Economic benefits of broadscale predator control in the Hawke's Bay Region

Economic outcomes of broadscale predator control in the Hawke's Bay Region

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Summary

Project and Client

- Landcare Research was contracted by Hawke's Bay Regional Council to summarise the economic outcomes of its current broadscale predator control programme.

Objectives

- Review integrated economic outcomes of predator (possum, stoat, ferret) control by building on existing work already completed, identifying conditions that may need to change to optimize outcomes, and outlining knowledge gaps

Methods

- Literature and web searches were undertaken to identify information about the economic costs and benefits of the control of possums, feral cats, stoats, and ferrets.

Results

- The regional economic benefit from possum control related to TB eradication has been estimated at a discounted Net Present Value of $380 million over 30 years – of which $103 million was for total non-TB related benefit. If the region is declared TB free in a shorter period, the benefits will be proportionally less. On a land area basis, the Cape to City project will provide about 2% of the regional benefits. However, if possum control was ultimately expanded to the proposed 500,000 ha then on a land area basis the benefits would be 35% of the regional benefits, giving a NPV of $133 million over 30 years, of which $36 million would be non-TB related benefit.
- Benefits of possum control for direct productive sector impacts were valued at a NPV of $4.2 million over 30 years for pastures losses and $1-3 million annually for losses in forestry, horticulture and cropping.
- Benefits of possum control for native biodiversity were valued at $1.8 million annually, with a discounted NPV of $19.9 million over 35 years. Other studies using contingent valuation and willingness to pay methods indicated people would pay $67–$392 per person/household per year to protect native biodiversity.
- The potential benefit of feral cat control to eliminate toxoplasmosis infection of sheep was valued at $15 million annually, assuming current use and cost of vaccination.
- Ferret control in high density areas for TB eradication may have economic benefit but this has not been estimated. No quantitative economic information was found about the benefits for native biodiversity of control of ferrets, stoats, and feral cats, but contingent valuation and willingness-to-pay values to protect native biodiversity are likely to be similar for these species and possums.

Conclusions

- Most of the direct economic benefits from the broadscale predator control programme in the medium term are likely to accrue from possum control as a part of OSPRI's National TB Eradication Programme. The value of these benefits is likely to greatly exceed the costs of predator control.
- Where rabbit numbers are high, the control of ferrets for TB eradication may also have an economic benefit, but this has not been estimated.
- Control of feral cats to reduce impacts of toxoplasmosis infection on the sheep industry has significant potential economic benefits, but the likelihood and cost of achieving the requisite reduction in feral cat numbers to eliminate the disease needs to be evaluated and compared to the efficacy and cost of vaccination.
- Although the impacts of predators on biodiversity values are relatively well understood, the economic value of mitigating these impacts (i.e. generating the benefits) is poorly quantified. Nevertheless, contingent valuation and willingness-to-pay approaches consistently show New Zealander's attach a high value to native plants and animals and the need to protect them from predation.
- Evidence from market and sector surveys indicate that many international markets value biodiversity and "clean-green" sources for primary products, but there are no dollar estimates available of how much these "green credentials" are worth.

Recommendations

Hawke's Bay Regional Council should:

- undertake a regional evaluation of native biodiversity both in total and for key indicator species relevant to its pest management and biodiversity restoration programmes. This should include green credential benefits and benefits to ecosystem services.
- assume, until more robust data become available, that the benefits for biodiversity from controlling predators other than possums (assuming their numbers can be reduced to levels below which most impacts are mitigated) will be broadly similar to the benefits for biodiversity from possum control (valued at $1.8 million annually, with a discounted NPV of $19.9 million over 35 years.
- investigate the likelihood and cost of achieving the requisite reduction in feral cat numbers to eliminate toxoplasmosis compared to the efficacy and cost of vaccination.
- keep detailed records of the costs of predator control and its efficacy to provide it with stronger evidence of the cost-benefits of its broadscale predator control as linked to native biodiversity benefits.
- continue its efforts to ensure the expected biodiversity benefits of regional-scale predator control or other pest management are supported by all parties involved and confirmed by a robust monitoring programme to measure native biodiversity responses.

- continue its efforts to derive density-impact functions for the key predators and impacted native prey species using the guidelines provided by Norbury et al. (2015). This might be best achieved through a combined approach with other regional and territorial authorities.

1 Background

Cape to City (C2C) is a broad-scale predator control and ecological restoration project over 26,000 ha of land between Hastings and Cape Kidnappers, and southwards to include Waimarama and forest remnants at Kahuranaki. C2C aims to carry out ultra-low cost integrated possum, feral cat, and mustelid control across a large area of farmland. In land area, C2C is about 2% of the Hawke's Bay region. Landcare Research was contracted by Hawke's Bay Regional Council to review and summarise the economic benefits of the current broadscale predator control conducted as part of the C2C initiative.

2 Objective

- Review integrated economic outcomes of pest control by building on existing work already completed, identifying conditions that may need to change to optimize outcomes, and outlining knowledge gaps.

3 Methods

Literature and web searches were undertaken to identify information about the economic costs and benefits of the control of possums, feral cats, stoats, and ferrets. Economic costs and benefits were identified at a regional level where possible, but were mostly extrapolated from national data related to TB eradication. Definition of the economic evaluation terms used in the report is provided in Appendix 1.

4 Results

4.1 Possums

Earlier accounts and estimates of the 'cost' of possums (e.g., Cowan 1991, 1993; Hackwell & Bertram 1999; Greer 2006, 2010; Nimmo-Bell 2009) and the recent extensive analysis compiled by OSPRI in support of their proposal to eradicate Bovine Tuberculosis (accessible at www.tbplanreview.co.nz/) clearly demonstrate the positive economic and non-market environmental benefits of possum control (Clough et al. 2014; Tait et al. 2014). The OSPRI analysis is highly relevant to assessing benefits of the Hawke's Bay landscape scale possum control programme for three reasons. First, the level of possum suppression required to eradicate TB is similar to the suppression level required for predator control to achieve its proposed benefits (Cowan 1991; Greer 2006; Byrom et al. 2016). Second, costs and benefits in the OSPRI analysis are computed relative to a no control scenario, which is what HBRC would face over much of its land area when TB is eradicated, OSPRI possum control ceases, and possum numbers start to increase again. Third, much of the Hawke's Bay region in 2016 is still classified by OSPRI as special TB testing areas or movement control areas, indicating ongoing potential for TB transmission from possums to livestock and Tb-associated possum control and its subsequent benefits (see www.tbfree.org.nz/dcamap).

The summary document of the OSPRI analysis of the TB eradication plan (anon. 2014) indicates a national total Net Present Value (NPV) over 30 years of $6.60 billion versus a cost of $0.571 billion, a 12:1 Benefit Cost ratio. While most of the contribution to NPV relates to benefits from TB eradication, the benefits that would not accrue solely to cattle and deer farmers amount conservatively to a national NPV of $1.8 billion over that time period, most of which derives from direct benefits to indigenous biodiversity (37%), and the removal of real option value impact (52%), that is, increasing the ability of landowners to change land use in the absence of TB (i.e. the costs to a sheep farmer, for example, of converting to cattle farming).

The direct impacts of possums through competition for pasture, damage to commercial forestry, consumption of a wide range of crops and horticultural products, destruction of erosion control plantings, infrastructural cost in preventing damage to electrical and telecommunication transmission, urban nuisance through damaging ornamental and vegetable gardens and fruit trees and denning in houses and outbuildings, and disease/parasite transmission to people were considered in the OSPRI evaluation to impose only relatively small costs (although generally still in the range of $1–5 million annually). However, that conclusion also highlighted the lack of current information on the costs of such damage (Clough et al. 2014).

Identifying costs specifically related to the Hawke's Bay Region is difficult. Greer (2010) estimated the cost to the agricultural sector in the Hawke's Bay Region from TB under the then proposed National Pest Management Strategy relative to a scenario of ad-hoc possum control as a NPV of $5.72 million (at an 8% discount rate). Projected losses from impact on international trade increased the NPV to $10.72 million. However, these costs did not include the cost of impacts other than TB. If the 12:1 Benefit Cost ratio calculated in the more recent and extensive OSPRI analysis was applied to contributions made by Hawke's Bay Regional Council and the region's beef, dairy and deer farmers to the TB programme at the time of Greer's (2010) analysis ($3.1 million in 2008/09), then the expected benefit would have been as much as $37 million. Another approximate estimate of the benefit to the Hawke's Bay Region can be made by apportioning the OSPRI 2014 national benefit estimates on a land area basis. The land area of the Hawke's Bay region is 5.26% of the land area of New Zealand. For individual land classes that cover the main habitats of possums, the land class area in Hawke's Bay region varies from 1.06% to 8.88% of the national total area (Table 1), with an average of 5.73%. The NPV for the Hawke's Bay Region from TB eradication, apportioned according to land area, would total about $380 million over 30 years, and, of that, the benefits that would not accrue solely to cattle and deer farmers would total about $103 million over the same period.

Table 1. Areas of various land cover classes in the Hawke's Bay Region as percentages of the total areas for those land cover classes across New Zealand. Data for 2012 from Land Cover Database version 4 (https://data.mfe.govt.nz/data/category/environmental-reporting/land/)

Land cover class	Hawke's Bay region land area as % of New Zealand land class total
Indigenous forest	4.46
Broadleaved indigenous hardwoods	5.77
Scrub	8.88
Tussock grasslands	1.06

Exotic forest	7.89
Exotic grassland	6.57
Cropping/horticulture	7.30

However, the benefits of possum control for TB eradication are calculated over the time scale for national eradication, and so do not take account of the different dates on which regions will be TB free. Given the low level of TB in the Hawke's Bay Region, this is likely to occur well before the date of a national declaration, in which case the benefits will be proportionally less than indicated above.

For economic benefits attributable to biodiversity protection from the TB eradication programme, Tait et al. (2014) concluded from their choice modelling that respondents to their survey were willing to pay between $0.50 (protection of forest plant species) and $2.01 (protection of forest canopies) for each 1% increase in the protection of various assets. From those data, and applying a number of assumptions (e.g. 85% of New Zealanders are not willing to pay), they derived a minimum estimate of national benefits for biodiversity of $56 million annually. The NPV of future national benefits was calculated at $621 million over a 35-year period at an 8% discount rate. On a straight population percentage basis, the 'share' of these benefits accruing to the Hawke's Bay Region would be a minimum of $1.8 million annually, and $19.9 million over a 35 year period at an 8% discount rate.

However, these calculations probably greatly underestimate the magnitude of the benefits of possum control. First, these non-market benefit calculations focus only on biodiversity in native forests and reserves and largely ignored native biodiversity on productive land, a land use that covers much of the Hawke's Bay region. Including data from valuation of biodiversity benefits on productive land from predator control would increase the overall magnitude of benefits (but this has not yet been assessed). Second, the estimated benefit is highly sensitive to the assumption about the percentage of New Zealanders willing to pay for conservation outcomes and the type of conservation benefit (e.g. trees vs invertebrates). The estimate assumes 85% of people will pay nothing, and the estimated benefit would quadruple if those people paid half as much as the original willing to pay respondents. The 85% estimate was acknowledged by Tait et al. (2014) as likely to be extremely conservative, given that only 4% of respondents indicated no interest in contributing to the conservation benefits. Tait et al (2104) also reviewed other national and international conservation benefit studies using willingness-to-pay methods and concluded that the estimates calculated for possum control were within the range of values found in other studies.

Possum control that is aimed at protection of native biodiversity and ecosystem services also has significant benefits (Johnstone Macleod et al. 2015). Beanland (1992) found, for example, that households would be willing to pay about $14 per year for biodiversity conservation (via possum control) in Aorangi Awarua native forest park. A recent extensive review of biodiversity outcomes from 47 possum-focussed control operations confirms that both ground and aerial control of possums has provided substantial collateral benefits for native biota (Byrom et al. 2016). Possum control benefitted native vegetation by increasing foliage and fruit production and by reducing tree mortality. Possum control and, for aerial application, its accompanying control of rodents together improved native bird populations. Although not addressed directly in the Byrom et al. (2016) report, possum control would eliminate impacts on the mānuka honey industry resulting from possum consumption of manuka leaves and flowers (Nugent et al. 2000) and reduction of mānuka seedling growth and survival (Quadling 2006).

However, each of the recent reports identifies a lack of robust data that quantifies many of the links between possum numbers and damage to various assets, particularly in relation to value gained from possum control per hectare treated. Although there are an increasing number of estimates of the value of New Zealand biodiversity, estimation of the value of biodiversity enhancement (of which pest control is one aspect) is often lacking. For example, the total economic value of New Zealand's land-based ecosystems and their services has recently been updated (Patterson & Cole 2014), but that revision lacks any information about the benefits of reducing impacts by possums or any other pests. 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 & Cullen 1995; Yao & Kaval 2008).

4.2 Feral cats

Feral cats may be infected with TB but they are considered to be spillover hosts under the conditions and densities at which they usually occur in the wild in New Zealand (Nugent 2011). They are therefore not specifically targeted as part of the OSPRI national TB eradication program. Feral cat control as a contributor to the TB eradication programme is therefore likely to have only minor benefits (which have not been quantified).

Toxoplasmosis is caused by *Toxoplasma gondii*, an intracellular protozoan parasite. Its main host is the cat, but many other mammal species are susceptible to infection. There is one report of mortality of native birds (kiwi, kererū, and kākā) due to toxoplasmosis, but no information on the extent of such infection and its morbidity (Howe et al. 2014). *T. gondii* is also a common human parasite although very few people have symptoms because their immune system usually prevents the parasite from causing illness. However, pregnant women and individuals who have compromised immune systems may be at risk of serious illness.

Feral cats play a key role in the transmission of *T. gondii* to sheep, and depending when pregnant ewes become infected with toxoplasmosis they can have a high rate of abortion (Hartley & Marshall 1957). While some flocks may only incur low losses, the introduction of an infectious agent to naive sheep flocks may induce a very significant abortion storm in 3–5% of those, with up to 30% of ewes aborting. In a 2,500 ewe flock lambing 130% when lambs are worth $95, lost income losses from such events could be as high as $71,250. Many farmers deal with these infections by vaccinating using Toxovax®. Sheep numbers in the Hawke's Bay as of June 2016 totalled 3,028,852 (Statistics NZ) with 1,776,913 two-tooth ewes and 160,722 ewe hoggets put to ram. Using pregnancy scanning, lambing, vaccination and disease data for 2012 for sheep that were or were not vaccinated against toxoplasmosis (Walker 2014), 163,536 lambs were estimated to be lost due to toxoplasmosis infection. At a current market price of $95 per lamb, the potential revenue loss in 2012 due to toxoplasmosis is estimated as $15,535,920. This potential loss due to toxoplasmosis is managed by farmers using the Toxovax vaccine at a cost of about $1.85 per ewe. About 28% of ewes enter a flock as replacements annually (Walker 2014). For the Hawke's Bay region this equates to a total vaccine cost of about $970,000 and a return on investment of about 15:1, or a vaccine cost of about $727,500 and a return on investment of about 21:1 if 75% of replacement ewes are vaccinated (Walker 2014).

For feral cat control to have a positive economic benefit, it would need to deliver the same or similar benefits as sheep vaccination for similar costs, or completely eradicate the parasite so future costs were avoided. Given that feral cat eradication has not been achieved anywhere on mainland New Zealand (outside fenced sanctuaries) and that there will be many farm and urban cats remaining as a source of infection and reinvasion, it is unlikely that toxoplasmosis could be easily eradicated. Nevertheless, Smith et al. (1992) and Weigel et al. (1995) predicted that toxoplasmosis could be eradicated if cat numbers were reduced by 80% (presumably of carrying capacity). If this target reduction can be achieved with feral cats, then the management challenge is how to address the source of infection maintained in domestic cats and prevent reinfection from rodents and perhaps birds (Hopkins 2011). Although there is no toxoplasmosis vaccine currently available for cats, the development of one is an active area of research (Verma & Khanna 2013). Such a vaccine could potentially contribute to a disease eradication programme. Similarly, if broadscale rodent control became part of the C2C programme and/or in the Hawke's Bay Region as part of a national Pest Free New Zealand programme, it could contribute to a disease eradication programme by reducing reinfection risk for feral cats.

Feral cats have significant negative impacts on native biodiversity, particularly birds and lizards, and on islands. They have therefore been eradicated from a number of islands around New Zealand and are currently controlled in many areas of the North and South Islands (Gillies & Fitzgerald 2005). There is increasing evidence indicating that domestic cats are also significant predators of native wildlife in urban and rural areas (Wood et al. 2016). However, the economic value of improvements in the populations of native animals and ecosystem services from feral cat control has not been quantified.

There is some evidence that feral cats may exert a level of control on rabbit populations, as demonstrated by increases in rabbit numbers after cat control (Gillies & Fitzgerald 2005), although Norbury and Jones (2015) argue that predatory effects on rabbits and economic benefits are likely to be small in most cases. Again, the economic costs and benefits under such circumstances remain to be fully assessed.

4.3 Stoats

Stoats live in any habitat that offers suitable prey – mostly birds, rodents and rabbits, although lizards, fish and invertebrates are also eaten. They are found throughout the Hawke's Bay region, and are generally more common than ferrets in forests and less common in grasslands. Stoats are only rarely infected with TB and so are not specifically targeted as part of OSPRI's TB eradication programme, although they are undoubtedly killed as by-catch in ferret control, and by secondary poisoning in aerial 1080 poisoning for possums and rats (King & Murphy 2005). Stoat control as a contributor to the TB eradication programme is therefore likely to have only minor benefits (which have not been quantified).

However, the impacts of stoats on native biodiversity are severe, especially in native forests following mast seeding events (King & Murphy 2005; Brown et al. 2015). Impacts from predation by stoats are greatest on native birds, but other species such as native bats, frogs, and land snails are also affected (Brown et al. 2015). The Department of Conservation's Battle for our Birds programme targeted c. 700,000 ha of native forest for stoat and rodent control associated with the 2014 mast seeding, and a similar effort is underway in 2016–17 (www.doc.govt.nz/our-work/battle-for-our-birds/). The diet of stoats on farmland appears to be dominated by lagomorphs and rodents, but birds may still feature as a common food item. Because of stoats' climbing ability, all land-dwelling bird species are vulnerable to predation. Large-scale suppression of stoat numbers is therefore highly likely to benefit native biodiversity, although this remains to be quantified for non-forest and forest-remnant habitats. It is also unclear if mast seeding in small forest patches is capable of triggering an increase in rodent and stoat numbers. If that is the case, then additional stoat control effort may be needed in some places in mast years to avoid an increase in predation.

Overall, stoat control will probably have little benefit for the TB eradication programme, but will have significant benefits for native biodiversity, particularly in forested habitats and if combined with feral cat control. However, neither of these benefits has been quantified. A suggested 'cost' of stoat control on farmland, in terms of additional damage from increased rabbit numbers, has been largely discounted (Norbury & Jones 2015).

4.4 Ferrets

While ferrets are probably widely distributed in the Hawke's Bay region, they are most common in rabbit prone areas. Their numbers are controlled both because they impact on native biodiversity and because of their involvement in the transmission of TB to livestock (Clapperton & Byrom 2005).

Ferrets play a complex role in the TB cycle in New Zealand; they are capable of contracting, transmitting and spreading TB infection. However, ferret population densities are usually too low to sustain infection independently, and transmission to other wildlife or livestock appears a rarer event than for possums. Nevertheless, management of ferrets remains a key part of the National Pest Management Strategy for TB. Control is prudent where high density ferret populations are infected with TB, to reduce the transmission risk of any self-sustained infection to livestock. When ferret numbers are well below the theoretical disease maintenance threshold (Caley & Hone 2005), ferret control is still sometimes warranted because of the animals' ability to acquire infection when young and, through dispersal, transport it outside TB-endemic areas (Byrom et al. 2015). Initial and ongoing suppression of ferret numbers as part of the Hawke's Bay region predator control programme and any Regional Council funded rabbit control is therefore likely to assist OSPRI in achieving TB eradication, particularly where ferret numbers are high. The OSPRI assessment of the monetary benefits of TB eradication focussed solely on possum control, with the implicit assumption that no control of other vectors would be required. Adding the costs of any necessary ferret control would tend to reduce the overall Benefit Cost ratio but, given the much smaller scale of any required ferret control, any reduction is likely to be minor.

Ferrets are known to prey on a range of native birds including kiwi, penguins, shorebirds, black stilt, southern crested grebe, and weka. In the McKenzie Basin, for example, ferrets were responsible for 18% of mortality at nest of ground-nesting birds. Native lizards, frogs, and some invertebrates are also preyed on by ferrets (Clapperton & Byrom 2005). The suppression of ferret populations is highly likely, therefore, to have benefits for native biodiversity, but the value of these benefits has not been formally assessed. This could be done using an approach similar to that used by Tait et al. (2014) to estimate the monetary value of non-market benefits accruing from possum control for Tb eradication.

4.5 Knowledge gaps

The biggest information gap is in the assignment of monetary values to the outcomes of pest control, particularly for biodiversity and ecosystem services responses (see Appendix 2). This applies to all predator species being controlled under the Hawke's Bay Region landscape predator control. There is national information for possums in relation to TB eradication, but little recent information relating to other non-biodiversity impacts. There is some information for control of cats as vectors of toxoplasmosis, but little else. There is no information for mustelids.

Obtaining monetary estimates for the biodiversity and ecosystem services benefits from control of all predator species could be done using an approach similar to that used by Tait et al. (2014) to estimate the monetary value of non-market benefits accruing from possum control for TB eradication. Other approaches could also be applied to estimating the value of predator control, given that much of predator control is directed at protection of specific individual native species (e.g. brown kiwi). Montgomery et al. (1994) provide an example based on benefits and costs associated with likelihood and degree of certainty of species survival. None of the estimates of economic benefits from predator control seem to have specifically addressed benefits derived from protection of nature/conservation tourism. If native species are lost or national or regional parks and reserves are degraded by the impacts of predators then there is potential loss of tourist revenue in the region. For example, analysis of the economic value of wildlife tourism on the Otago Peninsula indicated the potential impact of predation of iconic yellow-eyed penguins by ferrets and stoats on tourism revenue (Tisdell 2007; Busch & Cullen 2009). However, the different approaches to valuation all still suffer from significant assumptions in the face of inadequate data.

An additional knowledge gap is the increased revenue landowners might be able to leverage from "green credentials" associated with improved biodiversity values on their properties. Many international markets value biodiversity values associated with commodity production, and Saunders et al. (2013) reported that based on willingness to pay estimates, consumers of a range of commodities in the UK, India, and China would increase producer returns to 2020 by $68.5 million (this is for all of New Zealand).

4.6 Additional options for maximising the economic benefits of predator control

There are six options by which the benefits of broadscale predator control could be increased, some of which are complementary. First, HBRC could continue to invest in research to optimise the cost-efficiency of current predator control by reviewing costs and successes of the current control methodologies, assess where efficiencies could be made and invest in solutions. Second, HBRC could examine opportunities to better integrate the current predator control with related control activities of DOC and TBFree NZ to maximise potential biodiversity benefits. Third, predator 'target' RTC levels could be lowered if it can be demonstrated that the economic and biodiversity benefits sufficiently outweigh the additional costs. Fourth, HBRC could invest more in habitat and native species restoration to maximise the speed and extent of the recovery of native biodiversity. For some native species, recovery may only be possible with concurrent habitat restoration. Fifth, HBRC could extend the current predator control programme to feral cats to reduce impacts of toxoplasmosis infection on sheep and native biodiversity. This would have concurrent benefits for native animals. Sixth, HBRC could take account of spatial issues to define defensible boundaries to control areas to help minimise costs of dealing with predator reinvasion from surrounding areas.

4.7 Realising the costs and benefits from broadscale predator control

There are two approaches for achieving outcome benefits from predator control. Either a fixed sum (e.g. $X/ha) can be spent on predator control with the aim of maximising benefits of that expenditure (benefit maximisation), or the desired benefits can be agreed at the outset of the programme and the aim is then to minimise the costs of achieving those benefits (cost minimisation). The C2C programme is operating largely in a cost minimisation mode, since its stated focus is to "firstly carry out ultra-low cost integrated possum, feral cat, and mustelid control across a large area of farmland". The ultimate target is $3/ha, with a cost of $10/ha considered unsustainable (C Leckie, HBRC, pers. comm.).

Cost minimisation assumes that the relationship between impacts and predator density is known. That relationship is well established for possums for eradication of TB (Warburton & Livingstone 2015). The current Hawke's Bay Regional Pest Management Strategy target for possum control (5% residual trap catch), while not as stringent as targets imposed by OSPRI (usually ≤ 2% RTC), should be sufficient to prevent the re-establishment of TB after areas have been declared TB free by OSPRI. Thus, the HBRC current level of expenditure on possum control on farmland, extended to cover all areas currently or historically treated by OSPRI, is likely to be sufficient to realise the economic benefits that will accrue from TB eradication, assuming that land occupiers conduct the required maintenance control effectively.

However, for the other predators being targeted in the current broadscale control programme and for the wider set of resources being impacted, density impact functions (DIF) are not well known, especially for impacts on native biodiversity. One of the aims of the C2C programme is to try to develop DIFs for predators other than possums, and these will then be used to assist with prioritisation of predator species control cost minimisation. Norbury et al. (2015) reviewed information on DIFs for New Zealand native plants and animals and found that more than half of the functions were strongly non-linear, with substantial benefits for native species only when pests were suppressed to low levels. In the absence of information, adaptive management experiments or controlled pest removal experiments can be used to derive DIFs (Norbury et al. 2015). In a study on Hawke's Bay farmland where predators were controlled by low-cost trapping across 6,000 ha adjacent to a conservation reserve where intensive predator control had been in place for over a decade (Glen et al. 2016), there was evidence of positive responses of some native biodiversity. Occupancy rates of native lizards assessed from tracking tunnel use increased significantly in the treatment area, but not in the non-treatment area. Counts of cockroaches were higher in the treatment area, but other invertebrates were detected in similar numbers in both areas. Glen et al. (2016) concluded that low-cost predator control in a pastoral landscape was able to reduce invasive predator populations, with apparent benefits for some native fauna. Broadscale, low-cost predator control thus has the potential to achieve benefits for native biodiversity, but the question remains as to whether the magnitude and scale of the benefits achieved at the particular control cost in the Glen et al. (2016) study was sufficient to achieve the biodiversity outcomes desired from the control programme.

5 Conclusions

Possums have a much broader range of impacts than the other predators. Apart from their role in spreading TB and their impacts on native biodiversity through browsing and predation, they also cause damage to forestry, horticulture and cropping, infrastructure and urban gardens. However, these other types of damage are currently of much less economic importance at a regional scale than their role in spreading TB, although their importance would obviously increase if control was not continued after TB is eradicated in the region.

Most of the direct economic benefits to the Hawke's Bay Region of the C2C broadscale predator control programme are likely to accrue from possum control as a part of OSPRI's National TB Eradication Programme. The value of these benefits is likely to greatly exceed the costs of predator control. Where ferret numbers are high (mostly in areas with high rabbit numbers) the control of ferrets for TB eradication may have an economic benefit, but this has not been estimated. Control of feral cats to reduce impacts of toxoplasmosis infection on the sheep industry has strong potential economic benefits, but the likelihood and cost of achieving the requisite reduction in feral cat numbers to eliminate the disease needs to be evaluated and compared to the efficacy and cost of vaccination.

Although the impacts of predators on biodiversity values is relatively well understood, the economic value of mitigating these impacts (i.e. generating the benefits) is poorly quantified. This deficit is compounded by a similar lack of detailed estimates of the value of native biodiversity. Nevertheless, where contingent valuation and willingness to pay approaches have been used to address these questions, the results consistently show New Zealanders attach a high value to native plants and animals and the need to protect them from predation.

Evidence from market and sector surveys indicate that many international markets value biodiversity and "clean-green" sources for primary products, and for New Zealand as a whole the increase in value for biodiversity improvement is estimated at about $68 million through to 2020.

Evaluation of biodiversity benefits also has some constraints. Willingness to pay evaluation methods provide a guide to the size of economic value people assign to benefits, but they are often based on the assumption that specific biodiversity values are fully protected or willingness to pay is related to incremental improvements in benefits (such as percentage improvements). In the latter case these usually fail to take account of pest impact–density functions and the link to benefits and values.

6 Recommendations

Hawke's Bay Regional Council should:

- undertake a regional evaluation of native biodiversity both in total and for key indicator species relevant to its pest management and biodiversity restoration programmes. This should include green credential benefits and benefits to wider ecosystem services.
- assume, until more robust data become available, that the benefits for biodiversity from controlling predators other than possums (assuming their numbers can be reduced to levels below which most impacts are mitigated) will be broadly similar to the OSPRI benefits for biodiversity from possum control (valued at $1.8 million annually, with a discounted NPV of $19.9 million over 35 years).
- investigate the likelihood and cost of achieving the requisite reduction in feral cat numbers to eliminate toxoplasmosis compared to the efficacy and cost of vaccination.
- keep detailed records of the costs of predator control and its efficacy to provide it with stronger evidence of the cost-benefits of its broadscale predator control as linked to native biodiversity benefits.
- continue its efforts to ensure the expected biodiversity benefits of regional-scale predator control or other pest management are supported by all parties involved and are confirmed by a robust monitoring programme to measure native biodiversity responses.
- look at ways to derive density-impact functions for the key predators and impacted native prey species using the guidelines provided by Norbury et al. (2015). This might be best achieved through a combined approach with other regional and territorial authorities.

7 Acknowledgements

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9 Appendix 1

Definitions of Economic valuation terms referred to in the report.

Net present value (NPV) and discount rate: Net present value is a calculation that compares the amount invested today with the present value of the future cash receipts from the investment. In other words, the amount invested is compared with the future cash amounts after they are discounted by a specified rate of return. Because of the time value of money (TVM), money in the present is worth more than the same amount in the future. This is both because of earnings that could potentially be made using the money during the intervening time and because of inflation. The discount rate element of the NPV formula is a way to account for the time value of money. Companies may often have different ways of identifying the discount rate. Common methods for determining the discount rate include using the expected return of other investment choices with a similar level of risk, or the costs associated with borrowing money needed to finance the project. (http://www.accountingcoach.com/blog/npv-net-present-value)

Contingent valuation: The contingent valuation method (CVM) is used to estimate economic values for all kinds of ecosystem and environmental services. It can be used to estimate both use and non-use values, and it is the most widely used method for estimating non-use values. The contingent valuation method involves directly asking people, in a survey, how much they would be willing to pay for specific environmental services. In some cases, people are asked for the amount of compensation they would be willing to accept to give up specific environmental services. It is called “contingent” valuation, because people are asked to state their willingness to pay, contingent on a specific hypothetical scenario and description of the environmental service. The fact that CV is based on what people say they would do, as opposed to what people are observed to do, is the source of its greatest strengths and its greatest weaknesses. (http://www.ecosystemvaluation.org/contingent_valuation.htm)

Willingness to pay: Willingness to pay is the foundation of the economic theory of value. The idea is, if something is worth having, then it is worth paying for. The idea extends to environmental resources like water quality and natural resources like trees. The key assumption is that environmental values are anthropogenic. Whatever people think the environment is worth is what it is worth. Economic methods can be used to attach estimates of willingness to pay to changes in the level of environmental quality and natural resource use. (http://www.env-econ.net/2006/07/willingness_to_.html)

Choice modelling: Choice Modelling is a technique that tries to model the decision making process of a person or a segment with respect to a particular context. Choice Modelling can be used to estimate non-market environmental profits and costs. Choice Modelling can also be regarded as the most suitable procedure to estimate consumer’s willingness for paying to obtain qualitative improvements in multiple dimensions. (https://myassignmenthelp.com/marketing/choice-modelling-technique-of-modeling-a-consumers-decision-process.html).

Appendix 2

Summary of economic value of benefits derived from broadscale control of mammalian predators in the Hawke's Bay Region. Where applicable, regional benefits were calculated from national benefits on a proportional basis at the discount rate applicable to the original calculation (see text).

Species	Impact	Source/method of benefit calculation	Benefit to Region ($)
Possums	Bovine Tb transmission	OSPRI valuations for National TB Eradication Strategy – all benefits Greer (2010) – agriculture benefits	NPV $380 million over 30 years – of which $103 million for non-TB benefits NPV $5.7-37 million over 25 years
	Other productive sector damage	OSPRI valuations for National TB Eradication Strategy; Cowan (1991)	Pasture loss NPV $4.2 million over 30 years Other losses $1-3 million annually
	Predation on native biodiversity	OSPRI valuations for National TB Eradication Strategy Willingness-to-pay estimates	$1.8 million annually; $19.9 million over 35 years $67-$392 per person/household per year
Feral cats	Toxoplasmosis transmission	Walker (2014)	c. $15 million annually
	Bovine Tb transmission	Literature review	Not quantified but very low
	Predation on native biodiversity	Literature review	Not quantified but significant; benefit value similar order to possums
Ferrets	Bovine Tb transmission	Literature review	Not quantified but low, >

			cats and stoats
	Predation on native biodiversity	Literature review	Not quantified but significant; benefit value similar order to possums
Stoats	Bovine Tb transmission	Literature review	Not quantified but very low
	Predation on native biodiversity	Literature review	Not quantified but significant; benefit value similar order to possums