Report to Biosecurity New Zealand on valuing the coastal marine environment

Assessing the marginal dollar value losses of an estuarine ecosystem from an aggressive alien invasive crab: Follow up survey of Pauatahanui Inlet

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1 Summary

The aim of this study is to assess the dollar value of marginal changes to indigenous biodiversity and other attributes of the coastal marine environment from a potential incursion of an alien crab(Bell, et al., 2008). This information will form part of a database of non-market values for Biosecurity New Zealand to use when preparing cost benefit analyses of future incursions impacting on the coastal marine environment.

This addendum discusses the rationale, methodology and results of the follow-up survey on the Pauatahanui sample. An initial survey design did not obtain statistically significant WTP estimates of biodiversity.

The aim of the follow-up survey is to elicit dollar values from the Pauatahanui sample using a Bayesian efficient experimental design. The follow-up survey was designed using techniques for the derivation of efficient experimental design and was administered to a total of 47 respondents and collected 564 preferred choices of policy scenarios. Apart from the standard MNL model, three other econometric models were used involving random parameters for policy attributes and an error component for experimentally designed alternatives.

The results show that all models showed a high degree of statistical significance with Model 4 having the best fit. In addition, the range at the 95% confidence level is much reduced compared with the reallocation payment vehicle. Pauatahanui as a district values the maintenance of the current status of the estuary at $1.7 million (present value over 3 years of extra rates at 10% discount rate) with a lower bound estimate of $0.9 million.

Loss of indigenous biodiversity (3 shellfish species) has the highest value of the four attributes at $530,000 ± $280,000. Given the high statistical significance of the dollar estimates and their relatively narrow ranges confidence can be assumed in applying these values in cost benefit analysis to this area.

Extrapolating beyond this 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 $600 million with a lower bound of $325 million. 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 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.

2 Rationale for follow-up survey

The original survey aimed at eliciting dollar values for indigenous biodiversity in the coastal marine ecosystem used reallocation of existing government expenditure as the payment vehicle. Results showed exceedingly large estimated WTP values, a high level of difference in the valuation of the estuary attributes and the insignificance of the money attribute in the Dunedin and Pauatahanui sub samples. This is mainly attributed to the limited variation on the cost levels of incursion response (i.e. $0 and $2 million). Despite the lack of statistically significant WTP estimates the original survey remains useful in deriving ranking of attributes (i.e. marginal rate of substitution) for those people close, near and far from the Pauatahanui Inlet.

The aim of the follow-up survey is to elicit dollar values from the Pauatahanui sample using a new efficient experimental design. The hypothetical question will be the willingness to pay for maintaining or limiting deterioration of key environmental aspects of the inlet with the focus on indigenous biodiversity with a special tax as the payment vehicle, broadening the range and increasing the number of payment options from two to four. In addition, three new econometric models were tested with the aim of improving the statistical fit of the data compared with the MNL model.

3 Survey design and sampling method

3.1 Attributes

The environmental attributes considered in the follow-up survey are the same as used in the original survey:

RECN	Presence or loss of recreational shellfish take for 3 years
VEG	50% or 10% loss of vegetation
SHELL	Presence or loss of three shellfish species
NOPADDLE	Ability or inability of kids to paddle by the water's edge.

In contrast to the initial survey, the payment vehicle for the money attribute utilised a special tax on households through the local body rating system and justified under the Biosecurity Act (1993). The initial survey assumed a reallocation of existing government expenditure in the payment vehicle. The money attribute was set at 4 levels: ($0, $25, $50, $100) and presented as the cost to the respondent's household each year for the next 3 years.

3.2 Experimental design

Efficient design of surveys results in reliable parameter estimates characterised by small standard errors. In the follow-up survey, the experimental design is Bayesian in nature using the normal distribution for the coefficients of all environmental attributes and the uniform distribution for the money coefficient. The design benefited from use of priors based on the original survey. 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 original survey (see Table 1) were used as priors for the experimental design, which were assumed to be normally distributed with standard deviation equal to the estimated standard errors. The criterion to be minimized was the sum of the variances of the marginal WTP of each attribute, as suggested in Rose and Scarpa (2008).

Table 1. MNL estimate original survey (pooled data)

Variable	Coefficient	Standard Error	P[|Z|>z]
STATQUO	-2.2742**	1.1264	.0435
RECN	-1.2183***	.2111	.0000
VEG	-.0211***	.0053	.0001
SHELLS	-.6746***	.1149	.0000
NOPADDLE	-1.1189***	.2848	.0001
MONEY	0191	.1942	.9219

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

With regards to the money attribute, which was not significant in the initial survey, the uniform distribution was used in the new design and assumed a range of -0.04 to -0.01.

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 Rose and Scarpa *op cit* for review of these efficiency criteria.

The experimental design used dummy coding for the environmental attributes with a value of 1 for a damaged attribute (e.g. loss of recreational shellfish take for 3 years). The status quo is the do nothing option with a payment of zero dollars and with all environmental attributes as damaged.

The optimal design comprises 24 choice sets. These were randomly divided into a manageable grouping of 12 choice sets per respondent. Please refer to Appendix 1 for the complete experimental design.

4 Model specification

The generic utility of policy alternative *j* for respondent *n* in choice task *t* 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 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.

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:

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

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

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

In our case the assumed distributions are normal with mean vector $\mathbf{\mu}$ and variance covariance $\mathbf{\Omega}$, 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.

5 Results

5.1 Data

The follow-up survey gathered a total of 47 respondents from Pauatahanui. There are a few cases of serial non-participation where respondents chose the status quo for all choice sets and wrote a protest note to the survey form. These respondents argue that ratepayers have no monetary obligation for the crab incursion. Overall, the analysis consisted of 564 choices.

The population sample is generally representative of the relevant population (refer to Table 2 below) for gender, income and European and Asian ethnicity. In terms of qualification, polytech and degree are over-represented. The young and mid-age groups are also over-represented. NZ Maori ethnicity is under-represented. Lastly, the high-skill occupation group is over-represented.

Comparing the follow-up survey with the initial survey, the two are similar in terms of gender mix and degree qualification. There is a higher proportion of young age people in the follow-up survey. There is a decrease in the representation of high income households (the follow-up survey is reporting household income vs. personal income in initial survey as noted in Table 2) while there is an increase in high skill people. There is a decrease in the proportion of European and Maori people compensated by the participation of Asian and Pacific people.

Table 2. Survey demographics

	Sample Initial	Sample Follow-up	Population Census	Lower Limit	Upper Limit
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.

5.2 Modelling

Four models were tested. The summary statistics are shown in Table 3 while coefficients and t-values are shown in Table 4.

Table 3. Summary statistics of four models

Model	Adjusted McFadden's R^2	AIC Akaike information criterion	BIC Bayesian information criterion
1. Standard MNL	0.082	1.999	2.038
2. Normal coefficient and triangular price	0.489	1.133	1.202
3. Normal coefficient, triangular price and with kernel for hypothetical choices	0.496	1.118	1.195
4. Normal correlated coefficient, fixed price and with kernel for hypothetical choices	0.510	1.104	1.227

Model 1
The standard MNL model resulted in a low adjusted McFadden's R^2 and RECN attribute as not significant.

Model 2
The second model specified the normal distribution for the coefficient of the environmental attributes and a triangular distribution for the money attribute. Grouping the data into 47 panel groups and using 150 Halton draws resulted in a vast improvement in adjusted McFadden's R^2 and all environmental attributes as significant.

Model 3
The third model has similar specifications as the second model with the additional specification of random parameters for the alternatives (two alternatives and the status quo). This introduces a normally distributed random error term associated with alternatives. This resulted in a slight improvement in adjusted McFadden's R^2 and with slightly lower WTP values compared with the second model. The error term for alternatives is significant.

Model 4
The fourth model specified the money attribute as 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)).

It also specified random parameters for the alternatives. This resulted in the best adjusted McFadden's R^2 while all environmental attributes remain significant. The error term for alternatives is also significant.

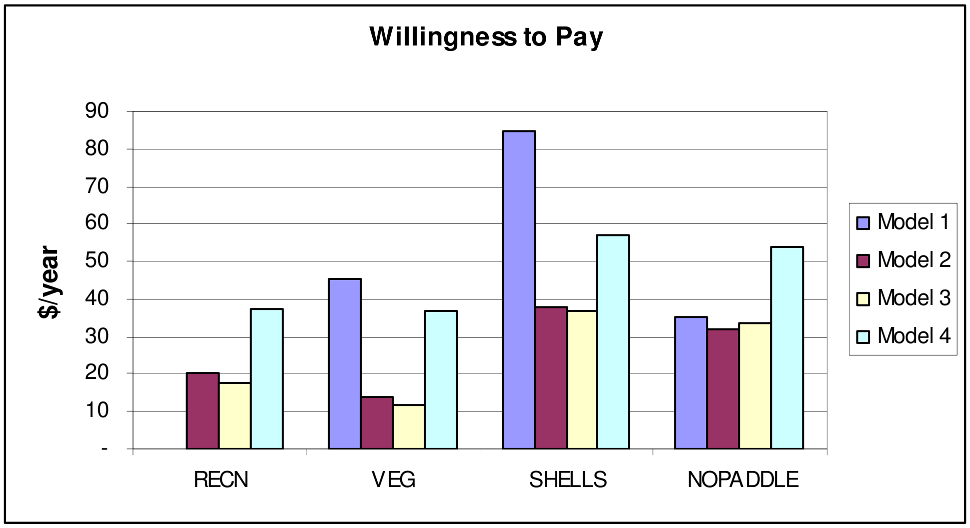
Table 4. Coefficients and t-values of four models

	Model 1		Model 2		Model 3		Model 4	
Variable	**Estimates**	**p-values**	**Estimates**	**p-values**	**Estimates**	**p-values**	**Estimates**	**p-values**
RECN μ	.0283	.8461	-1.8856***	.0000	-1.8984***	.0000	-2.2408***	.0022
RECN σ	-	-	.8325**	.0247	.9377*	.0656	3.3333***	.0000
VEG μ	-.5228***	.0000	-1.2974***	.0025	-1.2409***	.0058	-2.2125***	.0000
VEG σ	-	-	2.8706***	.0000	3.4436***	.0000	4.0735***	.0000
SHELLS μ	-.9816***	.0000	-3.5457***	.0000	-3.9789***	.0000	-3.4374***	.0002
SHELLS σ			4.9285***	.0000	5.2722***	.0000	7.9429***	.0000
NOPADDLE μ	-.4070***	.0040	-3.0150***	.0000	-3.5908***	.0000	-3.2393***	.0000
NOPADDLE σ	-	-	3.0426***	.0000	2.9355***	.0000	5.9363***	.0000
σ_η	-	-	-	-	1.2692	.0007	1.4805***	.0011
MONEY	-.0116***	.0000	-.0940***	.0000	-.1076***	.0000	-.0603***	.0000
Pseudo-R^2	0.082		0.489		0.496		0.510	
AIC	1.999		1.133		1.118		1.104	
BIC	2.038		1.202		1.195		1.227	

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

Model 4 also resulted in the highest WTP estimate (amount per household for next 3 years) for all environmental attributes (excluding Model 1 which has a low pseudo-R^2) as shown in Figure 1.

Figure 1. WTP estimates of four models



Willingness to Pay ($/year per household)

Attribute	Model 1	Model 2	Model 3	Model 4
RECN	NS	$ 20.05	$ 17.65	$ 37.18
VEG	$ 45.21	$ 13.80	$ 11.54	$ 36.71
SHELLS	$ 84.88	$ 37.71	$ 36.99	$ 57.03
NOPADDLE	$ 35.19	$ 32.07	$ 33.38	$ 53.74

NS – not significant

With a normal distribution for WTP, the 95% confidence interval is shown in Table 5.

Table 5. WTP confidence interval

95% confidence level for Model 4 ($/year per household)

Attribute	Mean	Std error	x<=2.5%	x>=97.5%
RECN	$ 37.18	$ 9.43	$ 18.69	$ 55.67
VEG	$ 36.71	$ 8.59	$ 19.88	$ 53.54
SHELLS	$ 57.03	$ 15.43	$ 26.79	$ 87.27
NOPADDLE	$ 53.74	$ 9.17	$ 35.76	$ 71.72

Similar to the original survey, the loss of three shellfish species (SHELLS) remains the environmental attribute with the highest utility. The value of the three other environmental attributes relative to SHELLS is shown in Table 6. The loss of recreational shellfish take and the loss of 40% vegetation is about 2/3 of SHELLS. The inability to paddle is nearly the same value as SHELLS. The original survey reported a similar ratio for the loss of recreational shellfish take but not for 40% loss of vegetation (half of SHELLS) and inability to paddle (less than 2/3 of SHELLS).

Table 6. Marginal rate of substitution for Pauatahanui

Value relative to loss of 3 shellfish species		
Model 4 ratio (x)	Follow-up	Original
RECN/SHELLS	0.65	0.65
VEG/SHELLS	0.64	0.49
NOPADDLE/SHELLS	0.94	0.63

The values for environmental attributes have been aggregated to the total number of households in Pauatahanui using the Statistics NZ 2006 Census data (please see Table 7). The loss of three shellfish species is valued at $192,310. As the extra rates has been presented as an annual rate for the next three years, the present value at 10 percent discount for three years of extra rates is shown in Table 8. The loss of three shellfish species has a present value of just over half a million dollars for Pauatahanui.

Table 7. Annual value for total Pauatahanui households

Value for Pauatahanui households per year			
Attribute	Mean	x<=2.5%	x>=97.5%
RECN	$ 125,366	$ 63,029	$ 187,703
VEG	$ 123,782	$ 67,036	$ 180,528
SHELLS	$ 192,310	$ 90,332	$ 294,289
NOPADDLE	$ 181,225	$ 120,599	$ 241,850

Table 8. Present value for total Pauatahanui households

Present Value for 3 years ($million)			
Attribute	Mean	x<=2.5%	x>=97.5%
RECN	$ 0.34	$ 0.17	$ 0.51
VEG	$ 0.34	$ 0.18	$ 0.49
SHELLS	$ 0.53	$ 0.25	$ 0.81
NOPADDLE	$ 0.50	$ 0.33	$ 0.66

6 Conclusions

This experiment provide estimates of WTP for impacts on four environmental attributes with a high degree of statistical significance over 3,372 households close to the estuary over three years (discounted at 10%) amounting to $1.7 million with a 95% confidence of lying within a range of -$4.7 million to $8.1 million.

Loss of indigenous biodiversity (3 shellfish species) has the highest value of the four attributes at $530,000. Given the high statistical significance of the dollar estimates and their relatively narrow ranges confidence can be assumed in applying these values in cost benefit analysis to this area.

Extrapolating beyond this 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 $600 million with a lower bound of $325 million. 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 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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