Choice modelling to estimate indigenous biodiversity values for a coastal marine ecosystem – reallocation or special tax?

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Choice modelling to estimate indigenous biodiversity values for a coastal marine ecosystem – reallocation or special tax? [1]

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Abstract:

Reallocation of government expenditure was used as the payment mechanism in a choice modelling experiment to estimate biodiversity values for several attributes of a coastal marine ecosystem. The European Shore Crab was used as the invasive impacting on shellfish species, marginal vegetation, recreational fishing and kids paddling along the shoreline. The results at the sub-sample level comparing local, regional and distant respondents were disappointing with wide ranges and non-significant means for the Willingness to Pay (WTP) estimates. Pooled results did give significant WTP estimates, but interpretation of these was an issue due to fat tails. Given deficiencies in the reallocation experiment one of the sub-samples was resurveyed using a special tax with much improved and significant results.

The problem

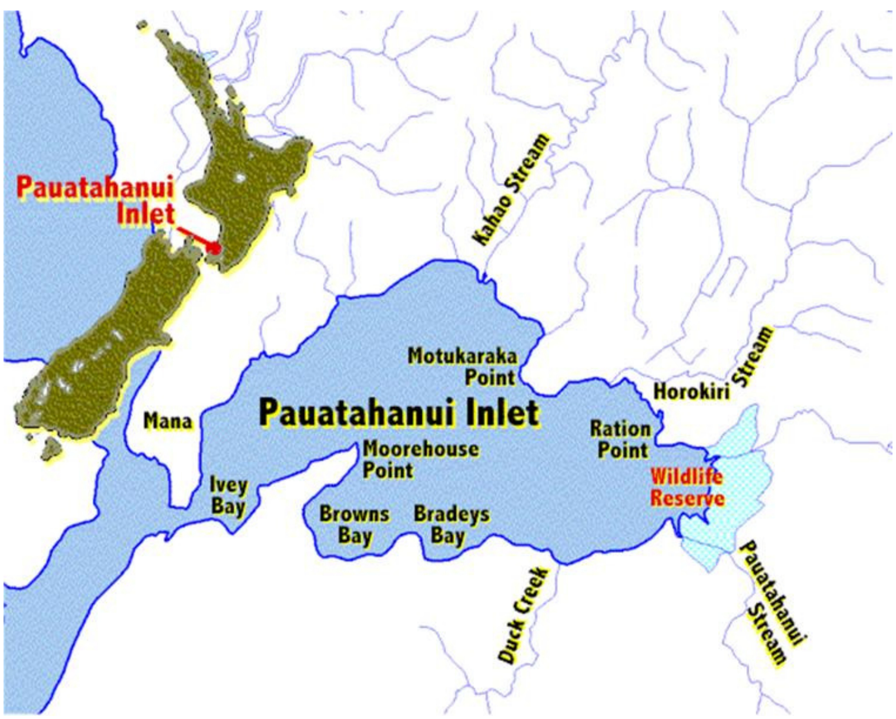
A key consideration when applying the tool of choice modelling is the payment mechanism used to elicit willingness to pay. The traditional theory of marginal utility used for choice modelling is based around individual respondent decisions where the respondents are asked to make choices trading off dollar cost to the household budget for increases in hypothetical environmental attributes. Some researchers have attempted to extend this concept whereby individuals are asked to trade off changes in government expenditure for environmental attributes. In the literature this is called reallocation. The proposition is that

[1] This paper draws on material from the FRST funded coastal marine project using reallocation as the payment mechanism presented at the AARES 52nd Annual Conference, February 2008, Bell, Menzies, Yap and Kerr Bell, B. A., et al. (2008) Assessing the marginal dollar value losses to an estuarine ecosystem from an aggressive alien invasive crab. Canberra ACT, pp. 32. along with the subsequent analysis of one sub-sample based on the special tax (Yap, M., R. Scarpa, and B. A. Bell. "Addendum to: Assessing the marginal dollar value losses of an estuarine ecosystem from an aggressive alien invasive crab." Technical report. Nimmo-Bell & Company Ltd, August 2008.). Thanks to Recardo Scarpa for the econometrics, Michael Yap for assistance on analysis of the data and Sharon Menzies and Charlotte Cudby for assistance on surveying.

respondents are asked to make a choice about a reallocation of government expenditure from an area that has value to them, such as education or health expenditure for expenditure on the environment. The question is whether such trade-offs, which are rather more abstract from the point of view of the individual than impacts on a personal budget results in similar estimates of willingness to pay for environmental attributes.

In a study of environmental and social values of a coastal marine ecosystem reallocation was used as the payment mechanism. Respondents were requested to make choices between different levels of environmental and social values given a reallocation of government expenditure under two scenarios. The first scenario, the status quo, was that there would be no change to the government's expenditure pattern, but this would result in negative impacts on the marine environment. In a hypothetical situation an invasive crab, the European Shore crab, which is high on Biosecurity New Zealand's list of potential invasive species and among the world's 100 worst invasive alien species invades a local estuary.

Figure 1. The Pauatahanui Inlet



Damage likely to occur from this crab includes:

- aggressive predation on shellfish
- destruction of vegetation along the shoreline
- reduction of recreational fishing and
- restrictions on children's ability to paddle along the water edge.

The national cost of a specific control programme for this crab was estimated at $2 million per annum and under this scenario there would be a high likelihood of lesser damage to the environment although there was a high degree of uncertainty around this. The attribute values are presented in Table 1 below.

Table 1. Attribute values

Attributes	Response 1	Response 2
Extra biosecurity cost each year	No change	$2 million
% reduced recreational shellfish take for 3 years	100%	0%
Percentage of vegetation dies	50%	10%
Number of shellfish species that disappear	3	0
Children paddling on water's edge	No	Yes

Reallocation as the payment mechanism

The topic of the payment mechanism was raised with the focus groups. It was a concern that there was no mechanism for individuals to pay directly for the biosecurity response. As a result, the proposition that the response would be paid through a reallocation of government expenditure was raised. The team explained the process that Biosecurity New Zealand would go through to obtain funding. Essentially, this is that a paper with the costs and benefits of the proposed response would be put before Cabinet, which would then weigh up the competing demands and decide on funding.

By way of example, it was suggested that the response could be competing with x hip replacements or y funded places in early childhood education. The reaction to this proposition was very negative to the extent that this was considered as black mail by one participant and not something that could be decided on by the group. Even when it was pointed out that these are the types of decisions that have to be made by politicians the group did not feel it could make such a decision. In other words, the group was not willing to make a specific trade-off in this context. Underlying this appears to be a concern about making decisions that could result in some people being worse off as a result of their decision.

Following on from this experience, it was decided to couch the trade-off in the questionnaire in more general terms – i.e. that each respondent should consider the $2 million per annum cost of response as having to be reallocated from another high priority area of government expenditure such as health or education – without being specific as to a particular programme.

Taking this approach has implications regarding the interpretation of the results as it has been shown that, for example, ground water quality protection WTP is significantly higher under reallocation than a new special tax (Bergstrom, et al., 2004). The authors found that the bundle of other public goods to be traded off for water quality also influenced the relative marginal values of public and private goods. They concluded that specifying one or only a few public goods to be traded off would help respondents to interpret and comprehend the tax reallocation vehicle more precisely. But, it also had risks of introducing bias if respondents objected to or protested to changing the levels of the other public goods selected.

These results were confirmed in a subsequent study (Swallow and McGonagle, 2006) which found that an individual's willingness to pay to reallocate existing tax dollars exceeded willingness to pay new taxes to conserve land. A more resent study (Morrison and Hatton MacDonald, 2007) found that reallocation of an existing tax produced aggregate results of similar magnitude to the imposition of a new tax. The authors suggest reallocation is a legitimate alternative approach when government agencies cannot reasonably impose new taxes.

Based on these three studies the evidence is that as long as the value derived from the reallocation exceeds the cost of the response then society will be better off. This is on the additional condition that the tax reallocation mechanism is the only trade-off available i.e. it is not possible to levy a new tax.

Sub-samples

In order to test the effects of distance on the estimates of willingness to pay samples were drawn from sub populations immediately adjacent to the estuary (Pauatahanui Inlet), within the region (Karori) and at distant points at either end of the country (Dunedin and Auckland). Unfortunately the Auckland sub sample had to be dropped due to a low response rate.

An open meeting survey method was adopted whereby respondents were brought up to a common level of knowledge about the issue through a PowerPoint presentation and this was followed by circulation of the questionnaire, which was filled out before respondents departed the meeting. The survey gathered a total of 190 respondents from Dunedin (76), Karori (47) and Pauatahanui (57). The raw sample produced 1,330 choices and after removing Auckland and underage respondents along with 86 irrational choices there were 178 respondents with 1,244 valid choices.

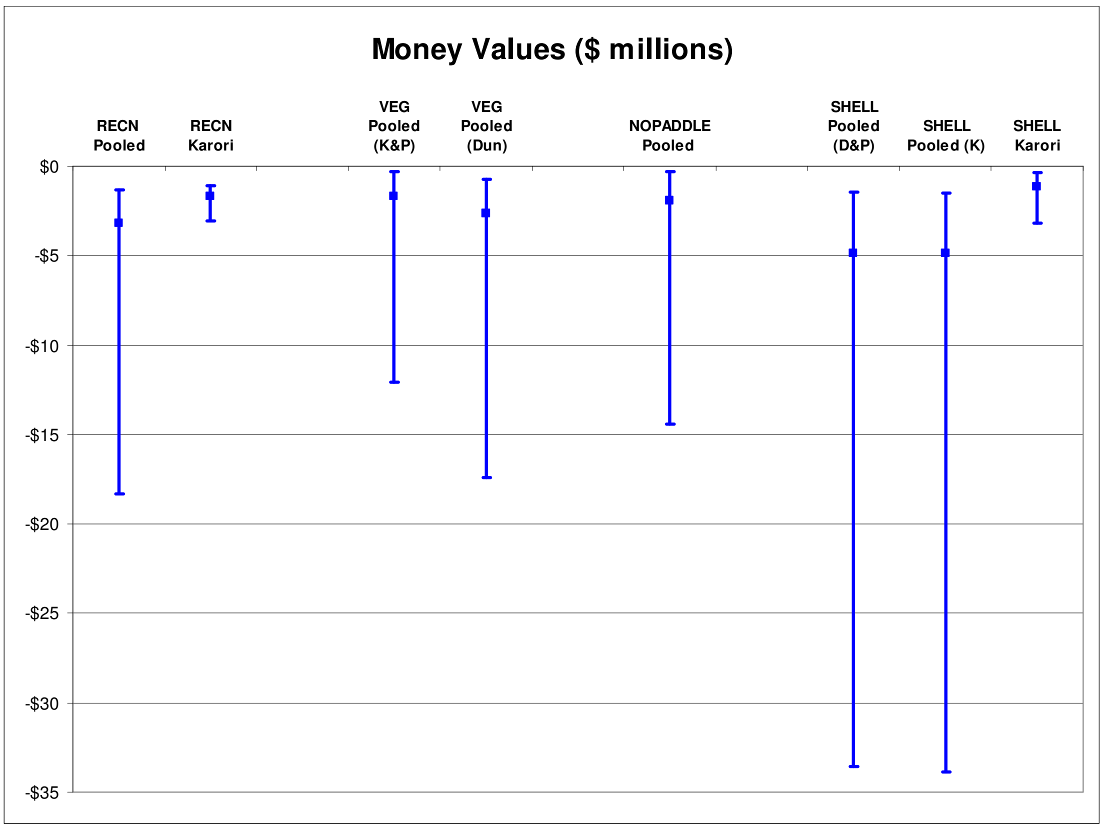
Modelling

Several econometric models were tested including Multinomial Logit (MNL), Latent Class (LC) and Heteroscedastic Extreme Value (HEV). The MNL model fitted the data relatively well, but money was significant only for Karori and to a lesser degree for the pooled data. The LC model which allowed for segmentation of heterogeneous decision makers into clusters did not improve model fit and was discarded. The HEV model was used to test for heterogeneity in variances between choices. For the MNL model pooled money was significant at the 95% level. The estimated willingness to pay for retention of shellfish species was $4.8 million per year, loss of recreational shellfish take over three years back to $3.2 million per year, loss of the possibility of children to paddle $1.9 million per year and loss of shoreline vegetation $1.67 million. Extremely wide confidence intervals around these estimates meant that little weight could be given to the willingness to pay. Analysis of the results indicated that the choice between zero dollars and $2 million per year was not wide enough (i.e. too close to zero) to force the trade-offs necessary to estimate willingness to pay. In other words, people were mostly always willing to pay $2 million per year for any level of environmental improvement above the status quo situation.

Follow-up survey

Given this disappointing result it was decided to resurvey the sub–sample from around the estuary, this time using a special tax on individual households instead of the a reallocation of government expenditure. In order to ensure the results would be consistent with the initial survey the only change made was the money variable which became a special tax with values of zero, $25, $50 and $100 per household per annum for three years instead of zero or $2 million reallocation of government expenditure.

Figure 2. Reallocation: money value estimates and confidence intervals



Model estimate and 95% confidence limits derived from simulating the model for 100,000 iterations.

The follow-up survey gathered a total of 47 respondents from around the Pauatahanui Inlet. As before, Paremata School arranged the venue and respondents with the same incentive of $50 as a donation to the school and a $20 voucher for each participant who satisfactorily completed the questionnaire.

The experimental design used the priors from the initial survey to produce the most efficient design, in this case the MNL estimates of the parameters, which were assumed to be normally distributed with standard deviation equal to the standard errors. The criterion to be minimized was the sum of the variances of the marginal WTP of each attribute (Rose and Scarpa, 2008). This means the results are specific to WTP estimation (C-efficiency) rather than to estimation of parameters (D-efficiency). The money variable, which was not significant, was assumed to have a uniform distribution with a range of -0.04 to 0.01. The optimal design produced by the algorithm comprised 24 choice sets. These were randomly divided into manageable groups of 12 choice sets per respondent. Overall the analysis consisted of 564 choices.

Model specification: special tax

Taking the generic utility functions as set out in Yap *et al op cit* and making them explicit to this problem gives the following.

The utility of policy alternative *j* (*j*=1, 2,..., 24) for respondent *n* (*n*=1,2,…, 47) in choice task *t* (*t*=1, 2,…, 12) is defined as:

$$U_{jnt} = V(\boldsymbol{\beta}_n \mathbf{x}) + \varepsilon_{jnt}$$

$$= \beta_{1n} RECN_{jnt} + \beta_{2n} VEG_{jnt} + \beta_{3n} SHELLS_{jnt} + \beta_{4n} NOPADDLE_{jnt} + \beta_{\$} MONEY_{jnt} + 1(1\text{-}SQ)\eta_n + \varepsilon_{jnt}$$

Where β_{kn} denotes random (across *n* respondents) taste intensities for attribute *k* (*k*=1, 2, 3, 4 – loss of recreational shell fishing, loss of vegetation around the estuary, loss of shell fish species and loss of ability for kids to paddle), η_n is a random normal error component with zero mean entering the utility of the experimentally designed policy scenarios (the non-Status Quo alternatives), and ε_{jnt} is the Gumbel distributed error component.

Given $\boldsymbol{\beta}_n$ and η_n the probability of observing alternative *i* (*i*=0, 1 or 2 - status quo or one of two policy alternatives) 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:

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

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

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

In our case 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 (Halton draws, Train (2003)) to take advantage of their good coverage properties and reduce the number of necessary draws to achieve high precision.

Results of follow-up survey – special tax

Four models were tested and the best fit provided by a model specification with the money attribute fixed (non-random parameter) and the environmental attributes as normal correlated coefficients, on top of a variance expansion error component as suggested in Scarpa, Ferrini and Willis (2005)and Scarpa, Campbell and Hutchinson (2007)[2]. This model (Model 4) also specified random parameters for the alternatives. It resulted in the best adjusted McFadden's R^2 with all environmental attributes and error terms significant (see Table 2).

Willingness To Pay (WTP) estimates are provided by dividing the coefficient of each attribute by the negative of the money variable coefficient. This resulted in a total WTP per Household over the four attributes of $185 per annum, with the greatest value placed on loss of shellfish species at $57. Interestingly, loss of ability for kids to paddle along the water's edge had only a marginally lower value at $54. Loss of recreational fishing had a value of $37 per annum and loss of vegetation around the estuary $36.

[2] The other three models were: 1. standard MNL, 2. normal coefficient and triangular price and 3. normal coefficient, triangular price and with kernel for hypothetical choices.

Table 2. Coefficients and p-values of best fit model

	Model 4	
Variable	**Estimates**	**p-values**
RECN μ	-2.2408***	.0022
RECN σ	3.3333***	.0000
VEG μ	-2.2125***	.0000
VEG σ	4.0735***	.0000
SHELLS μ	-3.4374***	.0002
SHELLS σ	7.9429***	.0000
NOPADDLE μ	-3.2393***	.0000
NOPADDLE σ	5.9363***	.0000
σ_η	1.4805***	.0011
MONEY	-.0603***	.0000
Pseudo-R^2	0.510	
AIC	1.104	
BIC	1.227	

*** Significant at 99% confidence level

When these figures are extrapolated across the whole of the community of 3,372 households[3] around the estuary and over the three years of the loss period then the present value of the total loss (discounted at 10%) is $1.4 million with $435,000 of this due to loss of shellfish species. Note that at a zero discount rate the values are $1.9 million and $577,000 respectively (see Table 4 for discount rates over 0%, 2.5%, 5% and 10%). A range of discount rates is presented as this issue continues to be controversial. Ten per cent is the Treasury discount rate hurdle for new projects while some economists prefer rate close to zero.

The Pauatahanui Inlet was chosen as being representative of the 350 estuaries that occur along New Zealand's coast line. Extrapolating to the national level assuming that the loss is the same for each estuary gives a national combined total of $493 million and $152 million for loss of three shellfish species. AT zero discount rate the value is $654 million and $202 million respectively (see Table 5 for the effect of discount rate). These estimates are approximate as each estuary is unique to a degree. Also, as the number of estuaries impacted approaches the total, the value of damage to the last few estuaries is likely to rise substantially particularly is it means a particular plant or animal is made extinct.

[3] Based on Statistics NZ 2006 Census data

Table 3. Estimates of Willingness To Pay

WTP	$p.a./HH	$'000 p.a. Pauatahanui Community	Present Value over 3 years $m*	Extrapolation to national level PV $m*
Attribute				
SHELLS	57.03	192	0.435	152
NOPADDLE	53.74	181	0.410	143
RECN	37.18	125	0.283	99
VEG	36.71	124	0.280	98
Total	184.66	622	1.408	493

* Discount rate 10%

Table 4. Affect of discount rate – PV over 3 years, Pauatahanui District

Discount rate	0.0%	2.5%	5.0%	10.0%
SHELLS	0.577	0.536	0.499	0.435
NOPADDLE	0.544	0.505	0.470	0.410
RECN	0.376	0.349	0.325	0.283
VEG	0.371	0.345	0.321	0.280
Total	1.868	1.735	1.615	1.408

Table 5. PVs extrapolated to national level

Discount rate	0.0%	2.5%	5.0%	10.0%
SHELLS	202	188	175	152
NOPADDLE	190	177	165	143
RECN	132	122	114	99
VEG	130	121	112	98
Total	654	607	565	493

Marginal Rates of Substitution

Marginal Rates of Substitution (MRS) indicate the relative values of the attributes compared with the most valued attribute. They are derived simply by dividing each attribute coefficient by the coefficient of the attribute with the highest value. As in the initial survey, the loss of three shellfish species (SHELLS) was the environmental attribute with the highest utility for follow-up survey respondents. The value of the three other environmental attributes relative to SHELLS is shown in Table 6. The MRS for the loss of recreational shellfish take (RECN) in the follow-up survey was also the same as the initial survey at 0.65, but the follow-up survey respondents had a higher relative value for the loss of ability for kids to paddle (NOPADDLE) at 0.94 compared with 0.63 in the initial survey and for loss of vegetation (VEG) at 0.64 compared with 0.49. Also the ranking order changed with the follow-up survey respondents rating NOPADDLE well above RECN.

Table 6. Marginal Rate of Substitution for Pauatahanui

Survey sub-sample	Initial		Follow-up	
	MRS	Rank	MRS	Rank
SHELLS/SHELLS	1.00	1	1.00	1
RECN/SHELLS	0.65	2	0.65	3
NOPADDLE/SHELLS	0.63	3	0.94	2
VEG/SHELLS	0.49	4	0.64	4

It may be the differences in the sample socio-demographic characteristics (SDCs) that explain why these MRS values vary between the initial and follow-up surveys. In general the follow-up sample is representative of the relevant population for gender, income and European and Asian ethnicity (refer to Table 7). But the sample is over-represented in terms of higher qualification (polytech and degree), young and mid-age groups, and high-skill occupation group. On the other hand NZ Maori ethnicity is under-represented. This compares with the initial survey which was less well qualified, older, had higher incomes, and had fewer in high skill occupations. There were also more Maori in the initial survey and no Asian or Pacific Island people.

Clearly both samples put loss of shellfish species at the top of their concerns and loss of vegetation at the bottom. Relative to loss of shellfish species respondents in the follow-up survey placed only a slightly lower value on loss of ability of kids to paddle along the water’s edge. Also they placed only a slightly higher value on recreational shell fish take compared with loss of surrounding vegetation. As the major part of the vegetation surrounding the estuary is highly modified this may explain its low ranking.

Table 7. Survey demographics

	Sample		Population Census	Lower Limit	Upper Limit
	Initial	Follow-up			
GENDER					
Male	43.6%	44.7%	49.1%	42.7%	55.5%
Female	56.4%	55.3%	51.0%	44.3%	57.6%
QUALIFICATION					
No Qual	1.8%	0.0%	13.4%	11.7%	15.2%
Fifth	9.1%	2.1%	11.6%	10.0%	13.1%
Sixth	5.5%	8.5%	25.2%	21.9%	28.5%
Polytech	27.3%	31.9%	22.1%	19.2%	25.0%
Degree	56.4%	57.4%	23.1%	20.1%	26.1%
AGE					
Young	7.3%	21.3%	13.9%	12.1%	15.7%
Mid-age	92.7%	78.7%	64.5%	56.0%	72.9%
Old	0.0%	0.0%	21.6%	18.8%	24.5%
INCOME*					
High income	54.5%	36.2%	34.3%	29.5%	39.2%
Low income	45.5%	63.8%	56.0%	48.0%	63.9%
ETHNICITY					
NZ European	86.2%	80.9%	78.7%	68.4%	89.0%
NZ Maori	6.9%	4.3%	10.4%	9.0%	11.8%
NZ Asian	0.0%	4.3%	4.0%	3.4%	4.5%
NZ Pacific	0.0%	8.5%	3.8%	3.3%	4.3%
Others	6.9%	2.1%	3.2%	2.7%	3.6%
OCCUPATION					
High skill	51.8%	59.6%	48.3%	42.0%	54.6%
Low skill	48.2%	40.4%	48.6%	42.2%	54.9%

* Income in follow-up survey is household income where more than $100,000 is high income.

Conclusions

The follow-up survey experiment provides estimates of WTP for impacts of four environmental attributes associated with a typical New Zealand estuary. All had a high degree of statistical significance. Over 3,372 households close to the estuary and over three years (discounted at 10%) the WTP to reduce the impact of an aggressive invasive crab amounted to $1.4 million.

Loss of indigenous biodiversity (3 shellfish species) has the highest value of the four attributes at $435,000. Given the high statistical significance of the dollar estimates confidence can be assumed in applying these values in cost benefit analysis to this area. These estimates are based on individual willingness to pay based on a special tax. A further line of evidence would be to check the confidence intervals for the estimates. A narrow band would indicate higher confidence while a very wide band (fat tails), as with the reallocation estimates, would indicate low reliability. These calculations have yet to be done.

In contrast results of an experiment to assess WTP using reallocation as the payment vehicle were inconclusive due to the respondents' willingness to trade off government expenditure way above the upper limit in the choice experiment. Recall that the choice option was zero or $2 million per year (the figure of $2 million came from MAF BNZ as the cost of achieving the outcome specified in the policy alternative to the status quo of doing nothing). The mean estimate of WTP using reallocation for pooled data was $4 .8 million with the 95% confidence interval of $1.5 million to $34 million. The money variable coefficient for Pauatahanui was not statistically significant meaning that the experiment was fatally flawed. Choice modelling validity relies on the upper limit being the high end of the range of possible choices in the choice questions. This experience adds to the evidence that reallocation as the payment mechanism provides additional challenges compared with a special tax. These challenges include setting the size of the tax and specifying where the reallocation will come from – health education or elsewhere. Note that some of the follow-up survey participants (3 out of 47) refused to participate in the experiment on the basis that they did not agree with a special regional tax being used at all to fund this type of expenditure and that it should be national taxes that should be used.

Extrapolating beyond district's physical area would depend on the degree of similarity of the particular physical environment, but if all New Zealand's estuarine areas were similarly impacted the expected loss would amount to between $490 and $650 million (depending on the discount rate in the range of 10% to zero respectively). It should be noted however that this estimate is likely to be conservative as values of loss would be expected to increase markedly if all estuaries were impacted. The complete loss of a species would have a much higher value than only a local loss. There are also site specific factors with some areas having higher or lower biodiversity values than others.

Comparing the MRS estimates between the initial reallocation sample and follow-up special tax showed a high degree of consistency. In each case loss of shellfish species ranked first and loss of vegetation ranked lowest in both samples. But the ranking of loss of ability for kids to paddle ranked higher in the follow-up survey ahead of loss of recreational fishing, which was the reverse in the initial reallocation survey. This may be explained by the socio demographic characteristics of the follow-up survey being more highly qualified, younger, had lower incomes, and had more people in high skill occupations compared with the initial survey.

The results of the case studies are important as the value estimates derived here, combined with information on the costs of species preservation, whether by managing current pests, responses to incursions or other methods, could form the foundations for cost-benefit analysis of indigenous biodiversity protection programmes. This has not been possible up till now.

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