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Does the economic benefit of biodiversity enhancement exceed the cost of conservation in planted forests?

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Abstract

The study evaluates a proposed programme that would sustain and enhance the provision of ecosystem services in planted forests. We focused on the evaluation of the benefits and costs of the conservation of the brown kiwi (an iconic yet threatened New Zealand bird species) that inhabits planted forests. Yao et al. (2014) found that a sample of 209 New Zealand (NZ) households would, on average, financially support a programme for conserving the brown kiwi in NZ planted forests. We extend that study using a proof of concept that integrates economic, ecological and spatial approaches. We undertake this in five steps: 1) supplementing a previous choice experiment survey by interviewing more than 900 additional georeferenced households; 2) estimating household-specific means of marginal willingness-to-pay (WTP) values; 3) using spatial econometrics to explore WTP determinants; 4) identifying 12 ecologically and economically feasible ecosystem-service sites (ranging from 5,000 to 11,500 hectares) and calculate the average annual costs of a conservation programme at each site; and finally 5) aggregating the public benefits of biodiversity at the regional and national levels and calculate the benefit cost ratio. We found that the value of the proposed biodiversity conservation initiative at the national level can be more than 100 times higher than the overall cost of the programme. To prioritise intervention of this initiative, we also identify the New Zealand region with planted forest sites that would produce the highest net economic benefit from the enhanced provision of ecosystem services.

Keywords

ecosystem services, choice experiment, planted forests, brown kiwi, New Zealand

1. Introduction

The original native terrestrial fauna of New Zealand (NZ) consisted of many bird species elsewhere occupied by mammals. Over the past few centuries, many NZ native species have been under threat of extinction due to the arrival of the Polynesian and the European settlers, who introduced a variety of exotic species (McGlone, 1989). Native habitats have significantly declined in quality and extent, and, in combination with these new predatory mammals, 40 terrestrial bird species are known to have subsequently become extinct (Wilson, 2017). Many other extant species are continuing to decline in number, and conservation efforts have been put in place to slow down or reverse this trend for some of these species (Department of Conservation, 2016). Much of this effort is taking place in native forest habitat, which sustains an intricate flow of ecosystem services. Yet, cost-effectiveness of conservation initiatives is important given the small economy of NZ and the number of competing species to which the conservation budget can be spent on. With this study we intend to inform this cost-effectiveness with the goal of enhancing native species richness in exotic planted forests, as opposed to native forests, which is a key aspect of biodiversity conservation.

Conservation of NZ wildlife is of local and global importance. Balmford, et al. (2002) suggested that, for every dollar invested in an effective wildlife conservation programme, the long-term benefits can be at least $100. Over the past two decades, initiatives that focus on species conservation on private land attracted significant attention globally and in NZ (Carnus, et al., 2006; Clough, 2000; Figgis, 2004; Humprey, et al., 2003; Karsenty, 2007; Langpap, et al., 2012). Virtually all of the 1.7 million-hectare NZ planted forest estate consists of exotic tree species, with 90% planted in *Pinus radiata* (Ministry for Primary Industries, 2015). These forests provide habitat to at least 118 threatened native species, including iconic birds such as the brown kiwi (*Apteryx mantelli*) and the bush falcon (*Falco novaeseelandiae*) (Pawson, et al., 2010). Conservation of key native species in planted forests is economically valuable to New Zealanders and their identity. Yao et al. (2014) found that a sample of 209 NZ households would, on average, financially support a programme for conserving key threatened native species in planted forests. They also identified key spatial and socio-economic factors that are statistically associated with the amount of money that people would be willing to pay for such conservation. However, that study used a relatively small sample size and did not address the comparative costs of undertaking such programme at different suitable locations.

The present study extends Yao et al. (2014) using a proof of concept that integrates economic, ecological and spatial approaches. The economic approach involves the use of stated preference survey data collected via a discrete choice experiment to value forest ecosystem services linked to changes in species abundance. The ecological approach includes expertise on the effective conservation of the native brown kiwi at various candidate forest sites and associated conservation costs. The spatial approach enables the integration of spatial data into the econometric analysis and the spatial aggregation of conservation values.

This paper aims to develop a better understanding of the perceived importance of increasing the abundance of a key threatened native species in various planted forests and the factors affecting those perceptions. Specifically, it aims to: 1) estimate how much NZ households would be prepared to pay, on average, for a proposed conservation programme in planted forests; 2) identify the key factors influencing average “willingness to pay” (WTP) per household for the proposed programme; 3) account for spatial dependence of the value placed on biodiversity; 4) identify and evaluate feasible biodiversity enhancement of the planted forest sites; and 5) further assess the suitability of non-market valuation techniques in NZ.

This paper has six sections. Section 2 presents the importance of studying biodiversity values by combining economic valuation techniques with other methods. Section 3 describes the methods. Section 4 provides an overview of how data were collected and a summary of their main statistics. The results are reported in Section 5. Discussions, policy implications and future directions are in Section 6.

2. Background

There has been a growing concern about the exclusion of biodiversity considerations in decision making aimed for economic development. Decision processes that omit these considerations have been shown to result in conservation investments that degrade natural capital and are Pareto sub-optimal (TEEB, 2010; UKNEA, 2011). To include economic values of biodiversity in such decision making it is necessary to provide sound estimates based on a framework that links economic, environmental and social thinking (Boyd, et al., 2016). Estimation of cost and benefits of biodiversity enhancement entails combining biophysical, spatial and social approaches to account for its multifaceted nature and their variation across space and people (Laurila-Pant, et al., 2015).

Globally, the conservation of threatened and endangered species is valuable. People whose immediate needs of shelter, clothing, food and basic healthcare are satisfied tend to display a positive willingness-to-pay for (or spend volunteer time on) conservation programmes (e.g. environmental Kuznets curve (Kuznets, 1955)). This may prevent threatened species from further decline, or it may increase the chance of their survival (Kaval, et al., 2009; Lew, 2015; Ninan, 2007; Richardson, et al., 2009; Yao, et al., 2010; Yao, et al., 2014).

There are a large number of endangered species unique to NZ. Some can be regarded as iconic because of their strong link to the NZ identity, others are also ecologically valuable globally (DOC, 2014; Loomis, et al., 1996). Recent assessments show that a considerable number of native species have become extinct and about 3,540 terrestrial species are considered as either “Threatened” or “At Risk” of extinction (Hitchmough, 2013; Newman, et al., 2013; Robertson, et al., 2013). Even the nation’s national symbol, the brown kiwi, has become notoriously threatened by extinction (Holzapfel, et al., 2008), mainly due to the high predation rates of juvenile kiwi by introduced predators (McLennan, et al., 1992). This type of situation has been found to contribute to the development of initiatives aiming to conserve the remaining threatened species in both public and private land in NZ and elsewhere (Langpap, et al., 2012; Yao, et al., 2010).

Conservation of threatened and of iconic species have been found to be valued in stated choice surveys of the general NZ public (thereby providing public benefits) (Yao and Kaval 2010; Yao et al. 2014). Sites of high conservation value can often occur on private land, and conservation initiatives under private management have been increasing (Figgis, 2004; Ministry for the Environment, 2010). The costs of management at these sites are usually shouldered by private organizations, which include forest owners and timber production companies (Yao, et al., 2017).

Studying biodiversity conservation in NZ is timely because of the on-going consultation meetings of the government to further develop the proposed National Policy Statement on Indigenous Biodiversity, which also aims to promote the maintenance of indigenous biodiversity on private land while also recognising the rights and responsibilities of landowners and the interests of indigenous people (Ministry for the Environment, 2015). In addition, although one-third of the country's land area is legally designated as conservation land, and therefore conservation objectives are mandatory, many conservation initiatives and incentives occur on private land (Clough, 2000; Ministry for the Environment, 2007) and need to be conducted in a socially cost-effective manner. More recently, the NZ government has passed the National Environmental Standards for Plantation Forestry which specifically stated the importance of protection of threatened bird species (including the brown kiwi) that inhabit planted forests (New Zealand Parliament, 2017).

3. Methods

We have combined synergistically four disciplinary approaches for this work consisting of a stated preference exercise (specifically a choice experiment), spatial econometrics, ecological suitability evaluation and a spatial forecasting approach. The choice experiment technique was used to estimate averages of individual specific WTP values of the biodiversity benefit from brown kiwi conservation. To evaluate the determinants of mean estimates of individual marginal WTP while accounting for the potential spatial autocorrelation, we used spatial econometrics. Candidate determinants included sociodemographic variables collected from the survey and census data at the meshblock[1] level collected from the Statistics NZ website. An ecological approach was also used to: 1) identify sites where conservation would be feasible; and 2) calculate the associated cost of a proposed biodiversity programme. For the forecasting of the average WTP at the meshblock level and its aggregation for the cost-benefit analysis, we employ a spatial approach. The key results informed a cost-benefit analysis to evaluate the private cost and public benefits from a biodiversity enhancement program aimed to increase the brown kiwi population at the sites identified as suitable for intervention. The following sections explain each step in turn.

[1] Meshblock is the smallest spatial unit for which we have census data in New Zealand.

3.1 Stated preference approach – choice experiment

The public benefit of the conservation of threatened native species in planted forests may produce both use and non-use values (Yao, et al., 2014). Use value includes, for example, benefits derived from non-consumptive recreational bird watching activities. Non-use values, instead, include existence and bequest values (Champ, et al., 2003). To account for both sources of value delivered by the proposed five-year biodiversity conservation programme, we used a stated preference method often referred to as discrete choice experiment (DCE, see (Carson, et al., 2011)). DCEs rely on the analyses of discrete responses from experimentally designed surveys. Respondents are assigned choice tasks and asked to choose between experimentally designed policy alternatives and a status quo option which can represent the current condition (Figure 1). In our case designed alternatives varied systematically in terms of endowment of environmental resources (Bateman, 2012; Bateman, et al., 2002) as determined by various levels of ecosystem services produced by conservation efforts.

In our survey, the attributes used to describe alternatives in the choice experiment included five iconic species native to NZ planted forests, which are currently threatened, as well as a cost attribute (Figure 1). Attributes and their levels were derived from results from focus groups and from one-on-one discussions with ecologists and fellow economists. Development of the choice task and how focus group sessions are described in detail in Yao et al. (2014). In brief, to allocate attribute levels to the alternatives in the survey choice tasks we have used three experimental design criteria (orthogonal design, optimal orthogonal in the difference and the Bayesian D-error minimising (see Scarpa and Rose (2008)).

The panel data from the choice experiment were used to estimate a random utility model using standard techniques based on mixed logit models, as described in the literature (Train, 2009). Specifically, to ease estimation of marginal WTP values for each attribute, a specification of utility in the WTP-space was used (Train, et al., 2005). This approach affords more control to the analyst about the distribution of values in the population (Scarpa, Thiene, et al., 2008) than conventional specifications on the preference-space. From the population estimates and the sample choices, we estimated conditional means of WTP distributions for each biodiversity attribute and for each respondent in the sample. These were obtained to allow us to further explore the determinants of their variation. This method is explained in the next section, with a focus on the conservation effort for brown kiwi.

3.2 Using OLS and spatial econometric models to identify WTP determinants

The individual specific estimate of means for the marginal WTP for an increase in abundance of each of the five threatened species are described in 3.1. In this benefit cost analysis, we decided to focus on the level 2 increase in abundance of brown kiwi. Only about two percent of the NZ meshblocks were represented in our sample. So, in order to be able to forecast mean values of WTP for those meshblocks that were not part of the sample, we searched for an equation capable of forecasting these values spatially. We assume that the individual means for the marginal WTP depend on two categories of determinants: socio-economic variables measured at the household level (including distance from planted forest) and geographical variables measured at the meshblock level.

Threatened Animal/Plant	*Current Condition*	*Option G*	*Option H*
Brown Kiwi (Frequency of hearing calls in planted forests in North Island) 	Kiwi calls heard **in 1 out of 200** planted forests	Kiwi calls heard **in 10 out of 200** planted forests	Kiwi calls heard **in 20 out of 200** planted forests
Giant Kokopu (Occurrence in slow moving streams with overhanging native vegetation in planted forests throughout New Zealand) 	Kokopu seen **in 1 out of 10** suitable streams	Kokopu seen **in 5 out of 10** suitable streams	Kokopu seen **in 1 out of 10** suitable streams
Kakabeak (Occurrence in 20% of the planted forests on the East Coast and Hawke's Bay) 	At least **3 naturally occurring** Kakabeak shrubs	At least **10 actively managed** Kakabeak shrubs	At least **20 actively managed** Kakabeak shrubs
Auckland Green Gecko (Gecko sightings in open grounds in planted forests in Northland, Waikato and Bay of Plenty regions) 	Gecko sighted **in 1 out of 50** walks	Gecko sighted **in 1 out of 50** walks	Gecko sighted **in 3 out of 50** walks
NZ Bush Falcon (Bush falcon sightings while driving through pine forests in Central North Island and Nelson) 	Bush falcon sighted **in 1 out of 8** drives	Bush falcon sighted **in 1 out of 8** drives	Bush falcon sighted **in 3 out of 8** drives
Additional amount to be paid yearly in your income tax for five years only	**$0**	**$35**	**$70**
I would choose (please tick)	☐	☐	☐

Figure 1. Example of a choice task used in the 2015 online survey.

In essence, we intend to explore how the variation of these WTP estimates can be explained on the basis of socio-economic characteristics of respondents and the characteristics of the area where respondent lives. Regression models using estimators such as Ordinary Least Squares (OLS), Spatial Lag and Spatial Error (Anselin, 1988) are used to explain the variation in WTP. The model specification is expressed as:

$$WTP_i = \alpha + X_{ki}\beta_k + Z_{qi}\gamma_q + F_i\theta + \varepsilon_i \quad (1)$$

where *i* denotes respondent, α is the constant value of WTP unexplained by other determinants, X_{ki} is a vector of *k* socio-economic characteristics, Z_{qi} is a vector of *q* characteristics of the meshblock where the respondent lives, F_i is an indicator variable if a respondent is residing between 10 and 50 km away from large planted forests (identified spatially), while γ_q, β_k and θ are parameters of associated marginal effects to be estimated based on the combined survey, meshblock and spatial data.

3.3. Ecological suitability approach

The NZ planted forest estate provides suitable and manageable breeding habitats for threatened native birds such as the brown kiwi and the bush falcon (Miller, et al., 1995; Robertson, et al., 2011; Seaton, et al., 2009). However, the degree of suitability varies across locations. On one hand, some planted forests are adjacent to a native forest where pest control and other conservation initiatives have been undertaken to conserve the native bird population (Bliss, 2007; Holzapfel, et al., 2008). This makes them ideal sites to establish a biodiversity enhancement programme as there is already some form of natural habitat nearby to build on. On the other hand, some planted forest areas cannot support a conservation programme at all. For instance, the brown kiwi are only found in certain areas of NZ North Island and there are areas where biodiversity enhancement may be unfeasible either for ecological reasons or because it is too costly to undertake (Holzapfel, et al., 2008). Therefore, we used our expert knowledge about the ecological potential of a forest to sustain a biodiversity programme, which includes extensive knowledge of brown kiwi conservation that can help identify feasible biodiversity enhancement locations across the North Island.

We focus on the brown kiwi because it is one of the most studied and best documented native birds in the country (Holzapfel, et al., 2008). There are several sources of information about the location of its habitats and the necessary activities or measures for a successful conservation programme.

In the valuation scenarios presented to respondents, we specifically mentioned in one choice task attribute that the proposed programme will focus on increasing the abundance of the brown kiwi in planted forests in the North Island (Figure 1). This corresponds to the fact that brown kiwi have a non-continuous distribution in the North Island based on Holzapfel et al. (2008) (Figure 2). There are other species kiwi in the South Island, but we have only considered the North Island brown kiwi in this paper.

The ecological component involved the following steps: 1) identification of the location of brown kiwi conservation sites in planted forests; 2) discussions of the requirements for having a conservation programme for each site; and 3) approximating the cost of conservation for each site.

To identify prospective biodiversity enhancement sites, we used the following criteria: (a) brown kiwi has an existing habitat that can be sustained or enhanced; (b) at least 5,000 hectares of a contiguous land area;[2] (c) the planted forest site should be adjacent to a native forest; and (d) there should be proportions of planted to native forest mix ranging from 10:90 to 90:10, which can be grouped into low, medium and high planted forest proportions. Using geographic information system (GIS) maps and knowledge of the kiwi conservation activities in NZ, the study team consisting of two economists, a geospatial scientist and an ecologist identified ecologically feasible forest sites for increasing the abundance of the brown kiwi. For each conservation site, it was assumed that appropriate mechanical predator-killing traps will be installed, monitored, baited and maintained to ensure effectiveness. An evaluation of the population of brown kiwi, which includes recording and analysis of kiwi calls by a kiwi expert, was also included in the five-year programme to get an indication of the effectiveness of the trapping activities.

[2] This minimum contiguous area requirement was employed by Yao et al. (2014) and has been recommended as a minimum area for this study by the author with the ecological background.

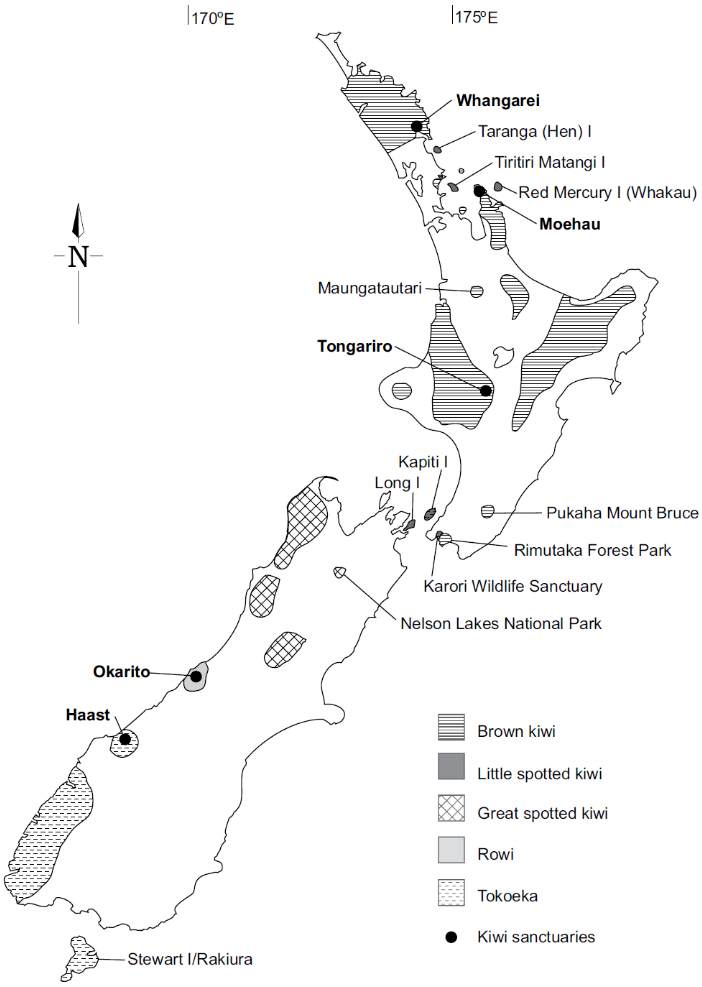

Figure 2. Map of New Zealand showing the location of habitats for the North Island brown kiwi and other kiwi species (Source: Holzapfel et al. 2008).

The most appropriate mechanical traps for each site could be either DOC 200 or DOC 250.[3] These traps are baited with a meat lure and checked fortnightly in summer and bimonthly in winter. Bait is replaced monthly in summer and bimonthly in winter. Traps are stainless steel and secured within a four-sided wooden box with wire mesh covering each end of the box.[4] A small hole is cut in each mesh to that allows the target pest animal (usually a stoat (*Mustela erminea*)) to enter, but which excludes larger native bird species). The traps have passed humane National Animal Welfare Advisory Committee guidelines for stoats (DOC 200) and for stoats and ferrets (*Mustela furo*) (DOC 250) (MAF, 2010). The conservation activities constitute the essence of the biodiversity conservation programme for each site on which we based our costing estimates and identification procedures to establish suitability.

3.4. Spatial approach for aggregating biodiversity values

[3] There can also be other approaches to enhance biodiversity in planted forests such as operation next egg and aerial dropping of poison baits. Those two approaches would be a good future study.
[4] For illustrations of traps we refer to the reader to visit the websites:
http://www.doc.govt.nz/Documents/conservation/threats-and-impacts/animal-pests/doc200-predator-trap.pdf; and
http://www.doc.govt.nz/Documents/conservation/threats-and-impacts/animal-pests/doc250-predator-trap.pdf

As biodiversity supply and demand vary across space, especially in consideration of the pattern of human settlement and planted forest location in the North Island of NZ, a spatial approach is needed. Average WTP forecasts were obtained for the representative household (HH) at each meshblock[5] and then expanded to the meshblock HH population to derive the aggregate benefits for a brown kiwi conservation programme. To forecast these values, information was generated using the above three approaches and combined with meshblock-level data published by Statistics New Zealand (SNZ).[6] Each meshblock is assigned a unique identifier, which enables these data to be merged with other GIS data in the GIS software ArcMap 10. ArcMap 10 was used to spatially aggregate the estimated averages of marginal WTP values and the factors affecting those values.

The benefit cost analysis is conducted at the level of four of the sixteen regions in NZ. For each of these four, three forest plantation sites were identified as suitable to host the conservation program. So, forecasts of benefits at each of these four regions, as well as at the national level, are necessary to inform the benefit-cost analysis of the conservation programme.

For the WTP aggregation, we employ a formula that includes the coefficient estimates from the regression model that determines the socio-economic and meshblock factors that influence marginal WTP (Equation 1). Equation 2 includes estimates for the constant α which represents the conditional mean of marginal WTP for brown kiwi, the vector of coefficients for K socio-economic characteristics β_k, and the of vector of coefficients for Q meshblock characteristics γ_q. The constant α is multiplied by the total number of HHs in the aggregation area (e.g. region, NZ); β_k coefficients are multiplied by the corresponding S number of relevant HHs for each meshblock; while γ_q coefficients are each multiplied by their corresponding number of relevant HHs for each meshblock (Equation 2). To account for the econometric result that indicate that HHs with higher income levels would likely pay more, we multiply the number of high income HHs in the meshblock by the estimated coefficient for higher HH income. There can also be other meshblock or socio economic characteristics that positively or negatively affect household WTP to the conservation programme. H_m represents the number of HHs in the meshblock, S_k is the fraction of HHs in the meshblock to which the socio-economic condition applies, and R_q is the fraction of HHs in the meshblock to which the meshblock condition applies. These above mentioned terms of the equation account mostly for non-use values, as use values are expected to be a function of proximity and hence to depend on distance of planted forest under the conservation program from the place of residence. In this regard, we included the term $\theta \times D$ to account for this distance effect on the forecasted mean of the marginal WTP, where θ is coefficient for residing within a particular distance band from a large planted forest and D is the number of households that have been spatially identified to be living within the 10-50km radius in terms of road distance from the planted forests where a proposed biodiversity enhancement programme will be undertaken. The term therefore represents the aggregated

[5] A meshblock represents the smallest geographical unit for which statistical data is collected.
[6] SNZ conducts a census every five years, with the last one being undertaken in 2013. Census data are compiled at the national, regional, district, and meshblock levels. This meshblock data is available as GIS data (www.koordinates.com) which can be combined with the census data (www.stats.govt.nz).

effect on marginal WTP of all HHs living close to the proposed conservation site. Results originally reported in Yao, et al. (2014), and confirmed here, suggest that respondents who lived within a distance band from large planted forests would be willing to pay more for a proposed biodiversity conservation programme.

$$\sum_{m=1}^{M} WTP_m = (\alpha_m + \alpha_q) \times H_m + \theta \times D + \sum_{k=1}^{K} \beta_k \times S_k, \text{ where } \alpha_q = \sum_{q=1}^{Q} \gamma_q \times R_q \qquad (2)$$

4. Data

The approaches described in the methods section were used to analyse four different sets of data. The first data set was elicited from a survey which aimed estimated preferences in the population for various conservation efforts, one of which included higher levels of conservation of brown kiwi in planted forests at an increased level of general taxation. The second dataset includes the construction of geo-referenced individual-specific estimates of WTP across residential location of respondents. This allowed the application of spatial econometric models to evaluate the association of marginal WTP estimates with socio-economic characteristics of respondents augmented by the socio-economics of the area of residence as reported from the local statistics from the most recent NZ Census (Statistics New Zealand, 2014). The third dataset concerned the costing of the conservation programme capable of preserving the ecosystem services to support an increased in the brown kiwi population to the levels used in the choice experiment survey. These costs were calculated at 12 selected planted forest sites. The fourth data set include meshblock level data from census data from SNZ that have been used in Equations 1 and 2 to compute aggregated value forecast of marginal benefits.

4.1 Choice experiment data

The first stage of data collection involved the administration of the DCE survey using the same questionnaire used by Yao et al. (2014), which was based on survey data collected in 2010. Yao, et al. (2014) and (Yao, 2012) describe the biodiversity valuation questionnaire in further detail. The DCE survey data used in this study consists of two sets: the first set was derived from the 209 respondents in the 2010 survey by Yao, et al. (2014) where each respondent was asked to evaluate nine choice tasks. Most respondents in 2010 completed the choice experiment questions using a paper-and-pen mailed out survey, which they returned using stamped self-addressed envelopes. The second set of DCEs data was collected using an online survey where 1,356 respondents completed the survey between January and June 2015. By merging the two sets of survey data we derived 12,537 choice observations. With a time difference of five years (2015 and 2010), we have inflated the bid levels (or cost attribute) in the choice tasks based on the NZ CPI inflation factor from $30, $60, $90 in the 2010 survey to $35, $70, $105 in the 2015 survey (Figure 1). As an incentive to take part, respondents in 2015 were provided the option to join the prize draw where each could win one of five NZD100 pre-paid debit cards. All 2015 online respondents were recruited in one of three ways and these methods are described in Appendix A.

4.2 Spatial econometrics data

Choice responses from georeferenced HHs surveyed in 2010 and 2015 were merged into a single dataset. After estimation of the mixed panel random utility logit model the data set resulted in 1,565 sets of HH-specific averages of marginal WTP estimates: one WTP series for each increase in abundance of the five threatened native species in planted forests. Given our focus on brown kiwi, we have only arranged the spatial econometric data set for the WTP estimates of brown kiwi. This included the respondent's characteristics (e.g. income level, age) collected from the survey questionnaire as well as the 2013 meshblock level census data of the electoral meshblock in which the respondent resides at the time of survey. As not all HHs were georeferenced and some were unable to report their socio-demographic data, the valid respondents in the spatial econometric data set was reduced to 1,032 HHs. These HHs resided in 840 NZ meshblocks out of the total of 46,621 meshblocks in the country (the sample represents about 2%). The location of each georeferenced respondent was matched with the meshblock identification number in the Statistics NZ meshblock database. This enabled us to assign the corresponding meshblock data for each respondent such as the percentage of HHs in the meshblock with mobile phones and the percentage of HHs earning on wages. The construction of this data set allows the identification of HH level and meshblock level factors that influence WTP for the proposed biodiversity programme (Table 1).

Table 1. Summary of variables used in the regression models for identifying WTP determinants (n=1,032).

Variable	Mean	Standard deviation
WTP for brown kiwi (NZD/year) (Min = NZD4, Max = NZD200)	89.41	29.21
Survey data		
Respondent's annual income ≥ $70,000/year	0.16	0.36
Either one or two adults in the household	0.73	0.44
Respondent's age 55 and above	0.18	0.39
Good understanding of the programme	0.48	0.50
Household surveyed in 2015 (1 if yes, 0 otherwise)	0.94	0.24
Respondent found the questionnaire easy to complete	0.29	0.45
Meshblock (MB) level data derived from SNZ		
At least one HH in MB works for mining industry	0.45	0.50
At least one HH in MB objects to religious questions	0.58	0.49
At least 75% of HH have access to mobile phones	0.89	0.31
At least 50% of HH were on wages and salaries	0.90	0.30
Spatial variable derived using spatial analysis		
Indicator if HH resides between a 10km and 50 km driving distance from a large planted forest	0.04	0.20

4.3 Ecological suitability and cost data

Following the site selection criteria described in Section 3, we compiled relevant GIS maps, which include the NZ Land Cover Database version 4.1, to locate areas where native and planted forests overlap. We also made use of brown kiwi management maps from the Department of Conservation to identify areas where conservation programmes have been undertaken. Using these maps and overlaying them enabled the team to identify 12 planted forest sites across the North Island distributed across four geographic locations: Central North Island (CNI) in the Manawatu-Whanganui Region; Bay of Plenty (BOP) Region; Coromandel in the Waikato Region and the Northland Region (Figure 3). The sites range in size from 5,000 to 11,500 hectares (Table 2). They also have varying proportions of planted-native forest mix, ranging from 19% to 61% planted forest. These sites are grouped based on the proportion of planted forest: (1) high (greater than 50%); (2) medium (26% to50%); and (3) low (less than 26%) (Figure 3 and Table 2). The larger stainless steel trap DOC 250 was assigned to the three sites in the CNI region and one site in the BOP region known to have ferrets present. For all other sites, DOC 200 traps were assigned as the majority of the predators consist of rats, stoats, weasels and hedgehogs which are effectively and humanely killed by these traps. As DOC 250 (NZD130/unit) is larger than DOC 200 (NZD120/unit), the former is NZD10 more expensive.

For all the 12 sites it is ecologically feasible to maintain and sustain a kiwi population based on the three conditions that each site has: 1) an area of at least 5,000 ha to encompass the dispersal distance of sufficient juvenile kiwi produced within the low mustelid (trapped) area to allow these kiwi, upon breeding, to also attain a sufficient kiwi chick survivorship in order to sustain the resident kiwi density; 2) square-shaped predator control area where it is practical to maximise the area of low mustelid abundance within the trapped area; and 3) an existing population of brown kiwi which provides an opportunity for the resident kiwi chicks produced to survive to breeding age as a result of the predator trapping intervention.

The costs of a biodiversity enhancement programme have two components: trapping predators and monitoring kiwi. The cost of trapping predators is generally lower in exotic forests due to the presence of roading infrastructure, allowing more cost-effective access to trapping apparatus (i.e. more traps can be checked per day in vehicle-accessible sites). To be effective in lowering predator numbers in order for brown kiwi and their offspring to survive, mustelid traps should be spaced about 1 trap per 5 ha, with larger sites requiring more traps. Trapping costs consists of the purchase cost of the stainless steel trapping unit (~NZD125/unit), labour for installing the unit at the site (NZD300/person-day at 50 units installed per day) and labour for checking traps for caught predators once a month (a labourer can check approximately 80 traps per day). For a five-year conservation programme, we assume that traps are purchased and installed on site at the onset (Year 0). Checking, cleaning and maintenance of installed traps occur every month for five years (Years 1 to 5). The predator trap is made up of stainless steel in a wooden box and will remain usable for the entire duration of the programme.

Table 2. The 12 biodiversity enhancement sites.

Site number	Region	Location	Type of DOC trap	Area (ha)	Proportion of exotic planted forest*	% of forest by type		
						% exotic	% native	% others
1	Manawatu-Whanganui	Rangataua-Karioi forest	250	10,000	medium	41	57	2
2	Manawatu-Whanganui	Waimarino Forest	250	10,000	high	61	34	5
3	Manawatu-Whanganui	Tongariro Forest	250	10,000	low	21	69	0
4	Bay of Plenty	Omataroa Forest	250	10,000	high	60	20	20
5	Bay of Plenty	Ohope	200	10,393	low	25	30	45
6	Bay of Plenty	Waioeka Forest - Waiotahi	200	10,553	medium	27	61	12
7	Waikato	Tairua	200	10,000	low	23	59	18
8	Waikato	Ohuka beach Peninsula	200	11,489	low	24	41	35
9	Waikato	Waiau-Coromandel harbour	200	5,257	medium	40	53	7
10	Northland	North of Whangarei Harbour - Waiparera	200	10,000	low	19	45	36
11	Northland	Marlborough/Kaihu Forest	200	10,000	high	53	44	3
12	Northland	Motatau Forest	200	10,000	medium	42	28	30

*Note: For proportion of exotic planted forest, the three categories are: (1) high - greater than 50%; (2) medium - between 26% and 50%; and (3) low - less than

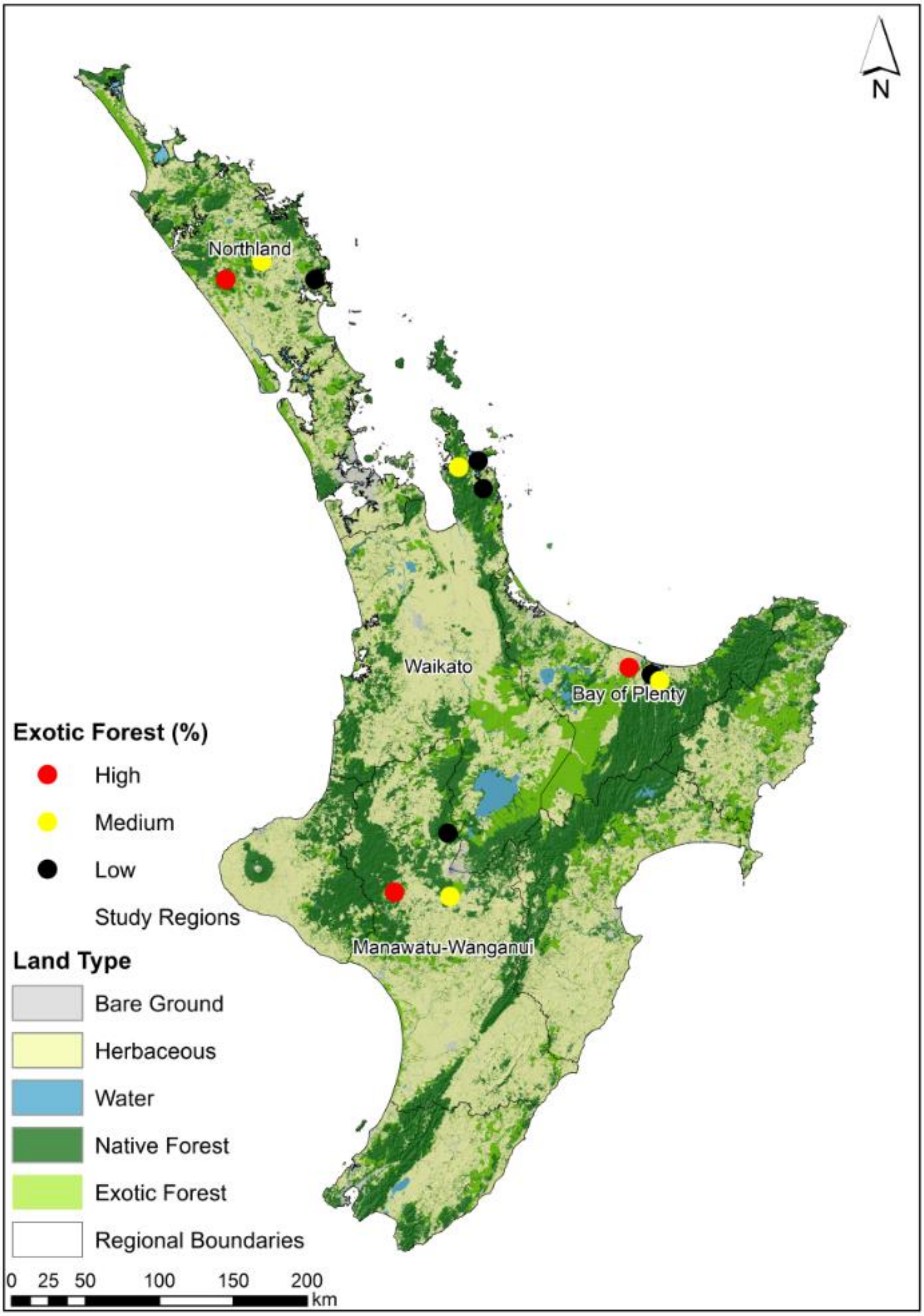

Figure 3. Map of the North Island showing the 12 biodiversity enhancement sites across four location groupings.

Monitoring consists of the purchase cost of the kiwi call recorders (NZD$200/unit), labour for installation of recorders, fees for analysing and reporting recorded data. We assume that purchase of recorders, installation and reporting will occur at the onset (Year 0) to monitor the initial level of kiwi abundance on site. Another set of recording activities will occur at the end of the programme to compare before and after scenarios.

4.4 Spatial aggregation data

We have used the 2013 socio-economic data by meshblock of Statistics NZ. This meshblock database contains NZ's 46,621 meshblock units; according to the data from the 2013 population census, 8% of these have no resident HHs (Table 3). The meshblock data were used to spatially aggregate the marginal WTP following Equations 2 and 3 to obtain national and regional values, inclusive of the four focus regions (Manawatu-Wanganui, Bay of Plenty, Waikato and Northland) of our conservation policy scenario.

Table 3. Summary of data by regional, island and national levels.

Region/Area	Population*	Number of households	Number of meshblocks units		
			Meshblock units	With households	Without households
Manawatu-Wanganui	236,900	87,003	3,191	2,957	234
Bay of Plenty	267,744	102,270	2,893	2,616	277
Waikato	151,689	58,944	2,067	1,886	181
Northland	403,638	150,174	5,163	4,673	490
North Island	3,237,051	1,160,670	34,108	31,649	2,459
South Island	1,004,400	388,965	12,513	11,370	1,143
New Zealand	4,242,051	1,549,890	46,621	43,019	3,602

Note: Data based on Statistics New Zealand's 2013 census

5. Results

We report three types of results: (1) the preference estimates from the choice model with utility in WTP-space and its sample estimates of individual means of marginal WTPs; (2) the regressions trying to explain the determinants of these individual means; and (3) the computation of costs and benefits of biodiversity enhancement in the biodiversity conservation sites identified in our policy scenario for the protection of brown kiwi.

5.1 Choice model estimates

We used the stated preference data collected from 1,565 respondents to estimate a mixed logit model with utility in WTP-space (Table 4). We employed the econometric model suggested by Train and Weeks (2005) and fixed the standard deviation to zero for those coefficient attributes that show no significant estimates for the spread. All Level 1 conservation efforts were shown to have no heterogeneity, while only for native fish was Level 2 conservation effort not heterogeneous. Coefficient estimates suggest that conservation efforts for all five species in question were valued, as indicated by significantly positive coefficient estimates for all marginal WTPs location parameters across all five species. We note that bird species, such as the brown kiwi and bush falcon, have higher WTP mean estimates than non-bird species. The native fish kokopu is the third most valued species, followed by the green gecko and the native plant kakabeak. The negative coefficient for status quo suggests that a typical respondent was not satisfied with the on-going decline of the native species in NZ, placing value on some conservation action.

Table 4. Estimates from the mixed logit model in WTP space used for calculating individual specific WTP (n = 12,537 choice observations).

Variable	Coefficient	Standard Error	t-statistic	*p*-value
Fixed				
Brown kiwi 1	63.93	3.46	18.48	<0.001
Bush falcon 1	52.80	3.24	16.31	<0.001
Native fish 1	27.15	2.79	9.72	<0.001
Native fish 2	35.30	2.99	11.81	<0.001
Green gecko 1	17.97	3.30	5.45	<0.001
Native plant 1	9.23	2.64	3.5	<0.001
Random				
Brown kiwi 2 mean	86.87	4.57	18.99	<0.001
Brown kiwi 2 st. dev.	54.18	4.92	11.02	<0.001
Bush falcon 2 mean	68.69	4.17	16.47	<0.001
Bush falcon 2 st. dev.	56.19	5.27	10.67	<0.001
Green gecko 2 mean	29.33	3.32	8.85	<0.001
Green gecko 2 st. dev.	64.20	4.49	14.29	<0.001
Native plant 2 mean	19.76	2.97	6.64	<0.001
Native plant 2 st. dev.	31.97	5.63	5.68	<0.001
Status quo	-70.45	10.66	-6.61	<0.001
Status quo st. dev.	280.29	15.79	17.75	<0.001
Random				
Cost/scale	-4.13	0.06	-69.85	<0.001
Cost/scale	0.75	0.05	13.78	<0.001
Log-Simulated likelihood at max	-9,651.01			

In the mixed logit model, we accounted for preference heterogeneity across respondents and have identified seven random parameters which include Brown kiwi 2, Bush falcon 2, Cost and Indicator for status quo. The estimated standard deviations of all seven random parameters are statistically significant at the 99.9% confidence level.

From the population estimates of the mixed logit model in WTP space, using the individual pattern of responses, we calculated the individual-specific means of marginal WTPs for increasing the abundance of brown kiwi as well as the other threatened species. However, due to space limitations, as an illustration we focus only on the WTP for the highest possible level of conservation effort in brown kiwi population (Brown kiwi 2). Figure 4 presents the sample distribution of these estimates for the 1,032 geo-referenced households. The graph shows a normal sample distribution with the 5th and 95th percentile of the respondents willing to pay $44 and $137 per year, respectively, for the five-year programme.

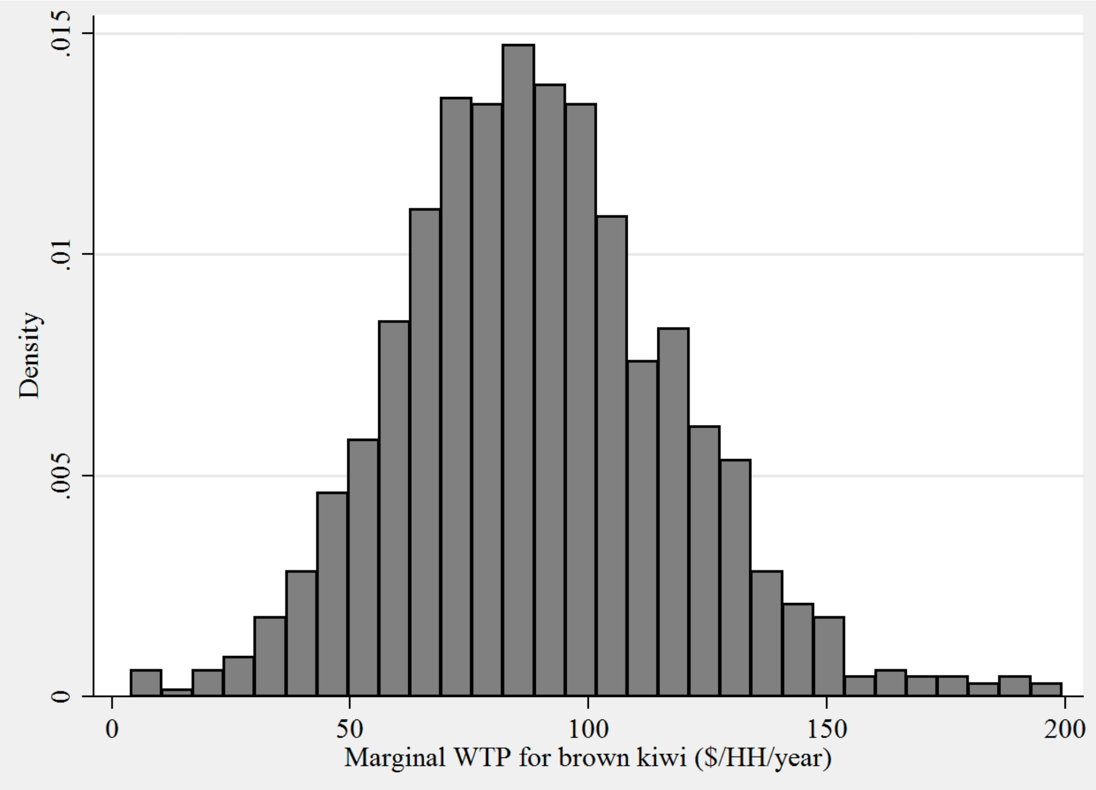

Figure 4. Individual specific marginal WTPs for brown kiwi 2 (n = 1,032).

Figure 5 plots the 1,032 georeferenced household specific WTPs for brown kiwi conservation in on a map of NZ. We found high WTPs estimates for conservation in both North Island and South Island, even though in the latter conservation cannot be implemented. This provides evidence of option, use and/or non-use values by respondents in the South Island. Looking closely at individual specific WTPs, there seems to be a pattern of spatial clustering between households, especially in key cities (e.g. Auckland, Christchurch, Wellington and Nelson). We have tested for the presence of spatial autocorrelation between WTPs across New Zealand using the global autocorrelation measure Moran's I but did not find statistically significant evidence of autocorrelation (Appendix B)

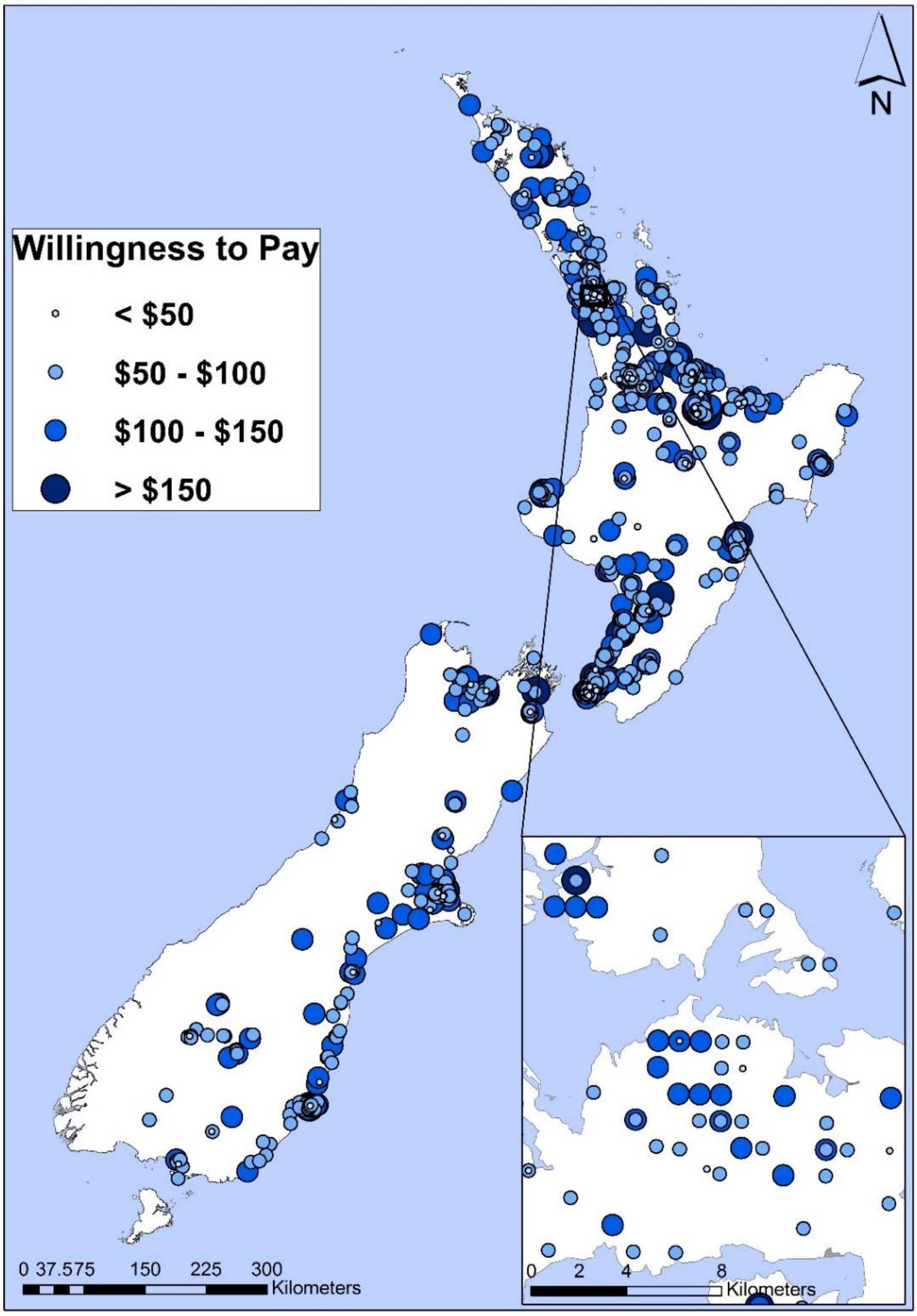

Figure 5. Geo-referenced WTPs for brown kiwi – Utility in WTP space

5.2 Determination of covariates of mean WTPs

Individual specific means of marginal WTPs may not only be influenced by covariates such as income, age, education and place of residence, but also by geographic factors (Campbell, 2007; Czajkowski, et al., 2016; Yao, et al., 2014). To determine the factors influencing WTPs we have created a data set with individual and location-specific covariates that can be analysed using linear and spatial econometric models. The latter models allow us to test and control for spatial autocorrelation effects within the regression model that explain the variation in WTP.

We have estimated three econometric models with spatial covariates (Models 1, 2 and 3). All models are specified in semi-log form where the dependent variable is the log of WTP while the explanatory variables are all binary indicator variables (Table 5). Model 1 is an OLS regression with Huber-White corrected standard errors (Greene, 2012) to account for heteroskedasticity. Results suggest that higher income levels (>NZD70,000 per year), number of adults, good understanding of the programme and respondents who completed the survey online positively influence WTP. WTP is positively affected also by having at least one HH objecting to religious questions in the census data at the meshblock level and by having more than half of the HHs reporting the reception of two or more wages. While being in a meshblock with more than 75% of HHs with access to mobile phones and being in a meshblock with at least one HH affiliated to the mining industry negatively affect WTP. The coefficient estimate on road travel distance from the residence to the nearest planted forest, which captures any use or option-use value, is positive and significant at the 90% level, which indicates that HHs within driving distance (between 10 and 50 km) to large forests would significantly pay more for the programme.

Models 2 and 3 are spatial lag and spatial error models, respectively. Their estimated coefficients suggest that we fail to reject the null hypothesis of no spatial autocorrelation at the 90% confidence level. The estimate of lambda (λ) in the spatial error model has a p-value of 0.287, and therefore insignificant.[7] Due to the absence of spatial autocorrelation, any kriging method is unwarranted in prediction. So, in the aggregation of WTP we use the OLS estimates from Model 1 which are statistically significant at the 90% confidence level. As this model is specified in semi-log form, we followed the formula described in Halvorsen, et al. (1980) to transform the coefficients into marginal effects or factors that can be used in the aggregation.[8] We present a summary of the transformed coefficients and describe the aggregation of WTP in section 5.3.2.

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[7] This result is in contrast to (Czajkowski, et al., 2016) and others that provide evidence that WTPs can be spatially autocorrelated in unrestricted regression models.

[8] Halvorsen and Palmquist (1980) suggest that to derive the marginal effect of a dummy variable from a semi-log specification, one should take the exponential of the coefficient of the dummy variable and then subtract by 1, or the relative effect of β on Y = $\exp(\beta) - 1$.

Table 5. Estimates from OLS and spatial econometric regression models (dependent variable: individual specific marginal WTP for brown kiwi; n=1,032; numbers in brackets () are standard errors).

	Model 1		Model 2		Model 3	
	Ordinary Least Squares		Spatial Lag		Spatial Error	
Constant	4.286	***	5.432	***	4.287	***
	0.066		(0.853)		(0.071)	
Annual income ≥ NZD70,000	0.103	***	0.101	***	0.098	***
	0.028		(0.032)		(0.032)	
One of two adults in household	0.072	**	0.071	***	0.071	***
	0.028		(0.027)		(0.026)	
Age ≥ 55 years old	-0.070	**	-0.069	**	-0.068	**
	0.029		(0.030)		(0.030)	
Good understanding of survey	0.079	***	0.078	***	0.079	***
	0.025		(0.025)		(0.025)	
Completed online surveyed in 2015 (1 if yes, 0 otherwise)	0.090	**	0.092	*	0.093	**
	0.039		(0.048)		(0.047)	
Found questionnaire easy to complete	-0.049	*	-0.048	*	-0.048	*
	0.025		(0.027)		(0.027)	
Household in meshblock in mining industry	-0.063	**	-0.064	***	-0.064	***
	0.024		(0.024)		(0.024)	
Household in meshblock objecting to religious questions	0.060	**	0.059	**	0.059	**
	0.025		(0.024)		(0.024)	
≥ 75% of households in meshblock have mobile phones	-0.092	***	-0.092	**	-0.092	**
	0.034		(0.039)		(0.039)	
≥ 50% of households in meshblock on wages	0.060	*	0.060		0.058	
	0.033		(0.041)		(0.040)	
Residing 10km to 50 km from a large planted forest	0.075	*	0.073		0.071	
	0.044		(0.058)		(0.059)	
Rho			-0.259			
			(0.192)			
Lambda					-0.204	
					(0.191)	
Squared correlation			0.056		0.053	
R-squared	0.053					

Note: ***, ** and * indicate significance at the 99%, 95% and 90% confidence levels, respectively

5.3 Costs and benefits of the biodiversity initiative

5.3.1 Cost of conservation per site

To calculate the cost of brown kiwi conservation at each site, we used our knowledge on the indicative costs of the appropriate traps and the required amount of labour for installing, monitoring and maintaining those traps. We verified these costings based on an interview with a forest manager who has been implementing a kiwi conservation programme in a 3,000-hectare planted forest in the Manawatu-

Whanganui region. Using these cost data, we calculated the overall cost of a five-year programme using the NZ forest industry's standard discount rate of 8%.

The proposed conservation programme starts with the purchase and installation of traps as well as monitoring of the existing kiwi population. This situation makes year 0 as the programme's most costly period (Table 6). For years 1 to 4, the main activities include checking and maintaining installed traps. Year 5 includes labour for checking and maintaining traps plus monitoring the kiwi population. An example of a spreadsheet calculation for one of the 12 sites is presented in Appendix C.

Table 6. Cost of the conservation programme for each identified site (assuming a discount rate of 8%).

Region, site number and location		Exotic forest area (ha)	Total area (ha)	% exotic forest	Approximate cost of conservation programme by period Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Total discounted cost of the 5-year programme (NZ$)	Average discounted $cost/year	Average discounted $cost/ha/year
Manawatu-Whanganui													
1	Rangataua-Karioi forest	4,057	10,000	41%	153,072	33,833	31,327	29,007	26,858	27,696	301,793	60,359	14.88
2	Waimarino Forest	6,062	10,000	61%	225,653	50,542	46,798	43,331	40,122	39,977	446,423	89,285	14.73
3	Tongariro Forest	2,093	10,000	21%	95,824	17,468	16,174	14,976	13,867	21,890	180,199	36,040	17.23
	Total for the region											**185,683**	
Bay of Plenty													
4	Omataroa Forest	5,980	10,000	60%	222,563	49,830	46,139	42,722	39,557	39,451	440,262	88,052	14.73
5	Ohope	2,604	10,393	25%	100,349	21,696	20,089	18,601	17,223	18,772	196,730	39,346	15.11
6	Waioeka Forest - Waiotahi	2,838	10,553	27%	108,830	23,649	21,897	20,275	18,773	20,207	213,631	42,726	15.06
	Total for the region											**170,125**	
Waikato													
7	Tairua	2,252	10,000	23%	87,650	18,792	17,400	16,111	14,917	16,637	171,507	34,301	15.23
8	Ohuka beach Peninsula	2,796	11,489	24%	107,301	23,297	21,571	19,973	18,494	19,948	210,583	42,117	15.07
9	Waiau -Coromandel harbour	2,096	5,257	40%	81,990	17,470	16,176	14,978	13,868	15,665	160,148	32,030	15.28
	Total for the region											**108,448**	
Northland													
10	North of Whangarei Harbour	1,946	10,000	19%	177,470	16,219	15,017	13,905	12,875	14,746	250,232	50,046	25.71
11	Marlborough/Kaihu Forest	5,282	10,000	53%	197,316	44,019	40,758	37,739	34,943	35,179	389,954	77,991	14.76
12	Motatau Forest	4,224	10,000	42%	49,181	35,197	32,589	30,175	27,940	28,695	203,777	40,755	9.65
	Total for the region											**168,793**	

For the 12 sites, we considered only the exotic forest areas in the "square site" as the place where we can install traps for the programme for each region (Appendix D). Large planted forests in NZ are generally accessible (e.g. roads present). We assumed a threshold level to indicate that the programme can only be feasible when the planted forest area of trapping is sufficiently large. [9] For Northland, as brown kiwi is in high density, a minimum programme intervention area of 1,500 hectares of exotic forest is sufficient. In other areas (e.g. Coromandel, CNI) where kiwi density is relatively low, a minimum area of 2,000 hectares is required. The Waiau-Coromandel site in the Waikato has the lowest programme cost due to the cheaper trapping system and having the second smallest programme area. The Waimarino forest (Site 2) has the highest cost because of a more expensive trap system and it has the largest programme area. In terms of cost per hectare, Motatau forest in Northland has the lowest cost at about $10/hectare while the forest North of Whangarei harbour has the highest at $26/hectare.

[9] We have also accounted for the fact that having a sufficiently large native forest area adjacent to this planted forest is also important for increasing the existing kiwi population.

5.3.2. Spatially aggregated values of the biodiversity initiative

The kiwi distribution map in Figure 2 shows the four regional areas: (1) Manawatu-Whanganui; (2) Bay of Plenty; (3) Waikato; and (4) Northland. WTP aggregation for each region used the 2013 HH census data reported by SNZ.

The marginal effects of the estimated OLS coefficients in Model 2 were calculated following Halvorsen, et al. (1980) and these aggregation factors are presented in Table 7. These factors enable us to account for the factors that either positively (e.g. higher income level) or negatively (e.g. proportion of mobile phone ownership) influence WTP which are expressed as β_k, γ_k and θ in Equation 3. Key assumptions for each factor and are listed in the fourth column of Table 7. Each factor is multiplied with the corresponding number of households that was calculated per meshblock and these are summarised in Table 8. The "sum product" of the factors in Table 7 and the number of households in Table 8 represent the aggregated WTP by meshblock (Table 9). The Waikato region has the highest number of HHs amongst the four regions, and gives the highest aggregated WTP of almost NZD11 million per year. This value captures mainly the non-use value. However, focusing on the use value which is captured by the road distance of 10 to 50 km to the conservation site, Waikato is only the third highest region. The three conservation sites in the Northland region are within a driving distance to the largest number of households (amongst the four regions) and its aggregated use value is more than four times as that in the Waikato. At the national level, the overall aggregate value of the proposed programme in the four regions, accounting for both non-use and use value would be approximately NZD111 million per year. The use value only account for less than 0.01% of the overall value and this can indicate that the willingness to pay mainly attributed to existence and bequest values for the brown kiwi. Although we have also accounted for socio-economic and meshblock level determinants of WTP, their combined effect compared to the conditional mean of WTP is minimal (i.e. only 0.28%).

Table 7. Marginal effects on WTP per HH per year derived from OLS regression estimates and the aggregation method used.

Variable/Characteristic	Model 1 – use and non-use values (NZD/HH/year)	Aggregation approach for each meshblock
Conditional mean of WTP	71.699	Multiply all HHs in the meshblock with the conditional mean of WTP (α)
Respondent with income $70K and higher	0.108	Identify the HH with this income range and multiply by the transformed marginal effect
Household with either one or two adults	0.074	Identify the HH in the with one or two adults and multiply by the marginal effect
Respondent aged 55 years old and higher	-0.068	Identify the HH with this characteristic and multiply by the marginal effect
Good understanding of the programme	0.082	Based on n = 1032, 47% had a good understanding of programme. Multiple the number of households by 47% then multiply by the marginal effect.
Completed the survey in 2015 (1 if yes, 0 if in 2010)	0.094	Respondents interviewed in 2015 completed the survey online, those in 2010 used pen and paper. This value therefore applies to HH with internet connection.
Survey questionnaire easy to complete	-0.048	Based on n = 1032, 29% of HH found the questions easy to complete. Multiple the number of households by 29% then multiply by the marginal effect
Meshblock (MB) with a HH member employed by the mining industry	-0.061	Check if the meshblock has a HH in the mining industry, if yes, multiply the total number of HH in the meshblock with the marginal effect.
Meshblock with HH objecting to religious questions	0.061	Check if the meshblock has a HH objecting to religious questions, if yes, multiply the number of HH with the marginal effect.
75% of HH with mobile phones	-0.087	Check if the meshblock has at least 75% of HH having mobile phones, if yes, multiply the total number of HH with the marginal effect.
50% of HH in MB on wages	0.062	Same as above
Distance of HH to the forest site is between 10 and 50 km	0.077	Using a spatial approach, we identified HH residing between 10 and 50 km by road from the intervention site and then we multiplied by the marginal effect.

Table 8. Meshblock data indicating the number of households by variable and by region.

Region/Area	1	2	3	4	5	6	7	8	9	10	11	12
	Number of households (HHs)	One or two adult HH	Good understanding of programme	Annual income above $70K	Questionnaire easy to complete	HH with internet connection	55 years old and above	At least one HH in mining sector	Object to religious questions	50% of HH with mobile phones	50% of HH on wages	HH residing 10 to 50 km from the site
Manawatu-Wanganui	87,003	55,131	40,891	25,281	25,231	62,642	15,661	1,017	70,710	58,653	71,583	2,943
Bay of Plenty	102,270	62,289	48,067	32,655	29,658	73,634	18,409	3,615	90,240	71,622	85,377	17,034
Northland	58,944	37,452	27,704	15,246	17,094	42,440	10,610	1,851	51,699	32,544	38,742	35,313
Waikato	150,174	88,101	70,582	53,934	43,550	108,125	27,031	10,764	126,216	110,079	129,177	7,749
North Island	1,160,670	641,355	545,515	455,658	336,594	835,682	208,921	42,255	967,029	835,404	1,019,103	63,039
South Island	388,965	241,434	182,814	144,453	112,800	280,055	70,014	22,617	312,315	294,327	353,022	-
New Zealand	1,549,890	882,960	728,448	473,874	449,468	1,115,921	278,980	64,872	1,279,344	1,129,731	1,372,125	63,039

Table 9. Aggregated WTP value (in NZD per year) by region and for all of NZ.

	Conditional mean WTP	One or two adult HH	Understanding of programme	Annual income >NZD70K	Survey questionnaire easy to complete	HH with internet connection	55 years old and above	HH working for mining	Object to religious questions	75% of HH with mobile phones	50% of HH on wages	Road distance 10 to 50 km from the site	Aggregate WTP
	Survey	Survey	Survey	Survey	Survey	Survey	Meshblock	Meshblock	Meshblock	Meshblock	Meshblock	GIS	($/year)
Manawatu-Whanganui	6,238,056	4,104	3,353	2,738	-1,204	5,870	-1,061	-62	4,339	-5,130	4,417	227.70	6,255,647
Bay of Plenty	7,332,689	4,637	3,942	3,536	-1,415	6,901	-1,247	-220	5,537	-6,264	5,268	1,317.91	7,354,681
Northland	4,226,245	2,788	2,272	1,651	-816	3,977	-719	-112	3,172	-2,846	2,390	2,732.15	4,240,734
Waikato	10,767,373	6,558	5,788	5,841	-2,078	10,133	-1,831	-654	7,744	-9,628	7,970	599.54	10,797,815
North Island	83,219,247	47,744	44,732	49,343	-16,064	78,315	-14,152	-2,568	59,335	-73,067	62,877	4,877.29	83,460,621
South Island	27,888,525	17,973	14,991	15,643	-5,383	26,245	-4,743	-1,374	19,163	-25,743	21,781	-	27,967,078
New Zealand	111,126,056	65,730	59,733	51,316	-21,451	104,578	-18,897	-3,942	78,497	-98,809	84,658	4,877.29	111,432,346

Following Equation 3, WTP was aggregated by meshblock for the whole of NZ (Figure 6). The equation accounts for the number of households for each meshblock as well as socioeconomic characteristics of HH within the meshblock. Meshblocks with the highest aggregated WTP of greater than NZD3,000 (shaded in green) are located in the country's largest cities which have the highest population densities. Future campaigns or crowd funding initiatives for financially supporting the conservation of brown kiwi in planted forests should prioritise those meshblocks. They should also consider other meshblocks that still have significant value of aggregated WTP (e.g. above NZD1,000).

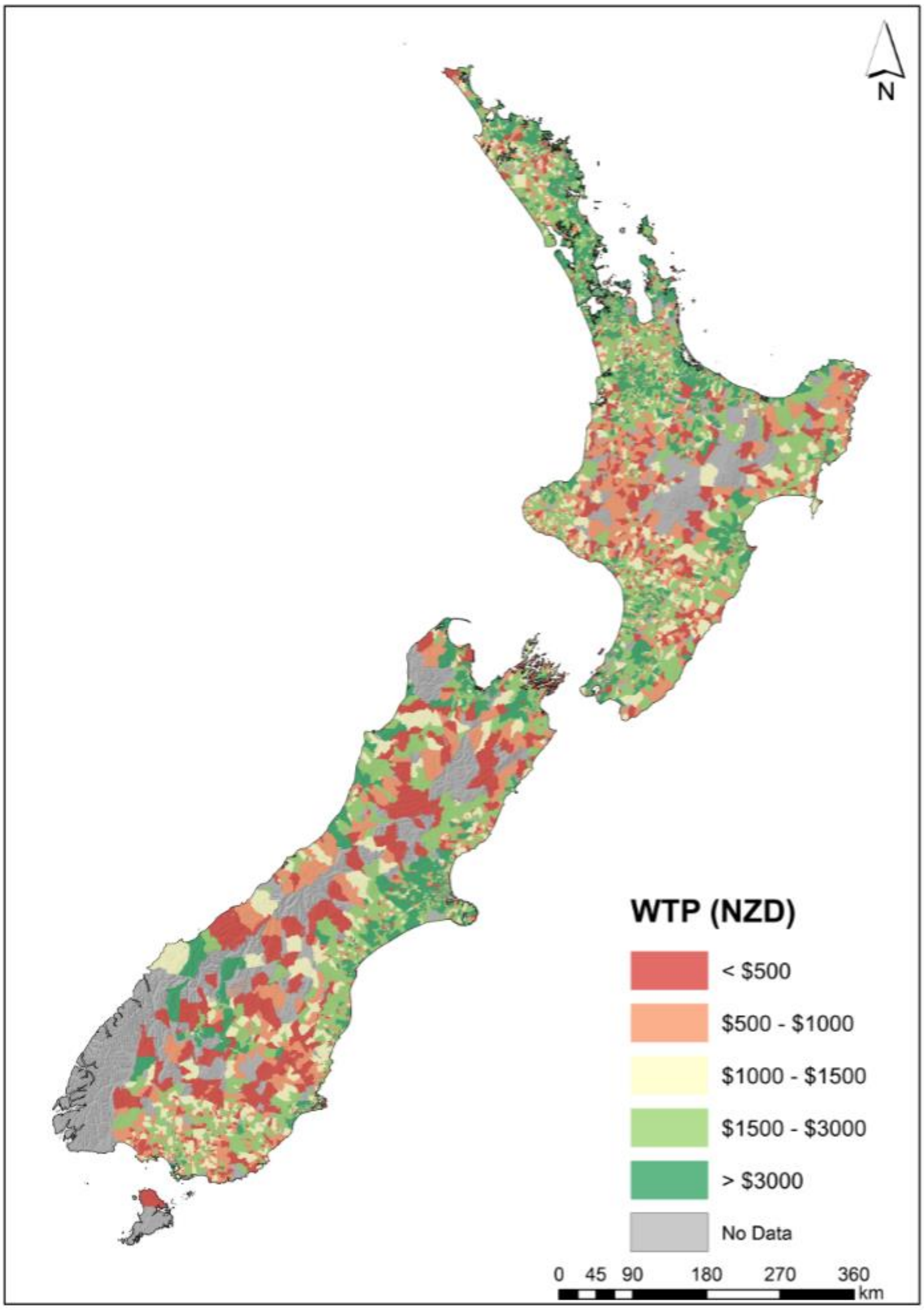

Figure 6. Map of the New Zealand showing aggregated WTP for brown kiwi conservation at the meshblock level. Meshblocks shaded in grey indicate no households residing in those areas based on the StatsNZ database.

Applying Equation 3 spatially, the kiwi conservation value map has been generated for the Coromandel area in the Waikato region (Figure 7). The left panel shows the value that HHs place on a proposed kiwi conservation programme considering only the non-use value while the panel on the right takes into account the distance effect. The right panel also illustrates the impact if the proposed initiative will be undertaken between 10 than 50 km away from residents (i.e. Forest 8). We find that at least one meshblock has moved up to a higher aggregated WTP range (from orange to cream shade). This is because as the fraction of the households who are situated close to the biodiversity enhancement site would pay a slightly higher WTP amount the impact to the aggregated WTP value at the meshblock level can be still significant.

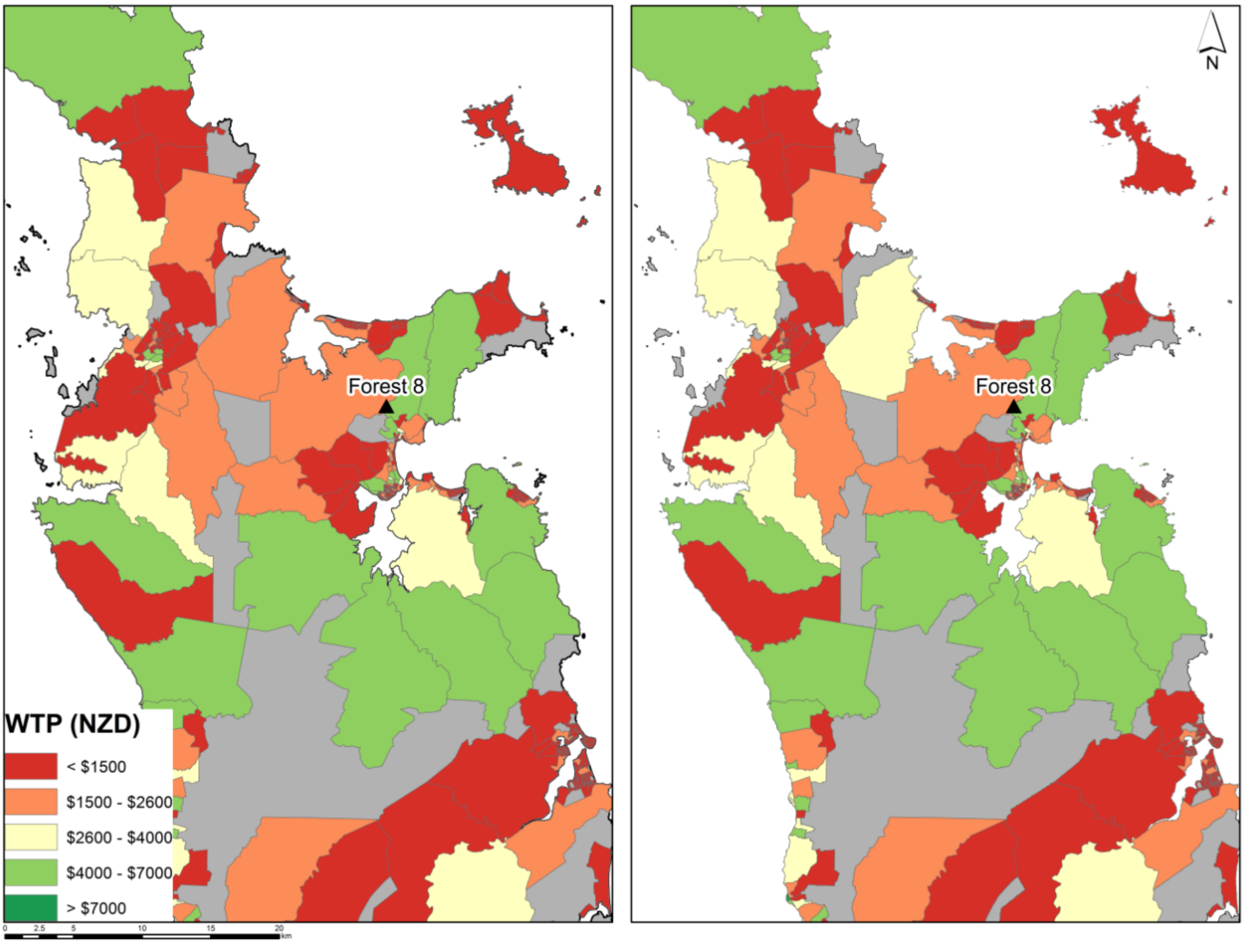

Figure 7. Map of the Coromandel showing benefits a biodiversity programme and accounting for socio-economic and meshblock characteristics and proximity to the biodiversity site.

5.3.3 Benefit cost analysis

Aggregated benefits and costs of the biodiversity initiative vary across the four regions. The Waikato region has the highest aggregated WTP while the Manawatu-Whanganui has the highest kiwi conservation cost (Table 10). The aggregated WTP value are at least 25-fold higher than the overall costs per region. The Waikato region has a benefit cost ratio (BCR) of 100 which suggest that for every dollar invested every year in the conservation programme, it generates a public benefit of approximately NZD100. At the national level, the BCR increases to 177 suggesting that if we are going to implement a biodiversity programme on the 12 feasible sites across the North Island, every dollar invested could produce approximately NZD177 worth of public benefit and this result is consistent with the study by Balmford et al. (2002).

Table 10. Ratio of aggregated WTP non-use value and total conservation cost by region.

Location	Aggregate WTP value (NZD per year)	Conservation cost (NZD per year)	WTP:Cost ratio
Manawatu-Wanganui	6,255,647	185,683	33.7
Bay of Plenty	7,354,681	170,125	43.2
Northland	4,240,734	168,793	25.1
Waikato	10,797,815	108,448	99.6
North Island	83,460,621	633,048	131.8
South Island	27,967,078	633,048	44.2
New Zealand	111,432,346	633,048	176.0

6. Discussions, Policy Implications and Future Directions

We found that biodiversity enhancement in planted forests is important to NZ households and they would likely financially support a programme to increase the abundance of key native species especially the iconic brown kiwi based on our sample of 1,032 household respondents. These results provide insights on identifying cost effective and ecologically suitable conservation investments for brown kiwi on private land. We also extend the study by Yao et al. (2014) by providing a new evidence of the non-use and use values of biodiversity conservation in planted forest. Using the choice experiment approach, combined with ecological, spatial and cost benefits frameworks, we have shown that every dollar invested on suitable conservation sites would likely benefit the public (non-use value) by several fold. While the previous study showed that households residing within the 10-kilometre radius would pay more for the conservation of the five key species, in this study we found that households who live within a driving distance (10 to 50 km by road) to large planted forests (use value), would be willing to pay more for the conservation of one specific native species – the brown kiwi.

NZ has a large private land area per capita, some of which can be suitable for specific conservation initiatives. It is therefore important to identify feasible and cost-effective locations using ecological knowledge combined with sound economics. The spatial and ecological components of the study have located the most ecologically and economically suitable sites for brown kiwi conservation in NZ planted forests. Each site has also been evaluated based on their private cost per hectare and public benefits for the region. These results can be useful for stakeholders with an interest in investing or in advocating biodiversity conservation on private land. This also allows a potential public or private investor to prioritise which conservation site they should focus on, especially because of the use value that can be generated by the programme. This addresses the issue of allocating scarce resources (e.g. tax payer's money, conservation donations, funds to renew product certification) for conservation into the areas that would provide the highest economic, social and environmental values of forestry related ecosystem services.

Results from this study can also help in the establishment of markets for enhancing biodiversity provision in key planted forests in NZ and elsewhere. As the public would be willing to pay for brown kiwi conservation, these estimated values can inform on-going partnerships between forest companies, government agencies and conservation organisations. There are also examples of institutions accepting donations for brown kiwi conservation management and are subsequently working with government agencies to further this management (Kiwis for kiwi, 2011). Having some indicative values of net public benefits of conservation also enables a forest company to demonstrate the broader value of their planted forest estate which can help in renewing their product certification (e.g. Forest Stewardship Contract) as discussed in (Yao, et al., 2017). This voluntary product certification scheme helps to provide access to major global timber markets. The indicative net public benefits values can also provide discussion points for establishing or maintaining innovative financial mechanisms (e.g. biodiversity offsets, payments for ecosystem services) (ten Kate, et al., 2014; Valatin, et al., 2017).

The study also provides evidence that planted forests does not just provide timber profits (or net private benefits) for a forest owner but also a biodiversity value that benefits the general public. This non-market biodiversity value remains less visible in policy alongside other non-market forest ecosystem services such as carbon sequestration, recreation, avoided erosion, water regulation and improved water quality (UKNEA, 2011; Yao, et al., 2017). Accounting for the non-market value of biodiversity conservation in planted forests (as well as other non-market ecosystem services) provides a better representation of the broader value of forests in national and international policies and investments (UKNEA, 2011). At the national level, the indicative biodiversity values can contribute to the discussions around the development of the national policy statement on biodiversity conservation on private land that fosters the establishment of private-public partnerships (Ministry for the Environment, 2015). At the international level, such values can contribute to discussions on international biodiversity strategies such as the Aichi Biodiversity Target 7 which states that "By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity." (Convention of Biological Diversity, 2010).

The multidisciplinary approach developed in this study for evaluating a future programme for kiwi conservation is a new function of the spatial economic tool called Forest Investment Framework (FIF) developed by Scion (Yao et al. 2016).[10] This new function in FIF can also be applied to estimate the public net benefits of enhancing other NZ iconic species such as the bush falcon, green gecko, kakabeak,

[10] The first three spatial economic functions of the Forest Investment Framework (FIF) are timber, carbon sequestration and avoided erosion (Yao, et al., 2016). New ecosystem service functions currently in development are avoided nitrogen, recreation and water regulation. FIF has already been used by New Zealand government agencies, indigenous groups investing in planted forests and the forest industry (Yao, et al., 2017).

giant kokopu and other native species. The ecological economic framework can also be expanded in the future to account for the ecological benefits of the programme through bird population modelling based on the proportion of native and exotic trees per conservation site.

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Appendix A

The Three Recruitment Methods for the 2015 Online Survey

The first recruitment method used telephone directories, randomly selecting and entering those landline phone numbers in Excel and ringing those numbers. This took place between January and February 2015. We found this method problematic as we experienced technological issues and the response rates for the phone calls, especially during the day, were extremely low. A very high proportion of phone numbers called were either answering machines or nobody answered. For people contacted on the phone, some reported that they did not have internet access (making them unable to participate in the online survey); while some were reluctant to state their email address for privacy reasons, and hence could not enter the active sample.

The second recruitment method employed for the online survey was sending a short letter sent by post, and took place between February and March 2015. This involved randomly selecting people from the NZ electoral roll and posting them a letter requesting to complete the survey. Initially about 10 names per electorate district were selected for the six southern-most South Island electorate districts and for the six Auckland electorate districts closest to the city centre. Selecting names, entering them into MS Word, getting the equivalent postal addresses from the NZ Post website, writing the address onto the envelope, and addressing and signing the letters took about 5-6 minutes per letter. The cost of printing and postage was one NZD per letter. Unfortunately, the results were disappointing with only five out of the 124 letters sent having respondents complete the online survey in the following two weeks, giving a response rate of only 4%.

The third recruitment method was undertaken between April and June 2015 using a web-based approach. This method included sending invitation letter to electronic bulletin boards of various organisations, and recruiting respondents through Facebook and Google. We also encouraged survey participants to share the online survey link with friends and colleagues to increase their chances of winning the prize draw (snowballing). This third method resulted in the collection of more than 1,300 completed HH surveys.

Appendix B

Testing for Spatial Autocorrelation Between WTPs

To test for the presence of spatial clustering or spatial autocorrelation between geo-referenced WTPs in the sample, we employ the widely used measure of global spatial autocorrelation called Moran's I (Moran, 1950). Moran's I measures spatial autocorrelation based on location and mean marginal WTP values simultaneously. The Moran's I correlation coefficient takes the value between -1 and 1. It evaluates whether the spatial pattern expressed is clustered (if between 0.001 and 1), dispersed (if in the range of -1 and -0.001), or random (if 0). The calculation of this coefficient includes the estimation of spatial weight matrices which we have implemented using the "sg162" package in Stata described by Pisati (2001). Calculated Moran's I coefficients and their statistical significance are presented in Table B.

Table B. Measure of spatial autocorrelation between mean marginal WTPs (n=1,032).

	Moran's I			
	I	E(I)	sd(I)	*p*-value
WTP for Brown kiwi 2	-0.006	-0.001	0.005	0.174
Log of WTP	-0.007	-0.001	0.005	0.116

The negative value of Moran's I for WTP for brown kiwi suggests a negative spatial autocorrelation indicating a correlation that has a dispersed, but uniform pattern. However, the *p*-value for the significance of the test of difference from zero is 0.174, suggesting a statistically weak autocorrelation effect. Basically the same results are found when we use the WTP in log form.

Appendix C

An example of a spreadsheet calculation for one of the 12 conservation sites

Cost of increasing abundance of native species for a Manawatu-Whanganui site											
	DOC 200 - stainless steel trap			$ 120	per trap						
	DOC 250 - stainless steel trap			$ 130	per trap						
	No. of traps required per ha			5	ha/trap						
	Labour = 1 person can install			50	traps/day						
	Cost of labour			$ 300	per day						
	Trap checking = 1 person can check			80	traps/day						
	No. of times traps checked per year			6							
	No. of times traps checked per year			12							
	Discount rate			0.08							
Site	Location	Exotic Forest Area	Type of trap								
1	CNI	4057	DOC 250		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	
	Rangataua-Karioi forest		No. of traps		811.37						
			Rounded off no. of traps		812						
			Cost of traps ($130/trap * # of traps)		$ 105,560						
			Trap installation cost ($300/day * # of i-days)		$ 4,872						
			Check (80 traps/day * $300/day) - 12X/year		$ 36,540	$ 36,540	$ 36,540	$ 36,540	$ 36,540	$ 36,540	
			Monitoring								
			Recorders (10 units * $200/uni)		$ 2,000					$ 50	batteries
			Putting and retrieving		$ 600					$ 600	
			Analysis and reporting		$ 3,500					$ 3,500	
				Year	0	1	2	3	4	5	***Undiscounted sum***
				TOTAL	**$ 153,072**	**$ 36,540**	**$ 36,540**	**$ 36,540**	**$ 36,540**	**$ 40,695**	**$339,927**
											Discounted sum
				Discounted cost (8%)	153,072	33,833	31,327	29,007	26,858	27,696	**$301,793**

Appendix D

Map of part of the Manawatu-Wanganui region with the identified "square" conservation sites