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ANALYSIS

Costs and Benefits of Rodent Eradication on Lord Howe Island, Australia

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1. Introduction

Invasive species compete with endemic species and if successful can displace native species in the host region (Cororaton et al., 2009). This can be a particular issue for island ecosystems which account for approximately 5% of the Earth's land area but a disproportionately high level of global biodiversity e.g. 19% of all bird species (Croll et al., 2016). In the Pacific, the largest cause of extinction of single-country endemic species is the impact of invasive species (SPREP, 2016). Invasive vertebrates, in particular rats and mice, are the main cause of extinctions and ecosystem changes on islands (Keitt et al., 2015; Howald et al., 2009) and one of the greatest threats to island biodiversity (Harris et al., 2012). This is due to their dispersal capabilities and their heavy impacts on a variety of native fauna and flora (Harris et al., 2012). They are able to 'hitchhike' aboard boats, ships and planes and swim between islands: *Rattus rattus* (black rat) and *Mus musculus* (house mice) have been known to swim channels up to 750 m and 500 m wide, respectively (Harris et al., 2012). Because they are omnivorous, once they find their way onto an island they predate on birds, mammals, reptiles, invertebrates, seeds and seedlings, thus having multiple impacts within an ecosystem (Ogden and Gilbert, 2009; Howald et al., 2007). Invasive rodent species are estimated to have colonised 80% to 90% of the world's island groups (Harris et al., 2012; Croll et al., 2016).

It is possible, however, to eliminate invasive rodent species from island habitats. This has been demonstrated by over 700 successful eradications globally (Croll et al., 2016), including Macquarie Island (Australia), Anacapa Island (USA) and Kaikoura Island (New Zealand) (Island Conservation, 2016).

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While island size has previously been seen as a limiting factor for rodent eradication, particularly for house mice, Howald et al. (2007) suggest that social acceptance and funding may now be the main challenges. While biologists have responded with prioritisation systems based on financial cost-effectiveness or long term conservation gains (Harris et al., 2012), a key approach to seeking both social acceptance and funding is to demonstrate whether the benefits to the affected community from rodent eradication exceed the costs. This is particularly important given that some of the benefits of rodent eradication occur outside of the market and hence are unpriced, while the direct costs of eradication are monetary and easily identified. Using cost benefit analysis (CBA), the biophysical consequences of an eradication program, including those elements of concern to the community such as use of poisons and impact on non-target species (Ogden and Gilbert, 2009), as well as the often unpriced benefits, can be considered, quantified and where possible valued, in a consistent manner. Eradication that is shown to provide net benefits to the community may quell some of the community's concerns and provide funding agencies with the confidence needed to justify the investment, when there are competing claims for funding.

Notwithstanding this apparent need for CBA, there would appear to be no published economic assessments of rodent eradication programs on islands. Here we report on a CBA of a proposal to eradicate rodents (*Rattus rattus* and *Mus musculus*) from Lord Howe Island (LHI), located 600 km off the cost of New South Wales, Australia (Map 1). While consideration is given to all the potential costs and benefits of the program, a particular focus is given in this paper to the estimation of the two main potential benefits of eradication - biodiversity and tourism.

The paper is set out as follows. Section 2 provides information on LHI and its rodent problem. Section 3 provides an introduction to CBA and the measures of economic value used. Section 4 outlines the results of the CBA of the LHI Rodent Eradication Project (REP). Conclusions are

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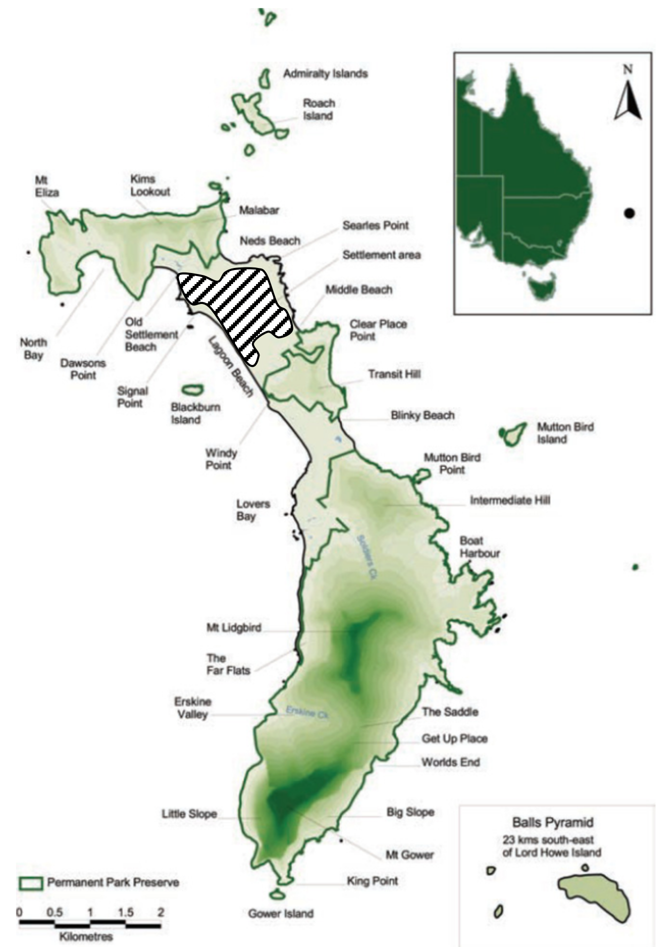

Map 1. Lord Howe Island location and primary current rodent control area (hatched). Source: LHIB (2016, p. 3).

provided in Section 5. The analysis provides a specific demonstration of how CBA can be used more generally to assess rodent eradication programs, where there are both biodiversity and tourism implications.

2. Study Area and Context

LHI together with outlying islands, islets and rocks is referred to as the Lord Howe Island Group (LHIG). The LHIG has outstanding natural features and values, and is on the Register of the National Estate. It is also listed as a World Heritage Area (WHA) and is located within the Lord Howe Island Marine Park (NSW) and the Lord Howe Commonwealth Marine Reserve (under Commonwealth authority). In addition to the natural and heritage values of the LHIG, LHI also generates significant financial values through the provision of tourism accommodation and a range of tourism and recreation activities that include:

- marine activities (beach and reef walking, swimming, snorkelling, scuba diving, fish feeding, surfing, underwater photography, windsurfing, sea-kayaking, fishing, sightseeing cruises and eco tours); and
- terrestrial activities (hiking, bird watching, bike riding, sightseeing and eco tours).

Financial values are also generated via the propagation and sale of the Lord Howe Kentia Palm (domestically and internationally) and nursery vegetables to local businesses.

The natural, heritage, tourism and industry values of LHI, are being impacted by introduced species of rats (*Rattus rattus*) and mice (*Mus musculus*), despite an ongoing rodent control program. The population of rodents on LHI is estimated at around 63,000 to 150,000 for rats and 140,000 to 210,000 for mice (LHIB, 2016). Both species have had, and continue to have, significant adverse impacts on the biodiversity of LHI. Rats are implicated in the extinction of at least five endemic birds and at least 13 invertebrates. They are also a recognised threat to at least 13 other bird species, 2 reptiles, 51 plant species, 12 vegetation communities and numerous threatened invertebrates (LHIB, 2009).

The impact of house mice on biodiversity of LHI is not as well understood, however, evidence from other sites shows that they eat eggs of small birds, reduce seedling recruitment of some plants, and compete with native seed-eating fauna. On other islands, mice have been implicated in declines of invertebrates, and in some cases this has greatly affected nutrient recycling processes (LHIB, 2009).

Predation by rodents on Kentia Palm and vegetable crops also reduces values associated with these commercial activities, via reduced production and/or added costs of control. In addition, rodents impose costs on residents and tourism operators via the spoiling of food stuffs and reduced amenity associated with presence of rodent excrement.

The current rodent control program involves the use of a first generation anticoagulant, coumatetralyl, in 1400 bait stations across the settlement area of the island which constitutes 15% of the land area. Coumatetralyl is also supplied to residents who wish to use it on their properties. The present control baiting program does not occur in the other parts of the Island as it is not practical given the large area and rugged terrain (LHIB, 2009).

A continuation of the current control program is predicted to be unable to prevent additional extinctions on LHI over the next 20 years, particularly of invertebrates (LHIB, 2016). Any impact on the natural values of LHI can also diminish tourism and recreation values since these are inextricably linked to the Island's unique biodiversity and World Heritage values.

An alternative to the continuation of the current rodent control program is the LHI Rodent Eradication Project (REP). This is a proposal to eradicate introduced rodents from the LHIG using cereal baits laced with the anticoagulant Brodifacoum dispersed from helicopters in the uninhabited areas, and a combination of hand broadcasting, bait stations and bait trays in the settled area (LHIB, 2009).

3. Cost Benefit Analysis and Measures of Costs and Benefits

A comparison of the additional costs and benefits "with" the REP, relative to "without" the REP can be undertaken using CBA. In this framework, costs are reductions in peoples' well-being as measured by changes in their 'producer surplus' or 'consumer surplus'. Similarly, benefits are improvements in peoples' well-being as measured by increases in producer or consumer surpluses. The conceptual model for providing an understanding of consumer and producer surplus is the supply and demand, or market, model (Refer to Fig. 1).

Consumer surplus is the difference between what an individual would be willing to pay (demand) for a good or service (the total benefit

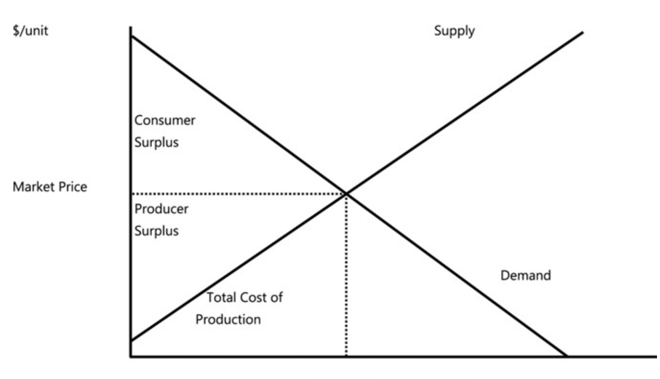

Fig. 1. Economic values and the market model.

Table 1
Potential additional costs and benefits of the LHI REP.

Category	Costs	Benefits
Direct costs	REP direct implementation costs	Avoided ongoing rodent control costs - Lord Howe Island Board (LHIB) and residents
Biodiversity	Potential for species extinction from the REP Costs of returning extant species to LHI	Biodiversity improvements – prevention of additional extinctions – increased abundance of species – return of extant species to LHI
Tourism	Foregone tourism business during REP implementation	Additional demand for accommodation during REP implementation Additional tourism business after REP implementation
Palms and vegetables		Increased productivity for Kentia Palm and vegetable industry and avoided direct costs Increased productivity of other vegetable gardens
Health and toxicity	Potential impacts on other species, water and human health	Reduced impacts to humans, livestock and pets from constant presence of rodent poison Elimination of health impacts from rodents for residents and tourists
Wastage and amenity		Elimination of spoiled foodstuffs and the presence of rodent excrement on LHI
Research		Research benefits of the program

to the consumer) and what they have to pay (the cost to the consumer i.e. consumer expenditure or price times quantity). In the market model, it is the area between the demand curve and the price line (Tietenberg et al., 2014). Producer surplus is the difference between the revenue (consumer expenditure) received for a good or service (total benefit to producer) and the costs (supply) of the inputs used in the provision of the good or service (economic cost to producer). In practical terms, it is the net revenue (before tax) that is earned by producers of goods and services. In the market model, it is the area between the price line and the supply curve (Tietenberg et al., 2014).

Even where goods and services are provided outside a market, the concepts of demand and supply can still be conceptualised and provide the basis for modelling and estimating changes in producer and consumer surpluses. For non-market use values, such as recreational fishing, swimming, snorkelling etc., and nonuse values such as protection of biodiversity, the concept of a demand curve exists as if it were a market good (Driml, 1994). The only difference is that the demand curve is not readily identifiable from market transactions and therefore needs to be derived from observing consumer behavior (real or hypothetical) using nonmarket valuation methods (Bennett, 2011).

Provided the present value of additional benefits exceeds the present value of additional costs (i.e. a net present value (NPV) of greater than zero or a benefit cost ratio (BCR) of greater than one), a project is considered to improve the well-being of society and hence is desirable from an economic efficiency perspective (Hanley, 1999).

The NPV presented in many ex-ante CBAs are based on future values being achieved with certainty. However, future values are subject to risk and uncertainty. In economic analysis, there is a difference between risk and uncertainty. Risk is measurable; it refers to situations with known probabilities. Uncertainty, in contrast, is less well specified; it is characterised by a lack of information on the likelihood of different impacts (Boardman et al., 2001). One way of incorporating risk into a CBA is to use expected values instead of certain values. This requires the range of potential outcomes being assigned probabilities. Expected values are the certain values multiplied by the probability of their occurrence. Where outcomes require a sequence of future events to occur, expected values will depend upon the product of the probabilities of each sequential event. The result is an expected net present value (ENPV)

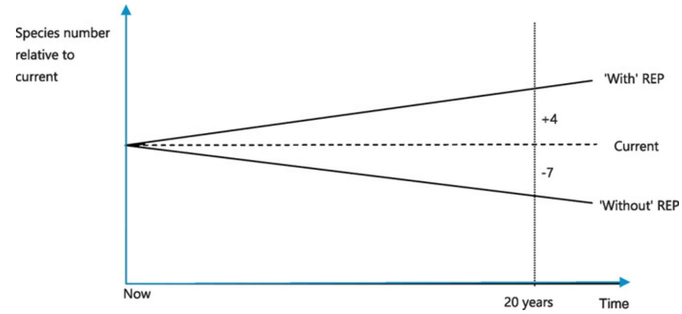

Fig. 2. Native species on LHI "With" and "Without" the REP.

(Boardman et al., 2001). If information is available on probabilities and their distributions for key parameters, the incorporation of risk can be enhanced through the simulation of expected outcomes using Monte Carlo techniques. When uncertainty is encountered in an economic appraisal, the most commonly applied technique is sensitivity analysis. This involves changing the values of critical variables in the analysis, to determine how the results might be affected (Boardman et al., 2001).

For the CBA of the LHI REP, where probability information was available, expected values were calculated. For these and other variables, sensitivity testing was undertaken.

4. Cost Benefit Analysis of the Lord Howe Island Rodent Eradication Project

4.1. Incremental Costs and Benefits

Relative to the "without" REP scenario of ongoing rodent control program, the REP would have the additional costs and benefits to the Australian community identified in Table 1.

4.2. Estimation of the Additional Costs and Benefits of the REP

4.2.1. Direct Costs and Benefits

The LHI REP has estimated capital costs of $10.6M[1] although approximately $1.5M of this was already spent at the time the CBA was undertaken. For the purpose of the CBA, which was to assess whether the proposal to eradicate rodents from Lord Howe Island should continue, the portion already spent is a 'sunk' cost and hence excluded from the analysis (NSW Treasury, 2007). Incremental ongoing biodiversity monitoring costs associated with the REP[2] are estimated at $50,000 per year for 10 years, with ongoing rodent detection (quarantine) costs[3] of $30,000 per year. "With" the implementation of the REP, the LHIB would avoid ongoing rodent control costs of $85,000 per annum and residents would avoid private bait costs of $4800 per annum. These cost savings are benefits of the REP.[4]

4.2.2. Biodiversity Costs and Benefits

The biodiversity benefits of the REP include:

- avoiding seven additional extinctions on LHI over the next 20 years[5];
- the ability to return four species that are extant from LHI due to the predation of rats and mice such as the Kermadec petrel, White-bellied

[1] Monetary figures quoted in this report are in Australian Dollars (AUD). As at April 2017 the AUD:USD exchange rate was 0.75.

[2] Of seabirds, landbirds, reptiles, land snails, other invertebrates, big and Little mountain palms, fruiting plants and woodhens.

[3] Using a combination of bait stations, rodent detection dogs, trail cameras, chew blocks/wax tags, traps and tracking tunnels.

[4] These cost savings only arise if the REP is successful and so this benefit was weighted by the probability of the REP success. This is discussed further in Section 4.2.2.

[5] A 20-year time frame is referred to here as this is the basis on which non-market valuation studies used in this report are based.

storm petrel, phasmid and wood feeding cockroach; and,
- an increase in abundance of plants, birds, reptiles and insects.

The net impact on species numbers is illustrated in Fig. 2.

Economic benefits of species conservation can be enjoyed by people who visit LHI and observe the biodiversity (use values) and by those who obtain an increase in their welfare from knowing that there has been an improvement in biodiversity (non-use values). The former categories of values are reflected in tourism demand and considered in Section 4.2.3.

Non-use values, defined as a person's willingness to pay (WTP) to obtain that biodiversity outcome (increased consumer surplus), can be estimated via stated preference methods such as choice modelling. In the absence of any specific study for LHI, benefit transfer (BT) is used to provide an indication of the possible non-use values from the REP.

The use of BT means that valuation is limited to those attributes and species that have been included in other studies. Desirable conditions for benefit transfer between a source study and target study include source study validity, biophysical compatibility, consistent socio-economic characteristics of populations and consistent scale and type of the change being valued (Rolfe et al., 2015). Pandit et al. (2015) undertook a global review of non-market valuation studies of threatened species and ecological communities. They reviewed 76 papers and found that there is strong evidence that the broader community does support and is willing to pay for the protection and recovery of threatened species. However, the values of threatened species and ecological communities varied considerably based on species valued and the sampled population of beneficiaries. In a meta analysis covering 31 studies, Richardson and Loomis (2009) found a WTP for species range from $8 per household per year to a maximum of $311 per household per year. Of the 76 studies examined by Pandit et al. (2015), 69 were non-Australian studies and therefore not ideally suited to BT to Australia because of socio-economic differences of populations and the types of species being valued. Furthermore, the Australian studies examined were also not well suited for BT to the current study since they related to specific mainland species such as the Northern Hairy Nose Wombat and Tree Kangaroo that are not found on LHI and not representative of the species on LHI impacted by rodents.

Three Australian studies that used Choice Modelling (CM), a non-market valuation technique that is better suited for BT (Rolfe and Bennett, 2006), and focused on the value of protecting native species from extinction are those of Van Bueren and Bennett (2000), Akter et al. (2011), and Mazur and Bennett (2009).

Van Bueren and Bennett (2000) in a survey of Australian households found an average WTP of $0.68/household/year (for 20 years) i.e. $7.20 per household (present value), per species protected from extinction. Aggregating per household benefits to the community requires adjustment for the survey response rate since not all the originally targeted respondents participated in the survey and it is difficult to determine the preferences of non-respondents. A lower bound approach is therefore to assumed that non-respondents were unwilling to pay for environmental improvements (Greyling and Bennett, 2012). The response rate for the questionnaire was 16%. Adopting this approach and aggregating to this percentage of Australian households gives an economic value estimate of $8.5M per species protected from extinction in Australia.

Akter et al. (2011) in a survey of households of south east Queensland found and average WTP of $21/household/year to protect one native species for being listed as threatened as a result of invasive species. No response rate for the survey was provided, but assuming the response rate was as reported for Van Beuren and Bennett i.e. 16%, and aggregating to this percentage of the south east Queensland households gives an economic value of $54M per native plant or animal species protected from becoming threatened as a result of invasive species.

Mazur and Bennett (2009) undertook a CM study to acquire information about different NSW community (local resident, distance rural and distance urban) attitudes and preferences for environmental improvements provided by a range of potential natural resource management (NRM) strategies in three NSW catchments (Lachlan, Namoi and Hawkesbury-Nepean). The attributes used to describe different environmental improvements included the number of native species protected (from extinction in each of the catchment). The context for elicitation for these values was a decline in native species numbers from the status quo over a 20-year period without any NRM actions and an increase in native species numbers relative to the status quo with NRM actions. This is the same as the context for the LHI REP. Community average WTP (implicit prices) estimates per household per annum for five years per species protected are provided in Table 2. Households from three different community types were sampled: Rural communities near the species' habitats, urban communities distant from the habitats and rural communities located at a distance. Statistically significant value estimates ranged from $2.43 to $6.97 per household per annum for five years. (See Table 2.)

Response rates for the Mazur and Bennett questionnaires varied from 30% for Sydney households to 60% for rural households (Greyling and Bennett, 2012). Conservatively, aggregating the lowest value per species across NSW households using the lowest response rate gives an economic value of $8M per species protected from extinction in the region. This is the value used in this analysis as the source study surveys the preference of the population that is relevant to the CBA i.e. NSW households,[6] most closely reflects the context and type of biophysical change of relevance to the REP on LHI and is the most conservative value.

However, there is risk and uncertainty associated with the future species outcomes from implementation of the REP. One way that this can be addressed is to weight the certain benefit estimate by the probability of it being realised (Greyling and Bennett, 2012) to estimate the expected benefit.

The probability of re-establishing species post REP or avoiding additional extinctions has two components, the probability that the REP will eliminate rodents and the probability that once this occurs species can be re-established or extinctions avoided. These probabilities are multiplicative. Probabilities assumed in this analysis are identified in Table 3 and are based on experience of other island eradication projects and expert judgements of NSW Office of Environment and Heritage ecologists. The probability of success of the REP i.e. 95%, is consistent with Keitt et al. (2015) who suggested success rates of 96.5% on tropical islands (where success rates are lower than other places) by following the recommended best practice.

Consequently, the economic benefit associated with reintroducing the LHI Phasmid is the certain benefit estimate of $8M for native species protection times by 95% for the probability of success of the REP times by 100% for the likelihood of success of reintroducing the LHI Phasmid i.e. $7.6M. The economic benefit from avoiding extinction of the LHI Passionfruit is the certain benefit estimate of $8M for native species protection times by 95% for the probability of success of the REP times by

Table 2
Implicit prices per household per annum for five years for protection of a native species. Source: Mazur and Bennett (2009) and Greyling and Bennett (2012).

Catchment	Community type		
	Local rural	Distant urban	Distant rural
Hawkesbury-Nepean	$6.97[b]	$5.25[b]	$4.97[b]
Lachlan	$4.51[a]	$8.11[b]	$7.45[b]
Namoi	$2.50[a]	$2.43[a]	$1.79

[a] Statistically significantly different from zero at the 5% level.
[b] Statistically significantly different from zero at the 1% level.

[6] The CBA is required by NSW Treasury (2007) to be undertaken from a NSW perspective.

Table 3
Probability assumptions.

Event	Probability
Success of REP in eradicating rodents	95%
Success of reintroducing species	
LHI Phasmid - *Dryococelus australis*	100%
LHI Wood-feeding Cockroach - *Panesthia lata*	100%
Kermadec Petrel - *Pterodroma neglecta*	95%[a]
White Bellied Storm Petrel - *Fregetta grallaria*	95%[a]
Additional extinctions "without" the REP	
Four species of land snails	100%
- Whitelegge's land snail - *Pseudocharopa whiteleggei*	
- Masters' charopid land snail - *Mystivagor mastersi*	
- Mt Lidgbird charopid land snail - *Pseudocharopa lidgbirdi*	
- Magnificent Helicarionid land snail - *Gudeoconcha sophiae magnica*	
One species of land snail	50%
- Lord Howe placostylus - *Placostylus bivaricosus*	
Phillip Island Wheat Grass - *Elymus multiflorus* var. *Kingianus*	75%
LHI Passionfruit - *Passiflora herbertiana* ssp. *insulae-howei*	50%

[a] If actions are taken to actively attract this species. Hence a cost of these actions is included in the CBA.

50% for the likelihood that LHI Passionfruit would become extinct in the absence of the REP i.e. $3.8M.

Jones (2010) suggests that some seabird augmentation measures may be required where seabirds have been extirpated by invasive predators. In this respect, the cost of reestablishment of species on LHI, subject to successful eradication of rodents, was estimated at $50,000 (O'Dwyer and Portelli,[7] 2016, pers. comms, 11 August). The expected value of these costs is therefore 95% times $50,000 i.e. $47,500.

In addition to benefits from protection of species, a further benefit of the REP would be an increase in species abundance including:

- a marked increase in birds, reptiles and insect density, diversity and distribution - this boost in diversity will increase food resources for predatory terrestrial vertebrates and potentially lead to population increases which will enrich the experience of both island residents and tourists; and
- increases in the abundance of plants, seeds and seedlings, thereby enhancing the process of forest regeneration (LHIB, 2016e).

This benefit remains unquantified in this analysis, although studies have found that the community are WTP for increases in species abundance. For example, Blamey et al. (2000) found that Brisbane households were WTP $1.69 each to avoid each 1% decrease in the population size of non-threatened species in the Dessert Uplands of Queensland. This value is not readily transferable to LHI.

Notwithstanding the potential species benefits of the REP, concern has been raised in relation to the potential impacts of the baits planned for use in the REP on soil, water, the marine environment and non-target species. Each of these is considered below.

The Brodifacoum bait is cereal based and designed to rapidly breakdown following the absorption of water, or after rain. Because of the physical chemical properties of Brodifacoum, it is unable to contaminate groundwater. When Brodifacoum breaks down it binds strongly and rapidly to soil particles with very slow desorption. It does not leach from the soil. It is non-toxic to plants, because it is not transported from water or soil into the plant (Toxicos, 2010). Soil residual concentrations decline rapidly over time. After aerial application of Talon 20P (0.002% Brodifacoum) over an island off New Zealand, Brodifacoum was not detected in soil when randomly sampled 2, 12, 34 or 210 days post application (Toxicos, 2010). Notwithstanding this evidence, additional tests on LHI will be conducted to test Brodifacoum residues in soil (LHIB, 2009).

[7] Ecologists at the NSW Office of Environment and Heritage.

The REP is designed to ensure that the bait is directed onto land. Nevertheless, it is inevitable that a small amount of bait will enter the marine environment, particularly where cliffs constitute the shoreline. In these settings, most of the bait will fall within a few metres of the shoreline and will be subjected to the mechanical effects of wave actions, resulting in disintegration within a few minutes. This, together with the high dilution factor, and the insolubility of Brodifacoum in salt water, means that the potential risk to marine organisms is negligible. The amount of Brodifacoum assimilated into the marine environment will be many orders of magnitude lower than the concentrations known to be toxic to fish (Toxicos, 2010).

Research indicates that the LHI woodhen will ingest baits and poisoned rodents in amounts that would be fatal and LHI pied currawongs consume rodents and so would be susceptible to secondary poisoning. To minimise the impact on these two threatened species, a substantial proportion[8] of each population will be taken into captivity on LHI and will remain there until baits have disintegrated and pose no further risk (LHIB, 2009). Consequently, the likelihood of extinction of the LHI woodhen and LHI pied currawong is considered by LHIB and the NSW Office of Environment and Heritage to be highly improbable ($1 * 10^{-5}$) and very unlikely ($1 * 10^{-4}$), respectively. Hence the expected value of this impact is also extremely small. This is consistent with other studies that found only ephemeral impacts on the populations of non-target species and successful reintroduction of captured populations (Howald et al., 2009).

4.2.3. Tourism Costs and Benefits

The conceptual supply and demand for current visits to LHI in tourism peak periods (Part A) and off-peak periods (Part B) is depicted in Fig. 3.

The whole of experience demand (or willingness to pay curve) for tourism visits is downward sloping: the higher the price charged per visit the less quantity will be demanded. By definition, the demand curve for off peak visitation lies to the left of the peak season demand curve. The whole of experience supply curve[9] (or marginal cost curve) is upward sloping reflecting the increasing costs of suppliers of the tourism experience: as the price per visit increases more will be supplied as more producers find it profitable to sell.

However, the maximum number of tourists on LHI at any one time (enforced as a limit on the number of 'tourist beds' permitted) is constrained to 400 (Lord Howe Island Tourism Association, 2015), a constraint that is reached in the peak periods of November to April. With a supply constraint in peak periods there is a vertical portion of the supply curve when bed capacity is reached. In peak periods, demand intersects with the vertical part of the supply curve (as shown in Part A of Fig. 3). Hence in peak times, the price per visit is higher than the marginal costs of providing the additional tourism experience. Hence, in addition to a normal producer surplus there is a scarcity rent (an extra producer surplus that does not induce increased production). However, this scarcity rent only accrues to components of supply that have the capacity constraint applied e.g. accommodation providers[10] and airlines. It is assumed that no scarcity rent accrues to tour operators as there are no capacity limits or limits on new entrants and minimal costs of entry for new participants.[11]

The net benefit of visits in peak periods therefore comprises:

- normal producer surplus to suppliers e.g. accommodation providers, tour operators, shops and restaurants;

[8] 80–85% and 50–60%, respectively.

[9] Comprising all components of supplying the visit including travel, accommodation, food, tours etc.

[10] The scarcity rent that accrues to accommodation providers in peak periods is implicitly recognised by the LHIB via its bed tax, which is essentially a scarcity rent tax

[11] It should be noted that some scarcity rent may potentially accrue to tour operators to the extent that the restriction on the number of Island residents provides a defacto restriction on competition in the tour operator market.

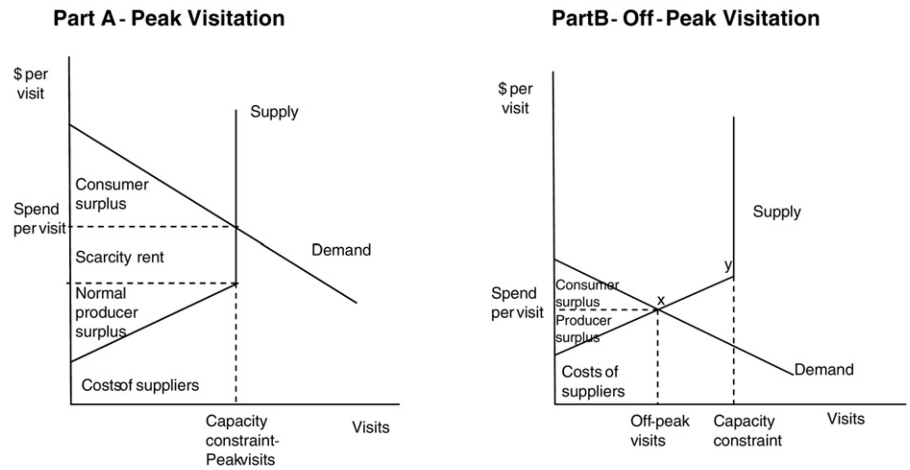

Fig. 3. Annual demand and supply for LHI tourism visitation in peak and off-peak periods. (In this analysis, the peak period is defined as November to April and the off-peak period is defined as all other months.)

- scarcity rent that accrues to accommodation providers and the airline; and
- consumer surplus to tourists.

In off-peak periods, demand intersects with the supply curve to the left of the vertical section of the supply curve and hence normal producer surplus is generated across all suppliers of the tourism experience, that supply services during this time. A segment of higher cost suppliers represented by the portion of the supply curve between x and y (in Part B of Fig. 3) close down during this period.

These conceptual models are used to estimate benefits and costs based on a range of data. Estimated visit numbers and expenditure estimates per visit in both peak and off-peak periods provide the point where supply intersects with demand. To enable specification of the remaining demand curve and so allow estimation of the consumer surplus associated with visits, a price elasticity of demand of −0.8 was assumed.[12] Price elasticity of demand would be expected to be less than 1 given the uniqueness of LHI and limited substitutes. Crouch (1994) suggest an average price elasticity of demand for international tourism (which is likely to be a better indicator for LHI than domestic tourism) of around −0.6 to −0.8. The higher figure −0.8, which was assumed in this analysis, would result in a lower consumer surplus and hence may be considered to provide a lower bound estimate.

Scarcity rent that accrues from the provision of accommodation in peak periods was estimated by summing the annual bed tax levied by LHIB and the annualised value that beds trade for in the market.[13] Subtracting this level of expenditure from the peak period expenditure of LHI visitors provides an indication of where the vertical part of the supply curve intersects with the upward sloping part of the supply curve.

Normal producer surplus to suppliers i.e. accommodation providers, tour operators, shops and restaurants, was estimated based on the estimated visitor expenditure on these items in peak and off-peak periods and using a fixed ratio of producer surplus to revenue for these sectors sourced from the National Input-Output Table.[14] For the peak period model, a supply curve was fitted that intersects with the vertical section of the peak period supply curve at the point identified from the consideration of scarcity rent and provides the level of estimated peak period produce surplus. For the off-peak model, a supply curve was fitted that intersects with the demand curve at the appropriate point and provides the estimated level of producer surplus in the off-peak period.

Based on this approach the economic benefits associated with current visitation levels in peak and off-peak periods were estimated as per Fig. 4.

A key motivation for visits to LHI is to experience the natural, undeveloped and unspoilt surroundings, as indicated by its WHA listing, Marine Park declarations of surrounding waters and incorporation of around 70% of the Island in a Permanent Park Preserve. Rodents are identified as a threat to LHIs Outstanding Universal WH values, having caused a reduction in biodiversity via extinctions on LHI and a reduction in species abundance.

Under the "without" REP scenario further degradation of World Heritage values could potentially result in the LHIG being inscribed on the "World Heritage in Danger List". This would have a 'signalling' effect to the tourism market of a decline in values and tourism experience (Tisdell and Wilson, 2002) and would be expected to result in a reduction in tourism demand in both the peak and off-peak periods. Whether LHIG is inscribed on the "World Heritage in Danger List" or not, the Lord Howe Island Tourism Association (2015) has identified the "potential increase in negative consumer perception of degeneration of pristine environment" as a key threat to tourism.

While some decline in tourism demand is expected to be associated with further degeneration of the environment of LHI, for the purpose of the analysis it has been assumed that "without" the REP, demand in the peak and off-peak periods remains constant[15] over the analysis period i.e. 30 years. Hence, the values estimated for current visitation levels are assumed to continue.

"With" the REP, two separate potential impacts were identified - short term effects during the REP and long term effects after the REP.[16] Short term effects included reduced tourist visitation during the REP and increased demand for accommodation from the non-local workforce.

The REP is proposed to be undertaken during the winter months when tourism is least and the group most sensitive to knowledge of the REP i.e. families with children, do not visit. Other groups are likely to be less sensitive and, in any case, have greater flexibility to adjust the time of their travel to other non-peak periods. Therefore, in the

[12] It was recognised that the travel cost method could be used to estimate the demand curve and price elasticity for visitation to Lord Howe Island. However, the time frame and budget for the study was insufficient for this to be undertaken. Nevertheless, travel cost method questions were provided to the Lord Howe Island Tourism Association for inclusion in future surveys of visitors.

[13] Tourism expenditure information was based on expenditure on the Island and so excluded expenditure on airfares. Also, no information was available on potential scarcity rent accruing to airlines. Consequently, the producer surplus and scarcity rent accruing to the airline was excluded from the analysis. This has the effect of understating the benefits of tourism and the REP and the short term costs of the REP.

[14] Gross operating surplus in the National Input-Output Table has been used as a proxy for producer surplus.

[15] All other things being equal (ceteris paribus).

[16] Long term effects are contingent on success of the REP and hence were weighted by the likelihood of success of the REP estimate at 95%.

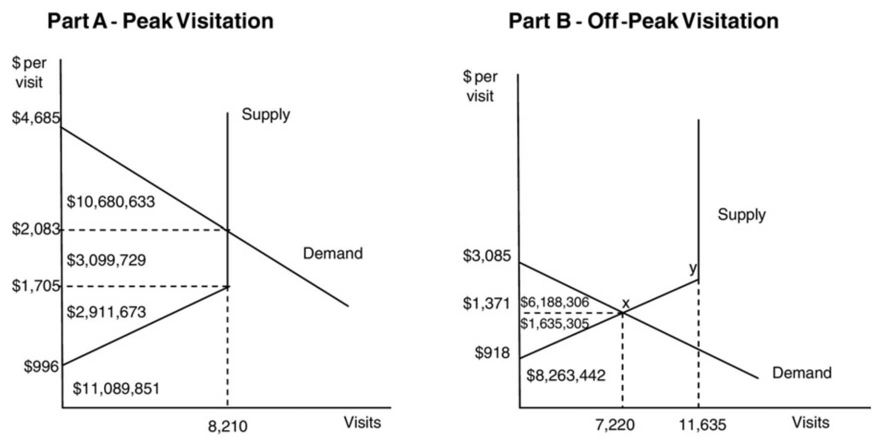

Fig. 4. Tourism economic values under base levels of demand.

absence of any evidence from surveys of prospective visitors to LHI, it is reasonable to expect that there will be minimal or no reduction in visitation at the time of the REP, or at least in the off-peak period overall (allowing for some substitution for an alternative off-peak times).

However, for the purpose of this analysis it is assumed that 50% of visitors who would otherwise have visited during the month of July (when the REP is likely to be implemented) i.e. 293 visits and 2051 visitor nights, would not visit and would not alter the timing of their booking. This impact was represented by a reduction in off-peak demand resulting in an associated reduction in annual consumer surplus to tourists and annual producer surplus to tourism providers of $490,000 and $130,000, respectively. Offsetting this short term impact would be additional REP workforce demand for 3050 bed nights and producer surplus to accommodation providers of $122,000. If these workers have similar spending habits to tourists, then producer surplus impacts on tour operators, food providers and shops will also be offset. However, to the extent that the REP workforce expenditure pattern is different to that of tourists, tour operators, and to a lesser extent food and shopping providers may be worse-off in the short term i.e. July 2017, if assumed reductions in tourist numbers eventuate.

Consultations with the LHI community elicited a range of views on the potential long term tourism impacts of the REP. However, evidence supports an increase in tourism demand post rodent eradication and economic principles indicate benefits to tourism providers from an increase in demand, even when constraints on visitor numbers apply. While Morgan and Simmons (2014) suggests that predator free status may lead to at least a 50–75% increase in tourism numbers, this paper adopts a lower assumption of a 20% increase in tourism demand, ramping up over five years. Sensitivity analysis is undertaken for different tourism demand assumptions given the uncertainty involved.

Increased demand in both peak and off-peak periods can be represented by a parallel rightward shift in the respective demand curves as depicted in Fig. 5. During peak periods this would result an increase in average expenditure (price) per visit on LHI from $2083 to $2817 and an increase in scarcity rent (producer surplus) that accrues to accommodation providers of $6M per annum. Normal producer surplus and consumer surplus remain unchanged.

In off-peak periods the increase in demand results in increased visits from 7220 to 8666, which can be accommodated within the capacity constraint, and an increase in price (or average spend) per visit (from $1371 to $1461). The result is an increase in annual producer surplus from $1,635,305 (Fig. 4) to $2,354,371 (Fig. 5) i.e. $719,066, and an increase in consumer surplus from $6,188,306 (Fig. 4) to $8,914,317 (Fig. 5) i.e. $2,726,011. These benefits are contingent on the success of the REP and hence the expected value of these benefits requires multiplication by 95%.

4.2.4. Kentia Palm and Vegetables Impacts

Kentia Fresh the company that operates the Kentia Palm and vegetable nursery on LHI identified that a successful REP would result in the following benefits to its operations:

- avoided costs of $10,000 per year on baiting;
- reduced seed collections costs from around $165/bushell to $50/bushell;
- avoided loss of $50,000[17] worth of Kentia production per annum;
- avoided loss of $25,000 of fruit and vegetable production per annum (Maxwell, 2016).

These benefits are contingent on the success of the REP and hence the expected value of these benefits requires multiplication by 95%.

4.2.5. Health and Toxicity Impacts

Many of the potential human exposure pathways to Brodifacoum will not occur due to the proposed management practices that are to be put in place during and after the REP e.g. removal of poultry and cattle from LHI, isolation of dairy cows from exposure (Toxicos, 2010; Pacific Environment Limited, 2015). Other direct and indirect exposure pathways pose negligible risk for human health (Toxicos, 2010; Pacific Environment Limited, 2015. The most important exposure pathway of Brodifacoum for humans is direct ingestion of bait pellets picked up off the ground. However, substantial quantities would need to be ingested to have any impact and with toxic signs apparent several days before the onset of any life threatening effects the toxicity of brodifacoum is easily treated with Vitamin K (Toxicos, 2010; Pacific Environment Limited, 2015). With the implementation of mitigative measures e.g. provision of muzzels and relocation of dogs susceptible to eating the bait (the cost of which is included in the Project budget), the risk to dogs is also negligible (Toxicos, 2010).

4.3. Cost Benefit Analysis Results

The present value of the incremental costs and benefits of the REP,[18] using a 7% real discount rate and a 30 year evaluation period, consistent with NSW Treasury Guidelines, is provided in Table 4. The REP is estimated to provide net social benefits of $142M (USD189M) and a benefit cost ratio of 17.0. This indicates that the aggregate well-being of the

[17] For simplicity lost production from rodent predation was assumed to result in no costs savings from reduced production levels and hence lost revenues also equated to lost producer surplus.

[18] With all costs and benefits that are contingent on successful eradication of rodents weighted by the probability of the REP being successful i.e. 95%.

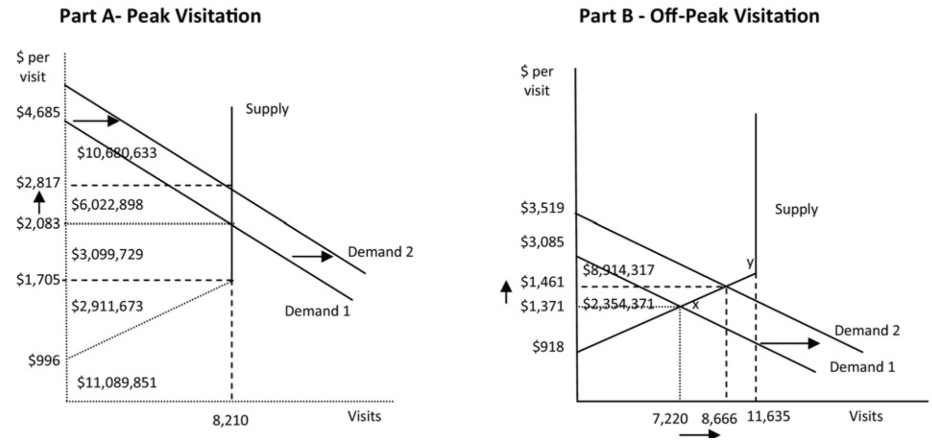

Fig. 5. Tourism economic values under increased levels of demand.

community is improved by implementing the REP i.e. the incremental benefits of the REP exceed the incremental costs.

Some benefits have remained unquantified:

- increased species abundance;
- increased productivity of private vegetable gardens;
- reduced risk to humans, livestock and pets from constant presence of rodent poison;
- elimination of potential health impact from rodents for residents and tourists;
- elimination of spoilt foodstuffs and the presence of rodent excrement on LHI;
- research benefits from the REP.

If these were able to be quantified they would increase the net benefits of the REP. However, the magnitude of these benefits is unlikely to affect the central CBA result that the REP improves the well-being of the community.

The main potential unquantified cost of the REP relates to short term toxicity risks to humans, dogs and aquatic species.[19] However, these are concluded to be negligible (Toxicos, 2010).

4.4. Distribution of Costs and Benefits

The CBA was undertaken from an Australian perspective. Distributional analysis found that there are net benefits from the REP for the residents of LHI and those who do not live on LHI, with NPVs (BCRs) for these groups of $58M (80.5) and $83M (11.2), respectively. The BCR for LHI residents is considerable higher than the BCR for non-residents. A particular focus of the distributional consideration is the impact of the REP on tourism and tourism providers i.e. producer surplus. If it assumed that there is a 50% decrease in tourists during July 2017 as a result of the REP then the reduction in producer surplus to tourism providers[20] is estimated at:

— $83,000 to $308,000 to accommodation;
— $18,000 to $68,000 to tours;
— $10,000 to 42,000 to shopping; and
— $20,000 to $111,000 to meals.

These economic costs would only accrue to those operators that are normally open during July. However, increased demand for worker accommodation as a result of the REP would more than offset the assumed reduction in accommodation demand i.e. 50%, and hence there will be a net benefit to accommodation providers. If these workers have similar spending habits to tourists, then impacts on tour operators, food providers and shops will also be offset. However, to the extent that the REP workforce expenditure pattern is different to that of tourists, tour operators, and to a lesser extent food and shopping providers may be worse-off in the short term i.e. July 2017, if the assumed reductions in tourists eventuate. However, a number of measures could be implemented to mitigate these potential impacts including promotion of local purchases to the incoming workforce; provision of tour and food vouchers to workers; and rent of tourist operators vehicles and boats where required for implementation of the REP.

Accommodation providers (and airlines), who would be no worse-off in the short term as a result of the REP, would be the main beneficiaries of any increase in peak season tourism demand. This is because benefits would mainly accrue via price increases for accommodation (and airlines)[21] rather than any increase in visitation because of the restrictions on visitation. An increase in off-peak tourism demand as a result of the REP would benefit all tourism service providers i.e. accommodation providers, tour operators, food outlets and shops, as it would result in both price increases and increases in visitation.

4.5. Sensitivity Testing

The sensitivity analysis indicated that the CBA results are not sensitive to substantive changes in key variables, including discount rates.[22] Fifty percent +/− changes in individual assumptions at different discount rates led to net benefits of the REP ranging from $83M to $351M i.e. a benefit cost ratio of 11.1 to 21.4. The key drivers of the CBA results are the estimated benefits from biodiversity improvements and increased demand for tourism arising from the REP but even large changes to either or both of these simultaneously would not result in the REP having net costs to the community.

The biodiversity benefits are based on BT of values from a study of catchments in NSW. The lowest value from this study was applied to the CBA of the REP. These values also related to local extinction or presence of species rather than global extinction of species and hence to the extent that the REP would avoid global extinction of species this approach would understate benefits. The estimate of biodiversity benefits also excluded the benefit of increase abundance of species.

[19] Toxicity risk to terrestrial species has be explicitly addressed.

[20] It should be noted that reduced net revenue is an overstatement of financial cost as it is gross of tax. Also these estimates are based on broad industry relationships and hence should be interpreted as order of magnitude estimates rather than specific estimates of impacts to individual businesses.

[21] Price increases would only occur for services where quantity is constrained.

[22] Sensitivity testing was undertaken at 4% and 10% discount rates as required by NSW Treasury (2007). However, the key driver of the analysis was the values for biodiversity improvements and increased demand for tourism.

Table 4
Present value of incremental costs and benefits (@7% discount rate).

Category	Costs	$	Benefits	$	Net benefits
Direct costs	REP direct implementation costs		Avoided ongoing rodent control costs		
	Capital costs	$7,658,155	LHIB	$845,425	
	Ongoing costs	$620,823	Residents	$47,742	($7,385,812)
Biodiversity	Potential for species extinction from REP	$1055	Prevention of additional extinctions	$40,599,970	
	Costs of returning extinct species to LHI	$38,774	Return of extinct species to LHI	$27,537,371	
			Increased abundance of species		$68,098,566
Tourism	Foregone tourism during REP implementation		Additional accommodation during REP implementation		
	Net revenue	$113,686	Accommodation net revenue	$106,773	
	Tourist benefits	$427,457	Net revenue to tours, food outlets and shops	NQ	
			Tourist benefits	NA	
			Additional tourism business after REP implementation		
			Net revenue	$57,175,022	
			Tourist benefits	$23,153,099	$79,893,751
Palms and vegetables			Increased productivity for Kentia Palm industry and avoided direct costs	$982,682	
			Increased productivity of other vegetable gardens	NQ	$982,682
Health and toxicity	Any impact to other species, water and human health	NQ	Reduced impact to humans, livestock and pets from constant presence of rodent poison	NQ	NQ
			Elimination of health impacts from rodents for residents and tourists	NQ	NQ
Wastage and amenity			Elimination of spoiled foodstuffs, rodent excrement for residents	NQ	NQ
Research			Research benefits of the program	NQ	NQ
Total	Total costs	$8,859,951	Total benefits	$150,448,082	$141,588,132
			Net present value	$141,588,132	
			Benefit cost ratio	17.0	

Note: reporting of calculations should not be misconstrued as conveying false accuracy.

Tourism benefits were based on an assumption of a 20% increase in demand post REP. This was less than the low estimate of tourism increases post eradication suggested by the review of Morgan and Simmons (2014). However, even if it were assumed that there would be no tourism benefits, the REP would still provide net benefits to the Australian community because of the level of biodiversity benefits.

Risk was incorporated in the CBA using the expected value framework. Enhanced risk assessment using Monte Carlo simulation was not undertaken because the results of the sensitivity analysis indicated that rodent eradication on Lord Howe Island would have a very large net benefit that would be unaffected by substantial changes in key assumptions.

5. Conclusions

The CBA of the REP indicates that it will have net benefits to the Australian community and hence is justified on economic efficiency grounds. It will provide biodiversity benefits, tourism benefits and benefits to the Kentia Palm and fresh vegetable industry. The REP will also provide net benefits to residents of LHI and net benefits to residents in the rest of Australia.

It is reasonable to expect that there will be minimal or no reduction in visitation at the time of the REP, or at least in the off-peak period overall (allowing for some substitution for an alternative off-peak times). Nevertheless, the maximum assumed short term impacts to tour operators, food outlets and shops[23] as a result of the REP implementation would be offset in present value terms if there was a sustained increase in off-peak visitation by 0.4% (29 people per annum) because of the eradication of rodents.

A key driver of the CBA results is the value estimated for biodiversity benefits. This was based on BT from another study undertaken in a different biophysical context. Future similar studies of island rodent eradication programs would be advantaged by undertaking a primary non-market valuation study e.g. using choice modelling, to estimate community willingness to pay for the project specific biodiversity benefits of the rodent eradication programs.

The results of a primary travel cost method study would also provide information relating to the demand curve for visits that could be used to inform the whole of experience demand and supply models for tourism.

CBA analysis of rodent eradication projects provide clarity around the relative magnitude of different impacts, whether the aggregate benefits exceed the costs and how costs and benefits are distributed among stakeholder groups. For decision-makers and funding agencies, if the benefits of a program can be shown to exceed the costs, CBA may provide the hard-edged analysis needed to have confidence in supporting rodent eradication. It may also be useful in obtaining social acceptance from both island inhabitants and the broader community.

[23] There will be no net impact on accommodation providers due to an increase in demand from workers.

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