Cost Benefit Analysis of the Natural Environment Investment Options for the Auckland Council Long-term Plan 2018-2028

Mehrnaz Rohani and Catherine Murray

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Te Kaunihera o Tāmaki Makaurau

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Executive summary

Auckland's natural environment is central to the health and wellbeing of the region's people, cultural and spiritual identity and economic success. Continuing biodiversity loss is an ongoing challenge for Auckland. In a region of 500,000 hectares, less than 30 per cent of Auckland's original native vegetation cover remains. Over 50 per cent of the remaining native vegetation is on private land, along with some of Auckland's most threatened ecosystems and species.

Introduced pest animals compete with native birdlife for food and habitat, eat the eggs and young, and attack adult birds. Pest plants smother and displace native plants and ecosystems. Effective pest control has the biggest impact in protecting native species.

This report contains a high-level analysis of the likely economic costs and benefits associated with two proposed investment options relating to Auckland Council's Natural Environment Targeted Rate for the 2018-2028 Long-term Plan (LTP). Expenditure on the natural environment in the LTP is based on planned activities that will occur according to the Regional Pest Management Plan which has eight outcome/investment areas. These include expenditure in both terrestrial and marine environments. In addition the LTP includes investment in marine ecology and the Pest Free Auckland initiative.

The LTP consultation took place in March 2018. The natural environment component of that includes three options: a 'current state' option (which is loosely based on a continuation of current expenditure) and two alternatives, Options A and B. The 'current state' is the status quo or counterfactual in this Cost Benefit Analysis (CBA). The CBA measures the changes in costs and benefits of policy options compared to the counterfactual, or status quo. The costs and benefits of the status quo *are not* assessed in this study.

Based on evidence, the status quo has a high risk of resulting in significant ecosystem and species loss. To avoid this eventuality, the two alternative options were proposed, with increased targeted expenditure on natural environment protection. Both, Options A and B, have differing levels of additional activity and investment in the 10 outcome areas, with Option B being more comprehensive than Option A (Figure 1). Both options *reduce the risk* of species loss and damage, based on the prevailing pest control practice, rather than guaranteeing avoided loss and damage.

The CBA methodology used in this study is in accordance with guidance on CBAs provided by the New Zealand Treasury and Auckland Council's CBA primer. For a programme or planned expenditure to be considered worthwhile, it should have a Net Present Value (NPV) greater than zero, and a Benefit to Cost Ratio (BCR) greater than one. A CBA in pest management is required under Sections 72 and 76 of the Biosecurity Act 1993.[1] This report

[1] There have been numerous assessments published by different councils in New Zealand over the last 25 years. Methods employed in such studies include species-by-species loss assessment and web based tools that estimate the value of losses prevented through pest management, and more recently tools to incorporate evaluations of marine pests.

addresses pest management outcomes from a holistic perspective, recognising that there are combined and synergistic effects of individual species on natural environment outcomes.

A Total Economic Value (TEV) framework is used, which is the state-of-the-art for environment and biodiversity accounting. It was considered the most appropriate framework for assessing the benefits arising from council's natural environment investment options. The study recognises alternative approaches of valuation, such as socio-cultural perspectives – where the cultural or spiritual values of indigenous people are a determinant to protect a particular species or landscape from pests (e.g., willingness to pay to protect a species is unlimited) or an ecological approach to valuation, which acknowledges that many sensitive or threatened species remain invisible or unknown to the majority of people and are therefore difficult to value. An ecological approach to valuation is based on the prevailing scientific knowledge of the ecosystem, while acknowledging 'known-unknowns' in the system.

A range of potential benefits may result from the increased investment in pest control and biodiversity protection. A level of uncertainty in our ability to control pests is acknowledged, and to reflect this uncertainty, the study adopted the most conservative assumptions regarding likely benefits throughout.

Overall framework and assumptions

The methodology and main assumptions in this study are:

- A Total Economic Value framework was adopted to measure benefits. It is not always possible to measure all benefits due to lack of data/information in some areas.
- A 'Benefits Transfer' method was used, adapting available estimates of the economic value for a change in pest control in other areas of New Zealand, to evaluate the proposed policy-induced change in Auckland. As part of the data triangulation process, studies that measured New Zealand biodiversity values and ecosystem service values were considered and consulted, but the focus remained on studies concentrated on the unique threat of New Zealand pest species.
- The time assessed in this CBA extends from 2019 to 2050, the target year for the Pest Free Auckland initiative. This comprises 22 additional years to the LTP and Regional Pest Management Plan (RPMP) period. Although beyond the evaluation cycle of the LTP, it can be considered a short timeframe for natural environment values, where species loss is at stake.
- Council staff estimated the detailed cost of the outcome areas, based on the cost of achieving the pest reduction targets which were set for each option which aim to lower the risk of pest spread and species loss.
- Ongoing costs after the LTP (between 2028 and 2050) are estimated as 90 per cent of the 2028 Opex budget for each outcome area.

- The study assumes that benefits would occur from year 11 (when the plan is fully implemented). It is a conservative assumption as some of the benefits would start occurring gradually even after the first year of the Plan's implementation.
- The benefits are measured for Aucklanders only. This is a conservative assumption as we know there are nationally and internationally significant species in Auckland that are under threat and others outside the Auckland region would benefit from their protection.
- There is a behavioural change assumption built into the analysis, based on the Pest Free Auckland initiative, which aims to engage more Aucklanders in environmental management. Pest Free Auckland set a target of engaging 85 per cent of Aucklanders who work toward achieving pest free status. This was translated to an increase in the number of all Aucklanders who would be willing to contribute to natural environment protection activities. The current estimate of Aucklanders who are willing to pay was taken from a Department of Conservation (2107) survey of Aucklanders. Increased awareness and engagement with environmental protection increases in value over time.
- Most of the benefits are the avoided cost of pests, or values of losses prevented.
- To avoid double counting the positive effects of controlling for pest species, the study combined some of the benefits into a composite effect, e.g., positive overall impact on tourism. The reduction of each pest species has a marginal impact on the overall outcome, so benefits were not considered for each pest species controlled.

Benefits

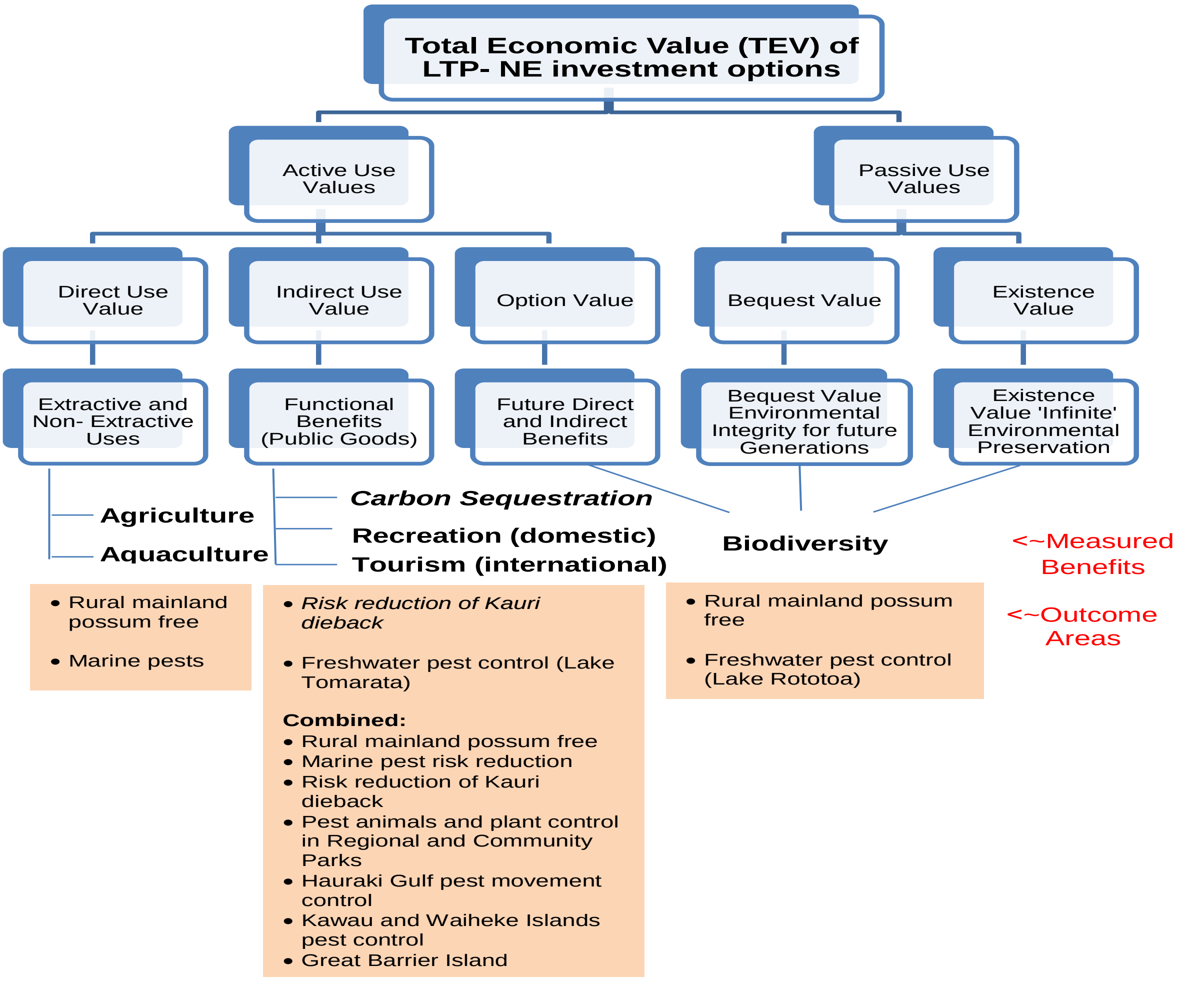
The benefits are associated with the increased additional 'value' that results from the proposed outcome/scenarios of additional pest control. There are a range of values, including those with a traceable or measurable market value – such as nature-based tourism and avoided losses in agriculture – as well as more intangible values such as avoiding species extinction and recreational value associated with 'being' in nature – that are all affected by the number of pest species present.

Figure 1 shows the benefits in relation to the TEV framework and outcome areas.

Other potential benefits *not* measured in the analysis include:

- Direct use values of avoided production losses in the horticulture and fishery sectors.
- Indirect use values of
  - ecosystem services other than kauri forest carbon sequestration;
  - the recreation value of threatened species other than birds; and
  - any physical and mental health benefits in connection with the specific pest controlled environment, which may manifest as cultural or spiritual values.
- Bequest and existence values associated with the biodiversity of threatened native species and Māori cultural values/spiritual values particularly associated with kauri forest and freshwater systems.

Figure 1. Measured benefits under TEV framework related to outcome areas



Cost Benefit Analysis results

For a programme or planned expenditure to be considered worthwhile, it should have a Net Present Value (NPV) greater than zero, and a Benefit to Cost Ratio (BCR) greater than 1.

The range of estimated net benefits (i.e., the extent to which society is better off because of the options) are $_{2017}$\$293.2 million and $_{2017}$\$734.2 million in present value terms for Option A and B, respectively, with a corresponding BCR of 1.08 and 2.80. Both Option A and B have a positive NPV for the base or Medium scenario, indicating that the cost of any investment is offset by the benefits resulting from that investment.

It is important to note that these results do not include the benefits that were not measured due to data/information constraints. Our assessment is that the effect of including such impacts would be to raise the net benefits significantly.

It is not envisaged that the analysis is missing cost estimates (due to lack of data): the CBA is an analysis of likely outcomes due to the level of spending identified in the two Options.

Uncertainty

An important step in a CBA is to assess the sensitivity of the Net Present Value and how changes in the parameter values change the overall Benefit to Cost Ratio (BCR). The study adopted a two-step method in this regard – scenario testing and sensitivity analysis.

The first step, **scenario testing**, involved calculating a base assessment of each option (which we named the Medium scenario). Two alternative scenarios were developed (Upper and Lower bound scenarios), to control for uncertainty in the assumptions and to incorporate any range of values provided from the benefits transfer literature.

All the alternative parameters in each scenario were assessed as a combined effect. The scenario testing for Options A and B used a range of values for all the factors; from worst-case non-realisation of benefits, to higher values for benefits. This resulted in a range of BCR values of between 0.61 and 2.98 for Option A, and 1.38 and 6.41 for Option B. Only the Lower bound worst case scenario for Option A results in a negative NPV, or BCR rate below 1.

The summary cost benefit analysis results for all three scenarios (Lower, Medium and Upper) of Options A and B are shown in Table 1. All figures are in $_{2017}$\$million.

Table 1. Summary Cost Benefit Analysis results

	Option A Present value ($_{2017}$\$million)			Option B Present value ($_{2017}$\$million)		
	Lower	Medium	Upper	Lower	Medium	Upper
Total benefits	$101.80	**$177.0**	$441.30	$585.49	**$1,141.4**	$2,193.02
Total costs	$167.55	**$163.7**	$148.08	$423.61	**$407.28**	$341.97
Net benefits (NPV)	-$65.8	**$13.3**	$293.2	$161.9	**$734.2**	$1,851.0
Benefit-cost ratio (BCR)	0.61	**1.08**	2.98	1.38	**2.80**	6.41

While the scenario analysis tested the assumptions that were used in the base or Medium case, the **sensitivity analysis** was undertaken to control for each of these parameters or assumptions to assess which individual factors had the greatest impact on the overall BCR.

The results showed that three of the parameters (rate at which kauri dieback spreads, proportion of Aucklanders who would be willing to pay for natural environment protection and the proportion of tourists who would stay longer in Auckland) individually reduced the BCR to lower than one for Option A in the sensitivity analysis.

In addition to the sensitivity analysis on parameters, a more traditional sensitivity analysis of changes in the value of the discount rate was undertaken. Furthermore a sensitivity analysis of the benefits that had the highest share of total benefits was also undertaken.

The estimated combined recreational benefits and discount rate have the highest impact on the results for both options.

Conclusion

While the study is exploratory and indicative in nature, it supports the view that society is likely to be better off from both the Natural Environment Investment Options for the LTP.

A conservative approach to measuring the benefits was adopted at all times. There are benefits that were not quantifiable, and hence not included in the analysis. Option B is the preferred option as it has much higher benefit to cost ratio and society would be better off even under the Lower bound scenario.

As is common in exploratory studies of this nature, the precision with which estimates of costs and benefits can be made could increase with further, more detailed work.

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1.0 Introduction

Auckland’s natural environment is central to the health and wellbeing of the region’s people, cultural and spiritual identity and economic success. Continuing biodiversity loss is an ongoing challenge for Auckland. In a region of 500,000 hectares, less than 30 per cent of Auckland’s original native vegetation cover remains. Over 50 per cent of the remaining native vegetation is on private land, along with some of Auckland’s most threatened ecosystems and species.

Introduced pest animals compete with native birdlife for food and habitat, eat the eggs and young, and attack adult birds. Pest plants smother and displace native plants and ecosystems. Effective pest control has the biggest impact in protecting native species. There are already many volunteers, landowners and groups who actively control pests, and restore Auckland’s natural environment.

Biological pest invasions can cause damage to indigenous ecosystems and economic activities (Courtois et al., 2018 and Bell, 2007). The ecological impacts of pest invasions are often uncertain, especially with new incursions, while the economic effects of established populations of pest species can be significant (Nimmo Bell, 2009; Covec, 2013; Cowan and Warburton, 2016).

Invasive species are considered the second biggest threat to biodiversity loss worldwide, after direct habitat loss or destruction (EEA, 2012). Valuing the benefits of pest reduction involves calculating the known damage of pests alongside estimating a value for the ‘known-unknowns’, such as biodiversity loss and ecosystem change. Methodologically these known-unknowns pose the greatest challenge to economists, despite advancement in valuation frameworks (Kerry et al., 1993; Costanza et al., 1997; TEEB, 2010).

One role of central and local government is to allocate funding to the various services desired by the people. Determining which services to fund is a complex political decision that involves trade-offs between areas such as health, education and biosecurity to ensure that welfare is maximised given a limited budget (Bell 2007). Cost Benefit Analysis (CBA) is a decision support tool that can be used to aide that political decision by showing the relative merits of choosing between options.

RIMU, Auckland Council’s Research and Evaluation Unit was asked by the Infrastructure and Environmental Services Unit to do a high level CBA for the two proposed investment options they put forward for the Long-term Plan.

This study uses the ‘benefit transfer’ method to estimate economic values using the Total Economic Valuation (TEV) framework, in which the ‘use’ and ‘non-use’ values of pest control are recognised.[2] Available information from studies completed on the effects of pest species in other locations in New Zealand was transferred for use in the Auckland context. Such

[2] The framework was originally developed by Kerry et al. (1993)[2], based on contingent valuation methods (CVM) of eliciting willingness to pay for environmental goods and services (Hanley and Spash, 1993).

information is transferable if original data pertained to a similar location; if this was not the case, the data can be adjusted to reflect the Auckland situation more closely. In measuring and monetising benefits this study used any relevant, available and transferable data, although it was not possible to measure all the benefits identified that would result from activities undertaken in each option. Therefore, the benefit to cost ratio is very conservative, even under the Upper bound scenario.

The results reported provide an indication of the likely economic, social and environmental benefits associated with each proposed option compared to the status quo. This differs from a more limited financial analysis. In terms of the level of detail, this analysis falls somewhere between a ‘preliminary’ and ‘indicative’ assessment, while at all times employing conservative assumptions.

The report is structured as follows:

- Section 2 describes the proposed investment options for the natural environment in Auckland’s Long-term Plan (LTP) (2018-2028).
- Section 3 discusses the nature of a CBA within a natural environment setting and presents a summary of literature on pest management studies in New Zealand.
- Section 4 outlines the nature of costs and benefits relevant to this analysis and details the estimated effects of each option, explains the basis of those estimates, including the base case, caveats and assumptions.
- Section 5 discusses the likely net effect of the proposal under each option and presents two additional Lower and Upper bound scenarios.
- Section 6 shows the sensitivity of the CBA results to the changes in scenario analysis components and discount rate.

2.0 The Proposal

This section provides an overview of the proposed investment options for the natural environment in Auckland's Long-term Plan (LTP) (2018-2028). Expenditure on the LTP is agreed upon and scheduled for the next 10 years. This study considers the LTP expenditure as the status quo, as developed within the Regional Pest Management Plan (RPMP – see 2.1 below).

The costs and benefits of the status quo are not assessed in this study. Based on evidence, the status quo has a high risk of resulting in significant ecosystem and species loss. To avoid this eventuality, the two alternative 'options', with increased targeted expenditure on natural environment protection were proposed. Both, Options A and B, have differing levels of additional activity and investment in the 10 outcome areas, with Option B being more comprehensive than Option A. Both options reduce the risk of species loss and damage, based on the prevailing pest control practice, rather than guaranteeing avoided loss and damage. Figure 1 shows a summary of the options, compared with the current LTP scheduled expenditure. It gives an indication of the different targeted pest management activities that would be pursued under the status quo and under each option.

This study measures the marginal changes that would likely occur if some 'ecosystem and species loss, with some kauri dieback protection' (Option A) was pursued, and if 'targeted ecosystem and species including kauri dieback protection' (Option B) was pursued (Figure 1).

Figure 1. Long-term Plan and Options for investment on natural environment

Outcome Areas		Status Quo: Significant ecosystem and species loss (Current state)	Option A: Ecosystem and species loss with some kauri dieback protection	Option B: Targeted ecosystem and species including kauri dieback protection
Investment ($ million)		Current = $9.7m per annum	Current + $12.3m per annum	Current + $27.9m per annum
	Risk of Kauri Dieback spreading	High risk (>80%)	Medium risk (30-50%)	Low risk (15-25%)
	Pest Free Auckland – enabling communities	Low level support for 250 community groups 25% of Auckland under community led pest control	Low level support for 450 community groups 40% of Auckland under community-led pest control	600 community groups well supported 50% of Auckland under community led pest control
	Pest Animal and Plant control on regional and community parks	30% high ecological value areas controlled No enforcement on surrounding properties	35% of high ecological value areas controlled No enforcement on surrounding properties	66% of high ecological value areas controlled Enforcement on surrounding properties including transport corridors
	Rural mainland possum free	28%		50%
	Freshwater pests	None		Pest control at two highest priority lakes (Tomarata and Rototoa). Proactive awareness raising/behaviour change
	Marine pests	Marine pests continue to establish and proliferate	Reactive marine biosecurity	Comprehensive marine biosecurity Lower risk of marine pests establishing
	Hauraki Gulf pest movement control	Limited Pest Free Warrant programme Moth plant and other pest plants spread	Expanded Pest Free Warrant programme Moth plant and other pest plants spread	Comprehensive Pest Free Warrant programme Moth plant and other pest plants spread
	Kawau and Waiheke islands	Feral pigs eradicated No capacity to support pest-free community	Feral pigs eradicated Some capacity to support pest-free community	Kawau and Waiheke Islands 'pest- free'
	Great Barrier Island	High priority pest plants controlled	High priority plants, skinks, ants and some mammals controlled	High priority pest plants plus skinks, ants and comprehensive mammal control
	Marine ecological	Habitat and species loss		Targeted habitat and species protection

Source: Auckland Council, Infrastructure and Environmental Services

2.1 Status Quo and the Regional Pest Management Plan

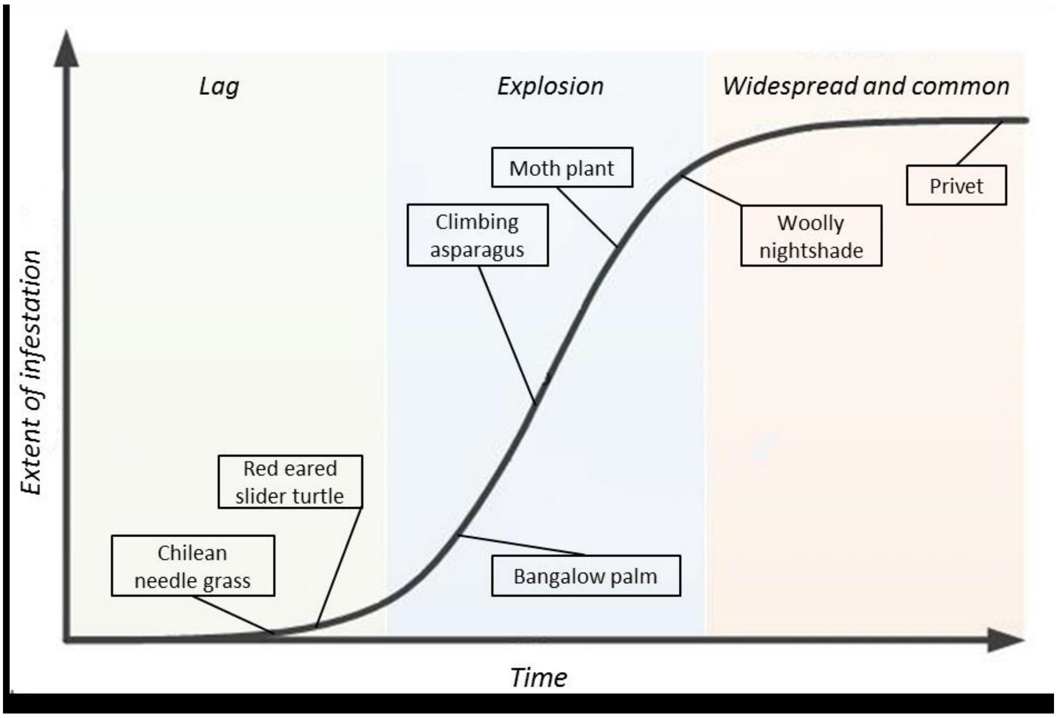
For Auckland Council, it is crucial to identify existing and known potential pests, the level of pest impact and the management tools that can and should be used to reduce the risk of pest species (both plant and animal). This information is contained within the Regional Pest Management Plan (RPMP). A range of pest management programmes are used to control pests and other unwanted organisms within the RPMP. The types of programmes are defined by the National Policy Direction set for pest management by the Ministry for Primary Industries (2015) and reflect outcomes in keeping with: 1) the extent of the invasion; and 2) whether it is possible to achieve the desired control levels for the pests.

The intermediate outcomes for the five programmes of the RPMP are:

1. Exclusion Programme: to prevent the establishment of the subject, or an organism being spread by the subject, that is present in Aotearoa / New Zealand but not yet established in an area.
2. Eradication Programme: to reduce the infestation level of the subject, or an organism being spread by the subject, to zero levels in an area in the short to medium term.
3. Progressive Containment Programme: to contain or reduce the geographic distribution of the subject, or an organism being spread by the subject, to an area over time.
4. Sustained Control Programme: to provide for ongoing control of the subject, or an organism being spread by the subject, to reduce its impacts on values and spread to other properties.
5. Site-led Pest Programme: that the subject, or an organism being spread by the subject, that can cause damage to a place is excluded or eradicated from that place, or is contained, reduced, or controlled within the place to an extent that protects the values of that place.

Intervention and pest control management do not have linear outcomes or effects. Auckland Council uses the pest infestation curve to assist decision-making on pest management in both regulatory and non-regulatory contexts (Figure 2). New or emergent pests, with low population and limited distribution are at the beginning of the curve. Pest control at this early stage often involves relatively low costs and high long-term benefits. For these pests, progressive containment or even eradication may be feasible, preventing or delaying them becoming the widespread problem pest plants of the future.

Figure 2. Pest Infestation Curve



Source: adopted from RPMP (2018-2028)

For widespread pests at the established stage of the curve, the costs of control can be high, and eradication is unlikely to be feasible for many species. The most notable exception to this is small mammals, for which control technologies are sufficiently advanced to enable eradication or suppression to very low levels over increasingly large areas. For most other widespread pests, control will be most effective if delivered as a site-led approach, in which the full suite of invasive species is managed at a given site, sufficient to protect the values of the site. Complete pest management at a targeted site avoids pest replacement: one widespread pest simply being replaced by another, yielding no net reduction in impacts. It also ensures that pests are controlled at a rate greater than their rate of reproduction. Site-led approaches are a feature of Auckland Council's RPMP, whereby the sites with the region's areas of highest biodiversity value and defendable geography are targeted.

Each pest reacts differently to pest control intervention, and the effects on native or indigenous biodiversity also varies by species, pest and location. There are a myriad of factors that contribute to enhancing biodiversity values after the risk from pest species is reduced. While acknowledging that there is a well-considered intervention logic behind each of the Outcome areas, involving pest risk reduction. These were developed by the natural scientists and subject experts in the Auckland Council, which were in turn translated to 'values' for measurement and inclusion in this study.

2.2 Outcome areas

This section provides an overview of the outcome areas presented in Figure 1, which are the object of pest management control under the status quo, and under the two additional options under consideration.

2.2.1 Risk of Kauri dieback spreading

Kauri are among the world's largest trees, growing to over 50m tall, with trunk girths up to 16m, and living for over 2000 years[3]. Kauri are culturally significant for Māori, who use kauri timber for boat building, carving and building houses.

Kauri dieback (*Phytophthora agathidicida,* PA) is a fatal disease of kauri trees and poses a very real threat to the continued existence of kauri forests in the region. At present, there is no known cure for kauri dieback and is known as 'Kauri's HIV'. Kauri trees are iconic and unique. They have tall trunks and broad canopies and have a particular effect on the soil at their roots. They are a keystone species in ecosystems. Loss of kauri would lead to changes in soil type and food-web interactions, and ecosystem modification. The loss of kauri-reliant habitat may be irreversible without an effective cure for PA being developed. However, the common occurrence of kauri in mixed tree stands lowers the risk of kauri dieback causing clearings in the forest with associated risks for additional species loss, water run-off, soil erosion and sediment discharge. The biodiversity risk of PA is primarily associated with the probability of survival of kauri as a species, and the attendant flow-on ecosystem effects.

Based on the data from Auckland Council's biosecurity team, 1008ha of Auckland's kauri forest is classified as 'confirmed infected', 'infected' and 'possibly infected'. Almost 60 per cent of the infected area is in the Waitākere Ranges. Kauri dieback is not currently known to be present at Kohukohunui/Hunua or Te Tikapa Moana o Hauraki/Hauraki Gulf islands except for Aotea/Great Barrier (RPMP, 2017).

Currently, the only way to manage the impact of kauri dieback on Auckland's indigenous kauri forest is to control its spread. The disease spreads predominantly through human movement of soil. Any introduction of infected soil around the roots of trees could spread the disease. Cleaning boots and equipment and avoiding walking on/near kauri tree roots is essential. Auckland Council along with the Department of Conservation (DOC), iwi, Ministry for Primary Industries (MPI) and local community partnerships, is aiming to reduce its spread.

A rāhui has been placed over the Waitākere Ranges by iwi Te Kawerau a Maki. This cultural restriction by the mana whenua of the area urges people to stay away from the ranges to allow the forest to heal. It is both a physical and a spiritual protection. The rāhui applies to all kauri forest within and up to the boundary of the Waitākere Ranges Heritage Area. In February 2018, Auckland Council decided to close some tracks in the forested area of the Waitākere Ranges Regional Park by the 1st of March. This is to support the principles of the

[3] http://www.doc.govt.nz/nature/native-plants/kauri/

rāhui. The council recommended alternative walking and tramping tracks across the Auckland region.

2.2.2 Pest Free Auckland

The Pest Free Auckland initiative is linked to the government's Predator Free NZ programme. Auckland's initiative is more ambitious, as it targets a broader suite of pest plants, animals and pathogens. In response to the Predator Free NZ Trust's national initiative to eradicate rats, possums and stoats by 2050, there is increasing community action and social expectation for conservation programmes. A programme that is focused on just predators (i.e. rats, possums and mustelids) would not realise the benefits without also controlling herbivores (grazers and browsers), weeds and pathogens. Auckland Council is scoping a broader programme outside of the LTP, which would also align with other central government conservation priorities. The initiative has the support of Predator Free NZ and the DOC.

A successful Pest Free Auckland programme would result in:[4]

- Healthy native terrestrial, marine and freshwater ecosystems supporting abundant populations of native species.
- Active engagement from Auckland's diverse communities, in ecological restoration and pest control activities.
- Economic benefits of a healthy natural environment are realised, in particular through strong and growing primary industry and tourism sectors.

Pest Free Auckland envisages widespread and significant community engagement and householder support of the programme, with a target set by Pest Free Auckland of 85 per cent of Auckland's adults engaging in the programme by 2050. This is a means of increasing general awareness of pest species, and transferring responsibilities of pest management onto householders and communities. As pest control in Auckland is occurring within this broader Pest Free New Zealand programme by 2050, the study dovetailed the regional and national goals of pest free status over the next 32 years. It was for this reason that a measurement period out to 2050 was adopted in the study, while the authors acknowledge that benefits extend beyond that date. Extinction is forever, and preserving endangered species is also an infinite prospect (Carse, 1986), which is a contentious issue in biodiversity accounting, because there may be infinite values associated with different species and the co-dependence of their ecosystem on that species.

[4] Auckland Council (unknown). Pest Free Auckland: Programme Execution Plan Stage 1.

2.2.3 Pest animal and plant control in regional and community parks

Based on the most recent Statistics New Zealand's land cover data (2012), 1817 km^2 of the Auckland region is parkland (approximately 37 per cent of the total land area). Recognition is given within the RPMP to the efficiency of controlling a whole suite of pest plants at sites of high biodiversity value compared with targeting a smaller list of species for region-wide enforcement. Therefore, the parkland that has high ecological value, that is Significant Ecological Areas (SEAs), are covered under the RPMP.

The Waitākere and Hunua ranges are particularly high value parkland, representing the two largest tracts of forest ecosystems of the region's mainland area.

2.2.4 Rural mainland possum free

Possums have devastating impacts on native biodiversity, as well as posing substantial risks to primary productivity through transmission of bovine tuberculosis and eating pasture and horticultural crops. By controlling possums over large landscape-scale areas, it is possible to substantially reduce costs, through economies of scale / purchasing power as well as by reducing reinvasion from surrounding uncontrolled areas. Landscape-scale possum control elsewhere in the country has seen kōmako / bellbird returning to farming landscapes. Auckland's RPMP implements possum control across the entirety of rural mainland Tāmaki Makaurau / Auckland.

2.2.5 Freshwater pests

Lake Tomarata and Lake Rototoa are two of Auckland's three identified iconic lakes, along with Lake Pupuke. Lake Tomarata is a high use recreation lake, while Lake Rototoa has high ecological value.

Lake Tomarata has a relatively low water quality value. However, in an Auckland context it is much better than most shallow lakes found in agricultural catchments. The wetland that surrounds Lake Tomarata likely contributes to its relative good status; neighbouring Te Arai lakes of similar size and depth have worse quality. Lake Tomarata is surrounded by a low intensity dairy farm and pine forest. Ngāti Manuhiri have strong association with Lake Tomarata. A catchment management plan for Lake Tomarata is currently under development.

Tomarata has high recreational value, with many access points and recreational facilities. It is a high-use motor boating and water skiing lake, which have put a strain on the ecology of the lake. Boat traffic and invasive fish are the primary stressors and have resulted in the loss of submerged macropytes (vegetation) in the lake in recent years. The main fish pests in the lake are perch, carp, tench and rudd. The carp feed on submerged and emergent plants, which in turn reduces the water quality and frees up nutrients that can fuel harmful algal blooms. Perch prey on several trophic levels throughout their life cycle are extremely detrimental to the overall health of the lake. In particular, they feed on zooplankton thereby reducing grazing pressure on harmful algal blooms, allowing them to proliferate. Perch also feed on native fish species and out-compete them often leading to complete displacement of native species.

Lake Rorotoa has the best water quality of lakes monitored by Auckland Council and has always been considered an ‘Auckland Gem’. Lake Rototoa is, at the moment, in medium trophic level, which is the best time to pursue pest management strategies. Lakes need to be controlled and managed for pests before cross their tipping points, and change their quality status.

2.2.6 Marine pests

Non-indigenous marine pest species pose a serious threat to the entire marine environment. The Port of Auckland is a high-risk area for the introduction, establishment and spread of non-indigenous species, given the high volume of marine traffic. The problem with many marine pests is that they form dense colonies with the potential to starve native marine species of food and living space. Disturbed benthic environments have a high risk of marine pest incursion. The goal of local elimination has been replaced by risk reduction of new incursions of many marine pest species, because elimination is expensive, and proved unsuccessful in areas such as Stewart Island and Lyttelton Harbour.

Reducing the risk of new incursions is being facilitated by increasing awareness of the threat of marine pests and encouraging better pest management practices on vessels travelling in New Zealand waters. This is a risk reducing strategy, rather than an attempt to control existing pests.

Marine pests can clog structures and have negative economic effects on marine industries. They can also have damaging effects on the ecosystem. Filtration capacity of marine habitat is important, irrespective of what species provides that filtration function (including pest species). However, cultural values are important for marine pest species as they could affect or damage the mauri or life force of the water.

The Hauraki Gulf State of Environment 2017 report identifies five species in particular, affecting the aquaculture industry. The Mediterranean Fan Worm clogs dredges and fouls aquaculture equipment. The Droplet Tunicate accounted for 50 per cent of biofouling waste removed from oyster farms during summer in northern New Zealand. The Asian Paddle Crab consumes shellfish, posing a threat to the aquaculture industry as well as a threat to kaitiakitanga and kaimoana (threatening pipis, scallops and mussels). Asian kelp is in the firth of Thames and Waitematā Harbour, commonly found on mussel farms. Sea squirt caused major fouling for the aquaculture industry in Auckland and Waikato, estimated to have cost the country $9.4m between 2006 and 2011.

2.2.7 Hauraki Gulf pest movement control

The Hauraki Gulf contains diverse ecosystems spread across 30 major island groups and over 400 discrete islands, including rock stacks, reefs and sand bars. These islands are home to one of the highest diversities of seabirds in the world. Ruapuke / Maria Island (1 ha) in the Noises group was New Zealand's first successful island rodent eradication in 1964. Since then, eradication technology has grown rapidly, so that now over half of the islands in the gulf are free of mammalian pests.[5] These eradications have enabled the reintroduction of numerous threatened species to the Hauraki Gulf islands. In addition to providing valuable contributions to national threatened species management, pest free islands in the Hauraki Gulf have become a major tourist attraction, with Rangitoto and Tiritiri Matangi receiving over 100,000 and 30,000 visitors per year, respectively. With human visitors comes the increased risk of pest incursions, inadvertently 'hitching' a ride.

Auckland Council runs the 'Treasure Islands' awareness and behaviour change programme in the Te Tikapa Moana o Hauraki / Hauraki Gulf in partnership with DOC, designed to reduce the risk of those pests hitchhiking ashore. As part of Treasure Islands, commercial transport operators can voluntarily apply for and attain a "Pest-free Warrant", which certifies that steps have been taken by that operator to reduce the risk of accidentally transporting pests to islands. Over 40 operators have a Pest-free Warrant and, combined with extensive networks of on-islands traps and other biosecurity devices, this programme has been remarkably successful at protecting the gulf islands. However, ongoing invasions are still a problem, especially for very small and easy to overlook species such as Argentine ants and plague skinks.

To address these ongoing invasions, this RPMP has extended the Pest-free Warrant to a regulatory approach, complemented by species-specific rules in some cases. Furthermore, the Pest-free Warrant will also be extended, on a voluntary basis, to other high risk businesses such as nurseries, building supply stores and quarries, to reduce the risk of their products accidentally containing stowaway pests when being moved to offshore islands. Note that in both the proposed options, moth plant and other pest plants continue to spread, which is recognition that it is not possible to eradicate all pests.

In addition to heightening efforts to keep pests off islands, this RPMP also prioritises control for a number of species on the Hauraki Gulf islands in recognition of the high biodiversity values on many of these islands, as well as their relative isolation and defendability that makes it possible to successfully control species that may be too widespread on the mainland to effectively control.

[5] Other pest free islands include: Beehive Island/Taungamaro, Broken Islands (Pig Islands), Te Hauturu-o-Toi/Little Barrier Island, Kaikoura Island (Selwyn Island), Mokohinau Islands, Motuhaku Island, Motuihe Island/Te Motu-a-Ihenga, Motuora Island, Pakatoa, Rakino Island, Rangitoto Island and Motutapu Island, Rotoroa, Tarakihi (east of Waiheke), Te Haupa Island (Saddle Island), The Noises and Tiritiri Matangi Island. Source: www.doc.govt.nz

2.2.8 Kawau and Waiheke Islands

Kawau Island holds the only population of wallabies in the Tāmaki Makaurau / Auckland region. This poses a very real risk to the mainland, with wallabies having severe impacts on native forest as well as pastoral farming. Expanding populations of wallabies in regions south of Tāmaki Makaurau / Auckland also pose a risk to our region. The RPMP aims to eradicate wallabies from Kawau and maintain the wallaby-free status of the remainder of the region. However, solely eradicating wallabies from Kawau has the potential to have perverse outcomes, such as creating an advantage for competing pests such as rats and possums or pest plants. In recognition of this, this RPMP combines the wallaby eradication programme with Kawau eradication programmes for possums, rats and stoats. Again, the Pest Free Warrant programme is considered critical in preventing reinvasion following eradication. This example of pest ‘replacement’ is important to consider from a methodological view of what is trying to be achieved with the RPMP. The benefits are often realised only after a combined effort to eradicate a number of species. This is important for the methodology chosen in this CBA also, as control of each species marginally contributes to the benefits.

Waiheke Island is home to many native shorebirds, wetlands with threatened kōkopu (galaxiid fish), and other high biodiversity values that are threatened by pests. Waiheke has the potential to be home to new threatened species introductions, such as kiwi, if pests are removed. In addition, Waiheke is within swimming distance of other pest-free islands, so rats and stoats remaining on Waiheke pose the risk as a source of ongoing reinvasion of surrounding islands. This RPMP therefore contains programmes for eradication of mammals such as stoats. Waiheke is an inhabited island, which places a higher risk of pest incursion from the marine traffic to and from the island.

2.2.9 Great Barrier Island

Aotea / Great Barrier has retained some of the region’s highest biodiversity values, including being home to threatened species such as the tāiko / black petrel and pāteke / brown teal. Because of the island’s relative isolation, some destructive and invasive pests such as mustelids and possums never made it to Aotea / Great Barrier. It is a key regional priority to keep it this way. Unfortunately human movement to the island comes the risk of stowaway pests; both Argentine ants and plague skinks have found their way to Aotea / Great Barrier in recent years. Goods, such as pot plants and landscape supplies, are identified as particularly high risk.

Aotea’s / Great Barrier’s distance from the mainland has also slowed the arrival of pest plants such as moth plant and woolly nightshade and many other pests found in gardens, which are increasingly common on the mainland. In many cases it is possible to remove populations of pest plants on the island before they get a serious foothold. Therefore, in recognition of Aotea’s / Great Barrier’s outstanding natural heritage and defendable geography, the RPMP gives special recognition to Aotea / Great Barrier and the surrounding smaller islands in this group through a range of programmes targeting low incidence pest plants for control, as well as managing pathways to prevent new incursions.

While possums and mustelids are absent from Aotea / Great Barrier, rabbits, rats and cats pose a serious threat to native fauna and island infrastructure. This RPMP proposed to manage these mammalian pests at high biodiversity value sites in the interim while the council (including the Great Barrier Local Board) works with mana whenua, DOC and the local community to progress conversations around ways to achieve a mammalian pest-free Aotea / Great Barrier in the future, taking into account diverse community perspectives and concerns.

2.2.10 Marine ecological

There are many acknowledged unknowns in our current understanding of Auckland's marine ecosystem. There is insufficient information on the location of many marine areas, including sub tidal habitats, significant bird wading areas and geological features. Seabird populations in the Hauraki Gulf are estimated to have declined by 69 per cent since pre human times. The greatest decline in seabird populations was likely to have been caused by introduced predators, reduction in prey availability, and loss of habitat. Following the implementation of legal protection in 1953 and conservation programmes, seabird numbers have been gradually recovering.

Much of the focus of the marine ecology portion of the LTP is to gather more data and survey marine habitats. It is known that the Hauraki Gulf is important for significant undisturbed habitats further away from the urban area. Marine ecology has a broad focus of habitat protection and restoration rather than targeting species in high biodiversity areas.

3.0 Methodology: Cost Benefit Analysis

Cost Benefit Analysis (CBA) is an optimisation tool, which attempts to identify the highest net benefits for society, based on potential Pareto efficiency[6]. CBA is valued by decision-makers as it is a decision support tool, enabling a clear understanding of the economic (resource) costs and benefits of proposals, that is, whether society will be better off from the proposal. In addition, the results of CBAs are readily comparable across a range of policy and industry areas, enabling comparison and prioritisation of initiatives in a manner that is consistent and coherent.

A CBA systematically compares the costs associated with undertaking a policy option with the anticipated benefits, relative to the 'base case'. The 'base case' or status quo is the situation if the policy option is not pursued. For a programme or planned expenditure to be considered worthwhile, it should have a Net Present Value (NPV) greater than zero, and a Benefit to Cost Ratio (BCR) greater than one (NZTA, 2016 and Treasury NZ, 2015).

The relevant perspective undertaken in a CBA is that of society as a whole, as opposed to groups or individuals or entities. This means that transfers of costs and/or benefits with no change to the underlying level of costs or benefits are not 'counted' in the analysis. It is important to understand if there is a significant redistribution of costs and benefits as this may have welfare effects. CBA is instrumental in measuring the extent to which society is made better off (wellbeing/welfare is improved) because of a policy proposal or action.

A distributional analysis is often undertaken in addition to a CBA, and it focuses on the financial impacts across various stakeholder groups, such as local government, producers, landowners, businesses, retailers, consumers and households. Such analysis considers in more detail the transfers between parties. The clear separation of efficiency and distributional issues is important for ensuring that stakeholder perspectives are not confused with implications for society.

CBA is also subject to limitations. Some generalisable insights include:

- Models are gross simplifications of the complexity of markets and make simple and at times misleading assumptions about market behaviour. Furthermore, many biodiversity and ecosystem values are not traded on markets (Greenhalgh et al., 2017).
- CBA often requires prediction of effects into the future. These are, by definition, expected values, and are subject to estimation biases (Boardman et al., 2014).
- Attempting to reduce everything to monetary terms can obscure the richness of the understanding of a project's or decision's effects (Murray, 2013).
- Given time and cost constraints of undertaking a CBA, priority is often placed on what is considered the most relevant costs and benefits. There are often data limitations

[6] Pareto efficiency: An allocation of resources is Pareto efficient if no alternative allocation can make at least one person better off without making anyone else worse off. CBA can be used to provide information about the relative efficiency of alternative policies.

necessitating assumptions, which can significantly impact the results of the modelling. Analysing the sensitivity of assumptions made in the study is therefore important.

- Often some of the most significant benefits are difficult to quantify (and monetise) and are therefore omitted from the studies (and reported results).
- There is no consensus in the discount rate that should be applied within CBAs. Organisations such as Auckland Council and Treasury provide guidance on discount rates, while the CBA literature on natural capital, biodiversity and ecosystems argue for low discount rates, given the threat of species extinction (Boardman et al., 2014).
- Assessments often overemphasise the benefits with little discussion of the costs of restructuring proposals, or additional costs that are required to realise or maintain those benefits.

The main lesson from this review is that the criteria for decision-making should in most cases be broader than the quantified information available from the CBA. A CBA is a decision support tool: it is a useful and often necessary input into decision-making but should not be the sole determinant. It should be used to evaluate the trade-offs between alternative policy/management strategies.

3.1.1 CBA and Total Economic Framework

In this section the framework used to measure the impacts of the two options, in addition to the LTP on pest management in the Auckland region, are described. The likely impacts of different pest management regimes were constructed by the relevant subject experts in the Auckland Council.

The impacts were expressed as either a reduction in existing pest levels, or the reduced risk of pest species expansion. The uncertainty associated with pest management is acknowledged, and the two options considered are scenarios of likely impacts. As such, these scenarios necessarily are predicated on a set of assumptions.

The likely impacts were given an ‘expected’ value, based on either existing market values or inferred non-market values. The CBA is constructed within a Total Economic Value (TEV) framework, due to the importance of ‘non-use’ values in evaluating biodiversity along with ‘use’ values (or market values). There are very few studies that measure the non-use value of biodiversity specifically in the Auckland region (Rohani, 2013).

The study used only New Zealand relevant data, given the unique attributes of New Zealand’s biodiversity and ecosystems. The study adopted a conservative approach, using lower values when a range of benefits were specified. This can be described as the minimum benefits that would be provided under each scenario. Data triangulation was undertaken, with a review and comparison of existing studies relevant to the CBA, to ensure that this study does not overstate the benefits. The study encountered benefits that could not be measured/valued through the benefits-transfer method and are not included in the measured analysis.

3.1.2 Use and non-use value in a Total Economic Valuation

Value is an attribute of worth – what people consider important. Value can be generated from using something (such as walking in a forest), or from non-use (knowing that the forest exists). In a CBA, values are expressed in the same unit of money, so they have a similar unit to add/subtract. Monetary value is relatively simple to estimate when a good or service is bought and sold on the market. Entrance fees to a forest park, or the amount of money an individual is prepared to pay to pursue a hobby such as kayaking are market based measures indicating the value that people place on, or are willing to pay for, things they 'use'.

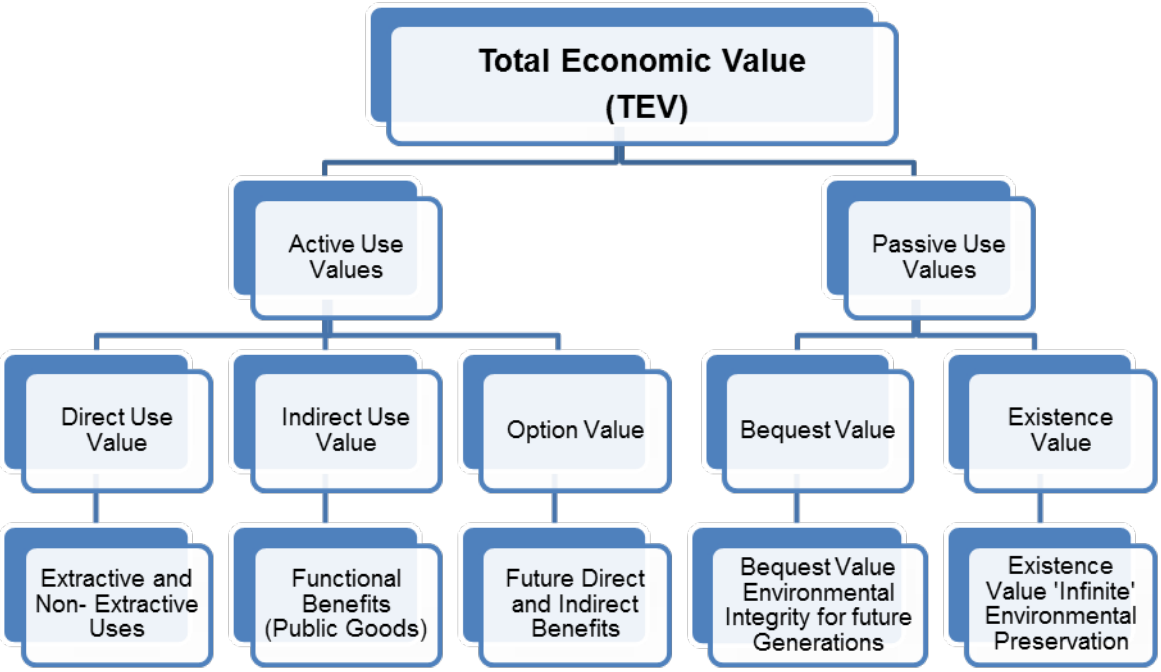
Within a Total Economic Valuation Framework, an allowance is conceptually made for people who are willing to pay for the continued existence of a particular landscape, ecosystem or species. This is of importance when assessing pest management practices, when there is a reduced risk of losing species and biodiversity is retained or enhanced. Such 'goods' will not be directly used or consumed by the individual making that judgement, but individuals/society might want to bequeath those goods to future generations or leave an option to the goods in the future.

The value of biodiversity is difficult to express, as much of the value exists as "known-unknowns". The precautionary principle applied to biodiversity protection is justified from the potential but yet unrevealed ecosystem services, such as the possibility of finding new medicines (Laurila-Pant et al., 2015). Evolutionary processes require continuity of species for continuity sake – not for any current use of species. Many sensitive or threatened species remain invisible or unknown to the majority of people and are thus difficult to value, even through revealed preference studies, which elicit willingness to pay measures.

When assessing the value of biodiversity, it is important to note that different human societies and communities place different values on species and ecosystems. For example the cultural or spiritual values of local people in certain regions may be sufficient to ensure their sustainable use and protection (TEEB, 2010). This is of relevance in this study in relation to iconic species found in Auckland, such as kauri, where the societal or cultural values attached to the species are much greater than the measurable use benefits of kauri forests (such as their ecosystem function of carbon sequestration).

In this study the utilitarian TEV approach was adopted to quantify the impact of increased pest control on the welfare of Aucklanders. At a conceptual level, it is relatively simple to delineate the use and non-use values attached to pest control (**Figure 3**). Conceptually, use-values were ascribed to the effects on agricultural production, aquaculture, carbon sequestration, recreation and tourism. Non-use values were identified as the biodiversity benefits resulting from pest control. The different proposed investment activities under consideration within Option A and B contributed to different improvements in the natural environment.

Figure 3. Total Economic Value Framework



3.1.3 Challenges encountered

The TEV framework offers a methodology to measure use and non-use values. It has its limitations and criticism, associated with inferring market values of goods and services. This CBA study had to overcome the methodological issues of obtaining sufficient information to separate out use and non-use values.

There are challenges in the measurement of non-use values, and the monetary values associated with biodiversity prove difficult to measure practically. This is often due to lack of information, but also due to a more fundamental philosophical issue with the valuation of biodiversity and ecosystems in themselves (Dymond, 2013).

A person derives use and non-use value from any given asset. Willingness to pay surveys can be conducted or used to assess the value of an asset – and methods such as surveying users of a resource (e.g., walkers in a bush area) on how much they are willing to pay for that resource alongside a survey of non-users (e.g., residents in another jurisdiction, who may or may not place value on the particular bush under study) can be used to distil total willingness to pay. This non-use value encompasses an existence value and an option or bequeath value (existence for future use, more altruistic – continuity for continuity sake).

When undertaking a study in which many factors contribute to biodiversity values, there is a risk of overstating or double-counting benefits due to interdependencies in natural systems. For this reason, a combined benefit was identified for some of the pest control species and activities, as the benefits are realised when damage from the control of all pests are considered – rather than one pest replacing another, if only one species is controlled.

With all CBAs, there is an inability to assess the preferences of future generations, and an assumption that future values should be discounted. Convention in CBAs introduces a social discount rate to this end. However, it is conceivable that biodiversity values appreciate in the future rather than becoming smaller. This is the case if their relative scarcity increases.

The issue of quantifying changes in a good/asset with existence value poses conceptual and methodological challenges in a study that is valuing natural capital or biodiversity. In general, non-use benefits tend to be less quantity sensitive than use benefits – e.g., people want to ensure that kauri forests do not die out (a tipping point between existence and non-existence) but may be uncertain or ambivalent regarding the amount/area of kauri forest that should be maintained/conserved. This links in with the point that non-use does not occur in easily defined geographic areas. There are spill overs between specific sites (e.g., kauri forest in the Waitākere versus Hunua Ranges), and between regions (e.g., if kauri are healthy and protected in Northland, does this have consequences for the value of Auckland kauri?). Another example relates to the values associated with willingness to pay for the protection of endangered birds such as the Fairy Tern, which is of national and international importance, in the context of conserving near extinct indigenous biodiversity. The benefits extend beyond the administrative Auckland region boundaries, and people outside of the Auckland region may be willing to pay to preserve Auckland's species or habitats. However, it is difficult to apportion such value in a fit-for-purpose cost benefit study, or to make any value judgements about relative value, in the absence of detailed surveys/evidence base regarding this topic.

Another challenge relates to undervaluing species due to uncertainty and/or ignorance. If there is little information about a species, a low value may be associated with it (Laurila-Pant et al., 2015). If someone does not know the attributes of a good or asset (ignorance), a zero or near zero value may be attached. In such cases, the 'precautionary principle' is often evoked to avoid the loss or destruction of a species or habitat.

While acknowledging the methodological issues of gathering sufficient information to populate the CBA study, a pragmatic and conservative approach was adopted. Given the scope and short time period for this analysis, the study adopted a benefits-transfer approach, while the authors acknowledge above challenges. Such an approach uses existing research and analyses to elicit monetary values for the benefits identified.

3.1.4 Benefits transfer

Benefits transfer is a method using data and research published in one study area and applying it in another area, when time and resource constraints are such that primary data cannot be collected (Boardman et al., 2014). Adjustments to data from secondary sources can be made to suit the study area. There is the risk of transfer error; to avoid such error, adjustments to the data were made for the population of Auckland, and the attitudes of Auckland toward environmental conservation/ willingness to pay. This CBA used only New Zealand studies for benefits transfer. However, international studies were also consulted for data triangulation and comparison.

3.1.5 Literature review

The extent and magnitude of damage costs caused by an invasive species on the natural environment depends on many factors. In particular the place on the infestation curve in Figure 3 is important in terms of how well established the pest species is, and the impact it will have on the indigenous ecosystem. The costs of the impacts are then measured as the difference in the value of ecosystem services with and without the pest/invader under study (Marbuah et al., 2014).

New Zealanders value both recreation and the existence value of biodiversity for the natural environment very highly (MacIntyre and Hellstorm, 2015, based on Kerr and Sharp, 2008). The value of ecosystem services (with no consideration of pest or invasive species impact) was measured by Patterson and Cole (2013) and (1999) using a benefit transfer approach to estimate economic values of New Zealand's land based ecosystem services under TEV use-values (provisioning, cultural, regulating, supporting) and non-use values (option, existence, bequest). They estimated the total net flow (not stock) value of ecosystem at $_{1994}$\$46 billion. To put this in perspective, this equates with more than half of the GDP for 1994 (\$84 billion). They used results from studies outside New Zealand to estimate total net flow because of a lack of New Zealand data, especially for supporting and regulating services and passive values. While the authors recognise there are some data and that there are methodological and theoretical issues that arise from this study, their estimate is used by many experts in natural environment valuation, and can be considered a yardstick or standard study for comparison[7].

In 2006 DOC commissioned a study to estimate the value of biodiversity to the New Zealand economy. The work used a number of case studies to measure the total amount spent by tourists and economic activity generated by national parks/conservation area. This value came to $920 million per year.

The values of ecosystem services and biodiversity from the studies above were not used directly in the benefits transfer approach of this CBA, as there was no explicit consideration of the impact of pests in the above studies. However, they are worth mentioning as they show the high values associated with ecosystem services and biodiversity, and they also reveal that tourism is dependent on high biodiversity values.

Although Patterson and Cole (2013) offer the most comprehensive TEV study of ecosystems in New Zealand, we focused our attention on reviewing studies that measured the change in ecosystem services or biodiversity values as the result of pests.

Nimmo-Bell et al. (2009) reviewed the economic analysis on the costs of major plant and animal pests to the primary sectors (agriculture, forestry, fisheries, horticulture). Their study showed that total production losses were at least $_{2008}$\$1.3 billion. In 1999, Bertram estimated

[7] https://scholar.google.co.nz/scholar?rlz=1C1GGRV_enNZ751NZ751&um=1&ie=UTF-8&lr&cites=3874007088277208770

this cost to be $4.7 million. The difference between these two studies conducted ten years apart may be the result of additional nine new invasive species in Nimmo Bell et al. (2009).

Sullivan and Hutchison (2010) assessed the impacts of plant and animal pests listed in the proposed Bay of Plenty Regional Pest Management Strategy (RPMS) and evaluated the costs and benefits of the proposed regional actions. They performed CBAs on each species using a modified version of the Harris Model.[8] They developed a detailed CBA based on the assessment of pests of special concern in the region. In a similar context a CBA of RPMP by Bassett et al. (2016) qualitatively analysed the costs and benefits of pest species for the Auckland Council (internal document).

Most of the quantitative New Zealand studies on the impact of pest management were focused on one or group of similar (in terms of impact) pests in the whole country or a region. For example, possum is the most prevalent pest in quantitative studies (OPSRI, 2014[9]; Greer, 2010 and Tait et al., 2014). Where contingent valuation methods have been used to estimate the benefits of possum control programmes, the willingness-to-pay amounts have been significant ($67-$392 per person/household per year; Lock 1992; Kerr and Cullen 1995; Yao and Kaval 2008).

Table 1 summarises the quantitative studies on the pest management in New Zealand that were reviewed in this study.

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[8] The Harris Model was developed in 2000 by economist Simon Harris specifically for RPMS assessments. The model was not considered to be applicable in this high level CBA, which focuses on broad overarching benefits to society. The Harris model measures the impact on a species by species basis, and not the aggregated effect of controlling multiple species together, at any given time. The benefits would be overestimated if added together on a species by species basis, given the overlap in effects of pests.

[9] OSPRI is a partnership between primary industries and the government, and manages two national programmes – NAIT and TBfree. NAIT provides the national animal identification and traceability system and TBfree aims to eradicate bovine TB from New Zealand. https://www.ospri.co.nz/about-ospri/our-company/

Table 1. A summary of pest management studies in New Zealand

Author	Year	Pest type in pest management/ Other interventions	Area	Value description	Unit	Base year value
Nimmo-Bell	2009	Around 20 pests	New Zealand	Primary production loss	Annual	$1,300m
Bertram	1999	Argentine stem weevil, rabbits, possums, Californian thistle, clover root weevil, gorse and blackberry, rose grain aphid, powdery mildew, wasps and other (10%)	New Zealand	Primary production loss	Annual	$358m
Williams and Timmins	2002	Weeds	New Zealand	Lose of native biodiversity	Annual	$1,800m
Tait et al.	2014	Possum	New Zealand	WTP[10] for biodiversity benefits of TB	PV 35 years	$621m
OPSRI	2014	Possum	New Zealand	Mainly benefits from TB eradication	PV 30 years	$6,600m
Greer	2010	Possum	Hawke's Bay	Cost pf TB to agriculture sector	PV 30 years	$5.72m
Kerr and Sharp	2008	Pest wasp	Lake Rotoiti	WTP to wasp control that halted the decline in insect numbers at the Lake	HH/annum PV 5 years for 300,000 South Island HH	$150 $195m
Philips	2014	Prevent the decline in quality of the Waikato river from the upper to central zone. Freshwater ecosystem health improvement from "poor" to "fair"	Hamilton	Additional visits	Per trip Annual	$5.16 $16m

[10] Willingness To Pay

4.0 Description of Costs and Benefits

This section describes the activities within the Outcome Areas, their associated costs under each investment option and the key impacts (expected benefit) likely to result from their implementation.

The following are the main assumptions in this study.

- The study area is the whole Auckland region and benefits are calculated for the region. Some of the benefits would be realised or would include a wider geographical area but benefits outside the region are not considered.
- The project time is 32 years from 2019 including 10 years of the LTP.
- The project life extends to 2050, to reflect the target year of the Pest Free Auckland initiative and to include some of the benefits that would occur years after the RPMP's implementation.
- The major factor driving the positive impacts (benefits) of the proposal is behaviour change of Aucklanders. All the activities under the Pest Free Auckland have been set to help this behavioural change. Therefore, the impact of Pest Free Auckland initiative has been added to the analysis through additional Aucklanders who would be willing to contribute to natural environment protection activities. The detail of this assumption is explained further below.
- It assumed that benefits would occur from year 11 (when the plan is fully implemented). It is a conservative assumption as some of the benefits would start occurring gradually even after the first year of the plan implementation.
- The benefits estimates are based on the avoided negative impact of pest, that would occur under the counterfactual (current state), as the result of each investment option implementation.

4.1 Costs

The total cost of each Option (A and B) is the sum of additional Operational Expenditure (Opex) and Capital Expenditure (Capex) of a series of activities related to each of the 11 Outcome areas, over and above the current planned LTP expenditure, or the status quo situation (counterfactual). An overview and description of the main cost components for the LTP Natural Environment Investment Options A and B are outlined in Appendix 1.

The total cost of activities under Options A and B were estimated by the Environmental Services (ES) Unit to be $117.47 million and $241.72 million respectively. It should be noted that these costs are slightly lower than the full set of LTP investment options for the natural environment (Figure 1), because there are some additional activities in each option that are not included in the defined Outcome Areas by ES for this analysis.

Strategic partner contributions are additional costs which are not sourced from Auckland Council rates but are contributed by DOC and other parties under Option B to achieve the intended outputs of pest free status for Waiheke and Kawau islands. In total other parties would contribute $10.71m.

The intended method to pay for the additional costs is through a targeted Auckland Council rate increase. This is a tax, and within economics, a deadweight loss of a tax is recognised. Deadweight costs or excess burden are costs associated with the distortions that result from a tax to raise necessary funding for public projects. In the absence of a tax, consumption choices would differ from what they would be with a tax (Boardman et al., 2014). That is, people move away from things that are taxed and towards things that are not. This reduces economic welfare. For the purposes of this analysis, no distinction is made between taxes and rates. Auckland Council rates are considered a tax. Treasury New Zealand recommends that 20 per cent be added to project costs that are funded by taxation and we apply this deadweight cost to all costs funded from rates.

To reflect the activities that would continue after the RPMP implementation (from 2029 onward) to maintain the levels of pest controlled, this study assumes 90 per cent of the last year's (2028) Opex continues over the rest of the project life.

Total cost of the Options A and B in the whole project life (32 years) including the deadweight cost of Auckland Council's contribution and additional partners' contributions are estimated at $247.56 million and $660.52 million respectively. A summary of costs for Options A and B is presented in Table 2.

Table 2. Estimated outcome area cost under each LTP investment option

	All figures in millions of dollars					
Outcome area	Option	2019-2050 32 years	2019-2028 10-year RPMP and LTP period	Strategic partners contribution 2019-2028	Deadweight cost	Total cost in the CBA time frame
Risk of kauri dieback spreading	A	$97.49	$83.43	$0.00	$19.50	**$116.99**
	B	$224.01	$95.47	$0.00	$44.80	**$268.81**
Pest Free Auckland – enabling communities	A	$81.70	$22.30	$0.00	$16.34	**$98.04**
	B	$90.59	$27.73	$0.00	$18.12	**$108.71**
Pest animal and plant control on regional and community parks	A	$4.42	$1.45	$0.00	$0.88	**$5.30**
	B	$65.93	$52.75	$0.00	$13.19	**$79.11**
Rural mainland possum free	A	$0.00	$0.00	$0.00	$0.00	**$0.00**
	B	$49.18	$18.60	$0.00	$9.84	**$59.01**
Freshwater pests	A	$0.00	$0.00	$0.00	$0.00	**$0.00**
	B	$6.59	$5.35	$0.00	$1.32	**$7.91**
Marine pests	A	$12.57	$4.20	$0.00	$2.51	**$15.08**
	B	$14.57	$4.92	$0.00	$2.91	**$17.48**
Hauraki gulf pest movement control	A	$3.72	$3.16	$0.00	$0.74	**$4.47**
	B	$72.57	$25.65	$0.00	$14.51	**$87.08**
Waiheke Island	A	$0.95	$0.95	$0.00	$0.19	**$1.14**
	B	$5.59	$5.59	$7.57	$1.12	**$14.28**
Kawau Island	A	$0.00	$0.00	$0.00	$0.00	**$0.00**
	B	$1.84	$1.84	$3.14	$0.37	**$5.36**
Great Barrier Island	A	$0.00	$0.00	$0.00	$0.00	**$0.00**
	B	$0.86	$0.29	$0.00	$0.17	**$1.03**
Marine ecological	A	$5.46	$1.99	$0.00	$1.09	**$6.55**
	B	$9.78	$3.55	$0.00	$1.96	**$11.74**
Total cost	**A**	**$206.30**	**$117.47**	**$0.00**	**$41.26**	**$247.56**
	B	**$541.50**	**$241.73**	**$10.71**	**$108.30**	**$660.52**

4.2 Benefits

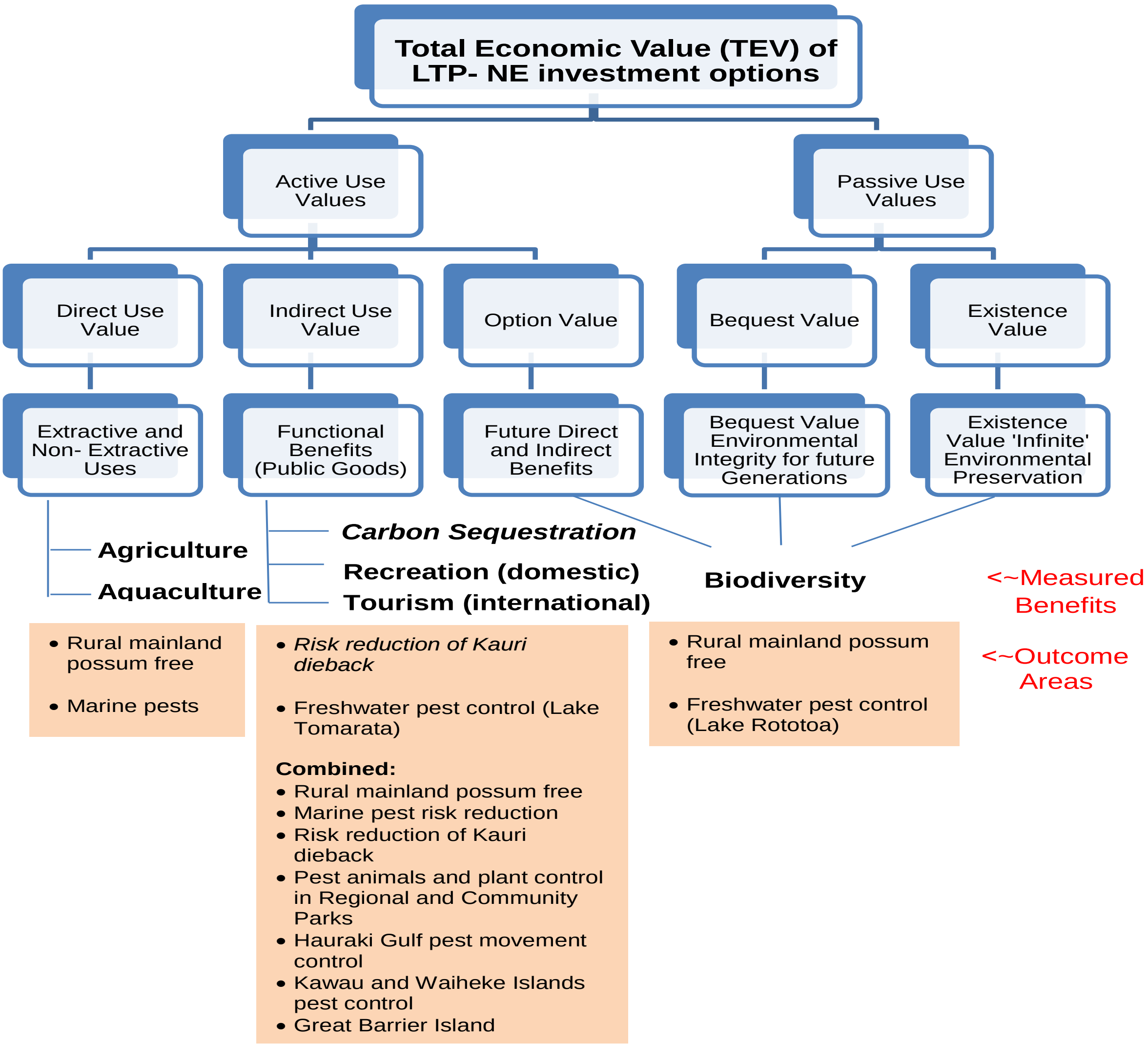
This section presents the method used to estimate benefits of each natural environment investment option. The benefits are presented in non-discounted (actual) terms. The estimates contained in this section are relative to a counterfactual of the status quo investment.

We have identified a range of possible benefits. However, due to time and resource constraints, we have focussed only on a subset of quantifiable benefits. As per Figure 4 the benefits are:

- Social carbon sequestration benefits of Kauri dieback control
- Recreational benefits of Lake Tomarata
- Biodiversity (existence, bequest and optional values) benefits of Lake Rototoa
- Biodiversity benefits, as the result of possum control
- Output loss avoided in agriculture as the result of possum control (partial, does not include avoided cost of horticulture)
- Output loss avoided in aquaculture
- Tourism benefits, combined effect of: possum control, marine pest control, parks, Hauraki Gulf islands, Kauri forest and Pest Free Auckland
- Recreational benefits, combined effect of: possum control, marine pest control, parks, islands, kauri forest and Pest Free Auckland.

For the tourism and recreation benefits, instead of measuring value related to each outcome area separately, a combined or composite approach was used. This was to avoid double counting and to ensure the benefits arising from overlap between outcome areas were not overestimated. A weighted multi criteria analysis framework was adopted (weighting system). The impact of the Pest Free Auckland initiative is included in the analysis to adjust Willingness to Pay (WTP) results, ‘transferred’ from New Zealand studies. The method of measuring each benefit is described further below.

Figure 4. Benefits and their link to pest management activities

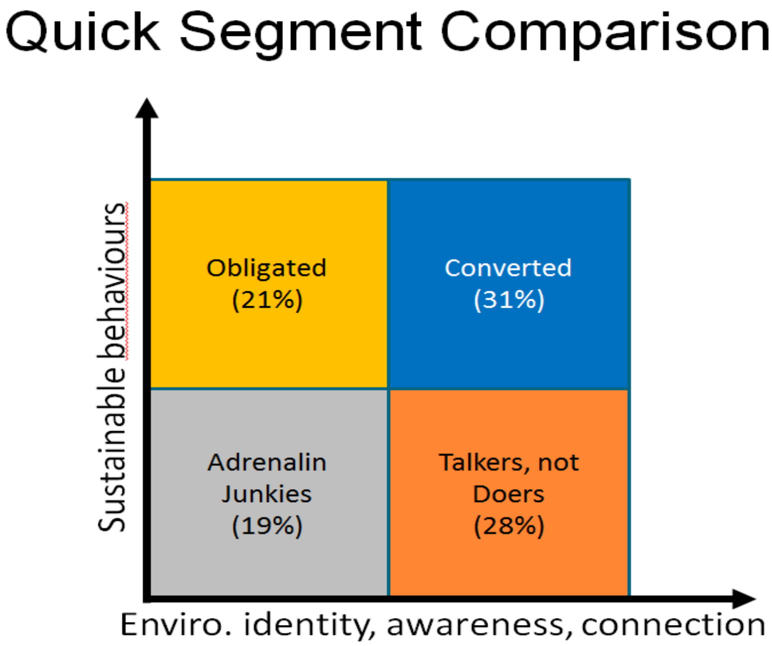


4.2.1 Pest Free Auckland

Pest Free Auckland is a supportive initiative to enable communities and individuals to protect Auckland's environment from pests. Pest Free Auckland has a set of goals, which are independent of Auckland Council's RPMS. One of the activities undertaken under the Pest Free Auckland initiative aspires to change behaviour amongst Aucklanders, regarding pest management. As a consequence, the contribution of Auckland households to achieving Pest Free status by 2050 increases, although the initiative does not imply the attainment of Pest Free Status by 2050, nor was such an assumption factored into this CBA. An assumption of increased community involvement in Pest Free Auckland is that there is a process of social learning, and subsequently the value that Aucklanders place on biodiversity increases over time. The analysis elicited figures for the proportion of Auckland households that currently would be willing to pay for biodiversity and environmental improvement now and in the future.

A DOC (2017) segmentation survey of 2124 Aucklanders reveals the environmental and conservation values, attitudes and behaviour of those surveyed. This data showed a high importance of nature; 85 per cent of those surveyed stated 'connection to nature improves their quality of lives'. However, a significantly lower proportion surveyed do anything: 31 per cent of the respondents, dubbed "the converted" were engaged, had a strong environmental identity and a high degree of sustainable behaviour (much less than New Zealand average 57%)[11]. In the survey, 28 per cent dubbed the "talkers not doers" stated they were connected to nature but revealed low levels of sustainable behaviour. Nineteen per cent were "adrenalin junkies", having an average connection to nature but a low degree of sustainable behaviour and low environmental identity. The remaining 21 per cent dubbed "the obligated" had the lowest connection to nature, and the lowest environmental identity but had high sustainable behaviour (see Figure 5).

Figure 5. Department of Conservation's 2017 Conservation Values



Source: adapted from DOC (2017)

This survey was used in this CBA to indicate the proportion of Auckland residents who would be willing to participate in pest reduction activity, within the Pest Free Auckland programme. We assumed that the "Converted" group are those who currently are willing to pay and contribute to environmental improvement in the status quo. We assumed that under the community engagement and awareness programme of Pest Free Auckland, Option A, the proportion of "Converted" would increase to 40 per cent and in Option B, increase to 50 per cent within the lifetime of the Auckland Regional Pest Management Plan. We also assumed that by 2050, the 85 per cent of those Aucklanders who felt that "connection to nature

[11] A survey of more than four thousands New Zealanders by Ipsos (2016) for DoC, show the participation in conservation-related activities of 57%. The most prominent actions taken were donating money (23%), actively seeking information (19%), raising awareness about an issue (17%) and expressing an opinion through online forums (17%),

improves their quality of lives" would become actively involved in environmental protection activities, aligning with the goal of Pest Free New Zealand, whereby place attachment becomes strengthened, and "people are more likely to act to protect places they feel connected to" (DOC, 2017).

The implication for the CBA analysis is that the proportion of Aucklanders who place value on biodiversity and the environment increases throughout the duration of the RPMP, through increased understanding and knowledge of their environment. Hence the number of people who are willing to pay for pest management activities increases over time. This proportion of the Auckland population was used to adjust the result of WTP studies we transferred from studies in other areas of New Zealand.

4.2.2 Kauri dieback

The benefits of preventing kauri dieback are challenging to measure under a TEV framework. When assessing the value of biodiversity or an iconic species such as kauri, it is seldom possible to assign a monetary value because different communities place different values on such unique and iconic species, tending to infinity if cultural and spiritual values are attached. In such cases, it is the socio-cultural value of the species associated with mental wellbeing and cultural identity (Laurila-Pant, 2015). While acknowledging that this CBA did not attempt to measure such a socio-cultural value for kauri, the study identified an indirect use benefit of kauri forest, which is measurable. This value of preventing kauri dieback is therefore partial, and does not consider the wider socio-cultural benefit. The indirect use benefit of preventing kauri dieback is the value of carbon sequestration, one of the ecosystem services that kauri provide.

The total area confirmed and possibly infected with kauri dieback in the Waitākere Ranges and elsewhere in Auckland is estimated at 606ha and 404ha respectively, based on the monitoring data by the council's Biosecurity Team. A conservative assumption based on literature (McKelvey and Nicholls, 1959 and Ahmed and Ogden, 1987) considered 65 per cent of the trees in a kauri forest are kauri trees.

If there is no intervention in the spread of kauri dieback (e.g., the status quo option) the rate of spread will increase. Based on monitoring from a currently infected forest, Hill et al. (2017) suggest that the rate of kauri dieback spread has been 2.2 per cent each year in the last five years. The rate of spread would increase if a wider area is infected by the disease. The study assumed the spread rate increases by 0.1 per cent per year, reaching 5.5 per cent by the end of the project life 2050. This CBA considered a 'contained' spread, whereby the disease does not spread to new disease-free areas. If that were this to happen, the rate of spread would be much higher, as the same rate of spread would apply to different kauri forest areas. There is a real risk of this happening, given the restriction of public access to the Waitākere Ranges. This is a plausible risk, given the restriction of public access to the Waitākere Ranges potentially increases demand for tracks in other forested areas.

It was assumed that kauri trees are capable of carbon sequestration until they are totally dead. Kauri dieback has a time lag of years between time of infection and confirmation of disease, and another lag until the tree dies. Hill et al. (2017) suggests that it takes 5 to 10 years from the time that the infected tree is identified until it is completely dead. For consistency in conservative assumptions, the analysis considered 10 years as the period in which the current affected trees would die, applying a simple linear death rate.

It is also known that when a kauri tree dies the replacement time to grow a substitute tree is between 100 to 200 years. Hence there are no replacement trees that can substitute the ecosystem function of kauri tree carbon sequestration within the project timeframe. Kauri dieback poses a real loss in terms of carbon sequestration, rather than a 'displacement', or that function transferring to another tree species, in the short-medium term. There would be the same impact on other ecosystem services related to kauri but these were not measured due to data constraints. The CBA analysis used a lag model to calculate the annual hectare of kauri forest that would be lost, given the current management practice (loss of 1245ha by 2050). The management practices in Option A would reduce the risk of kauri spread by 40 percent (saving 498ha). Option B would reduce the risk of kauri spread by 60 percent (potentially saving 747ha of kauri forest).

Based on the average New Zealand carbon sequestration rate from the National Vegetation Survey data (Hall, 2001), the average amount of carbon sequestration is 525 tonnes per hectare of forest.

The economic damage caused by a tonne of carbon dioxide emissions is often referred to as the "social cost" of carbon. It could be measured through damage cost avoidance of the marginal decrease in GHG emission as a result of kauri dieback spread control (Dobes et al. 2016).[12] The social cost of carbon usually includes market and non-market impacts and covers health, environment, crops and other property damage potential and wider social aspects. The social cost of carbon has been suggested for use by the New Zealand Transport Agency in their economic evaluation manual. This CBA uses NZTA's (2016) social cost of carbon value of $_{2017}$\$53 per tonne as a proxy for changes in carbon sequestration.

The benefits of avoided loss of CO_2 sequestration from kauri trees were estimated as \$133.8 million by 2050 under Option A and \$200.7 million for Option B.

4.2.3 Freshwater lakes

Option B has increased expenditure on pest control on two high priority lakes in the region – Lake Tomarata and Lake Rototoa. A separate analysis was undertaken for each lake, given the very different attributes of the lakes. Lake Tomarata is a high use recreation lake, while Lake Rototoa has high ecological value. The incorporation of freshwater lake benefits may

[12]There are three other approaches to measure the carbon cost including abatement cost (cost of achieving a given level of CO_2, e.g., under Paris agreement, New Zealand has to reduce its GHG emissions by 30% down 2005 levels in 25 years.), market price of carbon (the cost that is used to inform policy decision and is usually less than actual social cost of carbon due to political considerations) and willingness to pay estimates that use revealed or stated preference methods.

seem small in comparison to the benefits of other pest controlling outcomes (which have higher use value e.g., associated tourism values). However, they are an example of threshold levels that the council sets to determine in terms of the minimum level of biodiversity that society wishes to maintain (Laurila-Pant, 2017), as discussed in section 3.1.3 relating to quantity changes of biodiversity and threatened species or natural capital assets.

4.2.3.1 Recreational value of Lake Tomarata

The latest NIWA (2017)[13] assessment showed the lake has undergone a major vegetation decline from excellent condition in 2008 (LakeSPI Index[14] of 78 per cent in 2008 declining to 63 per cent in 2012) to its current non-vegetated status (LakeSPI Index 0 per cent). Therefore, the lake has lost biodiversity value within 10 years and the main value remaining for the lake is the recreational use of it.

Recreational use, specifically motor boats, are harmful to the ecological health of the lake (in conjunction with the pest fish). In order to avoid the lake getting to the point that it could not be used for recreational activities, due to negative health impacts for humans, the study assumes that motor boats will be prevented from entering the lake (recognising that this is not a policy proposal at this stage, but is a required assumption in this analysis to realise the benefits of pest management in the lake). As an implication, the recreational value of motor boats was excluded from the benefits. The value of non-motorised boats, specifically kayaking, was included.

Based on the rapid rate of decline of the health of the lake over the last decade, the CBA analysis created two Medium and Lower bound scenarios: that the lake quality continues its rapid decline and is not suitable for recreational use in 10 years; and the lake's health decline is slower but becomes unsuitable for recreational use in 20 years. The process of data triangulation used and the estimation of the monetary value of avoided loss of recreational use is summarised as:

- Finding an estimate of the proportion of adults who are a member of a recreational boating community in Auckland (38 per cent), based on national data of the recreational boating community (509,877)[15] and the estimated total number of Auckland adults in 2018 (1,342,921)[16].
- The lake is not close to the main roads, and its high use indicates a willingness to pay (travel) to use the lake but not for all Aucklanders. A catchment area of 25km radius

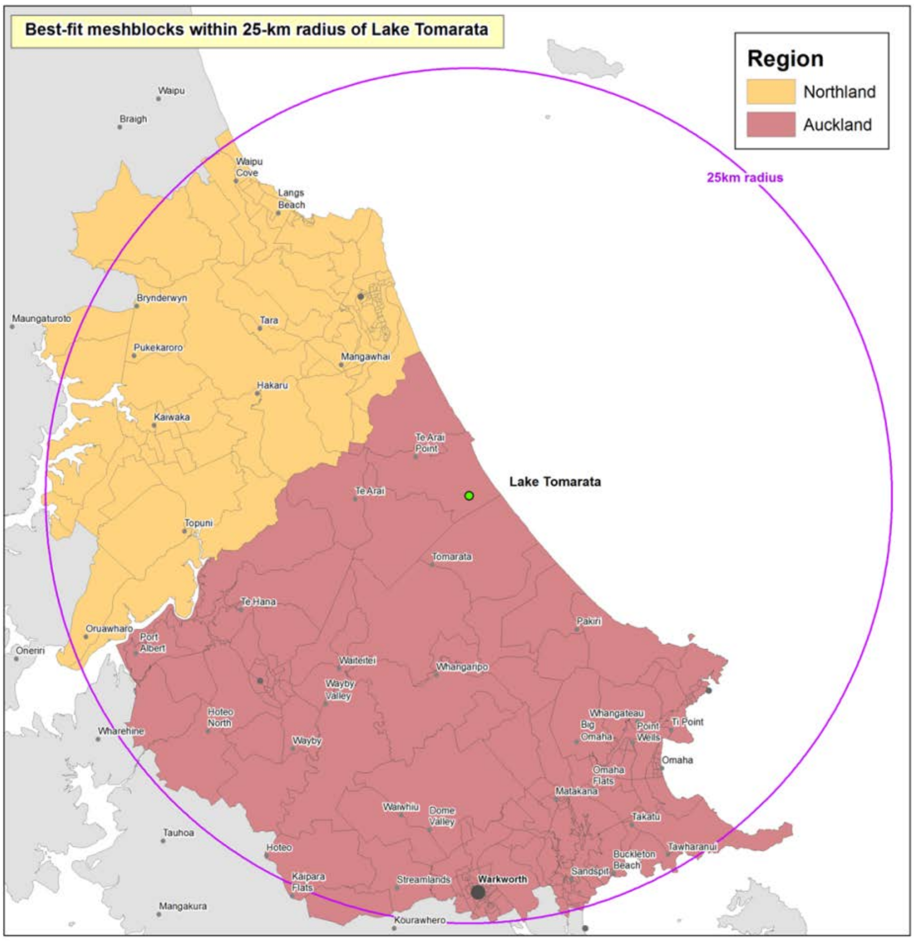
[13] De Winton and Burton (2017)
[14] "LakeSPI indices included a 'Native Condition Index' where higher values indicate better lake condition based on the diversity, depth extent and quality of indigenous plant communities; an 'Invasive Impact Index' where higher values show greater impact from invasive weed species and a lower lake condition; and a 'LakeSPI Index' which provides an overall indication of lake condition with higher values indicating better lake condition. LakeSPI indices are expressed as a percentage of a lake's maximum scoring potential to enable comparisons between lakes." (Auckland Council, 2017 p.7)
[15] Maritime NZ (2016). Summary of Recreational Boating
[16] Statistics New Zealand, Population projections (medium), 2013 (base)-2043 update

from the lake was assumed for recreational users, which includes Warkworth, the nearest town centre (see Figure 6).

- Triangulating data on recreational boat use for kayaks revealed that kayak ownership constitutes 30 per cent of total recreational boat ownership[17].
- A kayaker's willingness to pay ($\$_{2017}$113 per visit)[18] was calculated[19] within the lake catchment. This willingness to pay was extrapolated from Covec's (2013) study on freshwater values in Southland, on the value per household for a day kayaking.
- An assumption of annual frequency of use was made: each kayaker would use the lake five times per year.
- The pest free Auckland assumption was used for the WTP proportion of the catchment population.

The recreational value of Lake Tomarata (only for Option B) was estimated to be $54.7 million by 2050.

Figure 6. Lake Tomarata recreational use catchment



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[17] Maritime NZ (2016)_Summary of Recreational Boating

[18] The original value is $\$_{2012}$109.

[19] Who would contribute based on Pest Free Auckland percentage of contributors, are part of boating community and are likely to own a kayak.

4.2.3.2 Biodiversity of Lake Rototoa

The LakeSPI index for Lake Rototoa currently is “Good”. However, there has been an ongoing decline in the index from when it was monitored in 2007, 2010 and again in 2017. This CBA study assumed a continuation of this trend, under the status quo.

Change in the LakeSPI index for the lake was projected, and following the trend, it was possible to estimate when (which year) the status of the lake would switch from “good” (>50%) to “fair” (50%><20%) or “poor” (less than 20%). Impacts of pest species is one of two components of a LakeSPI.

Using a ‘benefits transfer’ method of ascribing value from another similar research study (Covec, 2013), this study adopted a Willingness to Pay (WTP) for the existence value of freshwater[20]. We assumed a LakeSPI value of 51 per cent is equivalent to "undeveloped" and a LakeSPI value of 21 per cent is equivalent to "developed" condition surrounding the lake. Therefore, an assumption of a one unit increase in LakeSPI is associated with a $1.57 WTP per household per year per lake.

Since the changes in level of invasive species is not the only component of the LakeSPI index we estimated the changes to the LakeSPI index to be 0.38 percentage point in relation to one percentage point change to the invasive impact index, based on the past trend.

Based on the assumptions developed for Pest Free Auckland (5.2.1), and Auckland residents’ attitude to the environment and willingness to contribute to environmental improvement, the study assumed that 31 per cent of Aucklanders would be willing to make a one-off payment in the magnitude of $4.9 million in 2019, to maintain the “Good” water quality status of the lake through pest control.

4.2.4 Possum control – avoided losses in agriculture

Currently, 28 per cent of rural Auckland is controlled for possums. This does not change for Option A. Under Option B however, an additional 22 per cent of the rural area would be controlled for possums. However, from that additional rural area, only 33 per cent is forest, while the remainder is in different types of rural land, including a variety of agricultural and horticultural land. Option B would result in benefits to the agricultural sector (along with the enhanced biodiversity values, as described in 5.2.5 below).[21]

[20] For existence value they estimated the change in average ecological health (measured using a Macroinvertebrate Community Index, MCI) across all river sites. They used an MCI of 120 to represent an “undeveloped” river, and an MCI of 80 corresponds to a “developed” river. Households are willing to pay $47 (lower bound) each per year to prevent an undeveloped river from being developed. They assumed this corresponds to a linear relationship where a one unit increase in MCI is associated with a $1.31 per household per year per river (for the four main rivers considered in this analysis) increase in existence values. We assumed Lake SPI 51 equivalent to "undeveloped" and Lake SPI 21 equivalent to "developed” condition. Therefore, one unit increase in LakeSPI is associated with a ($1.57) per HH per year per lake. (considering lower assumption $47/ (51-21)).

[21] There are other benefits to possum control (NZIER, 2014), which were not discretely measured for possum control, as the recreational and tourism benefits are included in the composite benefit measure.

Pasture damage from possums for the whole of New Zealand was calculated at $_{2017}$\$36 million per annum (Dodd et al., 2006). Auckland's share of this total damage was estimated at $3.9m, based on Auckland's proportion of exotic grass cover – 2.2 per cent of New Zealand total (Landcare, 2012). By 2029, the benefits of the 22 per cent increase in protection would be realised, equating to an estimated $175,867 per annum. Possums are known to damage horticultural and fruit crops. However we did not find sufficient evidence in published studies to include this value for Auckland.

4.2.5 Possum control – biodiversity benefits

The biodiversity value of possum control in Auckland was calculated using a benefits transfer method. A New Zealand choice modelling study of the biodiversity benefits of tuberculosis (TB) possum control shows that on average survey respondents were Willingness To Pay $3.69 for each one per cent increase in the protection of forest canopies, native birds, within-forest plants and large native invertebrates per annum (Tait et al., 2014).[22] We adopted this figure, using the proportion of Aucklanders who would be WTP (as per Pest Free Auckland assumption) for the targeted improvement in possum control (22 per cent additional coverage, as specified in Option B).

The additional biodiversity value for Option B possum control is $10 million over the life of the project.

4.2.6 Marine pest control – aquaculture benefits

The aquaculture industry bears the cost of biofouling on its lines. Some, though not all, of this fouling is from invasive pest species. Current estimates from a global study on aquaculture by the UN Food and Agriculture organisation estimates that between 5 to 10 per cent of the aquaculture value added is due to fouling. The study assumed that 50 per cent of biofouling on aquaculture equipment is due to invasive marine species. Our study conservatively attributed a five per cent bio-fouling cost of Auckland's aquaculture annual value added, $30.59 million (Murray and McDonald, 2011) due to biofouling, and attributed 50 per cent of this fouling to pest marine species.

The avoided cost of biofouling as the result of pest control for Options A and B were estimated as $1.5 million and $3 million over the project life, respectively.

[22] This estimate probably underestimates the magnitude of the benefits of possum control because this non-market benefit calculation focuses only on biodiversity in native forests and reserves and largely ignored native biodiversity on productive land.

4.2.7 Benefits of combined effects

This analysis recognises that the concerted effort of the separate pest control management activities have overlapping outcomes (see 4.1.2 and 4.1.3 above). Each pest control activity, on each targeted species, marginally contributes to the overall benefits to the Auckland region. To avoid double counting the effects of each activity on some use values (as manifest through tourism and recreation), we created a composite value of benefits for the combined pest management regime.

Ideally, and with more primary data specific to the Auckland region, the study could segregate the benefits using a strong evidential base. As such information was not available in the timeframe the study was undertaken, so an informed weighting system was developed for the combined improvement in recreational and tourism values.

4.2.7.1 Tourism benefit – combined effect

For tourism, the increase in popularity of the region due to a reduction in pests was considered. This benefit was calculated based on the likely changes to the length of stay of visitors to the Auckland region. To measure this effect, we considered that the benefits would manifest as one additional visitor night (based on literature, e.g., NZIER, 2013, Morgan, 2014 and Russell et al., 2015) for eco tourists, 18 per cent of international and domestic visitors to the Auckland region. The eco tourist share in the total Auckland visitors was estimated based on the percentage of international tourists who are on vacation/holiday (56%)[23] and would do natural environment related activities (33%)[24].

A weighting system that considers the contribution of each of the outcome areas to one additional tourist night was developed, assuming that Auckland was moving toward pest-free status. This additional visitor night could be spent on a range of natural environmental activities, all of which would be enhanced by the RPMP, the components of that one extra day and their relative weight (or importance, as a determinant of tourism).

The Hauraki Gulf Islands were considered to have the highest contribution to additional nature or biodiversity based tourism. There is evidence from increased visitor numbers to Tiritiri Matangi, that there is excess demand to visit the pest free island. Waiheke and Rangitoto/Mototapu islands have also steadily grown in popularity (HGSoE, 2018). This weighting system provides a framework and can be altered – if, for example, information on an increase in marine pests' impact on tourism became known, or if there were a spike in marine based tourism that depended on marine habitats.

[23] Statistics New Zealand: International visitors to Auckland and NZ by purpose of visit and guest nights by region and origin 1997-2016.
[24] Statistics New Zealand: Domestic Travel and International visitor activities 1999-2017.

The changes in the levels of pests between Option A and B were also considered as an additional percentage point difference[25], to calculate the increase in visitor nights as a proportion of one additional night stay. Table 3 summarises the weighing system.

Table 3. Weighting system for the contribution of activity areas on tourism

Figures in percentage point units (arithmetic difference of two percentages)	The impact share on tourism	The magnitude change under option A (percentage point)	The results of change under **Option A**	The magnitude change under option B	The results of change under **Option B**
Hauraki Gulf (Islands and vessel movement)	40%	10	4	50	20
Parks and kauri forest	30%	5	2	36	10.8
Pest Free Auckland	20%	9	2	19	3.8
Rural Possum free	5%	0	0	22	1.1
Marine pest	5%	0	0	50	2.5
Total overall change			**7**		**38.2**

The average expenditure per night by international visitors in New Zealand is $226 (Statistics NZ, 2017)[26]. Considering the average weighted value-added rate by the tourism sector (40%)[27] the value added to the economy as the result of tourism spent per night was estimated as $90.5. This figure is used for the value of the benefit of the additional visitor nights in Auckland.

The total tourism benefit under Option A is $129.8 million and $679.1 million under Option B. This significant difference results from the magnitude of change from the Hauraki Gulf and Parks components.

4.2.7.2 Recreational benefits – combined effects

As with the benefits to tourism, pest control and enhanced biodiversity have a combined effect on recreational users (defined as Auckland and New Zealand residents who visit and make use of the natural amenities). A benefit transfer method was used to calculate the partial biodiversity use value to the Auckland region, based on a willingness to pay study of additional native bird species presence. A sample survey of park visitors in the Waikato was undertaken by Lee et al. (2013), which focused on native bird species. The results showed

[25] For example, a proportion (30%) of parkland that contains Special Ecological Areas (SEA) is currently controlled for pests. Under option A, this proportion would increase by five percentage points. Under Option B, it would increase by 36 percentage points.
[26] Statistics New Zealand (2017). International Visitor Survey - Visitor expenditure average 20 years (to year ended September 2017)
[27] Chief Economics Unit, Auckland Council, personal communication

that on average, visitors to the park were willing to pay $_{2017}$$0.68 for the presence of an additional native bird species.

A similar weighting system used for international visitors (4.2.7.1 above) was used for recreational users, elucidating the contribution of the pest control activity on visitor numbers. Not all of the recreational users are willing to pay for enhanced biodiversity, so the Pest Free Auckland proportions (see Section 4.2.1 above: 31 per cent WTP in 2019 rising to 85 per cent of Aucklanders WTP by 2050) were used to calculated WTP for each year.[28]

Based on the RPMP, there are 48 native threatened bird species in Auckland region, which have the potential for protection under the pest control activities. The results showed that the probability of pest threat for native birds would decrease bird species by 6 and 57 per cent for Options A and B respectively. This equates to a high probability or likely protection of three bird species as a result of Option A and protection of 27 bird species under Option B.

Visitor numbers (domestic and international) in 2015-2016 for those Significant Ecological Areas (SEAs) in Auckland with data available were: the Waitākere Ranges (788,382); Hunua Ranges (240,962); other Southern parks (991,859) and Northern parks (2,055,099). The most recent visitor numbers for Waiheke island are from Baragwanath et al. (2009) (700,000)[29] and are likely to be underestimated, as the visitors to Great Barrier in 2006 (80,000), although growth in visitor numbers have not been as high as to the nearer Hauraki Gulf islands.

As total numbers of visitors include Aucklanders and other domestic visitors as well as international visitors, the Auckländer share (85 per cent) of the total was used, for recreation value.[30]

Visitor numbers do not remain static, and New Zealand has experienced considerable growth rates in domestic and international tourism. As such high visitor growth rates are unlikely to continue at such a rate (exponential growth), a conservative growth rate was considered (2 per cent, the lowest growth rate which was based on data from Northern Parks), to estimate future visitor numbers. This again is erring on the side of caution, adopting a conservative approach to calculating the benefits. The authors also acknowledge that there may be displacement among areas, given the restrictions of using forests with kauri dieback.

The results of calculating the recreational value, using a benefit transfer of the value of protected bird species as a proxy, are $167.4 million for Option A and $1,776.7 million for Option B.

[28] Therefore, the Pest Free Auckland is not included in the weighting system for recreational benefits and its share is divided to other areas.
[29] Since Waiheke's residents would also be willing to pay for increased sightings of native birds, their population was also taken into account in this figure.
[30] Based on the lowest share of Aucklanders as the result of visitors surveys done by Auckland Council in Auckland Domain (Wilson and Allpress, 2014), some selected parks (Panmure basin, Western Spring, Orewa reserve and Parrs park) (Allpress 2015a, b, c and d) and Waitākere Ranges (Hill et al., 2017).

4.2.8 Potential benefits not included in calculations

This section lists some of the benefits that were not included due to difficulty in measuring and monetising and/or data availability constraints within the timeframe that the analysis was undertaken.

Biodiversity benefits, which recreational users associated with birds, were calculated on the average value of the presence of an additional bird species. This does not take into account endangered species, and the value of preventing extinction (non-use values). There may be higher values associated with willingness to pay for threatened or endangered marine species (Lew, 2015). Average WTP values may underestimate society's preference for avoiding extinctions (bequest and existence values).

It is known that Auckland has some significant and unique marine and coastal habitats that are threatened by marine pests (Wiser et al., 2014). For example, there are shell barrier beaches in the Waitematā Harbour.[31] There are only about 12 of these shell plains in the world, with the largest in New Zealand located in the Firth of Thames at Miranda. Sites in the Waitematā Harbour include Shoal Bay (Jutland Road shell barrier beach, Eversleigh Road shell barrier beach), Ngataringa Bay (Norwood Road shell barrier spit), Hobson Bay (Hobson Bay shell Barrier Island and Portland Road) and Pollen Island (Pollen Island shell barrier). Seabird burrowed soils are another internationally unique habitat. These areas are where soils have been disturbed and enriched by seabirds burrowing for nesting, track formation, and excrement. These habitats are now largely confined to islands, but there are at least 22 known sites in the Auckland region (Wiser et al., 2014). As with values associated with preventing species extinction, there are also unknown values associated with protecting significant and unique habitats, which have the potential of pest species threat. Additional knowledge of the ecosystem interdependencies is required, particularly for marine systems. People cannot value something that they attach no importance to; and relative importance can only be attached through knowledge and understanding of the system. There is increased awareness of threatened marine mammals such as the Bryde's whale, which are found in the Hauraki Gulf, but less awareness of smaller species. There are benefits of avoiding extinction of species and habitats. These benefits accrue not just to Aucklanders or New Zealanders. There are universal benefits for species and habitats that are of international significance.

The above are some of the unique marine and coastal habitats that are known to exist in Auckland. Further information gathered and collated in future years will increase the marine knowledge base, and hence society's understanding of marine biodiversity and the complexities and intricacies of marine ecosystems. It is difficult to attribute value to 'known unknowns'.

Health benefits from connection to nature include lower levels of depression, ability to recover more quickly from illness and the benefits of activity and exercise that active

[31] A shell barrier beach is a prograded coastal plain comprising shell fragments and coarse sand that is moved by longshore drift and carried landwards through wash action to form bars on the foreshore (Woodroffe et al. 1983).

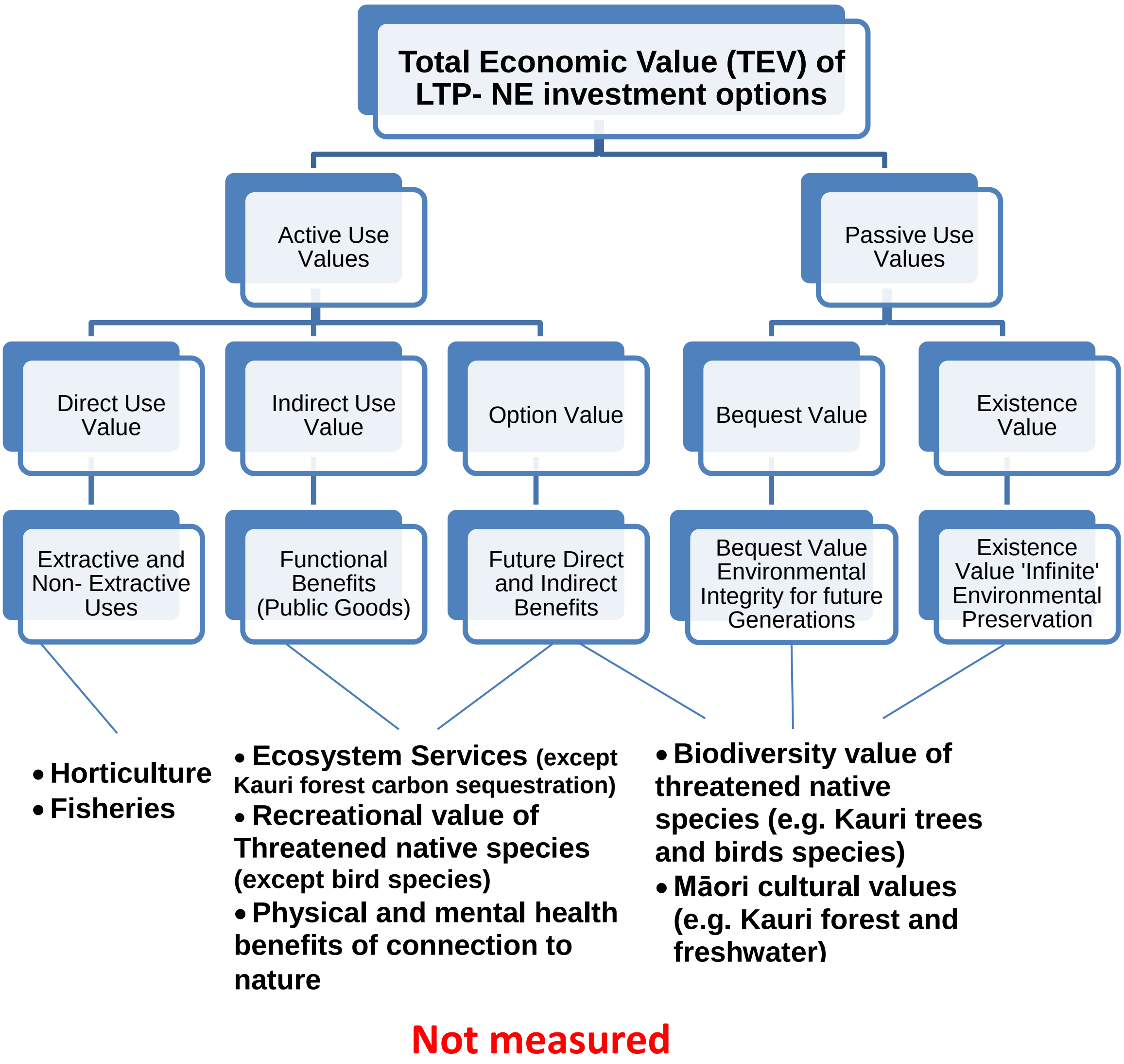
engagement in parks and open spaces contributes to. These health benefits were not explicitly measured in this study, given the time constraints to undertake the study. An analysis would be required to measure the health benefits associated with more ‘indigenous’ nature – whether there are differences between recreating in native bush/forest and recreating in modified landscapes, in which pests have modified. There was insufficient information to establish the deterrent effect of pests on engagement with nature, or to establish the tipping points for pest levels within the region to affect overall recreation effects. Determinants of the deterrent effect would include the ability to substitute activities in nature (for example, switching from water based activities to bush activities, or vice versa if tipping points were reached – e.g., inability to swim in a water body, or inability to walk in the bush).

Some Māori cultural values were mentioned with respect to Māori values of kauri and kaitiakitanga, specifically threats from invasive marine species. However, no specific Māori values were included in this analysis. The benefits presented here will be underestimated, given these values are not included.

Another large omission, due to lack of robust data, are the non-use biodiversity values of kauri trees. It is not just the trees themselves, but other unique species which are co-dependent on kauri trees/forest. The plants, animals and ecosystems that kauri create and support (such as kauri grass and a range of orchids and epiphytic plants in the branches of mature trees) are indirectly under threat from kauri dieback, as without kauri they cannot survive.

Ecosystem services (other than carbon sequestration of kauri, provisioning services of some agriculture and aquaculture, and cultural services relating to recreation and tourism) were not explicitly measured, and may exist. However, the methodology used was through a Total Economic Valuation lens, rather than being underpinned by an ecosystem services approach (Greenhalgh et al., 2017). The two approaches are not incompatible, but require considerable additional analysis to eliminate double counting of the benefits. These additional benefits are shown in Figure 7.

Figure 7. Additional benefits that were not measured



4.3 Summary of Benefits

Table 4 presents the Present Value (PV) of benefits for Options A and B, in the initial conservative analysis that is termed Medium. This gives an indication of which specific benefits were measured under each scenario, as well as the composite benefits within the tourism and recreation indicators. The total PV of benefits under Option A was $177 million and $1,141.5 million for Option B. The components of these benefits are presented in descending order – with recreation benefits dominating the total benefit for both Options (39% and 65% respectively). It is followed by share of tourism benefits (31% and 25%) and carbon sequestration benefits (30% and 7%).

Table 4. Present Value of Benefits, Options A and B

Present Value	**Option A** $million	(%total benefit)	**Option B** $million	(%total benefit)
Recreational Benefits*	68.70	39%	739.27	65%
Tourism Benefits*	54.97	31%	287.67	25%
Carbon Sequestration	52.76	30%	79.14	7%
Freshwater Benefits	-	-	28.32	2%
Possum control Benefits	-	-	5.90	1%
Aquaculture	0.58	0.3%	1.16	0.1%
Total PV Benefits	177.01	100%	1,141.45	100%

* Composite measure of benefits.

There are minor aquaculture benefits for both options. There are additional benefits in Option B, relating to the freshwater benefits from the additional activity in the two lakes and additional activity controlling possums on the rural mainland.

5.0 Costs and Benefits Combined

For illustrative purposes, the costs and benefits can be shown on a timeline of when they occur, or are realised (Figure 8 and Figure 9; note the difference in scale between the two graphs). Further details are given in Section 6.

Figure 8. Option A – Medium Scenario Costs and Benefits

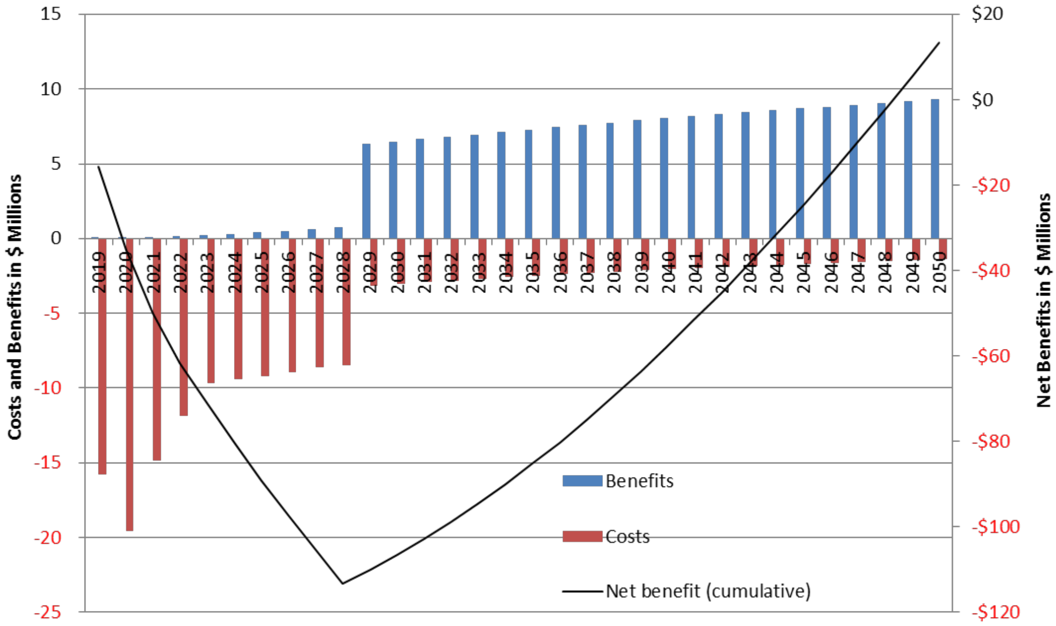
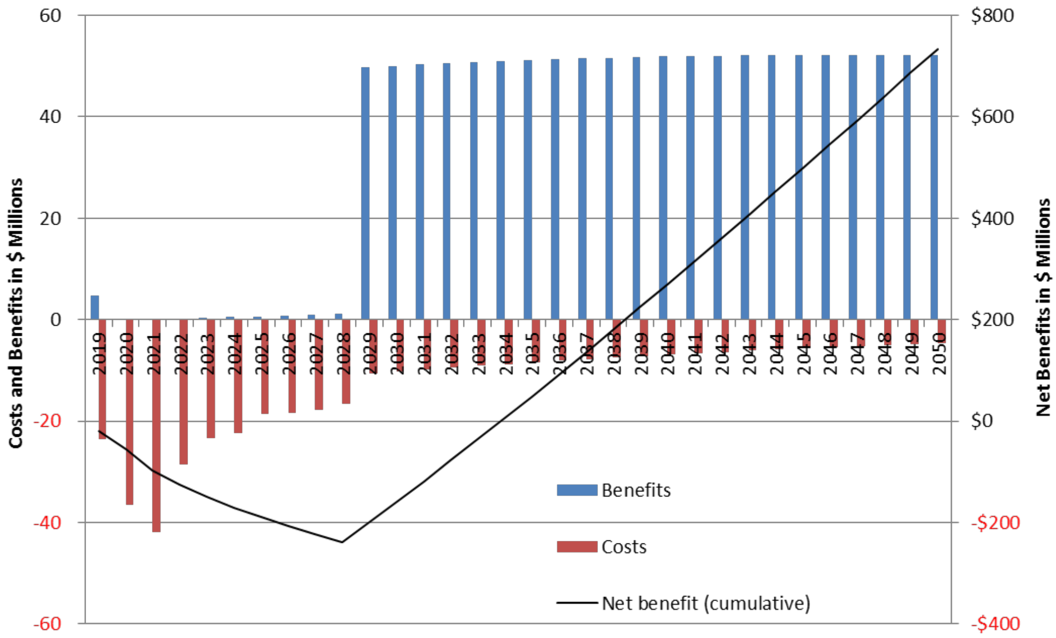


Figure 9. Option B – Medium Scenario Costs and Benefits



As can be seen the costs occur during the LTP period of 2019 to 2028, with a limited level of benefits realised through this time. Again, this is a conservative assumption, but also recognition that there is a lag in the length of time it takes for the benefits of pest control activities to be realised. Option A's net benefits become positive in 2044 (when the benefits outweigh the costs). Option B has a higher level of net benefits (right hand side axis), which are realised at an earlier date (2039) than Option A.

5.1 Scenario testing

As can be appreciated in a comprehensive study that is measuring the combined effects of numerous pest control activities in different areas of a particular region, there are a myriad of assumptions contained in the analysis. The preceding sections have discussed the construction of the Medium scenario, which was considered a conservative approach to measuring the benefits. Such an analysis is open to critique on many of those assumptions. In order to obtain a robust analysis the Medium scenario was tested, given that there are many known-unknowns associated with ecosystem change and biodiversity analysis.

A range of the assumptions on a set of parameters used in the Medium scenario were adjusted downward to test the Lower bound of this scenario. Therefore the Lower bound is a *combination* of the most pessimistic assumptions, for Option A and B. These parameters were adjusted upward for the Upper bound scenario, using the higher range of values that were obtained in the literature review for benefits transfer. As stated before, the Medium scenario used the Lower bound of any range of values, in order to err on the side of conservatism and not overstate the benefits.

The parameters included in the Lower and Upper scenario analysis compared to the main (Medium) scenario is summarised in Table 5.

Table 5. Changes in Upper and Lower bound scenarios compared with the main scenario (Medium)

Scenario	Lower	**Medium**	Upper
Opex in years 2029-2050 as percentage of 2028 Opex	100%	**90%**	50%
Benefit starts in year	2029	**2029**	2020
Kauri dieback: Additional spread speed factor each year	0	**0.1%**	0.5%
Pest Free Auckland: Proportion of Aucklanders who would WTP for natural environment protection (2019, 2029, 2050)	A: (20%, 25%, 50%) B: (20%, 31%, 50%)	**A (31%, 40%, 85%) B (31%, 50%, 85%)**	A (40%, 50%, 85%) B (40%, 60%, 85%)
Rototoa Lake: Average annual change in LakeSPI	-0.29	**-1.3**	-1.3
Tomarata Lake: Assumption, number of kayaking days per year	2	**5**	10
Tomarata Lake: The year when the lake could not be used for recreation	2038	**2028**	2028
Possum control: Auckland's proportion of NZ's area of exotic grass land	1%	**2.2%**	2.2%
Combined tourism benefit: Annual growth rate of number of international visitors Auckland	1%	**3%**	3%
Combined tourism benefit: Proportion of tourists who would stay more (in a pest free status area)	18%	**18%**	33%
Combined recreational benefit: Waiheke visitor number	400,000	**700,000**	836,565
Combined recreational benefit: Annual growth rate of parks /islands visitors	1%	**2%**	3%
Marine pests: Assumption, share of invasive pest marine species in fouling	25%	**50%**	75%

We combined all of the alternative parameters in each scenario.

5.2 Results of Net Effects

This section compares the benefits to the costs over the study period, in order to derive the net benefit to society from the proposed LTP, Natural Environment Investment Options A and B. To make this information most useful for decision-makers, costs and benefits are expressed in present value terms. All figures were expressed to 2019 terms to coincide with the start of the additional pest control activity, while results are expressed in 2017 dollar terms, to coincide with the cost figures obtained from council staff. The period for this analysis is 32 years (2019-2050) and a four per cent discount rate applied.

Table 6 shows the range of total benefits, total costs, net benefits and benefit to cost ratios for Lower, Medium and Upper scenarios for Options A and B. It is important to note that these results do not include qualitative impacts. Our assessment is that the effect of including such impacts would be to raise the net benefits significantly.

For a programme or planned expenditure to be considered worthwhile, it should have a Net Present Value (NPV) greater than zero, and a Benefit to Cost Ratio (BCR) greater than 1.

Table 6. Summary Cost Benefit Analysis results

	Option A Present value ($_{2017}$\$million)			Option B Present value ($_{2017}$\$million)		
	Lower	**Medium**	Upper	Lower	**Medium**	Upper
Total benefits	$101.80	**$177.0**	$441.30	$585.49	**$1,141.4**	$2,193.02
Total costs	$167.55	**$163.7**	$148.08	$423.61	**$407.28**	$341.97
Net benefits (NPV)	-$65.8	**$13.3**	$293.2	$161.9	**$734.2**	$1,851.0
Benefit-cost ratio (BCR)	0.61	**1.08**	2.98	1.38	**2.80**	6.41

We direct attention initially onto the Medium scenario, lightly shaded in Table 6. It is called the Medium scenario, as it was the initial scenario constructed, but with very conservative assumptions. The range of estimated net benefits (i.e. the extent to which society is made better off because of the options) are $13.3 million and $734.2 million in present value terms for Option A and B, respectively. This is a corresponding BCR of 1.08 and 2.80. Both Options

A and B have a positive NPV for the Medium scenario, indicating that the cost of any investment is offset by the benefits resulting from that investment.

In the Lower Scenario analysis, which changed the benefit parameters downwards and the costs upwards, the present value of Option A benefits were $101 million and the costs $168 million. This yielded a BCR less than 1, indicating that the net effect on society would be worse. The Lower scenario for Option B resulted in benefits dropping from $1.141 billion to $586 million. Even with costs rising in Option B’s Lower scenario, the net benefits remained positive, with a BCR ratio of 1.38.

The Upper Scenario for both Options A and B yielded higher BCR ratios than the Medium scenario, as expected (2.98 and 6.41), indicating that the net effect to society of these investment initiatives, under these assumptions were positive for society.

6.0 Sensitivity Analysis

This section describes a comprehensive sensitivity analysis undertaken in this study to test the impact of uncertain assumptions on the BCR result of the main (Medium) scenario.

6.1 Sensitivity Analysis each scenario parameter

While the scenario analysis tested the assumptions that were used in the base or Medium case, a sensitivity analysis was undertaken to control for each of these parameters or assumptions, to assess which factors had the greatest impact on the overall Lower and Upper BCR, individually. It was found that the assumption of the rate at which kauri dieback spreads was the assumption with the greatest impact on overall results for both Option A and B. The results showed that some of the parameters (rate at which kauri dieback spreads, proportion of Aucklanders who would be willing to pay for natural environment protection and the proportion of tourists who would stay longer in Auckland) individually reduces the BCR to lower than one for Option A. A summary table of the BCR's sensitivity to changes in each of the scenario analysis components is available in Appendix 2.

6.2 Sensitivity Analysis of the discount rate

In addition to the sensitivity analysis on scenario parameters, a more traditional sensitivity analysis of the discount rate was undertaken. As expected, the higher the discount rate the lower the net benefit and BCR.

The "break even" discount rate (i.e. where the BCR=1) for Option A is around 4.6 per cent, while the equivalent for Option B is 13.8 per cent. Table 7 shows the impact of changes in the discount rate on each option's BCR. Option A is sensitive to the higher discount rate (8%) and gets BCR less than 1.

Table 7. Alternative discount rates

	Option A (BCR)	Option B (BCR)
Base assumption 4%	**1.08**	**2.80**
8%	**0.66**	**1.84**
Change to the base assumption	-0.42	-0.96
2%	**1.4**	**3.4**
Change to the base assumption	0.30	0.62

6.3 Sensitivity Analysis of the greatest benefits

A sensitivity analysis of the benefits that had the highest share of total benefit (see Table 4) was undertaken to test the impact of a series of assumptions on the BCR. This enables analysis of a set of "what if" questions, such as what if international tourism figures are too optimistic? What if the social cost of carbon is less than the figure we used? What if the pest free initiative is not successful to increase the natural environment of Aucklanders and the participation rate is not improved**?**

Instead of testing benefit estimates assumptions individually, we set the result of each major benefit value at zero and 50 per cent (effectively assessing the overall effect if the benefits were halved or were not realised at all). If we overestimated any of the proxies used in the study, this latter sensitivity test would highlight this.

The impact of the Pest Free Auckland assumption of a higher contribution rate by Aucklanders (percentage of Aucklanders who would be WTP in the future) was tested, measuring the effect of using 2019 WTP rates for Aucklanders throughout the project life (ie.no behavioural change or social learning resulting in greater environmental awareness).

The results (see Table 8) show that, for example, assuming that the recreational benefits are halved for Option B would decrease the BCR from 2.80 to 1.9, which is a 0.91 percentage point reduction. The benefits are almost twice the costs.

The estimated combined tourism benefit has the highest impact on the results of both Options. All the factors reduce the BCR to less than one in Option A but none of them makes Option B's BCR less than one.

Table 8. Changes in major estimated benefits value

		Option A (BCR)	Option B (BCR)
Base assumption		**1.08**	**2.80**
Recreational benefit	**0.00**	**0.7**	**1.0**
	Change to the base assumption	-0.42	-1.82
	50%	**0.9**	**1.9**
	Change to the base assumption	-0.21	-0.91
Tourism benefit	0.00	**0.7**	**2.1**
	Change to the base assumption	-0.34	-0.71
	50%	**0.9**	**2.4**
	Change to the base assumption	-0.17	-0.35
Kauri dieback, Carbon sequestration benefit	**0.00**	**0.8**	**2.6**
	Change to the base assumption	-0.32	-0.19
	50%	**0.9**	**2.7**
	Change to the base assumption	-0.16	-0.10
Pest free Auckland Behavioural Change	**31%**	**0.8**	**1.8**
	Change to the base assumption	-0.29	-1.05

In summary, Option A is very sensitive to the assumptions about all main benefits and discount rates.

7.0 Conclusion

While the study is exploratory and indicative in nature, it supports the view that society is likely to be better off with either of the Natural Environment Investment options for the LTP compared to the current state planned investment. A conservative approach to measuring the benefits was adopted at all times. There are benefits that were not quantifiable, and hence not included in the analysis. To use a CBA effectively in decision making, the different options assessed should be compared against each other – it is the relative values of the benefit to cost ratio that should be taken into consideration. Option B is the preferred option as it has a much higher benefit to cost ratio and society would be better off even under the Lower bound scenario. Although it is the more expensive option, it reflects better value of spending money with benefits almost three times the costs (BCR=2.8). It should be compared with Option A's benefit to cost ratio, which has an eight per cent higher benefit, compared to its cost.

The estimated major benefits of; *carbon sequestration, combined tourism and recreation;* and the *discount rate* have the highest impact on the results of both options. The factors that reduce the BCR (just Option A) to less than one are changing the discount rate to eight per cent and assuming zero or fifty per cent of all major benefits estimated.

It is important to note that these results do not include the benefits that were not measured due to data/information constraints. Our assessment is that the effect of including such impacts would be to raise the net benefits significantly. Benefits not measured include Māori cultural values associated with improved biodiversity, values associated with preventing species and habitat extinction and health benefits associated with recreating and interacting with nature. As is common in 'exploratory' studies of this nature, the precision with which estimates of costs and benefits can be made could increase with further more detailed work.

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Appendix 1. Main activities under each investment options

Outcome area	Activities Option A	Activities Option B
Risk of Kauri Dieback spreading	• 190km of tracks upgraded • 313 phytosanitary stations installed and maintained • 12 washdown stations installed and maintained • Kauri dieback ambassadors • Disease distribution mapping and tracking over time across whole region, including data collection via aerial survey, ground-truthing, soils sampling on private land, and associated data management. • Awareness and behaviour change campaign, including signage, events, schools, electronic platforms including Facebook and website, hard copy collateral such as brochures. • Development of enhanced regulatory programme through implementation of Regional Pest Management Plan provisions. • Support to landowners for kauri protection on private land via resourcing such as phytosanitary supplies, tree felling, fencing. • Driving industry phytosanitary best practice, through nursery accreditation scheme, SOPs • Membership of multi-agency programme Co-facilitation of research projects including social science, epidemiology and control tools.	
Pest Free Auckland – enabling communities	•"450 community groups supported •40% of land under community-led pest control" •Awareness and behaviour change campaign, including electronic platforms, hard copy collateral such as brochures. •Facilitation of up-take of step-change technologies such as smart trap electronic network. •Database to support biosecurity and biodiversity data management	• "600 community groups supported • 50% of land under community-led pest control" • Awareness and behaviour change campaign, including electronic platforms, hard copy collateral such as brochures. • Facilitation of up-take of step-change technologies such as smart trap electronic network. • Database to support biosecurity and biodiversity data management
Pest Animal and Plant control on regional and community parks	• Best practice control of seven pest animal species and 30 pest plant species on approximately 35% of high ecological value council parkland • Targeted enforcement, education and behaviour change campaigns on surrounding private properties to reduce pest reinvasion of parks. • Implementation/roll-out costs, including marketing and education materials • Staff time involved in administration and oversight	• Best practice control of seven pest animal species and 30 pest plant species on approximately 66% of high ecological value council parkland • Targeted enforcement, education and behaviour change campaigns on surrounding private properties to reduce pest reinvasion of parks. • Implementation/roll-out costs, including marketing and education materials • Staff time involved in administration and oversight
Rural mainland possum free	Same as status quo	• 173863ha (50%) of total rural area (347725.2ha) under possum management (an additional 76500ha (22%) to current). Potential methods include combinations of ground and aerial application of pesticides and trapping including a network of approximately 90,000 bait stations (or equivalent) installed, maintained and audited ((Y1= 6.7%, Y2= +13.3%, Y4= +20%, Y5= + 20%, Y6= + 20% installed (see possums tab)
Freshwater pests	Same as status quo	• Adaptive management of five pest fish species and two pest plant species at two lakes. Control methods may include pesticides, netting and other methods. • Awareness and behaviour change campaign, including signage, events, electronic and other media channels, hard copy collateral such as brochures.
• Marine pests	<u>Prevention:</u> • Awareness and behaviour change campaign: including signage, events, electronic and other media channels, collateral, summer advocate at wharves and marinas, developing a relationship with marinas. • Policy (regulatory tools and guidelines): Implementation and regulation of the Unitary Plan biofouling (in-water cleaning and passive discharge) provisions, and other regulatory tools and guidelines including adapting to SeaChange. <u>Early warning and rapid response:</u> • Early warning: System developed to detect and manage new incursions and/or range extensions. Includes risk assessment, horizon-scanning and prioritization for emerging pest threats. • Monitoring and surveillance programmes: Surveillance of XX hulls, snorkel team readiness and deployments, incursion response and management. <u>Management:</u> • Inter-Regional Marine Pathway Management Plan developed and implemented, Top of the North Marine Biosecurity Partnership involvement and resource sharing, R&D work stream lead of TON Operational framework, policy effectiveness monitoring/review of prevention, surveillance and response effectiveness.	
Hauraki gulf pest movement control	• Control of mammals in all Biodiversity Focus Areas on Hauraki Gulf Islands (cats, rabbits, rats (and pigs excluding Waiheke) by: •ground baiting/trapping (rats) •potential methods may include burrow fumigation, ground baiting and night shooting (rabbits) •live capture traps requiring daily monitoring. Responsible pet ownership advocacy (cats). Shooting or control dogs (pigs).	

Outcome area	Activities Option A	Activities Option B
	• Argentine ants eradicated from current areas of known infestation on islands by: •Ground baiting across 23ha •Active surveillance across whole island using conservation dogs and detection devices. Further prevention accounted for in pest free warrant line. • Hauraki Gulf island containment of four pest plants (rhamnus, boxthorn, mile-a-minute, madeira vine) control delivered by AC using herbicide and other control tools and monitoring for reinvasion at known sites. Pest Free Warrants issued for 240 businesses and regularly audited. Awareness raising (education, signage) on wharves, at events, in schools and via electronic and other media channels, hard copy collateral such as brochures. Surveillance on islands and wharves using conservation dogs and detection devices. Incursion responses as required. Buildings and goods inspection prior to transport. Regulatory control as required.	
Kawau and Waiheke islands	**Waiheke Island (9000ha)** • Pigs eradicated from whole island over 10 year period by shooting or use of conservation dogs. • Rats and stoats eradicated from whole island: Potential methods include combinations of ground and aerial application of pesticides and trapping. Active surveillance across whole island using conservation dogs and detection devices. **Kawau Island (1950ha)** Rats, possums, wallabies and stoats eradicated from whole island: Potential methods include combinations of ground and aerial application of pesticides and trapping. Active surveillance across whole island using conservation dogs and detection devices.	**Waiheke Island (9000ha)** • Pigs eradicated from whole island over 10 year period by shooting or use of conservation dogs. • Rats and stoats eradicated from whole island: Potential methods include combinations of ground and aerial application of pesticides and trapping. Active surveillance across whole island using conservation dogs and detection devices. **Kawau Island (1950ha)** • Rats, possums, wallabies and stoats eradicated from whole island: Potential methods include combinations of ground and aerial application of pesticides and trapping. Active surveillance across whole island using conservation dogs and detection devices.
Great Barrier Island	• Possums, pest plants and other pests kept off the whole island by active surveillance using conservation dogs and detection devices. Incursion responses as required.	
Marine ecological	• Seabird habitats surveyed on XX Hauraki Gulf islands and changes tracked over time. • Seabird populations monitored using acoustics and ground survey. • Statutory plan change to SEA_M schedule 4 • Experimental restoration of XX seabird populations on pest free islands.	

Appendix 2. Result of sensitivity analysis of scenarios components

Assumptions	Value in each scenario	Description	Option A BCR	Option A Change in BCR	Option B BCR	Option B Change in BCR
Medium scenario			**1.082**		**2.803**	
Opex in years 2029-2050	90% of 2028 Opex	We considered a conservative proportion (90%) of the Opex cost of the plan's last year (2028) to continue in the project life.				
Lower bound	100% of 2028 Opex	Even higher cost continues after the plan	1.056	-0.025	2.684	-0.119
Upper bound	50% of 2028 Opex	Half of the Opex cost would continue	1.195	0.114	3.324	0.522
Benefit starts in year	2029	In a conservative assumption we estimated benefit from a year after the LTP and RPMP implementation (2029)				
Lower bound	2029	Same as the medium scenario				
Upper bound	2020	The benefit starts from the second year of the LTP implementation with 10 percent of benefit occurring in 2020 and is added linearly to 100 percent in 2029	1.231	0.149	3.344	0.541
Kauri dieback: Additional spread speed factor each year	**0.1%**	**Hill et al. (2017) suggests that the dieback infection spread rate has been 2.2 percent per annum based on the monitoring data. In a consultation process he suggests that the rate would be inflated as the result of more trees are infected. Therefore we considered a 0.1% increase in the spread rate. Although it is very conservative we even considered it zero in the Lower bound.**				
Lower bound	0		0.962	-0.120	2.730	-0.072
Upper bound	0.5%	More realistic assumption	2.015	0.933	3.365	0.562
Pest Free Auckland :Proportion of Aucklanders who would WTP for natural environment protection	A: (20%, 25%, 50%) B: (20%, 31%, 50%)	**The base value (31%) is from DOC (2017) Segmenting Aucklanders: towards greater insights and conservation gains.**				
Lower bound	A: (31%, 40%, 85%) B: (31%, 50%, 85%)	assumption: even lower proportion of Aucklanders are currently WTP for natural environment values	0.877	-0.204	2.040	-0.763
Upper bound	A: (40%, 50%, 85%) B: (40%, 60%, 85%)	assumption: higher proportion of Aucklanders are currently WTP for natural environment values	1.126	0.044	2.951	0.148
Rototoa lake: Average annual change in LakeSPI	**-1.3**	**Historic annual change (2007-2017)**				
Lower bound	-0.29	Historic annual change (2010-2017)			2.794	-0.009
Upper bound	**-1.3**					
Tomarata Lake: Assumption, Kayaking days per year	**5**	**Conservative assumption for area's population who potentially have Kayak**				
Lower bound	2	Lower number of visits than our base assumption.			2.768	-0.035
Upper bound	10	Higher number of visits than our base assumption.			2.861	0.058
Tomarata Lake: The year when the lake could not be used for recreation anymore as the result of the potential health threats for human	**2028**	**Assumption of the year that the lake can't be used for recreational purpose**				
Lower bound	2038	Later than our conservative assumption			2.772	-0.031
Upper bound	2028					

Assumptions	Value in each scenario	Description	Option A BCR	Option A Change in BCR	Option B BCR	Option B Change in BCR
Medium scenario			**1.082**		**2.803**	
Possum control: Auckland's proportion of NZ's area of exotic grass land	**2.20%**	**Landcare land cover data base (2012)**				
Lower bound	1%	The land cover has been changed following Auckland's urban development and would change more in the project time. Therefore we assumed under lower bound scenario Auckland would have lower proportion of New Zealand exotic grass land.			2.800	-0.002
Upper bound	**2.20%**					
Combined tourism benefit: Annual growth rate of number of international visitors Auckland	**3%**	**Average historic annual growth rate (Dec1997-Dec2016)**				
Lower bound	1%	assumption: Lower growth rate in the future	0.961	-0.121	2.549	-0.254
Upper bound	3%					
Combined tourism benefit: Assumption, Proportion of tourists who would stay more	**33%**	Russel et al. (2015): 33% of international tourists would spend one additional day visiting a pest free area. We adjust this rate with the weighting model of the impact of each outcome area that is not 100 percent pest free results.				
Lower bound	18%	Proportion of international Auckland visitors who are in holiday/vacation (56%) and would do a natural environment related activity.(Stats NZ: International visitors to Auckland and New Zealand by purpose of visit and Domestic Travel and International visitor activities 1999-2017)				
Upper bound	50%	Assumption: half of international tourism would spend one more night in pest free Auckland. we Adjust this figure with the impact of activities under option A and B that is not including 100% pest free in most of the outcome areas.	1.333	0.252	3.332	0.530
Combined recreational benefit: Waiheke visitor number	**700,000**	**Highest number in the visitor range for 2006**				
Lower bound	400,000	Lower number in the visitor range for 2009	1.064	-0.017	2.728	-0.075
Upper bound	836,565	Inflated higher number to 2019	1.089	0.008	2.837	0.034
Combined recreational benefit: Annual growth rate of parks /islands visitors	**2%**	**Annual growth rate based on Auckland Council, parks visitor counts (2006-2007 to 2015- 2016)**				
Lower bound	1%	Lower growth rate	1.003	-0.078	2.469	-0.333
Upper bound	3%	Higher growth rate	1.181	0.100	3.226	0.423
Marine pests: Assumption, share of invasive pest marine species in fouling	**50%**					
Lower bound	25%		1.080	-0.002	2.801	-0.001
Upper bound	75%		1.083	0.002	2.804	0.001

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Te Kaunihera o Tāmaki Makaurau