karori (where old is over-represented). Except in Rototuna, the European ethnicity is over-represented. The Maori and Pacific ethnicities are over-represented in Rotoroa and Rototuna but under-represented in others. Asian (except in Rototuna) and other ethnicity are generally under-represented. The high income group and high-skill occupation group are generally over-represented except in Rototuna.

Respondents were asked to indicate whether they were a member of a conservation group and this resulted in positive responses for Rotoroa (23 %), Rototuna (8 %), Morrinsville (14 %) and Karori (16 %).

Table 2: Survey demographics

	Sample				Population Census				Lower Limit				Upper Limit			
	Rotoroa	Rototuna	Morrinsville	Karori	Rotoroa	Rototuna	Morrinsville	Karori	Rotoroa	Rototuna	Morrinsville	Karori	Rotoroa	Rototuna	Morrinsville	Karori
GENDER																
Male	40.9%	42.5%	66.2%	51.6%	48.3%	48.5%	49.1%	47.7%	41.2%	41.0%	43.2%	41.8%	55.4%	56.0%	55.1%	53.5%
Female	59.1%	57.5%	33.8%	48.4%	51.7%	51.4%	50.9%	52.3%	44.1%	43.5%	44.7%	46.0%	59.3%	59.3%	57.0%	58.7%
QUALIFICATION																
No Qual	0.0%	0.0%	4.6%	1.6%	14.7%	16.3%	31.2%	7.8%	12.5%	13.8%	27.4%	6.9%	16.9%	18.8%	35.0%	8.8%
Fifth	9.1%	10.3%	4.6%	1.6%	9.5%	12.8%	16.5%	7.1%	8.1%	10.8%	14.5%	6.3%	10.8%	14.8%	18.5%	8.0%
Sixth	20.5%	12.8%	6.2%	1.6%	22.8%	24.3%	18.4%	25.2%	19.5%	20.6%	16.2%	22.1%	26.2%	28.0%	20.6%	28.3%
Polytech	38.6%	33.3%	56.9%	34.4%	19.3%	21.5%	17.1%	15.1%	16.5%	18.2%	15.0%	13.3%	22.1%	24.8%	19.1%	17.0%
Degree	31.8%	43.6%	27.7%	60.9%	24.8%	19.5%	6.4%	40.4%	21.2%	16.5%	5.6%	35.5%	28.5%	22.5%	7.1%	45.3%
AGE																
Young	22.7%	11.4%	35.4%	17.2%	35.2%	19.3%	21.8%	18.2%	30.0%	16.3%	19.1%	16.0%	40.4%	22.2%	24.4%	20.4%
Mid-age	77.3%	75.0%	46.2%	57.8%	47.9%	58.5%	51.8%	62.5%	40.9%	49.5%	45.5%	54.9%	55.0%	67.5%	58.0%	70.2%
Old	0.0%	2.3%	18.5%	25.0%	16.9%	22.3%	26.5%	19.3%	14.4%	18.9%	23.3%	16.9%	19.3%	25.8%	29.7%	21.6%
INCOME																
High income	31.8%	35.0%	43.1%	57.8%	22.1%	32.6%	13.7%	37.0%	18.9%	27.6%	12.1%	32.5%	25.3%	37.5%	15.4%	41.5%
Low income	68.2%	65.0%	56.9%	42.2%	62.3%	55.4%	72.1%	52.0%	53.2%	47.0%	63.4%	45.7%	71.4%	63.9%	80.8%	58.3%
ETHNICITY																
NZ European	70.5%	67.5%	90.8%	89.1%	60.3%	68.4%	72.4%	72.6%	51.4%	57.9%	63.6%	63.8%	69.2%	78.9%	81.2%	81.5%
NZ Maori	22.7%	12.5%	3.1%	0.0%	13.2%	7.2%	12.2%	5.0%	11.3%	6.1%	10.8%	4.4%	15.2%	8.3%	13.7%	5.6%
NZ Asian	0.0%	10.0%	1.5%	6.3%	13.7%	11.7%	2.7%	14.6%	11.7%	9.9%	2.4%	12.8%	15.7%	13.5%	3.0%	16.3%
NZ Pacific	4.5%	2.5%	0.0%	0.0%	2.6%	0.6%	1.0%	4.0%	2.2%	0.5%	0.8%	3.6%	3.0%	0.7%	1.1%	4.5%
Others	2.3%	7.5%	4.6%	4.7%	10.2%	12.1%	11.7%	3.8%	8.7%	10.2%	10.3%	3.3%	11.7%	13.9%	13.1%	4.3%
OCCUPATION																
High skill	38.6%	48.7%	27.7%	42.2%	45.5%	45.7%	36.0%	56.1%	38.8%	38.6%	31.6%	49.2%	52.2%	52.7%	40.3%	62.9%
Low skill	61.4%	51.3%	72.3%	57.8%	50.1%	52.3%	57.5%	39.9%	42.8%	44.3%	50.6%	35.0%	57.5%	60.4%	64.5%	44.8%

Source: Statistics New Zealand, 2006 Census area unit and territorial unit data

Definitions:

OLD Over 60 years
YOUNG Under 30 years
MIDAGE 30-60 years
HIGH INCOME High-income (household income > $100,000 pa)
HIGH SKILL Occupation = managers or professionals

Relevant population:

Rotoroa – Hamilton Lake area unit
Rototuna – Rototuna area unit
Morrinsville – Matamata-Piako District
Karori – Karori North, Karori Park, Karori East and Karori South area units
Confidence intervals relate to the population. The sample needs to be within the lower and upper limit for 95% confidence level.

Coding of attributes

The coding of the attributes for analysis reflects the change in the various levels for a particular attribute. For example, there is success in removing 35% of hydrilla cover in level 1 relative to the status quo (from 100% to 65% coverage, see Master Table in Appendix 1). Level 1 numeric coding is then 35 (see Table 3). Level 3 coding of 100 reflects total success in removing hydrilla.

Table 3: Numeric coding

Attribute	Level 0	Level 1	Level 2	Level 3	Description
HYD	0	35	70	100	Total success in removing hydrilla
CHA	0	7	14	21	Total success in preserving 21% charophytes cover
BIR	0	1	2	4	Total success in preserving 4 shags
FISHMUS	0	1	2	3	Total success in preserving 2 fish and 1 mussel (2+1=3)

Water quality utilised effects coding in order to account for non-linear effects in the attribute levels. The non-linear effects arise from differences in utility[2] between any two consecutive attribute levels (Hensher, Rose & Greene, 2005, pp 119-121). The four levels are coded into three variables as shown in Table 4.

Table 4: Effects coding

Water quality	WQ1	WQ2	WQ3
Level 0 - significantly worse than now	-1	-1	-1
Level 1 – moderately worse than now	1	0	0
Level 2 – slightly worse than now	0	1	0
Level 3 – OK, same as now	0	0	1

Reference: Hensher, Rose and Greene (2005), Applied choice analysis: A primer, page 121, Table 5.9.

Pooling test

Tests were undertaken to determine whether samples from different locations are significantly different to inform the question whether a group of locations can be pooled (e.g. pooling the samples from the Waikato region namely, Rotoroa, Rototuna and Morrinsville). The two tests involved interaction variables and the unobserved error.

Interacting the location variable with the environmental attributes (e.g. hydrilla, charophytes, birds, fish-mussels and price) will reveal if location is significant in accounting for the variance in taste intensities. Interaction variables account for interaction effect where the preference for the level of one attribute is dependent upon the level of a second attribute (Hensher, Rose and Greene (2005), p 116). Rotoroa, as the sample nearest to the affected lake, was used as the baseline location in creating the interaction variables. The interaction variables show that there is no significant difference accounted for by location in terms of the attributes hydrilla, water quality, charophytes, birds and fish-mussels. The interaction with the price attribute shows the Wellington interaction as significantly different from the Rotoroa, Hamilton and Morrinsville.

A complementary test for pooling is testing whether the unobserved error accounts for significant differences (Rose, 2009 pers. comm.). This test determines whether there is an error variance linked to choosing the status quo against the alternatives. Using this test for the Waikato region samples showed a significant error term at 99% confidence level. This means that the different locations are different due to the unobserved error.

Models

In choice experiments, we observe the choices made by individuals, the attributes of the alternatives they choose and the characteristics of the individuals. Assuming

[2] An analogy will be air travel where the difference between first class and business class is not the same as the difference between business class and economy.

utility maximising individuals, choice models represent the true but partially observed decision rule adopted with a probability of selecting that alternative which maximises relative utility.

The simple Multinomial Logit (MNL) model was used to initially analyse the responses from each sample. The standard MNL model assumes that respondents have similar preferences (i.e. unexplained error terms are Independent and Identically Distributed (IID)). The standard MNL model resulted in all attributes except for water quality[3] being significant at the 99% level for the four locations.

To increase explanatory power, the panel version of the Random Parameters Logit (RPL) model (also known as Mixed Logit model) was utilised. The RPL model relaxes the most restrictive assumptions of the MNL model (i.e. respondents have similar preferences) by allowing for heterogeneity of individual utility for the attributes. In addition, correlation among attributes and variance in choosing among alternatives (alternative1 and alternative2 vs. status quo) have also been investigated in RPL modelling. The latter introduces a normally distributed random error term associated with alternatives. Intelligent Halton draws were used to derive the estimates as this process only required one-tenth the number draws compared with simple pseudo-random draws (Bhat, 2001 cited by Hensher, Rose and Greene, 2005, pp 614 - 616). A total of 150 draws were used in the estimation.

The RPL model with normal distribution for the environmental attributes and random parameters for the alternatives (two alternatives and the status quo) yielded the best model fit with adjusted McFadden's R^2 for Rotoroa (0.468), Hamilton (0.390), Morrinsville (0.389) and Wellington (model further included correlation among attributes: 0.439). However, this model did not perform well for willingness to pay specifically the range for the 95% confidence interval as it resulted in some attributes with lower limits that are illogical (i.e. negative WTP).

To address the WTP issue, the heterogeneity of individual utility has been constrained to be negative for environmental attributes. Parameters that exceed zero (i.e. long tails in the distribution) are assumed to be zero utility. This is addressed by constraining the standard deviation to be a function of the mean (Hensher, Rose and Greene, 2005). The triangular distribution constrained to value of 1 (which forces the mean to equal to the spread of the distribution) was specified for the environmental attributes. This resulted in a slight deterioration but still a good level of model fit with adjusted McFadden's R^2 for all four locations ranging from 0.356 (Morrinsville) to 0.464 (Rotoroa). All attributes are significant for the four locations except for Statquo in the Waikato region locations. The additional specification of random parameters for the alternatives showed that the error term is not significant for Rotoroa and Hamilton.

The results of the four models are summarised in Table 5 and 6 (Rotoroa, Hamilton, Morrinsville and Wellington models). Both tables present the coefficient mean and standard deviation estimates and p-values of the parameters. The bottom part of the

[3] WQ (water quality attribute) is considered significant if any one of the three WQ variables has a significant p value.

tables shows several tests of model fit. McFadden's pseudo-R^2 cannot be interpreted in the same way as the R^2 in a linear regression model. Pseudo-R^2 values between 0.3 and 0.4 represent acceptable model fit in a discrete choice model as these are translated as an R^2 of between 0.6 and 0.8 for the linear model equivalent (Hensher, Rose & Greene, 2005, pp 338-339). The model has better fit the higher the LL (log likelihood; i.e. less negative number or closer to zero). The AIC (Akaike information criterion) and BIC (Bayesian information criterion) are also tests of model fit that trade off improvements in LL with increasing number of parameters (i.e. a higher LL or a lower number of parameters leads to better AIC and BIC). The smaller the AIC and BIC, the better the model fit.

Table 5a: Rotoroa model coefficients and p-values

	MNL		RPL1		RPL2	
Variable	**Estimates**	**p-values**	**Estimates**	**p-values**	**Estimates**	**p-values**
HYD μ	2.2082***	.0000	3.4253***	.0000	3.4306***	.0000
WQ1 μ	-.1199	.5728	-.2294	.3359	-.2198	.3149
WQ2 μ	.3945*	.0663	.4659*	.0704	.4660*	.0745
WQ3 μ	.3546*	.0919	.5897**	.0145	.5852***	.0084
CHA μ	1.8003***	.0000	2.7479***	.0000	2.7613***	.0000
BIR μ	1.4810***	.0000	2.1998***	.0000	2.1956***	.0000
FISHMUS μ	1.1657***	.0000	1.9046***	.0000	1.9064***	.0000
σ_η	-	-	-	-	.6797	.9264
STATQUO	-1.7094**	.0375	-1.0248	.2179	-2.1245	.7538
PRICE	-.0084***	.0000	-.0136***	.0000	-.0101***	.0000
LL	-328.547		-311.010		-310.961	
Pseudo-R^2			.464		.464	
AIC (Akaike information criterion)	1.279		1.212		1.216	
BIC (Bayesian information criterion)	1.351		1.285		1.297	

*** Significant at 99% confidence level, ** Significant at 95% confidence level, * Significant at 90% confidence level

Note: Standard deviation is the same as the mean.

Table 5b: Hamilton model coefficients and p-values

	MNL		RPL1		RPL2	
Variable	**Estimates**	**p-values**	**Estimates**	**p-values**	**Estimates**	**p-values**
HYD μ	1.3898***	.0000	2.1486***	.0000	2.0933***	.0000
WQ1 μ	.4250**	.0274	.4824*	.0712	.6042***	.0065
WQ2 μ	.4209**	.0369	.5441**	.0382	.6147**	.0115
WQ3 μ	-.0935	.6231	-.0222**	.9343	-.1356	.5003
CHA μ	1.3857***	.0000	2.0340***	.0000	1.8907***	.0008
BIR μ	.9064***	.0000	1.2856***	.0000	1.2185***	.0000
FISHMUS μ	1.1795***	.0000	1.6978***	.0000	1.6521***	.0000
σ_η	-	-	-	-	3.0854	.1184
STATQUO	-1.0823**	.0469	-.4893	.3571	-3.2378	.2519
PRICE	-.0078***	.0000	-.0115***	.0000	-.0112***	.0000
LL	-342.849		-333.007		-330.213	
Pseudo-R^2			.369		.374	
AIC (Akaike information criterion)	1.466		1.425		1.412	
BIC (Bayesian information criterion)	1.544		1.503		1.505	

*** Significant at 99% confidence level, ** Significant at 95% confidence level, * Significant at 90% confidence level

Note: Standard deviation is the same as the mean.

Table 5c: Morrinsville model coefficients and p-values

	MNL		RPL1		RPL2	
Variable	**Estimates**	**p-values**	**Estimates**	**p-values**	**Estimates**	**p-values**
HYD μ	1.5211***	.0000	2.4480***	.0000	2.1631***	.0000
WQ1 μ	.0373	.7977	-.3652**	.0315	-.1778	.2326
WQ2 μ	.1909	.1949	-.0053	.9741	.0708	.6884
WQ3 μ	-.0722	.6193	.5377***	.0008	.3272**	.0300
CHA μ	.8252***	.0000	1.4771***	.0000	1.1502***	.0016
BIR μ	.8608***	.0000	1.3834***	.0000	1.2037***	.0000
FISHMUS μ	.7745***	.0000	1.2037***	.0000	1.0296***	.0000
σ_η	-	-	-	-	3.2231***	.0000
STATQUO	-1.1508***	.0037	-.6220	.1223	-3.7056***	.0071
PRICE	-.0063***	.0000	-.0100***	.0000	-.0087***	.0000
LL	-576.387		-552.016		-542.192	
Pseudo-R^2			.356		.367	
AIC (Akaike information criterion)	1.501		1.439		1.416	
BIC (Bayesian information criterion)	1.555		1.492		1.476	

*** Significant at 99% confidence level, ** Significant at 95% confidence level, * Significant at 90% confidence level

Note: Standard deviation is the same as the mean.

Table 6: Wellington model coefficients and p-values

	MNL		RPL1		RPL2	
Variable	**Estimates**	**p-values**	**Estimates**	**p-values**	**Estimates**	**p-values**
HYD μ	1.5534***	.0000	1.9835***	.0000	2.0265***	.0000
WQ1 μ	.2377	.1394	.3775	.1049	.4301***	.0027
WQ2 μ	.4242**	.0108	.6777***	.0036	.7119***	.0000
WQ3 μ	.0303	.8487	-.0924	.6946	-.1379	.3684
CHA μ	1.3512***	.0000	1.6643***	.0000	1.6170***	.0001
BIR μ	1.3190***	.0000	1.6551***	.0000	1.6531***	.0000
FISHMUS μ	1.0511***	.0000	1.3147***	.0000	1.3350***	.0000
σ_η	-	-	-	-	2.5003***	.0000
STATQUO	-1.3340***	.0035	-.9760**	.0287	-2.8340**	.0337
PRICE	-.0107***	.0000	-.0129***	.0000	-.0130***	.0000

	MNL	RPL1	RPL2
LL	-525.588	-514.412	-509.801
Pseudo-R^2		.390	.396
AIC (Akaike information criterion)	1.392	1.363	1.354
BIC (Bayesian information criterion)	1.447	1.417	1.414

*** Significant at 99% confidence level, ** Significant at 95% confidence level, * Significant at 90% confidence level

Note: Standard deviation is the same as the mean.

Willingness to pay and marginal rate of substitution

The willingness to pay (WTP) is generated from the parameter estimates of the environmental and price attributes. As this results in a WTP per unit change, the result has been normalised to represent total success in removing hyrdilla (x 100), preserving charophytes cover (x 21), preserving 4 shags (x 4) and preserving 3 fish/mussel species (x 3).

The 95% confidence interval for the WTP is also generated. The WTP confidence intervals for the MNL models in the four samples have been calculated using the delta method (Greene, 2000). The delta method creates a linear approximation of the variance for functions of maximum likelihood estimates (Xu and Long, 2005).

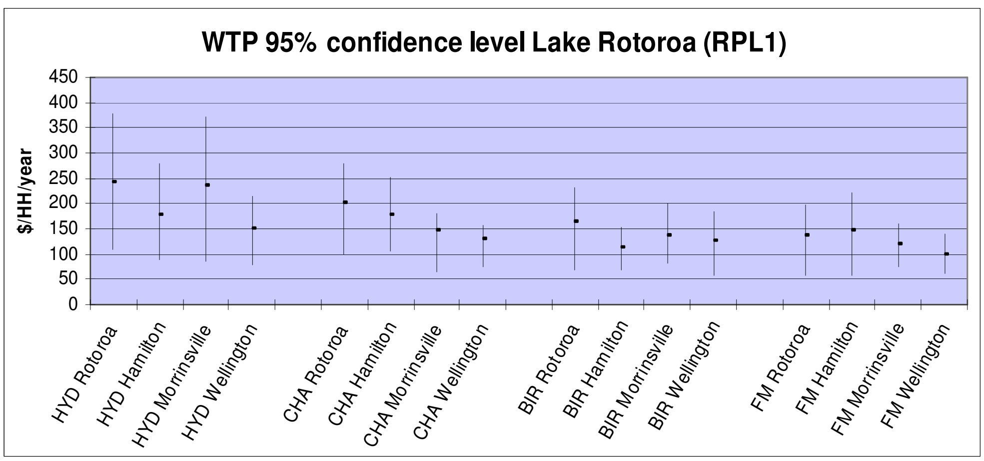
The confidence intervals for the RPL models were generated using parameter estimates for each of the 44, 40, 65 and 64 choices analysed (i.e. conditional parameter means) for the Rotoroa, Hamilton, Morrinsville, and Wellington samples, respectively. The parameter estimates for each choice is not a specific individual estimate but a distribution resulting from 150 intelligent Halton draws. The mean and 95% confidence intervals were generated from this range of part worth estimates.

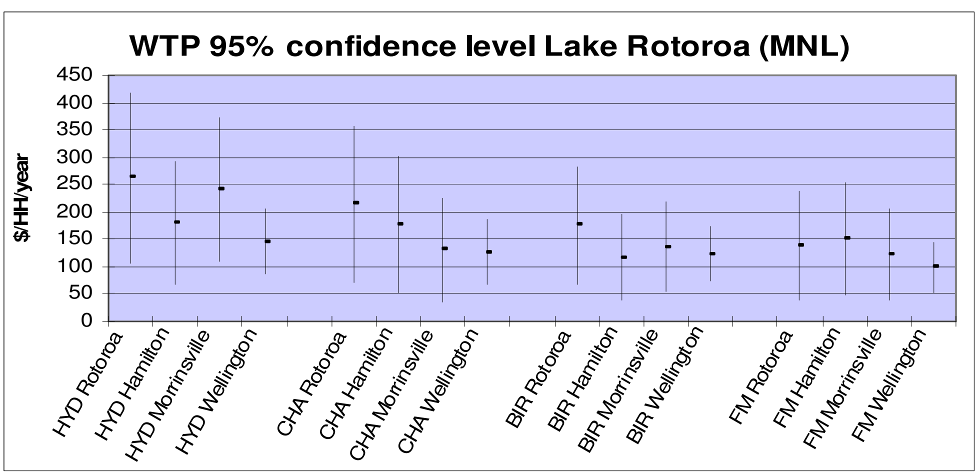
Except for water quality, the WTP and 95% confidence interval generated from both the MNL and RPL models are significantly different from zero and the lower limits are above zero. RPL1 has the advantage of better model fit and generally tighter confidence interval. The WTPs and confidence interval for the four locations are shown in Table 7 and Figure 2.

Table 7: Willingness to pay and 95% confidence interval ($ per HH/ year)

	MNL				RPL1			
Attribute	Rotoroa	Hamilton	Morrinsville	Wellington	Rotoroa	Hamilton	Morrinsville	Wellington
HYD	$262.46	$178.70	$240.56	$145.71	$243.71	$178.61	$233.81	$151.05
	(107,418)	(66,291)	(108,373)	(86,206)	(110,378)	(89,280)	(86,372)	(77,215)
WQ1	-$14.25	$54.65	$5.90	$22.30	-$16.91	$42.67	-$35.95	$29.38
	(-64,35)	(-2,111)	(-39,51)	(-8,53)	(-20,-15)	(33,52)	(-51,-29)	(24,35)
WQ2	$46.89	$54.12	$30.18	$39.79	$33.92	$47.06	-$0.51	$51.83
	(-10,104)	(-5,114)	(-18,79)	(6,74)	(26,40)	(37,60)	(-1,0)	(36,73)
WQ3	$42.15	-$12.03	$11.42	$2.84	$43.04	-$1.91	$52.79	-$7.13
	(-12,97)	(-60,36)	(-35,57)	(-26,32)	(26,56)	(-2,-2)	(35,73)	(-8,-6)
CHA	$213.98	$178.17	$130.51	$126.74	$200.34	$176.40	$145.53	$128.52
	(70,358)	(53,303)	(37,224)	(67,187)	(100,280)	(106,252)	(64,182)	(75,158)
BIR	$176.02	$116.54	$136.13	$123.72	$164.33	$111.64	$137.91	$126.87
	(68,284)	(38,195)	(53,219)	(73,175)	(69,232)	(68,154)	(81,200)	(58,183)
FISHMUS	$138.55	$151.65	$122.49	$98.60	$135.28	$145.54	$120.16	$99.24
	(40,237)	(49,254)	(39,206)	(51,146)	(58,197)	(59,223)	(76,160)	(63,141)

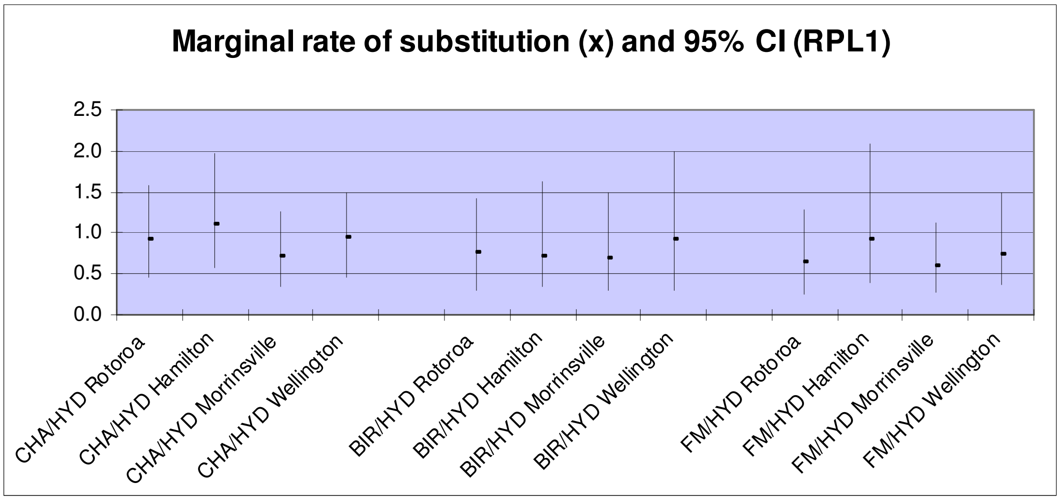
Figure 2: Willingness to pay confidence interval – by location





Apart from WTP, where relating the environmental attribute to the money attribute produces a dollar estimate, the marginal rate of substitution (MRS) shows the relative value of one attribute to a reference attribute. The avoidance of hydrilla, which is generally the highest valued attribute, is used as the reference. The mean MRS for Rotoroa, Hamilton, Morrinsville and Wellington and the 95% confidence interval are shown in Figure 3. While the chart shows that the mean MRS is generally below 1x, the upper limit of the confidence interval generally exceeds 1x.

Figure 3: Marginal rate of substitution and confidence interval – by location



The confidence intervals for WTP and MRS by sample and by attribute show some overlaps. To assess the statistical significance of differences in WTP and MRS, the equality of the estimates is tested using the asymptotically normal test statistic (Campbell, Hutchinson and Scarpa, 2008):

$$ANTS = \frac{WTP_k^{L1} - WTP_k^{L2}}{\sqrt{Var(WTP_k^{L1}) - Var(WTP_k^{L2})}} \qquad (4)$$

where k is the attribute of interest, L1 and L2 are the two locations to be compared and WTP is the WTP or MRS mean.

The results of these tests are shown in Table 8.

In terms of WTP for the attributes, each pair of locations is not statistically different at the 95% confidence interval (see Table 8a). By attribute, the WTP are also not statistically different across the four locations. This implies that the WTP for any particular attribute is similar across locations (e.g. near or distant from the lake).

Table 8a: ANTS Tests for equality of WTP

	Rotoroa vs. Hamilton	Rotoroa vs. M'sville	Hamilton vs. M'sville	Rotoroa vs. W'ngton	Hamilton vs. W'ngton	M'sville vs. W'ngton
HYD	1.10	0.60	0.55	1.26	0.64	1.16
CHA	0.85	1.48	1.29	1.86	1.83	1.59
BIR	1.56	0.96	0.72	1.53	0.40	-0.26
FISHMUS	0.20	0.51	0.85	1.23	1.56	-0.76

Note: ANTS of less than 1.96 is not statistically different.

Comparing each pair of locations, the MRS for the attributes are not statistically different at the 95% confidence level (Table 8b). Similarly, by attribute the MRS are also not statistically different. This implies that the relationships between attributes are stable across locations and between attributes within a location.

Table 8b: ANTS Tests for equality of MRS

	Rotoroa vs. Hamilton	Rotoroa vs. M'sville	Hamilton vs. M'sville	Rotoroa vs. W'ngton	Hamilton vs. W'ngton	M'sville vs. W'ngton
CHA/HYD	0.31	0.81	1.33	-0.06	0.76	0.54
BIR/HYD	0.45	0.77	-0.07	0.31	0.43	0.49
FM/HYD	0.53	0.26	-0.69	-0.87	-0.36	0.37

Note: ANTS of less than 1.96 is not statistically different.

Aggregate value

The aggregation of the mean WTP for the environmental attributes results in the Compensating Surplus (CS) illustrated in the equation below:

$$CS = 1/\beta_{PRICE} (\beta_{HYD} * \Delta HYD + \beta_{CHAR} * \Delta CHAR + \beta_{BIR} * \Delta BIR + \beta_{FISHMUS} * \Delta FISHMUS) \quad (5)$$

where conditional parameter means ($\beta_{attribute}$) is a summation for each sample and Δ represent total success in removing hydrilla (HYD), and preserving current levels of charophytes cover (CHA) and species of birds (BIR) and fish/mussels (FISHMUS).

The aggregation uses the 2006 census household population of Rotoroa (area near the lake), Hamilton (city population excluding Rotoroa), Waikato (regional population excluding Hamilton), and New Zealand (New Zealand excluding Waikato). The Net Present Value for 5 years for Compensating Surplus is calculated at $348 million for the Waikato region and $3 billion for New Zealand (aggregating relevant columns in Table 9a). These values have been estimated using a discount rate of 8%.

Table 9a: Annual and net present value of WTP

Annual value (NZ$m)	**Rotoroa**	**Hamilton**	**Waikato**	**New Zealand**
RPL1				
HYD	0.4	7.9	21.7	198.8
CHA	0.3	7.8	13.5	169.1
BIR	0.2	4.9	12.8	166.9
FISHMUS	0.2	6.4	11.1	130.6
Compensating surplus	1.1	27.1	59.0	665.4
Present value for 5 years				
CS @ 8% discount rate	4.4	108.2	235.7	2,656.8
CS @ 6% discount rate	4.6	114.1	248.7	2,803.0

Notes:
1. Hamilton is Hamilton households less Rotoroa households (i.e. rest of Hamilton)
2. Waikato is Waikato households less Hamilton households (i.e. rest of Waikato)
3. New Zealand is New Zealand households less Waikato households (i.e. rest of New Zealand)

These estimates of CS are based on estimates of community WTP to have a hydrilla-free lake with current levels of charophytes, birds, fish and mussels. CS is a conservative estimate of the value of the lake's natural environment as encapsulated by the four attributes because there is a portion of utility that is unexplained, although in this case the high level of explained utility gives confidence in the results.

Aggregation bias is caused by three main factors (Morrison, 2000): response rate, similarity of preferences of respondents and non-respondents, and correlation between preferences and socio-demographic characteristics (SDCs). As non-response is not applicable to our survey method, we investigated the correlation between preferences and SDCs, specifically income (i.e. high income and low income) and membership in conservation groups. Interaction variables of each SDC with the various attributes showed no significant effect on preferences except for income and price attribute in Wellington and membership in conservation group and price in Wellington, Morrinsville and Hamilton.

Despite the lack of significant effect, Table 9b and 9c show adjustments for income and membership in conservation group. Methods for adjusting the mean values include adjusting the sample mean, using weighted regression analysis, and the weighted average approach (Morrison, 2000).

Table 9b shows the mean household income between the sample and the population in each location. As the mean household income is higher in the sample, mean WTPs were adjusted by factors ranging from 0.72 to 0.85. The impact is a 28% reduction in the NPV for New Zealand.

Table 9b: Annual and net present value of WTP (adjusted for income)

Annual value - Adjusted for household income

(NZ$m)	Rotoroa	Hamilton	Waikato	New Zealand
RPL1				
HYD	0.3	5.9	15.5	142.3
CHA	0.3	5.8	9.7	121.1
BIR	0.2	3.7	9.1	119.5
FISHMUS	0.2	4.8	8.0	93.5
Compensating surplus	0.9	20.1	42.3	476.3
Present value for 5 years				
CS @ 8% discount rate	3.7	80.1	168.8	1,901.8
CS @ 6% discount rate	3.9	84.5	178.1	2,006.4

Notes:
1. Hamilton is Hamilton households less Rotoroa households (i.e. rest of Hamilton)
2. Waikato is Waikato households less Hamilton households (i.e. rest of Waikato)
3. New Zealand is New Zealand households less Waikato households (i.e. rest of New Zealand)

Mean household income

(NZ$)	Rotoroa	Hamilton	Morrinsville	Wellington
Sample	$ 73,068	$ 77,250	$ 77,154	$ 79,141
Population	$ 61,767	$ 57,184	$ 55,248	$ 56,651
Adjustment	0.85	0.74	0.72	0.72

Note: Population mean based on Statistics New Zealand 2006 census household income for Hamilton, Waikato and New Zealand.

Table 9c illustrates the adjustment for membership in a conservation group. The samples' ratio of membership in conservation groups is compared with the ratio reported by the Department of Conservation in its national survey (DOC, 2008). As the ratio of membership is generally higher in the sample, mean WTPs were adjusted by factors ranging from 0.39 to 1.13. The impact is a 41% reduction in the NPV for New Zealand.

Table 9c: Annual and net present value of WTP (adjusted for membership in conservation group)

Annual value - Adjusted for conservation group membership

(NZ$m)	Rotoroa	Hamilton	Waikato	New Zealand
RPL1				
HYD	0.1	8.9	13.9	111.8
CHA	0.1	8.8	8.7	95.1
BIR	0.1	5.6	8.2	93.9
FISHMUS	0.1	7.2	7.2	73.5
Compensating surplus	0.4	30.5	37.9	374.3
Present value for 5 years				
CS @ 8% discount rate	1.7	121.7	151.5	1,494.4
CS @ 6% discount rate	1.8	128.4	159.9	1,576.7

Notes:
1. Hamilton is Hamilton households less Rotoroa households (i.e. rest of Hamilton)
2. Waikato is Waikato households less Hamilton households (i.e. rest of Waikato)
3. New Zealand is New Zealand households less Waikato households (i.e. rest of New Zealand)

Membership in conservation group

	Rotoroa	Hamilton	Morrinsville	Wellington	New Zealand
Sample	23%	8%	14%	16%	
Population					9%
Adjustment	0.39	1.13	0.64	0.56	

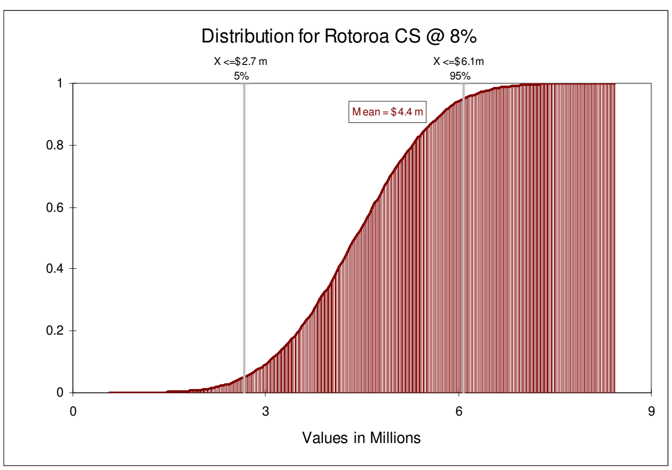
Note: Population based on Depatment of Conservation survey of people involved in conservation outside the home (DOC Annual Report 2008)

The uncertainty in the mean WTP estimates can be incorporated in the NPV analysis using the risk simulation technique QuRA™[4]. Combining estimates to determine the overall uncertainty need to account for the relationships between the uncertain estimates (i.e. correlation). The environmental attributes exhibit a moderate degree of positive correlation with correlation coefficients ranging from 0.6 to 0.7. Using @RISK, the Excel add-in, the probability distribution of the NPV has been estimated by incorporating the means, standard deviations and correlation coefficients between the uncertain WTP variables in the cashflow and simulated over 5,000 iterations. The expected NPV results for the four locations are shown in Table 9d. A sample NPV distribution is also shown for Rotoroa with an expected NPV of $4.4 million (8% discount rate) and a 90% chance that the NPV is between $2.7 million and $6.1 million.

Table 9d: Expected net present value of WTP (with risk simulation)

Compensating surplus - Expected NPV 5 years

(NZ$m)	Rotoroa	Hamilton	Waikato	New Zealand
CS @ 8% discount rate	4.4	108.1	236.1	2,659.2
CS @ 6% discount rate	4.6	114.2	248.3	2,804.1



[4] Nimmo-Bell has developed a standard approach to risk simulation called QuRA™ (Quantitative Risk Analysis), which utilises the Excel add-in @RISK to generate distributions of key risky variables and incorporate these into a distribution of the NPV of the project.

Discussion and conclusion

Our aim was to elicit quantitative estimates of key environmental values of a freshwater system that could be used for benefit transfer primarily under a situation of extreme time pressure such as in the early days of a pest response. The survey design, which was subsequently evaluated using Ngene (ChoiceMetrics, 2009), required a minimum sample size that was less than 10% of the actual sample size per location. This gave us confidence that the experimental design was suitable even for the relatively small sample size used.

The preferred RPL1 model (environmental attributes truncated triangular distributions and price fixed) had an excellent model fit for all locations equivalent to a linear R^2 of 70-80% and all attributes, except water quality, statistically significant at the 99% level of confidence. Water quality proved somewhat troublesome with lower levels of statistical significance due to the different interpretations people could place on the levels provided (significantly worse, moderately worse and slightly worse and no change).

Overall people were willing to pay more to avoid hydrilla infestation than to protect individual existing attributes of the environment. This is in line with the expected large negative impact of the weed and the likelihood that once in the lake there would be a high probability of it spreading to other waterways. Of the existing environmental attributes charophytes, which are of international significance and at high risk from hydrilla, rated highest followed by birds and fish and freshwater mussels.

There was a generally high degree of consistency in the ranking of WTP for different attributes within each location. While there appears to be a decline in WTP from close to the lake to more distant locations, tests for the confidence interval at 95% confidence level show that there is no statistical difference among locations for the environmental attributes. This may be explained by heterogeneity of preferences within each sample causing overlapping WTP confidence intervals.

Pooling tests to indicate significant difference between the different locations were inconclusive. The first test which tested whether there was a preference for the level of one attribute (environmental) being dependent on another variable (location) showed there was no significant difference for the Waikato region sub-samples, but Wellington was significantly different. The second test looked at the error variance between alternatives and found that there was a significant difference at the 99% level and it was due to the unobserved error.

Morrison (2000, p216) notes that distance-decay effect may not exist in all cases and may be more relevant for use values rather than non-use values and it may be that many factors apart from distance may affect WTP, such as environmental preferences in general. In another study investigating distance effects on environmental values, there is no strong decreasing utility with distance and that the distance effect is variable depending on the type of attribute (Concu, 2007). As this study focused on biodiversity, the lack of distance-decay effect is consistent with existence value behaviour where the location of species to be preserved, whether near or far, is not strongly relevant. On the other hand, the value on the eradication of hydrilla is due to the threat that it can easily spread across distances.

Aggregating the mean WTP for the environmental attributes to the 2006 census household population resulted in a Net Present Value for 5 years for Compensating Surplus (CS) for all environmental attributes of $348 million for the Waikato region and $3 billion for New Zealand using a discount rate of 8%. Analysis of aggregation bias using interaction variables of income and membership in conservation group SDCs with the various attributes showed no significant effect on preferences.

Despite the lack of a statistical distance-decay effect, on-going work on aggregation issues may suggest a lower value for compensating surplus possibly due to such factors as non-attendance (where respondents may ignore a particular attribute such as cost in stating their preferences). Thus, aggregation based on mean WTPs needs to be treated with caution. There is also the issue of mental account, which is the point that people would not be willing to pay for every lake in New Zealand at the same amount as one lake. This casts doubts on the sense of aggregating values beyond the local or district level (Marsh, pers. comm., 2009). On the other hand biosecurity issues represent a special case. It may be that respondents outside the region are thinking that stopping the spread of a pest at the local level means that it will not spread to their region. This may explain their willingness to pay amounts similar to those at the local level. Decision makers need to apply judgement and common sense to such estimates and depending on the situation restrict aggregation of values to the appropriate level, be that local, district, region or national.

Including the impact of adjustments for aggregation bias for income and membership in conservation group resulted in a reduction of 28% and 41% in NPV respectively. Incorporating uncertainty in the mean WTP estimates resulted in a 90% probability that the NPV for Rotoroa (local level) would be between $2.7m and $6.1m. Similar levels of uncertainty exist for the other results. The additional information that incorporating uncertainty into the analysis provides is that decision makers become aware of the uncertainty embodied in estimates and they can relate the extent of that uncertainty to the mean values.

The choice experiment to estimate environmental values for a freshwater lake has provided statistically significant WTP values that could be used in a CBA. By sampling communities at varying distances from the lake we have been able to show that WTP declines the further one is away from the environmental asset in question, however, this is not statistically significant at the 5% level. This is in line with intuition and gives credence to the aggregated values.

Choice modelling, benefit transfer and risk simulation provide a way of incorporating biodiversity values into CBA that is quick and relatively simple. Concerns about bias particularly in aggregating WTP values can be reduced by making adjustments to transferred values and by decision makers applying judgement and common sense to the level of aggregation that is relevant.

The results are presented as distributions of WTP which gives analysts and decision makers an improved understanding of the uncertainty embodied in the estimates. This uncertainty can be placed alongside the uncertainty inherent in the estimates of physical damage from a pest incursion when constructing and reporting on the costs and benefits of different response options.

By extending quantitative CBA beyond economic impacts to include impacts on environmental values, decision makers are likely to make better decisions on resource allocation.

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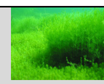
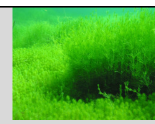
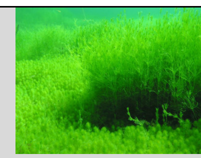
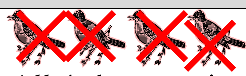
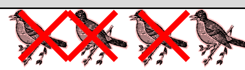
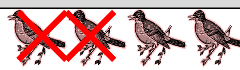
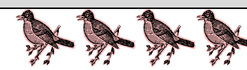
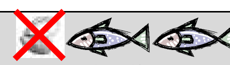
Appendix 1: Experimental design

Choice situation	alt1.price	alt1.hydr	alt1.wqual	alt1.char	alt1.birds	alt1.fish	alt2.price	alt2.hydr	alt2.wqual	alt2.char	alt2.birds	alt2.fish
5	40	0	2	1	3	3	20	3	1	3	0	0
13	20	3	0	0	1	1	40	1	3	0	1	2
15	160	1	3	0	1	1	160	0	1	1	0	0
23	10	1	0	1	3	1	80	3	3	2	0	0
28	0	0	2	1	0	2	160	1	1	1	3	2
37	0	3	2	0	3	1	160	1	1	3	1	3
39	80	2	3	2	2	0	0	1	0	1	2	2
43	40	2	3	0	1	1	20	0	0	0	2	3
44	40	1	2	2	3	0	10	3	1	2	0	3
46	20	2	3	2	1	0	40	0	0	3	2	3
59	80	1	1	2	2	0	10	2	2	0	1	3
60	0	2	3	1	0	0	160	2	0	1	3	2
2	80	0	1	3	2	2	10	3	1	1	1	2
6	80	3	1	0	1	2	10	0	2	3	2	1
7	40	0	2	3	0	3	10	3	1	2	3	0
8	20	3	0	1	1	0	40	1	3	0	2	2
10	40	3	1	1	1	3	20	0	2	3	1	0
14	10	1	0	0	0	3	80	2	3	0	3	1
19	0	0	0	0	2	1	160	1	3	1	2	1
21	80	1	0	3	3	2	10	1	3	2	0	2
27	160	3	3	2	2	2	0	1	0	2	1	2
35	40	0	2	3	3	0	20	3	1	0	0	3
52	40	1	1	3	0	3	20	3	2	3	3	0
58	160	2	1	1	2	3	0	1	2	1	1	0
1	0	1	2	3	0	3	80	2	1	3	3	1
4	160	3	1	3	2	1	0	0	2	2	1	2
17	20	3	1	3	1	0	40	0	2	1	2	3
20	160	3	2	1	0	3	0	2	1	1	2	0
22	80	1	3	2	2	3	10	3	0	3	1	0
24	0	0	3	2	0	2	80	1	0	3	3	0
26	160	2	0	1	1	2	0	0	3	0	1	1
30	0	2	0	2	1	1	160	3	2	0	3	3
36	160	1	1	2	3	3	0	2	2	2	0	0
41	80	2	3	3	0	2	10	0	0	3	3	1
42	40	0	1	3	0	0	20	2	2	0	3	3
54	20	1	0	1	2	2	20	1	3	0	2	2
11	10	0	2	2	1	3	80	2	2	2	2	0
16	80	3	2	0	3	1	20	0	1	3	0	3
18	20	0	1	3	3	0	40	2	2	0	0	3
25	20	0	3	2	2	2	40	3	0	2	0	1
31	20	0	2	1	3	1	40	3	0	2	0	2
33	10	2	0	1	0	3	80	1	3	1	3	0
45	0	2	0	0	1	2	160	3	3	0	3	1
47	80	1	3	2	3	1	10	2	0	3	0	1
48	10	2	0	1	2	1	80	2	3	1	2	1
50	10	3	0	2	1	1	80	2	3	3	2	1
53	0	1	0	0	3	1	160	1	3	2	0	2
56	40	2	0	2	2	3	20	2	3	2	1	0
3	20	1	2	0	3	1	80	1	1	1	0	1
9	160	2	3	2	2	2	0	3	0	1	1	1
12	10	0	3	0	2	2	80	2	0	0	1	3
29	10	3	1	0	1	0	160	0	3	1	2	3
32	160	2	1	3	3	2	0	0	2	3	1	2
34	40	3	1	0	0	0	20	0	2	0	3	2
38	10	0	2	3	2	0	40	3	1	0	1	3
40	10	0	1	3	3	3	40	3	2	3	0	0
49	0	3	3	0	0	0	160	2	0	2	2	2
51	160	2	2	1	1	3	0	0	1	1	2	1
55	80	3	2	3	0	0	10	0	1	2	3	3
57	20	1	3	1	0	2	40	1	0	2	3	1

Coding of attribute levels: Master table

	Level 0 (status quo)	**Level 1**	**Level 2**	**Level 3**
Hydrilla	 100% coverage	 65% coverage	 30% coverage	No hydrilla
Water quality and clarity	Significantly worse than now	Moderately worse than now	Slightly worse than now	OK Same as now
Native submerged plants	Eliminated from lake	 Reduced to 7% cover	 Reduced to 14% cover	 Same as now at 21% cover
Native birds	 All 4 shag species do not visit the lake anymore	 3 shag species do not visit the lake anymore	 2 shag species do not visit the lake anymore	 All 4 shag species happy to visit the lake
Mussels and native fish	 Mussels and 2 fish species disappear from the lake	 Mussels and 1 species of fish disappear from the lake	 Mussels disappear from the lake	 Mussels and all fish species remain in the lake

	Level 0 (status quo)	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Cost to your household each year for five years	$0	$10	$20	$40	$80	$160