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Assessing the marginal dollar value losses to an estuarine ecosystem from an aggressive alien invasive crab[1]

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Abstract

This paper reports on a case study to establish dollar values for loss of biodiversity in the New Zealand coastal marine environment. The study uses the European Shore Crab (*Carcinas maenas*) as the example alien invasive species and the Pauatahanui Inlet, Wellington, New Zealand, as the ecosystem representative of the coastal marine environment. Choice modelling is the stated preference tool used to elicit marginal dollar values for these various attributes of the inlet. Reallocation of existing government expenditure is used as the payment mechanism. Results indicate a wide range of dollar values for the marginal losses to the environment, with no clear trend on a distance-decay relationship. The probability distributions of the dollar values of the environmental attributes tended to have a concentration around the median with very wide tails, especially on the high side. This indicates that most people generally agreed on a dollar value, but a very few individuals expressed extremely high values. The study concludes that the dollar values for loss of biodiversity and other environmental attributes do provide useful information to decision makers, but considerable caution needs to be exercised when applying these values in benefit cost studies. Marginal rate of substitution estimates between environmental attributes will be useful for estimating money values for attributes identified given future work estimates a statistically significant money value for one. (221 words)

Key words: choice modelling, tax reallocation, biosecurity, coastal marine

1.0 Introduction

The objective of this study is to estimate the marginal dollar value of losses to an estuarine ecosystem as a result of a potential invasion by an aggressive alien crab and to assess the possibilities for transferring these values to other similar ecosystems.

Biosecurity New Zealand is responsible for protecting the country from unwanted plant and animal species that may invade from overseas. In order to determine the amount of effort expended in combating a particular invasive species they need to assess the costs and benefits of potential control programs. This is relatively easy where the invasive species attacks plants and animals that are used in the market economy for local consumption or for export.
When exotic pests and diseases attack native plants and animals, which do not enter into the market system, market prices are not adequate to guide decision makers on whether the benefits of pest control exceed the costs. If values that New Zealanders put on indigenous biodiversity could be elicited in dollar terms then analysts would be in a better position to estimate whether the benefits of a response exceed the costs. These costs include the loss in value associated with damage to the environment.

Environmental values encompass a number of attributes which people hold dear. These include:

- the native species in the ecosystem and in particular species that are unique to New Zealand and under threat of extinction
- the ability to gather food from the ecosystem
- the association of plants and animals in the ecosystem, and
- the activities people enjoy associated with the ecosystem.

Stated preference valuation, and in particular choice modelling, is a tool that allows us to estimate the values associated with these various attributes of the environment.

This paper describes:

- the invasive and risks it poses
- the ecosystem
- biosecurity protection measures
- assessing lost value through choice modelling
- the survey process of eliciting value losses
- the theoretical model and experimental design
- a description of the data
- results of the study
- lessons learned, and
- possibilities for benefit transfer to other situations.

2.0 The invasive

This case study uses the European Shore Crab (*Carcinus maenas*), a medium sized and particularly aggressive crab that appears well-suited to the New Zealand coastal marine environment, as the invasive species (Grosholz and Ruiz 2002; Carlton and Cohan 2003; Thresher, Proctor et al. 2003). Two other crabs: the Japanese swimming crab (Browne and Jones 2006); and the Chinese mitten crab were also considered for the case study, but the European Shore Crab was seen to pose the greatest potential risk and therefore was chosen.

This crab has not yet arrived in New Zealand, but is high on Biosecurity New Zealand's list of potential invasive species and is listed among the 100 "world's worst invasive alien species"(ISSG 2007). It originates in the waters of the Atlantic coast of Europe and has since spread to North and South America, South Africa and the southeast coast of Australia. It is a very prolific breeder and is well-suited to inshore and shallow water and sheltered or semi-exposed estuaries and bays. It appears at home on hard or soft substrates, inter-tidal zones and rocky shores in temperatures above 10° Celsius. It tolerates a wide range of salinity and can live from high water to depths of 60 metres (Cohen 2005). These conditions mean that it could potentially invade and establish itself around the whole coast of New Zealand.

2.1 The risks

At risk from aggressive predation are shellfish including oyster, paua, scallops, mussels, tuatua and cockles, native crabs and green algae. It could have flow on effects on fish stocks with a possible reduction in customary, recreational and commercial fishing. European Shore Crab burrows into soft sediment banks causing erosion and death of vegetation through salt inundation, thus changing the look of the environment. It is likely to cause restrictions on recreational activities such as paddling, wading and swimming. There are likely to be negative impacts on seabirds and shorebirds through reduced food supply and from the crab as a possible parasite carrier.

Figure 1. European Shore Crab *Carcinas maenas*

Source: http://en.wikipedia.org/wiki/Carcinus_maenas

The European shore crab has been they blamed for destroying local fisheries, such as the New England soft clam industry, the Washington State Dungeness crab fishery (a US $50 million industry) and the California Manila clam harvest (Cohen 2005) (WDFW 2008). It arrived in New South Wales, Australia in 1891, by 1976 it had spread to South Australia and by 1993 to Tasmania. In 2003 a single specimen was found in Western Australia (PricewaterhouseCoopers 2005). Australian authorities consider it poses a threat to oyster, scallop and blue mussel industries.

Most of New Zealand's coastal ecosystem is a natural environment for crab species from the northern hemisphere. In the past invasion by crabs has been limited by:

- slowness of vessels
- relatively few merchant ships or recreational vessels (yachts and motor launches)
- stopovers in Southern Hemisphere ports before reaching New Zealand.

Now and in the future there are likely to be increasing numbers of vessels, particularly recreational vessels, shorter travelling times and the likelihood of direct visits from the northern hemisphere or visits from southern hemisphere areas which have already been invaded. Thus the incidence of invasive crabs in New Zealand marine environment is likely to increase.

3.0 The ecosystem

The Pauatahanui Inlet, the inner arm of the Porirua Harbour about 25 kilometres north of Wellington on the West Coast of the North Island was chosen as the case study ecosystem. It has a shore line of 13 kms and is 3.5 kms long and 2 km at its widest point. It has many of the features associated with the 350 estuaries and harbours around the whole coast of New Zealand:

- there is a marina at the entrance to the inlet, containing around 300 yachts and launches with associated boat club, lift out and hard stand activities
- kids play around the water's edge and dinghy sailors, windsurfers and water skiers ply its protected waters
- there is a walking and cycling track around the inlet
- roads surround the inlet, as do urban housing, boathouses and sheep and beef farmland
- several streams run into the inlet and a wildlife reserve has been established at its head with walkways and hides for bird watching
- recreational fishing including shellfish gathering is undertaken, and commercial fishing, which once supported several set net operations, has now ceased.

Figure 2. The Pauatahanui Inlet

Source: http://www.converge.org.nz/gopi/where.html

4.0 Biodiversity protection

As coastal marine habitats are increasingly marginalised through human activity the remnants of these natural ecosystems become more valuable to people. Since European settlement in the 1800s coastal marine ecosystems have increasingly come under pressure. Coastal development including housing, ports, marinas and tourism has significantly altered habitats. Increased recreational use including fishing has changed the dynamics of these ecosystems. Industrial use of coastal waters by aquaculture such as mussel, scallop and oyster farms have taken over habitats. Pollution from human activity including sewerage, nutrient runoff, silt and chemicals has modified the seabed and reduced the quality of the water. Most of New Zealand's coastline has now been modified.

As natural ecosystems have become fragmented and lost buffer areas they have become more susceptible to biodiversity loss. Reduction in biodiversity includes:

- reduction in plants and animals
- modified physical layout
- change over time
- changes in the state of natural processes.

Biodiversity integrity is increasingly threatened as the original ecosystem is modified. When less than 30% of an ecosystem remains (i.e. 70% has been destroyed) it is considered that the ecosystem as is at risk, when less than 20% remains it is chronically threatened and when less than 10% remains it is acutely threatened.

Biosecurity New Zealand has the responsibility of protecting New Zealand from exotic pests and diseases. It does this through prevention and monitoring and surveillance activities. The key prevention method is control over ballast water exchange which is required to take place well outside port areas. A new international protocol is due to be implemented in 2008. Should a vessel be deemed a risk through bio-fouling of its hull then biosecurity New Zealand has the power to require that vessel to be slipped and the bio-fouling removed.

The key surveillance activities are surveys of high risk areas such as ports, marinas and aquaculture areas by teams of trained divers. These dive teams conduct baseline surveys to check on the species present along transect lines and then return on a three-year cycle. In a survey of 16 ports the average number of introduced species found was 13 compared to 144 native species. There were also 23 species where it could not be determined whether they were native or introduced. The species found along the transect lines are then compared with low risks areas to see if there are new species encountered in the baseline areas (BNZ 2007).

Should a new species be found a risk assessment is carried out and if the species is regarded as a threat a delimiting survey will be undertaken. The survey attempts to define the limits of the incursion as the first step in determining whether the benefits of attempting to eradicate, manage or just monitor the incursion exceed the costs. Browne and Jones (2006) set out a number of alternative mechanisms that could be used to control exotic crabs including:

- Chemicals such as chlorine, copper compounds and carbyrol baits
- Physical controls through trapping or netting
- Environmental modification where the substrate will be altered to an unsuitable state
- Biological controls such as parasites
- Sterilisation through irradiation or chemical means
- Natural predation
- Integrated pest management.

Integrated pest management (IPM) seeks to employ a combination of control methods to optimise the likelihood of control. IPM involves:

- Prevention and containment
- Detection and forecasting
- Eradication
- Control and mitigation
- Information access and data management.

The likelihood of a single solution is low and eradication is usually only possible if the invasive species population is small, contained and does not breed. If the population becomes established and breeds management, including attempts to slow the spread, is the most likely probable outcome.

The effectiveness of eradication or control depends on:

- The area the invasive species has spread
- The depth of water
- The degree to which water can be contained or retained
- Whether the invasive species is solitary or lives in groups.

Of these factors, the only one under the control of the authorities is the area to which the invasive species has spread. The nature of the marine environment means that eradication is usually difficult to achieve.

Experience overseas has typically shown limited success in controlling marine invasives and until recently it was thought not possible. Although the European Shore Crab has not arrived in New Zealand, there is a likelihood that it will. Currently there is no strategy for the control of invasive crabs and therefore the outcomes of potential control programs are uncertain. Monitoring, early detection and a prompt response are the keys to successful eradication (Grosholz and Ruiz 2002).

In certain circumstances eradication has been achieved. In March 1999 the black striped mussel was discovered in Darwin. The risk assessment found that this pest had the potential to decimate the local pearl industry worth A$225 million annually. A de-limiting survey determined that it was restricted to three enclosed marinas. The first attempt at eradication involved tipping 160 liquid tonnes of chlorine into the marina water. This was unsuccessful and the follow-up chemical was copper sulphate at the rate of six tonne. Eradication was declared successful by April 1999. It cost the Australian government $2.2 million and the private sector several hundred thousand dollars in lost revenue. The 750 vessels that had left the marina within three months prior to the discovery of the incursion were traced and where necessary vessels were slipped and hulls cleaned of bio-fouling (Ferguson 2000).

There are examples of successful eradication of pests and diseases in New Zealand, but they relate to land-based plants and animals. No studies could be found that reported the successful eradication of marine pests.

5.0 Assessing lost value

This study has used choice modelling to ask people in an experimental setting to reveal how much they value marginal changes to the environment in the Pauatahanui Estuary through a hypothetical incursion of the European Shore Crab. The aim is to put dollar values on the marginal changes to key attributes of the environment that people value. In essence the objective is to determine how people construct their utility function or preferences for the estuary. The model allows respondents to compare a range of potential scenarios to the baseline option (which is that no additional funding is allocated to respond to this particular invasive crab).

To determine the make up of a person's preferences, the worth of the estuary is broken down into a group of key attributes. These attributes represent parts of the total worth of the estuary, which are likely to have a greater or lesser appeal to different people. When bundled together they form a representative picture of the total worth of the estuary. The cost of the response programme has a monetary value and this is used to estimate values for the environmental attributes.

In order to generate estimates of value for the non-monetary attributes, each attribute must be assigned at least two levels. In this case, in discussion with Biosecurity New Zealand it was determined that there is essentially only one feasible alternative to the baseline option so each attribute is assigned two levels, one for the baseline and one for the alternative. The two biosecurity options are set out in table below.

Table 1. Response options

Response 1 Current programme *European shore crab* arrives	**Response 2** Current programme PLUS increased monitoring & awareness *European shore crab* arrives

• No additional cost
• Regulations to minimise bio-fouling on boats
• Ongoing monitoring programme of key sites – dive teams
• Overarching communications & awareness programme
• National ballast water management system
• Single incursion – response $1m completed in 1 year
	• **Response 1, <u>plus</u>**
	• Additional annual cost $2m – indefinitely
	• Species specific:
	  – R&D programme
	  – Bio-fouling protocols
	  – Communications & awareness strategy
	• Double the monitoring effort by including additional high risk sites – 2x dive teams

The proposition is that by increasing the level of monitoring and awareness the chances of the crab becoming established are significantly reduced thereby lessening the impact on the estuary.

After testing in three focus groups and discussions with biosecurity and marine ecology specialists the range of effects on the key attributes expected under the base case and a more intensive biosecurity progrmme were estimated (as set out in Table 2). In order to identify the value of a particular attribute it is necessary to vary them independently. This is done using the experimental design discussed later.

Table 2. Attributes 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

The final response options and likely subsequent changes in the attributes were derived in consultation with a Biosecurity New Zealand marine programme manager and a marine scientist.

By presenting a number of choices to the respondent with different combinations of the attributes it is possible to determine the relative importance of each attribute to the respondent.

Once the key attributes were determined and the levels estimated under the different options then a series of choice sets were generated based on an experimental design scheme. The choice sets compare the baseline Response 1 (Option A) with two different combinations of the levels of the attributes under Response 1 and Response 2, labelled Option B and Option C. In the choice set Option A provides a constant base for the comparison of the alternative combinations under Option B and Option C. An example of a choice set is provided in the Appendix 1.

Information about respondent preferences is achieved by asking them to choose one alternative from among the three choices in each choice set (Option A, Option B and Option C). Over the group of choice sets the preferred attributes and levels provide the basis for estimating each individual's stated preferences. When aggregated across a representative sample of the population estimations of preferences of the total population can be made. From these models of choice behaviour, dollar values can then be estimated.

6.0 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.

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 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 or protested changing the levels of the other public goods selected.

These results were confirmed in a subsequent study by Swallow and McGonagle (2006) who found that an individual's willingness to pay to reallocate existing tax dollars exceeded willingness to pay new taxes to conserve land. In 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. They suggest reallocation is a legitimate alternative approach when government agencies cannot reasonably impose new taxes.

Based on these three studies it can be inferred 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 condition that the tax reallocation mechanism is the only trade-off available.

7.0 Survey process

Before undertaking the survey proper the presentation was tested using focus groups, firstly with a group from Biosecurity New Zealand and then one based on Christchurch and another in Auckland. The purpose of the focus groups was to test the presentation to ensure it was pitched at a level that would inform but not bias the respondents. A key aim was to ensure that the language and the concepts were understandable. Also important was the testing of the questionnaire to ensure that the attributes captured the main features of the estuary that were important to people and that the levels associated with the options seemed reasonable.

Testing the approach with Biosecurity New Zealand was important to ensure that the biosecurity concepts and constructs met with their approval. This proved to be a very valuable stage and one that helped to ensure that the questions would elicit the information that Biosecurity New Zealand wanted. This process resulted in modifications to the survey approach.

Four sub-samples were drawn for the survey – local (Pauatahanui Inlet), regional (Karori) and distant (Dunedin and Auckland). These sub samples were to test whether distance was a factor in the value people placed on the estuary.

The survey method adopted was a presentation at an open meeting with the questionnaire handed out at the end and filled out by each individual respondent. Other forms of survey technique were considered including mail out, telephone and personal interview, but because of the complexity of the proposition being put before respondents it was felt that the meeting style would be most appropriate. It also allowed for some control over respondents to limit the possibility of strategic responses[3]. This was done by limiting the time available to answer the questions and restricting the ability to change answers. Other considerations were the length of time that mail out surveys take, the high cost of personal interviews and the inability to convey complex information in telephone surveys.

[3] Strategic responses or gaming is where respondents attempt to influence the results by choosing options that support a particular stance.

7.1 Survey samples

Professional marketing companies were used to put together the focus groups. This was feasible for small groups of 10 to 12 people, but the survey sub-sample aim was 50 to 60 people and the cost of using professional market companies to put together a cross-section of the population with these numbers was prohibitively high.

The approach adopted in the survey was to contact service group organisers and ask them to bring together a group of people representing their sub-population. The incentive for the organiser was a donation of $50 per respondent who completed a questionnaire with a $20 petrol voucher incentive for individuals. Service groups responded well to these incentives and met our minimum requirements in three of the four chosen locations. Appendix 2 has an example of the flier that was sent out to organisers for publicity purposes.

Unfortunately only 10 people turned out to the Auckland meeting and as a result it was decided to discard this sub-population. Certainly Aucklanders face much more difficult and expensive transport options compared with other locations. Another possible explanation for the low turn out is that the environmental issue was not of great interest to people in Auckland. As a result it appears that the level of donation or fee required to get people to attend in Auckland is about double that of the rest of New Zealand.

8.0 The theoretical model

In most non-market valuation studies the payment mechanism assumed is the implementation of a new tax which is an additional imposition on disposable income. Compensating surplus (CS) is defined as the change in disposable income that holds utility constant, given a change in an environmental attribute. When this payment mechanism is inappropriate and the expected mechanism is a reallocation of existing government expenditure then the welfare measure is the change in expenditure on other public goods that people are willing to forego to achieve the new environmental outcome. This is referred to as compensating tax revenue (CTR) (Morrison and Hatton MacDonald 2007).

Choice modelling relies on the application of random utility theory to describe choice as a function of the attribute levels. The observed choices are assumed to be a function of some explainable factors and some unexplainable or random components. The utility function (Swallow and McGonagle 2006) is expressed as:

$$U_{ij} = U(X_i, Y_j - C_i, T_j - C_i^{old})$$

Where U_{ij} is the utility for option *i* of individual *j*, X_i are the attributes of the environment, Y_j is disposable income for individual j, C_i cost in terms of a new tax, T_j is the current level of taxes, C_i^{old} is the use of existing general revenues.

It is possible to explain a significant proportion of the unobserved utility of each individual, but a certain proportion will always remain unexplained (Louviere 2001). That is:

$$U_{ij} = V_{ij} + e_{ij}$$

V_{ij} is the observable utility component and e_{ij} represents the observed random component of choice. The assumption is made that the respondents seek to maximise their utility when making trade-offs between choices. The probability that choice A will be preferred over choice B is the probability that the (V_{Aj} + e_{Aj}) is greater than (V_{Bj} + e_{Bj}).

Assuming that the error terms follow a particular distribution relevant to logit models the probability that a particular choice will be preferred can be calculated (Loch *et al*, 2001).

One model used to predict choice behaviour is the multinomial logit regression model (MNL), which takes the general form shown below.

$$P_{ij} = \exp\left(l V_{ij} \right) / \sum \exp\left(l V_{ih} \right)$$

Where *Pij* represents the probability that individual *j* will make choice *i* from all the *h* in choice set C, and ? represents a scale parameter commonly normalised to 1 for any data set. The MNL model typically uses conditional indirect utility functions for the explainable component as below.

$$V_j = b + \sum_i b_i Z_i + \sum_j b_j S_j + \sum_{ij} q_{ij} Z_i S_j$$

Where V_j is the observable utility, and ß is the vector of coefficients attached to the vector of attributes (Z) describing the estuary, where

Z_1	=	extra biosecurity cost each year
Z_2	=	number of shellfish species that disappear
Z_3	=	percentage reduced recreational shellfish take for 3 years

Z_4 = percentage of vegetation dies
Z_5 = children paddling on water's edge

Individual characteristics S_j, including income, gender, interests etc enter via the interactions $?_{ij}Z_iS_j$ with the attributes.

The underlying assumption in the statistical analysis of choice questions is that the respondent's underlying utility drives choice between alternatives. Indirect utility has two components: (1) deterministic component (a function of the attributes of alternative, socio-demographic characteristics and a set of unknown parameters) and (2) an error term (Alberini *et al* in Kanninen, 2007).

The workhorse model in choice modelling is the Multinomial Logit (MNL). Its non-linear property allows MNL to capture a wide variety of compensatory attribute-based trade-offs. With MNL's likelihood function as globally concave, its output is the maximum likelihood estimate (Swait in Kanninen, 2007). The MNL models were estimated using the software package LIMDEP.

8.1 Choice set design

An orthoganol main effects design was used to identify eight options in addition to the base case (Johnson, Kanninen et al. 2007), see Appendix 3. The foldover[4] of each option was used as the third alternative in each choice set.

9.0 Data Description

The survey gathered a total of 190 respondents from Dunedin (76), Karori (47), Auckland (10) and Pautahanui Inlet (57). As discussed previously, the 10 Auckland individuals were discarded. Also discarded were two under-aged respondents (14 year old and 16 year old) as adult decision-makers were considered to be the relevant population.

The raw sample produced 1,330 choices. Aside from removing Auckland and under-aged respondents, the analysis also discarded 86 irrational choices (e.g. dominated choices) from the total number of cases. As a result, the analysis considered 178 respondents with 1,244 choices.

The population samples are broadly representative of the relevant population (refer to Table 3 below) in terms of gender (except for Karori where male is over-represented), NZ European ethnicity (except for Dunedin where it is over-represented) and occupation (except Karori where low skill is over-represented).

[4] A foldover replaces an attribute level with its opposite

However, the samples are less representative of the population in terms of qualifications (bachelor or higher degree qualifications are over-represented), age (young over-represented in the Dunedin sample, middle age is under-represented in Karori, old is not represented at all in Pauatahanui and dominated by middle-age group), income (high income is over-represented especially in Karori and Pauatahanui) and non-NZ European ethnicity (specifically NZ Maori, NZ Asian and NZ Pacific ethnicity are mostly under-represented).

Table 3. Sample characteristics

	Sample			Population Census			Confidence interval at 95% confidence level Lower Limit			Upper Limit		
	Dunedin	Karori	Paua	Dunedin	Karori	Paua	Dunedin	Karori	Paua	Dunedin	Karori	Paua
GENDER												
Male	45.8%	56.5%	43.6%	48.0%	47.7%	49.1%	42.5%	40.8%	42.7%	53.4%	54.5%	55.5%
Female	54.2%	43.5%	56.4%	52.0%	52.3%	51.0%	46.2%	44.9%	44.3%	57.9%	59.8%	57.6%
QUALIFICATION												
No Qual	0.0%	4.3%	1.8%	19.5%	7.8%	13.4%	17.3%	6.7%	11.7%	21.7%	8.9%	15.2%
Fifth	6.7%	4.3%	9.1%	10.3%	7.1%	11.6%	9.2%	6.1%	10.0%	11.5%	8.1%	13.1%
Sixth	8.0%	8.5%	5.5%	27.9%	25.2%	25.2%	24.7%	21.6%	21.9%	31.0%	28.8%	28.5%
Polytech	32.0%	23.4%	27.3%	16.4%	15.1%	22.1%	14.6%	13.0%	19.2%	18.3%	17.3%	25.0%
Degree	53.3%	59.6%	56.4%	17.1%	40.4%	23.1%	15.1%	34.6%	20.1%	19.0%	46.2%	26.1%
AGE												
Young	46.6%	35.6%	7.3%	23.2%	18.2%	13.9%	20.6%	15.6%	12.1%	25.9%	20.8%	15.7%
Mid-age	37.0%	40.0%	92.7%	52.7%	62.5%	64.5%	46.8%	53.6%	56.0%	58.7%	71.5%	72.9%
Old	16.4%	24.4%	0.0%	24.0%	19.3%	21.6%	21.3%	16.5%	18.8%	26.8%	22.0%	24.5%
INCOME												
High income	15.1%	48.9%	54.5%	13.4%	35.1%	33.3%	11.9%	30.1%	28.9%	15.0%	40.2%	37.6%
Low income	84.9%	51.1%	45.5%	86.6%	64.8%	66.7%	76.8%	55.5%	58.0%	96.3%	74.1%	75.4%
ETHNICITY												
NZ European	90.7%	80.9%	86.2%	78.7%	72.6%	78.7%	69.8%	62.2%	68.4%	87.6%	83.0%	89.0%
NZ Maori	2.7%	0.0%	6.9%	6.4%	5.0%	10.4%	5.7%	4.3%	9.0%	7.1%	5.7%	11.8%
NZ Asian	2.7%	6.4%	0.0%	5.3%	14.6%	4.0%	4.7%	12.5%	3.4%	5.9%	16.7%	4.5%
NZ Pacific	0.0%	6.4%	0.0%	2.2%	4.0%	3.8%	2.0%	3.5%	3.3%	2.5%	4.6%	4.3%
Others	4.0%	6.4%	6.9%	7.3%	3.8%	3.2%	6.5%	3.3%	2.7%	8.1%	4.4%	3.6%
OCCUPATION												
High skill	36.0%	48.9%	51.8%	33.7%	56.1%	48.3%	29.9%	48.0%	42.0%	37.5%	64.1%	54.6%
Low skill	64.0%	51.1%	48.2%	61.5%	39.9%	48.6%	54.5%	34.2%	42.2%	68.4%	45.6%	54.9%

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

Definitions: Variables are described in the next 2 paragraphs

Relevant population:

Dunedin – Dunedin City territorial authority

Karori – Karori North, Karori Park, Karori East and Karori South area units

Pauatahanui – Papakowhai, Plimmerton, Mana-Camborne and Paremata-Postgate area units

Confidence intervals relate to the population. The sample needs to be within the upper and lower limit for 95% confidence.

9.1 Variables

The estuary attributes considered in the choice sets were:

Money attribute:

MONEY — Extra cost of biosecurity inputs from zero to $2 million p a on a species specific control programme paid by redirecting funds from another government programme

Environmental attributes:

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 of inability of kids to paddle by the water's edge.

In determining the best fit models for individual sites and the pooled level, socio-demographic characteristics (SDC) were tested for their influence on choices. These included: GENDER, DEGREE, AGE, INCOME, ETHNICITY, OCCUPATION, WATER, OUTDOOR and LOCATION. The SDC variables created to test influence on choices were:

FEMALE	Female gender
DEGREE	Qualification = university degree
OLD	Over 60 years
YOUNG	Under 30 years
MIDAGE	30-60 years
HIINC	High-income (> $50,000 pa)
PAKEHA	NZ European
HISKILL	Occupation = managers or professionals
WATER	Water-related leisure interests include swimming, fishing or beach activities
OUTDOOR	Leisure interests include "outdoor" types
DUNEDIN	Attended Dunedin meeting
PAUA	Attended Pauatahanui inlet meeting
KARORI	Attended Karori meeting
AUCKLAND	Attended Auckland meeting.

10.0 Modelling

SDC effects were estimated by interacting SDC variables with attributes in the choice model. For example (in the first row in Table 4 below), interacting gender SDC named FEMALE with recreational shellfish take attribute (RECN) covers females who value loss of recreational shellfish take (FEMRECN). The next three interaction variables in the first row cover the vegetation, shellfish species and kids' paddling attributes (FEMVEG, FEMSHELL and FEMKIDS). Of all the interaction variables, SDCs female, location and water were found to influence choices as shown in Table 4.

Table 4. Interaction variables

Interaction Variable	Socio-demographic characteristic
FEMRECN,FEMVEG,FEMSHELL,FEMKIDS,	FEMALE
DUNRECN,DUNVEG,DUNSHELL,DUNKIDS,	DUNEDIN
KARRECN,KARVEG,KARSHELL,KARKIDS,	KARORI
PAUARECN,PAUAVEG,PAUASHELL,PAUAKIDS	PAUATAHUNUI
WATRECN,WATVEG,WATSHELL,WATNOPAD,	WATER, RECREATION

10.1 Multinomial Logit

Location-based MNL models (Dunedin, Karori and Pauatahanui) and pooled models fit the data relatively well. However, money was significant only for Karori, and to a lesser extent, in the pooled model.

The variables with at least 95% confidence level for the best-fit location-based and pooled models are set out in Table 5 below.

The MNL model was extended to account for heterogeneity across decision makers and across alternatives. The Latent Class and Heteroscedastic Extreme Value models were applied and the results are discussed in the next two sub-sections.

10.2 Latent Class Models

Latent Class modelling allows for segmenting heterogeneous decision makers into clusters or classes. These clusters or classes are finite in number and exhibit within-segment homogeneity (Swait, 2007).

In an attempt to account for respondent heterogeneity, Latent Class Models (LCMs) were fitted to individual-site data (Karori, Pauatahanui, Dunedin) and to pooled data. LCMs did not improve model fit. Individual-specific variables were entered into the LCMs as class membership predictors, but none were significant. Consequently, this line of investigation was abandoned.

Table 5. Variables attaining statistical significance in the model

MNL POOLED

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
OPT2	1.78720177	.51640463	3.461	.0005***
OPT3	1.64482763	.45270272	3.633	.0003***
RECN	-1.06661586	.11583931	-9.208	.0000***
VEG	-.01396080	.00385096	-3.625	.0003***
DUNVEG	-.00811492	.00380151	-2.135	.0328**
SHELLS	-.69692112	.08656660	-8.051	.0000***
FEMSHELL	.21755118	.05579205	3.899	.0001***
WATSHEKA	.35350611	.18220985	1.940	.0524**
WATSHELL	.19992961	.06990645	2.860	.0042***
NOPADDLE	-.63771530	.17446468	-3.655	.0003***
MONEY	-.33529361	.16234625	-2.065	.0389**

MNL KARORI

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
STATQUO	-3.56105232	.76365627	-4.663	.0000***
RECN	-1.15740791	.17321769	-6.682	.0000***
SHELLS	-.35055110	.07538197	-4.650	.0000***
MONEY	-.69367829	.17151343	-4.044	.0001***
WATSHELL	.46523468	.18513470	2.513	.0120***

MNL PAUATAHANUI

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
RECN	-1.57161272	.19703729	-7.976	.0000***
VEG	-.02957940	.00498079	-5.939	.0000***
SHELLS	-.81064242	.07162759	-11.317	.0000***
NOPADDLE	-1.52365309	.21993196	-6.928	.0000***

MNL DUNEDIN

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
RECN	-.82392156	.13972955	-5.897	.0000***
VEG	-.02608159	.00328315	-7.944	.0000***
SHELLS	-.80332544	.06944208	-11.568	.0000***
FEMSHELL	.16132727	.08335373	1.935	.0529**
NOPADDLE	-.75834338	.15089915	-5.025	.0000***
WATRECN	-.66403753	.35549918	-1.868	.0618**

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

10.3 Heteroscedastic Extreme Value

To test for heterogeneity in variances between choices, the Heteroscedastic Extreme Value (HEV) model was applied in each instance. HEV allows alternative-specific characteristics to account for differential importance of systematic versus stochastic utilities across alternatives. In addition to socio-demographic effects, scale (variance) factors can be a function of exogenous attributes such as performance and price (Swait, 2007).

The HEV model was significant for Dunedin and Pauatahanui, but not for Karori. In both cases, the scale factor was significantly greater than one for the base case, indicating a lower standard deviation for the base case than for the other choices. This is consistent with the observed lack of selection of the base case, which was expected because it is frequently a dominated alternative. Summary statistics are shown in Table 6 below.

There is little to choose between the MNL and HEV models on statistical grounds. Both models fit reasonably well. Note that adjusted McFadden's R^2 cannot be interpreted in the same way as R^2 in a linear regression model. These scores (> 0.27) correspond roughly with a linear R^2 of about 0.6 (Hensher, Rose & Greene, 2005).

Table 6. Summary statistics for the different models

Model	Adjusted McFadden's R^2	AIC Akaike information criterion	BIC Bayesian information criterion	Number of choices analysed
Dunedin MNL	0.283	1.096	1.146	525
Dunedin HEV	0.273	1.117	1.184	525
Pauatahanui MNL	0.275	1.022	1.062	392
Pauatahanui HEV	0.277	1.023	1.090	392
Karori MNL	0.320	0.987	1.045	327
Pooled MNL	0.307	1.021	1.067	1,244

10.4 Confidence intervals

Confidence intervals were estimated for relevant outputs of the models (money measures of value and marginal rates of substitution) using the Krinsky & Robb procedure (Krinsky & Robb, 1986). This is a Monte Carlo simulation approach that develops a large number of parameter estimates, appropriately correlated, using the estimated coefficients and the variance-covariance matrix. A

procedure in the Excel add-in programme '@Risk' was developed to use the outputs from Limdep to undertake this process. Confidence intervals were developed using 10,000 iterations for the marginal rate of substitution and 100,000 iterations for money values.

10.5 Money value

Money values for attributes of the estuary have been estimated for the pooled sample (combining the data from all three locations) and for the Karori sample. For the pooled sample, the loss of three shellfish species (SHELL) attained the highest estimated value at $4.8 million per year followed by the loss of recreational shellfish (RECN) take for 3 years at $3.2 million per year (see Figure 4 and Table 7 below). The values for only two attributes (i.e. no recreational shellfish take for 3 years and loss of 3 shellfish species) were significant for the Karori sample and were generally lower than the value at the pooled level, but the difference was not statistically significant.

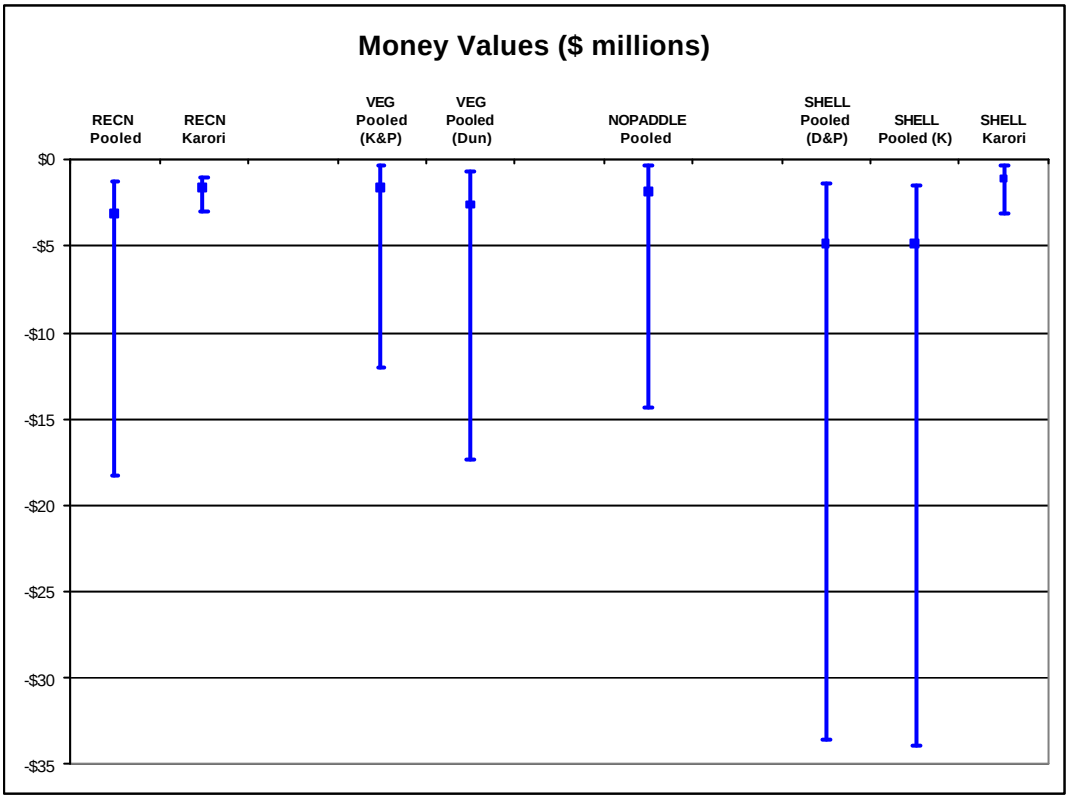
The money value estimates and confidence intervals are shown in Figure 4 below. Note that some of these values, and especially the upper bounds are well outside the range of the money attribute used in the choice experiment. This indicates that the dollar value in the survey was lower than some people were prepared to pay.

Table 7. Estimates of dollar values of the attributes

Money Values ($millions)		Estimate	95% Confidence Interval		
RECN Pooled	No recreational shellfish take for 3 years	$ 3.18	$ 1.35	~	$ 18.31
RECN Karori		$ 1.67	$ 1.09	~	$ 3.07
VEG Pooled (K&P)	40% vegetation loss	$ 1.67	$ 0.29	~	$ 12.10
VEG Pooled (Dun)		$ 2.63	$ 0.75	~	$ 17.44
NOPADDLE Pooled	No paddling for children	$ 1.90	$ 0.31	~	$ 14.40
SHELL Pooled (D&P)	Loss of three shellfish species	$ 4.84	$ 1.47	~	$ 33.56
SHELL Pooled (K)		$ 4.87	$ 1.47	~	$ 33.84
SHELL Karori		$ 1.15	$ 0.39	~	$ 3.18

MNL model, estimated by dividing the coefficient of the environmental attribute by the negative of the money attribute.

Figure 4. Money value estimates and confidence intervals



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

10.6 Marginal rates of substitution

Marginal rates of substitution among attributes have been expressed with the loss of three shellfish species as the base since the latter is the most valued attribute. These ratios are:

- R/S: value of loss of recreational shellfish take relative to value of loss of 3 shellfish species
- V/S: value of 40% loss of vegetation relative to value of loss of 3 shellfish species
- P/S: value of no paddling relative to value of loss of 3 shellfish species

All ratios are significant at the pooled and location level except for the 40% loss of vegetation (V/S) and no paddling ratios (P/S) for Karori. At the pooled level, the loss of recreational shellfish take has the highest marginal rate of substitution compared with 40% loss of vegetation and no paddling attributes (i.e. estimate for R/S Nat is 0.65x while V/S Nat and P/S Nat estimates are below 0.54x). Please refer to Figure 5 below.

This information is very interesting as it will enable money values to be estimated for all the attributes given a statistically significant money estimate for one. For example, if in a new study a statistically significant money value is estimated for one of these attributes the values of the others can be elicited by applying the marginal rates of substitution (MRS).

Taking the confidence intervals into consideration, the results are consistent with the point estimates for the ratios at the pooled level. Figure 5 and Table 8 show that the MRS estimate and its confidence interval for the loss of recreational shellfish take is higher than those for the 40% loss of vegetation and no paddling attributes.

The confidence intervals also show that the MRS for each attribute is consistent among individual locations and the pooled level. However, there are indications that Pauatahanui (as the location next-door to the affected estuary) exhibits a higher MRS. This is observed in the no paddling ratio (see Figure 5).

Figure 5. Value of loss compared with value of loss of 3 shellfish species

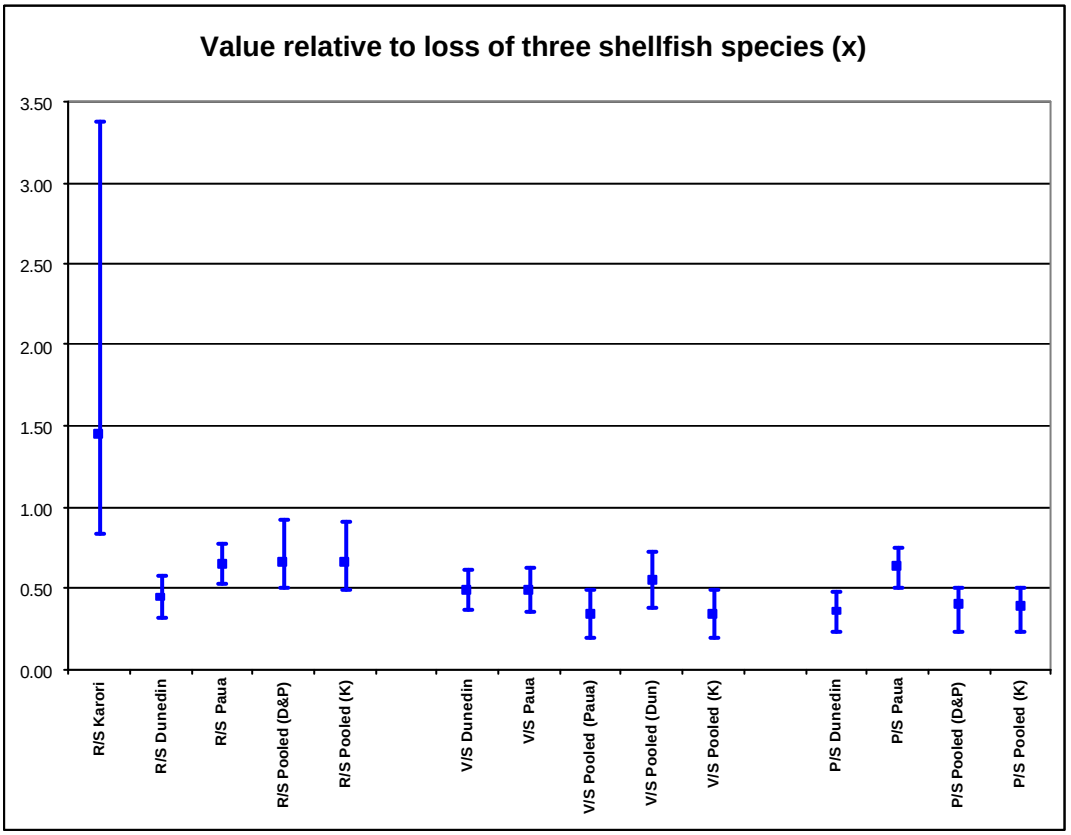


Table 8. Values relative to loss of three shellfish species

Value relative to loss of three shellfish species				
Ratios (x)	Estimate	95% Confidence Interval		
R/S Karori	1.45	0.83	~	3.38
R/S Dunedin	0.44	0.32	~	0.57
R/S Paua	0.65	0.52	~	0.78
R/S Nat (D&P)	0.66	0.49	~	0.92
R/S Nat (K)	0.65	0.49	~	0.91
V/S Dunedin	0.49	0.37	~	0.61
V/S Paua	0.49	0.35	~	0.62
V/S Nat (Paua)	0.34	0.19	~	0.49
V/S Nat (Dun)	0.54	0.38	~	0.72
V/S Nat (K)	0.34	0.19	~	0.49
P/S Dunedin	0.35	0.23	~	0.48
P/S Paua	0.63	0.50	~	0.75
P/S Nat (D&P)	0.39	0.23	~	0.50
P/S Nat (K)	0.39	0.23	~	0.50

Note that the MRS for the value of loss of recreational shellfish take of the Karori sample is significantly higher than that of the other locations including the pooled data. It is the only ratio that exceeds one indicating that the Karori sample placed a higher relative value on recreational fishing compared with the value of loss of three shellfish species. This may be due to the over representation of well qualified, younger, high income males in the Karori sample.

10.7 Summary of results

The money value estimate for two attributes on their own (loss of three shellfish species at $4.8 million p.a. and no recreational shellfish take for 3 years at $3.2 million p.a.) justifies the extra cost of the biosecurity programme of $2 million per year. Taking the low end of the confidence intervals (there is a 2.5% chance the value will be lower than these figures), a combination of the two attributes (the loss of three shellfish species at $1.47 million p.a. and no recreational shellfish take for 3 years at $1.35 million p.a.) also justifies the extra cost of the biosecurity programme. However, the wide band of the confidence intervals signifies the need for caution in the use of the values.

The marginal rates of substitution confirm the high significance placed on the loss of three shellfish species. By valuing only one attribute (e.g. loss of 3 shellfish species) the values of the other attributes can be estimated using the MRS ratios. Thus estimation of MRS ratios are important outputs of choice modelling studies and should be highlighted as such.

Based on the pooled data the annual value of the marginal loss of biodiversity due to this invasive crab in the Pauatahanui Inlet is estimated at $4.8 million per annum of foregone spending on other government activities. Capitalising these annual losses gives a net present value of $48 million, $80 million or $240 million depending on the discount rate used at 10%, 6% and 2% respectively (see Table 9 below). These discount rates represent the range generally considered in public policy decisions.

Currently Biosecurity New Zealand uses a discount rate of 10% and a cut-off benefit to cost ratio of three. This has the effect of promoting projects with immediate benefits over projects that have benefits in the longer term. This is because future benefits are more heavily discounted. As decisions about the environment are long term and often irreversible (impacting on future generations as well as the current one) a lower discount rate would mean more environmental projects would be accepted.

Table 9. Value of loss from a crab invasive at Pauatahanui Inlet

Attribute	Loss per annum ($million)	Cap rate	NPV Local loss ($million)
Loss of biodiversity	4.8	10%	48.0
		6%	80.0
		2%	240.0
Loss of fishing	3.2	10%	32.0
		6%	53.3
		2%	160.0
Combined loss	8.0	10%	80.0
		6%	133.0
		2%	400.0

11.0 Lessons

The high level of difference in the valuation of the estuary attributes and the insignificance of money in Dunedin and Pauatahanui could possibly be attributed to 1) the relatively narrow range of money values ($0 and $2 million per annum) and 2) the payment mechanism used. As $2 million amounts to less than $1 per household per year, it may have been considered an insignificant sum to many people. It would be prudent to include a broader range of money

values in future surveys and the values should be set after more extensive pre-testing amongst the target populations.

The payment mechanism may have induced some unwanted responses. People were told that other high priority government spending, such as health and education would be reallocated to generate the annual $2 million cost of the programme. Individuals' responses to this approach may vary widely, depending on what they see as the specific alternative use of funds. For example funds could be generated from:

- efficiency savings (no discernible cost to other outcomes),
- reduction in unwanted expenses in other areas (e.g. reducing administration costs compared with reducing primary health care costs),
- reduction in other valued government activities (unemployment benefits, public transport, etc.) In this case, the cost of responding to the crabs depends on the **VALUE** of the forgone activities, which is unknown, but can vary depending upon what the individual assumes about the source of funds
- an increase in taxation, which is recognised but excluded.

As there is no direct cost to households or individuals (it is a loss of other government services) the money values are likely to be higher than if a specific tax was introduced. An alternative approach, which was identified after the survey, is to frame the value question in terms of willingness to pay a levy under a regional or national pest management strategy (NPMS). Biosecurity New Zealand has the power to declare a NPMS under the Biosecurity Act subject to a process and certain conditions. This allows regional councils to raise a specific levy on rate payers to manage a pest.

The significance of income in estimated models may have been reduced by the structure of the income question. Respondents were asked for "your total income before tax last year" and may have responded in either of two ways as the income question was not specific as to whether it was asking for personal or household income.

Additional socio-demographic characteristics that may strengthen the model include questions on whether respondents had previously visited the study site or whether they recreate there now. Similarly, it may have been worth questioning whether respondents harvest shellfish, have kids who paddle in the estuary, or are members of environmental organisations.

12.0 Benefit transfer

Benefit transfer is the utilisation of results pertaining to one area and transferring them to other similar areas. The Pauatahanui Inlet is representative of many similar estuaries and harbours around the coast of New Zealand. A key question is how relevant are these results to possible like incursions in other estuaries around the coast of New Zealand? If there is a one off incursion that is restricted to a single estuary then the dollar values are likely to be of a similar order. If, however, the incursion spreads to other estuaries then the dollar value per estuary is likely to be conservative. Clearly the loss of value for the first estuary affected is going to be a lot less than the last estuary affected.

Caution needs to be exercised in using these figures in a policy context in making decisions about response programs. In making a transfer the dollar values depend on assuming that the marginal losses are permanent, transferable to other habitats, constant over time, representative of a range of invasive species, and most importantly represent the views of a cross-section of New Zealanders.

But many things are changing over time. For example, the composition of New Zealand's population is changing over time towards more Polynesian and Asian ethnic groups, each generation is becoming wealthier in material goods than the previous one, and there are increasing concerns over the negative impact of economic growth on the environment. Overriding all these changes is the likelihood of climate change. Potentially, climate change could have a much greater impact on the coastal marine environment by creating conditions that are more suited to invasive plants and animals that New Zealand's climate has not been suited to up to now.

The marginal values estimated in this study place dollar values on impacts on the environment due to an invasive species. Previous studies on possums (Lock 1992; Kerr and Cullen 1995) have estimated dollar values on the environment. Further research is required to give validity to these results and a great deal of caution should be exercised in using these values in a cost benefit analysis context.

13.0 Conclusions

The dollar values for loss of biodiversity and other environmental attributes due to a hypothetical aggressive crab incursion in Pauatahanui Inlet provide estimates of environmental loss values for use in analysing biosecurity response in the coastal marine environment. But, caution needs to be exercised when applying these values in benefit cost studies of other invasive species in other coastal marine environments.

The information on the marginal rates of substitution between environmental attributes will be useful for estimating money values for all the attributes given a statistically significant money value for one. Thus the MRS information is an important output of the study.

And finally, further research should be undertaken to assess the repeatability of these results.

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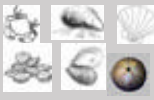
Appendix 1: Example of a choice set

1. Question 1: options A, B and C. Please choose the option you prefer by ticking ONE box					
Extra cost each year	% reduced recreational shellfish take for 3 years	% vegetation dies	Number of shellfish species that disappear	Children paddling on waters edge	I would choose ☑
Option A					
		R.I.P		No	A ☐
$0	100%	50%	3		
Option B					
$		R.I.P		Yes	B ☐
$2 million	0%	10%	0		
Option C					
$		R.I.P		Yes	C ☐
$2 million	100%	50%	0		

Appendix 2: Example of a flier sent to meeting organisers

11 June 2007

Research on the Coastal Marine Ecosystem affecting you

You are invited to take part in an evening aimed at finding out the values you place on the coastal marine environment. Your involvement will assist your community through a donation we will make of $1,500.

New Zealand is continually exposed to foreign pests and diseases that can potentially threaten our coast line. Some of the values threatened are difficult to place monetary values on as there are no market prices. Nevertheless these nonmarket values are important to people. Placing values on them will help Biosecurity New Zealand provide more informed advice to the government than is currently possible.

The evening will take the form of a group exercise where information will be given out prior to a series of questions. These questions will relate to values of the coast line including potential changes to what you see and experience, sea food catches and the costs of eradicating a new pest threatening the coast.

No particular qualifications or experience are necessary. We are interested in your personal views. The information you provide will be kept confidential, will not be disclosed in any way that will identify you and you may withdraw at any time. No preparation is necessary just come along.

Supper will be served at the end and everyone completing the exercise will be provided with a $20 petrol voucher to assist with travel expenses.

We can guarantee an interesting evening and look forward to seeing you. If you would like further information please contact me.

Date:	Monday 2 July 2007
Time:	7.00 to 8.30pm, followed by supper
Place:	Plimmerton Pavilion, opposite the fire station on the beach.

Brian Bell
Research leader
Phone: 04 472 4629
Email: brian@nimmo-bell.co.nz

Appendix 3

Experimental Design

	Attributes				
Rows	A	B	C	D	E
1	-1	-1	-1	-1	-1
2	+1	-1	-1	+1	+1
3	-1	+1	-1	+1	-1
4	-1	-1	+1	-1	+1
5	+1	+1	-1	-1	+1
6	+1	-1	+1	+1	-1
7	-1	+1	+1	+1	+1
8	+1	+1	+1	-1	-1

Source: Johnson, Kanninen *et al* 2007, p193

Note: -1 is the attribute level for Response 1 and +1 is the attribute level for Response 2 as set out in Table 2.